MINTEK

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THE DEVELOPMENT OF AN AUTOMATIC SAMPLE-CHANGER AND CONTROL INSTRUMENTATION FOR ISOTOPE-SOURCE NEUTRON-ACTIVATION ANALYSIS

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A.H. Andeweg and J.I.W. Watterson

15th March, 1983

COUNCIL FOR MINERAL TECHNOLOGY
200 Hans Strijdom Road
RANDBURG
South Africa

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(ANALYTICAL CHEMISTRY DIVISION)

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Printed and published by the Council for Mineral Technology

ISBN 0 86999 591 X

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Programme No.	013
Project No.	208801
Project Report No.	1

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SYNOPSIS

An automatic sample-changer was developed at the Council for Mineral Technology for use in isotope-source neutron-activation analysis. Tests show that the sample-changer can transfer a sample of up to 3 kg in mass over a distance of 3 m within 5 s. In addition, instrumentation in the form of a three-stage sequential timer was developed to control the sequence of irradiation transfer and analysis.

SAMEVATTING

'n Outomatiese monsterwisselaar is by die Raad vir Mineraaltegnologie ontwikkel vir gebruik in isotoopbronneutronaktiveringsanalise. Die toetse toon dat die monsterwisselaar 'n monster met 'n massa van tot 3 kg binne 5 s oor 'n afstand van 3 m kan verplaas. Verder is instrumentasie in die vorm van 'n drietrapvolgtydreëlaar ontwikkel om die volgorde van bestraling, oorplasing en ontleding te beheer.

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1. INTRODUCTION

Isotope-source neutron activation can be used for the accurate determination of manganese and fluorine, and can be applied to the determination of a number of elements such as chromium, antimony, copper, gold, and silicon.

Over the past few years, the Activation Analysis Research Group of the Council for Mineral Technology (Mintek) developed an isotope-source neutron-activation method that is capable of irradiating and counting samples with masses of over 3 kg. Manganese and fluorine have been determined with a high level of accuracy and reproducibility by this method.

Thus far the samples have been transferred manually from the irradiator to the detector (Figure 1). This manual transfer is a weak point in the procedure, particularly in the determination of fluorine, where rapid transfer is essential. An automatic transfer system would greatly improve the method with regard to speed of analysis, reproducibility, and convenience. However, such a transfer system must be capable of the rapid transfer of a large sample in a container like that shown in Figure 2 within a few seconds.

So far the measurements have been recorded in writing and calculated with a hand-held calculator. This procedure is clumsy and time-consuming, and has the major disadvantage that any errors become apparent only after the experimental procedure has been completed. The method would be considerably improved if the final result, i.e., the concentration of the element, were available at the end of the analysis, and this would be possible if a small computer were interfaced to the data modules.

The use of such a computer would also permit the use of more complicated corrections. For example, several single-channel analysers could monitor different sections of the spectrum and so improve the accuracy of the method.

This report describes an instrumental system with extensive flexibility for future requirements. A description is also given of the interfacing of the data modules to a computer (hardware only) by use of the RS232 communication link, of a crystal-controlled sequential timer, and of the test results of a sample-changer that transfers the sample from the irradiator to the counting station within 5 seconds.

2. DESCRIPTION OF THE SYSTEM

The apparatus described in this report was developed for the analysis of large samples by isotope-source neutron activation. It consists of six main items as follows.

(a) The sample container.
(b) The neutron-absorption apparatus.
(c) An irradiator.
(d) A detector.
(e) The electronic system.
(f) The sample-transfer system.

2.1. The Sample Container

The sample container (Figure 2) is in the form of a 'Marinelli beaker' to have the best possible geometry that can be obtained during irradiation and counting in that the container is located over the source or over the detector assembly. The re-entrant hole is large enough for an NaI (Tl) detector, 75 by 75 mm. The source, which is much smaller, is fitted with a polyethelene moderator.

The sample container is of clear Perspex, which allows it to be filled with ease to constant height.

Because samples with particle sizes of 5 mm or less and masses ranging from 0,3 kg upwards are analysed, the container shown in Figure 2 was constructed in three different sizes. A special handle (Figure 3) was developed for use with the sample-changer for automatic unloading.

2.2. Determination of the Neutron Absorption

The apparatus shown in Figures 4 to 7 was originally used as a delayed-neutron detector, and was modified so that it could be used for the determination of the neutron absorption.

A neutron source is mounted in the centre of the drum, and is covered with a polyethylene moderator. The source is mounted on the steel sample tube, which is surrounded by six BF_3 counters. These counters are not necessarily in the optimum position because the unit was constructed from existing equipment.

The ratio of neutrons measured with the sample to the neutrons measured without the sample determines the absorption of the neutrons emitted by the source.

2.3. The Irradiator

The irradiator depicted in Figures 8 to 10 was constructed from a steel pipe, with a pipe of high-density polyethylene, which acts as a reflector, mounted in the centre. The drum is filled with boron-loaded paraffin wax, which forms a biological shield. The wax was grated, and was stamped into place after the centre pipe had been fitted. The neutron-irradiator source assembly is fitted inside the centre pipe and is shown in Figure 9. The source is fitted to the source holder, which in turn is fitted to the bottom plate. A polyethylene moderator is mounted over the source.

Next to the moderator is a microswitch assembly to function as a sample sensor. The source and its accessories were mounted with the aid of a rod 2 m long, with an Allen key mounted at one end. The use of the Allen-key type of screw has the advantage that it is held on a long screwdriver far more easily than are ordinary screws. The source assembly is fitted into the irradiator drum, and, when the irradiator is not in use, a polyethylene plug (Figure 10) is inserted for shielding purposes.

2.4. The Detector

A 75 by 75 mm NaI (Tl) detector is mounted in a lead case, which consists of interlocking lead rings placed on top of one another. The top is closed with a swing-top lid. The detector assembly has a device that guides the sample container over the detector, and a sensing device has been incorporated to detect when the sample container is in position.

2.5. The Electronic System

A block diagram of the electronic system is given in Figure 11. Each electronic module is based on the configuration of the nuclear-instrument module (NIM) system, and can therefore be readily adapted to other requirements. The sequence of analysis of a sample is shown in Table 1.

TABLE 1

Sequence of steps in the analysis

Step No.	Description	Action or remarks
1	Determination of the mass	Place container on balance
2	Determination of the neutron absorption	Place container in absorption apparatus and initiate timing sequence manually
3	Irradiation	Transfer container and irradiation at end of period 1
4	*First measurement of gamma activity*	*Count starts automatically after* delay time 2
5	Second measurement of gamma activity	Count starts automatically after delay time 3
6	Transfer of data	The data are transferred to the computer for processing

2.6. Determination of the Mass

The mass of the sample is determined with the aid of an electronic top-loading balance. The data output of the balance is interfaced into a specially constructed buffered interface (Figures 12 to 14), which conforms to the interface standard of the NIM 'daisy chain' as adopted by Ortec and Tennelec. The measured data are transferred into the buffer of the interface by initiation of a push button. The contents of the buffer are displayed, and are transferred through the NIM 'daisy chain' when a 'Print' cycle is initiated. The unit was built into a single-width NIM module, and obtains its supply from a standard NIM-bin power-supply unit.

2.7. Neutron Absorption

The six BF_3 detectors used in the apparatus have a plateau voltage of 1600 to 1800 V. Through a distribution box the detectors are supplied with 1700 V. The output signals of the detectors are fed into

a pre-amplifier combination, and the output of the amplifiers is fed into a discriminator-mixer unit[1]. The output of the mixer is fed into a scaler/timer device, which is triggered manually when the sample is placed in the irradiator. When the sample is removed, a Delay 1 timer is started, allowing time for transfer to the second irradiator.

2.8. A Timing Sequence for the Measurement of Irradiation and Gamma Rays

When the sample container is placed in the second irradiator, the sample sensor (Figure 10) is activated, disables the Delay 1 timer, and starts the Irradiator 2 timer. When the timer completes its programmed time, a buzzer is sounded and the sample is removed manually or automatically. The irradiator timer is disabled when the sample container has been removed. The Delay 2 timer is started automatically after removal to the sample container, and activates a timer Count 1, which enables the scaler. The scaler collects the data of the detector system. The pulses of the NaI (Tl) detector are pre-amplified and pulse-shaped via a spectroscopy amplifier. The output of the amplifier is fed into an analogue stabilizer, which uses the AM-241 peak for reference. If in certain applications the AM-241 interferes with the region of interest in the spectrum, the stabilizer can be gated when no activity is present, and ungated when a sample is counted and the stabilizer set to a peak that is emitted by the sample. Optionally, single-channel analyser channels can be incorporated to count long-lived isotopes with the aid of Delay 3 and Count 2.

2.9. Transfer of Data

A Tennelec communications interface is used that transfers the data from the data modules into a computer. The data modules indicated with a 'P' in Figure 11 are connected in a 'daisy chain' to the interface.

The device incorporates a buffer into which the data are transferred when a 'Print' command is received at the end of analysis of the 'Count' timer. The data are retrieved from the buffer by a Universal asynchronous receiver/transmitter that converts the data to the RS232 communication standard, which is compatible with the computer.

2.10. The Sample-changer

A prototype sample-changer was designed and constructed that enables the user to load the sample at a reasonable distance from the irradiator, thus minimizing the risk of exposure to radiation. With the aid of the sample-changer, the irradiation time can be controlled accurately and the transfer time is constant, as opposed to that of manual operation. This is an important feature, especially when short-lived isotopes are counted, e.g., ^{16}N, used in the determination of fluorine, has a life of 7,2 s.

The design criterion is set at 5 s for the transfer of the sample from the irradiator to the counting station over a distance of 3 m with a mass not exceeding 4 kg for the sample container and sample.

2.10.1. Operation

The irradiator and counting stations are spaced 3 m apart. Over the stations an aluminium 'T' channel (Figure 1) functions as a guide rail for the sample trolley, which has an electric hoist (Figures 15 to 19) driven by a direct-current geared-down motor. The hoist drive is anchored by an electric magnetic brake. Between the two stations the sample container (Figure 2) is hung from the hoist hook, and the sample trolley is then pushed above the irradiator and held in position by the holding coil. At the depression of the 'Set run' button (Figures 20 and 21), the sample container is lowered into the irradiator by gravity. When the sample container is in position, the irradiator timer is started, and, after the relevant time has elapsed, the sample container is lifted out of the irradiator when the hoist has reached its limit, and the holding coil releases the trolley, which slides down by gravity to the counting station.

Upon reaching the counting station, the trolley is slowed down and critically damped to a stop by the brake cylinder. The sample container slides into the foam-rubber retaining bracket, the backlash of the container being absorbed by the anti-backlash pads. The container is then lowered into the counting chamber, and, when it is in position, the hook is detached automatically (Figure 3) and the cable is lifted out of the counting station, the lid is closed, and counting is started.

2.10.2. Automatic Unfastening of the Sample Container

The sample container hangs on the hoist cable. The hook of the cable (Figure 3) is clamped between the handle bars, which are hinged at an angle of 45°. On these handle bars are two rod springs, and, when the container is in the irradiator, these springs touch the side wall of the irradiator pipe, thereby preventing the handle bars from opening. When the container is positioned in the counting station, the handle bars open (because the springs do not touch the side wall), releasing the hook, and the cable is lifted out of the counting chamber.

2.11. The Sequential Timer

A sequential timer was developed for the accurate control of the irradiation, decay, and counting function used in neutron-activation analysis. Three timers were incorporated in a single-width NIM module (Figure 22).

The time base consists of a crystal-controlled oscillator (Figure 23), and can be programmed in intervals of 1 or 0,1 s. Each timer has its own 4-digit display and can be preset in the first three most significant decades. The timers can count up to 9999 or 999,9 s. They can be started with the aid of a push button or from an external source. Once the first timer has been started, the next timer is started when the preset time has elapsed. When the first timer has finished its programmed time, it can be restarted so that the next sample can be irradiated while the previous sample is being counted. Start and stop errors are prevented by the synchronization of each timer gate with the crystal time base, and this ensures that accurate and reproducible periods of time can be programmed.

Control input/output signals are made available on the rear panel for the control of irradiation time, and the counting time of external devices. The timer's contents can be printed out in the NIM 'daisy chain' format.

Three separate error-detection circuits are available and are indicated by a buzzer in the various sound formats as follows.

1. When a timer overlaps the next timer in its respective timing cycle, blips at intervals of 0,1 or 1 s are produced.
2. When the irradiation has been completed, a continuous 1000 Hz tone with blips at intervals of 0,1 or 1 s is produced.
3. When the irradiation has been completed, a continuous 1000 Hz tone is produced.

The timers can be used under various modes of operation by removal or installation of appropriate links. These options are described in the Appendix.

3. RESULTS AND DISCUSSION

A most important part of the sample-changer is the speed with which it can hoist and lower the sample. This speed depends to some extent on the mass of the sample, and the results obtained are shown in Table 2.

TABLE 2

Hoisting times for the sample-changer

Mass of sample g	Current of motor ma	Time, s
0	280	1,46
500	380	1,53
1000	500	1,6
1500	620	1,9
2000	750	2,04
2500	850	2,19
3000	900	2,48

Hoisting distance 600 mm
Mass of sample container 700 g.

The transfer time over a distance of 3 m at an angle of 10° is 1,2 s. The stopping time is controlled by the brake cylinder. In order to achieve an approximately constant transfer time, the air release of the brake cylinder is adjusted according to the mass of the samples, which can vary by as much as 250 g.

(a) Lowering time

The sample is lowered 350 mm by gravity into the detector chamber. The lowering time is controlled through the shunting of the motor by a resistor across the input of the motor terminals. This lowering time is adjusted to within 1 s according to the mass of the sample.

(b) Transfer times

The transfer times depend on the mass of the sample, and Table 3 indicates the time taken for the transfer of samples of different mass. It was found that the sample geometry was disturbed by the shock of deceleration, and, since the maintenance of a constant sample geometry is essential for high accuracy, the transfer system was not fully implemented.

TABLE 3

Total transfer times for samples

Mass of sample g	Transfer time s
500	3,66
1000	3,80
1500	4,10
2000	4,24
2500	4,39
3000	4,68

Mass of sample container 700 g.

The apparatus has proved to be very reliable and capable of a high degree of accuracy. The following features are particularly valuable.

The interfacing of the electronic balance into a data-handling device is reliable, reduces errors, and increases the handling speed.

The sequential timer has many useful built-in features. For instance, the crystal timebase allows the timer to be operated on a mains supply of unstable frequency; an example of this is a motor-generator supply in an industrial environment.

The control assembly, which synchronizes the timing-start impulse, together with the timer oscillator, enhances the total accuracy of the timing cycle.

The built-in control circuits for external devices, the alarm-error circuits, and the built-in link options make the unit an instrument that can be used in many ways other than that for which it was specially developed.

4. CONCLUSIONS

The sample-changer is able to transfer the sample within the set design limit of 5 s. This compares favourably with the best results obtained manually. A device with a much shorter transfer time, e.g., 2 s, would improve the counting statistics dramatically for the determination of fluorine. In addition, the changes in the sample geometry described are so marked that they cause errors. It is therefore proposed that a new project should be initiated for the further development of this transfer system.

5. REFERENCE

1. BIBBY, D.M., *et al.* The determination of uranium and thorium by the use of delayed neutrons. Johannesburg, National Institute for Metallurgy, *Report 1625.* 1974.

