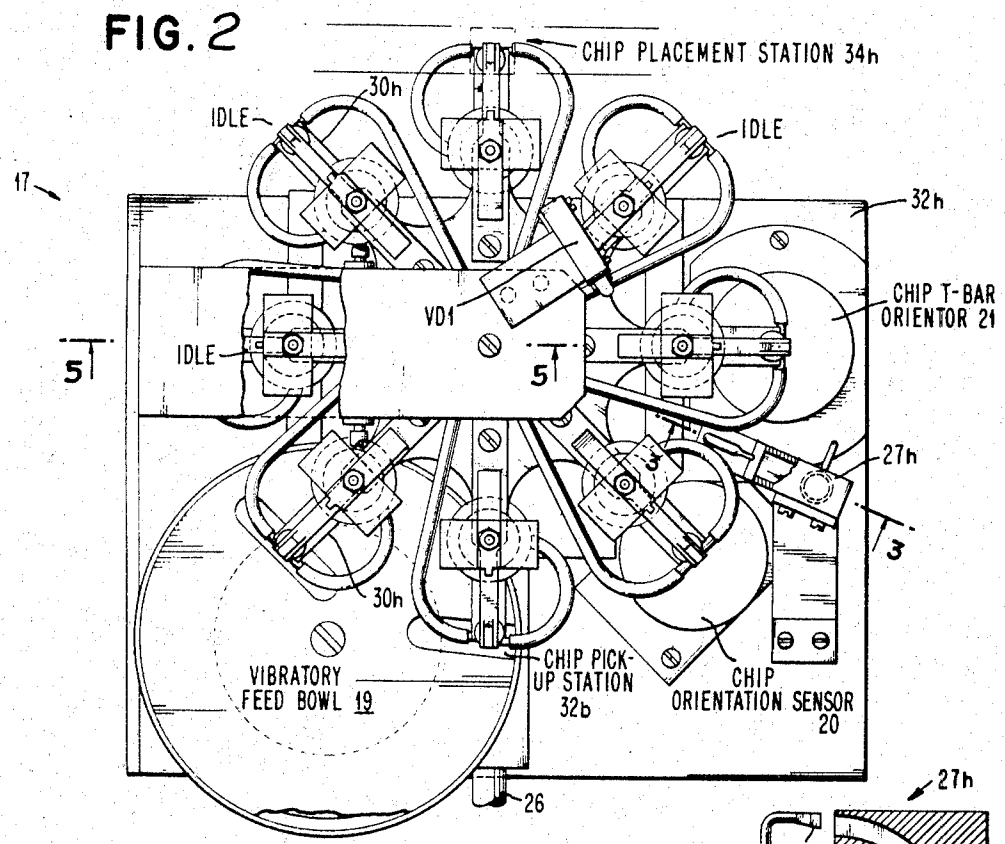
VACUUM OPERATED CHIP PLACEMENT HEAD

Original Filed May 27, 1965

FIG. 2



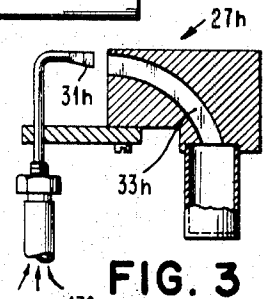
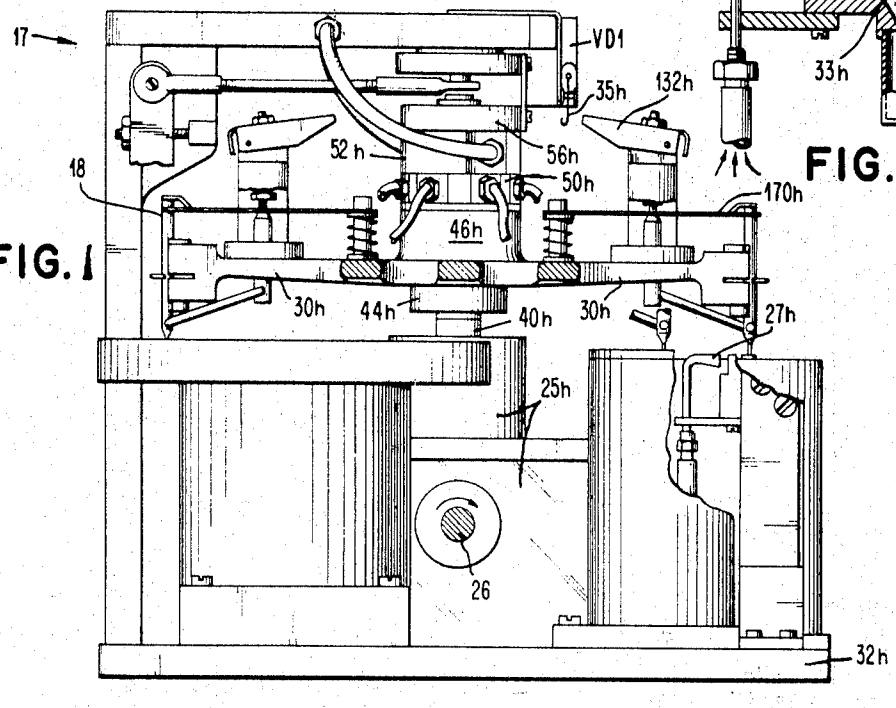


