final report

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An Electrical Conductivity Instrument for Carcass Fat Thickness Measurment

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CONTENTS

		Page No.
1.0	INTRODUCTION	1
2.0	DESCRIPTION OF INSTRUMENT	1
2.1	Probe	1
2.2	Driving Mechanism	2
2.3	Distance Sensor	2
2.4	Control Box	2
2.5	Electronic Measurement, Control and Indicating Circuits	3
2.5.1	Conductivity Measurement	3
2.5.2	Control	3
2.5.3	Indicating Circuits	4
3.0	PROCEDURE FOR SETTING AND ADJUSTMENT OF INSTRUMENT	4
4.0	EXPERIMENTAL PROCEDURE	4
5.0	RESULTS AND DISCUSSION	5
6.0	CONCLUSIONS	6
7.0	APPENDICES	
	Plates 1-2	
	Figures 1-2	
	Drawings 1201-1206	

1.0 INTRODUCTION

Preliminary experiments during 1971 with electrical conductivity probes showed that it was possible to estimate fat thickness on hot beef carcasses in about 70% of cases to within ± 3mm (0.118") and on chilled carcasses in about 70% of cases to within ± 2mm (0.08"). This early work indicated that factors such as the position of the electrode relative to the tip of the probe, the number of electrodes and their disposition along the stem of the probe, and the speed of probe traverse were of importance in obtaining accurate and consistent results.

These factors were taken into consideration when an improved fat thickness instrument was required for a carcass classification project under the direction of the Australian Meat Research Committee. Design and construction of the instrument commenced in April 1972 and the proving tests reported here were carried out in early June 1972. The instrument was supplied on loan to the Australian Meat Board on the 19th June, 1972.

2.0 DESCRIPTION OF INSTRUMENT

The instrument comprises a hand held probe assembly and control box. The unit is operated by pressing the end plate firmly against the carcass fat surface and operating a trigger which causes the probe to be driven into the fat. A direct read-out (in mm) of the fat thickness is displayed on the control box when the probe electrodes pass through the fat-lean interface. The instrument then automatically resets itself for the next measurement.

2.1 PROBE:

Probes are constructed of stainless steel tubing, outside diameter 1.78mm (0.070") and inside diameter 1.32mm (0.052"), attached to a BC type plug; two conductivity electrodes are formed by 0.33mm (0.013") diameter stainless steel wires running down the centre of the tubing and brought out into two slots (drawing number 1202). The tubing is filled with epoxy resin (araldite D and hardner HY956) to insulate the wires and to set the electrodes in position. The electrodes thus appear as two 0.33mm (0.013") diameter metal spots surrounded by araldite insulation; they are located diametrically opposite on the probe stem and their centres are separated by a distance of 2mm, measured along the long axis of the probe. A stainless steel point is attached to the tubing, the distance between the tip and the first electrode being 19mm (0.75") (drawing number 1202). A BC type socket attached to the drive nut enables the probe to be easily connected (plate 1). The electrodes are electrically connected in series and the electronic circuit (drawing number 1203) is arranged so that both electrodes must be in a zone of high conductivity in order to activate the stop and reverse mechanism.

2.2 DRIVING MECHANISM:

The probe is traversed into or out of the carcass at a constant speed of approximately 10mm (0.4") per second by operation of the nut and lead screw driven from the geared DC motor (Monoperm Super Motor, with Richard Gearbox) (plate 1). Probe speed can be altered by variation of the gear box ratios. A number of microswitches (Omron VV-15-1A) are fitted to control the driving mechanism (drawings number 1201 and 1203). Pressing the trigger actuates microswitch 5 and starts the motor; the nut with the probe attached moves forward, and continues to move until either the nut trips the limit switch (microswitch 1) or the electrodes detect a significant increase in conductivity. In either case, the motor is stopped and automatically reversed bringing the nut back to the start, at which position it trips the reset switch (microswitch 4) and the motor is stopped. There is then a five second delay until a lamp on the control box indicates that the next traverse may be started.

2.3 DISTANCE SENSOR:

The distance the probe has entered the carcass is measured by counting the number of revolutions of the lead screw. A vane is attached to the lead screw, one count being registered each time the vane passes between a reed switch (Hamlin MRL-DT) and a magnet. The lead screw has a pitch of 1mm (0.039"), so that each revolution represents a 1.0mm lateral movement of the nut and probe. The count from the reed switch, corresponding to the maximum forward displacement, is stored and then displayed as a two digit number on numerical fluorescent indicator tubes in the control box (plate 2). This read-out is held on display until a similar position has been reached on the next traverse, giving a new read-out. One other switch (microswitch 2, drawing 1201) is used to inhibit the reed switch from counting until the second electrode has moved to a position where it is just emerging from the base plate. With the dimensions used in the assembly described here, a maximum fat thickness of approximately 28mm (1.1") can be indicated.

2.4 CONTROL BOX

Electrical connections between probe assembly and control box are brought out from the lower end of the pistol grip of the probe assembly; the probe connecting wire is screened against pickup. The wires are enclosed in a flexible P.V.C. sheath and terminate in a 12 pin plug which is inserted into a socket on the rear panel of the control box (plate 2). Power supply may be either 240V AC 50 Hz mains or 12V DC battery connected to sockets on the back panel and selected by a switch on the front panel. On the back panel (plate 2) there are also two fuses and a multiway socket (Amphenol) allowing connection to an electrical data logging system. On the front panel (plate 2) in addition to the power selector switch, there is an on-off switch, "Ready to Operate" lamp, a panel cut out through which the indicator tube display may be viewed, and a reset button enabling a displayed reading to be cancelled.

2.5 ELECTRONIC MEASUREMENT, CONTROL AND INDICATING CIRCUITS:

2.5.1 CONDUCTIVITY MEASUREMENT:

A series resistance circuit comprising a 2K2 resistor, the conductivity electrodes of the probe, and a 4K7 resistor is formed between +5V and earth (drawing 1203). The voltage developed across the 4K7 resistor is dependent on the conductivity of the medium in which the probe is placed i.e., high conductivity gives high voltage, and low conductivity gives low voltage. This developed voltage, the value of which can be measured as indicated in Figure 2, is fed into the inverting input of an operational amplifier (type 741) where it is integrated and compared with a reference voltage generated in a 5K trim potentiometer. The reference voltage may be increased by turning the potentiometer screw clockwise and decreased by turning it anti-clockwise; its value can be measured as indicated in Figure 2. When the probe is in fat, the developed voltage is lower than the reference voltage and the output of the operational amplifier is +5V. When the probe is in lean, the developed voltage exceeds the reference voltage and the output of the operational amplifier is -4V. This output voltage is used to actuate the control logic.

2.5.2 CONTROL:

In the "start" condition, with the probe fully back in its housing, the switches of relay R1 are set to give forward movement of the probe, and all other switches are in the position shown in drawing 1203. At this stage the output of the operational amplifier is +5V.

When microswitch M5 is actuated, the charge held in the 640 mfd condenser is fed via the diode, 2K2 resistor, and transistor BFY 50 to operate the run relay. The motor is energised and the probe starts its forward movement. A small forward movement of the probe causes microswitch M4 to change over, thus maintaining motor energisation. The probe continues to move forward until either it enters a region of high conductivity or it reaches the limit of its forward movement, when the drive nut trips microswitch M1. When this happens, the output of the operational amplifier changes to -4V, causing the logic circuits to energise the "reverse" coil of relay R1, thus reversing motor direction. At the same time "one-shot" 9603 sends a pulse which actuates the indicating circuits.

