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(54) **Power tool.**

(57) A power tool comprising a motor (2); a rotatable output shaft (16) drivable by the motor and adapted to carry a tool (20); means (30) for generating a first electrical signal representing the torque applied to the output shaft; means (40, 41) for generating a second electrical signal representing the angular rotation of the output shaft; and means (100) for processing the signals whilst the tool is in operation to monitor the angle ($\theta_1 - \theta_2$) through which the drive shaft rotates whilst the applied torque rises from a predetermined threshold value (T_1) to its greatest value (T_2) and for generating an indicator signal if the said angle ($\theta_1 - \theta_2$) and the greatest value (T_2) both lie between respective predetermined maximum and minimum values ($\theta_3, \theta_4, T_3, T_4$), and for storing, in order, a predetermined number of values of the signals read at periodic intervals, and means (110) for displaying the stored values.

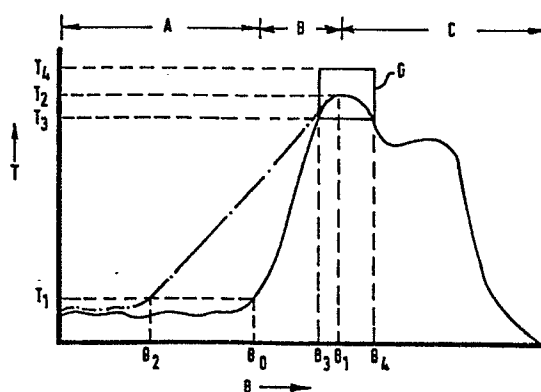


FIG. 1

DESCRIPTION"POWER TOOL"

1 This invention relates to power tools.

Power tools, such as those used in the assembly of motor vehicles, comprise a motor, which is usually driven pneumatically, and an output shaft rotatable by the motor and
5 which, in use, carries a tool for engaging a connector, for example a hexagonal socket. In many instances it is required that the connector should be tightened to a predetermined torque. In a conventional pneumatically-driven power tool, the torque applied by the tool to the connector will be directly proportional to the
10 pressure of air used to drive the tool. In order to allow the applied torque to be controlled therefore some power tools incorporate a pressure control valve which allows the pressure applied to the tool to be varied. In operation, the tool is applied to a connector and the connector is rotated until no further
15 rotation occurs. The operator then assumes that the joint has been fastened to the required tightness. Other power tools incorporate a torque detector which automatically shuts off the drive motor when the predetermined torque level is detected. In general, however the user cannot judge the quality of a joint
20 solely by the fact that a required torque has been correctly applied to the connector. For example, a damaged thread may have prevented the connector from properly fastening the joint.

A number of control systems have therefore been proposed in which the variation of applied torque with the angular rotation
25 of the connector is monitored electronically to enable the user to determine positively whether a good joint has been formed. For example British Patent Specification No. 1526948 discloses a power tool having a control system which deactivates the tool only when the rate of change of torque with angle of rotation has decreased
30 by a predetermined amount. This system however requires the connection to be tightened to the region of the yield point of one the elements of the fastener. In some connections tightening to

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the yield point may not be appropriate. For example connectors incorporating a spring washer may not require tightening to the maximum torque possible.

5 British Patent Specification No. 1527185 discloses
a power tool comprising a motor; a rotatable output shaft for carrying
a tool and driven by the motor; means for generating a first electrical
signal representing the torque applied to the output shaft; means for
generating a second electrical signal representing the angular rotation
of the output shaft; and means for processing the first and second
10 signals whilst the tool is operated to determine the angle through which
the drive shaft rotates whilst the applied torque rises from a
predetermined threshold value to its greatest value and for generating an
indicator signal if the said angle and the said greatest value both lie
between respective predetermined maximum and minimum values.

15 The operation of this power tool is based on the observation
that in all well-formed joints of a particular type, once a threshold
torque applied to the connector has been exceeded, the rate of change
of applied torque with respect to angular rotation of the connector is
substantially the same. Consequently, once these tightening
20 characteristics of a particular joint have been determined, they can be
used as a reference against which the quality of all similar joints can
be tested. The tool can therefore be used to make a wide variety of
different types of joint whether or not the joint is to be tightened
to yield point.

Although the power tool of British Patent Specification No. 1527186 can be used to check the tightening characteristics of different joints, it does not permit the permanent recordal of this information, for use, for example, for quality control, or for research investigations.

According to the present invention, there is provided a power tool comprising a motor; a rotatable output shaft drivable by the motor and adapted to carry a tool; means for generating a first electrical signal representing the torque applied to the output shaft; means for generating a second electrical signal representing the angular rotation of the output shaft; and means for processing the signals whilst the tool is in operation to determine the angle through which the drive shaft rotates whilst the applied torque rises from a predetermined threshold value to its greatest value, and for generating an indicator signal if the said angle and the said greatest value both lie between respective predetermined maximum and minimum values, characterised in that the means for processing the signals comprises means for storing, in order, a predetermined number of values of the signals read at periodic intervals and in that means is provided for displaying the stored values.

The stored values may be displayed on any suitable medium, for example a visual display unit, or a printer, and are then available for examination as a full record of the history of the joint tightening process.

The electrical signal representing torque can be generated in any suitable way, but, for simplicity, a strain gauge is preferably used. Where the output shaft is rotatable in a housing to which the motor is fixed, it is convenient to secure the strain gauge to the housing.

The electrical signal representing the angular rotation of the output shaft preferably comprises a train of electrical pulses, the frequency of which varies in accordance with the rate of rotation of the output shaft, and a counter for counting the pulses. The train of pulses may be generated by any means, for example a

graduated rotor driven by the motor and an electro/optical or electro/magnetic sensor for sensing the movement of the graduations on the rotor.

5 The indicator signal may be used to generate a visible or audible indication of the quality of the joint and/or to actuate a marking system for the connector, as described in British Patent Specification No. 2052333 and Application No. 8104216.

10 The means for processing the signals preferably comprises reading the level of the first signal at predetermined intervals, means for storing signals representing the level of the first signal, means for updating the stored signal with subsequent signals
15 representing levels of the first signal corresponding to higher torques, and means for comparing the stored signal with signals
15 representing threshold, minimum and maximum torque values.

 The comparison of the stored signal with the signals representing maximum and minimum torque value indicates whether the maximum applied torque is within the required limits. The comparison of
20 the stored signal with the signal representing the threshold value indicates whether or not the threshold torque has been exceeded.

 The means for processing the signals preferably also comprises means for reading the levels of the second signal at periodic intervals, means for determining differences between consecutive
25 levels of the second signal and means for summing the differences whilst the level of the first signal increases from a level corresponding to the threshold torque value to a level corresponding to the minimum torque value.

A preferred embodiment of the invention will now be described, by way of example only, with reference to the drawings, in which:-

5 Figure 1 is a graph showing the torque characteristics of a connection.

Figure 2 is a cross-section through a power tool in accordance with the invention.

Figures 3 and 4 are block diagrams showing the control system of the power tool of Figure 2.