FIG. 3

FIG. 1



VACUUM OPERATED CHIP PLACEMENT HEAD

Original Filed May 27, 1965

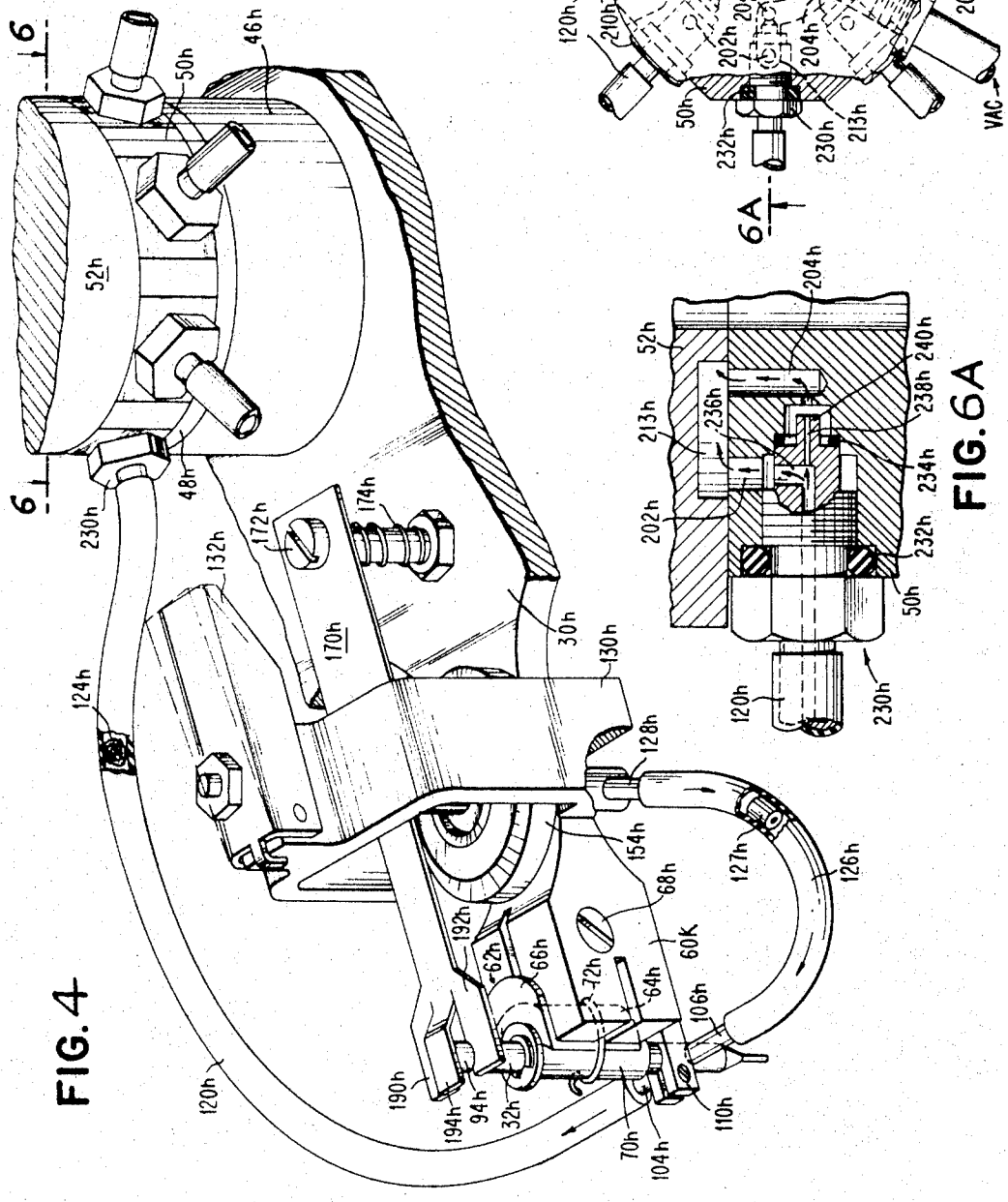


FIG. 4

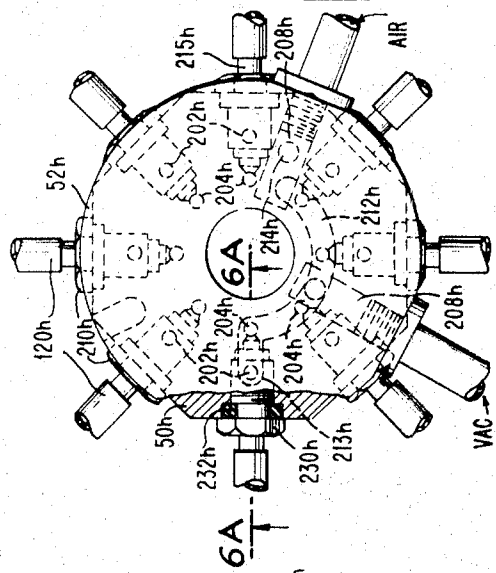


FIG. 6

FIG. 6A

VACUUM OPERATED CHIP PLACEMENT HEAD

Original Filed May 27, 1965

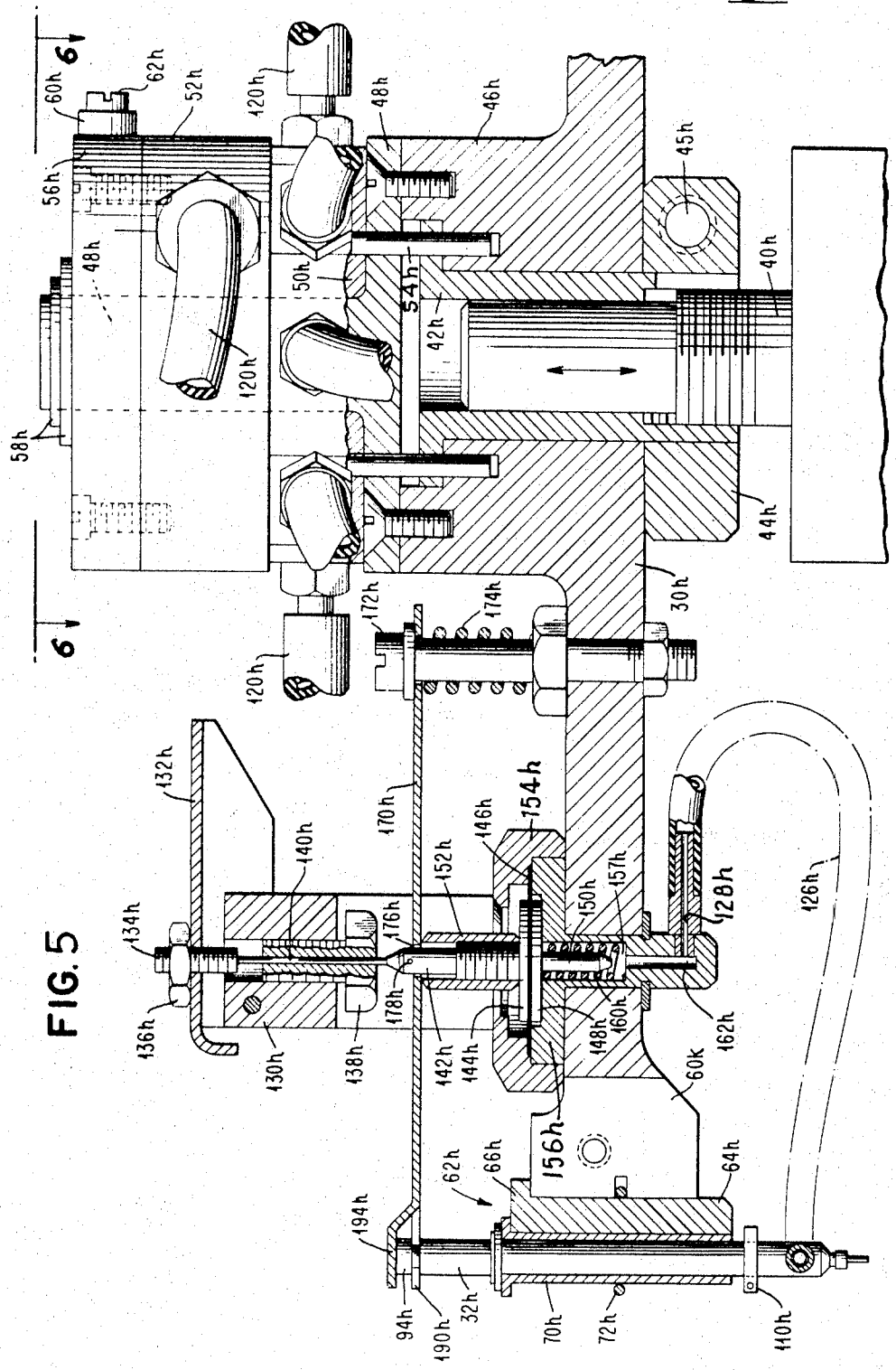


FIG. 5

FIG. 10

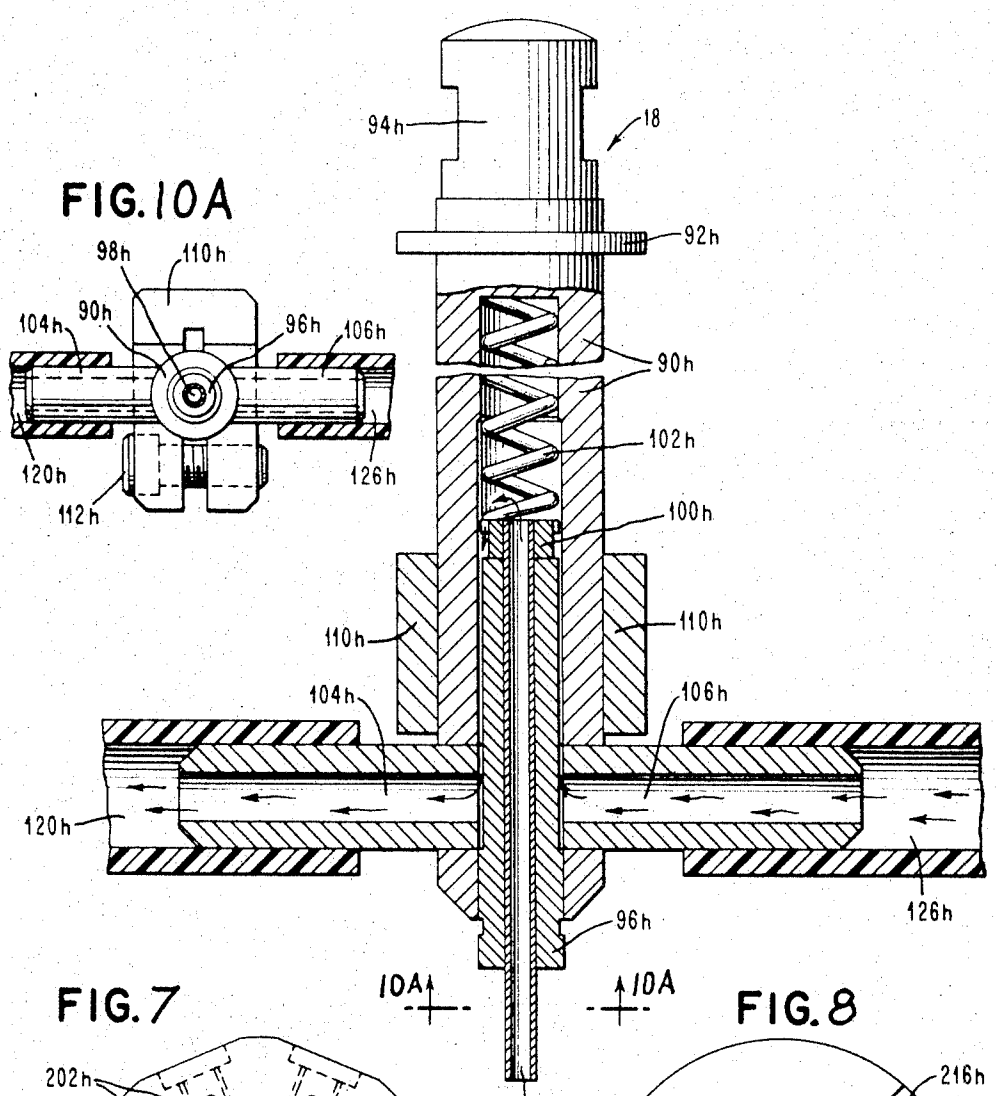


FIG. 10A

FIG. 7

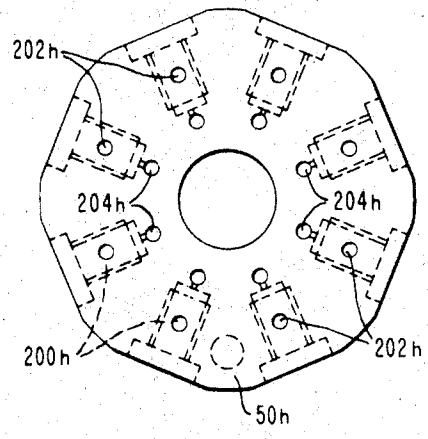
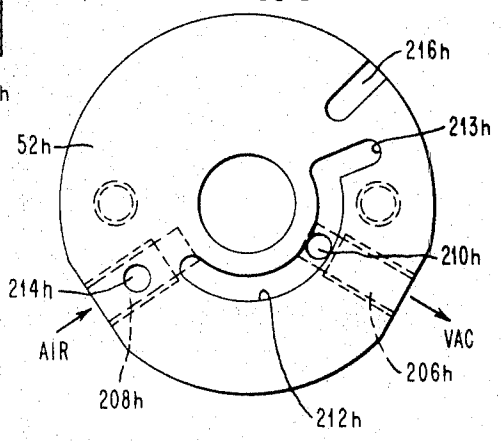