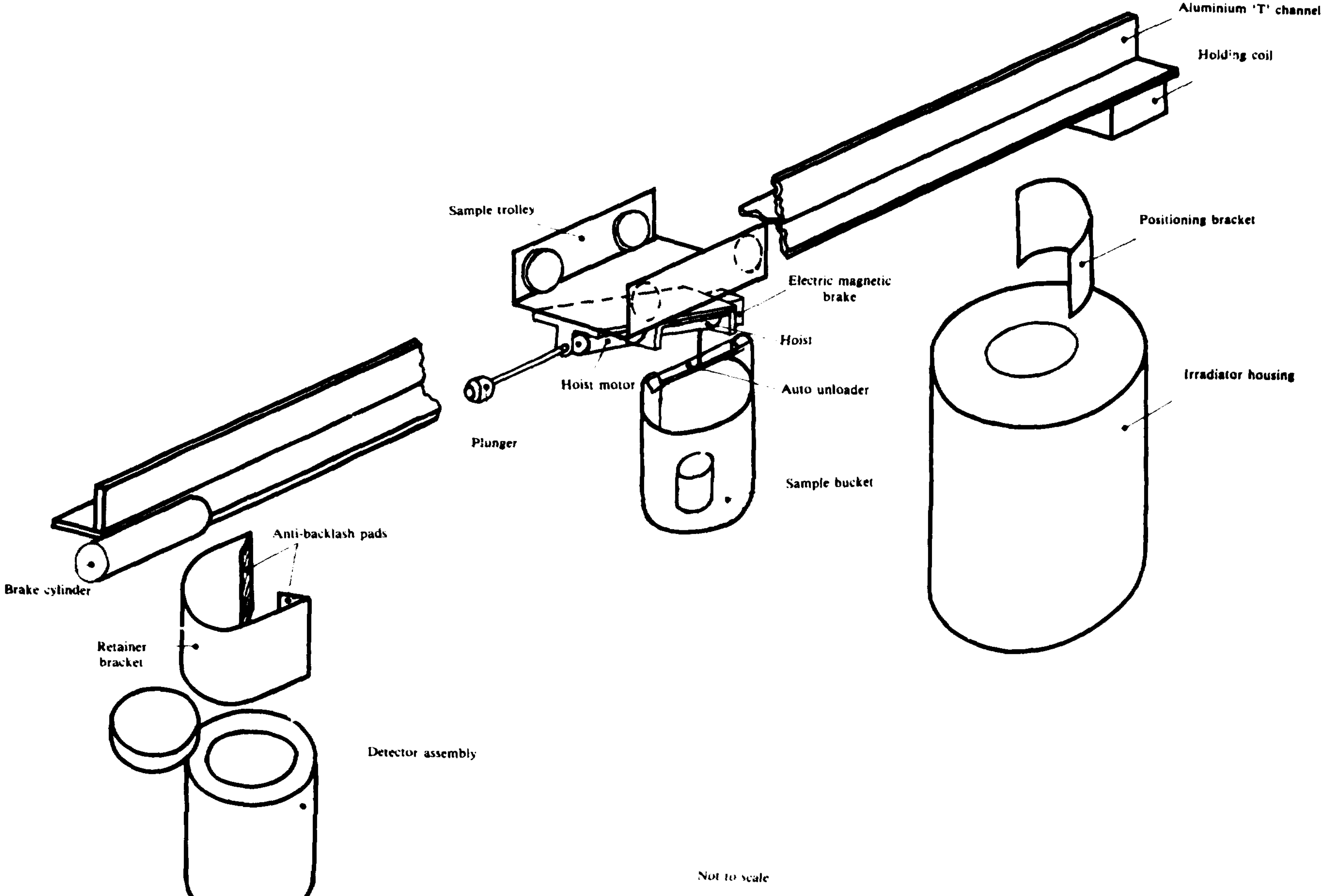
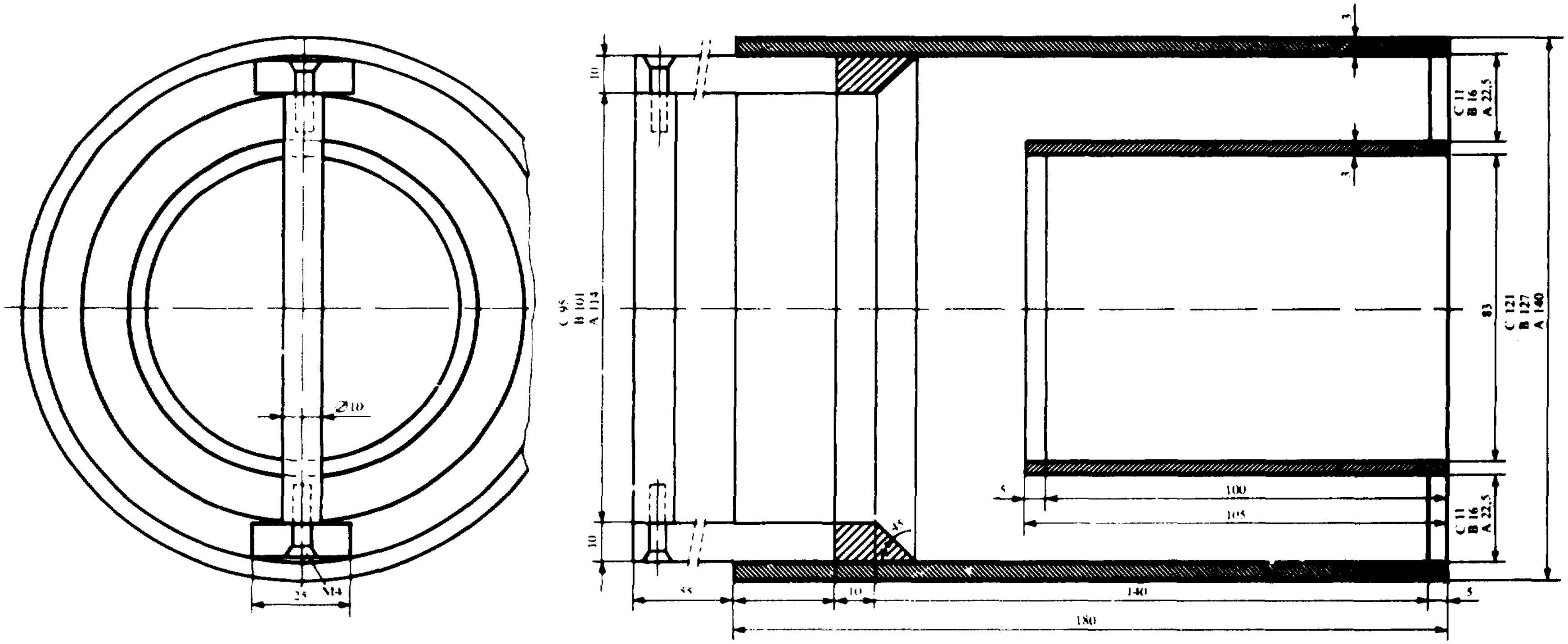


FIGURE 1. The apparatus for the manual changing of samples



All dimensions in mm
A – largest size container
B – medium size container
C – smallest size container

Not to scale

FIGURE 2. The sample container of the neutron irradiator

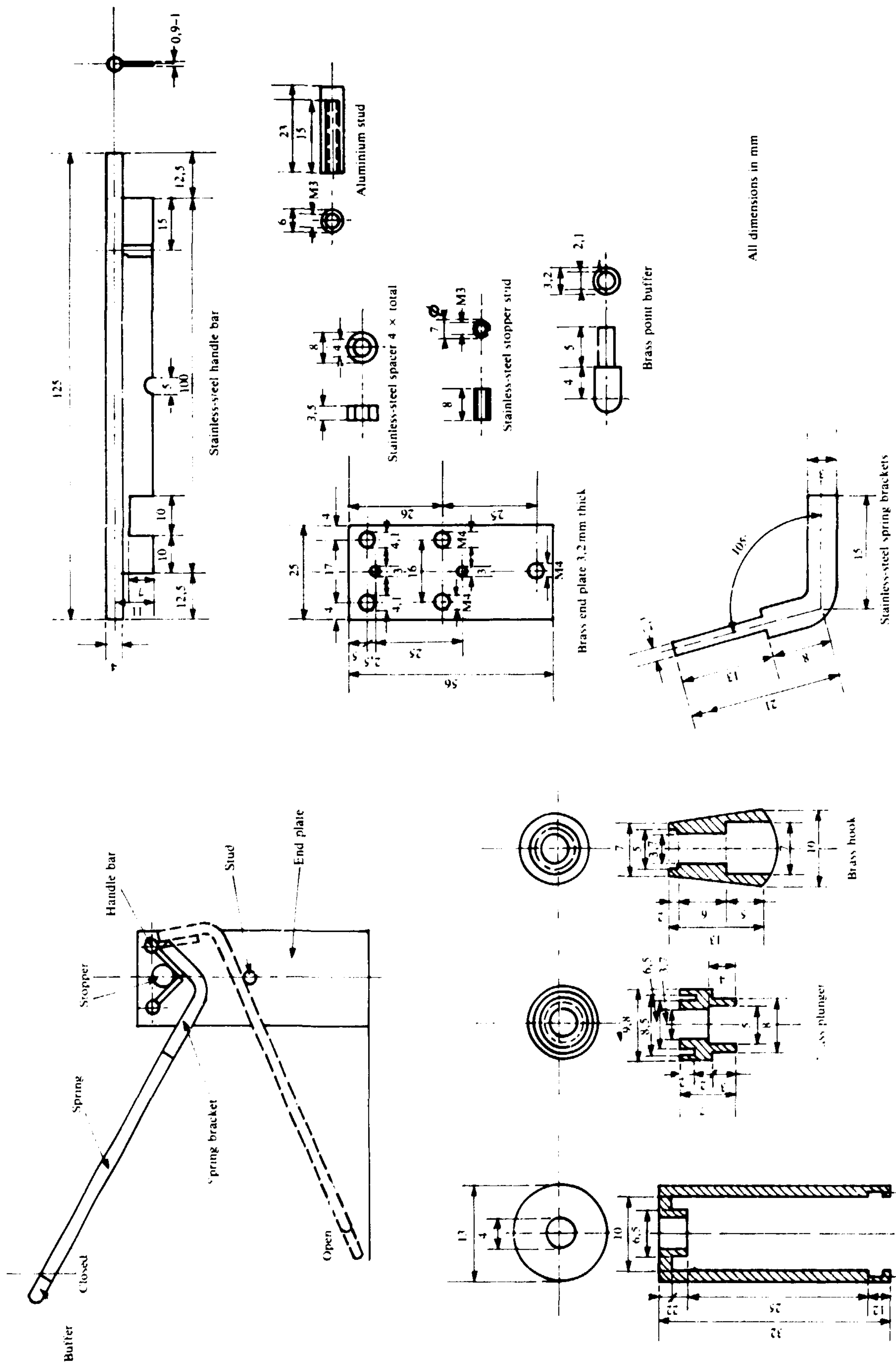
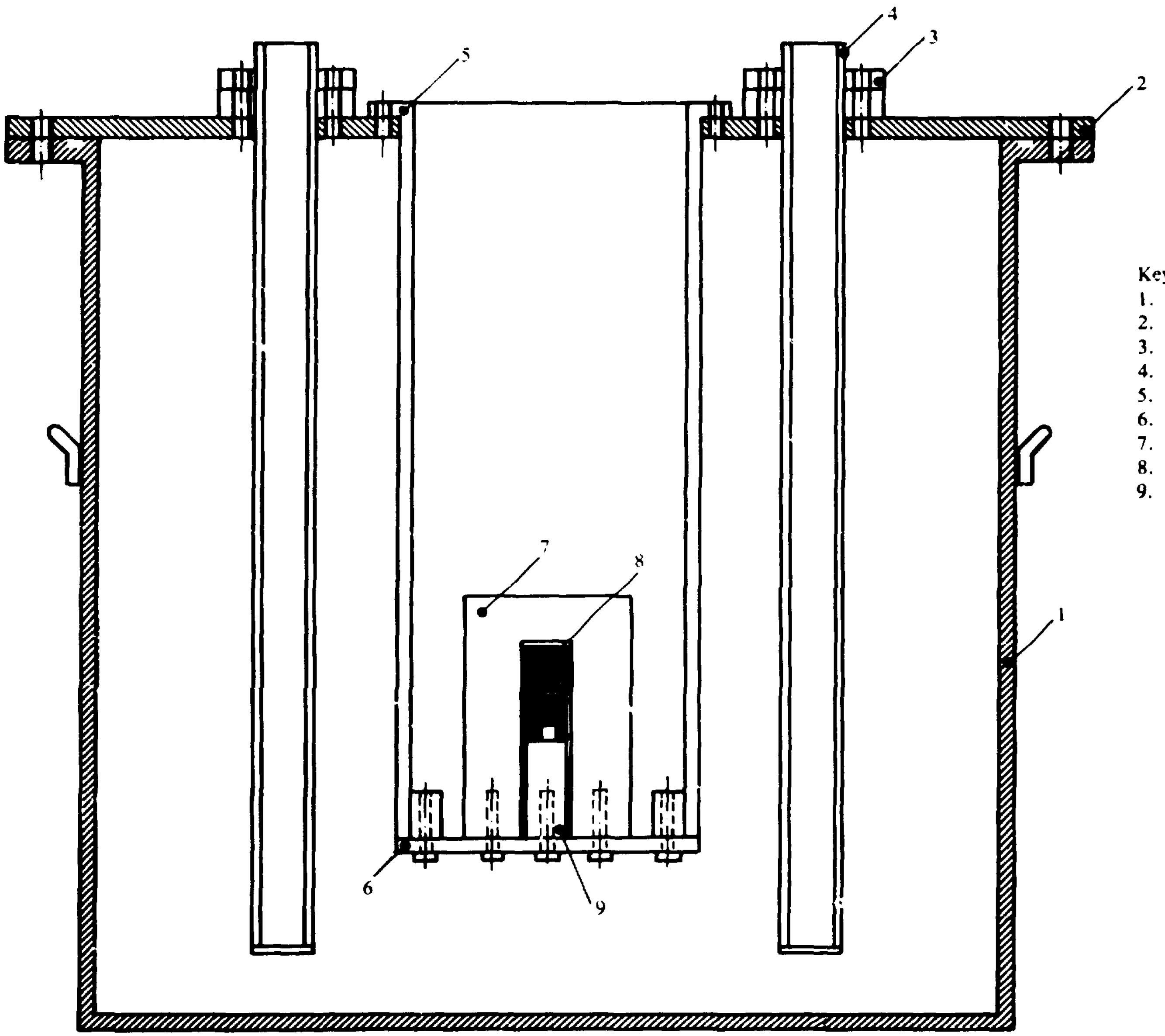
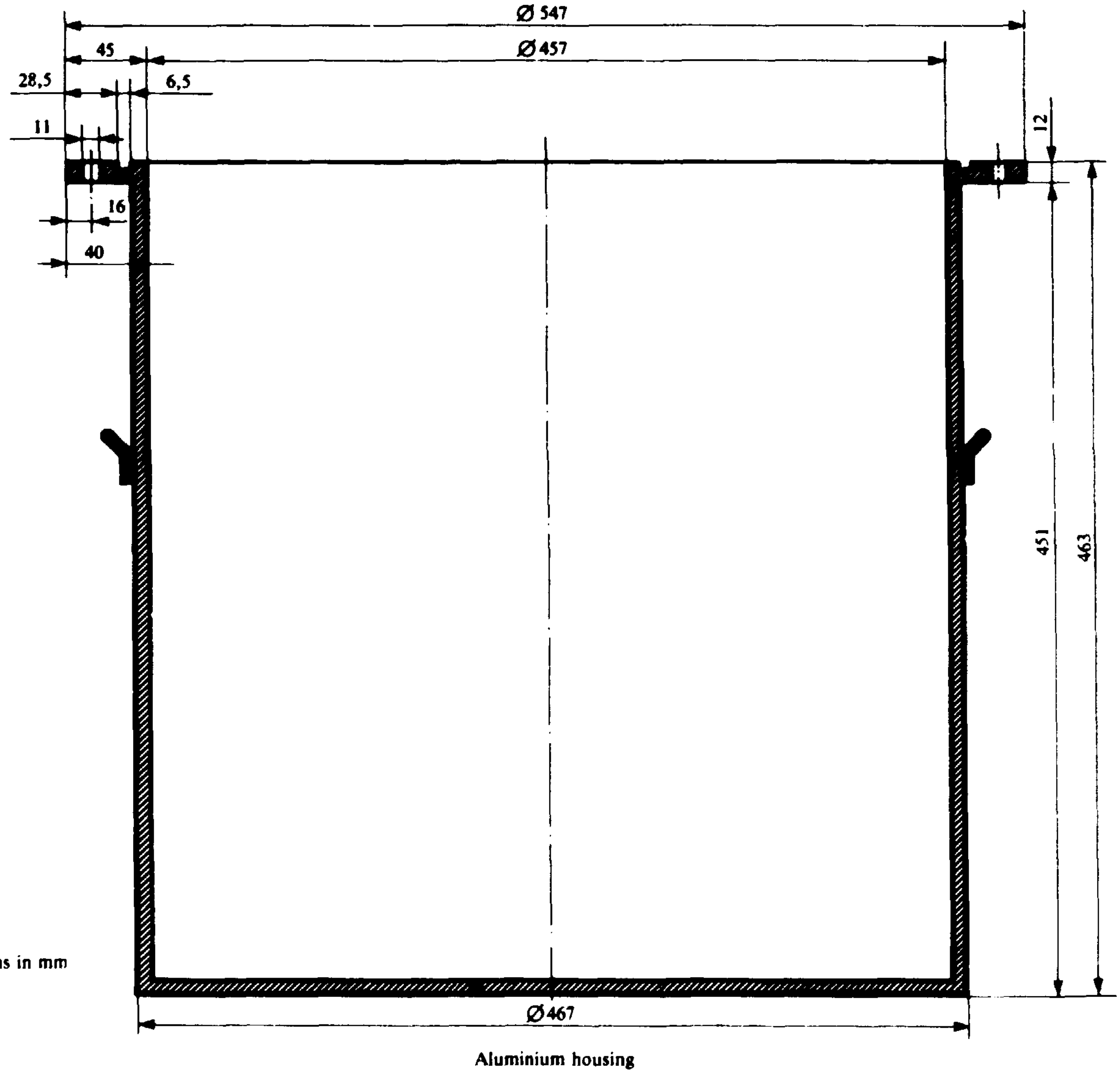