10 Figures 5,6 and 7 are flow charts illustrating the operation of the control system of Figures 3 and 4.

In Figure 1 the solid line is a graph showing the variation

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1 of the torque T applied by a power tool to a connector, such as a
threaded nut and bolt with the angle of rotation θ . In the region A
of the graph, the applied torque remains at a low, relatively
uniform level whilst the nut runs freely down the bolt. In this
5 section of the graph, the applied torque never exceeds a threshold
value T_1 . In the region B, the nut encounters resistance as it
engages the surface of the component which is being secured. After
passing the point (θ_0, T_1) , the torque rises to a peak value T_2 ,
between a maximum value T_4 and a minimum value T_3 . At this point,
10 (θ_1, T_1) the power tool is deactivated, and the applied torque falls
to zero in accordance with the characteristic illustrated in the
region C of the graph, the irregularities in the line being caused
by the inertia of the power tool and the resilience in the connection.

If the joint has been made properly, the characteristics of
15 region B of the graph are such that, after the torque has exceeded
the threshold value T_1 , it rises to its peak level T_2 within a
predetermined angular rotation from the point (θ_0) at which the
threshold torque T_1 was exceeded, $(\theta_1 - \theta_0)$.

The broken line in Figure 1 illustrates the variation
20 applied torque with angular rotation in the case of a threaded
connection having a faulty thread. The torque begins to rise
earlier as a result of the resistance to the travel of the nut
caused by the faulty thread. The rate of increase of the torque
with angular rotation is however smaller than for the good joint, so
25 that the peak torque T_2 is achieved after a much greater angle
of rotation measured from the point (θ_2) at which the threshold
torque T_1 has exceeded. Hence, good joints can be distinguished
from bad joints by monitoring the applied torque and angular
rotation of the connector, and by determining whether the applied
30 torque exceeds a minimum desired value within a predetermined angular
rotation after exceeding the threshold value.

The particular threshold values and angular rotations will
vary for each type of connector. Thus, a connection incorporating
a spring washer will require a larger angular rotation to achieve
35 its maximum torque than that required by a similar connection without

a spring washer. Additionally, manufacturing tolerances within the connection will cause a variation within narrow limits of the precise angle of rotation at which any desired torque is achieved.

5 In practice therefore for each type of connection, a range of applied torque values from a desired minimum T_3 to a desired maximum T_4 and a range of angular rotations from a desired minimum θ_3 to a desired maximum θ_4 , measured with reference to the point θ^0 at which a threshold torque is exceeded, is required to identify all good connections. This range of values is identified by the
10 rectangular area G in Figure 1.

Referring now to Figures 2 to 5, a power tool 1 which utilises these principles is illustrated. The power tool 1, which is in this instance suitable is a handheld/^{tool}for use in assembly-line production of motor vehicles comprises a pneumatic motor 2 of conventional
15 construction not shown in detail.

The pneumatic motor is driven from an air supply line which includes a pressure control valve which permits the maximum pressure applied to the motor to be set to a desired value. Since the maximum torque applied by the motor will vary in direct proportion
20 to the maximum applied pressure adjustment of the pressure control value allows the maximum torque of the motor to be selected.

The pneumatic motor 2 has a drive shaft 3 which is coupled coaxially to a first intermediate shaft 4 by a splined connection 5. The intermediate shaft 4 is rotatably mounted in the housing 6 of the
25 tool by bearings 7, 8 and is, in turn coupled coaxially to a second intermediate shaft 10 by means of a splined connection 12.

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The second intermediate shaft is rotatably mounted in the housing 6 in needle bearings 13 and terminates in a bevel gear 14 which meshes with a further bevel gear 15 secured to a hollow output shaft 16 arranged at right angles to the second intermediate shaft 10 and rotatably mounted in bearings 17, 18 in the end portion 19 of the housing 6. A drive socket 20 is removably mounted in a conventional manner on the end of the output shaft 16 for engagement with a connector, indicated schematically as a hexagonal bolt head 22.

10 A marking unit 23 is mounted on the end portion 19 of the housing 6. The details of the construction of the marking unit 23 are described in our British Patent Application No. 8104216. Briefly, the marking unit 23 includes a stylus 24 which is reciprocable by air pressure within the hollow centre of the drive shaft 16. A marking fluid is fed to the stylus so that, when the tip of the stylus contacts the bolt head 22, marking fluid is deposited thereon,

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1 indicating, for example for quality control purposes, that the bolt
head 22 has been tightened to the correct torque.

The marker unit 23 is operated by the
control system illustrated in Figures 3 and 4. The control system
5 operates from two sensor signals. The first sensor signal is
generated by a strain gauge 30 mounted on the housing 6 adjacent
the second intermediate shaft 10.

The strain gauge 30 comprises four transducers 31
cemented in two diametrically opposed pairs on to the exterior of
10 the housing 6. As indicated in Figure 3, the transducers 31 are
connected together into a bridge. A reference voltage is applied
across the bridge from a power supply 32. Torsional reaction
forces applied to the housing 6 as a result of application of a
torque load to the output shaft 16 will cause the resistances of
15 the transducers to alter, thereby causing a change in the voltage
across the bridge. This voltage is amplified in an amplifier 33
and converted to an analogue current signal in a voltage-to-current
isolation amplifier 34. The conversion of the voltage signal in
the bridge to an analogue current signal renders the signal less
20 sensitive to interference from extraneous sources. The effect of
interference is further reduced by positioning the power supply and
amplifier close to the power tool.

The second sensor signal is generated by a slotted disc 40,
mounted coaxially on the first intermediate drive shaft 4, which
25 interrupts beams of infra-red light passing between four emitters
41 and their respective detectors 42. In the embodiment illustrated,
the disc 40 has 90 radial slots and the four pairs of emitters and
detectors 41, ^{are} 42/spaced circumferentially around the disc 40. Each
emitter and detector pair is connected with a respective
30 amplifier, one of which is illustrated at 43, so that the output
from the amplifier increases when the signal from its associated
detector 42 decreases and vice versa. Since each detector responds
to the passage of both edges of every slot of the disc 40 through
the beam of infra-red light from its associated emitter, the output
35 from each of the four amplifiers 43 is in the form of a sine wave

with a period equal to 2° of rotation of the disc 40. The outputs from the four amplifiers 43 are each fed to a respective level trigger 44 and a monostable circuit 45 which generate a positive square pulse for each half cycle of the sine wave. The four trains of pulses are then fed to an OR gate 46. The relative circumferential spacing of the emitter/detector pairs is such that the four trains of pulses are out of phase with each other by $\frac{1}{4}$ of one cycle so that the output from the OR gate 46 will consist of a train of square pulses with a spacing equal to $\frac{1}{2}^\circ$ of rotation of the disc 40, and therefore of the output shaft 16. The generation of a sinusoidal output from the emitter and detector pairs is particularly convenient in that the trigger levels of the level triggers 44 may be adjusted to produce pulses at points earlier and later in each half cycle to compensate for inaccuracies in the relative circumferential positioning of between the emitter/detector pairs.

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The train of pulses from the OR gate 46 is fed into a differential driver 47. This produces equal and opposite voltage signals at two outputs thus reducing the noise sensitivity of the signals transmitted therefrom.