The motor, which has now reversed direction, drives the probe back into its housing until microswitch M4 is again actuated, de-energising run relay R2 and, via the logic circuitry, energising the "forward" coil of relay R1. The system has now returned to the "start" condition.

2.5.3 INDICATING CIRCUITS:

In the "start" condition, the decade counters (type 9390) are held in the reset (zero) condition. Operation of micro-switch M4 at the start of the forward traverse activates the decade counters.

When the probe has travelled far enough for inhibit micro-switch M2 to be actuated, the count reed switch M3 produces pulses which are fed to the decade counters. When the "one-shot" produces a pulse, the count existing at that moment is transferred to the "stores" and thence to the computer socket and "decoder-drivers" for the indicator units. The stored value is held up to the time that the next "one-shot" pulse occurs, although the decade counters may have been reset to zero in the meantime.

3.0 PROCEDURE FOR SETTING AND ADJUSTMENT OF INSTRUMENT:

(a) Removal of the rear cover of the probe assembly gives access to a switch mounted on the motor.

(b) The probe is traversed forward in air, until both electrodes are exposed; further forward movement is stopped by switching the motor switch to the centre (off) position.

(c) The probe is inserted into a carcass or a piece of meat so that one electrode is in lean and the other electrode is in fat. The probe voltage is measured as shown in Fig. 2.

(d) The probe is then inserted so that both electrodes are in lean and the probe voltage is again measured.

(e) The reference voltage is measured as shown in Fig. 2 and is adjusted, using the trim potentiometer, to a value between the probe voltage measured in (c) and that measured in (d). To increase the reference voltage turn pot screw clockwise; to decrease reference voltage turn pot screw anti-clockwise.

(f) The motor switch is returned to the forward run position and the probe allowed to run until it returns to the "start" position.

(g) The probe is operated normally, allowing the electrodes to enter fat only. If the stop and reverse mechanism actuates, the reference voltage is too low and it is necessary to re-adjust and test again.

(h) The probe is operated normally, allowing the electrodes to enter lean only. If the stop and reverse mechanism does not actuate, the reference voltage is too high and it is necessary to readjust and test again.

4.0 EXPERIMENTAL PROCEDURE:

During initial tests, probe traverses were carried out on several hundred carcasses; several minor faults were corrected and operating procedures were established. With practice, fat thickness estimates could be made on up to 6 carcasses per minute - fast enough to keep up with the slaughtering rate on the beef rail of most abattoirs.

Control tests were carried out in June 1972, during which a total of 135 measurements were made on 80 hot beef carcasses, approximately 1 to 1½ hours after slaughter. With the carcasses hanging vertically by the Achilles tendon, traverses were made horizontally, and at right angles to the carcass surface, as near as possible to the quartering cut which was normally made between the eleventh and twelfth ribs. In some cases, several traverses were made in the above horizontal plane, at distances of 10-15cm (4-6") measured around the carcass from the centre line of the backbone. Fat thickness varies considerably in this part of the carcass; after chilling and quartering, fat thickness can be measured by ruler in the vicinity of the traverse points without further cutting. In most cases, the points at which traverses had been made coincided to within 2.5cm (1") of the quartering cut.

5.0 RESULTS AND DISCUSSION:

The fat thickness in mm estimated by probe (y) has been plotted against the measured fat thickness in mm (x) in Fig. 1. A line

$$y = 9.04 + 0.91\ (x)$$

drawn through the points is the line of best fit.

A line is also drawn through the points at

$$y = x + 8.0$$

The constant in the above equation (8.0) may be assumed to represent the extent of surface and fat/lean interface deformation by the probe as it is driven through the carcass. This deformation may be expected to be greatest on carcasses just following slaughter and to be least on chilled carcasses, where the fat and lean have both become firm.

From the 135 points plotted it was found that 70% were within ± 2mm, and 84% within ± 3mm of the line of best fit; 16% were greater than ± 3mm from the line, and 3 points indicated a probe estimate 7mm greater than the measured fat thickness. In one carcass, the stop and reverse mechanism was not actuated, even though the electrodes were known to have entered the lean layer. In this case, and in others in which poor correlation was noted between the estimated and measured fat thickness, low values of lean conductivity (known to occur in high pH muscle) may have been encountered. In one series of runs erratic probe readings appeared to be due to smears of fat fouling the electrode surfaces. Occasional cleaning, about once every four traverses, was found to eliminate the variability due to this cause.

In considering the correlation between estimated and measured values, it should be borne in mind that the measured value is subject to error. It is obtained by placing a ruler on the cut surface of the quarter carcass and measuring the distance between the outer fat surface and the fat/lean interface. Under the most favourable conditions it would be difficult to measure this distance to better than ± 1mm; in a crowded chiller measurements would be less accurate. It is suggested therefore that part, at least, of the lack of close agreement between estimated and measured values of fat thickness, is due to the inaccuracies inherent in the method of obtaining the measured values.

However, there remain the 16% of points in Fig. 1 which represent differences between estimated and measured values of greated than ± 3mm, and which cannot be explained by measurement inaccuracies. It is believed that improvements in instrument operating technique may reduce this percentage, but it is probable that in some 10% of traverses, unusual physical factors associated with the carcass will give rise to significant differences between estimated and measured values. Low conductivity in the lean, and inclusions of lean, or conducting fluid, in the fat layers are more obvious examples of carcass factors that could cause false instrument readings.

6.0 CONCLUSIONS:

(a) An instrument has been developed to estimate the thickness of fat on hot beef carcasses. It operates on the electrical conductivity principle; a prototype instrument has been found to be simple to operate and capable of taking readings at the rate of 6/minute. Readings are displayed on electronic tubes as 2 digit numbers and connections are provided on the input of a data processing computer.

(b) During extensive initial trials of the prototype instrument its performance mechanically and electrically, was very satisfactory.

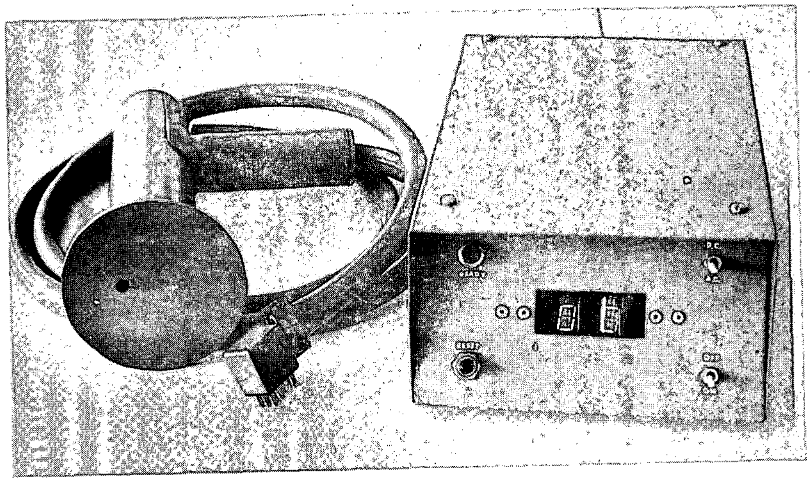
(c) Using a constant correcting factor it was possible to correlate estimated values of fat thickness (by instrument on the hot carcass) against measured values (by ruler on the chilled quarter).
70% of estimated values were within ± 2mm of measured values;
84% were within ± 3mm

(d) 16% of estimated values differed by more than ± 3mm from measured values. It is probable that in many of these cases unusual carcass factors were responsible for the poor agreement.

