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Practical Aspects of Electrical Stimulation of Beef Carcasses in Abbatoirs

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SUMMARY

Laboratory experiments and works trials have demonstrated that electrical stimulation effectively hastens the onset of rigor mortis, and inhibits toughening caused by cold shortening, in both conventionally chilled and "hot-boned" carcasses.

Although carcasses can be successfully stimulated with relatively low voltages (e.g. 110 V peak), much higher voltages (around 1000 V peak) appear more effective, and allow simpler mechanical systems to apply the current to moving carcasses. Safety regulations require the complete guarding of the electrodes and the carcass at any applied voltage above Extra Low Voltage (32 V r.m.s. or 45 V peak). Only the rectal probe method (where a special probe is inserted into the rectum shortly after slaughter) has been shown to work satisfactorily at voltages below this Extra Low Voltage (ELV) limit.

Three alternative systems are described. Two are fully automatic, high voltage systems, requiring isolation in a protective enclosure. In one method, the current flows lengthwise along the carcass, from a live electrode making rubbing contact at the neck region, through the Achilles tendon roller hooks to the earthed rail. In the other method, the trailing roller is diverted on to a parallel, isolated, electrified rail, and the current flows down one leg and up the other to the earthed rail. Both methods require sufficient length of line for 90 secs. stimulation.

Most existing slaughter floors will not have space for such a system. The third alternative, therefore, is the rectal probe method, which uses existing space on the bleeding rail. No guards are required as ELV is used. This method can therefore be implemented very simply, and at a very low capital cost, but has a recurring labour cost.

INTRODUCTION

Electrical stimulation of a freshly slaughtered animal increases the rate of glycolysis, leading to a rapid fall in muscle pH and early onset of rigor mortis. The ability of the muscle to shorten (and hence toughen) when cooled rapidly, by either conventional chilling or after hot boning, is greatly reduced (Davey et al. (1976), Gilbert and Davey (1976), Walker et al (1977)). Electrical stimulation therefore has two potential benefits for beef processors (and consumers): an improvement in meat tenderness (comparable with that produced by the "tenderstretch" process (Bouton et al. (1978)), and/or a reduction in costs associated with the introduction of hot boning.

Cold shortening is not just a laboratory phenomenon associated with extreme chilling conditions. Several works trials of electrical stimulation have shown that it can produce a real improvement in tenderness, even with only moderately effective commercial chillers, as shown in Figure 1. Electrical stimulation can therefore be of immediate benefit to all processors.

This paper describes very briefly some of the recent experimental work on beef stimulation at the CSIRO Meat Research Laboratory, and outlines several possible methods of implementation. Much research has yet to be done to optimise electrical parameters and define more clearly the relative merits of the various methods, but enough information is given here to construct a workable system.

Any abattoir concerned about the quality of its product now has an opportunity to eliminate unnecessary toughening of its meat at a very low cost.

ELECTRICAL SAFETY

The practical implementation of electrical stimulation is dominated by considerations of electrical safety. Although it is well known that it is "the current that kills", electrical safety regulations are of necessity worded in terms of voltage. The Standards Association of Australia Wiring Rules define "Extra Low Voltage" (ELV) as "not exceeding 32V alternating current (A.C.) or 115V direct current (D.C.)". Effective stimulation requires some sort of pulsed excitation - steady D.C. has little or no effect. Electrical Authorities have generally agreed that a pulsed waveform, whether the pulses are of constant polarity ("pulsed D.C.") or alternating polarity ("bi-directional pulses" or "pulsed A.C."), is similar to A.C. of the same peak voltage as far as risk of electrocution is concerned. It is the pulsing, not the alternating polarity, which increases the risk of fibrillation of the heart.

A.C. voltages are conventionally described by their "root mean square" (r.m.s.) value. The peak voltage is $\sqrt{2}$ (i.e. 1.41) times larger. (See Figure 2(b)). Thus the agreed maximum peak voltage for a pulsed waveform to be classed as ELV is 1.41 times the A.C. ELV limit of 32V, i.e. 1.41 x 32V = 45V.

The significance of ELV is that it is generally accepted as being safe to touch. The State Electricity Commission of Queensland has stated that if ELV is used for stimulation, there is no need to guard either the electrodes or the carcass, but at any applied voltage above ELV, the electrodes and the entire carcass must be guarded from human contact.

EXPERIMENTAL BACKGROUND

It is not intended to give a detailed description of the experimental program, but a brief account will help to explain our recommendations for practical systems. The program has been generally directed towards the development of stimulation using voltages low enough to be safe without guards. An early misunderstanding regarding the interpretation of the Wiring Rules led to much experimentation with pulsed D.C. at voltages up to 110V (believed at the time to be ELV). 32V A.C. was also used for some experiments. A stepped voltage program was adopted, partly from the observation that at low voltages, relaxation of the muscles on the stimulated carcass is evident after about 30 secs, but an increase in voltage causes renewed contraction. Sides were used for most work for experimental convenience. Thus a standard "MRL (Meat Research Laboratory) side stimulation" method evolved (Shaw et al. (1977)):

7-prong piercing electrodes are inserted into the hind leg and shoulder regions of dressed sides. Stimulation is applied for a total of 90 secs, using pulsed D.C. (40 x 2ms pulses/sec), rising to a nominal voltage of 110V peak in 4 steps (10, 50, 70, 110V for 0-10, 10-30, 30-60 and 60-90 secs). Muscle pH fall is monitored, but the main measures of stimulation effectiveness are Warner-Bratzler shear force measurements on cooked meat, and assessments by a trained taste panel.

The MRL side stimulation method is quite effective, and was used for 3 of the works trials in Figure 1. Experiments in side stimulation have also used 32V AC, 45V pulsed D.C., and 800V pulsed AC (1130V peak).

A number of experiments have also been conducted using rectal electrodes of several types, with various electrical parameters. This method involves the insertion of a special probe, with two or more electrodes, into the rectum of the animal shortly after stunning. It is described in more detail later.

The main conclusions from the experimental work to date are:

a) MRL side stimulation (i.e. 110V pulsed D.C. and piercing electrodes) is quite effective against cold shortening caused by conventional chilling, but is somewhat less successful in maintaining tenderness in hot boned meat.

b) Side stimulation using high voltage (i.e. 1130V peak pulsed A.C.), with a pin in the neck and the Achilles tendon hook as electrodes, is slightly better than 110V pulsed D.C. for prevention of cold shortening on the carcass, and considerably better for hot boning.

c) Extra low voltage (either 32V r.m.s. A.C. or 45V peak pulsed D.C.) is only moderately and inconsistently effective for side or carcass stimulation, and cannot, at this stage, be recommended. Further experimentation may yet result in an acceptable system for ELV stimulation of carcasses.

d) Rectal stimulation at ELV works well on the hindquarter muscles, less well on the L.D. (striploin) and seems to have little effect on the forequarter.

e) The stimulation waveform and pulse frequency do not appear to be critical. Pulsed D.C. at 40 x 2 ms square pulses/sec, pulsed A.C. at 14.3 x 10 ms half-sinusoid pulses/sec, and even unmodified A.C. (50 Hz - effectively 100 x 10 ms half-sinusoid pulses/sec if polarity is ignored) have all been used successfully, though it is suspected that unmodified A.C. may be less effective than pulsed waveforms. It also causes heating problems at high voltages.

f) The recommended stimulation duration is 90 secs. Stimulation for more than 90 secs. appears to have little advantage, while shorter stimulation times seem less effective. Further research may result in this time being reduced. Most of the work at low and extra low voltage has involved a stepped voltage program and this is recommended at this stage, although it may prove to be unnecessary. The experiments with high voltages did not use a stepped program. The effects of varying the time after slaughter at which stimulation is applied have not been investigated, but earlier stimulation is almost certainly preferable, if only because more time is available for rigor to be approached before chilling.

CONTACT RESISTANCES

Different methods of making electrical contact with a carcass have different contact resistances, and it is reasonable to suggest that the associated voltage drops are parasitic, i.e., it is the voltage across, or the current through, the main body of the animal which is important. The total resistance is the sum of two components - "contact resistance" (the resistance between the electrode and the adjacent muscle tissue) and "body resistance" (the resistance of the current path through the body of the carcass). A number of measurements of contact and body resistance have been made, and though approximate, are of interest:

Contact resistances:

a) Single piercing probes - from 80Ω to 500Ω, depending on size and length.

b) Multi-prong piercing probes - from 15Ω to 100Ω, depending on number and length of prongs (e.g. 7 x 5 cm prongs - 30Ω).

c) Achilles tendon hook to lower leg (approx. 15 cm from hook) - 80Ω to 110Ω.

d) Surface contact (50 cm^2) - approx. 300Ω (very variable - depends on contact area, pressure, and surface condition. In particular, fat cover will greatly increase the contact resistance).

Body resistances (not including contact resistances):

a) Beef side, shoulder/neck to lower end of hind leg - 180Ω to 220Ω.

b) Whole carcass, lengthwise - not measured, but should be half the above, i.e. 90Ω to 110Ω.

c) Whole carcass, lower leg to lower leg - 120Ω to 140Ω.

From these figures, it can be seen that the use of the Achilles tendon hooks as contacts involves appreciably higher contact resistances than can be achieved with multiprong piercing probes. A higher applied voltage (1.5 to 2 times higher) must be used to achieve the same voltage drop across the body of the carcass. Conversely, multiprong piercing electrodes are essential for carcass stimulation at very low voltages.

POSSIBLE PRACTICAL SYSTEMS

1) Side stimulation

This is not considered a particularly practical method, at least as an automatic system. Because of its assymetry, a side bends violently as the muscles contract during stimulation. It would be very difficult to automatically insert and remove probes, while allowing them free movement to accommodate this distortion. Similarly, rubbing contact would be erratic because of these contractions. It would be possible to manually insert and remove electrodes attached to flexible cables, with suitable safety precautions. Usually very little time is available for stimulation to take effect before chilling, and twice as many "units" have to be stimulated, requiring a longer length of line. In some works, such a length of line may be available on the run to the chillers, but we would still consider this method to be a poor alternative.

2) Carcass stimulation during dressing.

a) The "Rake" system:

Because of the difficulties of making contact using piercing electrodes at the lower end of carcasses of varying size, the concept of leg-to-leg stimulation was devised. If a multi-prong piercing electrode is inserted into each hind leg, the current can be passed down one leg and up the other. A pneumatically-actuated arm, pivotted above the rail, brings a bar carrying the two sets of electrodes down into the back side of the hind legs (Fig. 3). This is a very simple mechanical arrangement, suitable for stationary carcasses (i.e. a gravity rail with a cycle time of 100 secs. or more). It can be situated anywhere on the line prior to splitting, as long as the hide has been cleared from the hind legs. (Hygiene considerations will not permit electrodes piercing the hide, and even after hide removal, electrodes, piercing or otherwise, must be sterilised between carcasses).