5 Figure 4 illustrates a further part of the circuitry of the control system. In this diagram the thick lines represent 8-channel connectors for the transmission of 8-bit digital signals. In the part of the system illustrated in Figure 3, the sensor signals are converted into forms which are relatively insensitive to noise
10 and interference. The part of the system illustrated in Figure 4 can therefore be safely positioned remote from the power tool 1 itself.

 Referring to the first sensor signal, generated by the strain gauge 30, the analogue current signal from the isolation
15 amplifier 43 is fed into a differential amplifier 50, which converts the current signal into a voltage signal; thence to a gain control 51 in which the voltage signals are set to fall within a desired range; and thence to an analogue-to-digital (A/D) converter 52 which produces an 8-bit digital signal representative of the torque applied
20 to the output shaft 6. The A/D converter 52 is connected via an 8-channel line to an output control 53 which allows the digital signal of the A/D converter 52 to be read.

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1 The second sensor signal, generated by the slotted disc
40, is also fed into a differential amplifier 55, which converts
the voltage pulses into undirectional pulses, which are then shaped
in a pulse shaper 56 and fed into a counter 57. In the embodiment
5 illustrated, the counter 57 is an 8-bit counter giving a capacity
of 256 counts. The counter 57 is connected by an 8-channel line to
an output control 58 which allows the count in the counter 57 to be
read.

 The required values for the minimum, maximum and threshold
10 torques T_3 , T_4 , T_1 , can be selected for the particular connection
under consideration by three thumbwheel switches 61, 62, 63,
respectively. Each of these thumbwheel switches feeds a digital
signal representative of the required torque level into a respective
output control 64, 65, 66. A fourth thumbwheel switch 67 allows
15 the selection of a desired angular rotation (measured from the point
at which the threshold torque T_1 is exceeded ($\theta_1 - \theta_0$)) within
which the desired torque must be achieved and feeds a digital signal
representative of this value into an output control 68. It should
be noted that, if desired, the thumbwheel switch 67 and output control
20 68 could be replaced by two similar switches and controls, one of
which allows the selection of a minimum angular rotation ($\theta_3 - \theta_0$) the
other of which allows the selection of a maximum angular rotation
($\theta_4 - \theta_0$). In most joints however, provided that the required torque
range is specified, the range of angular rotation within which these
25 values are achieved in good connections always falls within fixed
angular rotation on either side of a mean value. In the present
embodiment of the invention therefore, the control system is
programmed to calculate from a predetermined mean value the maximum
and minimum values of the angular rotation after the threshold
30 torque T_1 has been exceeded within which the minimum torque must be
exceeded. This simplifies the setting of the control system.

 The output controls 53, 58, 64, 65 66 and 68 are all
connected by a common 8-channel input bus 70 to an input interface
card 71 which relays, via an 8-channel line 72, the signals on the
35 input bus 70 to one input port of a 4-port input and output gate 73.

The other input port of the gate 73 is connected by a separate 8-channel line 74 to the input interface card and receives calibration and display signals from a further 8-channel bus 76 which is connected to calibration and display control switches.

5 The gate 73 includes two output ports, which are connected by separate 8-channel lines 77, 78 to an output interface card 80. The output card 80 includes a decoding circuit which decodes signals on one of the output lines 77 from the gate 73 and transmits the resulting address signals to the output controls 53, 58, 64, 65, 66
10 and 68 along six address lines 81 interconnecting the output interface card 80 and the output controls. Three additional address lines 81 are connected to respective latches 82, 83 and 84. One latch 82 controls the operation of a set of seven indicator lamps 86 and the marker unit 23, the other two latches 83, 84 control the X- and Y-
15 inputs to an oscilloscope 91 . Each latch is also connected to the output interface card 80 via a common 8-channel output bus 85, to which signals are fed from the second output port of the gate 73 along the 8-channel line 78.

20 The latch 82 has eight output channels corresponding to each digit of the 8-bit bytes stored therein. Seven on the channels are connected via respective amplifiers 87 to the indicator lamps 86. The eighth channel from the latch 82 is connected via an amplifier to a driver for a solenoid which controls the supply of air to the marker unit 23.

25 The two latches 83, 84 are each connected to a respective digital to analogue (D/A) converter 89,90, the outputs of which are amplified and fed to the X and Y controls of the oscilloscope 91.

Electrical signals are fed to and received from the gate 73 by an 8-bit microprocessor 100 along an 8-channel line 101. The micro processor 100 receives instruction input signals along line 101 from a control programme stored in a programmable
5 read - only memory (PROM) 105, and supplies signals to, and receives signals from, a random access memory (RAM) 106 along line 101.

The storage capacity of the RAM 106 is allocated to two main functions. A joint memory section of the RAM 106 stores data
10 concerning the torque/angle of rotation characteristics of the joint and comprises four areas each capable of storing 256 8-bit bytes. The information stored in this area is used to generate a permanent record of the tightening characteristics of the joint. If a permanent record of the joint is not required, this part of
15 the RAM 106 can be dispensed with, together with the oscilloscope 91 and the printer 110. A scratch pad section of the RAM 106 stores working data relating to the joint and is used to generate a signal indicative of the quality of the joint. The scratchpad includes a memory for storing digital values corresponding to the torque
20 and angle values set by the operator on the thumbwheels 61, 62 63 and 67, similar values calculated during calibration of the system, and actual values read during operation of the system, as described later. The scratch pad also includes a joint pointer, which is incremented by the control programme as described later
25 to allow the 256 storage units in each of the four areas of the joint memory to be addressed in sequence; a 256-count joint memory counter; storage facilities for two stop flags; a 256 count loop counter; a stop counter and storage facilities for information concerning the status of the indicator lamps 85.

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The operation of the control system will now be described. The system is first calibrated using the sequence of steps illustrated in the flowchart illustrated in Figure 5. The events described below correspond to the numbered boxes shown in the flowchart. The power supply to the system is first switched on (001). The joint memory and the input and output interface cards 71 and 80 are then enabled (002); the scratch pad and the joint pointer are set (003); and the scratchpad memory is brought to zero (004). No further action occurs until the operator indicates that he is ready to calibrate the system (005). When a "ready to calibrate" signal is received along line 76, a coded address signal is supplied to the output interface card along line 77. This signal is decoded in the output interface card 80 and is passed along the appropriate address line 81 to the output control 53 of the AD converter 52

Simultaneously a coded address signal is passed along line 78 via the output interface card 80 to the common output bus 85 together with an address code signal ^{along} the address line 81 to the latch 82 controlling the operation of the indicator lamps, with the result that the first of the seven lamps 85 is illuminated, indicating that the power tool should be allowed to run freely (006).

When the power tool is ^{running freely} the joint memory counter is set to 255 (077) and successive digital signals representative of torque in the A-D converter 57 are transmitted sequentially to the scratchpad memory and accumulated therein. This procedure is repeated until at least 32 counts have been received in the counter 57 (009) and the count in the joint memory ^{counter} is zero (010). The value of the accumulated torque signal in the ^{scratchpad} memory is then divided by 256 to produce a digital signal representative of a zero applied torque (011). This signal is then increased by a predetermined offset so as to avoid the generation of signals representing negative torque (012).