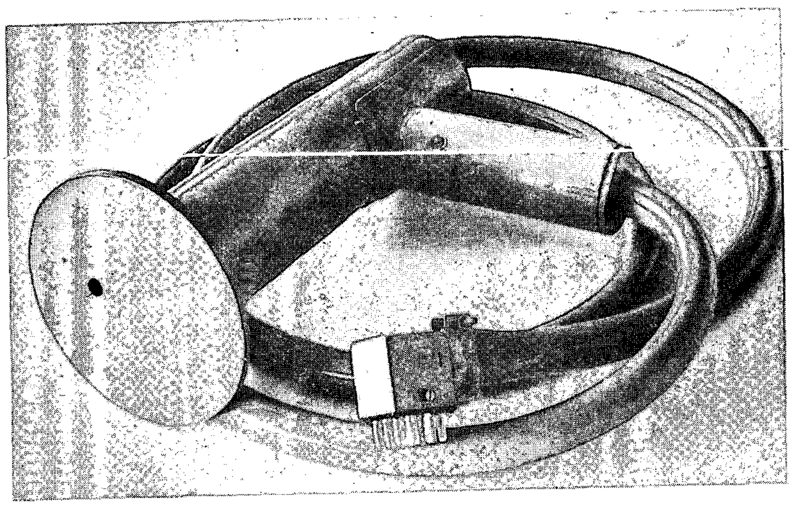
(e) Results from field trials during the course of the classification project should indicate the reliability and accuracy of the instrument and indicate the direction for future development.

7.0 APPENDICES:

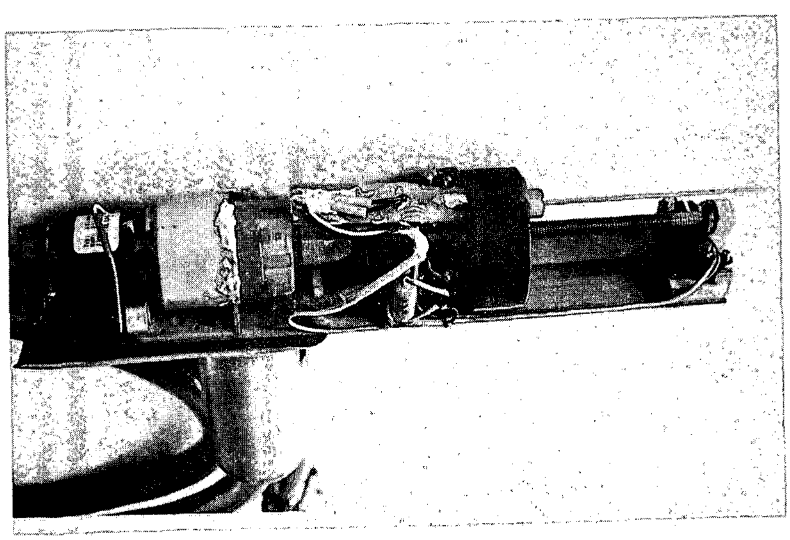
PLATE 1



PROBE ASSEMBLY AND CONTROL BOX



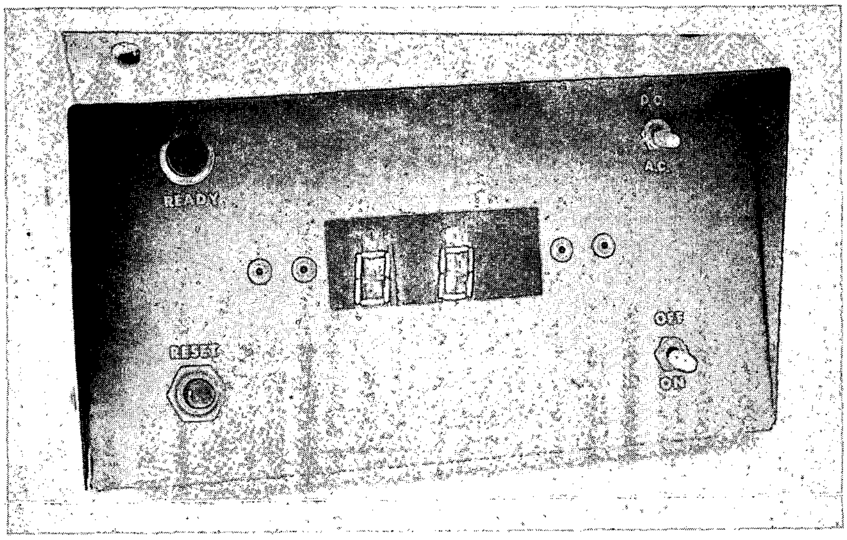
PROBE ASSEMBLY



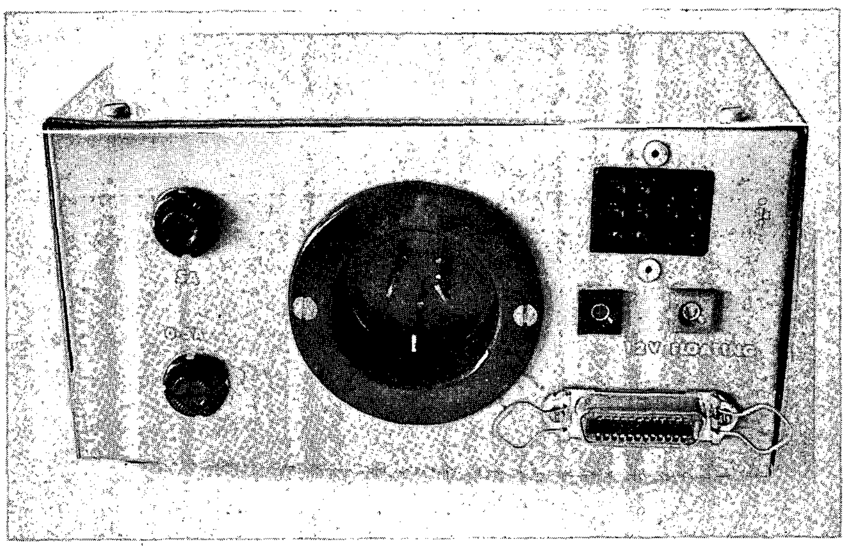
INTERNAL VIEW OF PROBE ASSEMBLY

PLATE 2

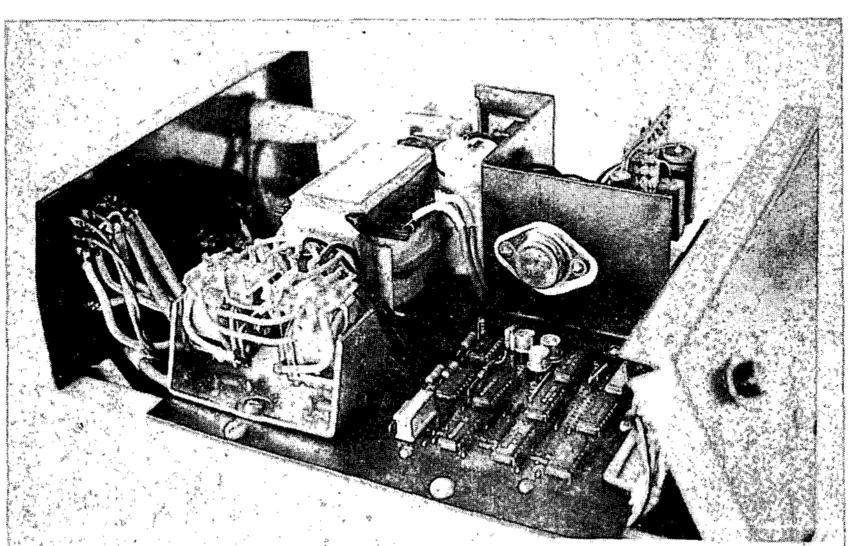
CONTROL BOX



FRONT



REAR



INTERNAL ELECTRONICS

FIG. I.

