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(54) METHOD AND APPARATUS FOR MOUNTING INTEGRATED CIRCUIT SEMI-CONDUCTOR DEVICES ON A SUBSTRATE

(71) We, COMPAGNIE INTERNATIONALE POUR L'INFORMATIQUE CII-HONEYWELL BULL, a French Body Corporate, of 94 Avenue Gambetta, 75020 Paris, France, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:-

The present invention relates to a method and apparatus for mounting integrated circuit semi-conductor devices on a substrate.

In the modern tehcniques which are currently employed for producing electronic equipment, and particularly data processing assemblies, increasingly frequent use is being made of integrated-circuit semiconductor devices which are not enclosed. These unenclosed devices are normally referred to as integrated circuit chips. They are generally rectangular in shape and are provided on at least one of their sides with output conductors. Such devices are distinguished on the basis of their operational type or the categories into which their dimensions fall (these dimensions generally being of the order of a few millimeters). In order to make such devices easier to handle, it has been proposed to attach them to a flexible plastics film containing a plurality of rectangular openings which each have a device at their centre. This device is attached to the film by an array of conductors which each have one end soldered to a contact on the chip and the other end attached to an edge of the opening. To obtain one of the chips it is merely necessary to cut through the conductors in the gap between the chip and the film.

Also known is the use of connecting substrates, which frequently take the form of a board generally made of an insulating material, which is provided with connecting conductors produced in the form of circuits printed on the board. These conductors generally extend from connecting areas distributed around spaces each reserved for one type of chip and they terminate either at similar connecting areas or at outward connecting terminals intended to link the substrate to an item of electronic equipment.

Accordingly from a first aspect the present invention consists in a method of mounting different integrated semiconductor devices on a substrate having a plurality of spaces each intended to receive one of said devices, comprising positioning the substrate with regard to a first geometrical coordinate reference system, selecting the appropriate device for each of said spaces, positioning said selected devices with respect to a second geometrical coordinate reference system, successively shifting the substrate by altering the first reference system relative to the second reference system so as successively to line up each space on the substrate with the device selected therefor, successively positioning each device on its respective space, and attaching to the substrate each device which has been positioned on it.

From a second aspect the invention consists in apparatus for carrying out the aforesaid method comprising a table movable in a first direction and carrying a plate for supporting a substrate which is movable in a second direction transverse to said first direction, a plurality of tools for attaching devices of different dimensions to said substrate arranged in at least one line, and control means operative to position each space on said substrate in register with an appropriate attaching tool and to actuate said tool.

In order that the invention may be more clearly understood an embodiment thereof will now be described by way of example and with reference to the accompanying drawings.

In the drawings:

Figure 1 is a perspective view of a film supporting integrated-circuit semiconductor devices co-operating with a connecting substrate,

Figure 2 is a perspective view of an embodiment of apparatus according to the invention consisting of a soldering machine and a monitoring and control unit,

Figure 3 is a side view of the machine shown in Figure 2,

Figure 4 shows an embodiment of reel-identifying tag according to the invention,

Figure 5 is a longitudinal sectional view of a cutting head according to the invention of line V-V of Figure 6,

Figure 6 is a section on line VI-VI of the head shown in Figure 5,

Figure 7 is a front view looking along arrow VII of Figure 5, and illustrates the systems associated with the tool,

Figure 8 is a partially cut-away perspective view of the U-piece which is associated with the table for supporting the substrate and which is intended to cooperate with perforated plates carried by the cutting and soldering heads,

Figure 9 is a schematic view of the electrical circuit associated with each photo-electric cell carried by the U-piece shown in Figure 8.

Figure 10 is a schematic view of the means for setting up the substrate on the plate of the machine shown in Figures 2 and 3,

Figure 11 shows a means of defining positions representing the centres of the spaces for the semi-conductor devices with which the substrate is to be equipped,

Figure 12 shows a slotted abscissa plate resulting from the application of the method of definition illustrated by Figure 11, this slotted plate being intended to co-operate with the U-member shown in Figure 8,

Figure 13 shows a slotted ordinate plate resulting from the application of the method of definition illustrated in Figure 11, this plate being intended to co-operate with the U-member on the substrate-supporting plate,

Figure 14 is a block diagram of the circuits for monitoring and controlling the apparatus shown in Figure 2,

Figure 15A shows another example of a connecting substrate to be equipped by means of an apparatus according to the invention,

Figure 15B shows an external equipping plan for the substrate shown in the Figure 15A,

Figure 15C shows an internal equipping plan intended for the monitoring and control unit of the machine shown in Figure 14,

Figure 15D shows a non-optimised cutting sequence for the substrate shown in Figure 15A,

Figure 15E shows a cutting sequence which has been optimised by the monitoring and control unit,

Figure 15F shows the cutting path resulting from implementing the optimised sequences shown in Figure 15E,

Figure 15G shows a non-optimised soldering sequence for the substrate shown in Figure 15A,

Figure 15H shows a soldering sequence which has been optimised by the monitoring and control unit,

Figure 15I shows the soldering path resulting from implementing the optimised soldering soldering sequence shown in Figure 15H,

Figure 16 illustrates, by way of example, a manner of relating the designations for the positions used in drawing up the equipment programs shown in Figures 15 and the relative x and y co-ordinates associated with the substrate,

Figure 17 illustrates relationships which enable a changeover to be made from the relative x axis of the first reference system to the absolute X axis of the second reference system for the substrate-supporting table,

Figure 18 shows an example of the path which will be used to show how the optimum sequences are defined as this affects the Y axis movements of a substrate,

Figure 19 is a general flow-chart for the operation of a machine according to the invention,

Figure 20 is a flow chart relating to the drawing up and optimisation of the cutting sequence of a machine according to the invention,

Figure 21 is a flow chart representing the beginning of the cutting sequence and of the positioning of the table, the plate and the films,

Figure 22 is a flow-chart relating to the advance of the strip and the check that the semiconductors devices are satisfactory,

Figure 23 is a flow-chart relating to the descent of a cutting head,

Figure 24 is a flow-chart relating to the linking-up and formulation of the soldering sequence,

Figure 25 is a flow-chart relating to the positioning of the table and the plate and the descent of the soldering head,

Figure 26 is a flow-chart relating to the soldering and the cooling of the soldered joints,

Figure 27 is a flow-chart relating to the ascent of a soldering head,

Figure 28 is a flow-chart relating to the conclusion of operation of the machine, and

Figure 29 shows the successive positions of the head to which Figures 29 to 28 relate.

The object of the invention is clearly illustrated by Figure 1 of the drawings. This Figure shows a connecting substrate 10 having an array of internal conductors 12 which originate from connecting areas 14 distributed around the various spaces 16 which are each intended to receive a device or component. In the present case this device or component is a semiconductor device 18 of a certain type which is more generally referred to as a chip. Certain of the conductors 12 lead to terminals 20 for external connections which are intended to be connected into an item of electronic equipment, such as a data processing assembly for example.

The chips 18 may be classified in two ways. A first way is to consider them from the point of view of their operational type. As an example, chips 18*a* and 18′*a* may be of a first type whilst chip 18*b* may be of a second type. A second way is to categorise them by their dimensions. In the example illustrated, chips 18*a* and 18*b* belong to first and second categories respectively. It is however possible for devices of different types to belong to the same category.

Devices of any one type which are intended for placing on the substrate 10 are obtained from a support member 22 such as a film or strip which is made from an non-extensible flexible material. Along each of its edges this film is provided with a series of equidistant perforations 24 which are symmetrical about the longitudinal axis of the film. In addition, the film contains, in its central portion, a series of rectangular openings 26 around each of which is an array of conductors 28. At the beginning, each opening is occupied by a chip of the same type (type 18*a* in the present case), as shown in openings 26*a* and 26*b*. The conductors forming the arrays 28 rest on the overhang from the film 22 in order to support the chip by respective ones of its output contacts. A special feature of the film 22 is that it incorporates marks associated with those chips on the film 22 which have not met predetermined criteria in an operating test which is performed beforehand on all the devices on the film. The drawing shows one of these marks identified by the reference numeral 30. In the example illustrated, this mark is a small hole made in the edge of the film, between the perforations at the corresponding edge and the array 28 associated with the chip in opening 26*a*. Any other type of mark may of course be used. In other words, the device 18 in opening 26*a* has been judged unsatisfactory during a test performed beforehand on the film 22. The operation of the other devices 18 shown in Figure 1 has been judged satisfactory.

Thus, using a film 22, and with reference to opening 26*c*, the substrate 10 is shifted so as to align the centre of opening 26c with the centre 34 of a space (space 16*c* in the presence case), along the axis 32 shown in chain lines. Chip 18′*a* is then separated from the film 22 by cutting the array 28 between the chip and the edges of opening 26*c*, the conductors attached to chip 18′*a* being referred to in the text as the chip's external conductors. Chip 18′*a* is then set down in space 16*c*. As a result of this operation, chip 18′*a* will be disposed in the same way as chip 18*a* in Figure 1, this latter chip being assumed to have come from opening 26*d* in the film 22. Following this, an attaching tool, such as a soldering tool (not shown) will be pressed against the external conductors to attach them to the appropriate connecting areas 14 associated with space 16*c*. The final state is demonstrated in Figure 1 by chip 18*b*, which has its output conductors soldered to the conductors of the substrate 10.

In conclusion, the foregoing description shows that it is necessary to have a different film 22 for each type of chip required by the substrate. Consequently, as many cutting tools will be needed as there are types of chip required for a substrate, to enable the chips to be cut from the corresponding films. Conversely, given that the soldering is performed by applying pressure and heating the external conductors of a chip, it is only the dimensions of the chips which determine the number of soldering tools required. In other words, at least as many soldering tools are required as there are categories of device required to equip a substrate 10 with all its devices.

In what follows, the respective centres 34 of the spaces 16 on a substrate will be referred to as the "predetermined positions" on a connecting substrate.

Figures 2 and 3 given an overall view of an embodiment of apparatus according to the invention which is intended to solder the external conductors of semiconductor devices to a connecting substrate. The method of solder-mounting will be described below on the basis of this apparatus.

The apparatus 40 consists of a soldering machine 42 associated with a monitoring and control unit 44 which is designed to monitor and control the operation of the machine 42. In the present instance, unit 44 is a computer manufactured by the American Honeywell

Company and designated H316. An outline description of this unit is given below with reference to Figure 14.

The machine 42 illustrated in Figures 2 and 3 has a chassis 46, on which can be mounted cutting heads 48 and soldering heads 50 the number of which, in the embodiment being described, is equal to a maximum of ten, this number not being limiting. The description of Figure 1 showed that the number of cutting heads and the number of soldering head were functions respectively of the number of types and the number of categories of device required to fully equip a substrate. In the example being described, it will be assumed that five types of device and four categories of device are required. Consequently, the machine has to have five cutting heads 48A to 48E and four soldering head 50*a* to 50*d*. The tenth head 48F is not required and is not involved in the normal operation of the machine 42. For reasons which will be given below, it will be assumed that it is a cutting head.

The chassis 46 also incorporates a movable table 52 which carries a movable plate 54 intended to hold a connecting substrate 56 such as the substrate 10 shown in Figure 1. The table 52 moves on a threaded spindle 58 which is driven by a motor 60 controlled by unit 44. It is useful for the motor 60 to be a motor of low inertia such as a DC motor having a flat rotor. Plate 54 moves on a threaded spindle 62 which is driven by a motor 64 controlled by unit 44. It is useful for the motor 64 controlled by unit 44. It is useful for the motor 64 to be a low-inertia motor such as a DC bell motor (having an iron-free rotor).

Secured to the table 52 is a U-member 66 whose two sides are paralle to the threaded spindle 58 and which is intended to co-operate with first slotted plates 68 connected to respective cutting and soldering heads 48 and 50, as will be described below. Similarly, plate 54 has secured to it a U-member 70 whose sides are parallel to threaded spindle 62 and which is intended to co-operate with a second slotted plate 72, which is fixed to, but detachable from, table 52.

Figures 2 and 3 also show that the table 52 moves on two guides 74 parallel to the threaded spindle 58 by means of a bearing system employing mutually inclined rollers, such systems being well known in the art by reason of the stability which they confer on a moving part. Similarly, plate 54 moves on two guides 76 by means of a similar bearing system.

The chassis 46 also includes means for unrolling the films step-by-step, these means being formed in the present case by ten step-by-step film unrolling devices 78 associated respectively with the said heads of the machine. The unrolling devices 78 are of conventional construction and are each driven by a system provided with a motor 80, such a system being described in French patent No. 2,225,977 for example.

Figure 3 also illustrates the position of the film corresponding to each cutting head 48. In this Figure, the film 22, which is of the kind shown in Figure 1, is unrolled from a reel 82. The chassis 46 includes ten shafts 84 each able to hold one reel 82. Associated with the reel 82 is a tag 86 which identifies the reel by means of any desired code and this tag is connected to unit 44. Figure 4 shows an embodiment to the tag 86. This tag has a common line 88 and seven lines 90 which end in terminals 92. The connection or not by a link 93 to the common line 88 represents a binary number. A link may designate binary "0" for example and the absence of a link binary "1". With the tag shown in Figure 4, 126 different types of semiconductor chip can be identified by the unit 44 to which lines 88 and 90 are connected. With this code, it would also be possible for example to indicate the absence of a reel by the code 0000000 and the absence of coding by the 11111111. In other applications, the code could of course be selected as a function of the number of types of chip for the purpose of identifying them.

Returning to Figure 3, it can be seen that the film 22 from reel 82 runs on various rollers 94. The machine 42 also includes a detector 96, for detecting the end of the strip, which is electrically connected to unit 44.