FIGURE 3. The bracket and hook for the sample container, showing special handle



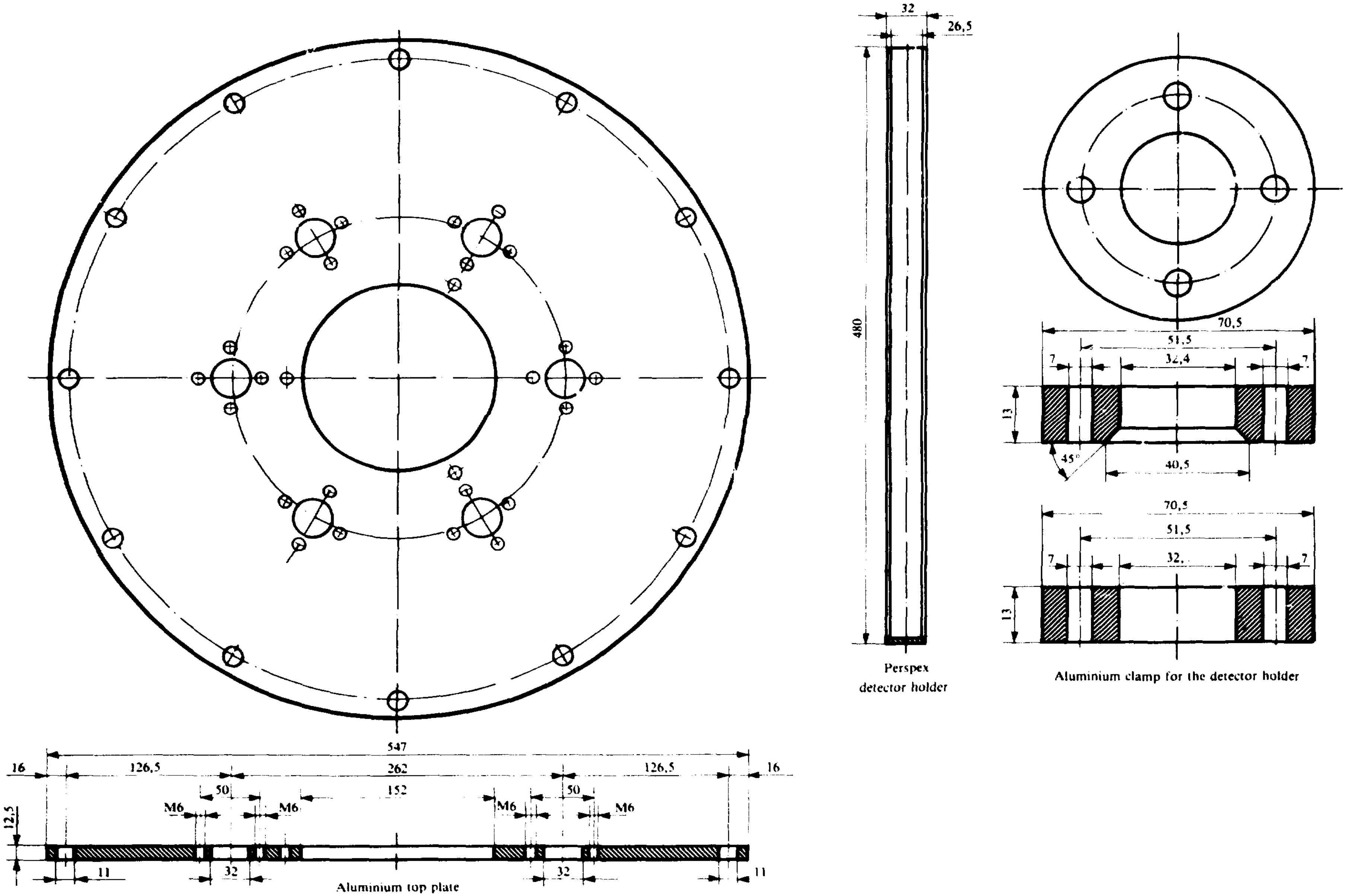
Key:
1. Housing
2. Top plate
3. Clamp for the detector holder
4. Tube of the detector holder
5. Sample tube
6. Bottom plate
7. Moderator
8. Neutron source
9. Source holder