ESTIMATED FAT THICKNESS vs. MEASURED FAT THICKNESS.

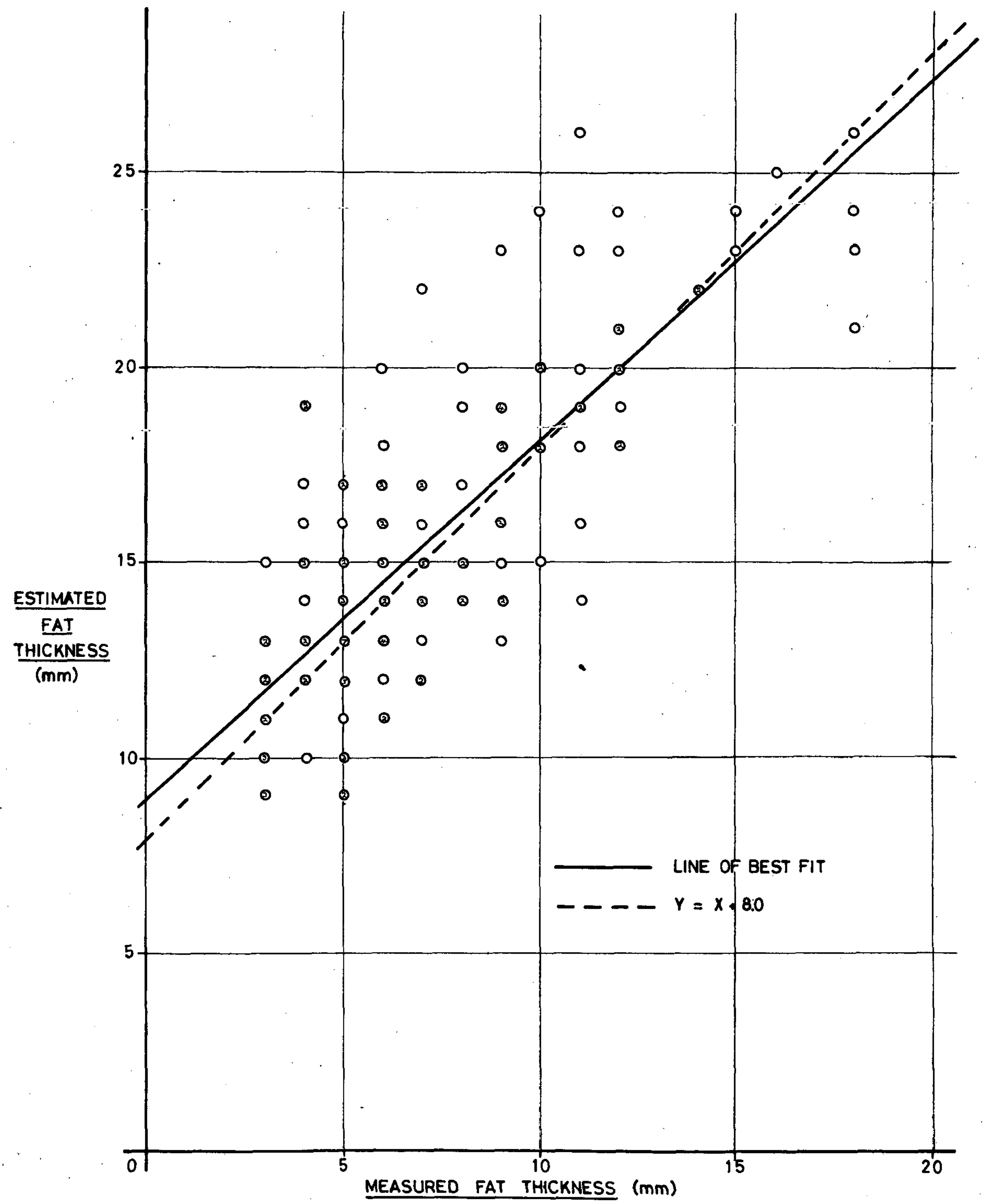
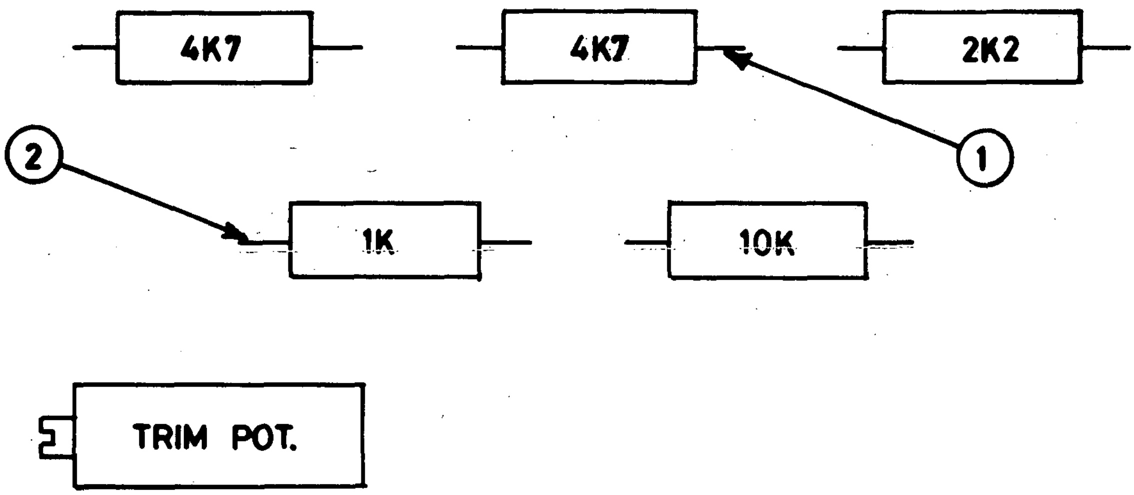