Figure 5 is a schematic sectional view of the structure of a cutting head 48. Similar heads have already been described in British Patent Specification No. 1444406. The head 48 in Figure 5 has a substantially rectangular body 98 which is provided on one side with a groove 100 intended to be co-operatively engaged with a rib 102 (Figure 2) on the chassis 46 of the machine 42 to enable the head to be detachably mounted on the chassis 46. The side of the head 48 opposite from that bearing the groove 100 contains an opening 104 through which passes a support member 106 which is secured on one side to a slider 108 carrying a cutting tool 110 and on the other side to a leaf spring 112. The other end of the leaf spring is attached to a transmission piece 114 which co-operates with a threaded spindle 116 which is driven by gearing 118 coupled to a DC motor 120. The threaded spindle 116 is coupled to upper and lower stop members 122. The threaded spindle 116 passes through the transmission piece 114 and the latter is prevented from turning to enable the rotary movement produced by the motor 120 to be converted into a linear movement of transmission piece 114 along the axis of the threaded spindle. On the side facing member 106, the transmission piece 114 incorporates pressure detecting means which are formed in the present case by a linear potentiometric sensor which, in the example illustrated, has its fixed part secured to piece 114 and connected to a source of voltage (not shown) and its moving part 126 (the moving contact of the potentiometer) attached to the support member 106. Member 106 also incorporates the moving part (moving contact) 128 of a means of monitoring the travel of the tool, which is formed in the present case by a linear potentiometer 130 which is attached to the body 98 of the head 48 and is connected to a source of voltage (not shown), the moving contacts 126 and 128 are individually connected to unit 44 by means which are not shown.

Unit 44 is also electrically connected to the motor 120 in order to control it.

The bottom wall of the body 98 of the head 48 contains a slot 132, intended for a film 22 to pass through as shown in Figure 3. Under the tool 110, the bottom wall is extended to form a die 134 which will be described below in detail in reference to Figure 7. However, mention will be made of the presence of a detector 136 for checking the quality of chips, which is intended to co-operate with the holes 30 (Figure 1) which are formed in a film 22 to indicate that a semiconductor device is unsatisfactory. In the example illustrated, the detector 136 is a micro-switch which receives a member which acts by means of the pressure of a gas to detect the presence of a hole 30. The means of supplying this detector are now shown. The detector is connected to unit 44 and to the step-by-step unrolling device 78 corresponding to head 48 to enable it to cause the unrolling device to skip the unsatisfactory semiconductor device and to bring a satisfactory semiconductor device under the tool 110.

Figure 6 is an enlarged scale sectional view on line VI-VI- of Figure 5.

The Figure 6 shows in detail the way in which the support member 106 is guided in the opening 104 in the body 98 of the cutting head 48. Member 106 contains two opposing lateral grooves 138 which co-operate with respective ones of two other V-shaped grooves 140 in the sides of opening 104. Coupling is by ball-bearings 142 which use the V-grooves 138 and 140 as guides. The slider 108 shown in Figures 5 and 6 contains a tool supporting member 144 which is made of a mechanically rigid material.

Figures 5 and 7 show the structure associated with the tool 110. As shown in Figure 5, the cutting tool 110 contains a central passage 146 which is connected to an external duct 148 which communicates with a suction source (not shown). The purpose of this is to retain the semiconductor device which has been cut free during the travel of the tool towards the substrate 56. This feature is described in the aforementioned French Application No. 72-39747.

With the cutting tool 110 is associated a system 150 for positioning the film 22 and holding it in position. System 150 includes two shafts 152 which are provided with respective retaining heads 154 and respective coiled return springs 156, of which one end bears against the lower end of the slider 108. The two shafts 152 are fixed to a bar 158 against which the other ends of the springs 156 bear. This bar is intended to press against the film 22, while the shafts are intended to be thrust a little way into the perforations 24 in the film, in order to ensure that the position of the film is steady whilst a chip 18 is being cut free. The bar 158 and die 134 are of course provided with central holes to allow the tool 110 to pass through. The die 134 is also provided with orifices 160 which are intended to accept the ends of the shafts 152 and to locate them and the film 22 during the cutting operation.

The soldering heads 50 may be of the same type as the head 48 shown in Figures 5 to 7, although in the case of the former, the tool 110 is a soldering tool. In the example being described, the soldering tool is one associated with an electrical heat element. The time for which current flows can be monitored in a known fashion by means of a thermocouple (not shown). It is also possible to add to the head a circuit for cooling the soldered joints by means of nitrogen (not shown). In addition, since the soldering head 40 does not co-operate with a film 22, it will incorporate neither the slot 132 nor a system 150 for positioning the film and holding it in position.

Finally, the cutting and soldering heads 48 and 50 are both provided at the bottom with a rib 162 intended to act as an adjustable seating for a removable slotted plate 68 (Figures 2, 8 and 12).

Figure 8 illustrates the transmitter/receiver system which is associated with a U-member 66 co-operating with a slotted plate 68. It will be assumed that the plates 68 contain four rows of oblong slots 164 (see Figure 12) which all have their major axis parallel to a given direction (the vertical direction in the drawings). The transmitter/receiver system consists of a transmitting device which, in the present example, is formed by an electric lamp 166 of elongated form which is orientated in the given direction (vertically in the drawings), and the length of which is sufficient for it to extend across all four rows of slots 164. This lamp is mounted in one side of the U-member 66 and is electrically connected to a source of electrical energy (not shown). The transmitter/receiver system also includes a receiver device 168 which takes the form of a panel 170 containing four photoelectric cells 172 which are in line in the said given direction (the vertical direction in the drawings). Each of these cells has two adjacent receiving areas 174*a*, 174*b* which are separated along a line parallel to the said given direction. The panel 170 is mounted in the other side of the U-member 66 in such a way that the light beam 176 which passes through a slot 164 (a slot in row R4 in Figure 12) covers the entire length of the areas 174 in the said given direction but only a proportion of the width of these areas.

Figure 9 is a schematic illustration of the electrical circuit associated with each of the cells 172. The areas 174*a*, and 174*b* are connected, by connecting lines 176*a* and 176*b* respectively, to the positive and negative inputs of an operational amplifier 178 which is also connected to two voltage sources +V and −V. The output of the operation amplifier 178 is connected to an energising terminal of motor 60, whose second energising terminal is connected to earth. The lines 176*a* and 176*b* are also coupled to the control unit 44, which latter selects the row of slots which is to be looked at counts the number of slots in this row which pass by, as will be described below.

The positioning of the U-member 66 relative to a slot 164 takes place as follows. When the light beam 176 inpinges in a random fashion on the two areas 174*a* and 174*b*, the latter generate electrical currents which are of different respective values. The difference between the currents results, via operational amplifier 178, in motor 60 being energised to drive the table 52 and the U-member 66 in a direction which depends on the sign of the difference between the currents. In this way, the table 152 and the U-member 66 will come to a halt when areas 174*a* and 174*b* are receiving equal luminous fluxes and emitting electrical signals of equal magnitude.

The plate 54 is positioned by means of U-member 70, which has a transmitter/receiver system similar to that of U-member 66. Its photoelectric cells are similarly connected by operational amplifiers to the motor 64 driving the plate. Similarly, the U-member 70 will stop at a slot in the plate 72 determined by unit 44.

A description will now be given of the means of positioning the substrate 56 on the plate 54 of the machine 42. Figure 10 illustrates these means. Before these means are described, it should be mentioned that the positioning of a substrate 56 takes place with reference to a system consisting of three selected points 180*a*, 180*b* and 180*c* at the periphery of the substrate. In order better to bring out one of the features of the invention, the irregularity of the edges of the substrate 56 is exaggerated in Figure 10. The three points 180*a* to *c* are three points at these edges which have been defined in relation to a given reference system so that when transposed into a similar reference system, the substrate occupies precisely the same position as that which was defined with reference to the original reference system. In the case of Figure 10, this reference system is formed by three rollers 182*a*, 182*b* and 182*c* which are free to pivot on fixed shafts. When substrate 56 is in place, the points 180*a*, *b* and *c* should correspond with points on the peripheries of rollers 182*a*, *b*, and *c* respectively. This is a convenient means of reproducing the position originally selected. To set up the substrate 56 in this way and hold it in position, three other rollers 184 are provided, these rollers being free to rotate on respective shafts which are able to move in slots 186. By withdrawing the rollers 184, the substrate 56 can be inserted between rollers 182 and 184 and a mechanical system (not shown), when released, then draws the shafts of rollers 186 towards rollers 182, thus automatically positioning the substrate. Figure 10 shows an intermediate stage of this positioning operation. From Figure 10 can be seen that the movement of the long edge of the substrate in response to the pressure from rollers 184, will cause the rollers 182 to turn as dictated by the irregularities. It should be mentioned that if the rollers 182 were pegs incapable of rotation the edges would rub against them. Depending upon the irregularities countered, the frictional forces would be more or less pronounced and would hamper the movement of the substrate. In addition, there would be a danger of removing material from the irregularities, which might detract from the accuracy with which the substrate needs to be positioned. The use of movable rollers solves all these problems. Once the substrate has been positioned on the plate, it is held in position by a suction system (not shown) which acts from below the substrate.

Now that all the details of the structure of the machine 42 have been described, the operation of the machine will be described with reference to a particular substrate, which is given solely by way of example. It will be recalled that reference numeral 34 was used for the centres of the spaces reserved for each chip on the substrate shown in Figure 1. In the case of the substrate 56 which is shown in Figure 11, the centres 34 of these areas are identified by references (relative co-ordinates) relating to a first reference system which is defined in the example being described, where the co-ordinates are cartesian, by two mutually perpendicular axes Ox and Oy which represent two adjoining edges of the substrate. In this way the centres 34 may be defined by the points of intersection of pairs of lines parallel to these axes. For reasons which will because clearer at a later stage, the substrate is divided into four rows (also referred to as "corridors") R1, R2, R3 and R4, and four columns C1, C2, C3 and C4, the centres 34 thus each occupying a single box defined by a a column and a row. For convenience when discussing the positions 34, they will hereafter be referred to by the letter P followed by the figures for their columns and rows. In each box, the positions (centres 34) are defined by the points of intersection of two line-segments parallel to the axes. The horizontal segments are marked by the letter H followed by the same references as are used for the corresponding positions, and the vertical segments by the letter V plus the corresponding references. As an example, position P44 has corresponding segments H44 and V44. The slots in the plates 68 are formed by using the vertical segments V as a basis as shown in Figure 12. The length of the slots is of course independent of the length of the segments V. Similarly, slots in plate 72 are formed by using the H segments, as illustrated in Figure 13.

The types of chip intended for the substrate 56 are then determined as a function of the respective positions P of the chips 18 intended for the substrate 56. It was assumed above that five types of chip were needed to equip the substrate, which called for five cutting heads 48A to 48E. It was also assumed that these five types represented four dimensional categories, requiring there to be four soldering heads 50*a* to 50*d*. The table below gives an example of correspondences between the positions P and the types and categories of chips to be positioned on the substrate. The cutting and soldering heads are referred to by letters corresponding to the types and categories.

Type	*Category*	*Positions*
A	a	P_{14} P_{34} P_{42}
B	b	P_{11} P_{13} P_{24} P_{44}
C	a	P_{32}
D	c	P_{21} P_{22} P_{33} P_{43}
E	d	P_{23} P_{41}

In this example it is assumed that types A and C are of the same category a.

To produce the machine 42, a second reference system (absolute co-ordinates x, y) is established which is independent of the first reference system and with reference to which are defined the sitings of the devices intended to be positioned on the substrate and the points where soldering is to take place. In the machine 42, the said sitings correspond to the axes of the cutting tools of heads 48A to 48E and the said soldering points correspond to the axes of the soldering tools of the heads 50a to 50d (Figure 2).

In the present embodiment, the axes of the cutting tools are arranged in a first straight line, and the axes of the soldering tools in a second straight line which coincides with the first. As can be seen in the drawings, the cutting and soldering tools lie along a line parallel to the threaded spindle 58 for moving the table 52. In the present case, this also corresponds to a direction parallel to the axis Ox defined above by the substrate 56 (Figure 11) when the substrate is mounted on the plate 54 in the way shown in Figure 10. The slotted plates 68 are aligned in this direction.

It is now a simple matter to explain the operation of the machine 42. First of all, the substrate 56 is set up on the plate 54 in an extremely accurate fashion, as shown in Figure 10. In the example illustrated, this means that the substrate 56 is disposed in such a way that its x-axis is parallel to the common line of alignment of the cutting and soldering tools. At the beginning, the table 52 and the plate 54 also occupy absolutely precise positions (Xo, Yo) relative to the line of alignment of the tools. This position is determined by unit 44 as indicated below.

With the table and the plate in the starting position (Xo, Yo), the unit 44 brings the motors 60 and 64 into operation to position the substrate correctly under the tool of head 48*a*. Assuming that the types and categories which appear in the table above correspond to respective ones of the heads shown in Figure 2, unit 44 will operate the motor 60 and 64 in such a way as to line up the axis of the tool of head 48*a* with, for example, position P14. The table and the plate 54 then adjust themselves respectively to the slot V14 in the plate 68 associated with head 48A and to slot H14 in plate 72, in the fashion which was described above with reference to Figures 8 and 9. The slots are known to unit 44, which has been provided with details of the first reference system, the types and categories of semiconductor device to be used, the correspondence between the positions P and the types and categories, and the arrangement of heads relative to one another. Assuming that the plate 68 for head 48A takes the form shown in Figure 12, unit 44 selects the first slot in the complete row R4 formed by a line of plates 68. After bringing the substrate to a halt with position P14 on an axis similar to axis 32 in Figure 1, unit 44 actuates head 48A to cut the device from the film 22A (for devices of type A). The operation of this head will be described further on. When the chip has been laid down at position P14, unit 44 then selects position P34 (see the above table), for example, and operates motors 60 and 64 accordingly.

Position P34 (the third position in the present case) is selected by unit 44 by counting the slots in row R4 in plate 68, whilst the ordinate position remains the same. After all the operations involving head 48A have been performed, the table and the plate position themselves relative to the head 48B in conformity with the above table. This involves shifting the substrate and the first reference system in relation to the line of alignment of the tools which defines the said second reference system, in order to line up each position with the corresponding semiconductor device 18.