FIGURE 4. The neutron-absorption detector



All dimensions in mm
Not to scale

FIGURE 5. The housing of the neutron-absorption detector



All dimensions in mm
Not to scale

FIGURE 6. The cover for the neutron-absorption detector

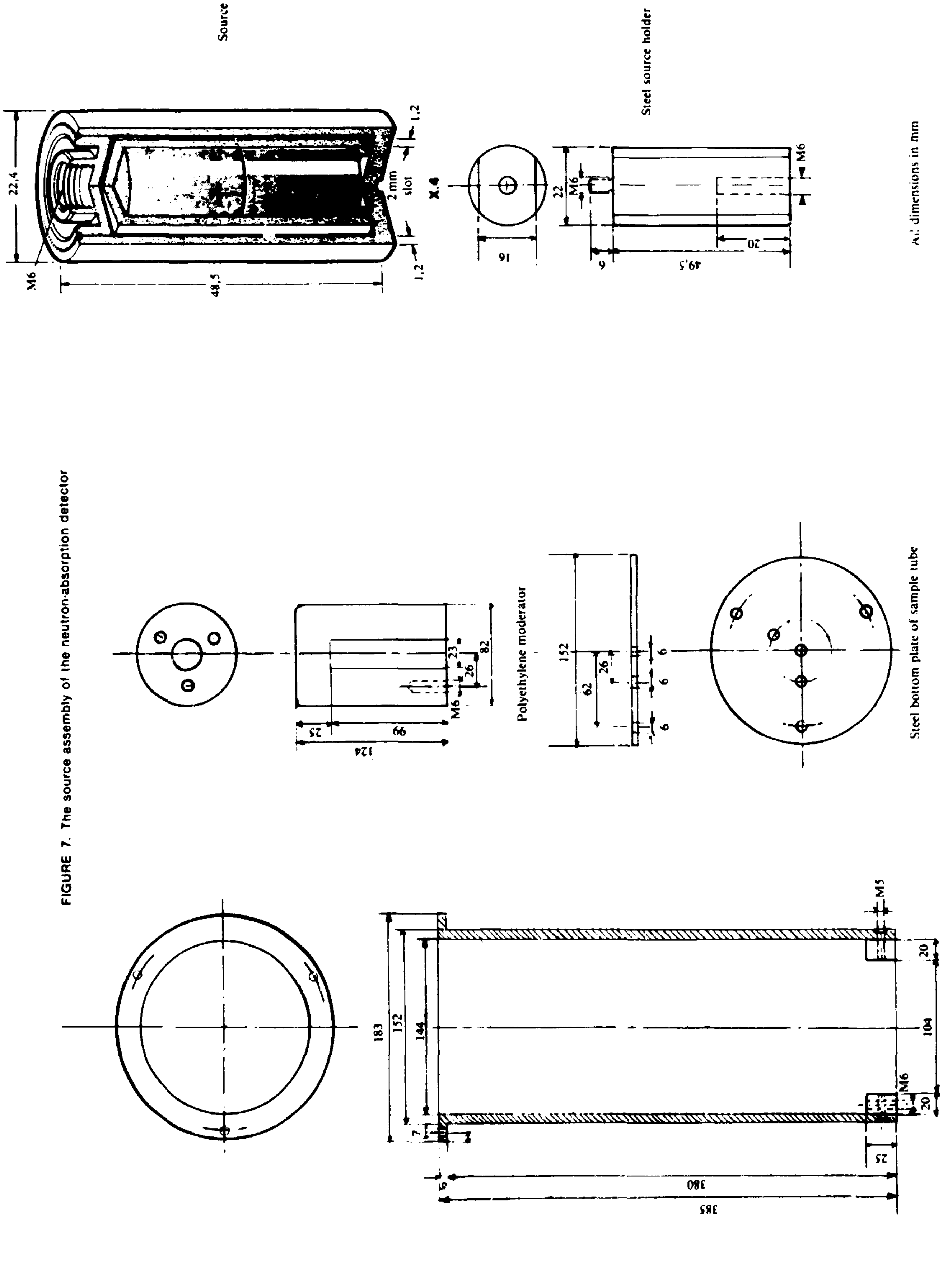


FIGURE 7. The source assembly of the neutron-absorption detector

FIGURE 7. The source assembly of the neutron-absorption detector

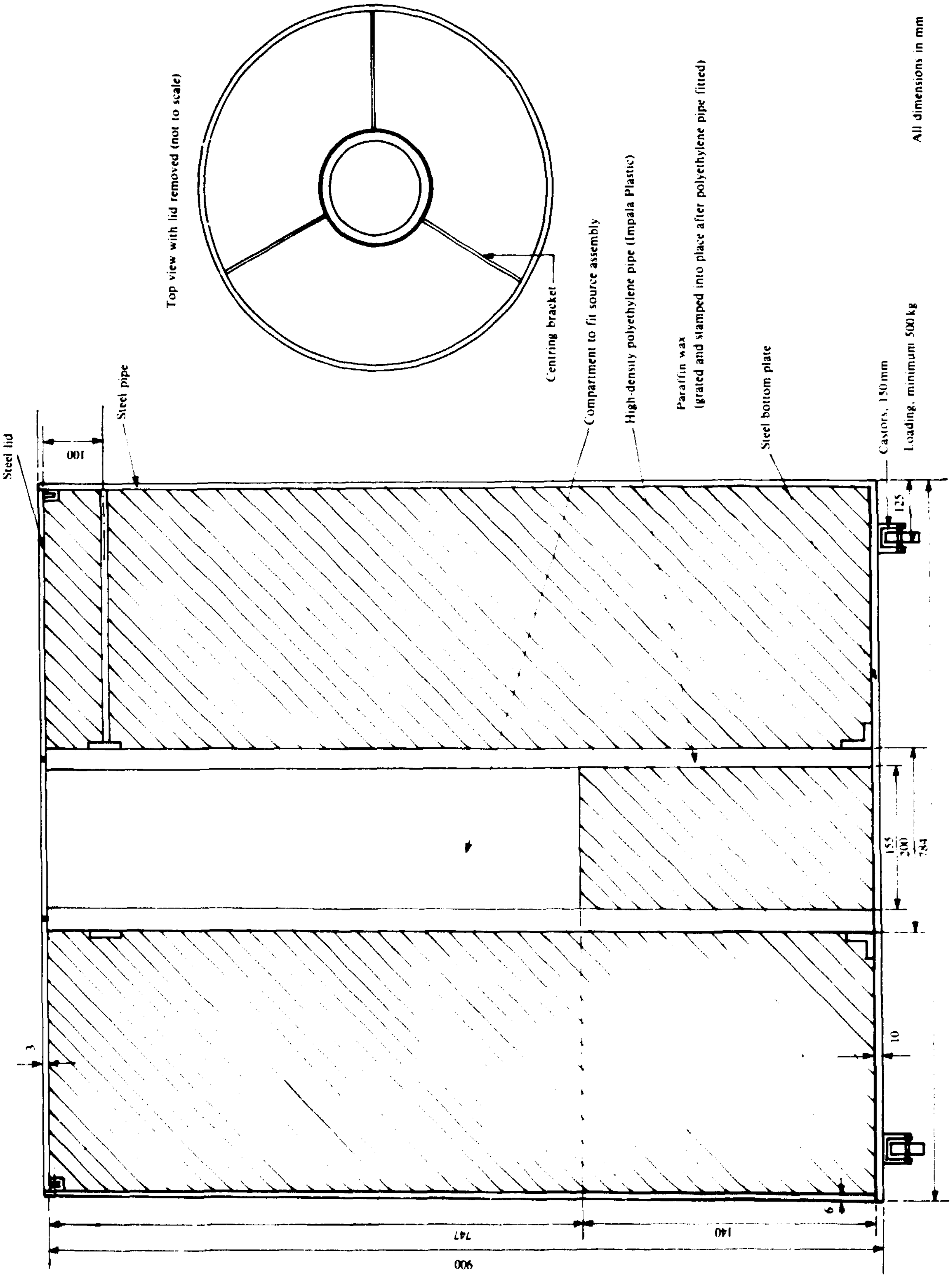


FIGURE 8. Flow Diagram 2 showing retrieval of data from magnetic tape

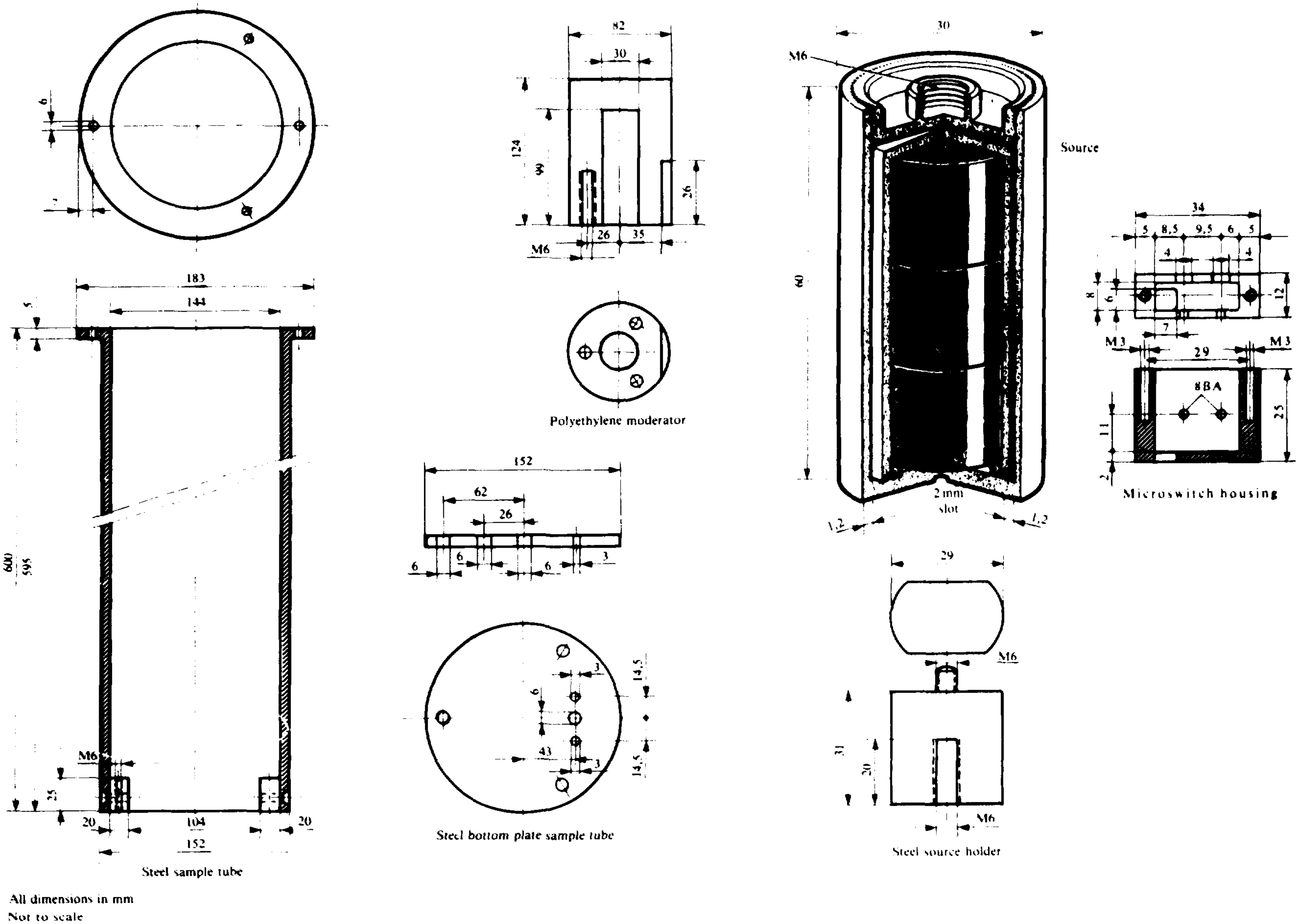
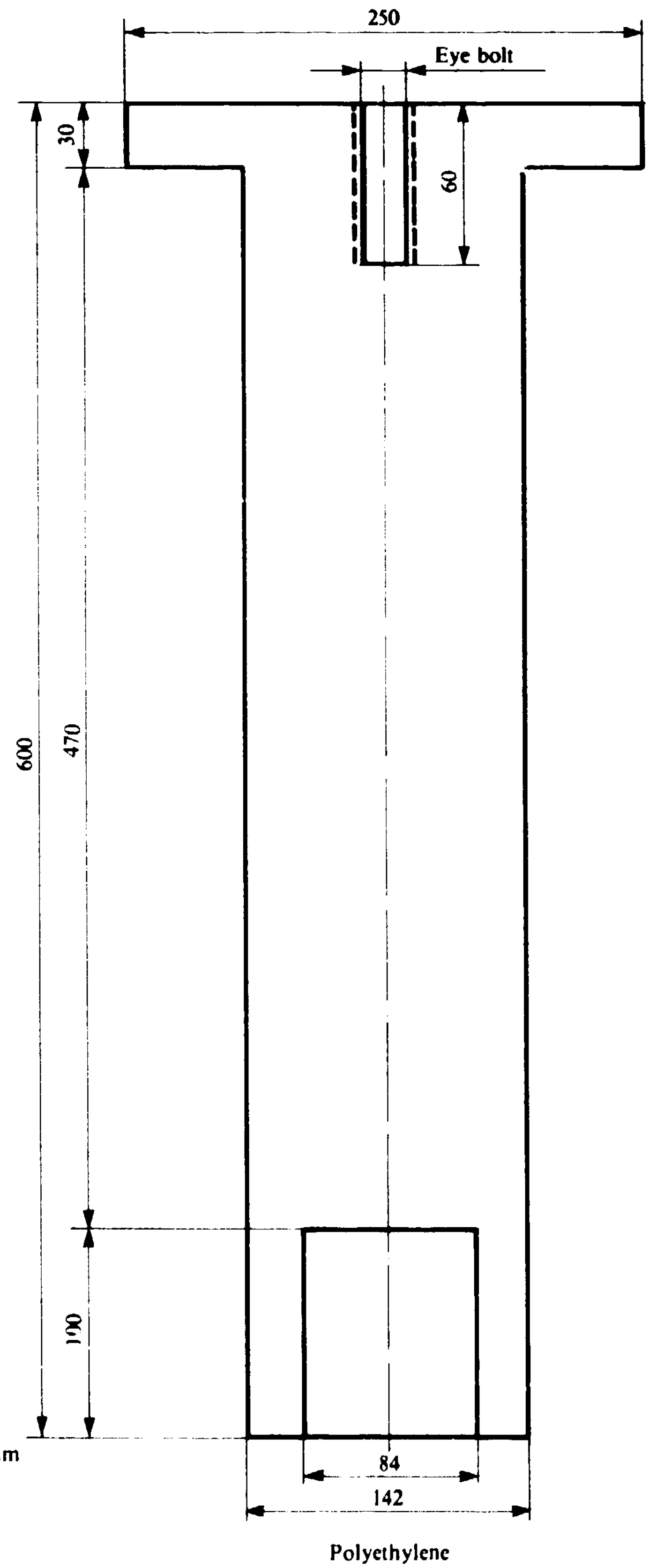


FIGURE 9. Flow Diagram 3 showing magnetic-tape search for tag word



All dimensions in mm
Not to scale

FIGURE 10. The shielding plug of the neutron irradiator

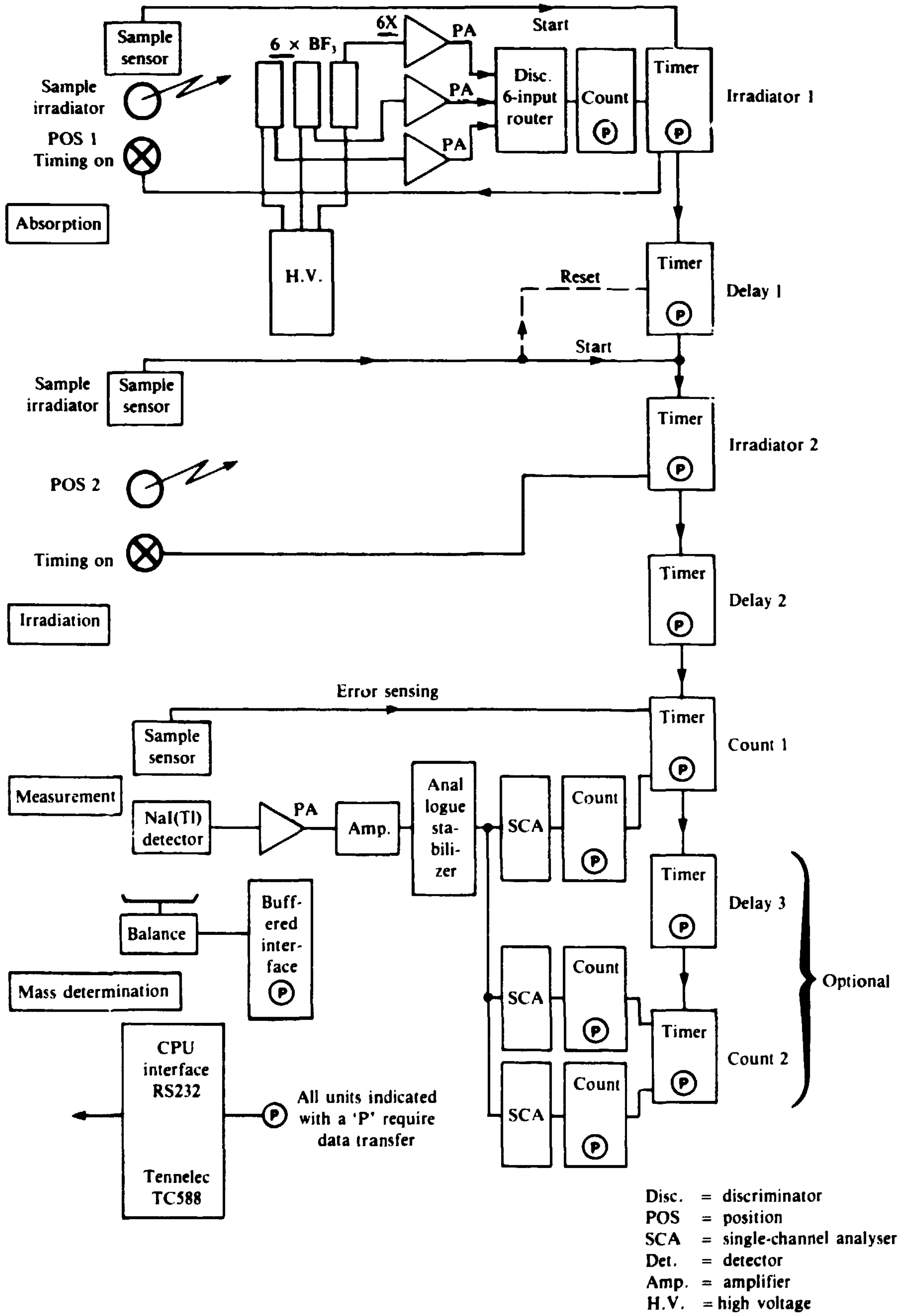


FIGURE 11. Block diagram of the electronic system

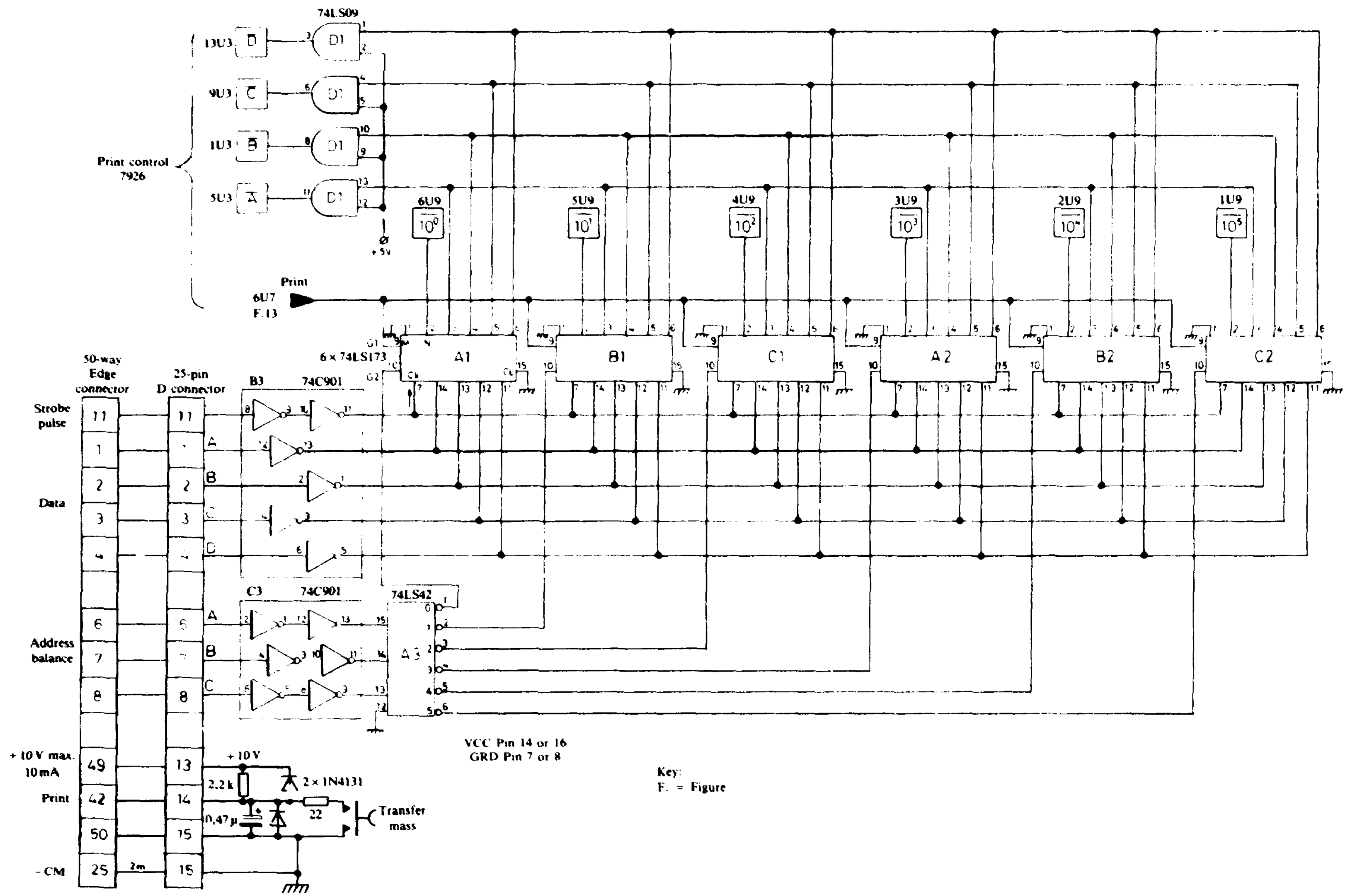


FIGURE 12. Buffer interface for the balance (Sartorius model 1364 MP)