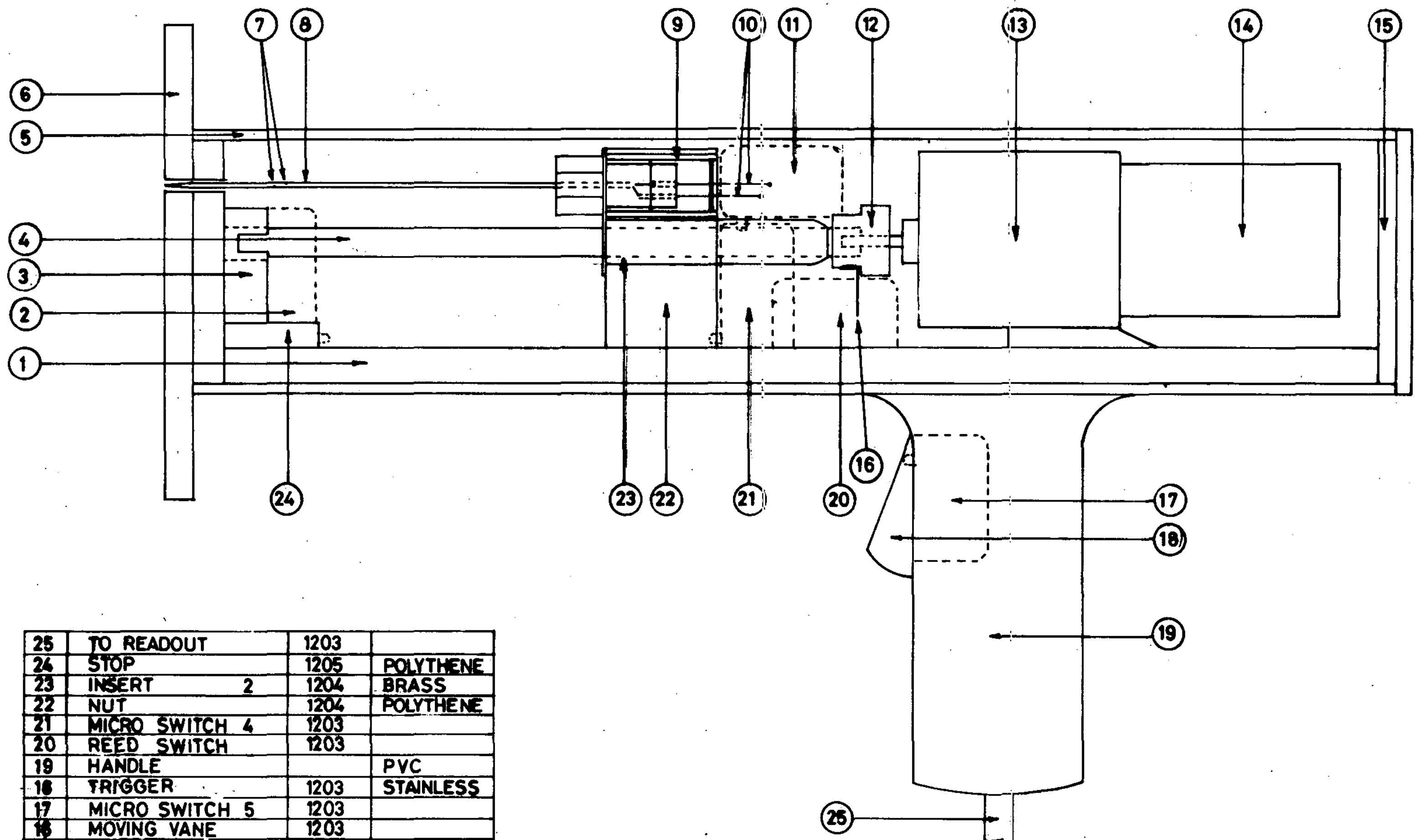
FIG. 2

INTERNAL ELECTRONICS CIRCUIT BOARD LAYOUT.



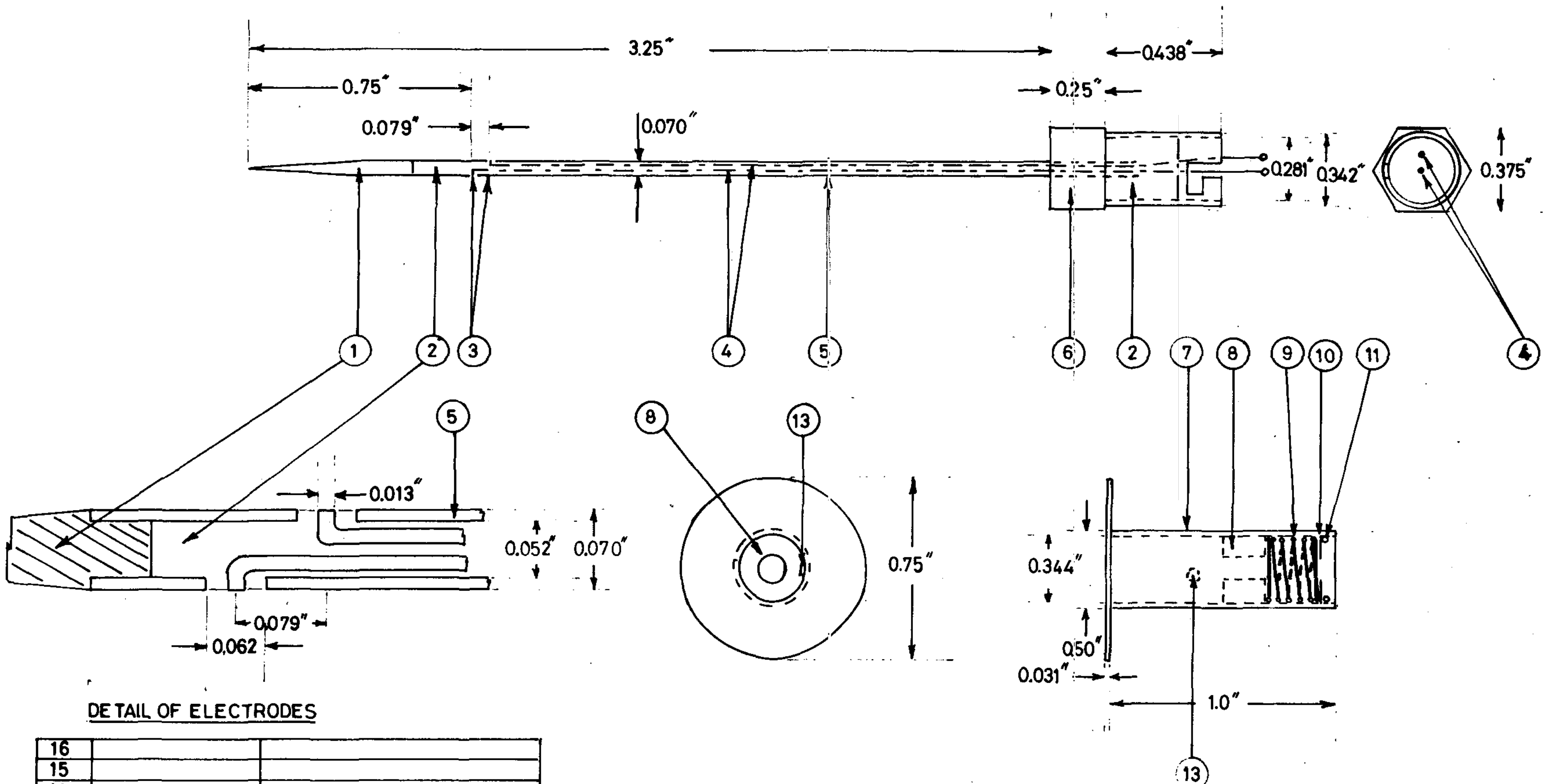
MEASURE PROBE VOLTAGE BETWEEN 1 AND GROUND

MEASURE REFERENCE VOLTAGE BETWEEN 2 AND GROUND



Nº	DESCRIPTION	DRG. Nº	MATERIAL
25	TO READOUT	1203	
24	STOP	1205	POLYTHENE
23	INSERT 2	1204	BRASS
22	NUT	1204	POLYTHENE
21	MICRO SWITCH 4	1203	
20	REED SWITCH	1203	
19	HANDLE		PVC
18	TRIGGER	1203	STAINLESS
17	MICRO SWITCH 5	1203	
16	MOVING VANE	1203	
15	END PLATE 2	1206	POLYTHENE
14	MOTOR		
13	GEARBOX		
12	SLIPPING CLUTCH	1205	BRASS
11	MICRO SWITCH 2	1203	
10	PROBE LEADS	1202	STAINLESS
9	PROBE CARRIER	1202	BRASS
8	PROBE	1202	STAINLESS
7	ELECTRODES	1202	STAINLESS
6	END PLATE 1	1206	POLYTHENE
5	TUBING	1206	PVC
4	LEAD SCREW	1205	BRASS
3	BEARING	1205	POLYTHENE
2	MICRO SWITCH 1	1203	
1	BASE	1204	POLYTHENE