The resulting value is then stored in the scratchpad memory and a coded output signal is fed along the common output bus 85 to the latch 82 together with an address signal along the address line 81 connected thereto so as to illuminate a second one of the lamps 85, indicating that the system is ready for use (013).

The sequence of steps followed in using the tool to fasten a connection is illustrated in the flow chart shown in Fig. 6. When the desired minimum torque T_3 , maximum torque T_4 , angular rotation θ and threshold torque T , have been set on the thumbwheel switches 61, 62, 63 and 67, the output controls 64, 65, 66 and 68 are addressed in turn. The signals representing their values are transmitted along the input bus 70, and processed for storage in the scratchpad memory (014-017). In these steps, the digital signals in the output control representing the torque levels T , T_3 and T_4 are expressed relative to the digital value of from zero torque determined during the calibration. The signal representing the desired angular rotation θ is further processed (018) to generate maximum and minimum angular rotation values $\theta_{\min}$ and $\theta_{\max}$ which are also stored in the scratchpad memory.

The loop counter in the scratchpad memory is set to 255 and the joint pointer is incremented (019). The output control 53 of the AD converter 52 is then addressed and the sampled torque value is stored in the scratchpad memory (020) and in the first of the four areas of the joint memory. The output controls of the counters are also addressed and the sampled values of the angular rotation

stored in the scratchpad and in the second of the four areas in the joint memory (021). The sampled torque value is then compared with the last sample torque value stored in the scratchpad memory (022) and, if it is greater than the stored value, it is substituted therefor (023). The torque value is then compared with the minimum torque value T_3 (024) and if it is equal to or greater than this value, a count flag in the scratchpad is reset (025). In the initial stages of the tightening of the connection (part A of the graph of Figure 1) the minimum torque value T_3 will not be reached. Stage (025) will therefore be bypassed and the count flag therefore remains unset.

The increase in the torque value over the last torque value is then calculated and stored in the third area of the joint memory (026) and the increment in the angular rotation over the last value is calculated and stored in the fourth area of the joint memory (027).

The count flag is then interrogated (028). In the initial stages of the tightening the count flag is not set, since the minimum torque T_3 has not been exceeded. In this case, the next stage (029) is bypassed. A stop flag set during a later stage of the processing is then interrogated (030). In the initial stages of the tightening this stop flag will not be set, in which case the torque value is compared with the threshold value T_1 (031). If this value has not been exceeded the next step (032) is bypassed and the second stop flag is again interrogated (033). In the initial stages of tightening this second stop flag will not be set, in which case the next two stages (034, 035) are also bypassed. The loop counter is then decremented (036) and the level of the loop counter determined (037). If the loop counter is not at zero, the cycle of events from stage (019) is repeated. In this way the maximum torque and angular rotation values detected in 256 cycles will accumulate in the scratchpad memory together with a set of 256 values in the joint memory for the absolute values of the torque and angular rotation and of increments over the respective previous values (see steps 20,

21, 26, 27). If 256 such sets of values should accumulate in the joint memory without the threshold torque value T_1 being exceeded, the joint loop count will be decremented to zero (step 036). At this time, the system repeats the cycle of events from step (014) (step 037). This ensures that any changes which may have been made to the torque and angular rotation values T_1 , T_3 , T_4 and Θ are taken into account.

As the tightening process approaches the end of section A of the graph in Figure 1, the torque values begin to increase and eventually exceed the threshold torque T_1 . Thereafter, when stage (031) is reached in the next process cycle, the count and stop flags are set (032). In addition, the stop counter in the scratchpad memory is set. The stop counter has a number of counts equal to or greater than the number of increments in the torque and angular rotation during the remainder of the joint (i.e. parts B and C of the graph in Figure 1).

The stop flag is interrogated (033) and, since it is now set, the stop counter is decremented by one count (034). After determining that the count in the stop counter is greater than zero (035) the cycle continues as described previously.

In each cycle thereafter, when the count flag is interrogated at stage (023), the increment in angular rotation in that cycle is stored in the scratchpad memory and summed with successive increments (029). This accumulated value therefore represents the angular rotation of the connection since the threshold torque was exceeded.

As the tightening process approaches the end of section B of the graph of Figure 1, the minimum torque T_3 is reached, whereupon, after stage (024) in the next process cycle, the count flag is unset (025). When the count flag is interrogated at stage (028) and found to be unset, the next stage is bypassed so that no further rotational increments are added to the accumulated value in the scratchpad memory.

The accumulated value of angular rotation

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therefore represents the value $(\theta_3 - \theta_0)$ in Figure 1.

The peak torque T is reached when the pneumatic motor is switched off by its own control system and the applied torque then decrease in accordance with the characteristics of part C of the graph in Figure 1.

Throughout this last part of the tightening process, torque and angular rotation values continue to be accumulated in the joint memory on each cycle, and the count in the stop counter is decremented on each cycle (stage 34). When the stop counter reaches zero no further data is stored, and the stored data in the scratchpad memory is used as a basis for a decision as to the quality of the joint (stage 035).

The flow chart of the decision process is illustrated in Figure 7.

When a zero count is detected in the stop counter, a coded signal is transmitted along the common output bus 85 to the latch 82 together with an address signal along the line 81 associated therewith so that the first lamp 85 indicating that the system is "ready", is turned off (038).

The value of the maximum detected torque T stored in the scratchpad memory at stage (023) in the processing cycle is compared with the corrected value of the maximum desired torque, T_4 also stored in the scratchpad memory (039). If this value is exceeded, a coded output signal is passed along the common output bus 85 to the latch 82, together with an address signal so that a third indicator lamp is illuminated, indicating that the maximum applied torque is too high (040). The condition of this lamp is also recorded in the scratchpad memory.

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If T_4 has not been exceeded, stage (040 is bypassed and the maximum torque is compared with the corrected value of the minimum desired torque T_3 (041). If this value has not been reached a fourth lamp 85 is illuminated indicating that the maximum applied torque is too low (042). The condition of this lamp is also recorded in the scratchpad memory.

If T_3 has been exceeded, the accumulated value of the angular rotation ($\theta_1 - \theta_0$) is compared with the minimum angle θ_{min} (043). If the accumulated value for the angular rotation is lower than the minimum angle, the next stage is bypassed, and a fifth lamp 85 is illuminated indicating an incorrect slope in part B of the tightening characteristics (045). If the accumulated value for the angular rotation is greater than the minimum angle, it is compared with the maximum desired angle θ_{max} (0.44). If it is greater, the fifth lamp 85 is illuminated (045). If it is smaller, stage (045) is bypassed. The condition of the fifth lamp is recorded in the scratchpad memory.

The conditions of the indicator lamps are then interrogated (046) and if they indicate that an unsatisfactory joint has been made, the next two stages are bypassed. If interrogation of the condition of the indicator lamps indicates that a satisfactory joint has been made, a sixth indicator lamp 85 is illuminated (047), a relay for the solenoid controlling the marker unit 23 is operated and a relay timer is initiated (048). A timer for the lamps 85 is then initiated (049). The relay timer is then interrogated (050) and if it is not at the end of its cycle, the next stage is bypassed. If the relay timer is at the end of its cycle, the relay for the solenoid is switched off (051). The lamp timer and relay are then interrogated (052).