Once the substrate has received its last device 18 from head 48A, it then passes under the corresponding soldering heads. Head 50*a* for example, which is for category *a*, will operate at positions P14, P34, P42 and P32.

Some comments may now be made regarding the sub-division into rows and columns of the x and y axes defined on the substrate, as shown in Figure 11. If this subdivision were not made, plate 68 for example could contain a series of slots 164 occupying the entire width of the plate. As a result, the slots corresponding to line segments V34 and V32, for example, would be very close together, and this would upset the positioning of the substrate and the servo-control of the motors. By virtue of the subdivision shown in Figure 11 for example, the slots in each row are sufficiently far apart for the servo-control to be satisfactory and to allow the substrate to be properly positioned.

The operation of a head 48 will now be described with reference to Figures 5 to 7. When a desired position P on the substrate is on the axis 32 of the tool 110, unit 44 operates the motor 120 to cause transmission piece 114 to descend together with, via leaf spring 112, the tool 110. The travel of the tool 110 is represented in Figure 5 by an axis 88 whose origin 190 is situated at the lower level of tool 110 when the latter is in its initial raised position. A mark 192 corresponds substantially to the plane of the array of the conductors 28 on the substrate 22 (Figures 1 and 7). Between 190 and 192, the tool does not encounter any obstacles and the leaf spring 112 is thus under a normal stress of a magnitude which is indicated electrically by the moving contact 126 of potentiometer 124. At the same time, the movement of piece 114 is indicated electrically by the moving contact 128 of potentiometer 130. The positions 190 and 192 are shown close to potentiometer 130 in Figure 5 by the corresponding positions of its moving contact. Consequently, over the predetermined interval 190 to 192, unit 44 monitors the stress on leaf spring 112 by means of potentiometers 124 and 130. When the tool reaches level 192, it comes into contact with the conductors Forming array 28 which are attached to a chip 18, whilst a drop in pressure is brought about in passage 146. The force of impact of the tool against the array 28 is reflected via leaf spring 112 at moving contact 126 and is translated into an electrical value by potentiometer 124. Unit 44, which knows position 192 from potentiometer 130, is in a position to evaluate the magnitude of the force of impact. If for example such a force had been produced in the interval 190 to 192, the impact force would have been considered as a fault on the part of the machine and would have caused head 48 to be stopped. Similarly, unit 44 recognises the force of impact at level 192, and is advised of its magnitude by potentiometer 124. Means are provided in unit 44 to compare the magnitude of this force with a predetermined upper-limit value. Should the force of impact exceed the limit value, unit 44 would consider the force of impact to be a fault on the part of the apparatus and would stop head 48 from operating. Between level 192 and the level 194 representing the upper face of substrate 56, the tool descends with its chip 18 held suspended from it by means of the reduced pressure in passage 146. The travel involved as detected by potentiometer 130 and the pressure is measured by means of potentiometer 124. In this case too the unit makes the same checks on pressure. When unit 44 knows from potentiometer 130 that the tool has reached the level 194 representing the upper face of the substrate 56, the reduced pressure in passage 146 ceases in order to drop the chip 18, whilst unit 44 returns the tool 110 to its original position 190. At level 194, it also checks the force with which the tool presses against the substrate.

The soldering heads 50 may be similar to the heads 48 with tool 110 and its passage 146 replaced by a soldering tool associated with leads for supplying power to the electrical soldering heating element. When this is the case, level 192 no longer has to be allowed for. The soldering operation may be controlled by a thermocouple associated with the soldering tool 110, or as a function of the time for which the soldering current is applied.

The unit 44 will now be described. The above description has set out the functions by which it monitors and controls the operation of the machine 42. Unit 44 is also provided with a programme for optimising the performance of the machine, by selecting the way in which the operating sequences succeed one another and by reducing to a minimum the amount of time they take. In other words, unit 44 calculates the shortest path to equip a given substrate in a minimum time. It does so on the basis of a plan for equipping the substrate, as illustrated by Figure 11 and the above table, on the basis of the arrangements of the heads, and on the basis of monitoring data which the unit at all times receives from machine 42 (the pressure exerted by the tools, whether the semiconductor devices 18 are satisfactory, whether the end of the film has been reached, etc.). If, for example in the course of an operation the detector 96 for detecting the end of the strip should make such a detection, the process would continue while the operator was replacing the film, either on the appropriate head or on another head such as head 48F which had been kept in reserve.

Figure 14 is a block diagram of the apparatus 40 as seen by unit 44. Figure 14 shows the principal components of the unit 44 operating in relation to machine 42. In block form, unit 44 considers unit 42 as being formed by a monitoring block 196 connected to the mechanical assembly 198 of machine 42, this assembly consisting in particular of the cutting and soldering heads, the means for shiting the substrate, the means for advancing the strips and so on. As for unit 44, it was stated above that it was formed in essence by the computer H316 already mentioned. In Figure 14, this computer is represented by a cabinet 200. This cabinet contains a power supply block 202 connected to a desk 204 which communicates with an interface block 206 which acts as an interface between unit 44 and machine 42. The interface block 206 communicates with a memory block 208 which, in the example illustrated, has a capacity of 8K words. The monitoring and control block 196 communicates with the desk 204 and the interface block 206, and vice versa. The memory block receives from a tape reader 210 information relating to the equipment plans for the substrates, represented by block 212, and information relating to the monitoring by calculator 200 of the operation of machine 42, this information being represented by block 214. This monitoring is performed by means of a programme which will be termed the "monitor" in what follows. The memory block 208 is also in communication with a teleprinter 216. In addition, a tape perforator 218 receives from the memory block information for safeguarding the monitor, this information being represented by block 220.

Certain preliminary remarks should be made before examining the way in which the process is monitored by the computer. The operation of the machine, from the operator's point or view is as follows. He first of all ensures that the machine 42 is loaded with reels 82. No specific station is alloted for a given type of chip. The operator is under no obligation, before starting the process, to check that all the types of chip required are present, that the numbers available are adequate, that the chips available at a station are compatible with the type of cutting head at the station, or that all the soldering heads required are present. The operator then places the substrate which is to be equipped on plate 54. He feeds in the type of substrate using the teleprinter 216 and initiates the process. From this moment the operator will have no more to do except in case of incident. Any action taken by him will however still be monitored by the computer.

The computer extracts from its memory 208 the plan for equipping the substrate to be equipped, checks whether all the types of chip 18 required are present by means of the tags 86, determines the shortest path which the table will have to follow, and starts up the process.

The substrate is equipped as described above.

With the machine described above, it takes approximately ten minutes to equip a substrate having sixty-four positions, during which time the operator has nothing to do.

It is possible for the operator to interrupt the automatic process of equipping a substrate at any time during its course. This interruption is however monitored by the computer so that the process can be resumed and finished in the normal way.

It was stated above that the process was monitored by the computer by means of a programme termed the monitor. The general organisation of this programme and details of how it is put into effect appear in the flow charts shown in Figures 19 to 29, which form part of the text of the specification. Certain additional pieces of information will be given here.

Regarding the general organisation of the monitor, the equipment plans are fed into the monitor either "on line" from the teleprinter in the case of occasional simple plans, or individually from punched tape for use in sequence, or collectively from punched tape so that the computer can assemble a file of equipment plans. The section of the memory block 28 not used by the monitor is set aside for such a file. Approximately fifty equipment plans for substrates having sixty-four positions may be stored there. Loading such a file takes only approximately thirty seconds and can be done independently of the loading of the monitor. Under production conditions, it is obviously the third method of feeding in equipment plans which will be used as a rule.

The working options provided are the equipment of substrates as a main option and, as service options; the up-dating in the monitor of a table containing the recognised types and categories of device and the associated types of cutting and soldering heads, which table is used when checking the feasibility of the equipment plan and when drawing up the equipment sequences; printing out the state of this table; printing out a list of equipment plans contained in the memory file; printing out the state of the machine 42, the kinds and categories of devices 18 and the kinds and categories of cutting heads 48 and the welding heads 50 present, and the state of the reels; and finally safeguarding the monitor, this option enabling the monitor to be preserved in its current state in the form of a self-loading punched tape, in particular after the table of devices and heads has been up-dated or the parameters of the process have been altered.

Some space will now be devoted to the tasks performed by the monitor. The list below presents a summary of the operations which are described in greater detail in the flow-charts shown in the accompanying drawings (Figures 19 to 28).

Before starting the equipment process, the monitor:

- calls up the equipment plan (from the memory file or from outside).
- checks the general state of the machine,
- checks whether the types of device required are present (which types need not be mounted in the machine in any specific way),
- checks for compatibility between types of device and types of cutting head,
- checks that the requisite soldering tools are present (which tools need not be mounted in any specific way in relation to one another),
- indicates to the operator any corrective action to be taken and monitors this action,
- and determines a sequence for equipping the substrate which minimises the time taken to do so, given that equipment the plan may be given in any order and allowing for the siting of the tools.

Whilst the equipping process is going on, the monitor;

1) In the cutting phase:

- brings about and monitors the XY movements of the table which bring the position P to be equipped under the requisite cutting head,
- checks the state of the supply reel, warns the operator if the reel becomes empty, and if necessary re-optimises the cutting sequence in the event of a change of reel,
- simultaneously with the movement of the table, it causes the film 22 to be advanced until a satisfactory device is reached.
- checks the descent of the cutting tool, the suction on the device which is cut free, the tool's arrival against the substrate with a monitored force, and then the ascent of the tool,
- and links up with the next cutting and positioning operation.

2) It automatically links up the cutting phase with the soldering phase.

3) In the soldering phase it:

- brings about the monitors the X, Y movements of the substrate which bring the device to be soldered under the requisite soldering tool,
- brings down the tool and brings it to a halt against the substrate with a monitored force,
- monitors the welding of the device with reference either to temperature or time, with the parameters depending upon the type of soldering tool employed,
- monitors the cooling of the soldered joints and then the upward movement of the tool,
- links up with the next soldering operation.

4) It keeps a permanent watch on the safety functions of the machine (that suction is present, that there are no excessive strains on the tools, that the electrical soldering generator is in a satisfactory state) and intervenes in case of incident to warn the operator and inform him of the corrective action which needs to be taken, and then monitors this action.

At the end of the equipping process, it returns the substrate to the loading point, links up with the next job and increments.

Details will now be given on how the sequences are drawn up and optimized.

All the states through which the data passes whilst operations are going on are shown in Figure 15, using a simple example which is different from that already given above so that the invention can be more satisfactorily illustrated.

Let it be assumed that the substrate is to be equipped with devices of given types 3 and 5 at the points indicated in Figures 15A. It will be assumed that these devices are avilable at two stations 4 and 5 which are represented in Figure 2 by the positions of heads 48D and 48E. It will also be assumed that the two kinds 3 and 5 belong to the same category and are dealt with by a soldering head of type 1 which is located at a station 1 occupied in Figure 2 by head 48A.

The equipment plan, in its external format, (Figure 15B) gives for each position to be equipped the type of device which is to be installed there. This list may be in any order whatever. In the monitor it will be in the internal format shown in Figure 15C.

Each position to be equipped has associated with it one memory word in the computer 200 which consists of the X, Y co-ordinates of the position on the substrate and a code for the type of device.

The relationship between the designations for the positions used in drawing up the equipment plans and the relative X, Y co-ordinates is shown in Figure 16.

The transition from the equipment plan to the cutting and soldering sequences consists in replacing the data (x, y, type of device) given by the quipment plan by the absolute co-ordinates X, Y for the position which the plate needs to occupy if the x, y position to be equipped is to be situated under the head of a tool containing the requisite type of device (during the cutting sequence) and under a compatible soldering head (during the soldering sequence).

Consideration will now be given to the system of absolute X, Y co-ordinates for plate 54. The monitor knows the position of the plate by means of a system of absolute co-ordinates or scales XY. The X scale will first be considered. The various aspects of the X scale are shown in Figure 17. When the table is moving forward, a scale is used in which the successive positions in which the table is to stop, are numbered 1, 2, etc. from the loading point Xo = O.

It has been seen that each row or corridor on a slotted plate has its own scale, with points in the same serial position not necessarily occupying the same physical position. In the case which is now being considered the maximum value of X on the "forward" scale is $8 \times 10 = 80$.

When a table is moving backwards, the scale used is one in which the successive positions in which the table stops are measured from an imaginary point on the extreme right of the machine 42, as seen in Figure 2, (Xn = 128) and they are numbered 129, 130 etc. Each row obviously has its own scale for backward movement.

From the monitor's point of view, the forward and backward scales form a single scale with intersecting abscissas. This expedient makes it possible to use the same algorithm for optimising the equipment sequences whether the table moves forwards or backwards.

The correlations which make it possible to change from the relative x axis position to the absolute X position of the table are illustrated in Figure 17.

As regards the Y scale, the relative y axis position and the absolute Y position of the table correspond (Y = y).

There will now be described the transition from the equipment plan to the un-optimised cutting sequence. In all cases, the cutting sequence is always drawn up and initiated by pre-planning for the table a succession of movements in the forward direction.

In the case of the example selected, a transition will be made from the equipment plan (Figure 15C), to the un-optimised cutting sequence (15D), using the equations (1) from Figure 17, with:

- the station 4 address for devices of type 5
- the station 5 address for devices of type 3.

It will be noted that in both tables in Figures 15, the various positions to be equipped appear in the same order.

Before being carried out, the cutting sequence is optimised.

The optimising procedure consists in minimising the distance travelled by the table and plate assembly both in the abscissas direction and in the ordinate direction.

Since the two movements are independent and simultaneous, the X path and the Y path are minimised independently of one another.