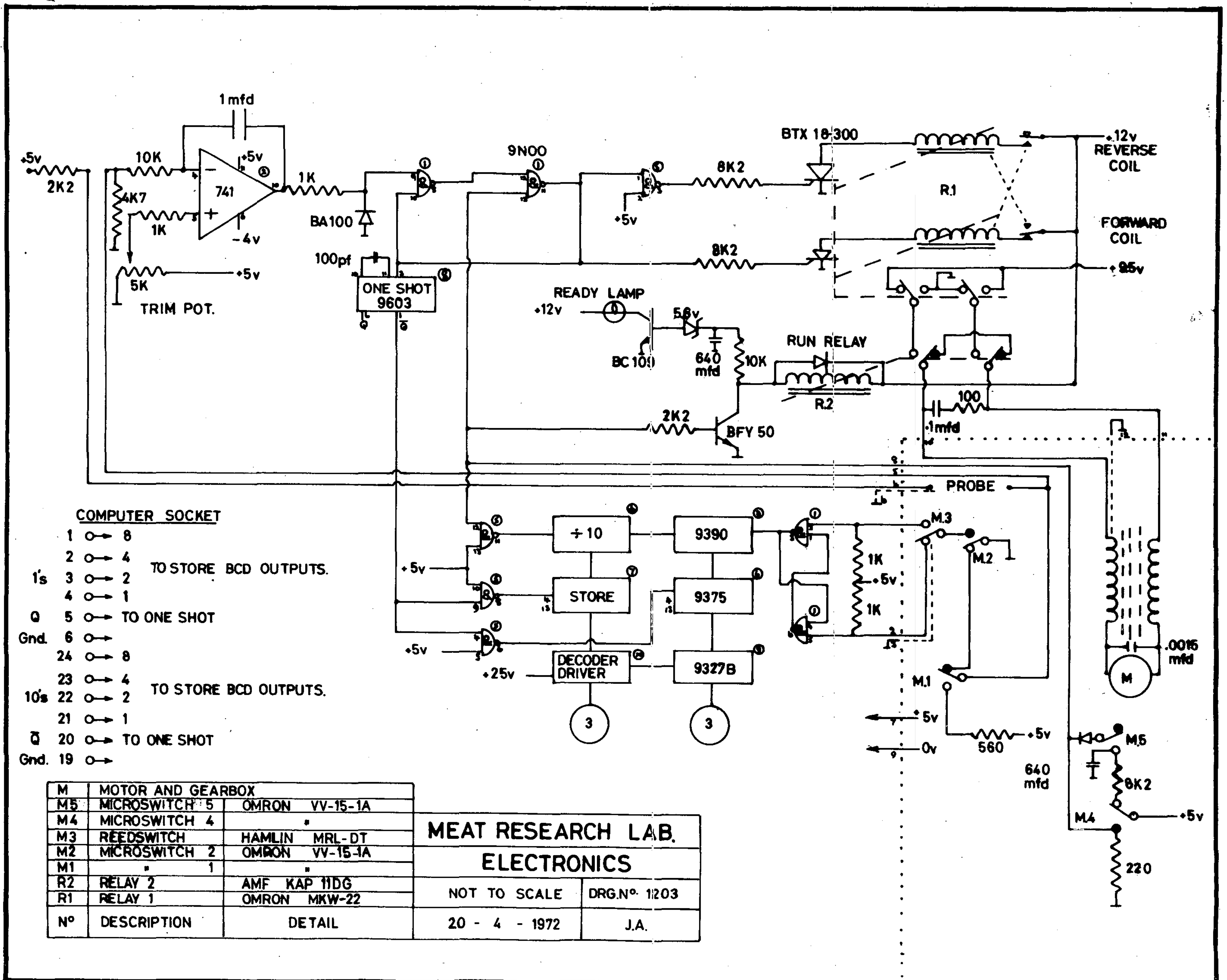
MEAT RESEARCH LAB.	
CONDUCTIVITY PROBE	
SCALE — FULL SIZE	DRG. Nº P.E. 1201
20. 4. 1972	J.A



DETAIL OF ELECTRODES

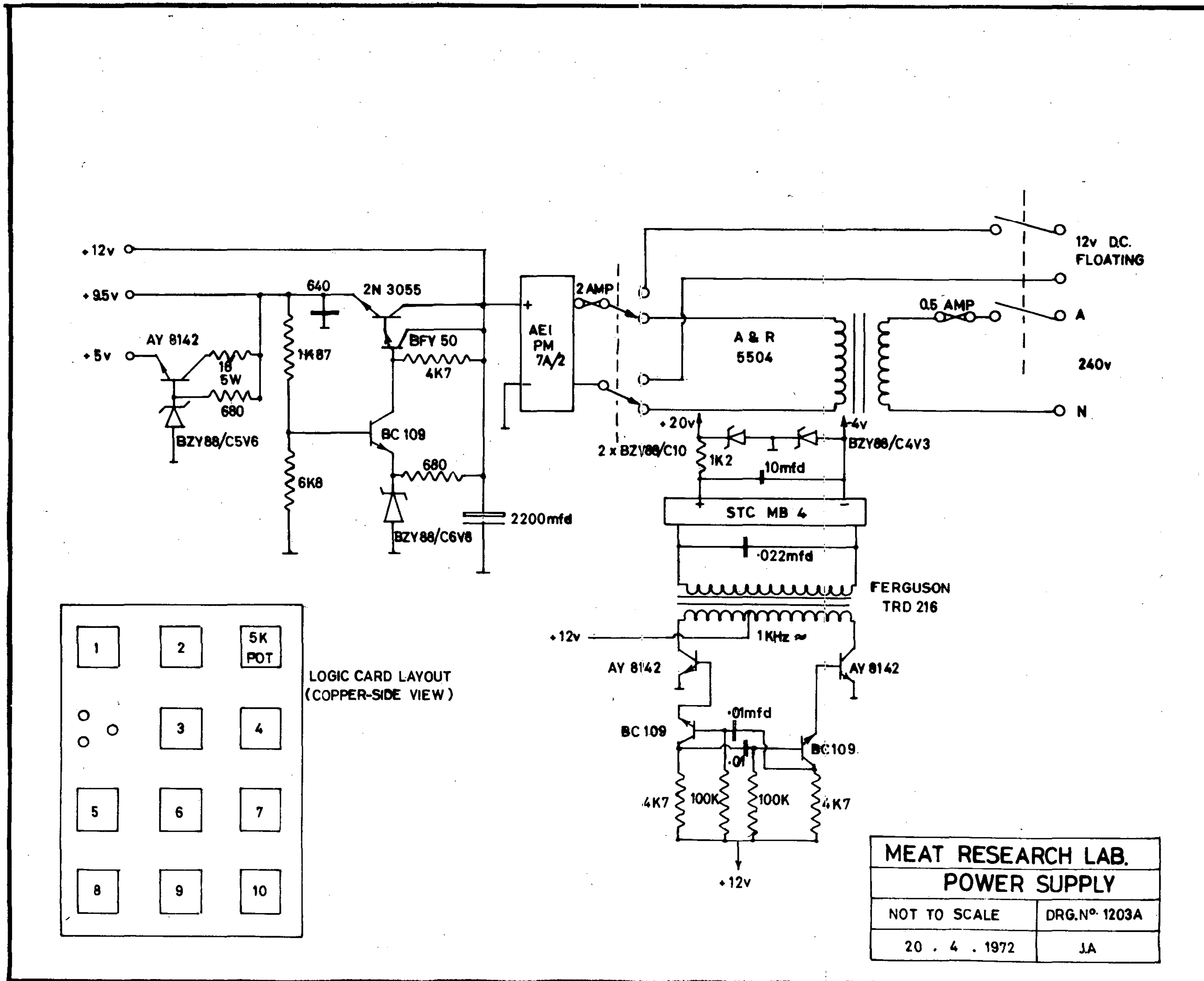
Nº	DESCRIPTION	MATERIAL
16		
15		
14		
13	PIN	BRASS
12		
11	CIRCLIP	STEEL
10	WASHER	BRASS
9	SPRING	STEEL
8	INSULATION	TEFLON
7	CARRIER	BRASS
6	HEXAGON BAR	BRASS
5	TUBING	STAINLESS
4	LEADS	STAINLESS WIRE
3	ELECTRODES	STAINLESS
2	ARALDITE	
1	POINT	STAINLESS