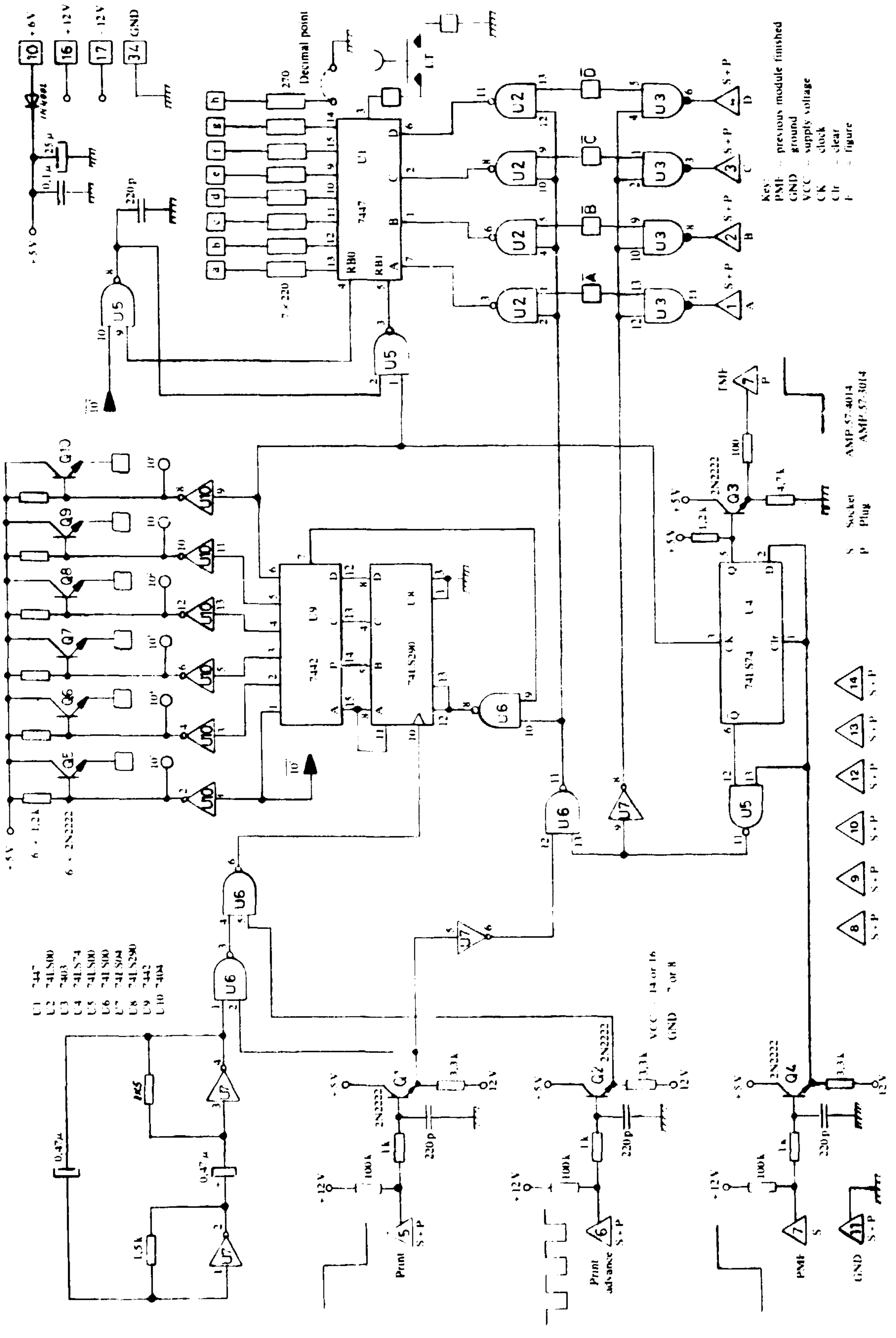
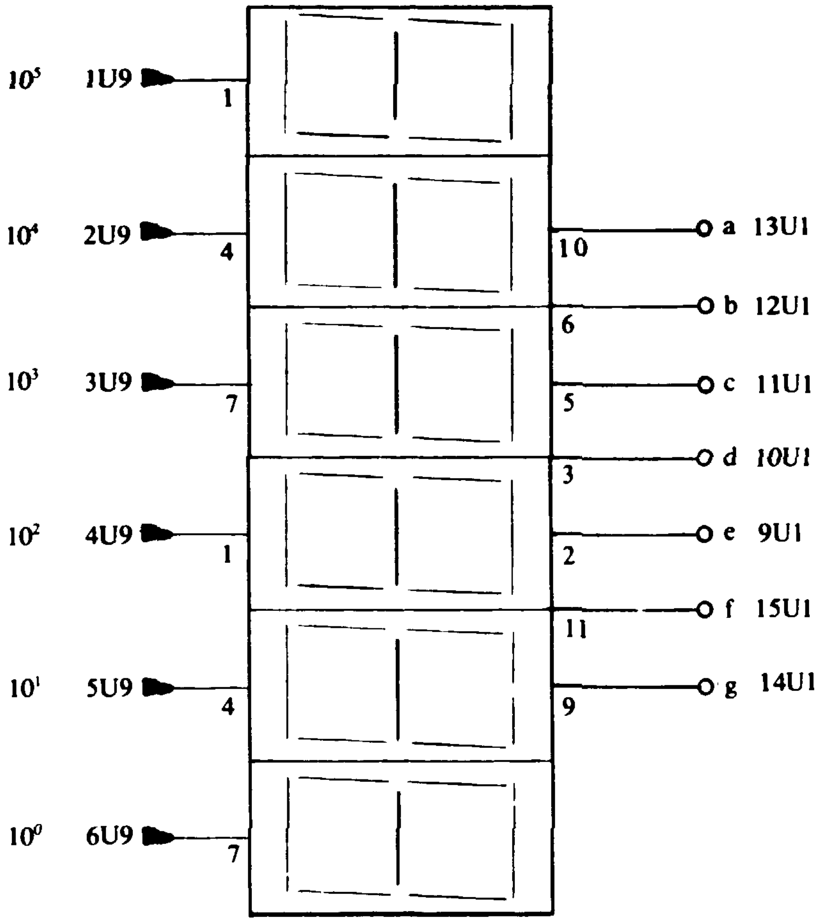


FIGURE 13. The display driver and printout control



Note: For operation of the NSN 333 display (common cathode) with the 7926 display driver and print-out control, the following changes must be made:
Change U1 7447 to 7448
Change 7 × 220Ω resistor to 680Ω resistors
Connect display (NSN 333) as indicated
Connect 680Ω resistors to + 5 V
(U10 and Q5 through Q10 are not used)