FIG. 8



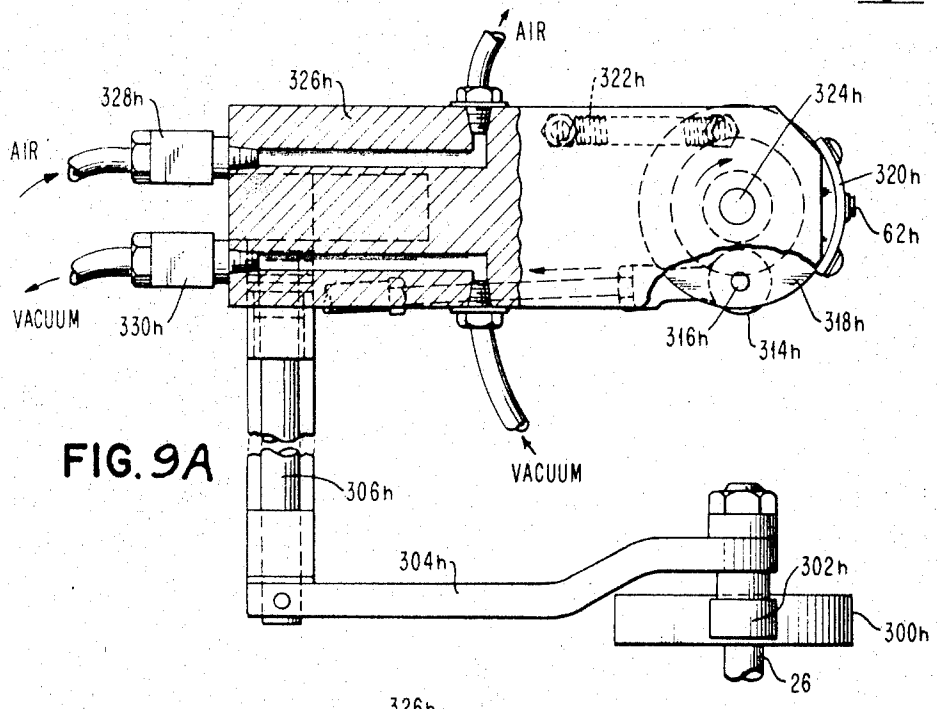

AIR
326h
322h
328h
324h
AIR
320h
62h
VACUUM
330h
316h
314h
318h
VACUUM
306h
304h
302h
300h
26

FIG. 9A

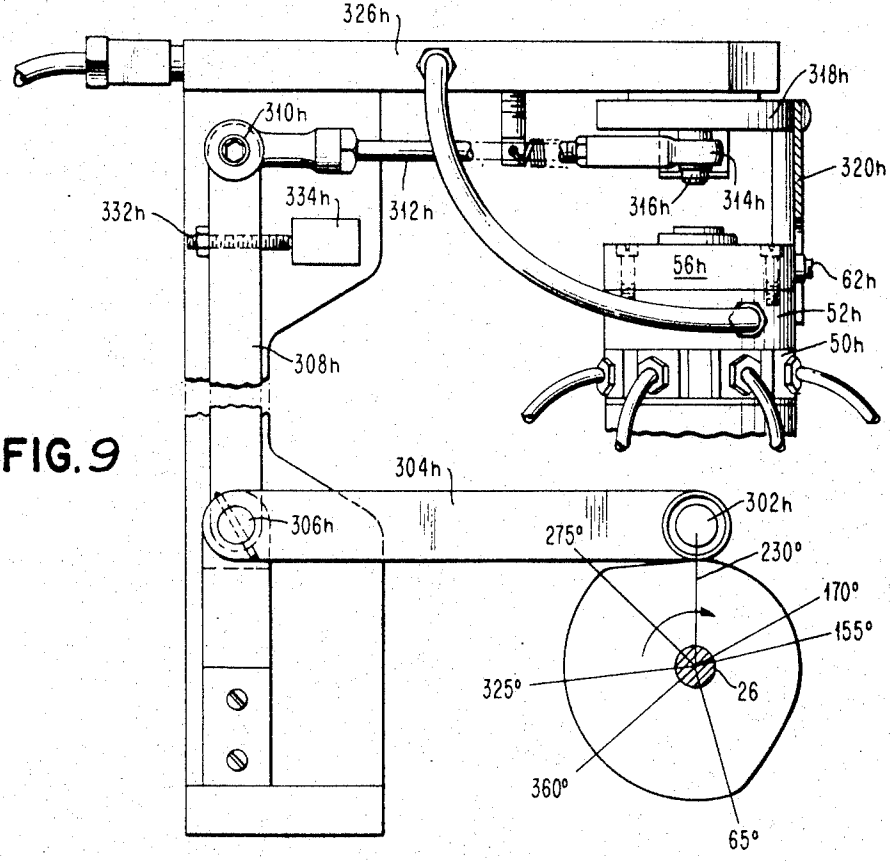

326h
318h
310h
320h
334h
312h
316h
314h
332h
56h
62h
52h
308h
50h
304h
302h
306h
275°
230°
170°
155°
325°
26
360°
65°

FIG. 9

FIG. 11

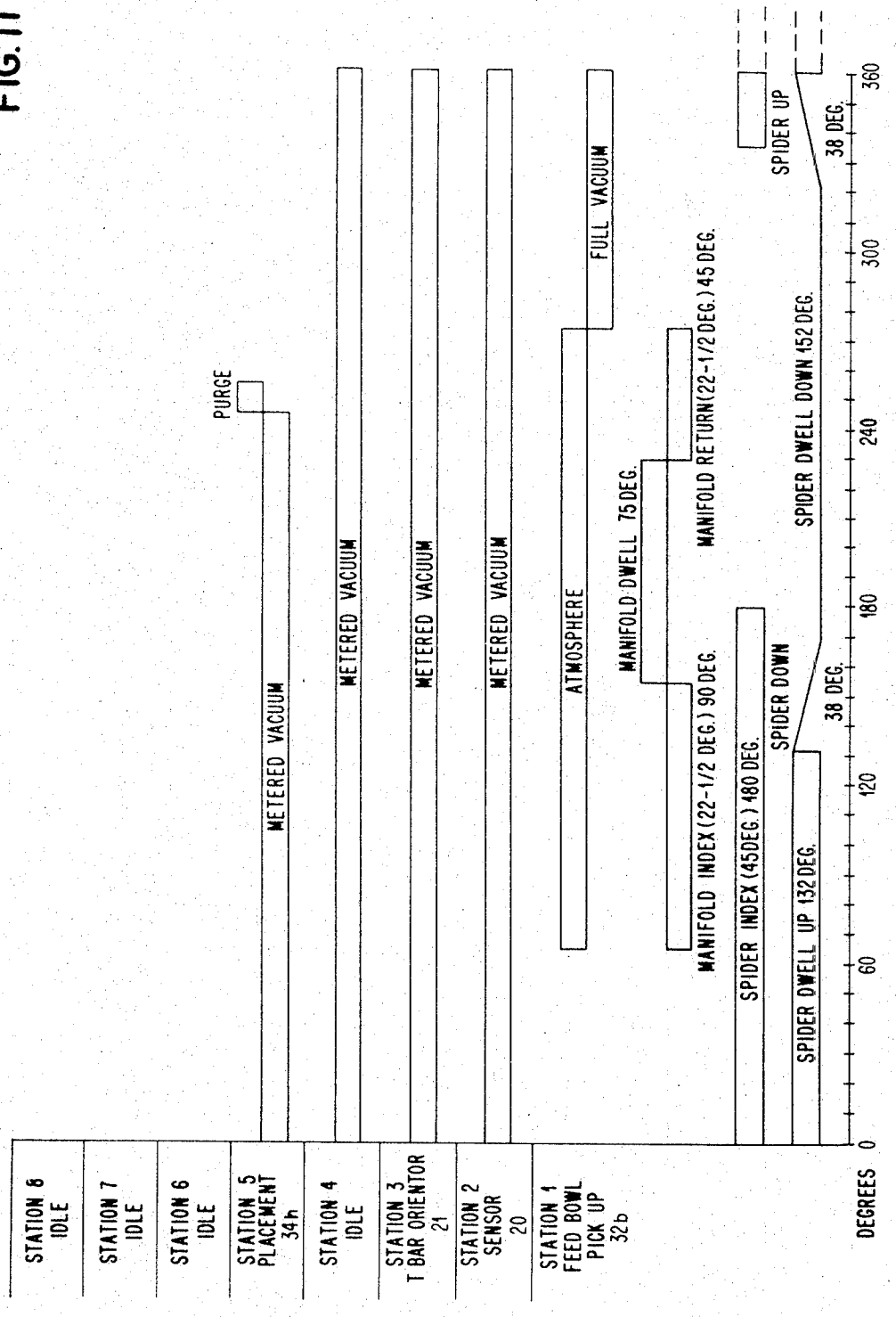

STATION 8 IDLE
STATION 7 IDLE
STATION 6 IDLE
STATION 5 PLACEMENT 34h
STATION 4 IDLE
STATION 3 T BAR ORIENTOR 21
STATION 2 SENSOR 20
STATION 1 FEED BOWL PICK UP 32b
PURGE
METERED VACUUM
METERED VACUUM
METERED VACUUM
METERED VACUUM
ATMOSPHERE
FULL VACUUM
MANIFOLD INDEX (22-1/2 DEG.) 90 DEG.
MANIFOLD DWELL 75 DEG.
MANIFOLD RETURN (22-1/2 DEG.) 45 DEG.
SPIDER INDEX (45DEG.) 180 DEG.
SPIDER DOWN
SPIDER DWELL UP 132 DEG.
38 DEG.
SPIDER DWELL DOWN 152 DEG.
SPIDER UP
38 DEG.
0
60
120
180
240
300
360
DEGREES