Consideration will first be given to the X optimisation. In the case of X, the practical situation which exists is one which simplifies the operation; the distance between two successive heads (55 millimeters in the examples selected) is greater than the size of the largest substrate accepted by the machine (approximately 50 millimeters). As a result, if the table is shifted with a movement in a constant direction from one end of the machine to the other, the substrate which it carries is completely clear of one head before arriving under the next head. Consequently, to minimise the X path, it is merely necessary to control the table in such a way that it travels from the loading point Xo to the requisite point furthest to the right in a succession of advances (with halts at the required points), and then to cause it to return to Xo in a succession of backward steps (with halts at the requisite points).

This result is achieved by arranging the various items in table 15D in order of ascending value. The result of this arrangement is an optimised cutting sequence in the X direction. It will be noted that, as a result of this re-arrangement, all the Y plots which share the same X plot are likewise in ascending order.

The & optimisation will be understood by referring to Figure 18, which shows the following general case. With a certain X measurement Xo, the last position YO to be equipped has been equipped. The next positions are situated at X measurements X1, and then X2. The measurements XO X1, and X2 not necessarily contiguous. Between the extreme positions Y11 and Y1n, there may be any number of positions to be equipped. The same applies between the Y21 and Y2n.

To minimise the Y path, the following rules are applied,

1) If the path (YO, Y11) < the path (YO, Y1n), the course will be from YO to Y11 ..... Yn.

2) If the path (YO, Y11) < the path (YO, Y1n), the course will be from YO to Y1n ..... Y11.

3) If the two paths are the same, consideration will be given to the situation on the X2 line.

3.1) If (the shorter of the paths Y11, Y21 and (Y11, Y2n)) < (the shorter of the paths (Y1n, Y21) and (Y1n, Y2n))

the course will be from YO to Y1n ..... Y11.

3.2 If (the shorter of the paths (Y11, Y21) and (Y11, Y2n)) ⩾ (the shorter of the paths (Y1n, Y21) and (Y1n, Y2n))

the course will be from YO to Y11 ..... Y1n.

Bearing in mind the fact that after the X optimisation all the Y measurements on the same X line will already be in ascending order, the application of the foregoing rules will result either in all the Y measurements on the same X line being left in this order, or in this order being reversed in the equipping sequence. The application of this Y optimisation to the example in Figure 15A results in the Y measurements crossed through in table 15E being reversed.

As a consequence of this optimisation, the devices are cut free and positioned in the order indicated by the cutting path shown in Figure 15F.

Whilst the cutting sequence is being carried out, it is altered if at any given moment the reel at the station which is supplying the devices 18 empties and if the monitor finds identical devices available at another station either to the right or left of the station which has emptied. To allow for this new situation, the part of the cutting sequence which has not yet been carried out is re-evaluated and re-optimised. In cases where the new station is to the left of the old one, the positions which it has not been possible to equip will be so equipped during the return phase of the table before the soldering sequence. In all cases, the re-optimisation employs the same algorithm as was used for the firsrt optimisation. This operation may be performed repeatedly with the single proviso that, during the return phase of the table, the monitor must not look for a replacement cutting station to the right of that which has emptied.

After the cutting sequence has been completed, the monitor returns to the equipping plan (Figure 15C), and, for each device to be soldered, looks for the address of a soldering station which has a soldering tool compatible with the category of the device. In the present example, all the devices require the same soldering head, which is situated at station 1. The soldering sequence always takes place during the return phase of the table. The X positions will thus be defined on the return scale. By applying equation (2) in Figure 17 with the address of station 1 a change is made from the equipment plan (Figure 15C) to an un-optimised soldering sequence (15G). By applying the optimising algerithm to this sequence, an optimised soldering sequence (Figure 15H) is obtained. To carry out the optimised sequence it is necessary to follow the soldering path indicated in (Figure 151).

The apparatus 40 which has just been described may be subject to many modifications. As an example, when associated with a circular substrate, the first reference system will preferably be a reference system employing polar co-ordinates. Similarly, the lines defining the second reference system associated with the cutting and soldering tools may be different and may be other than straight lines.

In addition, the cutting and soldering may be performed with the same tool without exceeding the scope of the invention. This will be clearly apparent from the preceeding description.

Broadly speaking, the invention is in no way restricted to the embodiments described and illustrated and in fact covers all means which form technical equivalents of the means described, as well as combinations thereof, if these are within the scope of the invention as defined in the following claims.

WHAT WE CLAIM IS:

1. A method of mounting different inegrated semiconductor devices on a substrate having a plurality of spaces each intended to receive one of said devices, comprising positioning the substrate with regard to a first geometrical coordinate reference system,

selecting the appropriate device for each of said spaces, positioning said selected devices with respect to a second geometrical coordinate reference system, successively shifting the substrate by altering the first reference system relative to the second reference system so as successively to line up each space on the substrate with the device selected therefor, successively positioning each device on its respective space, and attaching to the substrate each device which has been positioned on it.

2. A method according to claim 1, wherein the first reference system is a system employing cartesian coordinates with respect to the centres of said spaces.

3. A method according to claim 1, wherein the first reference system is a system employing polar coordinates.

4. A method according to any of claims 1 to 3, of the kind in which the said devices are of various types, and devices of the same type are mounted on a supporting element and are cut free from this element by a cutting tool, and including positioning the cutting tools for different types of device along at least a first line belonging to the said second reference system.

5. A method according to claim 4, wherein the devices are divided into various categories determined by their dimensions, and the devices, once cut free, are mounted on the substrate by attaching tools each corresponding to one category, and including positioning said attaching tools on at least a second line belonging to the said second reference system.

6. A method according to claim 5, wherein said first and second lines correspond.

7. A method according to any of claims 1 to 6, wherein the setting up the substrate in relation to the second reference system consists of using a third reference system involving three fixed points which respectively correspond to three predetermined points on the substrate, and defining each of the fixed points as any point on the circumference of a member which is rotatable so as to facilitate the setting up of the substrate and to increase the accuracy thereof.

8. A method according to one of claims 1 to 7, wherein shifting the substrate relative to the second reference system comprises shifting the substrate relative to a set of slots through which radiation representing the movement of the substrate successively passes, and the lining up a position on the substrate with the corresponding device comprises balancing the radiant flux passing through a given slot, which flux is received on two adjoining reception areas which are separated in a direction substantially normal to the plane of movement of the said substrate.

9. A method according to claim 8, wherein at least one of the axes of the first reference system is parallel to one of the aforesaid lines of the second reference system, and comprising associating a first group of the said slots with each of the said tools, each of the said slots representing an abscissa meaurement for the said positions, and associating with the plate supporting the substrate a group of slots which represent ordinate measurements for respective ones of the said positions of the substrate.

10. A method according to claim 9, including dividing each group of slots into a plurality of parallel sub-groups of slots.

11. A method according to one of the preceding claims, comprising performing the positioning and attaching the devices on the substrate by following a path which involves the minimum movement of the substrate relative to the second reference system.

12. A method according to claim 11, wherein the minimum-path movement involves continuously monitoring the arrangement of the tools relative to one another and the types and categories of device which correspond to them, as well as the said substrate positions intended for the said devices, and controlling the tools and shifting the substrate in accordance with the results of the said monitoring.

13. A method according to claim 12, wherein said monitoring includes monitoring the pressure experienced by the cutting tool along its travel.

14. A method according to claim 13, wherein the monitoring of pressure consists of monitoring the travel of the tool, defining predetermined sections of travel corresponding to predetermined pressures, monitoring the pressure in at least one of the sections, and providing means for halting the travel which are triggered when the observed pressure exceeds a predetermined limit for each section.

15. A method according to one of claims 12 to 14, wherein said attachment phase includes monitoring the pressure exerted by the attaching tool against the substrate.

16. Apparatus for carrying out the method claimed in claim 1, and comprising a table movable in a first directon and carrying a plate for supporting a substrate which is movable in a second direction transverse to said first direction, means for positioning a substrate with regard to a first coordinate geometry system, means for selecting and positioning an appropriate device with reference to the spaces on said substrate, means for positioning each selected device on its respective space, a plurality of tools for attaching devices of

different dimensions to said substrate arranged in a line, and control means operative to position each space on said substrate in register with an appropriate attaching tool and to actuate said tool.

17. Apparatus as claimed in claim 16, wherein devices of the same type are mounted on a flexible supporting element rolled on a reel, and including a cutting tool associated with each type of device, and means for unrolling each supporting element so as to bring each device on a supporting element successively into line with a cutting tool.

18. Apparatus as claimed in claim 17, including means for detecting marks indicating faulty devices on said supporting elements.

19. Apparatus as claimed in any one of claims 16 to 18, including positioning means for controlling the position of said table and said plate, said positioning means comprising fixed slotted means, and movable means for emitting radiation and receiving radiation which has passed through said slotted means.

20. Apparatus as claimed in claim 19, wherein the fixed slotted means comprise first slotted plates respectively coupled in an adjustable fashion to the said cutting and attaching tools and movable means comprise a first radiation emitter receiver system coupled to the table.

21. Apparatus as claimed in claim 20, wherein said fixed slotted means further comprise at least one second slotted plate coupled to the said table, and the said movable means further comprise a second radiation emitter/receiver system coupled to the said plate.

22. Apparatus according to claim 20 or 21, wherein the radiation emitter receiver systems each include a receiving device having two adjoining radiation-sensitive reception areas separated along a line parallel to the slots of the slotted plate associated therewith.

23. Apparatus as claimed in claim 22, wherein the positioning means include means for servo-controlling means for shifting the table and the plate, the said servo-control means including means for counting the slots in the said slotted means.

24. Apparatus as claimed in claim 23, wherein the means for shifting the table and plate comprise first and second electric motors coupled to the table and plate respectively.

25. Apparatus as claimed in any one of claims 16 to 24, including means for monitoring the pressure exerted by said tools.

26. Apparatus as claimed in claim 25, wherein the means for monitoring pressure include flexible means having one end connected to a transmission piece and the other end connected to a tool, the said other end being connected to means for detecting pressure.

27. Apparatus as claimed in claim 26, wherein the means for detecting pressure comprise a sensor whose fixed part is secured to the said transmission piece and whose moving part is coupled to the said other end of said flexible means.

28. Apparatus as claimed in any one of claims 23 to 27, wherein the said means for monitoring pressure includes means for monitoring the travel of a tool.

29. Apparatus according to claim 28, wherein the means for monitoring travel consist of a sensor having a part which is fixed in relation to the body of the head carrying the tool and having a moving part connected to the tool.

30. Apparatus as claimed in any one of claims 16 to 29, wherein the plate incorporates three rollers mounted with freedom to rotate on fixed shafts for accurately positioning a substrate thereon.

31. Apparatus as claimed in any one of claims 16 to 30, and including means for continuously monitoring the operation of the apparatus which are connected to means for determining the minimum path of movement of the substrate.

32. Apparatus as claimed in claim 31, characterised in that the means for monitoring the operation include means for identifying the reels.

33. Apparatus according to claim 31 or claim 32, wherein said operation monitoring means are connected to the said pressure monitoring means and to the said shifting and positioning means.

34. A method of mounting integrated semiconductor devices on a substrate substantially as hereinbefore described with reference to the accompanying drawings.

35. Apparatus for mounting integrated semiconductor devices on a substrate substantially as hereinbefore described with reference to the accompanying drawings.

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1590545 COMPLETE SPECIFICATION

18 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig. 1.

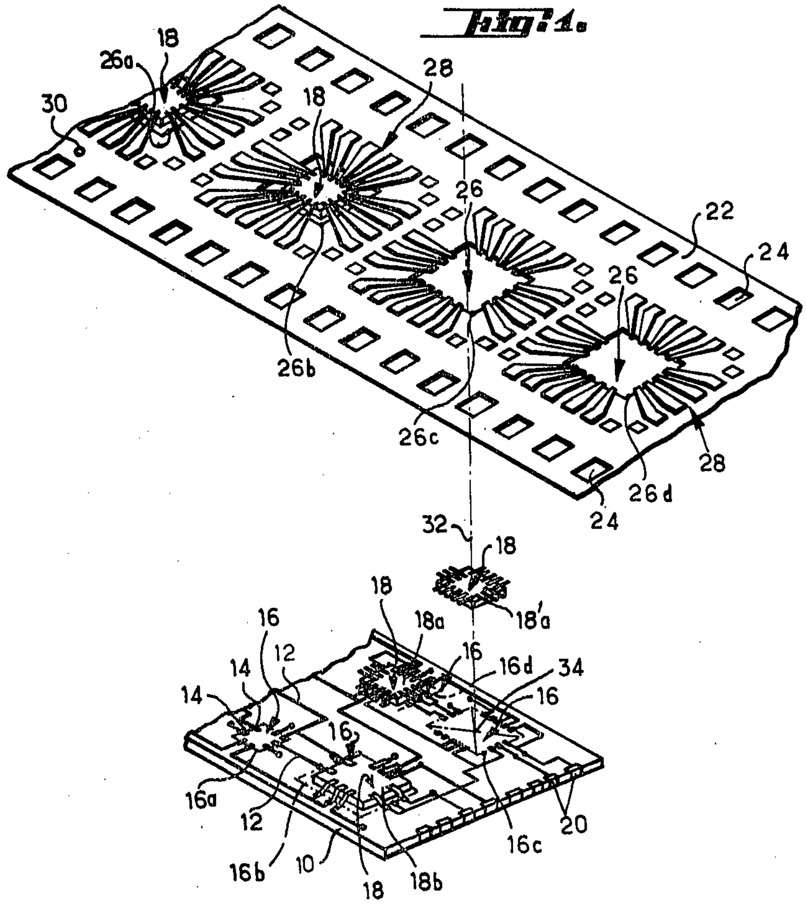
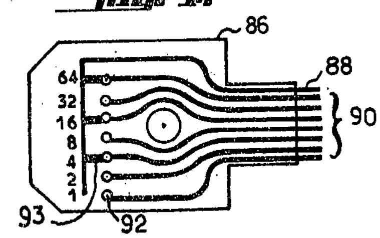


Fig. 4.