FIGURE 14. The display for Model 8121

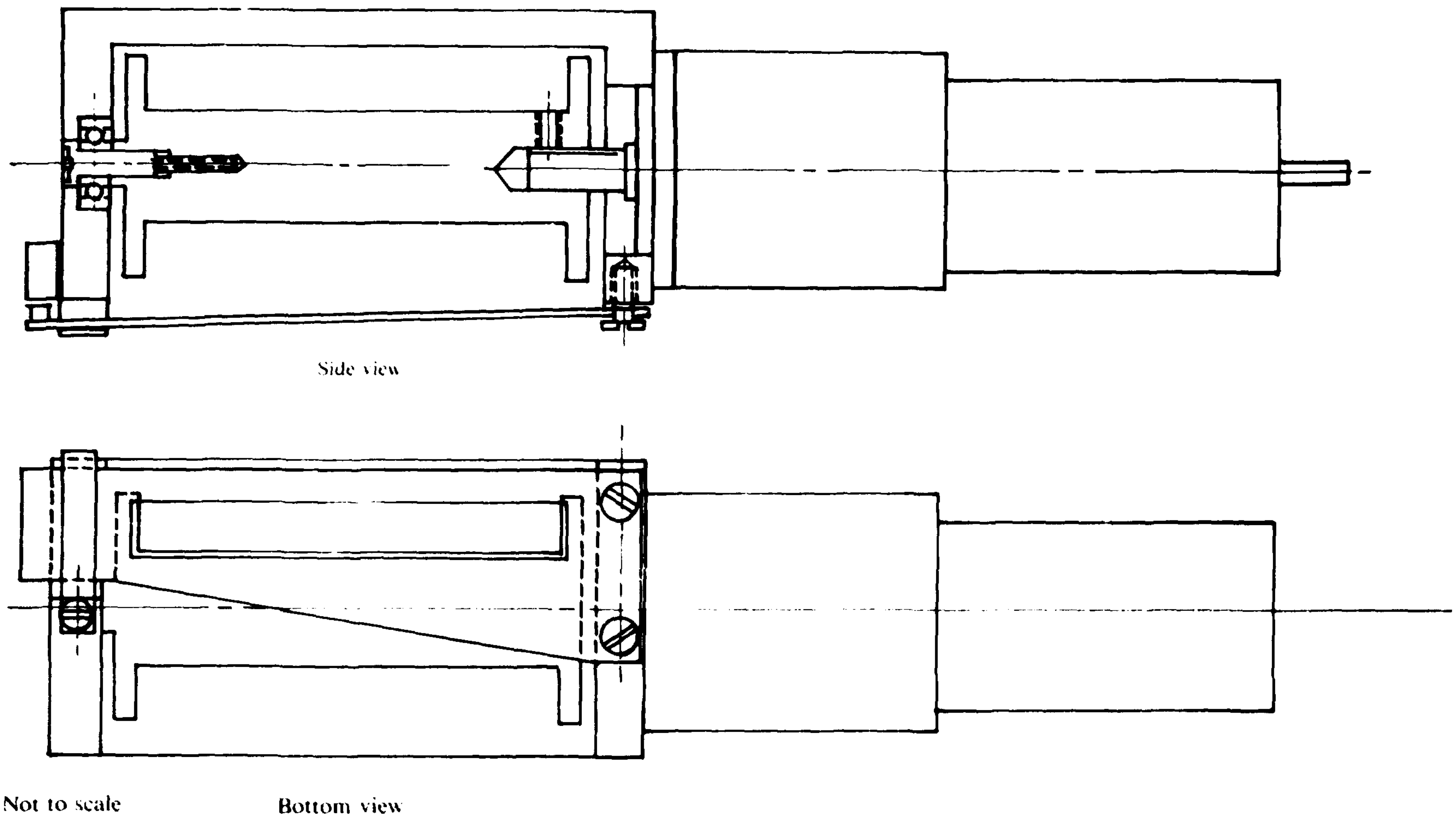


FIGURE 15. The hoist assembly

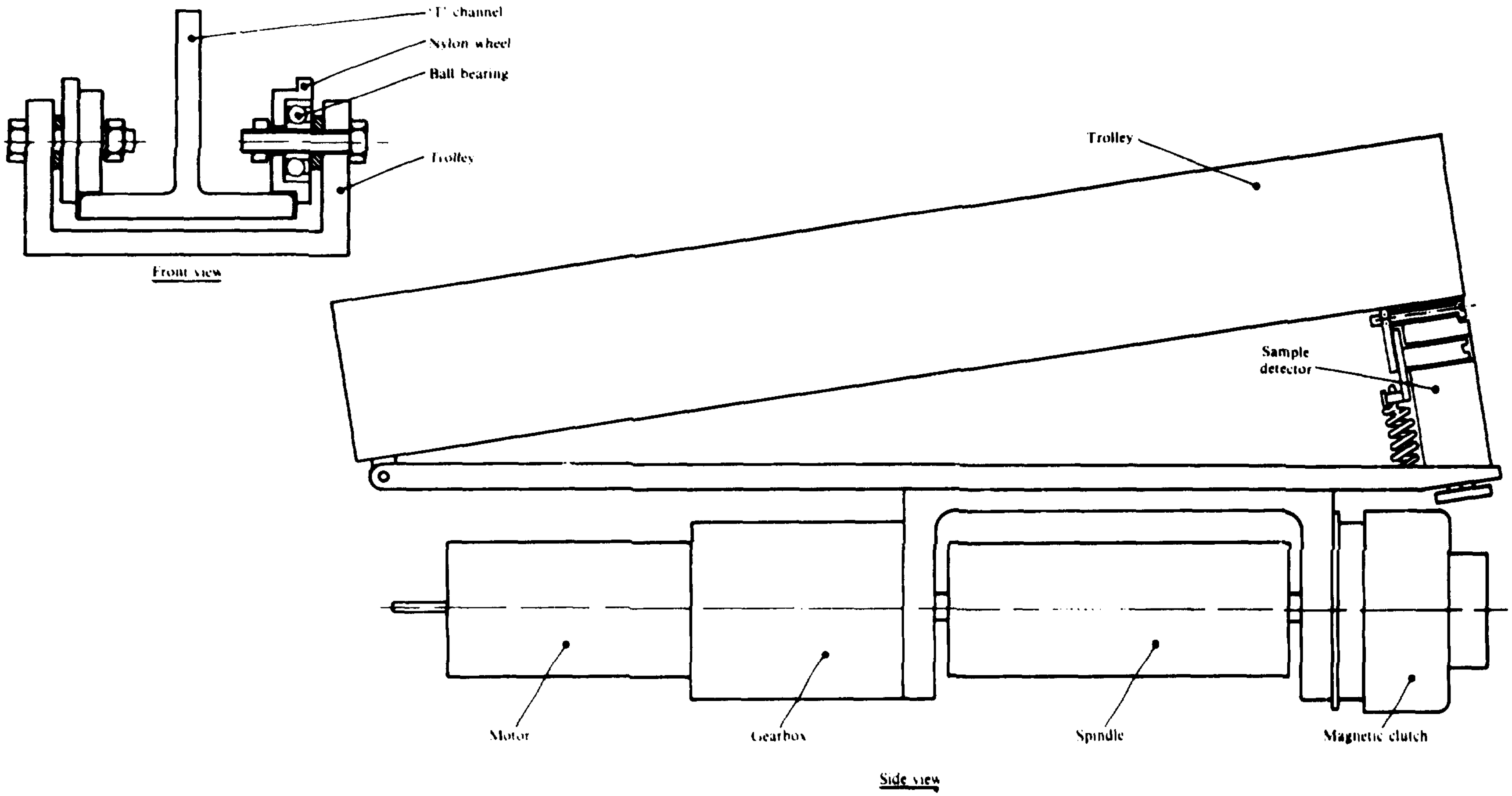


FIGURE 16. The hoist and trolley

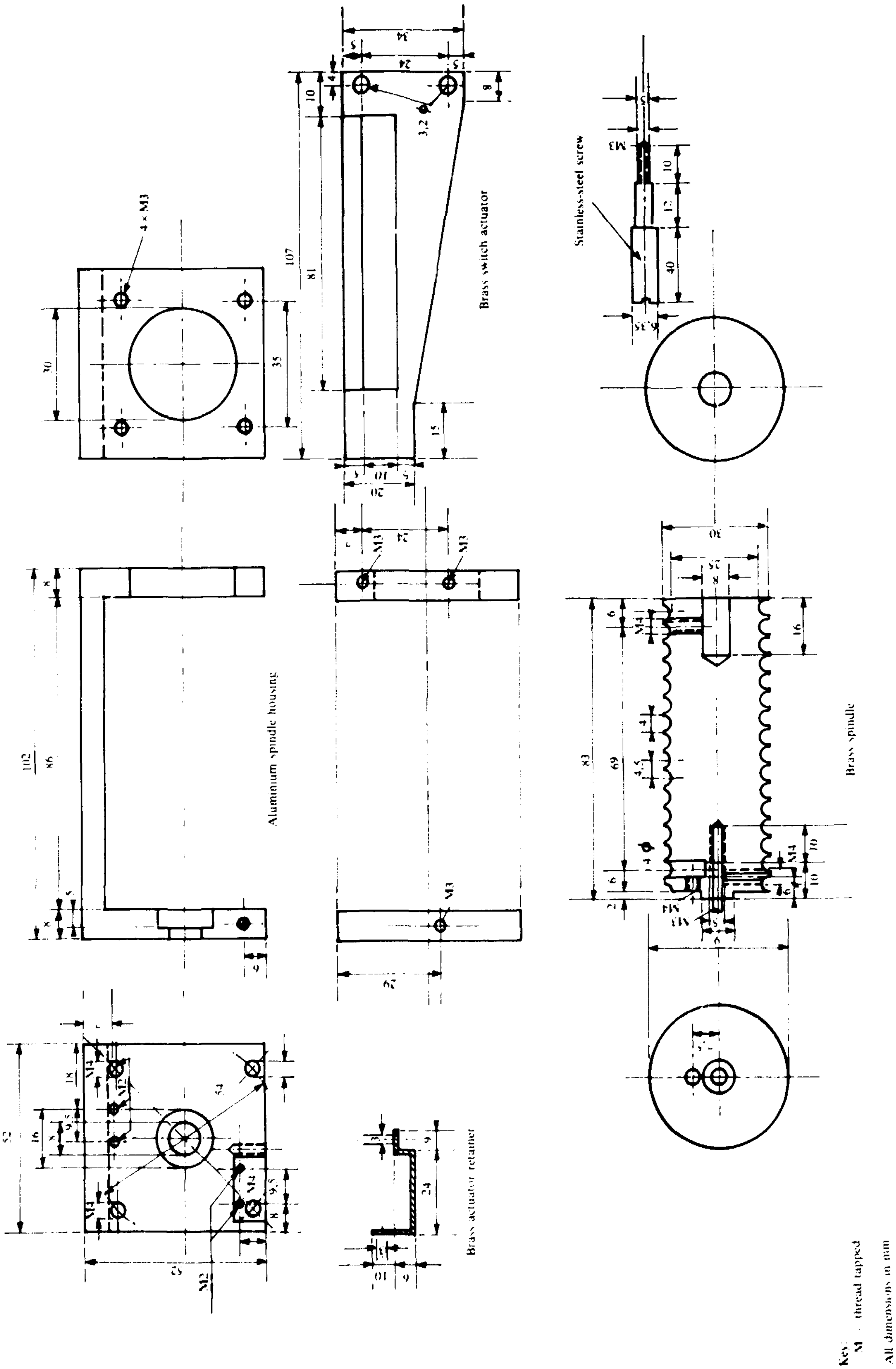


FIGURE 17. The hoist spindle

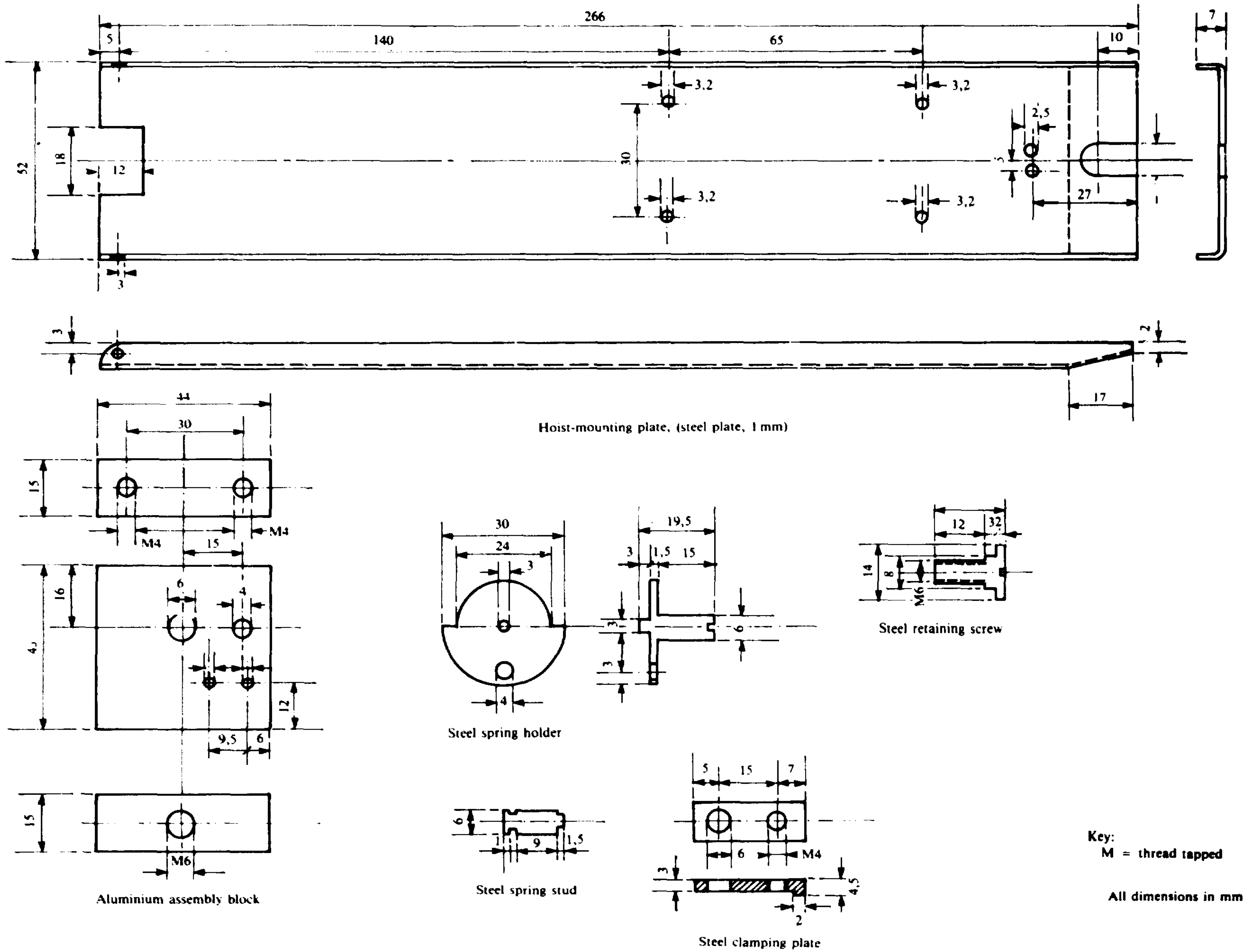


FIGURE 18. The mounting of the hoist motor

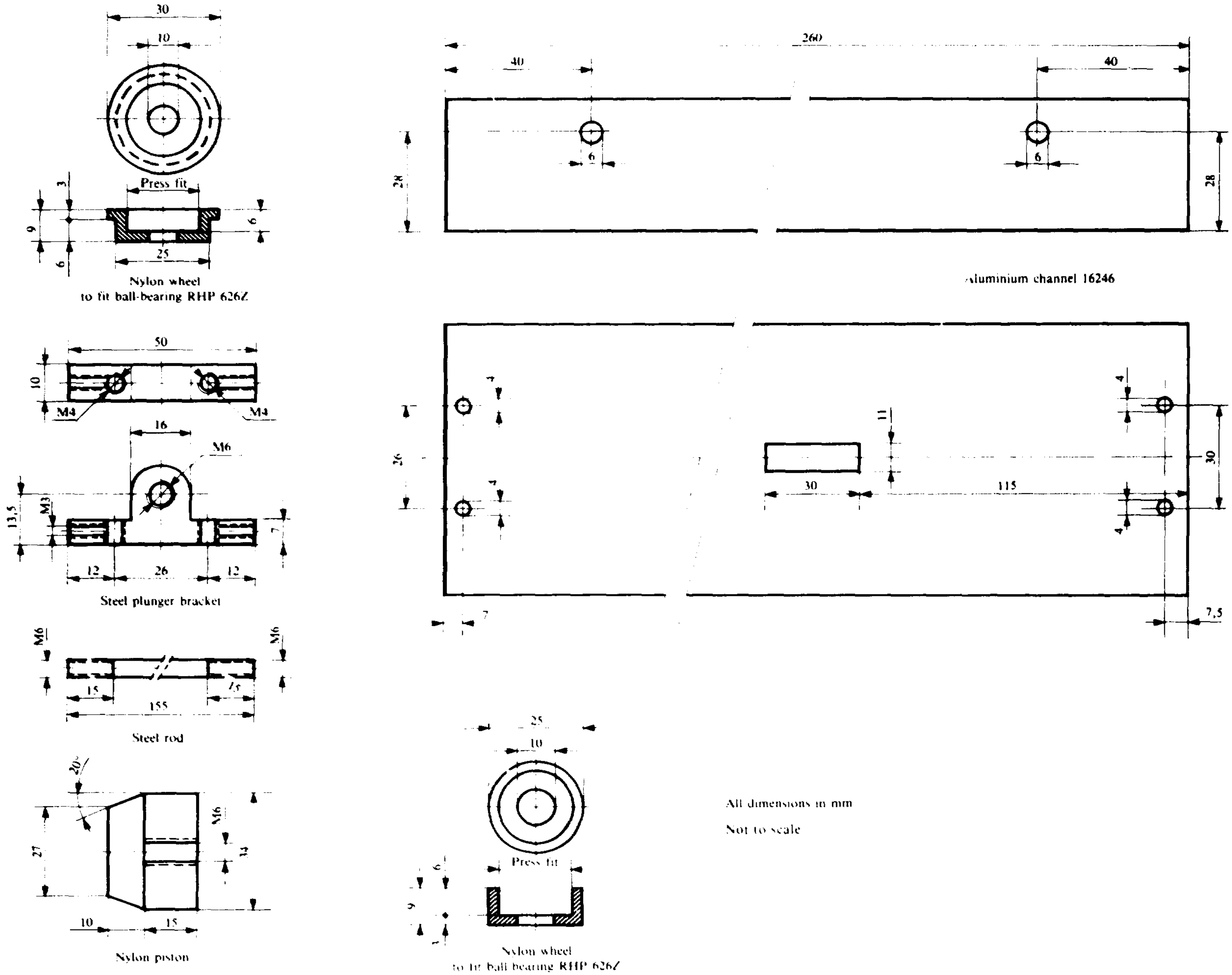
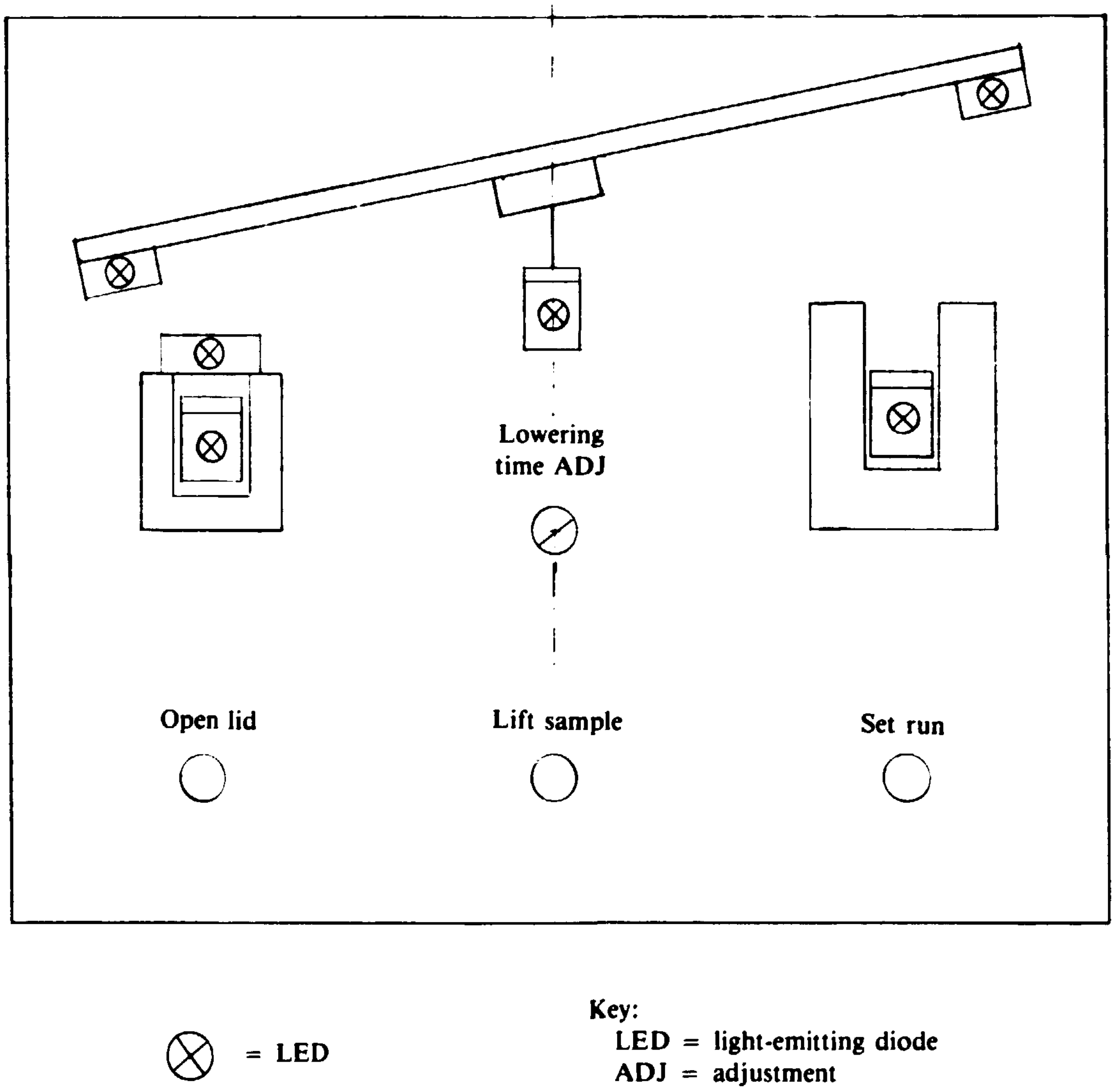