This system has been built and successfully tested, using the same electrical parameters as "MRL side stimulation" - i.e. a stepped voltage program at up to 110V pulsed D.C. The results are shown in Fig. 4(a). As might be expected, this system works well with the hindquarter muscles, though there is some doubt as to its effectiveness on the forequarter and striploin (L.D.).

It was thought that this system would be adequately safe at this voltage if the electrodes and that part of the carcass immediately adjacent to them were guarded, as the touch voltage at the carcass surface falls away very rapidly to a safe value. However, this approach has not been accepted by the State Electricity Commission of Queensland, who insist on full carcass guarding at any electrode voltage above ELV. A few trials have been made at ELV with only moderately successful results. Further experimental work may produce an acceptable ELV system along these lines, but at present we can only suggest that the "rake" system, using 110V pulsed D.C. or higher voltages, and full guarding, is a possible method for a gravity line.

b) Extension of the "rake" contact principle to powered lines:

The principle of leg-to-leg stimulation with piercing electrodes could be adapted for a powered line, with an auxiliary conveyor carrying sets of piercing electrodes, and a suitable mechanism for inserting and retracting them. However, the mechanical complexity of such a system (relative to other methods using rubbing contacts or using the roller hooks as contacts) could only be justified if there were some clear advantage, such as being able to use ELV and dispense with guards. Development of the mechanisms for such a system will therefore be delayed until the method can be shown to work at ELV.

c) Lengthwise carcass stimulation with one rubbing contact:

A live electrode, in the form of a broad stainless steel strip, makes rubbing surface contact at the neck/shoulder region of the carcass. The return path is through both Achilles tendon hooks to the earthed rail. (See Fig. 5). High voltages (i.e. around 1000V peak) are essential, because of the high contact resistances of the surface electrode and the Achilles tendon hooks, and the entire system must be enclosed in a personnel-proof tunnel. Such a system has been designed and built by R. & W. Hellaby Ltd., in New Zealand, following experimental work at the Meat Industry Research Institute of N.Z. (Gilbert (1978)).

Although simple in principle, it has certain minor practical problems. The carcass may jerk away from the electrode, breaking contact and causing juddering; the position of the electrode in relation to the carcass must be a compromise, especially if a wide range of stock sizes is processed; and resistive heating at the electrode may damage the hide (if stimulation is before hide pulling) or mark the carcass (if after hide pulling). If the carcass is stimulated after hide pulling, the high voltage electrode must be sterilised between carcasses. However, this is definitely a practical system, and can be positioned anywhere on the line from second legging to splitting, though prior to hide pulling is preferable because there is no need for sterilisation (assuming fears of possible hide damage are unfounded).

d) Leg-to-leg carcass stimulation through the Achilles tendons:

This is a further extension of the principle of the successfully-tested "rake" electrode method. If higher voltages are used to overcome the extra resistance of the lower legs and the Achilles tendons, the two roller hooks can be used as the two contacts, eliminating all the problems of piercing electrodes, sterilisation, hide/carcass damage, erratic contact and compromise electrode height. This can be arranged very simply on a gravity line, with suitable stops and isolated rail sections. On a powered line, due to the difficulty of isolating the conveyor as well as the rail, a simple solution is to use an automatically operated gate to divert the trailing roller onto a parallel rail, say 150 mm from the main rail. This rail is isolated and live, while the main rail is earthed and acts as the return path for the current. At the end of the stimulation period, a second automatic gate diverts the trailing roller back onto the main rail. (See Figure 6).

Mechanically, this system is extremely simple, and can be positioned anywhere between second legging and splitting, where space can be found. Slight complications are caused if the conveyor system spreads the legs, or if the rollers have plastic bearings, but both problems are easily solved. As with the lengthwise system, the high voltages needed will require complete guarding and personnel exclusion, although the fact that all live parts are at rail height adds a further degree of safety. The main possible drawback of this method is that it may be less effective on the forequarter and L.D. (striploin) than lengthwise stimulation. This is currently being investigated.

3) Stimulation on the bleeding rail

All the foregoing carcass stimulation systems require a length of rail in the middle of the dressing line, long enough for 90 secs. stimulation plus entry and exit, to be set aside for a stimulation tunnel. Few, if any, existing powered lines, particularly high speed lines, could make such space available without fairly substantial alterations to the floor layout. Thus the cost of implementing electrical stimulation in an existing works would be much higher than the cost of the stimulation tunnel alone. There is a need for an alternative system, able to make use of the only part of a conventional line where space is normally available - on the bleeding rail.

a) The Rectal Electrode System

With the above in mind, and also to stimulate as early as possible on the line to give the maximum time for pH fall before chilling, experiments were conducted using several designs of rectal electrode (similar to those used for electro-ejaculation), and various electrical parameters. The electrode is manually inserted into the rectum, before or after sticking, and the stimulation excitation applied for 90 secs. after sticking. The electrode is then removed and can be washed manually, or automatically. The recommended configuration of electrode is shown in Figure 7. Full details of all the necessary equipment are given in Appendix II.

This method is successful, and though the mechanism by which it operates is not fully understood, it is thought to stimulate the muscles via the nervous system (still functioning in the freshly slaughtered animal) rather than directly - the current flow through the musclature being almost negligible. The method works reasonably well at ELV (see Figure 4(b)), which gives it a great advantage over other methods, as no guards are required. Pulsed D.C. (40 x 2 ms pulses/sec) at 25V (0-30 secs), 35V (30-60 secs) and 45V (60-90 secs) was used for this experiment.

Thus rectal stimulation at ELV is a system which can be implemented immediately, at very low capital cost, in almost any works. Its disadvantages are its manual operation (possibly requiring two men on a very fast line) and its dubious effectiveness on the forequarter and L.D. (striploin). However, it may be the only alternative for a works with no space to spare on the floor.

A self-contained probe with rechargeable batteries is being considered. This would eliminate problems of trailing wires, and possibly allow operation within existing manning levels at low throughput, e.g. insertion by the shackler, removal at 1st leg operation, gravity return (via washing).

SAFETY REQUIREMENTS OF HIGH VOLTAGE SYSTEMS.

Any system using voltages above the ELV limit will require full guarding of the electrodes and the carcass from human contact. This implies an enclosed cabinet or tunnel, which will allow carcasses to pass through, but which will exclude personnel, or at least disconnect the power if someone attempts to enter. Precautions must also be taken to prevent high pressure hoses being directed onto live electrodes or the live carcass.

The simplest and most effective means of detecting personnel attempting to enter the tunnel is to have hinged footplates at each end, with microswitches interlocked with the power supply. Photoelectric cells could also be used.

Automatic doors at the ends of the tunnel will also be needed, partly to assist the exclusion of personnel, and also to prevent hoses being directed onto live parts.

The safety interlock circuits should be arranged so that if any detector (door, footplate, etc.) is tripped, all power to the electrodes is shut off, and can only be restored by an authorised person performing a check of all safety devices, including visual checking that the tunnel is empty. Lockable manual isolating and earthing switches should be provided. The circuitry and components should be arranged to be as "fail-safe" as possible.

In short, all efforts must be made to ensure that the system is not only safe, but demonstrably safe, to the satisfaction of the Electrical Authorities and the workforce.

HOT-BONING

"Hot-boning", or boning the carcass without the usual 24 hrs of chilling, offers potentially large savings in processing costs (Visser (1977). Muscles boned out before they are set in rigor, and then rapidly cooled, will suffer severe cold shortening, and be excessively tough.

At MRL, the effectiveness of stimulation for reducing cold shortening has been investigated, with conventionally-chilled carcasses, and "hot-boned" meat. Muscles have been "hot-boned" at various times after slaughter, and placed immediately in iced water. This represents very severe cooling conditions, as may be required to prevent bacterial growth.

The results have indicated that muscles from stimulated carcasses, boned out at 2-4 hours post stunning, are generally intermediate in toughness between stimulated, 24-hour boned muscles, and unstimulated, 24-hour boned muscles, i.e. generally at least as tender as conventional processing. With high stimulation voltages, some hindquarter muscles boned out at two hours were as tender as their stimulated, 24-hour boned counterparts.

Thus early boning, i.e. boning out the morning's kill in the afternoon, after (say) 3 hours in the chiller, should be possible with no sacrifice in quality. True "hot-boning", straight off the slaughter floor, or much less than 2 hours post stunning, will probably produce somewhat tougher meat than conventional processing, though optimised stimulation parameters and/or less severe cooling post-boning (if this can be tolerated) may ease this compromise.

RECOMMENDATIONS, EQUIPMENT REQUIRED, AND COSTS.

1) If space is available on the line, or if a new line is being built, a fully automatic system for carcass stimulation is recommended. Either lengthwise stimulation with a rubbing contact (Figure 5) or leg-to-leg stimulation through the Achilles tendons (Figure 6) may be used. Both systems require a safety enclosure long enough for 90 secs. stimulation plus entry and exit (say from 4m up to perhaps 12m, depending on line speed), somewhere between legging and splitting, and preferably just after legging (to give the maximum time for stimulation to take effect before chilling). Of the two alternative systems, the leg-to-leg method is thought to have fewer problems, but it may be slightly less effective on the forequarter and the L.D. (striploin).

The recommended voltage and waveform for both systems is pulsed A.C. (14.3 pulses/sec, as in Figure 2(e)), derived from A.C. of 600-800V rms, without stepping. The corresponding peak currents will be around 3-4 amps per carcass. One power supply (transformer and pulsing unit), rated for the appropriate number of carcasses, is required. Details of the pulsing unit are given in Appendix III. Other pulsed waveforms may well be equally effective, but unmodified A.C. at this voltage will cause burning at the contacts, and is not recommended.

The estimated costs of the stimulation power supply ($1200 complete) and automatic gate system ($500, components only) or rubbing electrode and supports, are relatively low. The major cost will be that of the enclosure and its associated safety devices, tentatively estimated at from $5,000 to $20,000.

2) If space for an automatic system is not available, the rectal electrode method with ELV is recommended. If a suitable work platform already exists, all that is required is one set consisting of the probe, transformer, program timer and pulsing unit, for each 30-35 head processed per hour. Full details of this equipment are given in Appendix II. The cost per set is estimated at $600-$800.