FIG. 11A

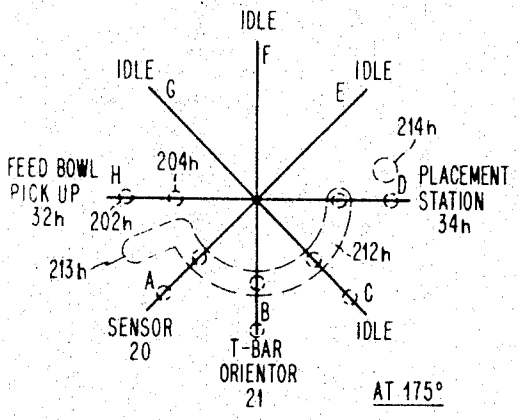


FIG. 11B

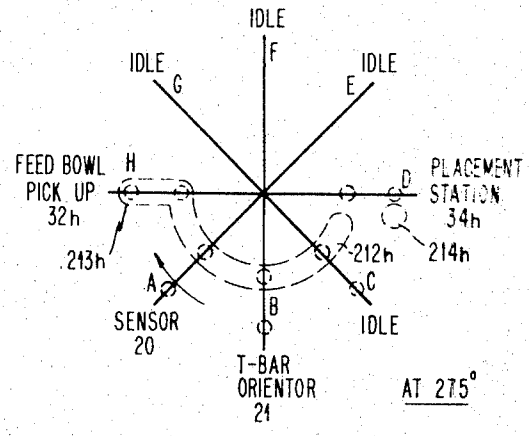


FIG. 11C

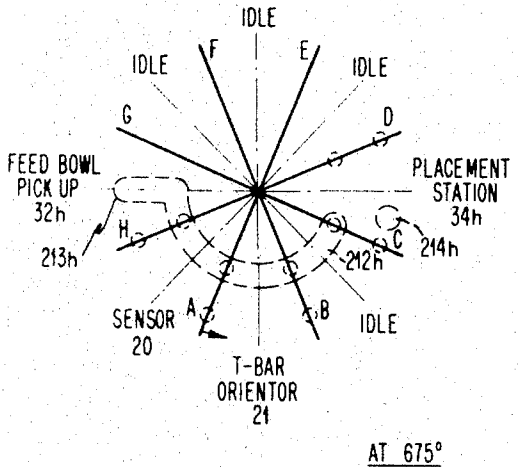
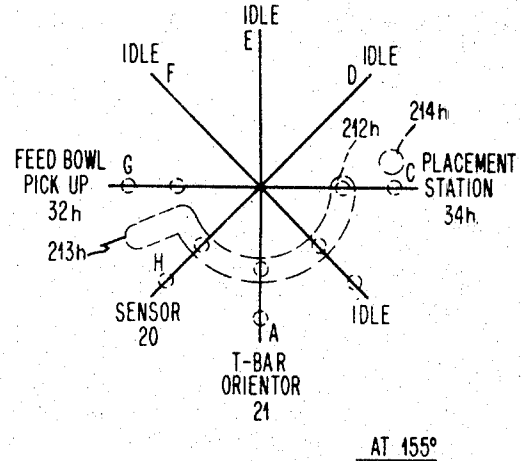


FIG. 11D



United States Patent Office 3,453,714 Patented July 8, 1969

3,453,714

VACUUM OPERATED CHIP PLACEMENT HEAD

Kendall Clark, Thomas J. Rajac, George R. Santillo, Jr., and Walter J. Schuelke, Poughkeepsie, N.Y., assignors to International Business Machines Corporation, Armonk, N.Y., a corporation of New York

Continuation of application Ser. No. 459,340, May 27, 1965. This application Feb. 10, 1967, Ser. No. 615,262
Int. Cl. B65g 65/00
U.S. Cl. 29—203 18 Claims

ABSTRACT OF THE DISCLOSURE

An article-handling apparatus having a head with pick-up means for an article, such as a semiconductor chip, from a supply thereof, transporting it in an elevated position to a placement station at which it is lowered for deposit on a concurrently arriving new support, as for example on a conductive land pattern of a substrate. The pick-up means is provided with sensing means which detects for the presence of an article on the pick-up means to prevent the pick-up from being lowered when an article is absent or dislodged from the pick-up means. Also included is a provision for preventing discharge of the support or substrate from the placement station when the pick-up means arrives without an article for deposit. The support or substrate remains at the station for the next cycle of the pick-up means. On deposit of an article (or chip) on the support (or substrate) the latter is permitted to be discharged and replaced by a new unit.

This application is a continuation of prior copending application, Ser. No. 459,340, filed May 27, 1965, now abandoned, entitled, "Vacuum Operated Chip Placement Head," Kendall Clark et al.

This invention relates to semiconductor chip positioning machines and, more particularly, to a vacuum operated chip placement head usable therewith.

With the advent of hybrid transistor circuit technology, there arose more stringent requirements for precision, speed and uniformity than had theretofore been achieved in the art of automated circuit manufacture. This hybrid technique involves first the screen printing of resistors and conductive lands on an alumina substrate. A layer of solder flux is then applied to the substrate and then transistors or diodes in the form of thin, square or rectangular semiconductor chips are positioned on to the lands, with the flux providing the necessary adhesive qualities to keep the chips in place. Because the chips are almost microscopic in size, each measuring .028 inch square, and are joined to the lands by contact elements in the form of copper balls which are only .005 inch in diameter, they cannot be handled by conventional automated assembly techniques. The problem was further complicated by the need for extreme accuracy and precision in positioning the chips on the relatively small and closely spaced conductive lands which are only .005 to .015 inch wide and .005 inch apart, as well as by the extreme delicacy of the structure involved. Furthermore, the vast number of circuit substrates required in the manufacture of each digital computer, which is at present the primary use for this hybrid circuit technology, demands that the chip positioning and placement operation be performed at relatively high speeds and with a high yield in order to maintain the high volume required in production.

In co-pending U.S. patent application 459,179, filed on even date herewith, May 27, 1965, entitled Chip Positioning Machine, by Clark et al. (IBM Docket 14,415), a machine capable of automatically preparing a substrate to receive semiconductor chips, placing the chips in place on the substrate, and testing for their proper placement is disclosed. In co-pending U.S. patent application 459,379, filed on even date herewith, May 27, 1965, now abandoned, entitled Semiconductor Chip Placement Head, by Clark et al., (IBM Docket 14,416) a semiconductor chip placement head usable with the aforesaid chip placement machine is described which sequentially picks up a chip from a vibratory feed bowl, senses the chip's orientation, reorients the chip to a desired configuration, and places it upon the prefluxed substrate. The placement head basically comprises a plurality of vacuum needles which are selectively actuated to pick up and place the semiconductor chips. Two problems may occur in the operation of this head which serve to deteriorate both its own operation and its operation in combination with the overall chip positioning machine. First, if for some reason a chip is not picked up at the vibratory feed bowl, and the vacuum needle arrives at the chip placement station and is lowered into placement position, it may immerse itself in the substrate's prefluxed surface. This obviously causes the vacuum needle to become clogged and useless during succeeding operations. The flux adhering to the vacuum needle also acts to adhere to anything which the needles contact thereby completely "gumming up" the machine. The second problem relates to the fact that the prefluxed substrates are continually being indexed past the placement station. Thus, if any vacuum needle comes down at the placement station without a semiconductor chip, and the substrate is allowed to continue on its travels, it is obviously a reject which subtracts from the overall production capability of the machine.

Accordingly, it is an object of this invention to provide a highly reliable vacuum operated chip placement head.

It is a further object of this invention to provide a vacuum operated chip placement head with means to prevent vacuum needles from being emersed in the flux coating on prefluxed substrates.

It is still another object of this invention to provide a chip positioning head with means for indicating when no chip is carried at the end of a vacuum needle.

In accordance with the above stated objects, there is provided a multi-headed apparatus in which each head is adapted to transport a device from a pick-up point to a placement point and deposit it at said placement point upon a coincidentally arriving prefluxed substrate, a new substrate presenting itself to the placement point coincidental with the arrival of each head. A vacuum pick-up means is associated with each head of the apparatus and is adapted to manifest a signal indicating whether or not it is carrying a device. An actuation means is associated with each head of the apparatus and is responsive to a signal from the vacuum pick-up means that it is not carrying a semiconductor device, to raise the vacuum pick-up sufficiently to prevent it from contacting the prefluxed substrate and thereby becoming clogged.

A switch actuating lever is also connected to the actuation means and is adapted to interact with a reset switch which, when closed, delays the departure of a substrate from the placement point. Control means couples the vacuum pick-up means with the actuation means on each head and is responsive to a signal from the vacuum pick-up means that it is not carrying a semiconductor device to position the switch actuating lever to a switching interacting position. Thus, a substrate is delayed in its travel until a device bearing vacuum pick-up arrives at the placement point.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of

the invention, as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a side elevation of the chip placement head.

FIG. 2 is a plan view of the chip placement head in combination with each of the specific stations associated therewith.

FIG. 3 is a partial sectional view of the chip blow-off mechanism.

FIG. 4 is an isometric view of a representative arm of the chip placement head showing details of the vacuum pin arrangement.

FIG. 5 is a section view of a representative arm of the chip placement head taken along line **5—5** in FIG. 2.

FIG. 6 is a view taken along line **6—6** in FIGS. 4 and 5 to show the superimposed positions of the vacuum distributor and vacuum manifold.

FIG. 6A is a section view showing a representative vacuum nozzle and portion of the vacuum manifold taken along line **6A—6A**.

FIG. 7 is a plan view of the vacuum distributor with the vacuum manifold removed.

FIG. 8 is a view of the bottom portion of the vacuum manifold which normally mates with the upper portion of the vacuum distributor.

FIG. 9 is a side elevation of the cam and drive mechanism which causes relative movement between the vacuum distributor and vacuum manifold.

FIG. 9A is a plan view of the mechanism of FIG. 9.

FIG. 10 is a complete section of a vacuum probe.

FIG. 10A is a view of a vacuum probe taken along line **10A—10A**.

FIG. 11 is a timing chart helpful in understanding the operation of the chip placement head.

FIGS. 11A–11D are line drawings showing the relative positions of the vacuum manifold and the vacuum distributor at discrete times during the operation of the chip placement head.

Chip placement head

Referring now to FIGS. 1 and 2, chip placement head **17** includes eight stations, four of which are idle and four of which perform specific functions in regard to feeding, orienting and placing the transistor chips in their proper position upon a substrate. The major moving part of chip placement head **17** is spider **30***h* which is provided with eight radial arms, each of which supports a vacuum needle **18**. Each vacuum needle **18** is adapted to pick up a transistor chip, transport it between stations, and place it in its proper position upon a prefluxed substrate. The spider is actuated by an index mechanism to be described hereinbelow. Prior to each arm of the spider reaching a station, the entire mechanism is in an elevated position to allow the needle to clear obstructions between stations. Upon arriving at the stations, the spider is lowered by the indexing mechanism and lower the vacuum needles into the respective stations. At the termination of the stations' operations, the indexing mechanism raises the spider and rotates the spider arm to succeeding stations.

