THE DESIGN OF AN ELECTRONIC MUSCLE & NERVE STIMULATOR

by

Stephen Lennon

NCAD - IND DESIGN

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THE NATIONAL COLLEGE OF ART AND DESIGN

THE DESIGN OF AN ELECTRONIC MUSCLE AND NERVE STIMULATOR

A DESIGN REPORT SUBMITTED TO:

FACULTY OF DESIGN
DEPARTMENT OF INDUSTRIAL DESIGN

BY

STEPHEN LENNON

JUNE 1981

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ACKNOWLEDGMENTS

The author gratefully acknowledges his debt and offers his thanks to the followimg people who have generously helped him with advise and information for the duration of this project:-

All the staff of BIO-MEDICAL RESEARCH LIMITED, who helped with this project, especially Mr Clive Matthews.

Professor Michael Ozmin, and all the staff of N.C.A.D. Dublin and N.I.H.E. Limerick, who gave assistance.

Finally, the author gratefully thanks Marie Buckley for her patience in typing this report.

SYNOPSIS

The initial stage of this report was to establish whether a need existed for a new unit. This having been assessed the various currents used in electrotherapy and their physiological effects were investigated. (Some initial research into the other modes of treatment in physiotherapy was also undertaken). Through literature searching, and talking with various experts in the field, the most useful currents and the various parameters associated with these were established.

The next stage of the project was the actual design of the unit and assessories. These involved sketching, experimentation, construction of mock-ups and detail designing. Following this the layout of the elements on the control panel and inside the unit were discussed with the Electronics Engineer involved in the project.

The next stage involved an analysis of the various materials and manufacturing processes which could be used in the different sections of this project.

When all the details of the design had been formalised, a section explaining the operation of the equipment was included. The final cost review was then carried out. The results of this work are given in this report.

FOREWARD

There is a great need in this Country for people who are qualified in Industrial Design and Product Development. Many firms have not kept abreast of the market need. Consequently, there is a need for designers who can work with marketing and advertising, as well as engineering staff to produce a complete package. This project serves as an example of such a package. The design of a muscle and nerve stimulating unit engulfs many disciplines of designing and engineering, such as:-

Aesthetics

Ergonomics

Mechanical Engineering

Electronics Engineering

Production Engineering

Materials Engineering

An appreciation of these areas in invaluable to someone embarking on a career in Industrial Design.

SECTION I

PROJECT BRIEF AND INTRODUCTION

SECTION 1.1

The following pages are a copy of the project proposal submitted to the Faculty. It is included here because it outlines the motivation for the project and its objectives. It also serves to illustrate the thinking behind the design project before it was actually started.

FACULTY OF DESIGN

PROPOSAL FOR DEGREE PROJECT IN INDUSTRIAL DESIGN (ENGINEERING)

STEPHEN LENNON

OCTOBER 1980

MOTIVATION:

1.1. To stimulate design interest in an area which is in need of development.

1.2. To develop a product which can be manufactured in Ireland (at present this Country imports most of its medical technology).

1.3. To increase my awareness of real life problems associated with design and development.

1.4. To familiarize myself with the business problems and risks involved in bringing a new product into the marketplace.

1.5. Proposed project was arrived at in consultation with Mr John Porter, Managing Director, BIO-MEDICAL RESEARCH.

1.6. The reason I have choosen this project is that it satisfies all my criteria for a worthwhile Degree Project; this does not necessarily mean I will specialize in the medical area after graduation. I do intend however, to work in Ireland.

OBVECTIVES:

2.1. To utilize all areas of design/engineering studies during the Industrial Design Course.

2.2. To design a product which will satisfy a social need and will have good commerical potential.

2.3. To demonstrate the advantages of employing an Industrial Designer from the initial stages of a project.

2.4. To demonstrate my ability as a professional Industrial Designer by designing a product to suit a particular company, BIO-MEDICAL RESEARCH LIMITED, SHANNON.

INTRODUCTION:

3.1. At present BIO-MEDICAL RESEARCH (B.M.R.) manufacture a number of "Slendertone" units based on electronic muscle stimulation. These are designed for cosmetic purposes during slimming programmes.

Recently B.M.R. has developed a new unit which is aimed at the medical market. This unit which is an adaptation of the "Slendertone" signal is designed to stop Deep Vein Thrombosis during operations.

3.2. In the area of physiotherapy there exists a potential for developing a new electronic and nerve stimulator.

In designing this new equipment the following factors will be considered:

3.3. Interfacing to patient.

3.4. Redesign of housing and control panel to suit hospital/physiotherapy needs.

3.5. Adaptation of "Slendertone" signal to the particular needs of physiotherapy.

3.6. Possible additions to the equipment to suit the market.

PROCEDURES AND TIMETABLE

STAGE 1 - RESEARCH

MARKET RESEARCH: Evaluation of data received from questionnaire and research into possible auxiliary segments of the main market.