At high throughputs (>100 head/hr), one power supply with a distributor system supplying several electrodes will be cheaper than several complete sets. The major cost with this method is the labour cost of manually inserting and retrieving the probes. One operator should be adequate for all but the fastest lines.

To put these costs in perspective, they represent an added cost per kg of carcass meat of between one hundredth and one tenth of a cent, depending on throughput, while noticeably improving the eating quality of the product.

ACKNOWLEDGEMENTS The co-operation and assistance of several abattoirs, and the following MRL staff members, are gratefully acknowledged:

P.E. Bouton, A.L. Ford, S.B. Penna, F.D. Shaw.

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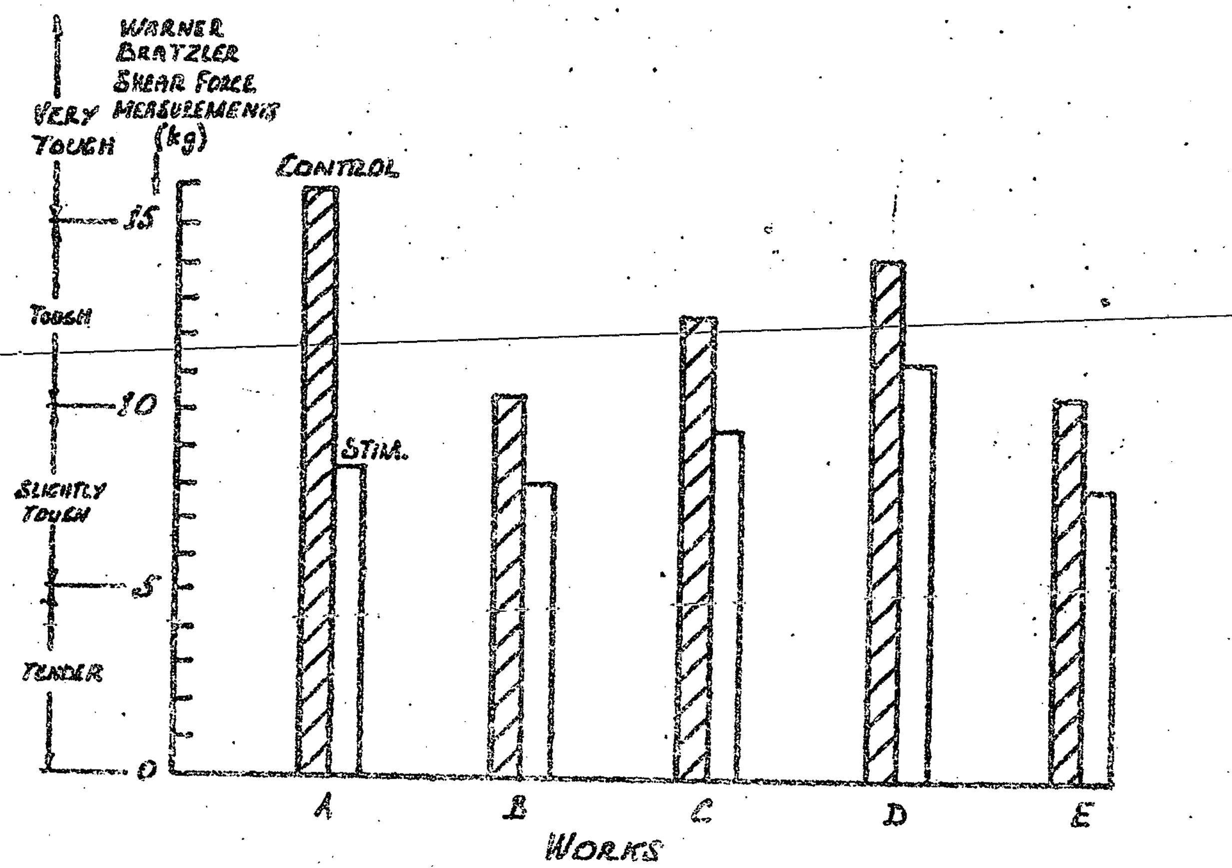


FIG. I - RESULTS OF WORKS TRIALS OF ELECTRICAL STIMULATION WARNER BRATZLER SHEAR FORCE MEASUREMENTS ON COOKED SAMPLES OF LONGISSIMUS DORSI [STRIPLOIN].

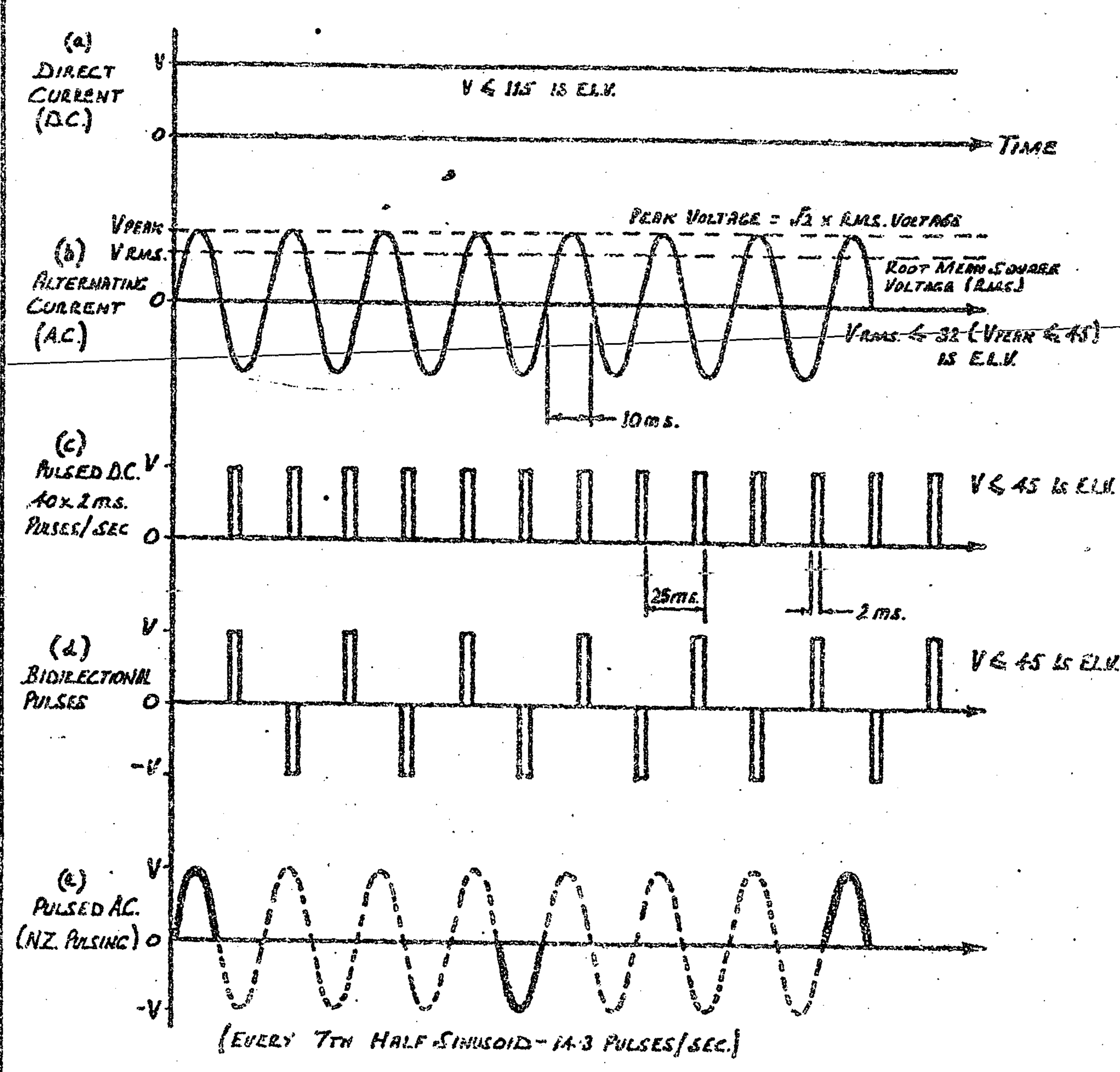


FIG. 2 EXPLANATION OF TERMINOLOGY OF STIMULATION WAVEFORMS.