Before proceeding to a more detailed description of chip placement head **17**, the following summary of operations performed at each of the stations will aid in understanding the operation of the system. The ultimate purpose of chip placement head **17** is to provide a transistor chip at placement station **34***h* (FIG. 2) with its copper ball contacts oriented in such a manner as to exactly mate with the dimple pattern on the substrate land configuration, and deposit the chip in place upon the substrate at the correct time. To accomplish this function, vibratory feed bowl **19** performs the function of providing chips to a chip pick-up station **32***b* in a queued-up ball-contact down configuration. While the ultimate desire is to place each semiconductor chip on a substrate, this cannot be done unless the chip's ball-contacts are arranged to precisely mate with the substrate dimpled land pattern. Vibratory feed bowl **19** is incapable of assuring this required preset orientation. Accordingly, a vacuum needle **18** picks up a chip at pick-up station **32***b* and carries it to chip orientation sensor **20**. Upon receiving a semiconductor chip, chip orientation sensor **20** performs two functions. First, a pair of guide jaws within the sensor **20** precisely locate the chip with respect to the tip of vacuum needle **18**. In addition, when vacuum needle **18** inserts a chip in the ball-contacts down orientation into chip orientation sensor **20**, an oddly placed ball-contact acts to deflect a lever arm thereby providing an indication of the chips orientation. A signal is produced indicating the sensed orientation and is transmitted to chip T-bar orientor **21**. The T-bar orientor responds to the signal by pre-rotating to a position where its T-bar head will mate with the ball contact pattern. The aforemenioned guide jaws are opened and the chip is readied for the next index step. When vacuum needle **18** and its associated chip are next indexed to T-bar orientor station **21**, the vacuum needle places the chip upon a rotatable T-bar which as aforestated has been prerotated to fit within the interior of the chip's contact pattern. The T-bar orientor **21** then rotates the chip on the end of vacuum needle **18** to the correct orientation for placement. In addition to correcting the angular orientation of the chip, the mating of the T-bar with the contact pattern of the chip provides a final precise orientation of the chip and assures that its contacts will exactly mate with the substrate dimple pattern. Vacuum needle **18** and its associated chip is then indexed through an idle station to chip placement station **34***h* where it is placed upon a prefluxed substrate borne by a conveyor tape (not shown).

In addition to the above-described stations, chip placement head **17** is provided with blow-off mechanism **27***h* and a recycle switch VD1. Blow-off mechanism **27***h* is positioned intermediate chip orientation sensor **20** and chip T-bar orientor **21**. Blow-off mechanism **27***h* is shown in section in FIG. 3 and comprises an airblast head **31***h* and an operatively disposed channel **33***h* which leads to a receptacle. Blow-off station **27***h* is so positioned that during the indexing of a vacuum needle from chip orientation sensor **20** to chip T-bar orientor **21**, the needle tip and its associated semiconductor chip pass directly between airblast head **31***h* and channel **33***h*. If for any reason chip orientation sensor **20** provides an output which is indicative of a malformed chip, a chip held on end, a chip with insufficient ball-contacts, etc., it energizes a logic circuit which causes a blast of air to be applied to head **31***h*. This airblast is sufficient to dislodge a chip from the tip of a vacuum needle and cause it to enter channel **33***h* to the receptacle.

Recycle switch VD1 (FIG. 1) is basically a microswitch with a downwardly extending switch actuating lever **35***h*. Its operation in combination with other portions of chip placement head **17** will be described in greater detail hereinafter.

The main drive for chip placement head **17** comes from shaft **26** which feeds directly into head indexing mechanism **25***h*. This mechanism is described in greater detail hereinafter, but for the time being it will suffice to say that the mechanism provides an indexing drive motion via shaft **40***h* to spider **30***h*. It also provides a required vertical displacement of shaft **40***h* and spider **30***h* during the time when vacuum needles **18** are being indexed between stations (to prevent damage to the needle tips). As shown in FIG. 5, shaft **40***h* has a threaded portion which threads into interior threads in bushing **42***h*. Clamp **44***h* prevents rotary movement between shaft **40***h* and bushing **42***h* once the desired orientation between them has been established. Clamp **44***h* is tightened by virtue of a bolt which extends through hole **45***h*. Bushing **42***h* is shrunk to fit into spider collar **46***h* to prevent any relative movement therebetween. A centering plate and shaft **48***h* are rigidly affixed to spider collar **46***h* via a plurality of set screws. Vacuum distributor **50***h* fits down over the centering shaft **48***h* and provides the means for distributing both vacuum and positive air pressure to the respective arms of spider **30***h*. Directly over and mating with dis-

tributor **50***h* is vacuum manifold **52***h* which provides the function of supplying and switching vacuum and positive air pressure between various ones of the outputs of distributor **50***h*. Distributor **50***h* is rigidly affixed to and rotates with spider collar **46***h* by virtue of pins **54***h* which extend through centering plate **48***h*, bushing **42***h* and into collar **46***h*. A manifold top plate **56***h* fits directly over manifold **52***h* and is affixed thereto by set screws. Retaining plates **58***h* fit down over shaft **48***h* and rigidly force manifold **52***h* to bear against distributor **50***h* and provide an airtight seal therebetween. A bushing **60***h* is rigidly attached to the side of manifold top plate **56***h* by set screw **62***h*. The relative position of vacuum manifold **52***h* with respect to vacuum distributor **50***h* can be varied by causing a force to be applied to bushing **60***h* thereby causing a rotation of manifold top plate **56***h* and manifold **52***h* about centering plate shaft **48***h*. The specific operation of this apparatus will be described in detail hereinafter.

Since each arm of spider **30***h* is structurally identical, only one need be explained. An isometric view of one arm is shown in FIG. 4 and the same arm in section is shown in FIG. 5. Spider arm **30***h* has an enlarged and slotted end portion **60***h* with a vertical hole drilled therethrough which is adapted to accommodate a vacuum needle holding fixture **62***h*. Fixture **62***h* comprises a round portion of bar stock **64***h* which has been slotted to accommodate vacuum needle **18**. A cap **66***h* is attached to bar stock portion **64***h*. The center line of bar stock portion **64***h* falls to the right of the end of enlarged portion **60***h* of spider arm **30***h*. If it is thus desired to adjust the exact location of vacuum needle **32***h*, cap **66***h* may be grasped and rotated with a resultant lateral movement of vacuum needle **18** occurring due to the offset between the center line of bar member **64***h* and the enlarged end **60***h*. When set screw **68***h* is tightened, it draws the slotted portions of enlarged member **60***h* together, thereby gripping vacuum probe holding fixture **62***h* and preventing any further lateral movement thereof. Vacuum needle **18** is slidably mounted in necked cylinder **70***h* which is in turn held to vacuum probe holding fixture **62***h* by spring clip **72***h*.

The structure of a vacuum needle **18** is shown in FIG. 10. Outer housing **90***h* is a hollow tube with one closed-off end. At the upper extremity of housing **90***h*, a downward limiting stop **92***h* and slotted nut **94***h* are attached. Interior to housing **90***h* is a fixed bushing **96***h* which has slidably mounted therein hollow probe pin **98***h*. Attached to one end of probe pin **98***h* is an extended diameter collar **100***h*. A compression spring **102***h* bears down upon extended collar **100***h* and acts to maintain probe pin **98***h* in a downwardly extended position. Extending through housing **90***h* are a pair of tubes **104***h* and **106***h*. It should be noted that bushing **96***h* is attached to the inner surface of housing **90***h* only below the entry point of tubes **104***h* and **106***h*. Above their attachment point, there is a clearance space between housing **90***h* and the outer circumference of bushing **96***h*. Thus, if a vacuum is applied to tube **104***h*, not only will air be drawn up through probe pin **98***h* and down through the clearance area between bushing **96***h* and probe body **90***h*, but also, air will be drawn into tube **106***h*, around bushing **96***h* and into tube **104***h*. Thus, if a vacuum is applied to tube **104***h* and there is a semiconductor chip held at the end of probe pin **98***h*, all of the air drawn through vacuum needle **18** must come via tube **106***h*. If on the other hand, there is no chip held by probe pin **98***h*, a significant portion of the air drawn into tube **104***h* will be drawn through probe pin **98***h* thereby considerably reducing the vacuum applied via tube **106***h*. As will become hereafter apparent, this fact is utilized to control the recycle actuating mechanism.

An adjustable stop **110***h* surrounds housing **90***h* and provides a lower limiting stop for the travel of vacuum needle **18**. FIG. 10A better shows the details of stop **110***h*. By causing nut **112***h* to be loosened, stop **110***h* may be moved either up or down on housing **90***h*. As can be seen by examining FIG. 55 of the aforesaid co-pending application Serial No. 459,379, vibratory feed bowl **19** has a stop normally associated therewith. When vacuum probe **32***h* is lowered into feed bowl **19**, stop **110***h* is adjusted to impact with the stop to prevent the tip of probe pin **98***h* from touching the surface of a semiconductor chip and thereby being damaged.

Returning now to FIG. 4, hose **120***h* connects tube **104***h* to a vacuum outlet nozzle **230***h* from vacuum distributor **50***h*. A filtering agent **124***h* is shown in a cut-away portion of hole **120***h* and prevents debris from being drawn up into the vacuum mechanism. An additional hose **126***h* connects tube **106***h* to the recycle lever actuation mechanism via vacuum port **128***h*. A constrictor **127***h* is inserted into hose **127***h* for a purpose to be hereafter discussed.