DATA COLLECTION: Visits to the two main schools of physiotherapy in Dublin at James Street and the Mater Hospital.

DATA COLLECTION (MEDICAL): Research into the various muscle groups and the best points for the electrodes. (This research to include areas not covered by general "Slendertone" treatment such as hands, feet etc).

DATA COLLECTION (MEDICAL): Research into the various techniques used in physiotherapy (especially electrotherapy).

STAGE 2 - CONCEPTUAL STAGE

This stage is self-explanatory and consists of sketches and rough models of various ideas which may have resulted at the research stage.

CONCEPT REFINEMENT STAGE: At this point the various ideas are classified and the best ones are choosen to refine. This is the mid-way stage in the project and a reasonable concept of the finished product should be emerging.

BREAD-BOARDING AND INITIAL MOCK-UPS: A good deal of this stage will be spent in B.M.R., since this is when modification in the electronics will be needed. This work will be done in conjunction with the mock-ups of the final concept.

STAGE 3 - DETAIL DESIGN AND FINAL PROTOTYPE

The prototype stage will be spent mostly in the Industrial Design Department, Dublin. The final electronic stage will be completed in B.M.R. with N.I.H.E. co-operation.

STAGE 4 - PRESENTATION

This final stage of the project consists of:-

- Design Report
- Data Collection
- Engineering Drawings: Detailed sets of engineering drawings of the casing and related components.

- Completed Prototype
- Presentation Drawings

4.2 TIMETABLE

November	1980	Stage 1
December	1980	Stage 2
January	1981	Stage 2
February	1981	Stage 2
March	1981	Stage 2/3
April	1981	Stage 3/4
May	1981	Stage 4

STAGE 5 - TUTORS/COUNSELLORS

- Professor M Ozmin

SECTION 1.2 INTRODUCTION

ELECTROTHERAPY

Electrotherapy is a part of physiotherapy and denotes the treatment of disease and disability by electrical means. This project is primarily concerned with muscle and nerve stimulating currents, (although there are other modes of treatment used in electrotherapy, such as micro-wave, diathermy (heat treatment), U.V. light, ultrasonics and others).

Electrical stimulation involves an electronic unit which generates a series of pulses which are designed to artificially stimulate either muscles or nerves. These pulses are interfaced to the patient via conductive pads and leads. Its therapeutic uses include:-

(a) Re-education of muscle action after damage.
(b) Exercising muscles which would be too painful to exercise by normal means.
(c) Educating muscles which have been transplanted.

The content of this report is arranged in a systematic and chronological order which relates directly to the sequence taken during this project. Although there are a large number of technical terms included in this report, it is felt they have been adequately explained to be understood without the addition of a glossary.

SECTION 1.3 HOW PRESENT 'SLENDERTONE' UNITS OPERATE

At this introductory stage of the report, it would be helpful to become familiar with what is involved in a 'Slendertone' unit.

The 'Slendertone' units are electronic muscle stimulators which tone the muscles for body fitness and figure control. They are designed to produce an electronic signal which is transmitted to the desired areas of the body via pads and leads.

Any one of the units may be broken down into four main parts:-

(1) Printed circuit board. Here current is applied to the board which is designed to produce the desired output signal.

(2) The desired signal having been produced is then fed into the transformer where the voltage is boosted to the desired output level.

(3) This signal is then fed to the output sockets and controlled by the variable potientiometers which vary the voltage from zero to maximum, (as defined by the output transformer).

(4) This signal is then transmitted from the output sockets to the mucles of the body via leads and muscle pads.

SECTION II

MARKET RESEARCH

SECTION 2.1 MARKET RESEARCH

Before the project could be undertaken on a commerical basis it was necessary to see if a market actually existed for a new unit, and if so what was the extent of it.

The first step was to find out the number of Physiotherapists registered in the U.K. (The United Kingdon was choosen as the biggest and most similiar to the home market). The size of the potential market was obtained from THE PHYSIOTHERAPISTS REGISTER 1980; which contains a list of approximately 16,000 practising Physiotherapists in the U.K. and Northern Ireland.

A questionnaire was complied (see appendix) to assess the scope of this market and whether the area of muscle stimulation was in need of development. When this was completed a random sample of 250 Physiotherapists (one from each page) was selected from the register, and a questionnaire was sent to each.

The following pages contain a graphic representation of the information derived from the questionnaires.