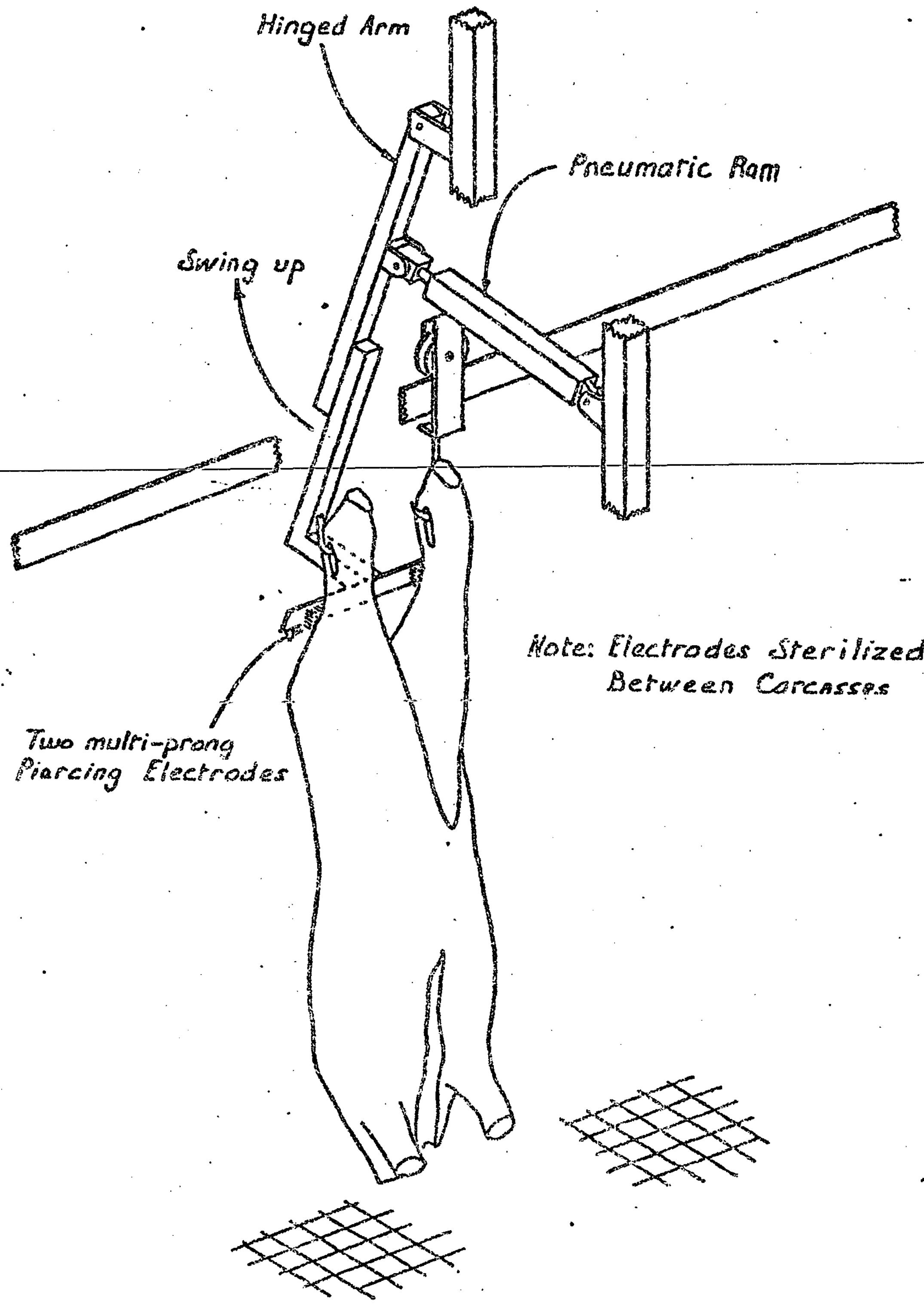


FIG. 3. "RAKE" SYSTEM FOR STIMULATION OF A STATIONARY CARCASS.

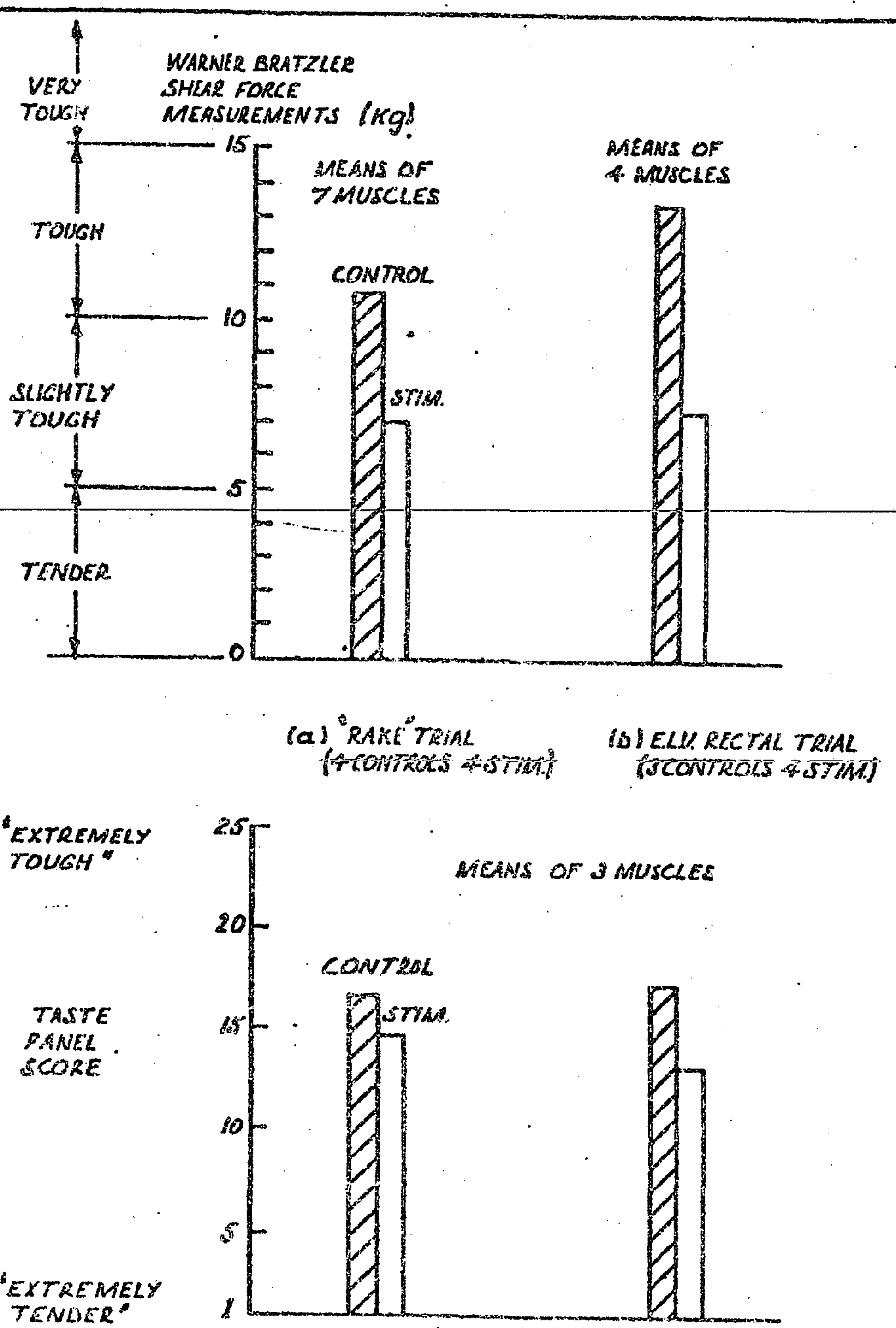


FIG 4 SUMARISED RESULTS OF TRIALS OF :-
(a) "RAKE" SYSTEM - Stepped Voltage Program to 110v Pulsed D.C.
(b) E.L.V. RECTAL SYSTEM - Stepped Voltage Program to 45v Pulsed D.C.

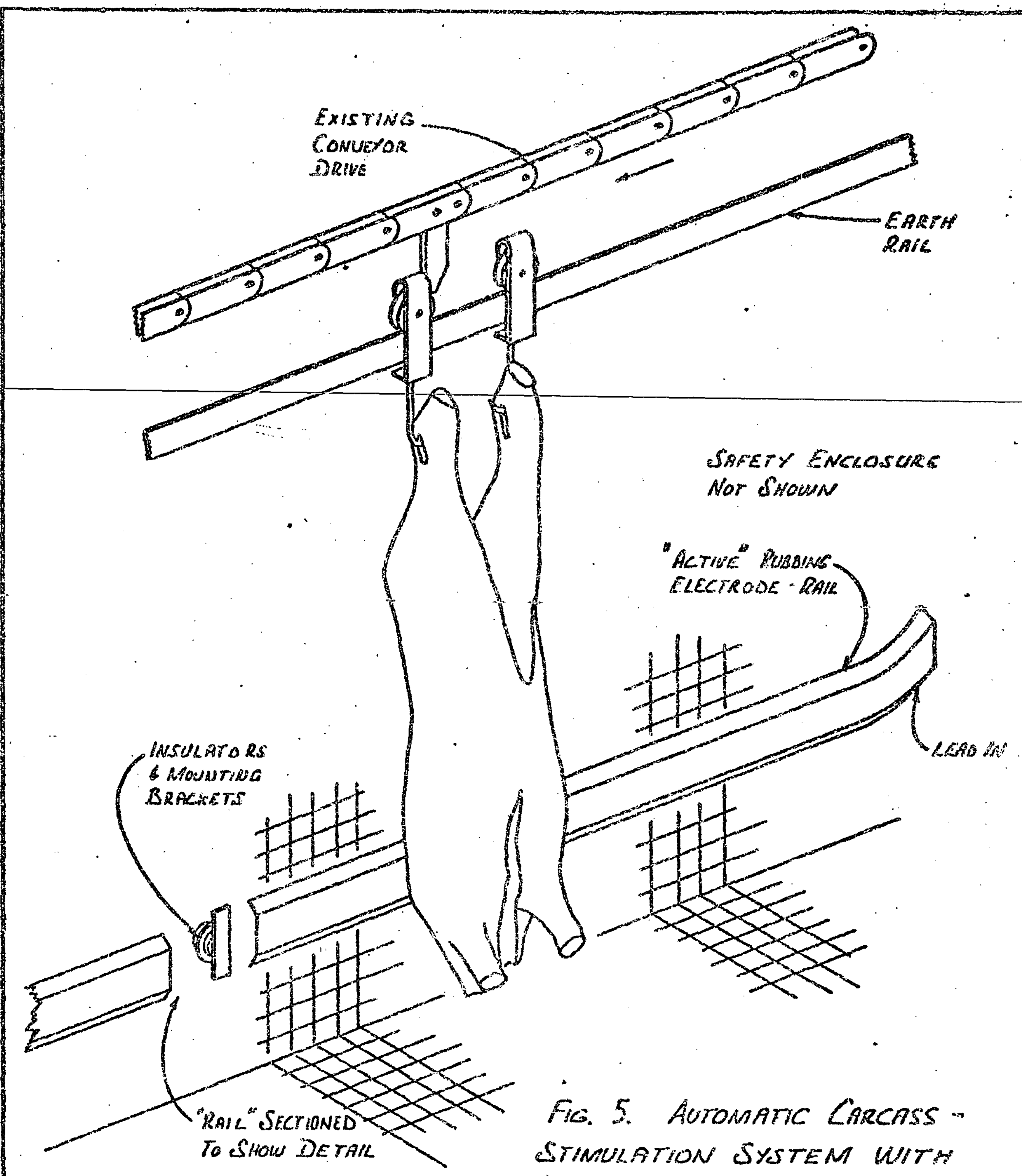


FIG. 5. AUTOMATIC CARCASS - STIMULATION SYSTEM WITH RUBBING ELECTRODE.