The purpose of the recycle lever actuation mechanism is twofold. It is basically a pneumatic logic element which reacts to the absence of a semiconductor chip at the tip of a vacuum needle by (1) raising the vacuum needle and (2) raising the switch actuating lever so that it may engage the recycle switch. The recycle lever actuation mechanism is supported by a vertically disposed housing **130***h* which is rigidly affixed to spider arm **30***h*. Pivotally mounted on the upper extended portion of vertical housing **130***h* is recycle actuation lever **132***h*. As can be more clearly seen in FIG. 5, a screw is threaded through recycle actuation lever **132***h* and is held in place by nut **136***h*. A hollow hex-head screw **138***h* is threaded into the extended portion of vertical housing **130***h* and forms the guide for a slidably mounted push pin **140***h*. Push pin **140***h* rests at its lower extremity upon impeller **142***h*. The lower portion of impeller **142***h* is threaded and extends through washer **144***h*, and diaphragm **146***h* to a diaphragm hold plate **148***h*. A guide pin **150***h* is attached to and points downwardly from diaphragm hold plate **148***h*. A bushing **152***h* is threaded onto the threaded portion of impeller **142***h* and holds washer **144***h*, diaphragm **146***h* and diaphragm hold plate **148***h* in a sandwich-like configuration. The outer circumference of diaphragm **146***h* is clamped between members **154***h* and **156***h*. Member **156***h* has an orifice **157***h* which houses compression spring **160***h*. A communicating orifice **162***h* connects to vacuum port **128***h* and hose **126***h*.

A leaf spring **170***h* is restrained at one end by a nut and shaft arrangement **172***h*. Compression spring **174***h* allows leaf spring **170***h* to pivot in the plane of the paper while maintaining it in its indicated position. A clearance hole **176***h* in leaf spring **170***h* mates with impeller **142***h* and locking pin **178***h* holds leaf spring **170***h* against bushing **152***h*. At its far extremity (see FIG. 4), leaf spring **170***h* is arranged to lock with slotted nut **94***h* via its separated arms **190***h* and **192***h*. Arm **194***h* bears upon the upper portion of slotted nut **94***h*.

In brief, the actuation of recycle lever **132***h* causes it to be tilted upwardly so that its end engages the downwardly extending arm **35***h* of recycle switch VD1 (FIG. 1). This indicates to the machine that no semiconductor chip is held by the tip of the associated vacuum needle and that when the placement operation occurs with this respective vacuum needle, that the conveyor tape must be held in place until the next vacuum needle is indexed into the chip placement station **34***h*. If this does not occur, the substrate which arrives at the chip placement station at the same time with the particular needle without a chip arrives, the substrate will obviously have no chip placed thereon and will be defective. At the same time lever **132***h* is raised, leaf spring **170***h* also raises vacuum needle **18** and prevents it from being immersed in the prefluxed surface of the substrate at chip placement station **34***h*. This action thereby prevents the needle from being clogged and carrying the flux to other portions of the chip placement head. It is vitally important in the operation of this machinery that no flux enter any portions thereof.

In the detailed description of the operation of recycle

lever actuation mechanism which follows, FIGS. 4 and 5 will be primarily referred to. When spider arm **30***h* arrives at chip pickup station **32***b* it is lowered into place over the station through the action of the spider's movement. Stop **110***h* engages stop **40***b* in vibratory bowl **19** and causes leaf spring **170***h* to be flexed upwardly thereby preventing any vacuum needle bounce. At this time, no vacuum is applied via tube **120***h* to vacuum needle **18**. In the recycle lever actuating mechanism, compression spring **160***h* pushes diaphragm **146***h* upwardly until washer **144***h* engages the bottom of member **154***h*. Impeller **142***h* is thus also moved upwardly and push pin **140***h* bearing against threaded screw **134***h* causes recycle lever **132***h* to be tilted upwardly (as shown in phantom in FIG. 4).

When vacuum needle **18** is placed over chip pickup station **36***h*, a vacuum is applied via hose **120***h* to the needle. The air which is thus caused to be drawn up through probe pin **98***h* (FIG. 10) picks up a semiconductor chip and causes the tip of probe pin **98***h* to be sealed. The vacuum applied via hose **120***h* must thereby be satisfied by the air flow through hose **126***h*. The increased vacuum in hose **126***h* is reflected into orifice **157***h* in the recycle lever actuation mechanism via port **128***h* and orifice **162***h*. The increased vacuum opposes the action of compression spring **160***h* and thereby brings diaphragm **146***h* down to the unstressed position shown in FIG. 5. Note that diaphragm **146***h* completely seals the vacuum system from the atmosphere and so long as a significant vacuum is applied via hose **126***h* diaphragm **146***h* will remain in its indicated position. When diaphragm **146***h* is drawn downwardly by the applied vacuum, the impeller **142***h* and push pin **140***h* are also drawn down with the result being that recycle actuation lever **132***h* is lowered to the horizontal position.

Immediately after a chip is picked up by vacuum needle **18** the amount of vacuum applied to tube **120***h* is somewhat lowered by vacuum manifold **52***h* (in a manner to be described hereinafter), but so long as a chip remains on the tip of probe pin **98***h*, the vacuum reflected through hose **126***h* is sufficient to overcome spring **160***h* and maintain diaphragm **146***h* in its unstressed position.

Should it occur that no semiconductor chip is picked up at chip pickup station **136***h* or, that during the indexing operation of the chip placement head, the chip is dislodged from the tip of probe pin **98***h* (e.g. by chip blowoff mechanism **27***h*), the following action occurs. The aforementioned reduced vacuum which was applied immediately after vacuum probe **32***h* left chip pickup station **36***h* is of sufficient quantity to maintain diaphragm **146***h* in its unstressed position only so long as the tip of probe pin **98***h* is sealed. If for any reason a semiconductor chip is dislodged therefrom, the resulting reduction in vacuum through hose **126***h* allows compression spring **160***h* to expand and raise diaphragm **146***h* to a point where washer **144***h* bears against the bottom of member **154***h*. This action, through the aforedescribed mechanism, causes leaf spring **170***h* to raise thereby raising vacuum needle **18** and also raises recycle lever **132***h* to its tilted position. Thus, when this particular vacuum needle leaves the chip T-bar orientor **21**, the tilted portion of recycle lever **132***h* engages arm **35***h* of recycle switch VD1 (FIG. 1). The actuation of recycle switch VD1 inhibits the indexing of the conveyor tape for one cycle and allows a substrate on the tape to await the arrival of the following vacuum needle. The action of leaf spring **170***h* in raising vacuum probe **32***h* prevents the tip of probe pin **98***h* from being dipped into the flux on the surface of the positioned substrate, thereby preventing it from being clogged.

With reference now to FIGS. 6 to 8, vacuum manifold **52***h* and distributor **50***h* will be described. In FIG. 6, vacuum manifold **52***h* is shown in place over vacuum distributor **50***h*. The center shaft of centering plate **48***h* extends up through and aligns vacuum distributor **50***h* and vacuum manifold **52***h* with each other. To better visualize the structure of vacuum distributor **50***h*, refer to FIG. 7 where it alone is shown. A plurality of threaded fittings **200***h* are provided therein and adapted to accept vacuum nozzles (to be hereinafter described). Each threaded fitting is provided with two holes **202***h* and **204***h* both of which communicate with the upper surface of vacuum distributor **50***h*. Turning now to FIG. 8, a vacuum manifold **52***h* has been flipped over to show its underside which normally mates with the upper side of vacuum distributor **50***h*. Vacuum manifold **52***h* is provided with two inlet fittings, fitting **206***h* being utilized to provide vacuum and fitting **208***h* being utilized to provide pressurized air. Vacuum fitting **206***h* is provided with a hole **210***h* which communicates with a semicircular indented channel **212***h*. At one extremity, indented channel **212***h* is provided with a perpendicular leg **213***h*. Air inlet **208***h* is also provided with a hole **214***h* which communicates with the surface of vacuum manifold **52***h*. An atmospheric inlet **216***h* is also formed into the surface of vacuum manifold **52***h*.

Referring now back to FIG. 6, the relative positions of the air and vacuum inlets **206***h* and **208***h* respectively are shown as is also hte location of channels **212***h* with respect to holes **204***h*. Note that hole **202**h only has vacuum applied to it when it is coincidently positioned with perpendicular vacuum channel **213***h*. Note also that hole **214***h* in an inlet **208***h* is coincident with hole **202***h* in vacuum fitting **215***h* when both the air inlet and fitting are aligned.

Referring to FIG. 6A, a sectional view of a representative vacuum nozzle **230***h* in place in a vacuum fitting in vacuum distributor **50***h* is shown. When nozzle **230***h* is inserted into the vacuum fitting and tightened down, it compresses O rings **232***h* and **234***h* to provide airtight seals. Hole **236***h* provides communication between the interior hollow section of nozzle **230***h* and hole **202***h* in vacuum distributor **50***h*. An additional smaller diameter hole **238***h* is drilled in aligning pin **240***h* and opens the interior of nozzle **230***h* to hole **204***h* in vacuum distributor **50***h*. With vacuum manifold **52***h* in place as shown, perpendicular channel **213***h* communicates with both holes **202***h* and **204***h*. Thus, if a vacuum is applied via vacuum inlet **208***h*, air may be drawn through both holes **236***h* and **238***h* and **202***h* and **204***h* respectively, to create a substantial vacuum at the outlet of vacuum nozzle **230***h*. If now, vacuum manifold **52***h* is rotated with respect to vacuum distributor **50***h* allowing only hole **204***h* to communicate with vacuum channel **212***h*, a "metered" vacuum is applied via hole **238***h* to vacuum nozzle **230***h*. This is the same reduced vacuum referred to hereinbefore which is applied to vacuum needle immediately after it leavs pickup station **32***b*.