FIGURE 19. The hoist trolley



Key:
LED = light-emitting diode
ADJ = adjustment

FIGURE 20. The front panel of the control for the sample-changer

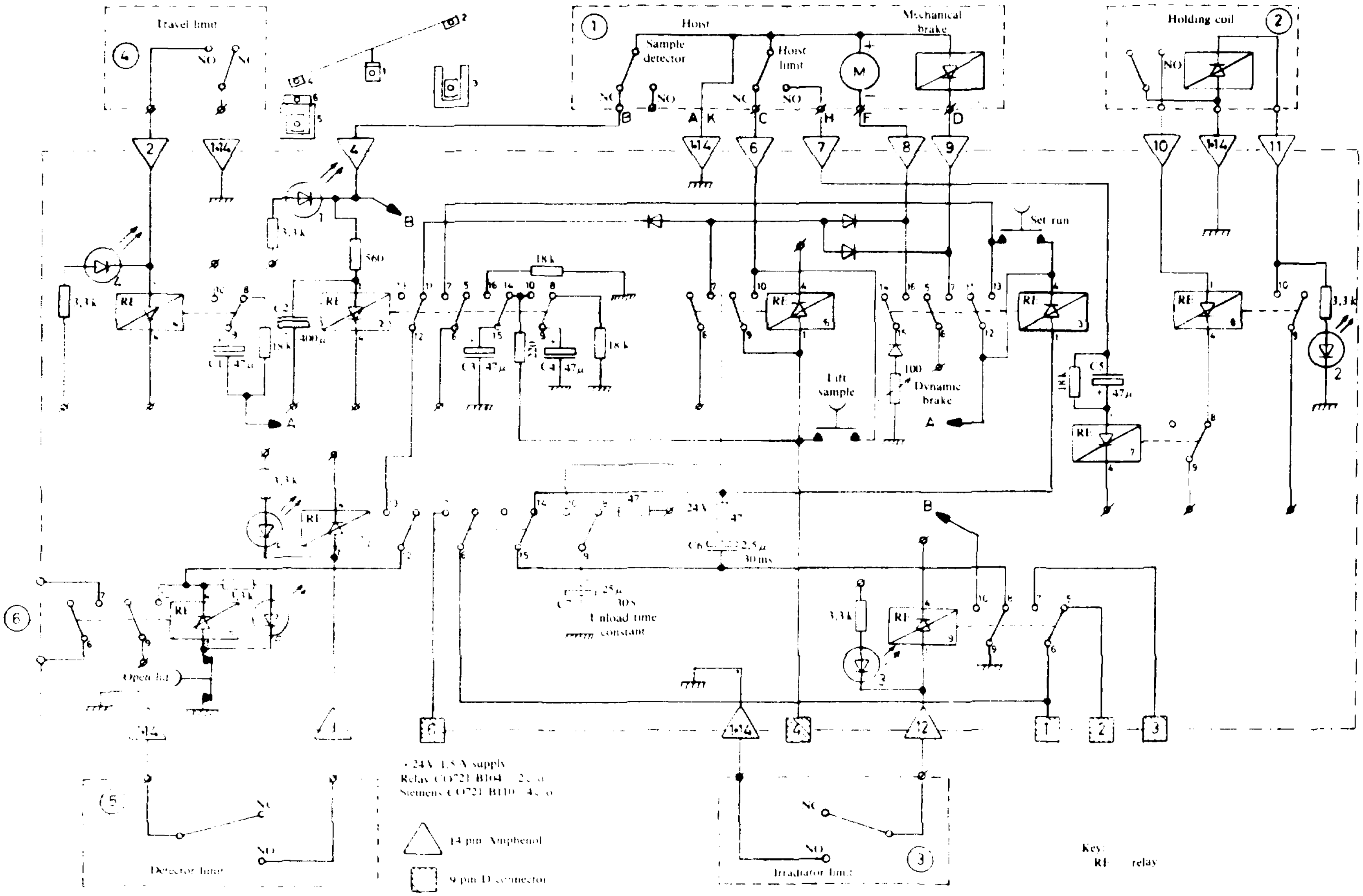
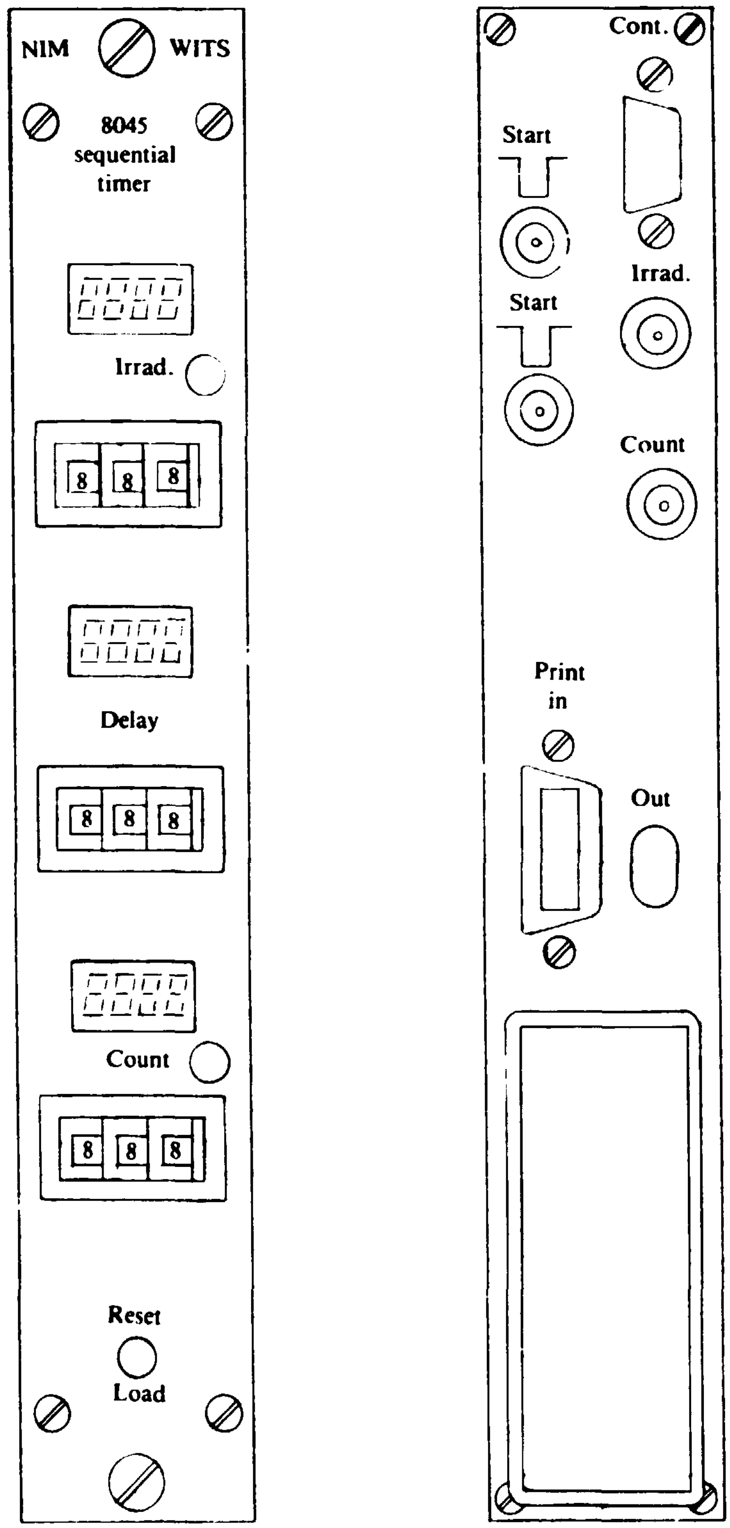
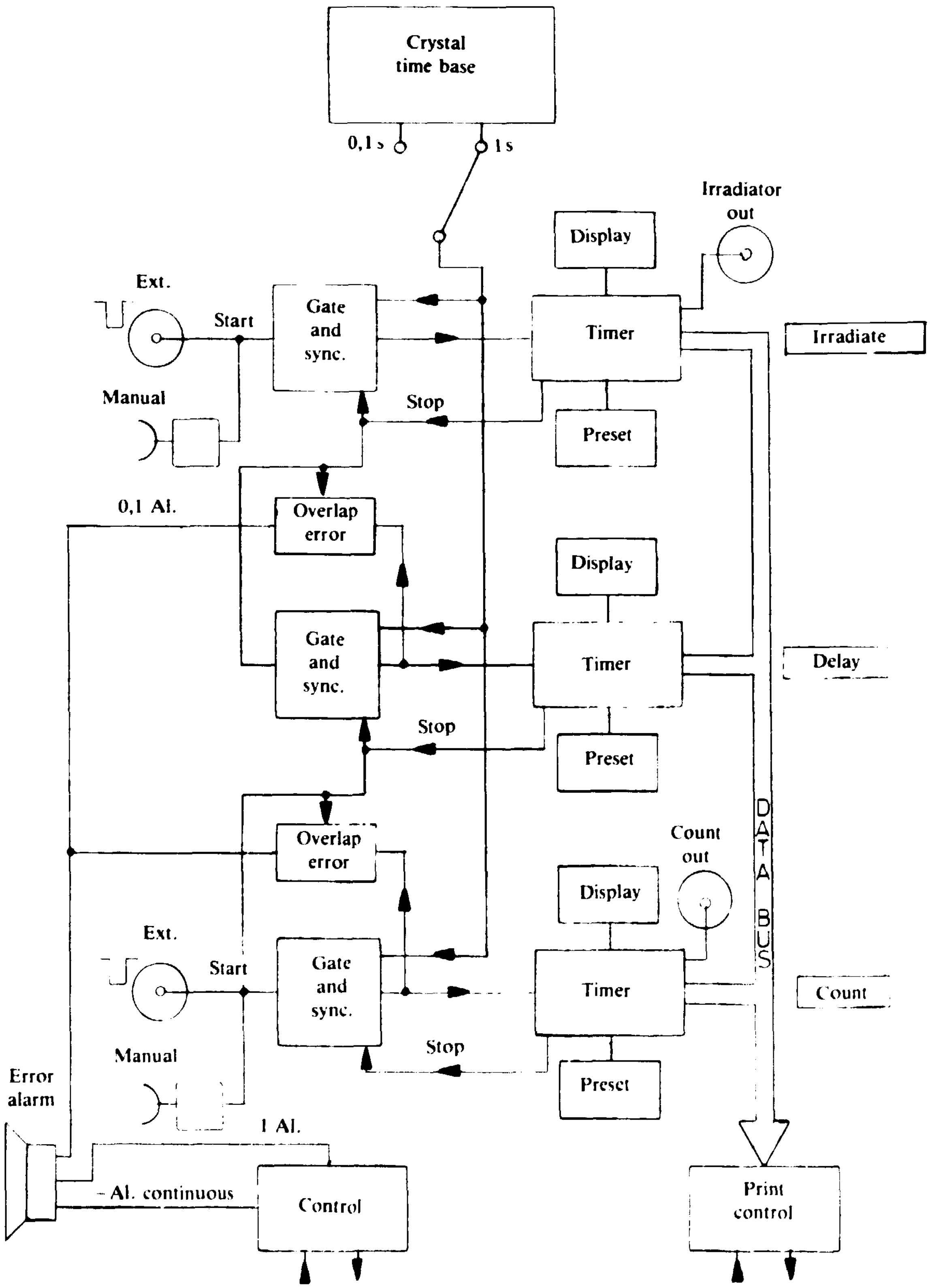


FIGURE 21. The sample control for isotope-source nuclear-activation analysis



NIM = National Institute for Metallurgy
WITS = University of the Witwatersrand
Cont. = control
Irrad. = irradiation

FIGURE 22. Front and rear panels of the sequential timer



Sync. = synchronizer
Ext. = external source
Al. = alarm

FIGURE 23. Block diagram of the sequential timer

APPENDIX

OPERATION OF THE EQUIPMENT

1. UNITS OF EQUIPMENT

Most of the equipment used is of commercial origin. The units that were specially developed and constructed are as follows.

(1) A buffered interface for the balance.
(2) A sequential timer.
(3) A sample-changer.

1.1. The Buffered Interface

The buffered interface performs the following two functions.

(a) It stores the mass into a buffer (memory).
(b) It converts the data into binary coded decimal (BCD) 'daisy chain' format.

1.1.1. Operation

The data are made available by the balance (Sartorius model 1364MP) in BCD code, and are loaded via CMOS to TTL translators B_3 and C_3 (Figure 12) into six 4-bit D-type registers via the decade scanner A_3. During printout, 'Print 5' (Figure 13) goes low and the registers are disabled from loading new data via 6U7. When 'Previous module finished' (PMF) $\frac{7}{S}$ goes high, the counter U8 is enabled via 8U6 and data are made available from the most significant register (10^5) to $\overline{ABCD}$. The decades are scanned via 'Print advance 6'. When the last register is scanned via U9, the D-type flip-flop (FF) is clocked, and the TMF $\frac{7}{P}$ signal is supplied to the next unit to be printed.

Pin-connections, data timing, and notes on the balance are shown in Table I–1.

1.2. The Sequential Timer

The sequential timer incorporates a 4-digit CMOS counter manufactured by Intersil Type ICM 7217A. The counter has a register that can be preset, and directly drives a multiplexed 7-segment common-cathode display (Figure 23).

The input/output port is TTL compatible and has BCD multiplexed input/outputs.

The time base is derived from a crystal oscillator and is divided down to output pulses of 0,1 or 1 s.

The timer is started manually or externally. An RS FF is set, B7 (Figure I–1), and prepares the FF JK (A7). The negative-going pulse CKD, generated by the crystal timebase, sets the FF, and the timebase pulses are enabled to the counter A1 via B7. When the counter reaches the preset time, $\overline{EQ}$ output goes low and RS FF B7 is reset and FF JK is clocked by CKD on negative transition. The $\overline{EQ}$ output starts the next timer and resets (RS) FF 5B. The process is then repeated as before.

When a printout is required, the signal on 'Print 5' (Figure I–2) goes low, which disables the display oscillator E9. When the signal 'PMF 7' goes high, the 'Print Advance 6' scans the registers of the counter A1 via E8, E2, E1.

After six 'Print advance' pulses, the D-type FF is clocked by a positive-going pulse that originates from counter E3 and is supplied through 2E8, 11E4. The Q output of 5E6 goes high and enables the second stage, and the process is repeated as already described.

1.2.1. Resetting of Load

The counters are reset and loaded by operation of a push button on the front panel. During this operation, the counters are reset via RS FF 4C5 (Figure I–1.) On the negative-going pulse generated by the display oscillator, the FF JK 5C6 changes state and loads, via TR6, the registers 'LR' with the preset value on the thumbwheel switches. After the 'Reset/load' button is released, the counter is reset.

The complex resetting and loading procedure is required because the equal output interferes with this process, and, when the counters are loaded, EQ becomes active and starts the next counter. Resetting of the counters after load operation negates this problem.

1.2.2. Ancillary Control Circuit

This circuit is incorporated for the resetting and starting of the irradiation counter and for control of the sample-changer hoist.

When the sample sensor is activated, 11D6 (Figure I–3) generates $\overline{RSC}$ and starts the irradiation timer;

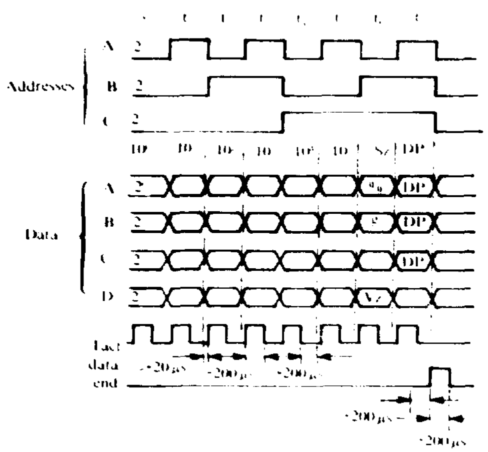
TABLE I–1

Data output terminal distribution and time diagram for the Sartorius model 1364MP

Data output for models 1200 MP, 3700 MP, and 3800 MP
Terminal distribution of 50-pin Amphenol-socket (57-405 00)

Pin		Pin	
1	2^0 Data	26	Keyboard
2	2^1 Data	27	Keyboard
3	2^2 Data	28	Keyboard
4	2^3 Data	29	Keyboard
5		30	Keyboard
6	2^0 Address	31	Keyboard
7	2^1 Address	32	Keyboard
8	2^2 Address	33	Keyboard
9		34	Keyboard
10		35	Keyboard
11	Strobe pulse	36	Keyboard
12	Tare ext.	37	Keyboard
13	Data end	38	Keyboard
14	Sync. Keyboard	39	Keyboard
15		40	Keyboard
16		41	
17		42	Print
18		43	Busy output
19		44	
20		45	
21		46	
22		47	
23		48	+5 V max. Last 10 mA, max. load 10 mA
24		49	+10 V max. Last 10 mA, max. load 10 mA
25	CM	50	CM

Data output time diagram for models 1200MP, 3700MP, and 3800MP



Sz Special signs

2^0 high: %

2^1 high: g

2^2 high: Vz

DP			Decimal point
2^2	2^1	2^0	
0	0	0	x x x x x x
0	0	1	x x x x x x
0	1	0	x x x x x x
0	1	1	x x x x x x
1	0	0	x x x x x x
1	0	1	x x x x x x
1	1	0	x x x x x x

Positive logic

High: +8 to 10.5 V } CMOS comp.
Low: 0 to +2 V } CMOS comp.

Note: Data can be accepted at the leading or trailing edge of the tact.

The data output is released by a print command which can be generated by the balance or by an external command. **Prior to the data output, the 'Busy'** input (Pin 43) is interrogated as to whether the data receiver is ready for the data transfer.

Busy – Low – data receiver not ready }
Busy – High – data receiver ready } for data transfer

In case of a print command at busy – low, the actual data output is released automatically as soon as busy – **high is obtained and stability control indicates** standstill. During waiting time, the indicators for mass and stability (g or %) are blanked out.
The data are valid with tact – high (Pin 11). The end of the data transfer is indicated by the signal 'data end' (Pin 13). **The data block is released only** once. The output is available in bit-parallel and decade serial.