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If both are not at the ends of their cycles, the sequence of operations is repeated from step (050). As a result, if a satisfactory joint has been produced, the bolt head 22 will have been marked by the marker unit 23. If an unsatisfactory joint
5 has been produced the bolt head will not be marked, and an indicator light will show the reason for failure of the joint. If both the relay timer and the lamp timer have completed their timing cycles, all the indicator lamps 85 are switched off (053). The first lamp is then switched on again (054) indicating that the
10 system is ready, the two . . . flags are reset and the maximum torque count and angular rotation count cleared from the scratchpad (055). The cycle thereafter continues from stage (014), allowing another joint to be made.

If it is desired to obtain a written record of the marking
15 of the connection , the information accumulated in the joint memory during the making of the connection can be supplied via the second latch to a printer 110. The printer is optionally activated after stage (052) of the cycle and may for example be supplied with instructions to print out the applied torque, angular rotation
20 ($0_3 - 0_0$), whether connection was good, or if not the reason for its failure.

In addition or alternatively, the accumulated data in the joint memory may be displayed on the oscilloscope. For example, after stage (052), the whole of the information accumulated in
25 the joint store may be supplied in sequence to the latches for the X and Y drives of the oscilloscope thereby producing a graphical analysis of the joint.

Although the power tool described above is a hand held tool suitable for production line assembly, of motor vehicles, it will be
30 appreciated that the invention is applicable to other types of power tool, e.g. fixed tools.

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CLAIMS.

1. A power tool comprising a motor; a rotatable output shaft drivable by the motor and adapted to carry a tool; means for generating a first electrical signal representing the torque applied to the output shaft; means for generating a second electrical signal
5 representing the angular rotation of the output shaft; and means for processing the signals whilst the tool is in operation to determine the angle through which the drive shaft rotates whilst the applied torque rises from a predetermined threshold value to its greatest value, and for generating an indicator signal if the said angle and the
10 said greatest value both lie between respective predetermined maximum and minimum values, characterised in that the means for processing the signals comprises means for storing, in order, a predetermined number of values of the signals read at periodic intervals and in that means is provided for displaying the stored values.
- 15 2. A power tool according to Claim 1 wherein the means for generating the first electrical signal comprises a strain gauge.
3. A power tool according to Claim 2 wherein the output shaft is rotatable in a housing and the strain gauge is mounted on the housing.
4. A power tool according to any one of Claims 1 to 3 wherein
20 the means for generating the second signal comprises means for generating a train of pulses the frequency of which varies in accordance with the rate of rotation of the output shaft, and a counter for counting the pulses.
5. A power tool according to Claim 4 wherein means for generating the train of pulses comprises a slotted disc and a optical sensor.
- 25 6. A power tool according to any one of Claims 1 to 4 further comprising means for marking the connector engaged by the tool, the said marking means being operable in response to the indicator signal.

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7. A power tool according to any one of claims 1 to 6 wherein the means for processing the signals comprises means for reading the level of the first signal at predetermined intervals, means for storing signals representing the level of the first signal, means for updating
5 the stored signal with subsequent signals representing levels of the first signal corresponding to higher torques, and means for comparing the stored signal with signals representing the threshold, minimum and maximum torque values.

8. A power tool according to any one of Claims 1 to 7 wherein the
10 means for processing the signal comprises means for reading the levels of the second signal at periodic intervals, means for determining differences between consecutive levels of the second signal and means for summing the differences whilst the level of the first signal increases from a level corresponding to the torque threshold value to a level
15 corresponding to the minimum torque value.

9. A power tool according to any one of claims 1 to 8 wherein the means for displaying the stored values comprises a visual display unit and/or a printer.