Referring now to FIGS. 9 and 9A, the means for providing controlled relative movement between vacuum manifold **52***h* and vacuum distributor **50***h* will be described. Cam **300***h* is mounted on shaft **26** and makes a single revolution for each index of chip placement head **17**. Cam **300***h* is provided with a high dwell which extends between 275 degrees–65 degrees and a low dwell which extends from 155 degrees–230 degrees. From 230 degrees to 275 degrees is a relative "steep" rise to the high dwell, whereas from 65 degrees–155 degrees is a relatively gradual slope to the low dwell. Follower **302***h* is coupled to arm **304***h* which is in turn rigidly affixed to shaft **306***h*. Also rigidly affixed to shaft **306***h* is vertical arm **308***h* which terminates in ball joint **310***h* (not shown in FIG. 9A). A threaded screw **332***h* is mounted on **308***h* and engages fixed stop **334***h* to provide a forward limit to the movement of arms **308***h*. Emanating from ball joint **310***h* in a generally horizontal direction is manifold actuating arm **312***h*. The other extremity of arm **312***h* terminates in a bearing **314***h* which is rotatably mounted via pin **316***h* to disc **318***h*. Extending downwardly from, and rigidly affixed to disc **318***h*, is camming bar **320***h* which engages the bearing surface of nut **62***h*. Also attached to disc **318***h* is a preloading spring **322***h*. Disc

318*h* is mounted to rotate about shaft 324*h* which is anchored in a portion of frame 326*h*. Also forming a portion of frame 326*h* (FIG. 9A) are pressurized air inlets 328*h* and vacuum inlet 330*h*.

As cam 300*h* rotates, follower 302*h* rises up on the high dwell and causes arms 304*h* to rotate in a counter clockwise direction. This rotation imparts a like rotation to arm 308*h* which draws manifold actuating arms 312*h* to the left. This in turn causes a clockwise rotation of disc 318*h* which is transmitted to manifold top plate 56*h* via camming bar 320*h* and nut 62*h*. This action causes a relative clockwise rotation to occur between manifold 52*h* and distributor 50*h* and results in a movement of the relative positions of the vacuum channel and communicating holes respectively contained therein.

Referring now to FIGS. 11 and 11A and B, the complete operation of chip placement head 17 will be described. Before proceeding, however, it should be noted that in FIGS. 11A and B, each of the eight arms (*a–h*) of spider 30*h* is represented by a straight line and each of the patricular stations is located as shown. Each straight line also denotes the location of the vacuum distributor nozzle associated with a respective spider arm. Superimposed on the line drowing is a representation of vacuum channel 212*h* and pressurized air hole 214*h* as they are both contained in vacuum manifold 52*h*. For purposes of explanation, only spider arm H will be hereinafter discussed. In FIG. 11, to which reference is now made, the horizontal axis is plotted in degrees of rotation of index shaft 26. The bars running horizontally in the figure are indicative of the actions at each station as well as the actions of the various portions of chip placement head 17.

Assuming now that index shaft 26 is at 170 degrees, index mechanism 25*h* has just lowered the spider down to its low dwell and spider arm H is positioned directly over chip pickup station 32*b*. The stop on vacuum needle 18 is an engagement with the stop in vibratory feed bowl 19 and all is in readiness for a chip pickup operation to occur. Shaft 26 continues to rotate and at 230 degrees, cam 300*h* (FIG. 9) begins to cause follower 302*h* to rise towards the high dwell. This, in the course of events, causes a clockwise rotation to occur in disc 318*h* with a like rotation occurring in vacuum manifold 52*h*. Thus, manifold 52*h* begins a clockwise rotation of 22½ degrees with respect to vacuum distributor 52*h*, causing vacuum channel 212*h* to also rotate clockwise. At approximately 245 degrees, vacuum channel 212*h* loses communication with vacuum hole 204*h* associated with spider arm D. Substantially simultaneously, positive pressurized air hole 214*h* is positioned over hole 202*h* and causes a flow of pressurized air therethrough. Since at this time, spider arm D is directly over the prefluxed substrate at placement station 34*h*, the puff of pressurized air is transmitted to vacuum needle 18 via hose 120*h* (FIG. 4) and positively pushes the chip down onto the fluxed surface of the substrate thereby assuring a positive connection therebetween. At this point restrictor 127*h* in hose 126*h* comes into play and delays the amount of the puff of pressurized air to the recycle lever actuation mechanism. This allows the chip to be set before the pressurized air causes the actuation of the recycle lever mechanism via diaphragm 146*h*. At 275 degrees (FIG. 11B) perpendicular vacuum channel 213*h* is in full communication with holes 202*h* and 204*h* of vacuum nozzle 230*h* associated with spider arm H. This applies a full vacuum to the associated vacuum needle 18 and causes a chip to be drawn up to the end of probe pin 98*h*. The application of the *full* vacuum to the vacuum needle acts to draw diaphragm 146*h* to its nonstressed position whether there is a chip present at chip pickup station 32*b* or not.

When shaft 26 and cam 300*h* reach approximately 325 degrees, index mechanism 25*h* raises the spider and begins to rotate it and vacuum distributor 50*h* in a counterclockwise direction. Vacuum manifold 52*h* does not change position, however, since came follower 302*h* is still riding on the high dwell of cam 300*h*. As can be seen from FIG. 11C, spider arm H has only hole 204*h* communicating with vacuum channel 213*h*. This relative rotation results in metered vacuum being applied via hold 204*h* to the vacuum needle on spider arm H. It is at this time that the operation of the recycle lever actuation mechanism occurs if no chip was picked up at chip pickup station 32*b*. As will be recalled, the metered vacuum which passes through hole 204*h* is sufficient to maintain diaphragm 146*h* in its nonstressed position only if a chip seals the bottom of probe pin 98*h*. If no chip has been picked up, recycle actuation lever 132*h* is tilted to interact with recycle switch lever 35*h*. At 65 degrees each arm of spider 30*h* is halfway between stations (FIG. 11C). At this point, follower 302*h* enters the gradual fall on cam 300*h* to the low dwell. Thus, vacuum manifold 52*h* begins to rotate in a counter-clockwise direction back to its original position. The combined rotations of vacuum manifold 52*h* and spider 30*h* continue until at 155 degrees (FIG. 11D) follower 302*h* reaches the low dwell of cam 300*h*, at which point the rotation of vacuum manifold 52*h* ceases. As can be seen from FIG. 11, spider 30*h* is at this point in the middle of its downward travel in preparation for the next cycle of operation.

In FIG. 11D, the positioning of the various spider arms A–H at the end of the cycle is indicated. The next cycle commences immediately after the operations at each of the respective stations.

What is claimed is:

1. In a multi-headed apparatus each head adapted to transport a device from a pick-up point to a placement point and deposit it at said placement point upon a coincidently arriving substrate, a new substrate normally presenting itself to said placement point coincidently with the arrival of each head, the combination comprising:

switch means positioned between said pick-up and said placement points for delaying the departure of a substrate from said placement point;

device pick-up means associated with each head of said apparatus said pick-up means adapted to manifest a signal indicating whether or not it is carrying a device;

switch actuating means associated with each head of said apparatus, said actuating means adapted to be positioned to interact with said switch means; and

control means coupling the device pick-up means and the switch actuating means on each head, said control means responsive to a signal manifesting the fact that said device pick-up means is not carrying a device, to position said actuating means to its switch interacting position;

whereby said substrate is delayed in its travel until a device-bearing pick-up means arrives at said placement point.

2. The invention defined in claim **1** further including means coupling said device pick-up means to said switch actuating means for retracting said device pick-up means in response to the positioning of said switch actuating means to its switch interacting position to a position which prevents it from contacting a substrate at said placement point.

3. In a multi-headed apparatus each head adapted to transport a semiconductor device from a pick-up point to a placement point and deposit it at said placement point upon a coincidently arriving substrate, a new substrate, normally presenting itself to said placement point coincidently with the arrival of each head, the combination comprising:

recycle switch means positioned between said pick-up and said placement points for delaying the departure of a substrate at said placement point;

a source of vacuum;

vacuum pick-up means associated with each head of said apparatus, each said pick-up means connected

to said vacuum source and provided with an output which manifests a vacuum signal indicating whether or not said pick-up means is carrying a semiconductor device;

recycle switch actuating means associated with each head of said apparatus, said actuating means adapted to be positioned to interact with said recycle switch means; and

control means coupling said pick-up means output with the recycle switch actuating means on each head, said control means responsive to a change in vacuum signal manifesting the fact that said pick-up means is not carrying a semiconductor device to position said actuating means to its recycle switch interacting position;

whereby said substrate is delayed in its travel until a semiconductor device-bearing pick-up means arrives at said placement point.

4. The invention as defined in claim **3** wherein said control means comprises:

a diaphragm;

a shaft connecting said diaphragm to said recycle switch actuating means;

resilient means coupled to said diaphragm for biasing said diaphragm and shaft to cause said recycle switch actuating means to be in its recycle switch interacting position;

a vacuum connection between the output of said vacuum pick-up and said diaphragm, the vacuum applied therethrough when said vacuum pick-up means is carrying a semiconductor device being sufficient to overcome the action of said resilient means and to return said recycle switch actuating means to a position where it does not interact with said recycle switch means.

5. The invention as defined in claim **4** further including:

leaf spring means coupling said shaft to said vacuum pick-up means, said spring means responsive to the biasing of said shaft to raise said vacuum pick-up means to a position where it is prevented from contacting a substrate at said placement point.

6. The invention as claimed in claim **4** wherein said vacuum pick-up means comprises:

a vacuum inlet connected to said source of vacuum;

a resilient tube, one end of which communicates with said vacuum inlet, and the other end of which is adapted to contact and be sealed by a semiconductor device;

a vacuum output, communicating with said vacuum inlet, the vacuum at said output being greatest when a semiconductor device contacts and seals said other end of said tube, the absence of a semiconductor device at said other end of said tube allowing air to be drawn up into said tube which thereby lowers the vacuum at said output.