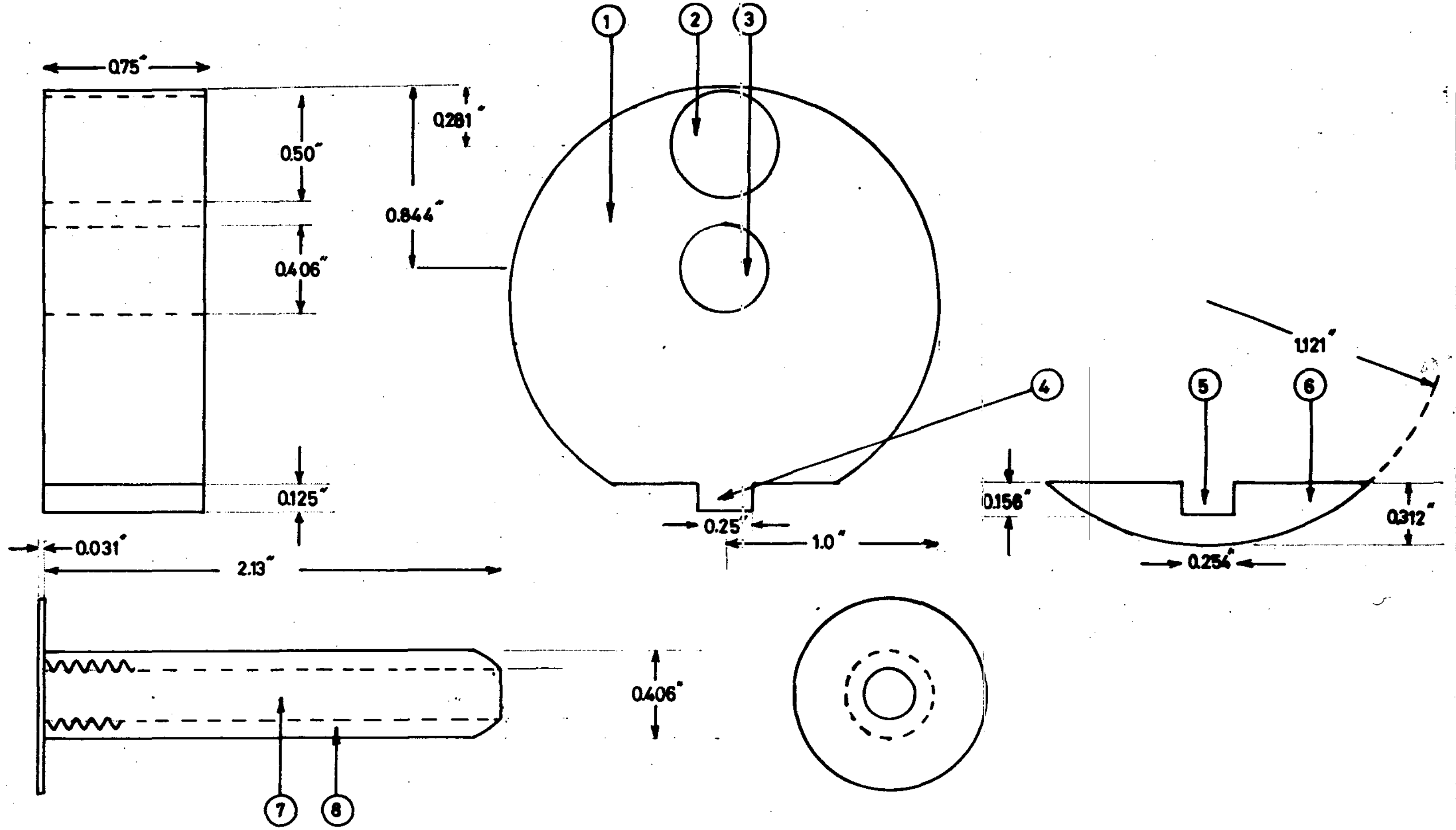
MEAT RESEARCH LAB.	
PROBE AND CARRIER	
SCALE — TWICE FULL SIZE	P.E. 1202
19 . 4 . 1972	J.A



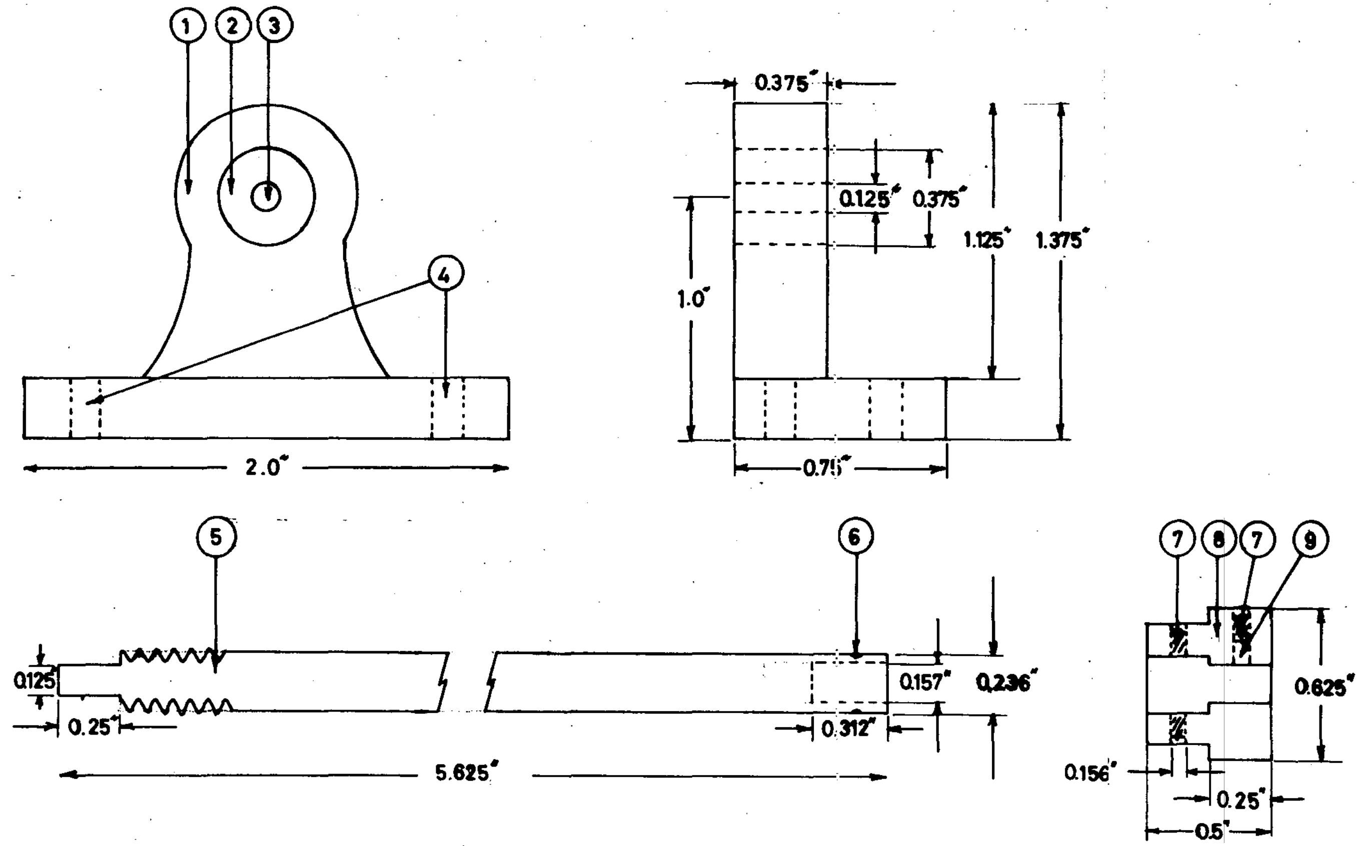
Nº	DESCRIPTION	DETAIL
M	MOTOR AND GEARBOX	
M5	MICROSWITCH 5	OMRON VV-15-1A
M4	MICROSWITCH 4	"
M3	REEDSWITCH	HAMLIN MRL-DT
M2	MICROSWITCH 2	OMRON VV-15-1A
M1	" 1	"
R2	RELAY 2	AMF KAP 11DG
R1	RELAY 1	OMRON MKW-22