1590545 COMPLETE SPECIFICATION

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Sheet 2

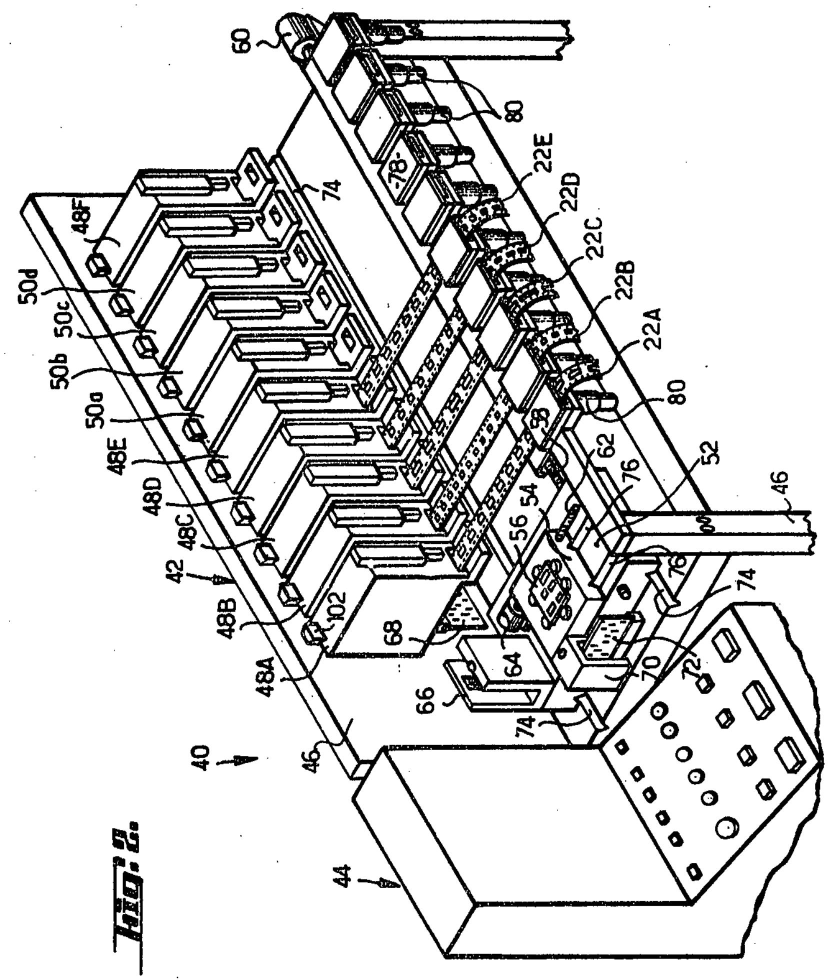

Fig. 2

Fig. 3.

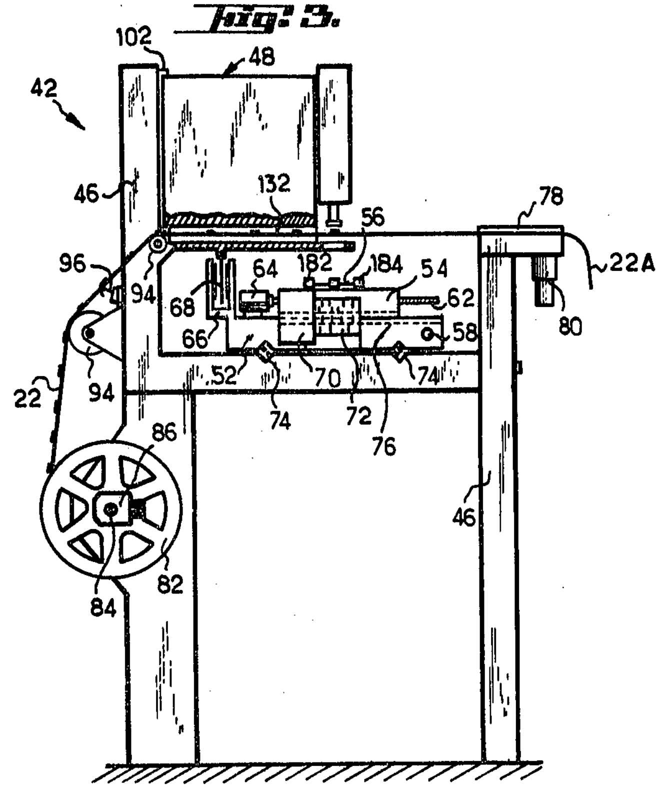
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Fig. 10.

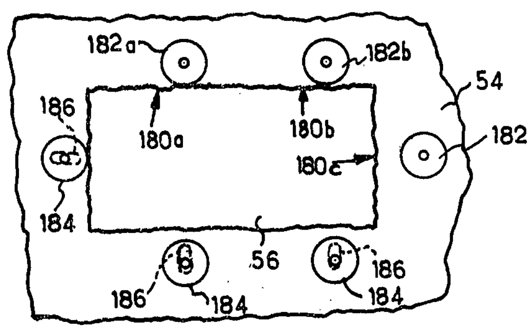
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Fig. 5.

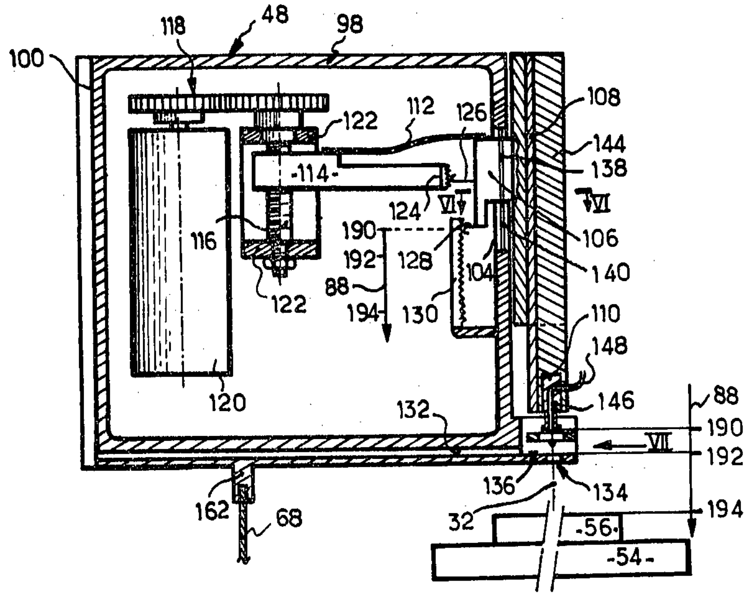


Fig. 7.

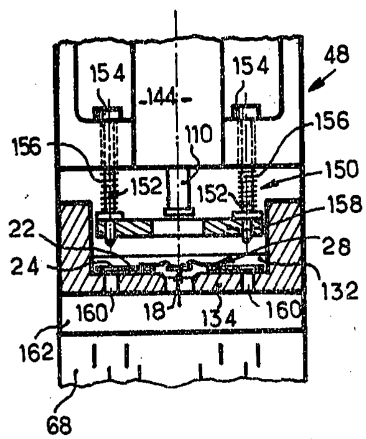


Fig. 6.

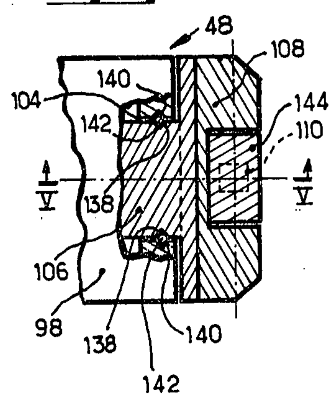


Fig. 8.

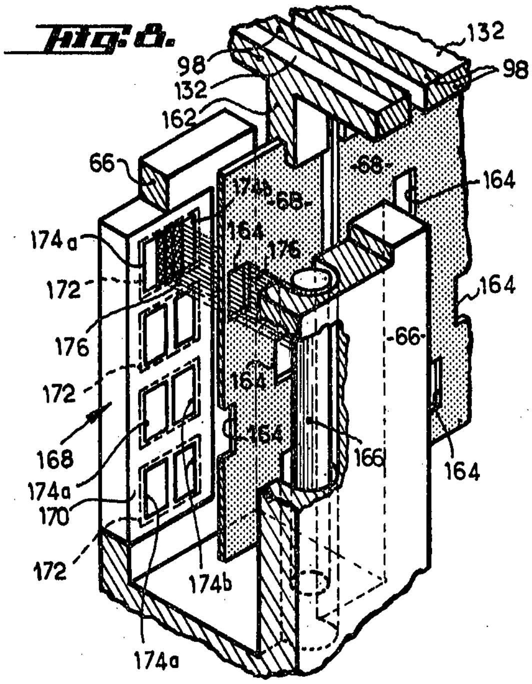


Fig. 11.

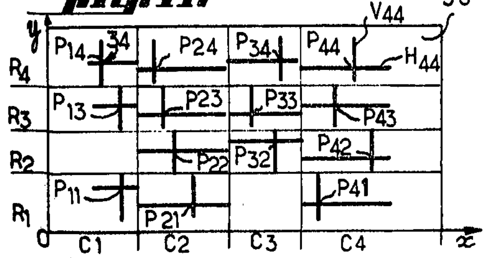


Fig. 9.

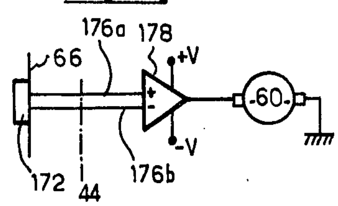


Fig. 12.

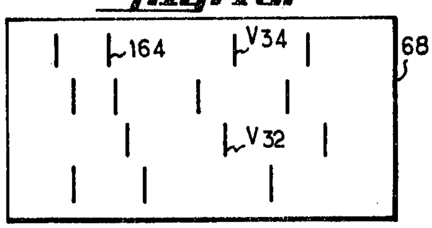


Fig. 13.

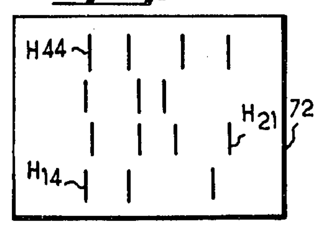


Fig: 14.

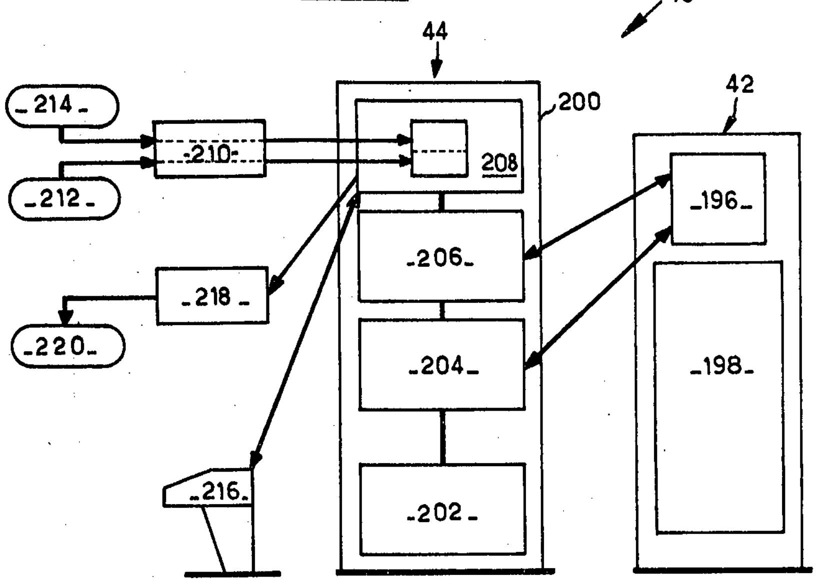


Fig: 18.

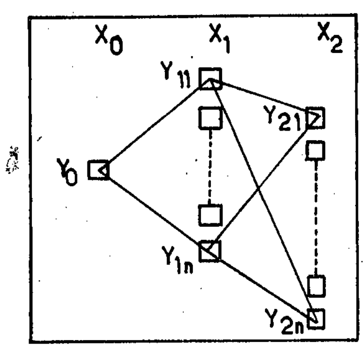
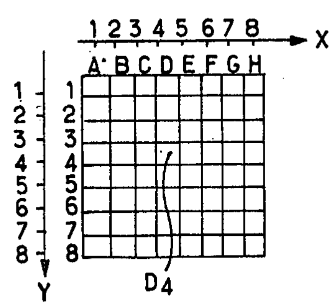


Fig: 16.



1590545 COMPLETE SPECIFICATION

18 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 7

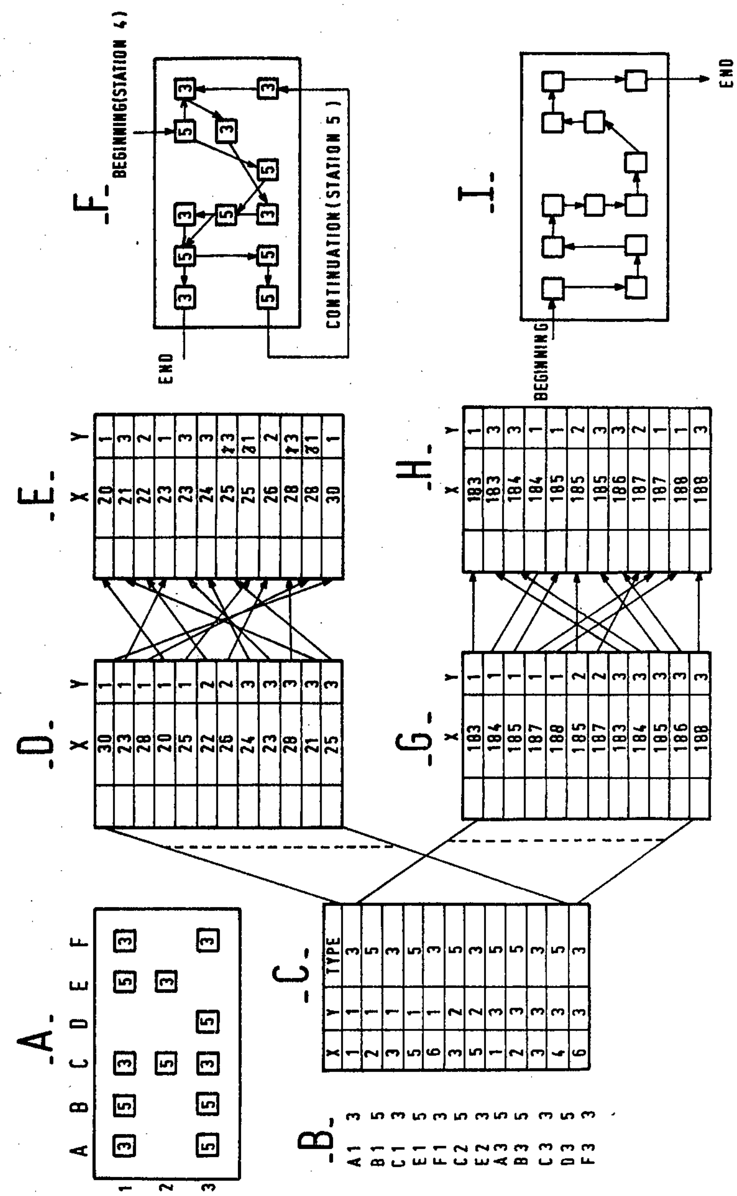


Fig. 15.