7. In a multi-headed chip handling apparatus, each head adapted to transport a semiconductor chip from the pick-up point to a placement point and deposit it at said placement point upon a coincidently arriving prefluxed substrate, a new substrate normally presenting itself to said placement point coincidental with the arrival of each head, the combination comprising:

a recycle switch positioned between said pick-up and said placement points for delaying the departure of the substrate from said placement point;

a vacuum pick-up needle attached at an extremity of each head of said apparatus, said vacuum needle having a vacuum inlet, a vacuum outlet communicating with said inlet, and a resiliently mounted tube, one end of which communicates with said vacuum inlet and the other end of which is adapted to contact and be sealed by a held semiconductor chip, said vacuum outlet adapted to provide to substantially lessened vacuum when no chip is held by said resilient tube;

a diaphragm connected to said vacuum outlet;

a recycle switch actuation lever operatively connected to said diaphragm;

a spring coupled to said diaphragm for moving said diaphragm to a stressed position, the action of said spring being normally overcome by the vacuum applied via said vacuum outlet except when no chip is held by said resiliently mounted tube, at which time said spring moves said diaphragm and actuation lever to its recycle switch engaging position.

8. In a multi-headed apparatus, each head adapted to transport a semiconductor device from a pick-up point to a placement point and deposit it at said placement point upon a coincidently arriving prefluxed substrate, a new substrate normally presenting itself to said placement point coincidently with the arrival of each head, the combination comprising:

vacuum pick-up means associated with each head of said apparatus said pick-up means adapted to manifest a signal indicating whether or not it is carrying a device;

actuation means associated with each head of said apparatus and responsive to a signal from said pick-up means that it is not carrying a semiconductor device to raise said vacuum pick-up sufficiently to prevent it from contacting said prefluxed substrate and becoming clogged.

9. In a multi-headed apparatus, each head adapted to transport a semiconductor device from a pick-up point to a placement point and deposit it at said placement point upon a coincidently arriving prefluxed substrate, a new substrate normally presenting itself to said placement point coincidently with the arrival of each head, the combination comprising:

vacuum pick-up means associated with each head of said apparatus said pick-up means provided with a vacuum outlet and adapted to manifest a reduction in vacuum at said outlet indicating that it is not carrying a device;

spring biased actuation means associated with each vacuum pick-up means of said apparatus said actuation means connected to said vacuum outlet and normally held inactive by the vacuum from said outlet, said reduction in vacuum at said outlet allowing said spring bias to actuate said actuation means and raise said vacuum pick-up sufficiently to prevent it from contacting said prefluxed substrate and becoming clogged.

10. In a multi-headed apparatus, each head adapted to transport a semiconductor device from a pick-up point to a placement point and deposit it at said placement point upon a coincidently arriving prefluxed substrate, a new substrate normally presenting itself to said placement point coincidently with the arrival of each head, the combination comprising:

a source of vacuum;

a vacuum pick-up means including a vacuum inlet connected to said source of vacuum, a resiliently mounted tube, one end of which communicates with said vacuum inlet, and the other end of which is adapted to contact and be sealed by a semiconductor device;

a vacuum output, communicating with said vacuum inlet, the vacuum at said output being greatest when a semiconductor device contacts and seals said other end of said tube, the absence of a semiconductor device at said other end of said tube allowing air to be drawn up into said tube which thereby lowers the vacuum at said output;

a diaphragm;

a leaf spring having one end coupled to said vacuum pick-up and another end to a pivot point;

a shaft connecting said diaphragm to a point between said ends of said leaf spring;

a compression spring coupled to said diaphragm for biasing said diaphragm, shaft, leaf spring and vacuum pick-up means to their upper limit of travel, the tip of said vacuum pick-up being thereby prevented from contacting said prefluxed substrate at said placement point;

a vacuum connection between the output of said vacuum pick-up and said diaphragm, the vacuum applied therethrough when said vacuum pick-up means is carrying a semiconductor device being sufficient to overcome the action of said compression spring to return said diaphragm, shaft, leaf spring and vacuum pick-up means to their lowermost point of travel.

11. The invention as defined in claim **10** further including:

a source of pressurized air;

a restrictor air delay connected in said vacuum output;

switchable means connecting both said source of pressurized air and said source of vacuum to said vacuum pick-up means;

means for actuating said switchable means when said vacuum pick-up means is positioned at said placement point, said switchable means being actuated to apply said pressurized air to said vacuum pickup means to push said chip from said pick-up means onto said substrate, said restrictor air delay acting to delay the application of said pressurized air to said diaphragm until said chip has left said vacuum pick-up means.

12. In a feed mechanism having a head adapted to transport an article from a pick-up point to a placement point and deposit it on a support which is automatically fed from a supply thereof one-by-one to said placement point and having means for subsequent discharge of said support from said placement point with a new support fed to said placement point upon the said discharge of the first said support, the combination comprising:

retention means operatively associated to said placement point and adapted upon activation thereof for preventing the said discharge of the first said support;

means associated with said head to pick-up said article from a supply thereof for said transfer between said pick-up point and said placement point;

sensing means cooperatively associated with said pick-up means and adapted to provide a signal indicating whether or not said pick-up means is carrying said article; and

actuating means responsive to said sensing means for activating said retention means in response to a signal indicating that said pick-up means is not carrying said article thereby preventing discharge of the first said support from said placement point.

13. In a feed mechanism having a head adapted to transport a semiconductor device from a pick-up point to a placement point and deposit it on a substrate which is automatically fed from a supply thereof one-by-one to said placement point, and having a means for a subsequent discharge of said substrate from said placement point with a new substrate fed to said placement point upon the said discharge of the first said substrate, the combination comprising:

retention means operatively connected to said placement point and adapted upon activation thereof for preventing the said discharge of the first said substrate;

means associated with said head to pick-up said device from a supply thereof for said transport between said pick-up point and said placement point;

sensing means cooperatively associated with said pick-up means and adapted to provide a signal indicating whether or not said pick-up means is carrying said device; and

actuating means responsive to said sensing means for activating said retention means in response to a signal indicating that said pick-up means is not carrying said device thereby preventing the discharge of the first said substrate from said placement point.

14. In a multi-headed apparatus each head adapted to transport a device from a pick-up point to a placement point and deposit it on a substrate which is automatically fed one-by-one from a supply thereof and having means for subsequent discharge of said substrate from said placement point with a new substrate fed to said placement point upon discharge of the first said substrate in timed relationship with the arrival of a succeeding head of said mechanism carrying a second said device, the combination comprising:

retention means operatively connected to said placement point and adapted upon activation thereof for preventing the said discharge of the first said substrate;

means associated with each said head to pick up said device from a supply thereof for the said transport between said pick-up and said placement point;

sensing means cooperatively associated with each said pick-up means and adapted to provide a signal indicating whether or not said pick-up means is carrying a device during the said transport movement thereof;

an actuating means responsive to said sensing means for activating said retention means in response to a signal indicating that said pick-up means is not carrying a device during the said transport thereof thereby preventing the discharge of said substrate from said placement point until a device bearing pick-up means arrives at said placement point.

15. In a feed mechanism having a head adapted to transport an article from a pick-up point to a placement point and deposit it on a support, the combination comprising:

means associated with said head to pick-up said article from a supply thereof for said transfer between said pick-up point and said placement point, with said pick-up means mounted reciprocable movement between a retracted inoperative position and an extended operative position wherein said operative position is adapted for the said deposit of said article on said support and wherein said pick-up means is normally disposed in the said retracted inoperative position;

sensing means cooperatively associated with said pick-up means and adapted to provide a signal indicating whether or not said pick-up means is carrying an article; and

actuation means operatively associated with said pick-up means and responsive to said sensing means on a signal therefrom, that said pick-up means is carrying an article, to orientate said pick-up means in the said extended operative position.

16. In a feed mechanism having a head adapted to transport a semiconductor device from a pick-up point to a placement point and deposit it on a substrate, the combination comprising:

pick-up means associated with said head to pick up said device from a supply thereof for said transfer between said pick-up point and said placement point, with said pick-up means mounted for reciprocable movement between a retracted inoperative position and an extended operative position with said operative position adapted for the said deposit of said device on said substrate and wherein said pick-up means is normally disposed in the said retracted inoperative position;

sensing means cooperatively associated with said pick-up means and adapted to provide a signal indicating whether or not said pick-up means is carrying a device; and

actuating means operatively associated with said pick-up means and responsive to said sensing means upon a signal therefrom, that said pick-up means is carrying a device, to orient said pick-up means in the said extended operative position.

17. In a multi-headed feed apparatus with each head adapted for transport movement to transport a semiconductor device from a pick-up point to a placement point and deposit it on a substrate, the combination comprising:

pick-up means associated with each head to pick-up said device from a supply thereof for said transport between said pick-up point and said placement point with said pick-up means mounted on its respective head for reciprocable movement between a retracted inoperative position and an extended operative position wherein said operative position is adapted for the said deposit of the said device on said substrate and wherein said pick-up means is normally disposed in the retracted inoperative position;

sensing means cooperatively associated with each pick-up means and adapted to provide a signal indicating whether or not said pick-up means is carrying said device during the transport movement thereof between said pick-up point and said placement point; and

actuating means responsive to said sensing means upon a signal therefrom, indicating that said pick-up means is carrying a device to orient said pick-up means in the extended operative position.

18. In a multi-headed apparatus with each head adapted to transport a semiconductor device from a pick-up point to a placement point and deposit it at said placement point upon a coincidentally arriving pre-fluxed substrate, with a new substrate normally presenting itself to said placement point coincidentally with the arrival of a subsequent head, the combination comprising:

pick-up means associated with each head of said apparatus, with said pick-up means adapted to manifest a signal indicating whether or not it is carrying a device; and

actuating means operatively associated with each pick-up means of said apparatus and responsive to a signal from said pick-up means that it is not carrying a semiconductor device to orient said pick-up means in a raised position sufficient to prevent it from contacting said prefluxed substrate and becoming clogged.

References Cited

UNITED STATES PATENTS

2,494,474	1/1950	Fermanian et al.	219—85
3,056,317	10/1962	Huber et al.	228—6
3,083,291	3/1963	Soffa et al.	214—158
3,165,818	1/1965	Soffa et al.	29—203 X
3,337,941	8/1967	Drop	29—203
3,344,900	10/1967	Drop	29—203

THOMAS H. EAGER, *Primary Examiner.*