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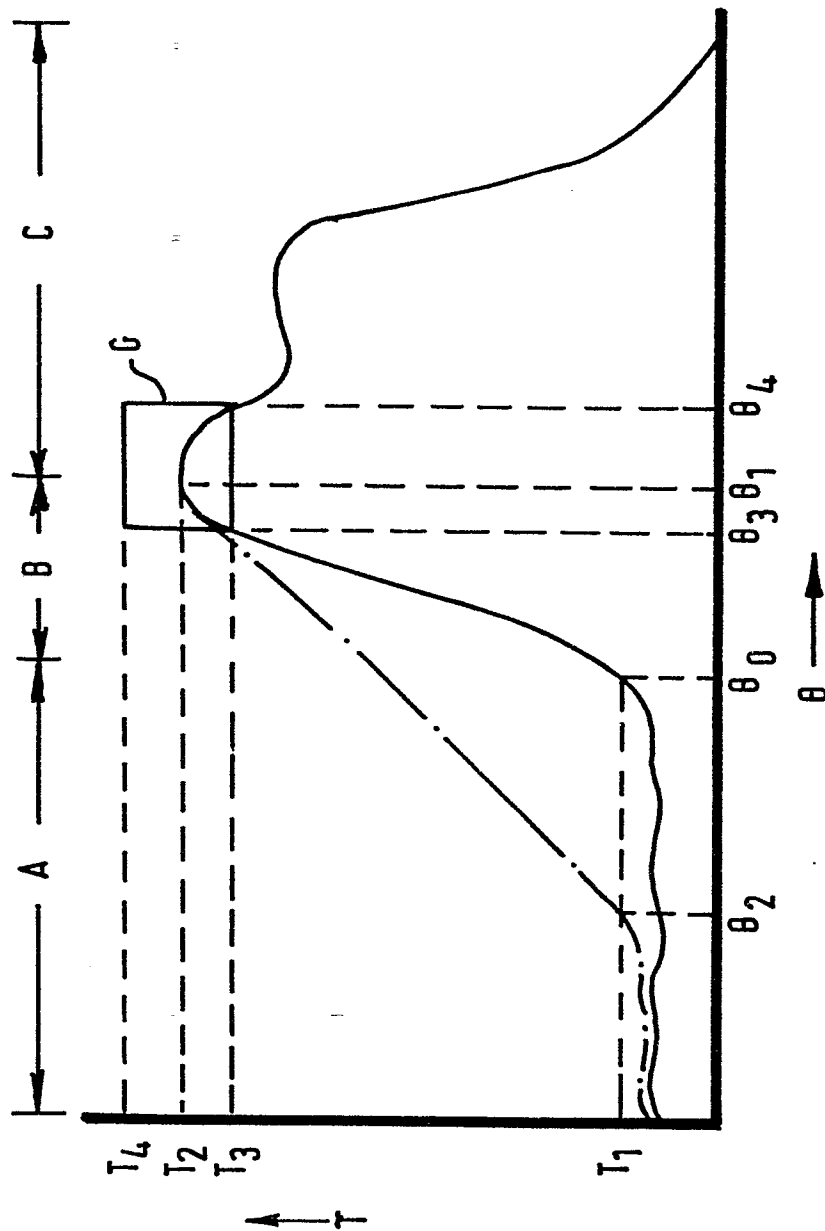
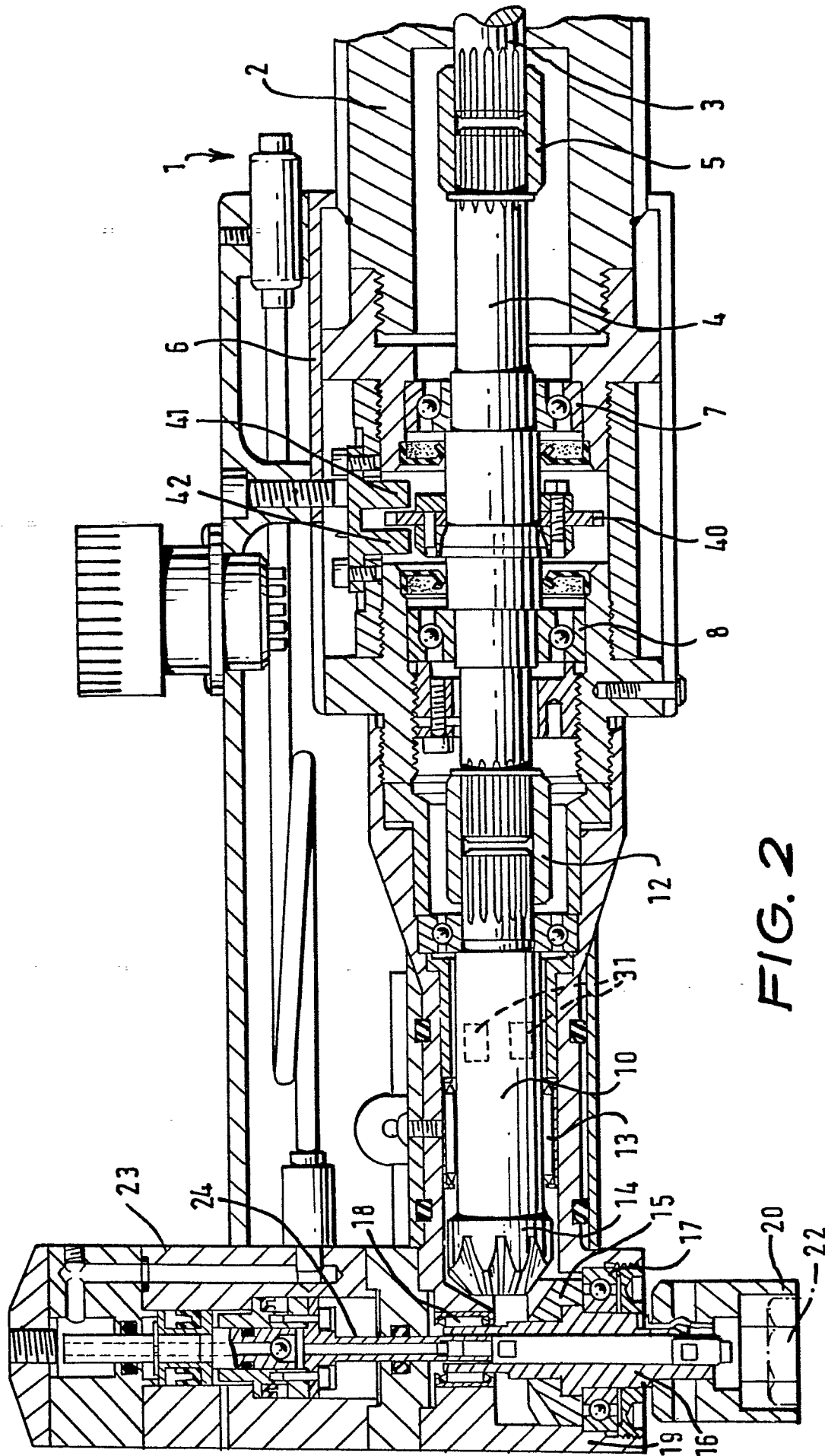
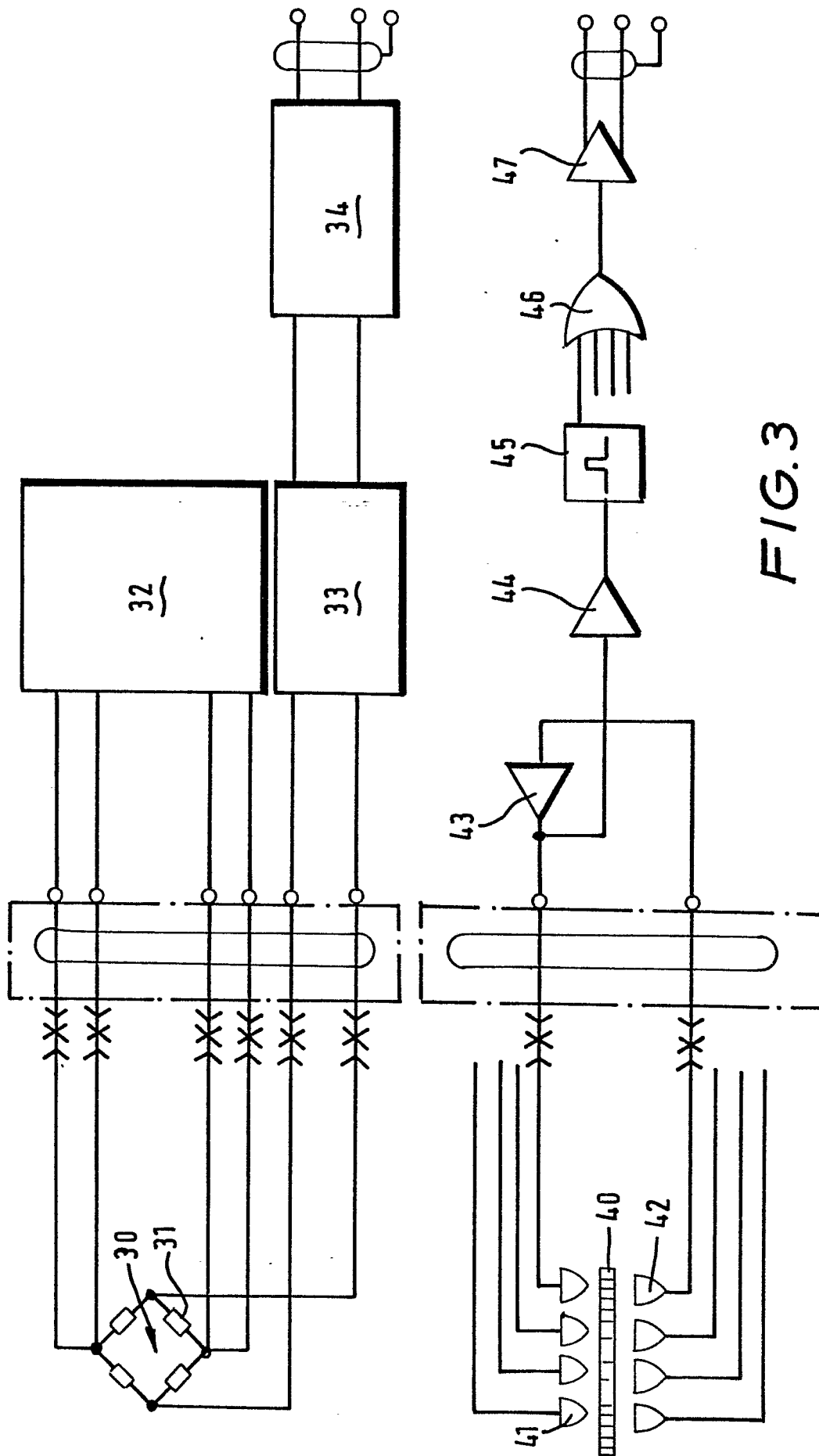