1590545 COMPLETE SPECIFICATION
18 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 8

Fig. 17.

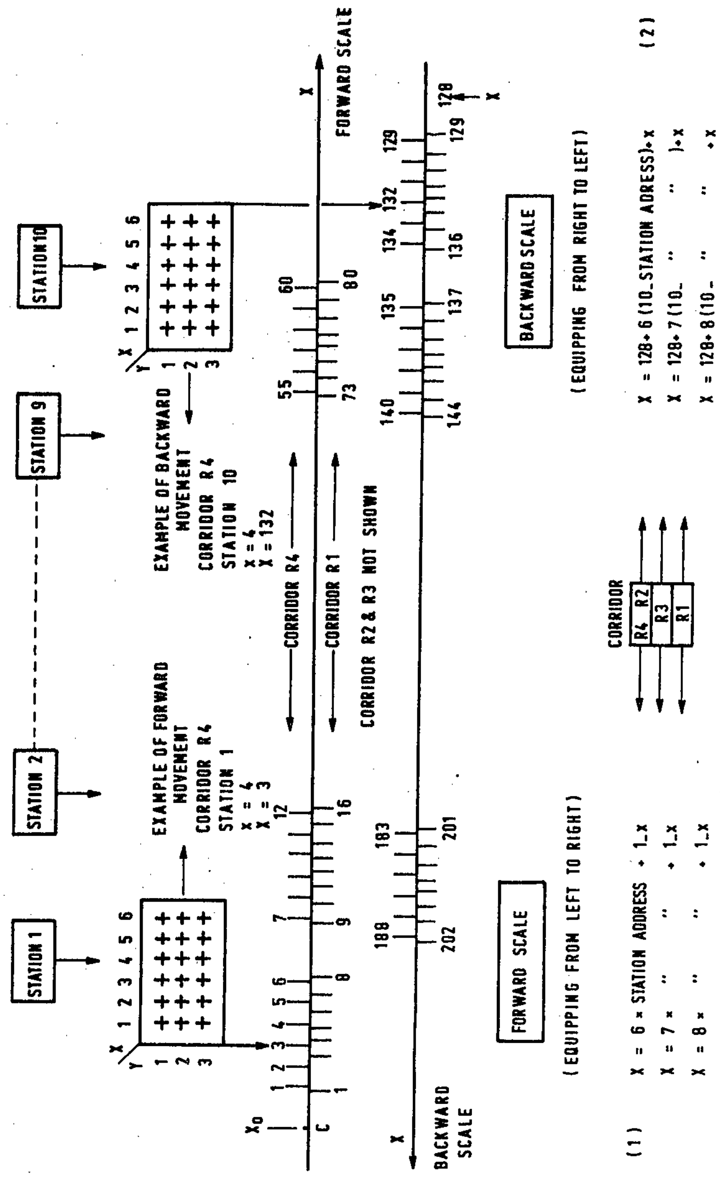
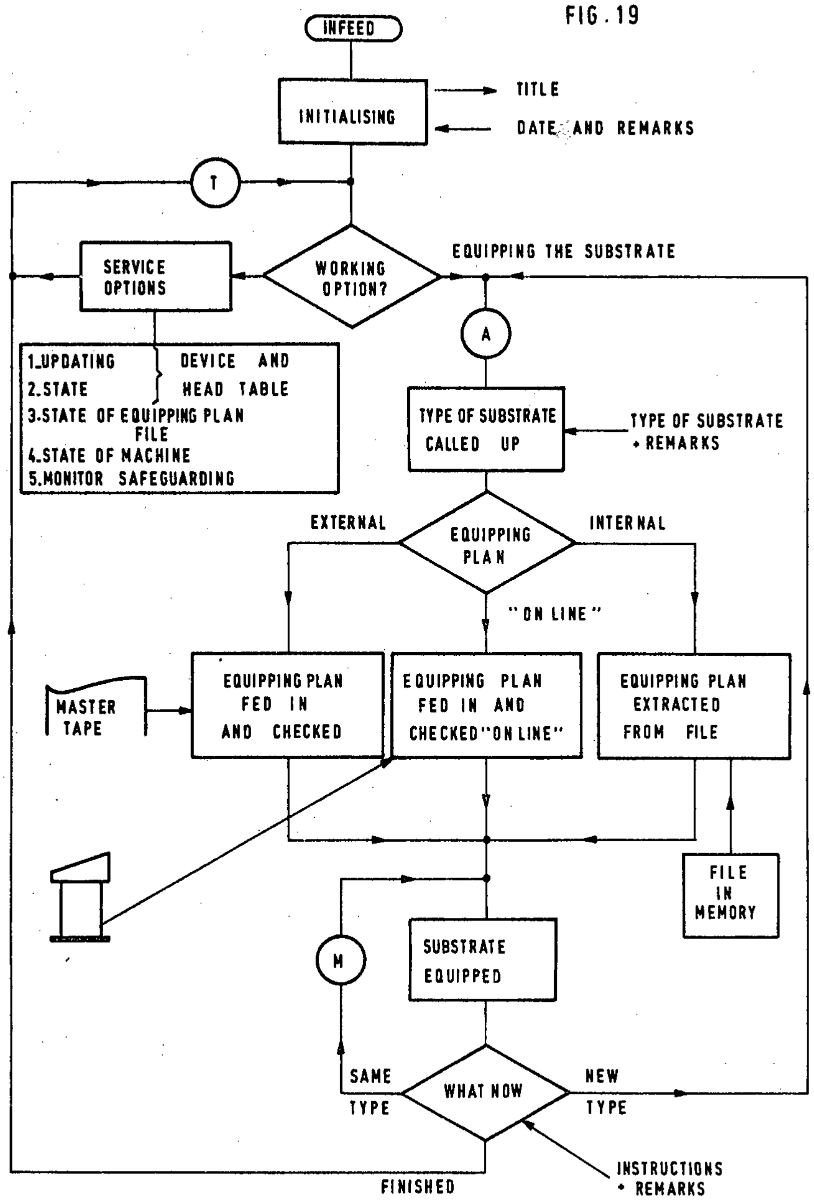


FIG. 19


INFEED
INITIALISING
TITLE
DATE AND REMARKS
T
WORKING OPTION?
SERVICE OPTIONS
EQUIPPING THE SUBSTRATE
1. UPDATING
2. STATE
DEVICE AND HEAD TABLE
3. STATE OF EQUIPPING PLAN FILE
4. STATE OF MACHINE
5. MONITOR SAFEGUARDING
A
TYPE OF SUBSTRATE CALLED UP
TYPE OF SUBSTRATE + REMARKS
EXTERNAL
EQUIPPING PLAN
INTERNAL
"ON LINE"
MASTER TAPE
EQUIPPING PLAN FED IN AND CHECKED
EQUIPPING PLAN FED IN AND CHECKED "ON LINE"
EQUIPPING PLAN EXTRACTED FROM FILE
FILE IN MEMORY
M
SUBSTRATE EQUIPPED
SAME TYPE
WHAT NOW
NEW TYPE
FINISHED
INSTRUCTIONS + REMARKS

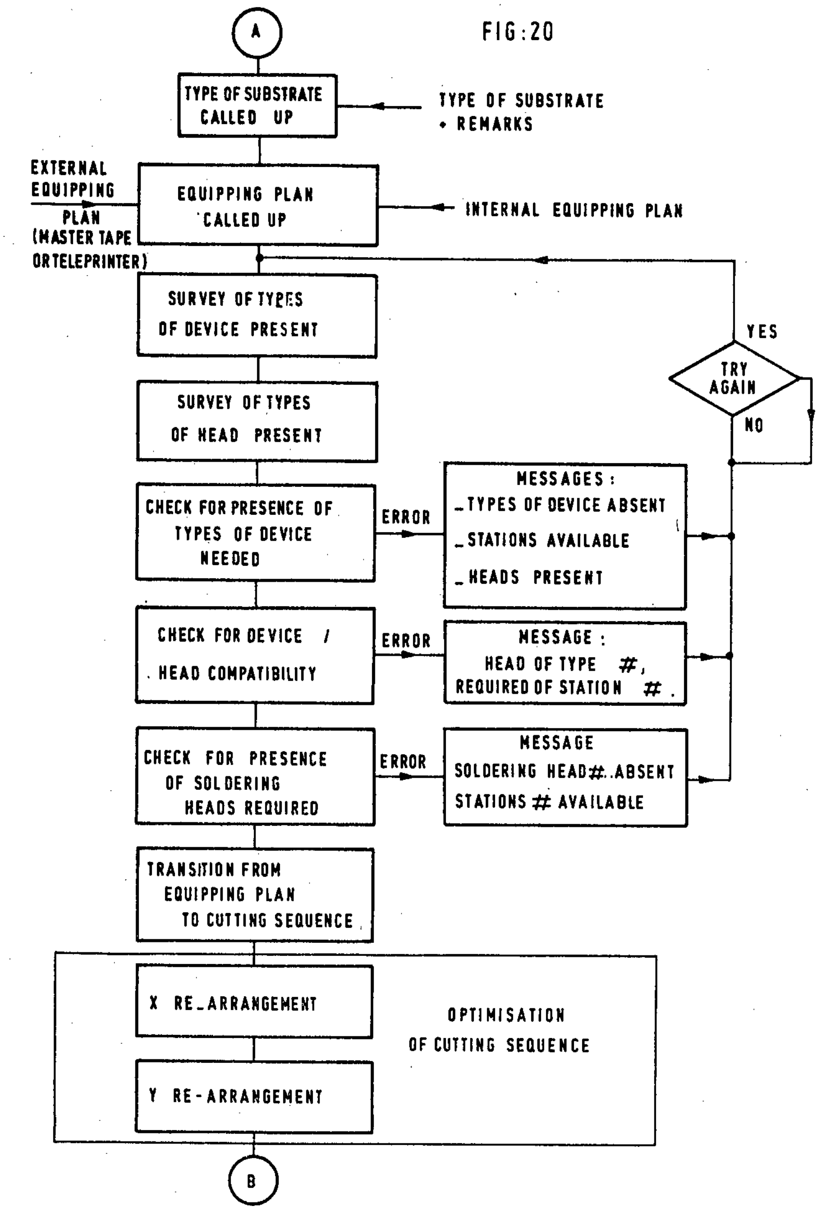

A
TYPE OF SUBSTRATE CALLED UP
TYPE OF SUBSTRATE + REMARKS
EXTERNAL EQUIPPING PLAN (MASTER TAPE OR TELEPRINTER)
EQUIPPING PLAN CALLED UP
INTERNAL EQUIPPING PLAN
SURVEY OF TYPES OF DEVICE PRESENT
SURVEY OF TYPES OF HEAD PRESENT
YES
TRY AGAIN
NO
CHECK FOR PRESENCE OF TYPES OF DEVICE NEEDED
ERROR
MESSAGES : _TYPES OF DEVICE ABSENT _STATIONS AVAILABLE _HEADS PRESENT
CHECK FOR DEVICE / HEAD COMPATIBILITY
ERROR
MESSAGE : HEAD OF TYPE #, REQUIRED OF STATION #.
CHECK FOR PRESENCE OF SOLDERING HEADS REQUIRED
ERROR
MESSAGE SOLDERING HEAD#.ABSENT STATIONS # AVAILABLE
TRANSITION FROM EQUIPPING PLAN TO CUTTING SEQUENCE
X RE_ARRANGEMENT
Y RE-ARRANGEMENT
OPTIMISATION OF CUTTING SEQUENCE
B