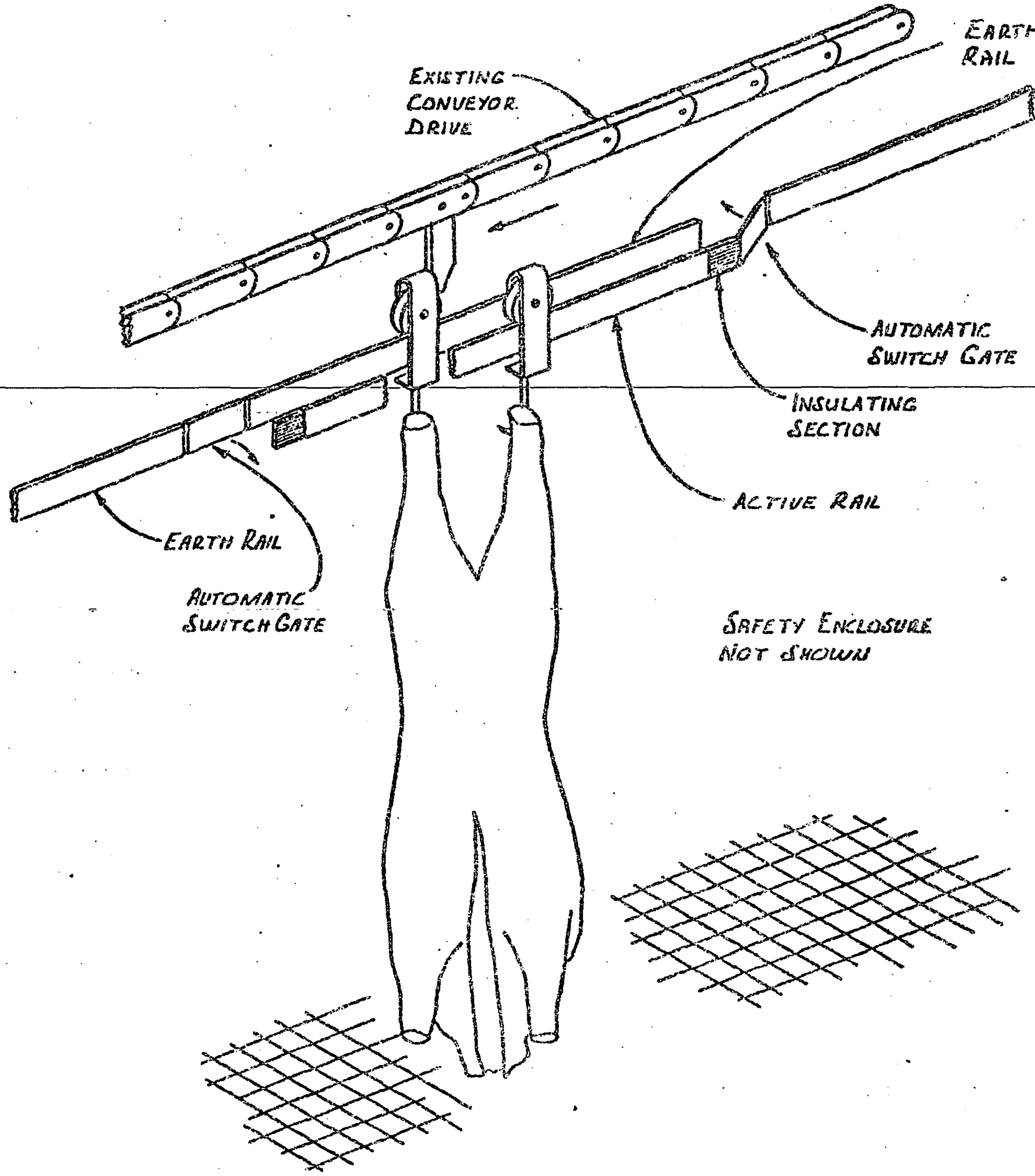


FIG. 6. AUTOMATIC LEG-TO-LEG HIGH VOLTAGE STIMULATION SYSTEM.

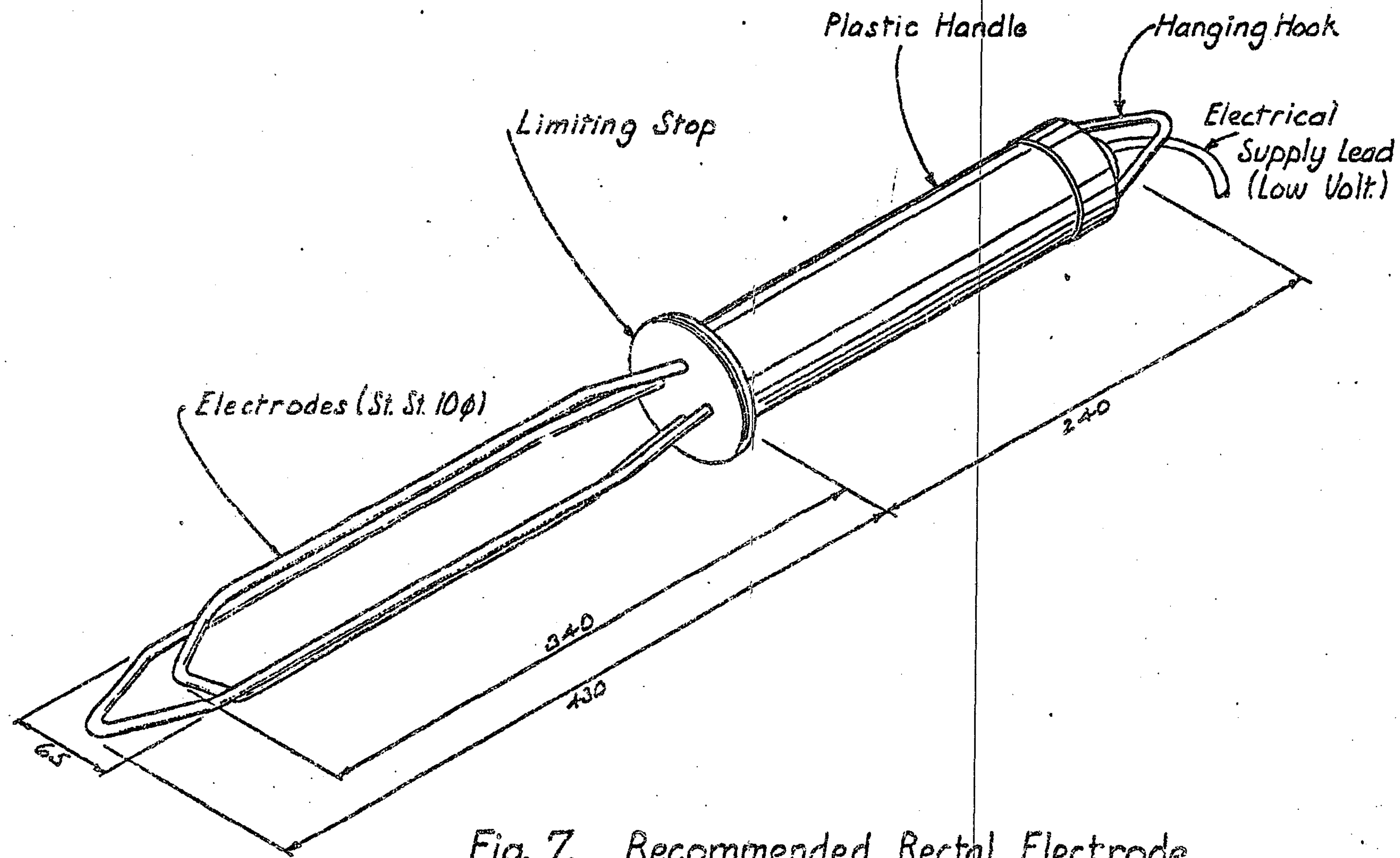


Fig. 7. Recommended Rectal Electrode Configuration - For use with Extra-Low Voltage Only.

APPENDIX I

110V PULSED POWER SUPPLY

The circuit shown in Fig. 8 was designed at MRL to provide a pulsed D.C. output (40 pulses/sec, 2 ms pulse width) at 4 progressively increasing voltages up to approximately 110V, and has been used for much of the early experimental work at MRL, including the trials of the "rake" system.

As mentioned in the main text, these voltages cannot be used safely without guards. The details of this unit are given here for the sake of completeness, rather than as a recommended practical system.

CIRCUIT OPERATION

The rectified outputs of the multi-tapped transformer, when selected, charge the two storage capacitors to peak voltage. This supply voltage, the value of which is dependent on selected switch position and to an extent on load, is applied to the series control transistor. This transistor then switches the supply to the load.

The LM555CN, used in the astable mode, with its associated circuitry, determines the output pulse rate and pulse width.

The output of the LM555CN gates the BF338 allowing the 12k ohm resistor to either supply drive to the output Darlington pair or be shunted to ground, thus creating the output stimulation pulse.

The voltage and current meters are fed by an integrated waveform from the output to give an approximate indication of value.

A current in excess of 5A through the series 1 ohm resistor will develop a voltage sufficient to trigger the thyristor into conduction, thus terminating the present pulse and protecting the output transistor.

For use at Extra Low Voltage (less than 45V peak) a transformer with tappings at 18, 25 and 32V (r.m.s. A.C.) could be substituted for that shown. Alternatively, the unit described in Appendix II could be used.

APPENDIX II

THE RECTAL ELECTRODE SYSTEM

EQUIPMENT REQUIRED

One or more sets of equipment, consisting of a rectal probe, transformer, program timer and pulsing unit (all described in detail below) will be required (see Figure 9). Roughly 30-35 head/hour can be stimulated per set. At throughputs over 70 head/hr, requiring 3 or more sets, a system which uses one power supply with a rotating distributor supplying several electrodes would be cheaper, but has not yet been developed.

The recommended electrical parameters are:-

Waveform:	Pulsed D.C. at 40 x 2 ms pulses/sec.
Voltage:	Increasing in three steps - 25, 35 and 45V peak.
Duration:	90 secs minimum in three steps of 30 secs.

OPERATION

The probe should be inserted soon after stunning, either at the dry landing area or after the animal has been hoisted onto the bleeding rail. A high platform or possibly an elevating platform (if the shackler is to insert the electrode at rail height) will be required. The current should not be switched on until after insertion, and preferably after sticking, and should be switched off before the electrode is removed.

Operations in the bleeding area (e.g. sticking, rodding, horn and hock removal) should not be done during carcass stimulation as the violent physical responses of some carcasses to the current can endanger employees.

If subsequent dressing is done on a bed system, minor problems may arise due to the stiffening of the hind legs of the stimulated carcass.

STEPPED VOLTAGE PROGRAM

In the experiments with the rectal method (both at E.L.V. and earlier work at somewhat higher voltages) a stepped voltage program (i.e. increasing the applied voltage in 3 or 4 steps during the stimulation period) was used. This is the recommended procedure, and requires a program timer unit in addition to the transformer and pulsing unit.

However, this may not be essential, and a constant pulse voltage for the whole period may give adequate results, particularly if the stimulation period can be extended (e.g. in a small slaughterhouse). Whether the program timer is used or not, the 90 secs. period should be regarded as a minimum, and longer times used where convenient.