FIG. 1

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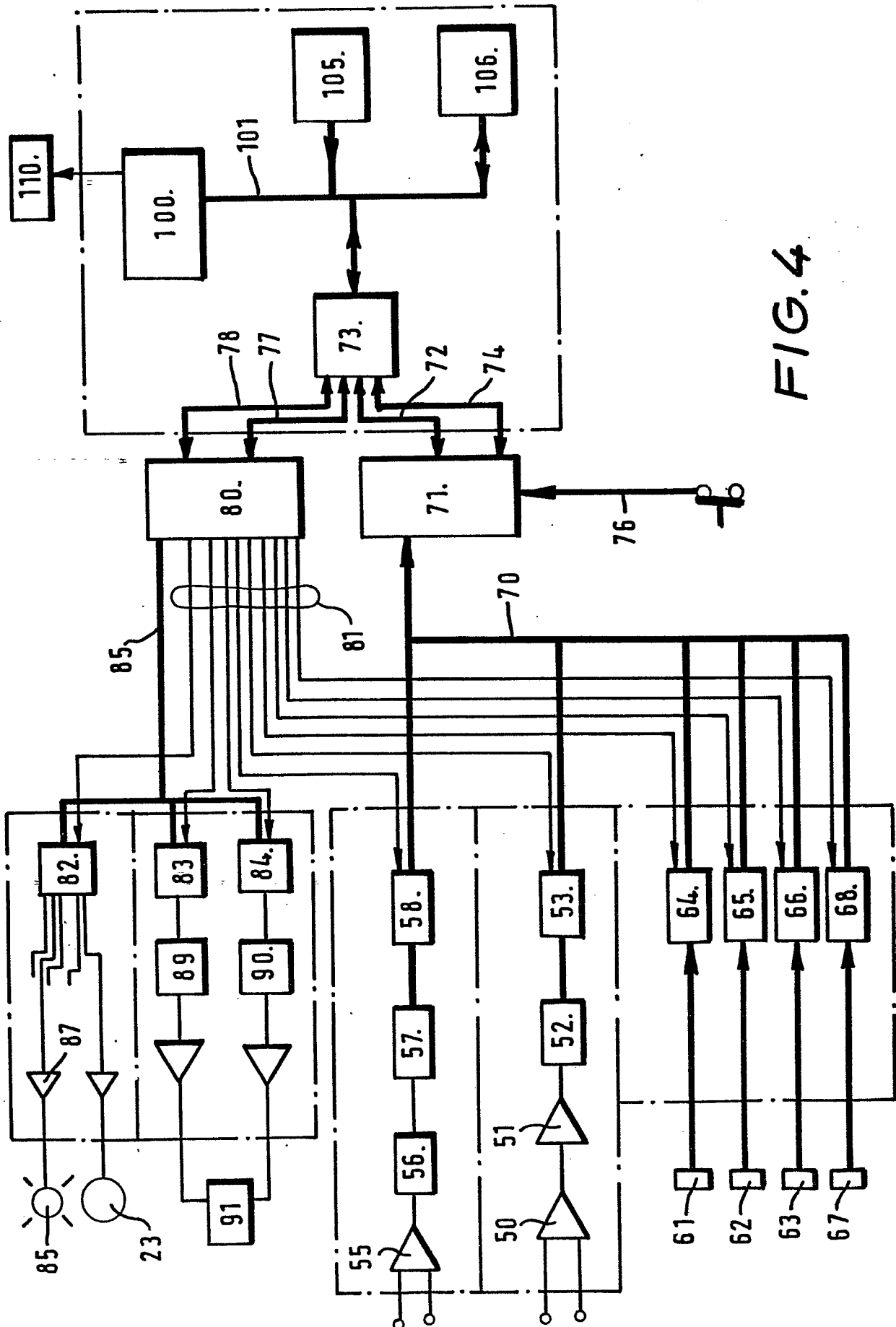