FIG:20

FIG. 21

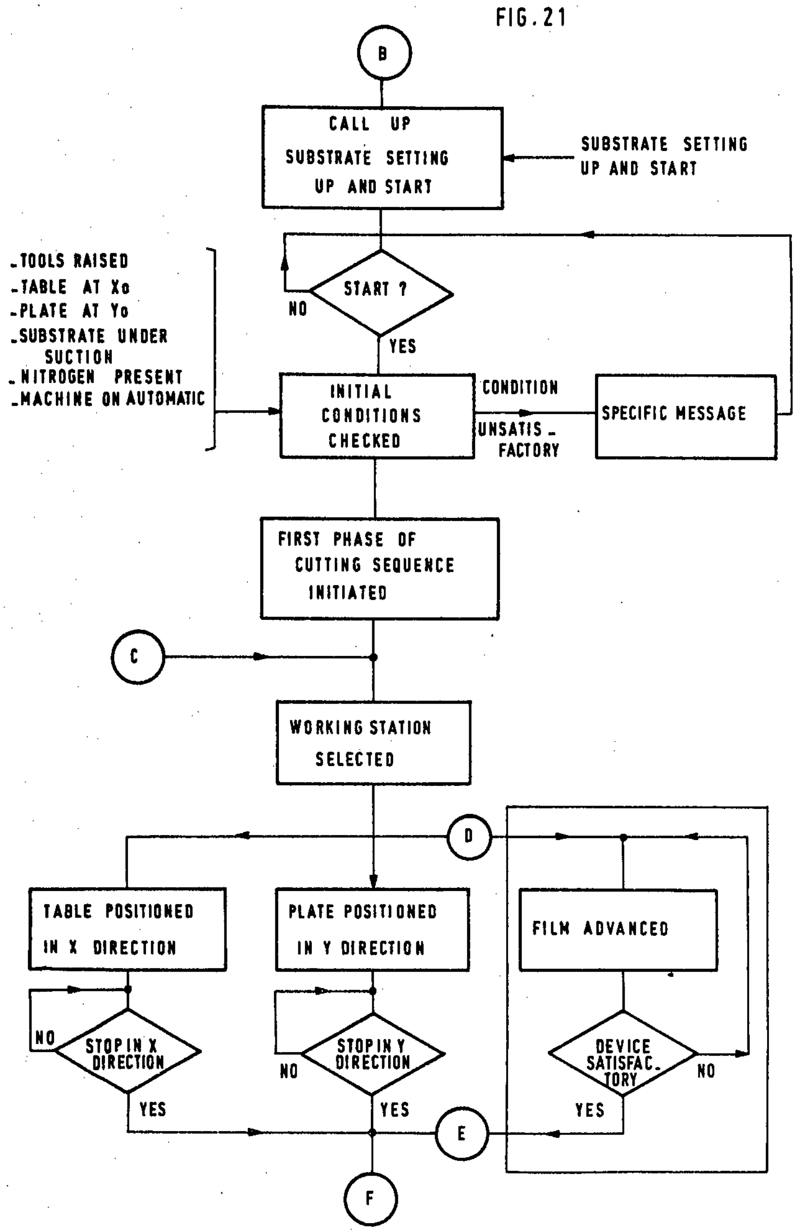
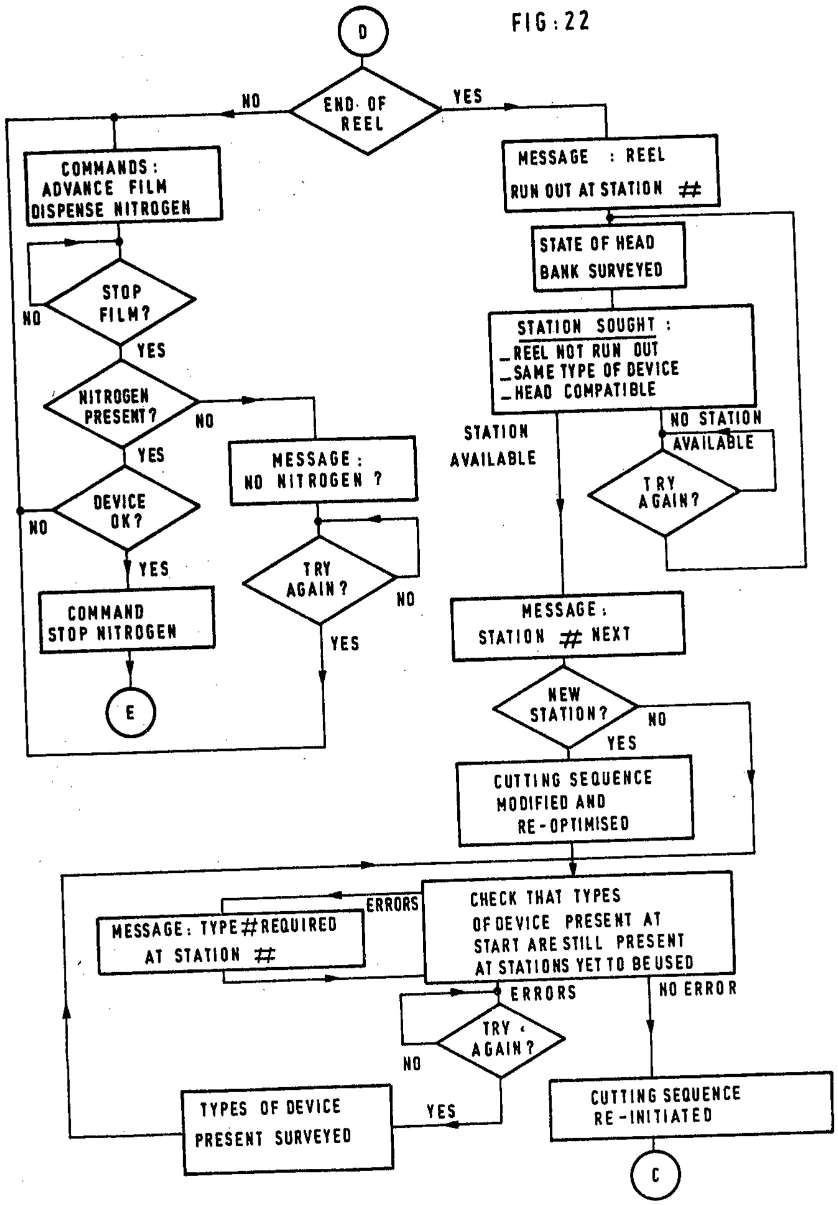

B
CALL UP
SUBSTRATE SETTING UP AND START
SUBSTRATE SETTING UP AND START
START ?
NO
YES
-TOOLS RAISED
-TABLE AT Xo
-PLATE AT Yo
-SUBSTRATE UNDER SUCTION
-NITROGEN PRESENT
-MACHINE ON AUTOMATIC
INITIAL CONDITIONS CHECKED
CONDITION UNSATISFACTORY
SPECIFIC MESSAGE
FIRST PHASE OF CUTTING SEQUENCE INITIATED
C
WORKING STATION SELECTED
D
TABLE POSITIONED IN X DIRECTION
PLATE POSITIONED IN Y DIRECTION
FILM ADVANCED
NO
STOP IN X DIRECTION
YES
STOP IN Y DIRECTION
NO
YES
DEVICE SATISFACTORY
NO
YES
E
F

FIG: 22


D
END OF REEL
NO
YES
COMMANDS: ADVANCE FILM DISPENSE NITROGEN
STOP FILM?
NO
YES
NITROGEN PRESENT?
NO
YES
DEVICE OK?
NO
YES
COMMAND STOP NITROGEN
E
MESSAGE: NO NITROGEN ?
TRY AGAIN?
NO
YES
MESSAGE : REEL RUN OUT AT STATION #
STATE OF HEAD BANK SURVEYED
STATION SOUGHT :
_REEL NOT RUN OUT
_SAME TYPE OF DEVICE
_HEAD COMPATIBLE
STATION AVAILABLE
NO STATION AVAILABLE
TRY AGAIN?
MESSAGE: STATION # NEXT
NEW STATION?
NO
YES
CUTTING SEQUENCE MODIFIED AND RE-OPTIMISED
CHECK THAT TYPES OF DEVICE PRESENT AT START ARE STILL PRESENT AT STATIONS YET TO BE USED
ERRORS
MESSAGE: TYPE # REQUIRED AT STATION #
ERRORS
NO ERROR
TRY AGAIN?
NO
YES
TYPES OF DEVICE PRESENT SURVEYED
CUTTING SEQUENCE RE-INITIATED
C

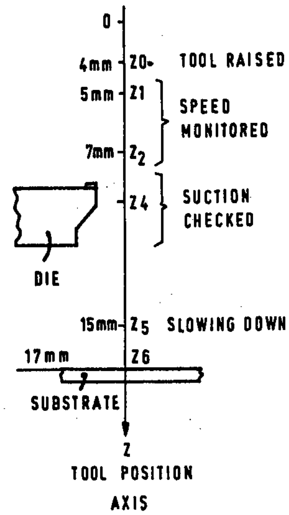

0
4mm
Z0
TOOL RAISED
5mm
Z1
SPEED
MONITORED
7mm
Z_2
Z4
SUCTION
CHECKED
DIE
15mm
Z_5
SLOWING DOWN
17mm
Z6
SUBSTRATE
Z
TOOL POSITION
AXIS

FIG : 29

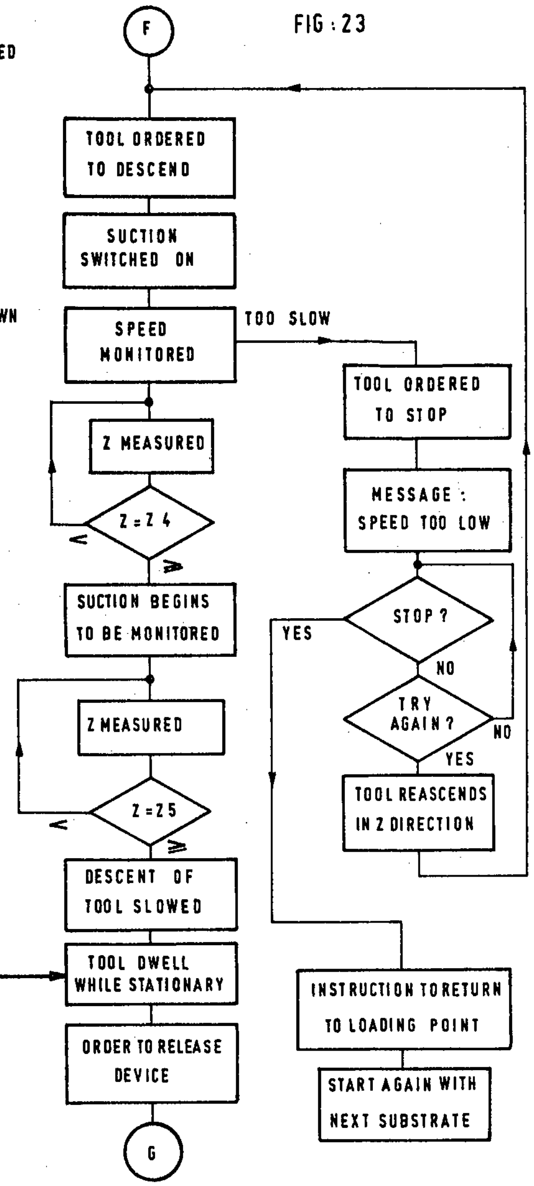

F
TOOL ORDERED
TO DESCEND
SUCTION
SWITCHED ON
SPEED
MONITORED
TOO SLOW
TOOL ORDERED
TO STOP
MESSAGE :
SPEED TOO LOW
Z MEASURED
Z = Z 4
SUCTION BEGINS
TO BE MONITORED
STOP ?
YES
NO
TRY
AGAIN ?
NO
YES
TOOL REASCENDS
IN Z DIRECTION
Z MEASURED
Z = Z 5
DESCENT OF
TOOL SLOWED
FORCE
FROM TOOL
TOOL DWELL
WHILE STATIONARY
ORDER TO RELEASE
DEVICE
G
INSTRUCTION TO RETURN
TO LOADING POINT
START AGAIN WITH
NEXT SUBSTRATE

FIG : 23

FIG. 24

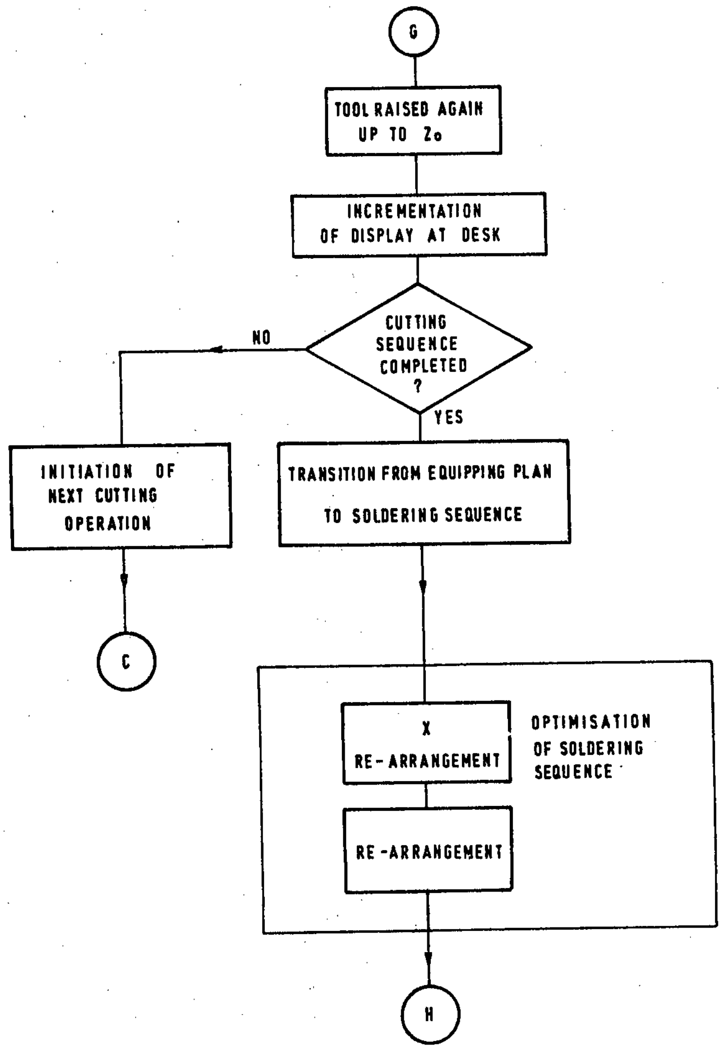

G
TOOL RAISED AGAIN UP TO Zo
INCREMENTATION OF DISPLAY AT DESK
CUTTING SEQUENCE COMPLETED ?
NO
YES
INITIATION OF NEXT CUTTING OPERATION
C
TRANSITION FROM EQUIPPING PLAN TO SOLDERING SEQUENCE
X RE-ARRANGEMENT
OPTIMISATION OF SOLDERING SEQUENCE
RE-ARRANGEMENT
H