ELECTRODE DESIGN AND CONSTRUCTION

The three types of rectal electrode used so far in the experimental work at MRL are shown in Figs. 10, 11 and 12. All three appear to have worked satisfactorily, but type III (Fig. 12) is recommended as the open design eliminates the possibility of poor contact due to faeces, though it draws more current than the others. The dimensions are not critical, and those shown have been successfully used on calves and large cattle.

The electrode must be robustly constructed to withstand abuse, and well sealed against moisture if the internal electrical connections are to remain free from corrosion. The external electrode surfaces will require washing between carcass applications (to remove faeces) and occasional more thorough cleaning to ensure good contact.

The electrode should be suspended from a counterbalancing device to keep it off the floor.

TRANSFORMER

An approved Extra Low Voltage Isolating Transformer (to A.S. C126 and C167) must be used. Output tappings at 18, 25 and 32V r.m.s. A.C. will give the recommended outputs from the pulsing unit of 25, 35 and 45V pulsed D.C. The transformer should be rated for continuous operation at 10 amps output.

PROGRAM TIMER

This comprises a series of solid-state timers and relays, arranged to give the desired steps in output voltage at pre-determined times. The circuit diagram is shown in Figure 13.

Operation

When the START push-button is closed, power is applied as follows:

1) via the STOP push-button and STOP RELAY contacts RD1-4 to energise START RELAY RE. START RELAY contacts RE1-3 close to latch the relay on.

2) to timer TA

3) via timer TA contacts TA8-5 to relay RA.

Timer TA, being energised, times out to the set time (30 secs), when contacts TA8-5 open, de-energising relay RA, and closing contacts TA8-6. This then energises relay RB and timer TB.

This operation continues in sequence through to the time-out of timer TC. When this occurs, STOP RELAY RD is energised, thus opening contacts RD1-4, allowing START RELAY RE to de-energise and the system to revert to the "ready" condition.

As the timers progress through their cycle, so do the stimulator transformer connections between C and 1, C and 2, etc. Thus the pulsing unit is supplied in turn with 18, 25 and 32V r.m.s. A.C. (See Fig. 9). The switching is arranged so that the previous connection must be broken before the next can be made, this being the reason for RA5-8 and RB5-8, which ensure that a short-circuit cannot occur during relay change-over.

If the STOP push-button contacts are opened, START RELAY RE is de-energised, cutting off power to all timers and relays. Stimulation will cease, and the system will immediately revert to a "ready" condition.

PULSING UNIT

The circuit diagram of the pulsing unit is shown in Figure 14. The circuit converts an A.C. supply (at up to 32V r.m.s.) to a pulsed D.C. output (40 pulses/sec, 2 ms pulse width) of up to 45V peak, 10 amps.

The applied A.C. voltage is rectified via the bridge rectifier to D.C., charging the storage capacitor to peak voltage. This peak voltage value sets the output pulse height.

A twelve-volt regulator, supplied by an 1,800 ohm resistor from the storage capacitor, supplies a 556 dual integrated circuit timer.

The first half of the 556, in conjunction with the 220K ohm, 68 ohm resistors and 0.47 microfarad capacitor, forms an astable multivibrator which creates the pulse repitition rate of 40 pulses per second.

This astable multivibrator then drives the second half of the 556 which is configured in the monostable mode, the 150 K ohm resistor and 0.015 microfarad capacitor then creating the pulse width of 2 milliseconds.

The monostable output of the 556 then enables the BC300 driver transistor to gate the MJ4502 output transistor on and off to create the output waveform.

The standby switch enables the reset line of the 556 to halt all output.

If overloading occurs, the voltage developed across the 0.1 ohm resistors triggers the BRY39 to terminate the current pulse. This same voltage, if used in a charging circuit, can be used to give an indication of current value.

APPENDIX III

HIGH VOLTAGE PULSING UNIT

At the high voltages and currents recommended for the on-line stimulation systems, it is difficult and expensive to produce the pulsed square waveforms used for the experiments at lower voltages (i.e. Figs. 2(c) and 2(d)). Unmodified A.C. at 600V r.m.s. has been used but causes severe heating problems at the Achilles tendon contacts. The simplest method of producing a pulsed waveform at high voltage is to use thyristors and a suitable counting circuit to select every nth half-sinusoid from the A.C. mains frequency. This method was adopted by researchers at the Meat Industry Research Institute of New Zealand, whose earlier work had indicated that a value of n = 7 was optimum (Chrystall & Devine, 1978). This gives the waveform shown in Figure 2(e), at 14.3 pulses/sec.

A circuit was designed at MIRINZ to produce this waveform at a peak voltage of 1130V (i.e. from an 800V r.m.s. A.C. supply). M.R.L. has details of this unit, which was built and used for the high voltage stimulation experiments at M.R.L.

Similar equipment is commercially available in New Zealand from at least one supplier (Thornton Engineering Ltd., P.O. Box 22-223, Otahuhu, Auckland, New Zealand).

A more versatile unit, capable of higher voltages, variable pulse width, and variable pulse rate, is under construction for installation in an experimental stimulation cabinet in an abattoir. Details of this unit will be available shortly.

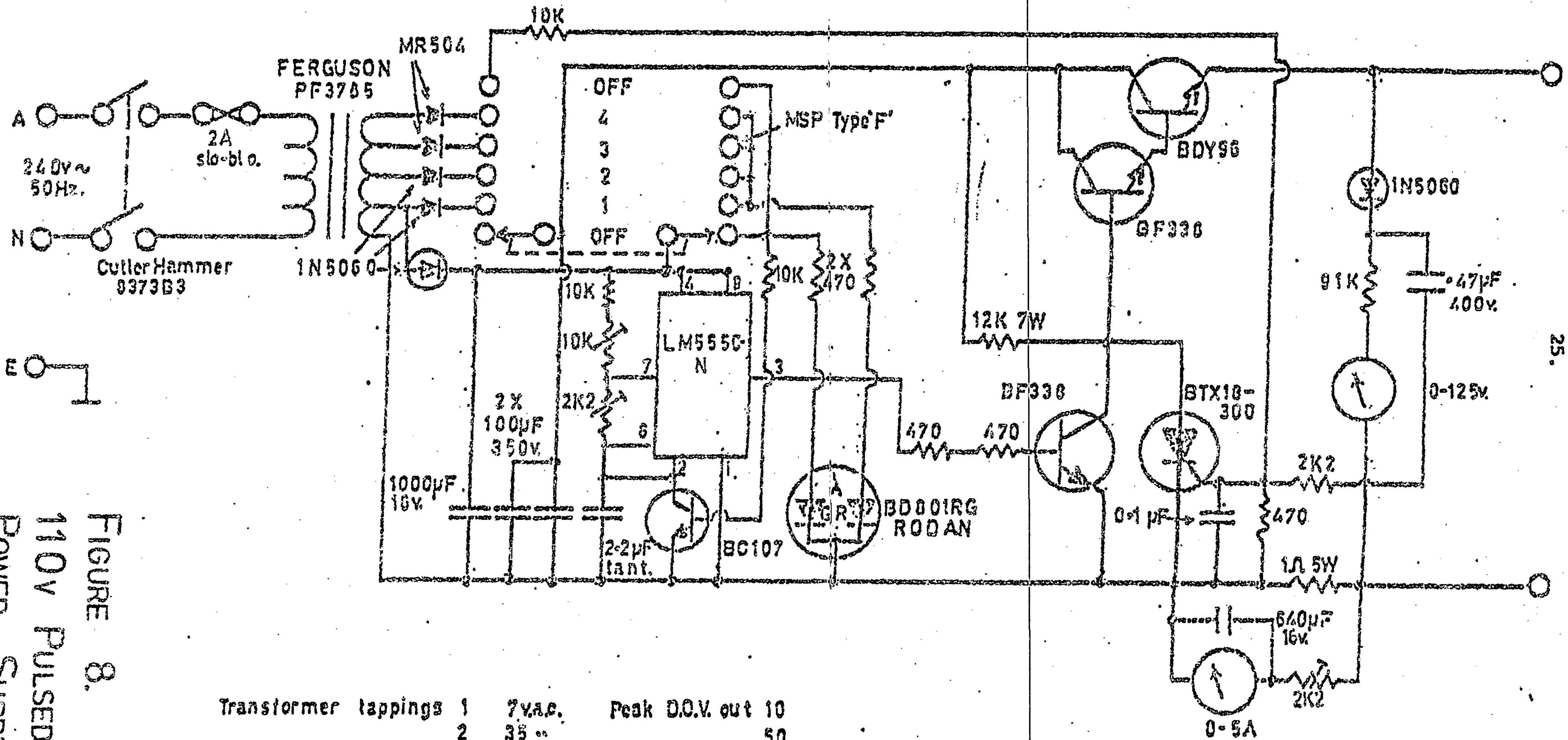


FIGURE 8.
110v PULSED D.C.
POWER SUPPLY

Transformer tappings	1	7v.a.c.	Peak D.O.V. out	10
	2	35 "		50
	3	42 "		60
	4	70 "		100

Meters 1mA D.C. 100Ω. S.E.W. Type SD-460.

Current limits at 5A.

40p.p.s. 2 mS output waveform.