FIG. 4

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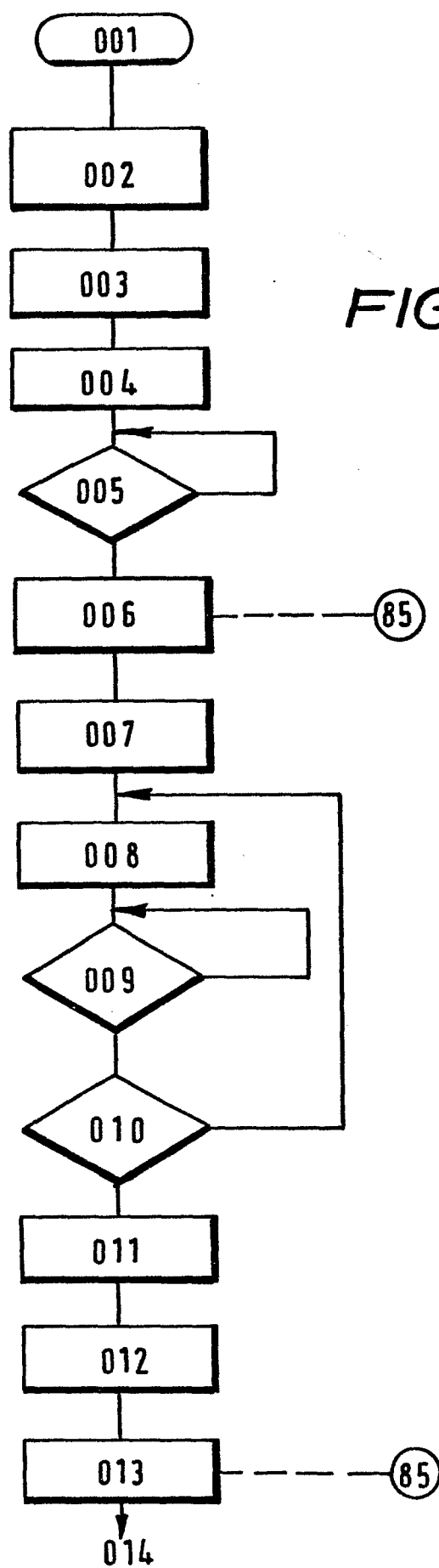
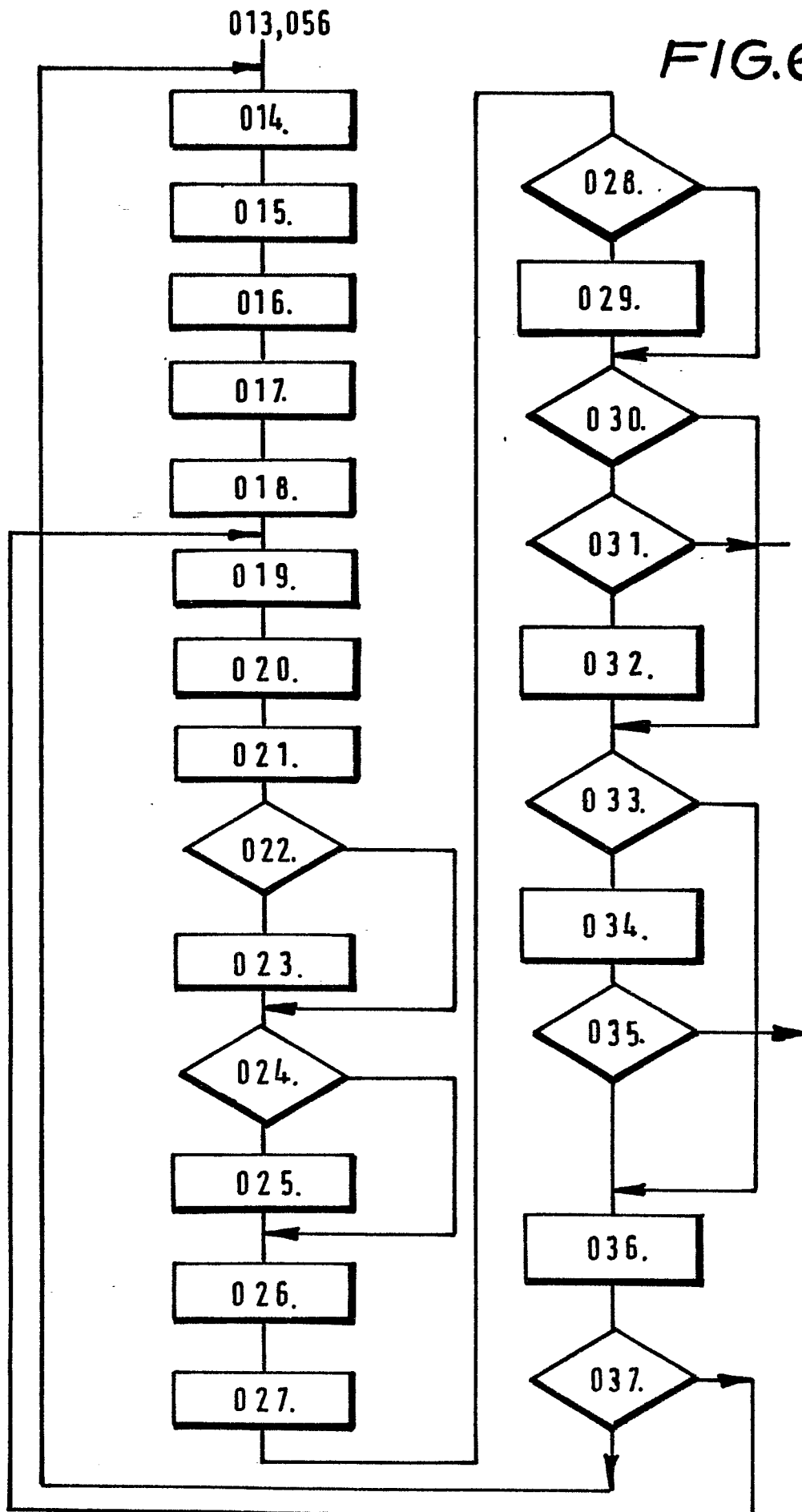


FIG. 5

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FIG. 6



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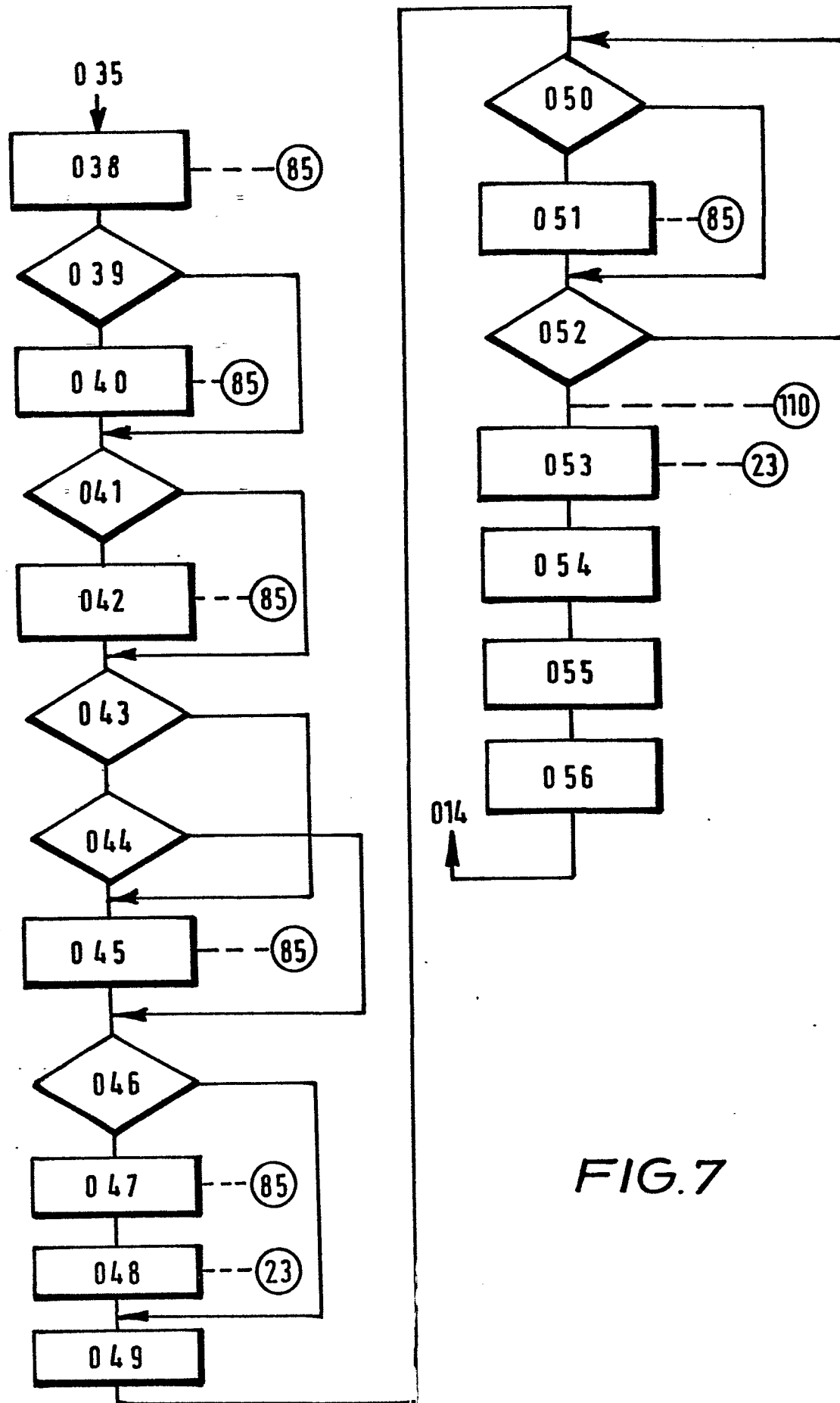


FIG. 7