FIG:25

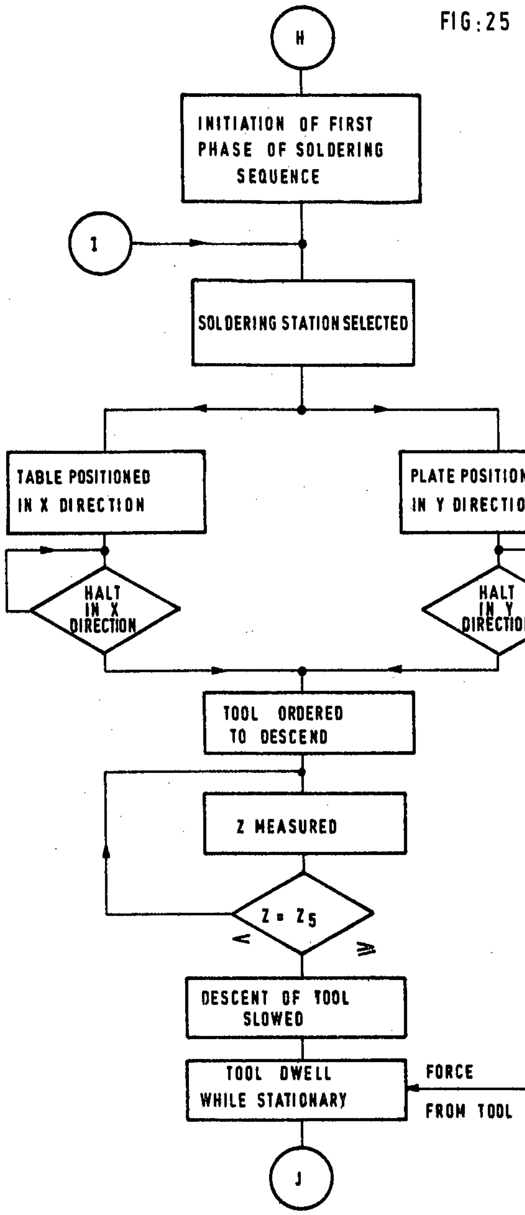

H
INITIATION OF FIRST PHASE OF SOLDERING SEQUENCE
1
SOLDERING STATION SELECTED
TABLE POSITIONED IN X DIRECTION
PLATE POSITIONED IN Y DIRECTION
HALT IN X DIRECTION
HALT IN Y DIRECTION
TOOL ORDERED TO DESCEND
Z MEASURED
Z = Z5
<
≥
DESCENT OF TOOL SLOWED
TOOL DWELL WHILE STATIONARY
FORCE
FROM TOOL
J

FIG : 26

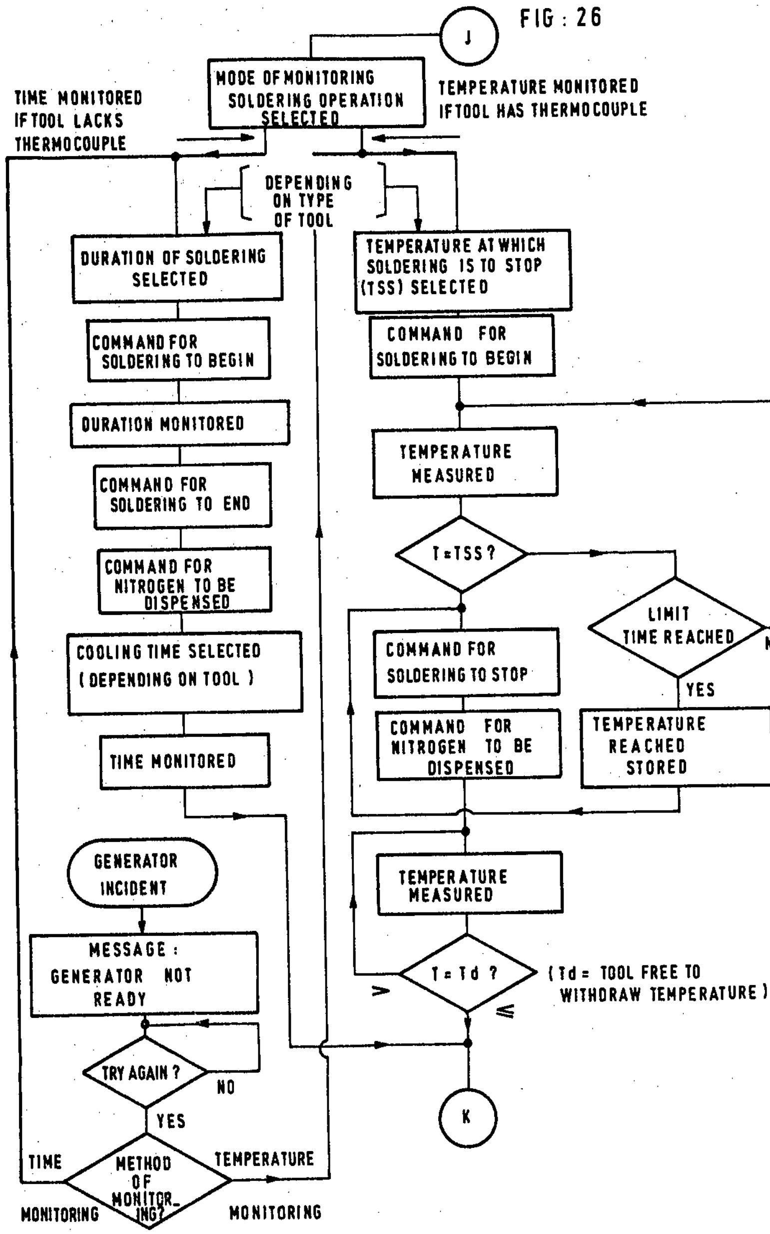

J
MODE OF MONITORING SOLDERING OPERATION SELECTED
TIME MONITORED IF TOOL LACKS THERMOCOUPLE
TEMPERATURE MONITORED IF TOOL HAS THERMOCOUPLE
DEPENDING ON TYPE OF TOOL
DURATION OF SOLDERING SELECTED
COMMAND FOR SOLDERING TO BEGIN
DURATION MONITORED
COMMAND FOR SOLDERING TO END
COMMAND FOR NITROGEN TO BE DISPENSED
COOLING TIME SELECTED (DEPENDING ON TOOL)
TIME MONITORED
GENERATOR INCIDENT
MESSAGE : GENERATOR NOT READY
TRY AGAIN ?
NO
YES
METHOD OF MONITOR_ ING?
TIME MONITORING
TEMPERATURE MONITORING
TEMPERATURE AT WHICH SOLDERING IS TO STOP (TSS) SELECTED
COMMAND FOR SOLDERING TO BEGIN
TEMPERATURE MEASURED
T=TSS ?
LIMIT TIME REACHED
NO
YES
COMMAND FOR SOLDERING TO STOP
COMMAND FOR NITROGEN TO BE DISPENSED
TEMPERATURE REACHED STORED
TEMPERATURE MEASURED
T=Td ?
>
≤
(Td = TOOL FREE TO WITHDRAW TEMPERATURE)
K

FIG: 27

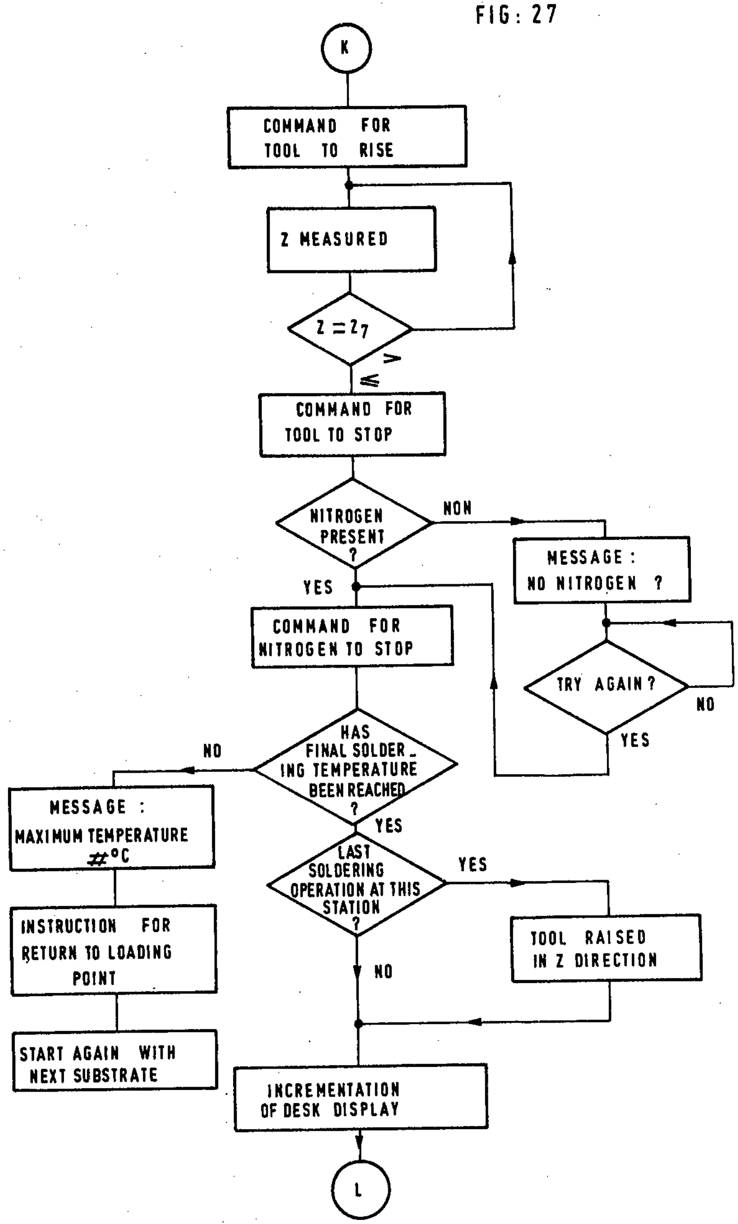
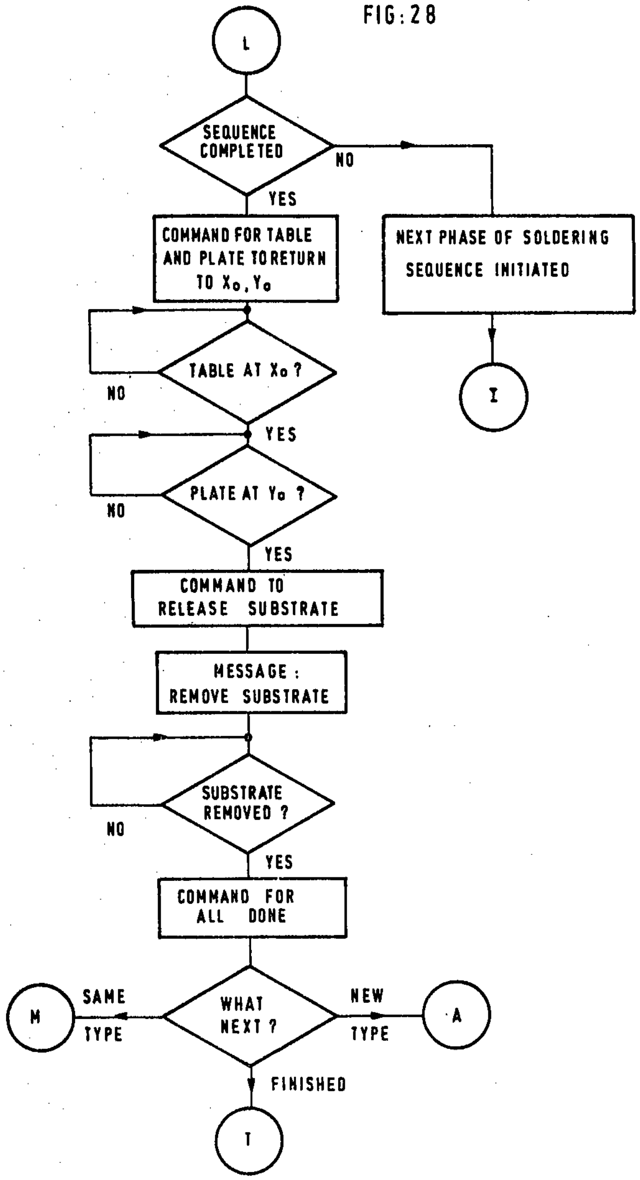

K
COMMAND FOR TOOL TO RISE
Z MEASURED
Z = Z7
>
≤
COMMAND FOR TOOL TO STOP
NITROGEN PRESENT ?
NON
MESSAGE : NO NITROGEN ?
TRY AGAIN ?
NO
YES
YES
COMMAND FOR NITROGEN TO STOP
HAS FINAL SOLDER_ING TEMPERATURE BEEN REACHED ?
NO
MESSAGE : MAXIMUM TEMPERATURE #°C
INSTRUCTION FOR RETURN TO LOADING POINT
START AGAIN WITH NEXT SUBSTRATE
YES
LAST SOLDERING OPERATION AT THIS STATION ?
YES
TOOL RAISED IN Z DIRECTION
NO
INCREMENTATION OF DESK DISPLAY
L

FIG:28


L
SEQUENCE COMPLETED
NO
YES
COMMAND FOR TABLE AND PLATE TO RETURN TO X_o, Y_o
NEXT PHASE OF SOLDERING SEQUENCE INITIATED
I
TABLE AT X_o ?
NO
YES
PLATE AT Y_o ?
NO
YES
COMMAND TO RELEASE SUBSTRATE
MESSAGE : REMOVE SUBSTRATE
SUBSTRATE REMOVED ?
NO
YES
COMMAND FOR ALL DONE
WHAT NEXT ?
SAME TYPE
M
NEW TYPE
A
FINISHED
T