R.R.W. 6.4.77

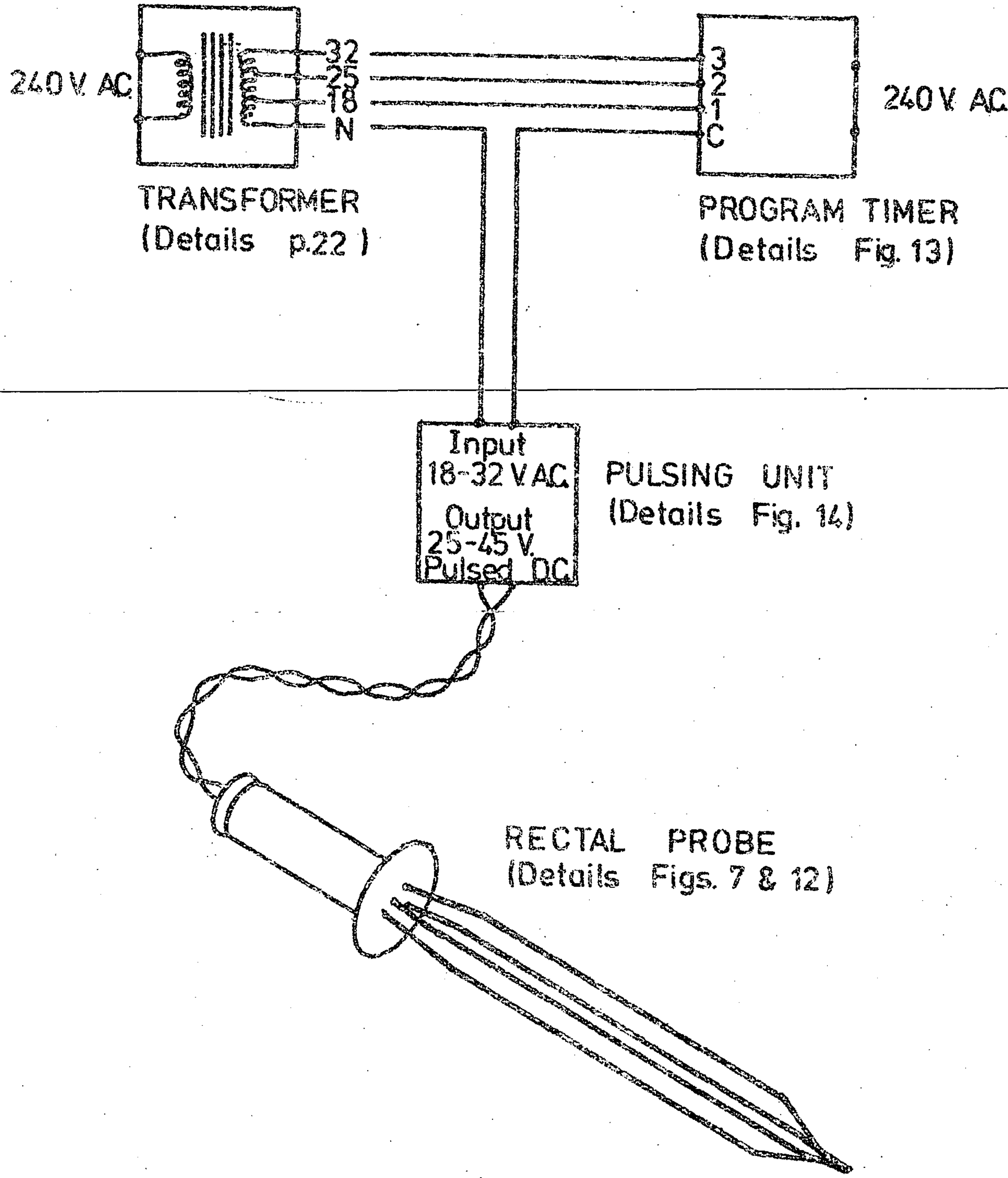


Figure 9

The Complete Rectal System

(Showing electrical connections)