Data connections

A 2^0 Pin 1
B 2^1 Pin 2
C 2^2 Pin 3
D 2^3 Pin 4

Address connections

A 2^0 Pin 6
B 2^1 Pin 7
C 2^2 Pin 8

The data are released in 8 decades

Time t_0 – t_5	Mass value 10^0 – 10^5 (10^0 = decade with lowest value)
Time t_6	Special signs
	% Stability indicator only (in connection with data input)
	g Stability indicator
	Vz Prefix
Time t_7	DP Decimal point

If the balance is overloaded and has reached stability (indication of 'H g' or 'H %'), a binary '11' is released during time t_0.
The balance can be tared externally with a low signal > 250 ms (Pin 12).
The data transfer can be activated externally with a low signal > 250 ms (Pin 42).
In addition, the following supply voltages are available at the data output: +10 V (Pin 49) and +5 V (Pin 48). **The Pins 14, 26 to 29, 31 to 39, and 41 are** used for keyboard 'data input' 7042.
For the digital inputs and outputs the specifications of CMOS series 4000 are applicable.
On request, models 1200MP, 3700MP, and 3800MP are available with an analogue output (Pins 45 to 47).

8D6 prepares FF 6D6. When the irradiation time has elapsed, FF 1D6 is set, and energizes the lift motor $\overline{LM}$ via monostable 5D7 and TR1. As soon as the sample sensor operates, the display counter is started $\overline{SD}$ via monostable 4D7.

1.2.3. Options

The sequential timer can be used under various modes of operation by removal or installation of appropriate links (Figure I–1).

When the links $\overline{ARES}$ H-G, J-K, and L-M are in place, the counters are reset when the preset time is reached and are therefore ready to accept the next cycle.

This mode of operation* is used when samples are being irradiated while other samples are being counted.

If a printout is required, the counters can be reset by the print-control unit and the $\overline{ARES}$ links must be removed.

When the links A-B = $\overline{EQ}$, E-D = $\overline{SD}$, and F-G = $\overline{RSC}$ are in place, the ancillary-control circuit that, as already described, controls the irradiation timer, is in operation. The irradiation timer provides a start pulse to the sample-changer control to remove the sample and display the total duration of irradiation.

The printout facility is now available, and the timers are reset by the print-control unit or when the next sample is irradiated by $\overline{RSC}$.

1.3. Electrical Operation of the Sample-changer

The control circuit of the sample-changer is depicted in Figure 21. Relays are used for switching and logic control. Relays are used in this role because they have a high immunity to noise and are capable of switching large currents, simultaneously making use of the additional contacts available, and logic functions can be derived.

The sample container is loaded at position 1 (Figure 21), and this sets the sample detector in the NC position, and energizes RE_2, which has a delayed action by RC_2. Relay RE_6 is energized through C4R and winds the hoist cable until the 'Hoist limit' switch operates. When the holding-coil sensor is activated, the holding coil is energized with RE_8 and the sample-changer is primed to start its sequence by depression of 'Set run'. This energizes RE_3, which controls the mechanical brake, and the sample is lowered into the irradiator. The lowering rate is determined by the mass of the sample and controlled by the setting of the dynamic brake. When 'Irradiator limit 3' is activated, relay RE9 is energized and starts the irradiation timer. When the irradiator cycle has been completed, relay RE6 is energized by the command of the sequential timer and the sample container is lifted out of the irradiator via RE6/6,7. As soon as 'Hoist limit' operates, RE6 de-energizes both the brakes and the motor. The 'Hoist limit' energizes RE7 and de-energizes the 'Holding coil'. The trolley with the sample slides down by gravity until the travel limit operates (4), thereby energizing RE4, which energizes RE3 via C_1, RE4/10,9. When the sample is in position, Rel is energized by 'Detector limit' (5). 'Sample detector' changes to NO position, and de-energizes RE2, which, through C_1 RE2/15,14, energizes RE6. The automatic unloader unhooks the hoist cable, the cable lifts out of the counting chamber, and the lid of the chamber is closed.

* In this instance, a printout is of no value because, after the preset time, the counters are being reset.

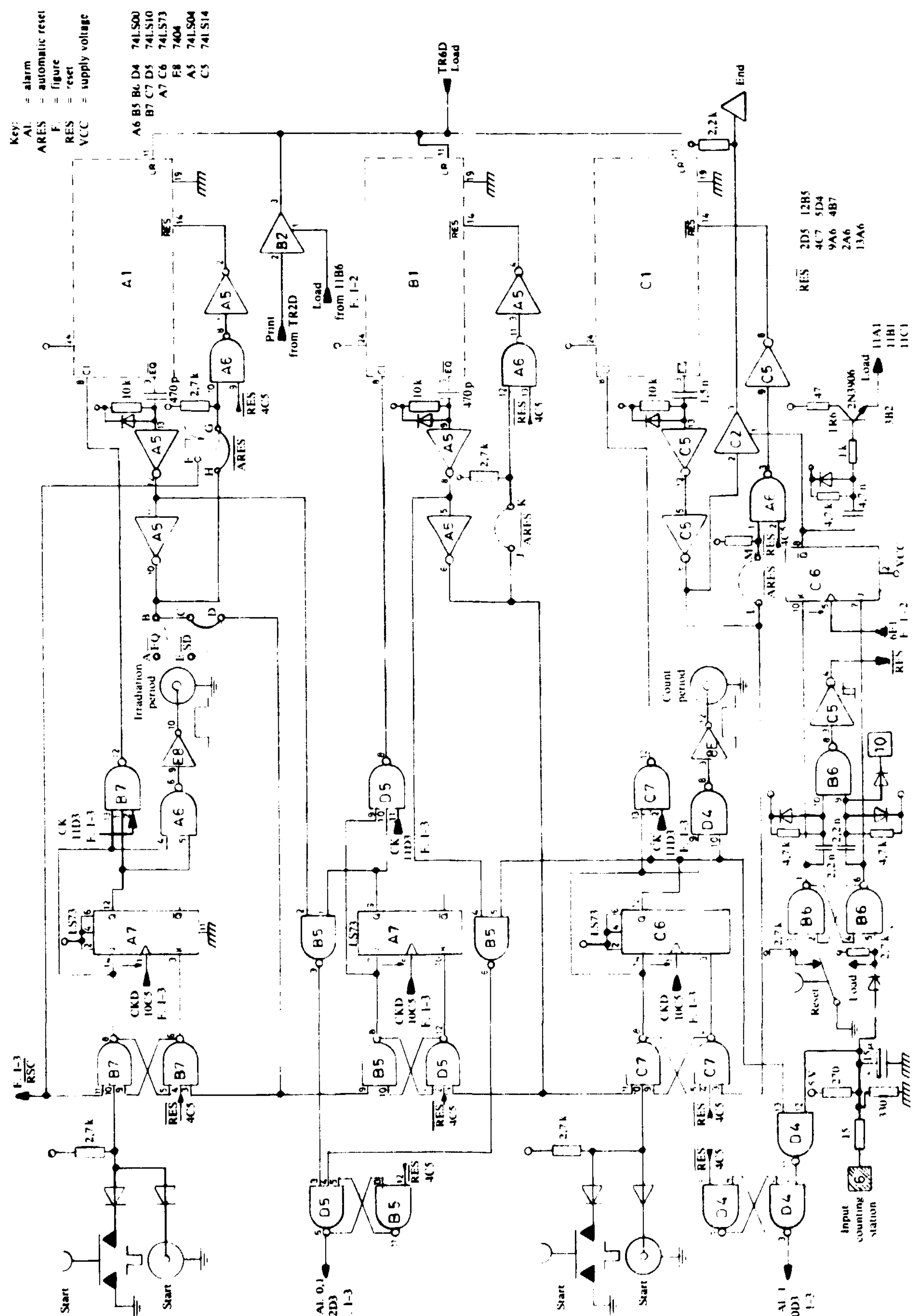


FIGURE I-1. The control of the sequential timer

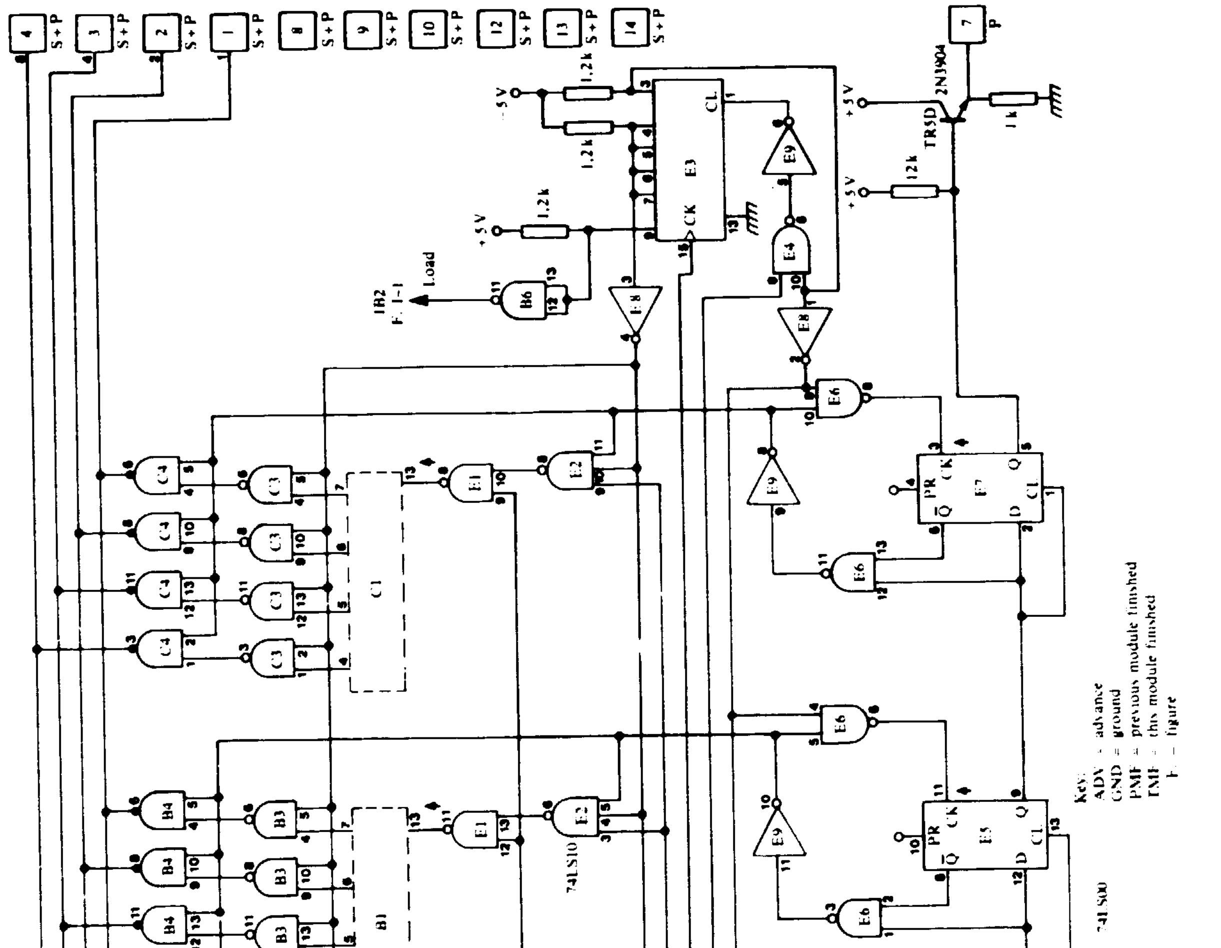


FIGURE I-2. The printout section of the sequential timer

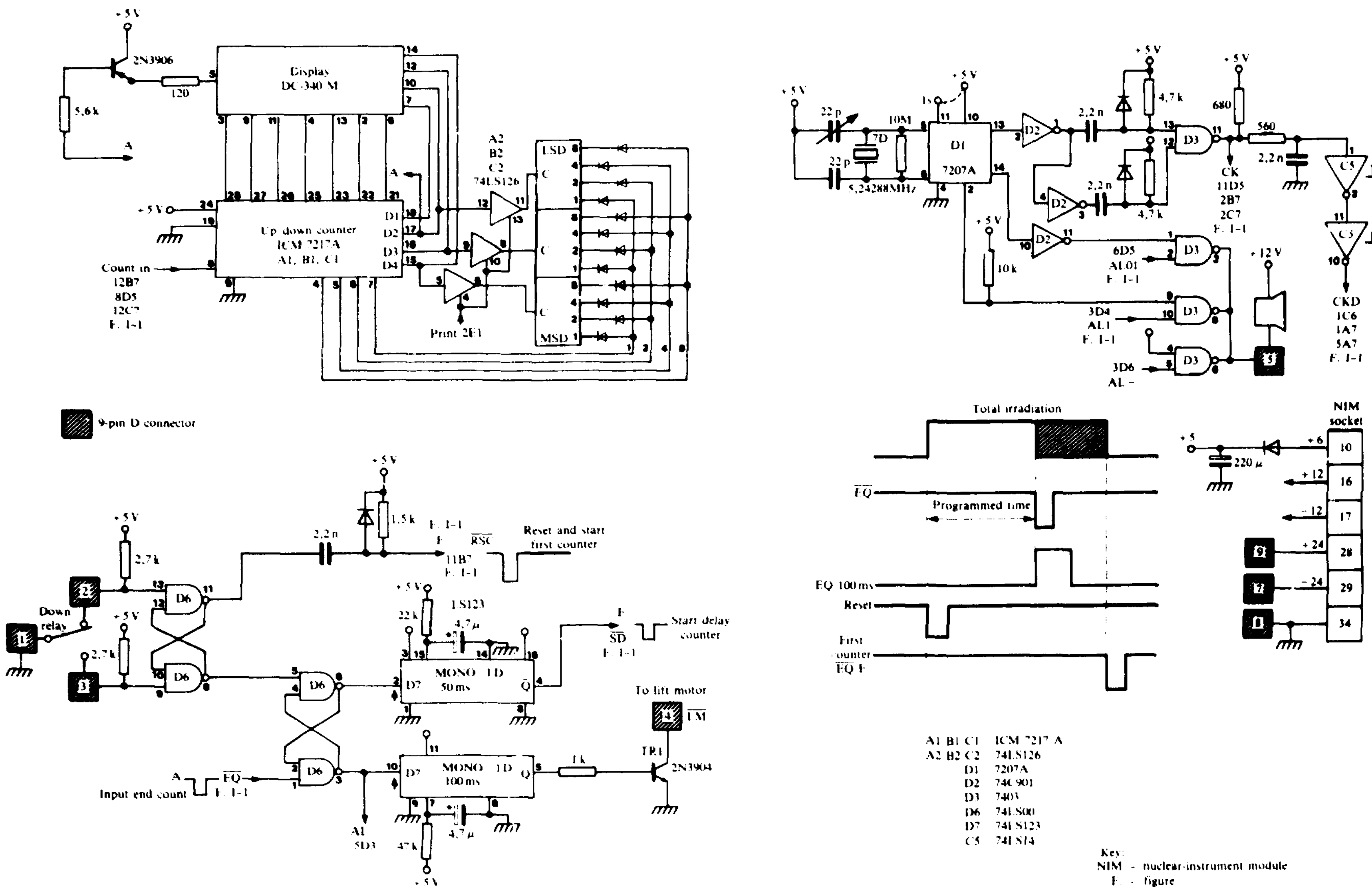


FIGURE I-3. The clock time base and control of the sequential timer

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Corrigenda: Report M53

(1) Page 13. The caption to Figure 8 should read as follows:
The casing of the neutron irradiator

(2) Page 14. The caption to Figure 9 should read as follows:
The neutron irradiator source assembly

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