MEAT RESEARCH LAB. ELECTRONICS	
NOT TO SCALE	DRG.Nº. 1203
20 - 4 - 1972	J.A.


+12v
+9.5v
+5v
AY 8142
18
5W
680
BZY88/C5V6
640
1K87
6K8
2N 3055
BFY 50
4K7
BC 109
680
BZY88/C6V8
2200mfd
AEI
PM
7A/2
2 AMP
2 x BZY88/C10
A & R
5504
0.5 AMP
12v D.C.
FLOATING
A
240v
N
+20v
-4v
BZY88/C4V3
1K2
10mfd
STC MB 4
·022mfd
FERGUSON
TRD 216
+12v
1KHz ~
AY 8142
AY 8142
BC 109
·01mfd
·01
BC109
4K7
100K
100K
4K7
+12v
1
2
5K
POT
3
4
5
6
7
8
9
10
LOGIC CARD LAYOUT
(COPPER-SIDE VIEW)
MEAT RESEARCH LAB.
POWER SUPPLY
NOT TO SCALE
DRG.No. 1203A
20 . 4 . 1972
JA



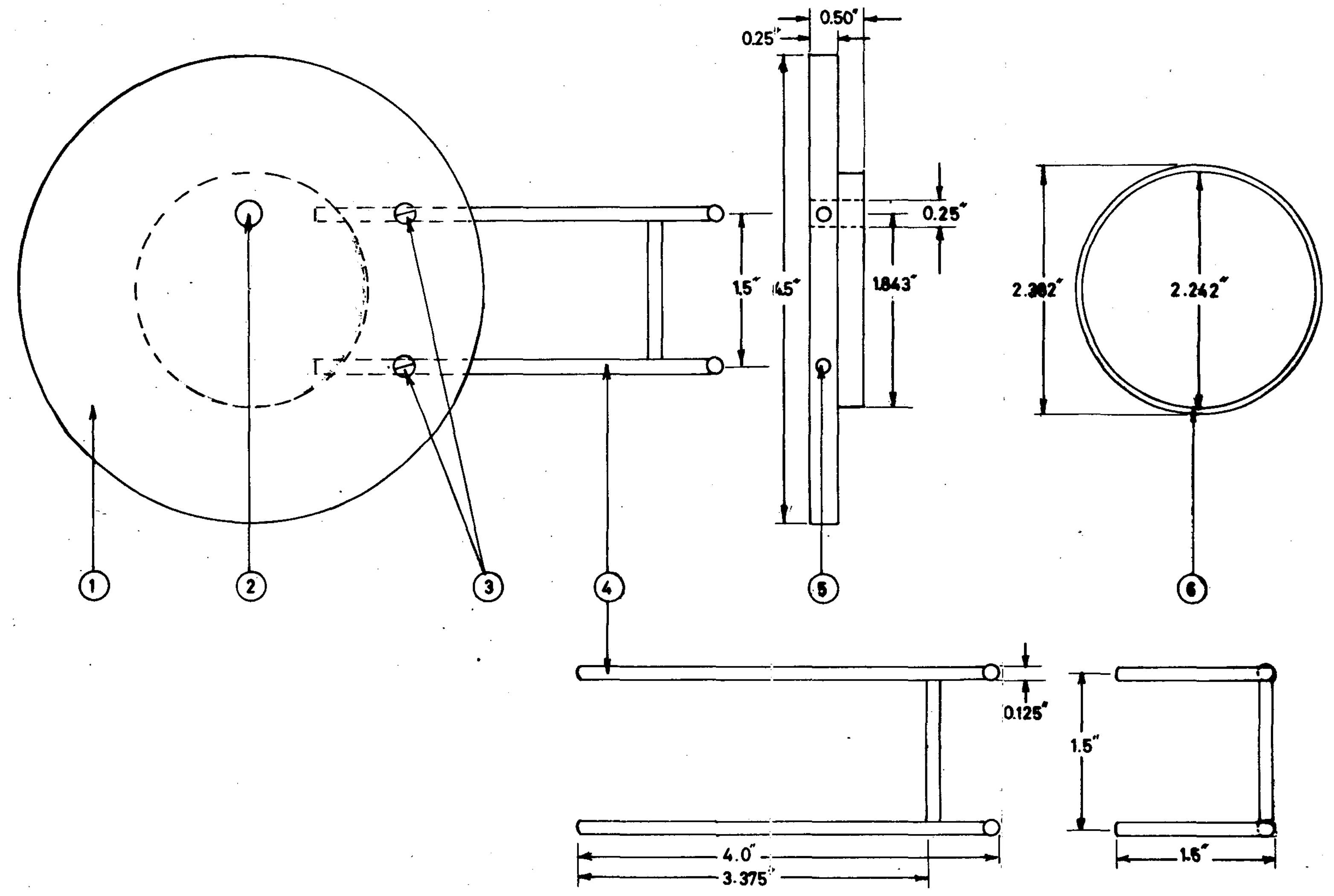
8	INSERT	BRASS		
7	LEAD SCREW			
6	BASE	POLYTHENE	MEAT RESEARCH LAB.	
5	KEYWAY			
4	KEY		NUT ASSEMBLY	
3	POSITION OF LEAD SCREW			
2	POSITION OF PROBE		SCALE—TWICE FULL SIZE	DRG. N° 1204
1	NUT	POLYTHENE		
N°	DESCRIPTION	MATERIAL	18 . 4 . 1972	J.A.



Nº	DESCRIPTION	MATERIAL
10		
9	TEFLON PLUG	
8	SLIPPING CLUTCH	
7	ALLEN SCREW	STEEL
6	DIMPLES FOR ALLEN SCREWS	
5	LEAD SCREW	BRASS
4	HOLES FOR BOLTS	0.125" DIA.
3	POSITION OF LEAD SCREW	
2	BEARING	TEFLON
1	HOUSING	POLYTHENE

MEAT RESEARCH LAB.	
LEAD SCREW ASSEMBLY	
SCALE—TWICE FULL SIZE	DRG. Nº 1205
21 . 4 . 1972	J.A.

MRR.672 - An Electrical Conductivity Instrument for Carcass Fat Thickness Measurment



Nº	DESCRIPTION	MATERIAL
6	TUBING	P.V.C.
5	HOLES FOR FENCE	
4	FENCE	STAINLESS
3	SCREWS	STAINLESS
2	HOLE FOR PROBE	
1	END PLATE	POLYTHENE

MEAT RESEARCH LAB.	
END PLATE & FENCE	
SCALE FULL SIZE	DRG.Nº 1206
21 . 4 . 1972	J.A