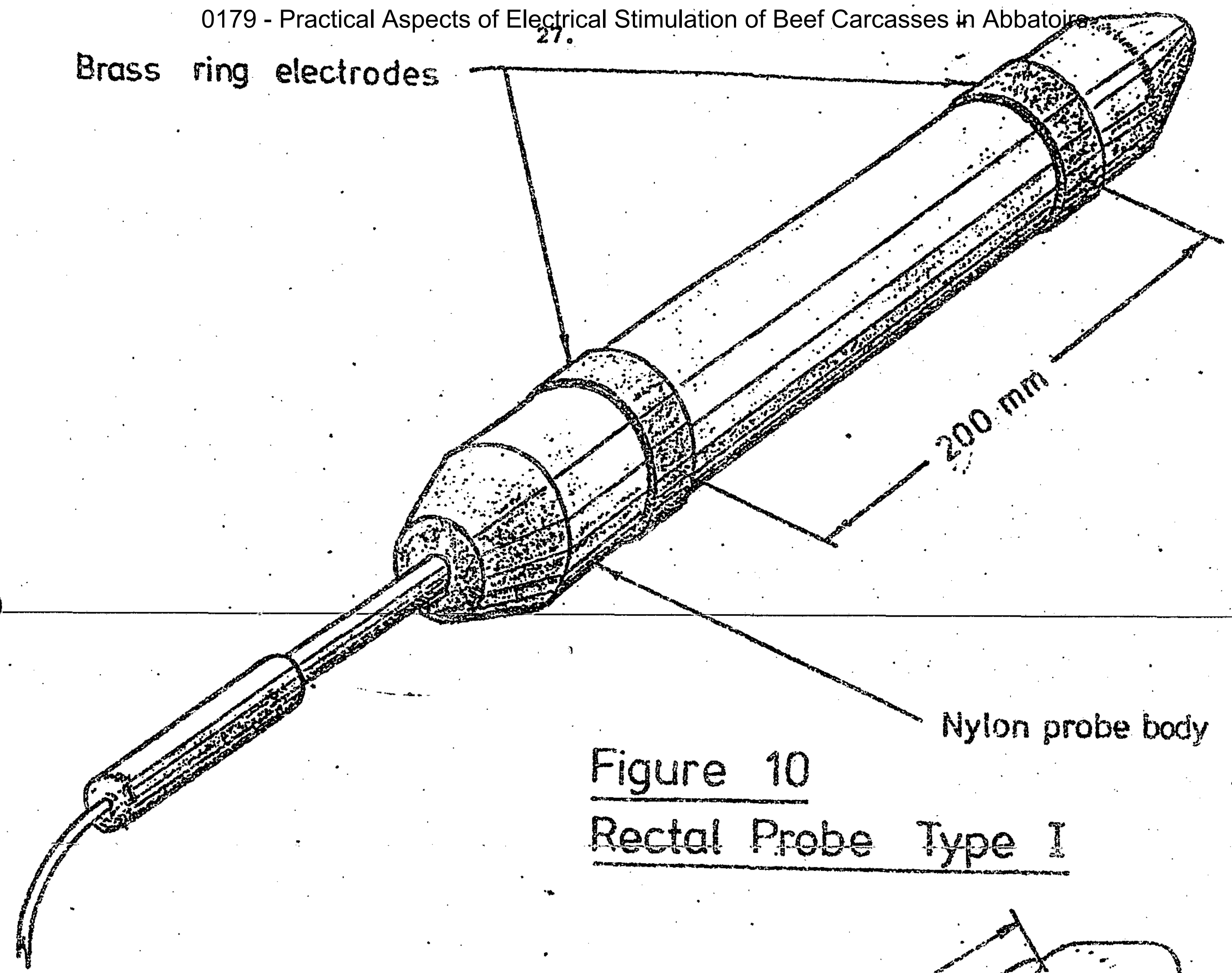


Figure 10

Rectal Probe Type I

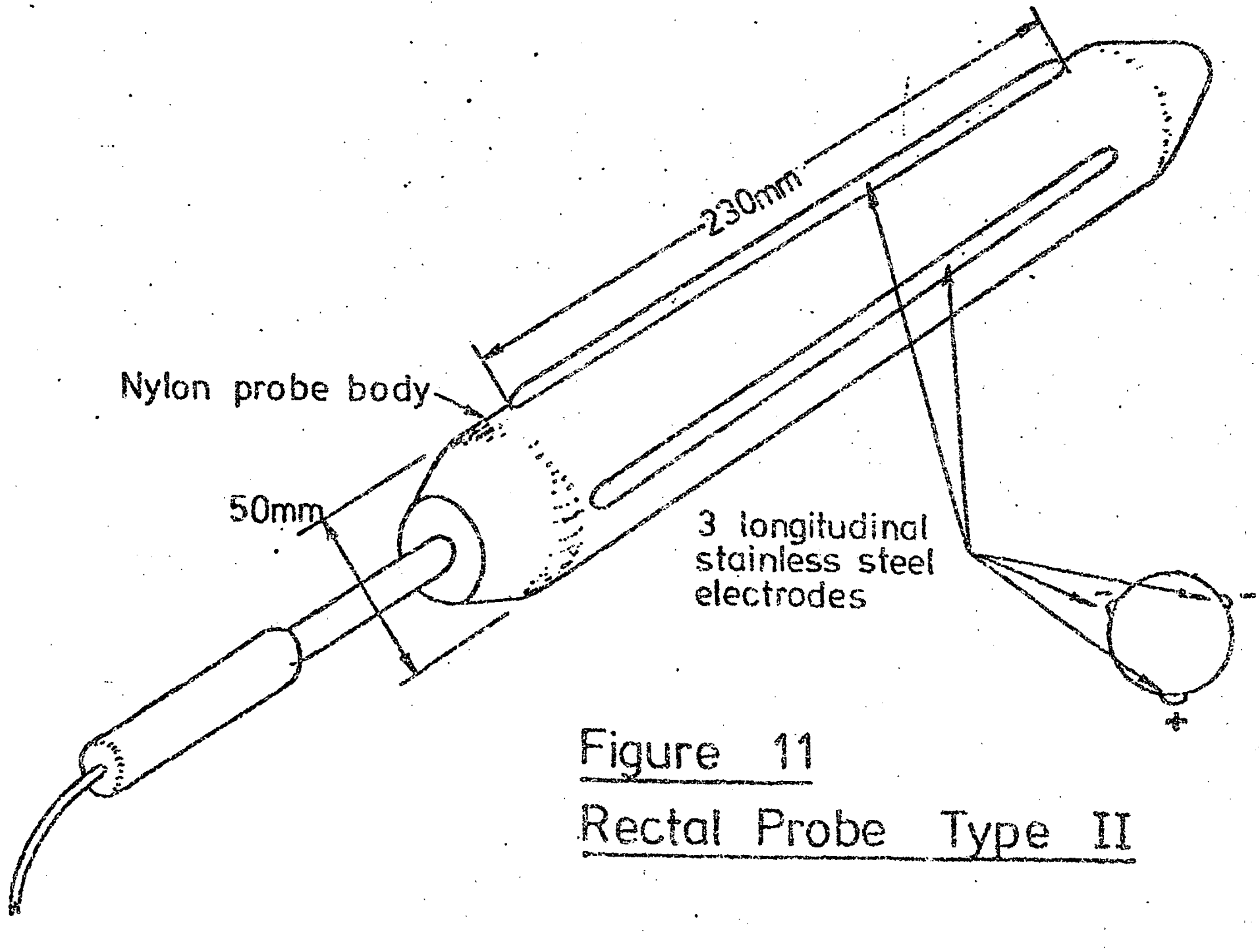


Figure 11

Rectal Probe Type II

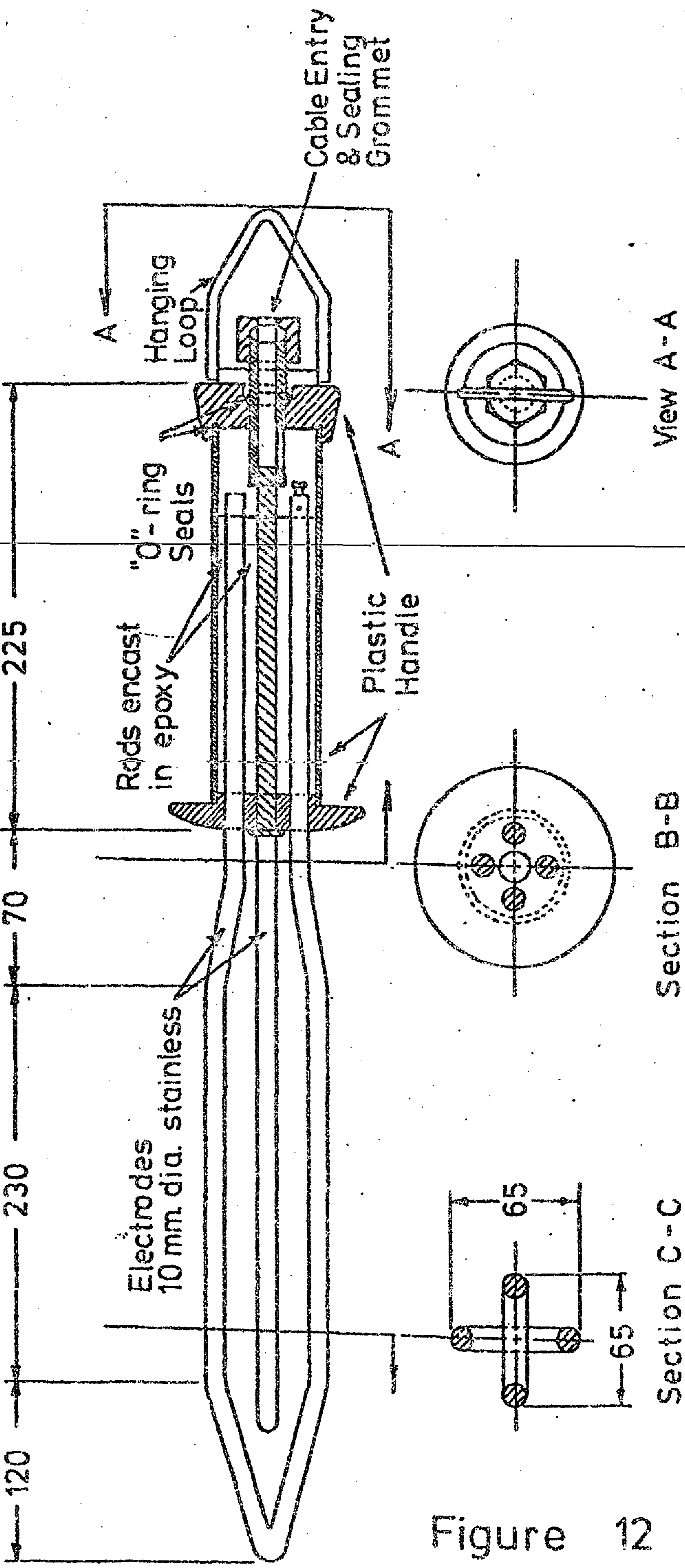
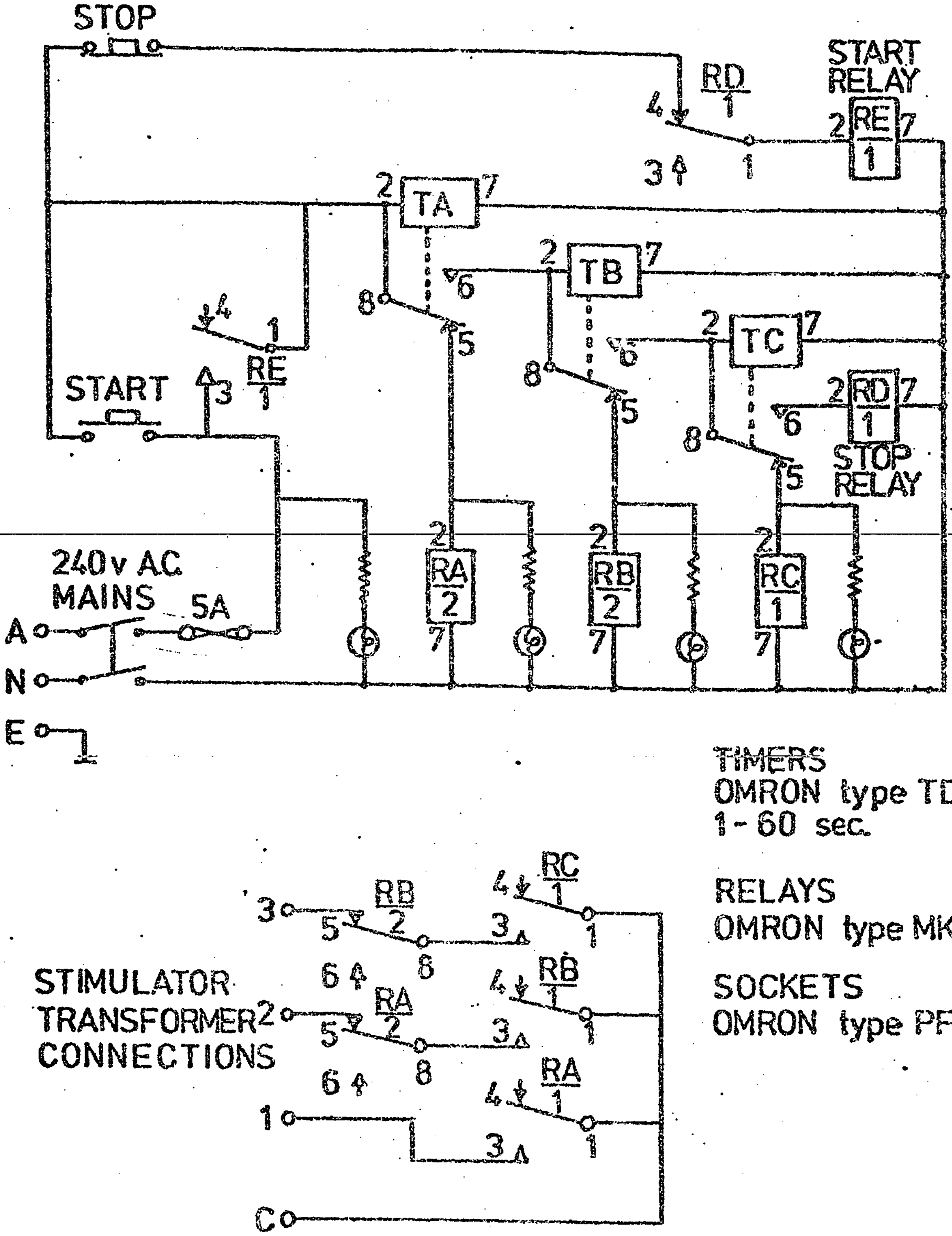


Figure 12

Rectal Probe Type III

(M.R.L. "Open" Design)



~~TIMERS~~
OMRON type TDL
1 - 60 sec.

RELAYS
OMRON type MK-2P

SOCKETS
OMRON type PF083

Figure 13

Program Timer

(Three Step)

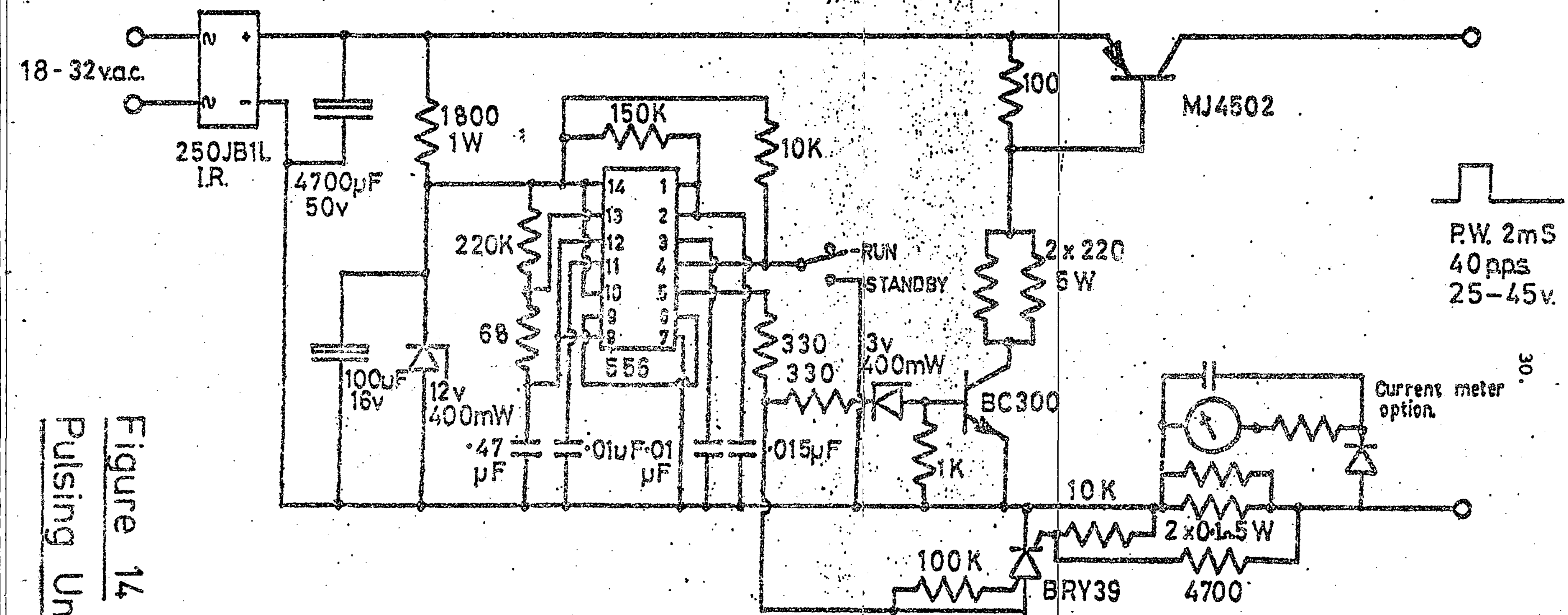


Figure 14
Pulsing Unit