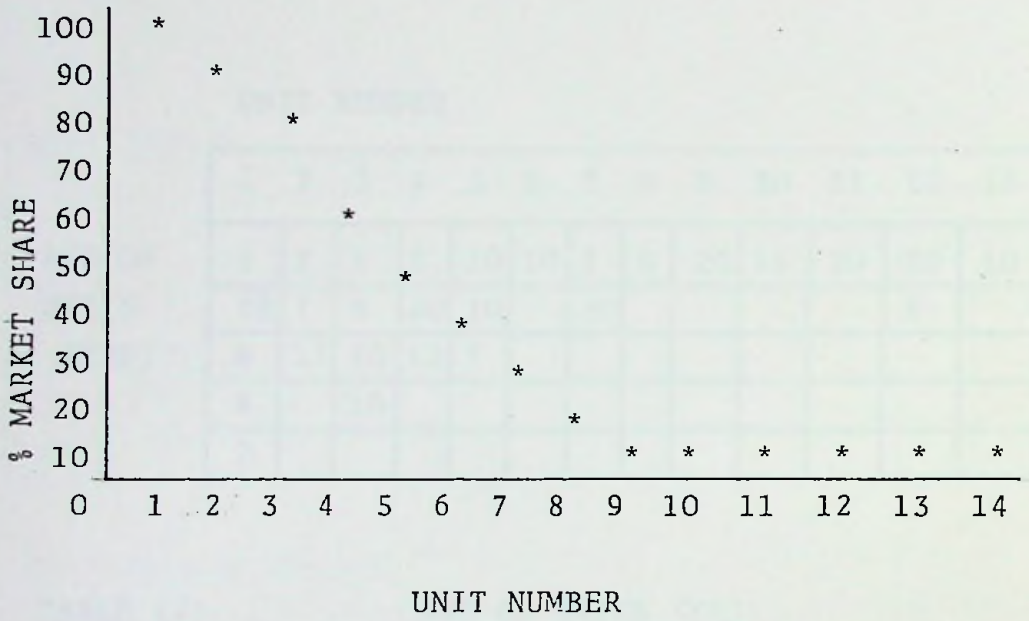


fig 1 - MARKET DISTRIBUTION

UNIT	PRODUCT NAME	UNIT	PRODUCT NAME
1	MINIDYNE	8	RANK UNIVERSETTE MK 2
2	SELECTED TREATMENT UNIT	9	PROGRESSIVE TREATMENT UNIT
3	MEMCO PROGRESSIVE TREATMENT UNIT	10	SUPER UNIVERSETTE
4	TRIODYNE MK 3	11	SMART BRISTOW FARADIC BATTERY
5	MYODYNE MK 2	12	NEUROTONE PMS
6	RANK UNIVERSETTE MK 3	13	R.S.C. MK 4
7	SUPER TRIODYNE	14	MEMCO PULSE STIMULATOR

TABLE (1) UNIT IDENTIFICATION

UNIT NUMBER

AGE OF UNITS (YRS)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	3	2	5	5	10	10	5	6	20	15	20	20	10	10
	10	7	6	20	10		10					6		
	6	17	10	12	7									
	8		10											
	7													

TABLE (2) AGE OF UNITS (YRS)

Table (2) shows the distribution of the ages of the units received from the questionnaires. Of the seventy replies received only 29 had actually filled in this section of the questionnaire; it is felt however, that even with this small sample size the results are a reasonable representation of the overall trend. A breakdown of table (2) gave the following results:

$$\text{Average age of units} = \frac{\text{AGE (YRS)}}{\text{No of units}} = 10.24 \text{ yrs}$$

Newest Unit - 2 Years Old
Oldest Unit - 20 Years Old

UNIT NUMBER

1	2	3	4	5	6	7	8	9	10	11	12	13	14
**	***	**	****	***	**	***	**	**	*	***	***	**	**
**	**	***	***	***		**				**	**		
***	***	***	***	**									
***	**	**	**	**									
**													

Performance Rating

**** Very Good *** Good ** Fair *Poor

TABLE (3) PERFORMANCE OF UNITS

COST: The average cost of the units worked out at £278.88, the cheapest being No 1 at £70 and the most expensive No 13 at £450.

COMMENTS: A section of the questionnaire asked the reader to give comments on the equipment in his or her possession. The following are examples of some of the more constructive comments:-

(a) "More bulky and heavy than they need to be.... ....., a lack of competition in this field."

(b) "Disadvantages of some machines are that Faradism cannot be given to two legs or arms at once".

(c) "The unit has two output channels, this we find very useful. The control knobs have a tendency to come off which we find very frustrating".

(d) "Multi-treatment units give direct, interrupted sinusoidal and Faradic currents. The units are good, but the attachments poor. Better attachments to terminals could be made and ready made pads of different sizes to attach electrodes to patient".

(e) "A Rank Stanly Cox MK4 has been recently purchased and is in regular use for muscle stimulation, but cannot be used for assessing nerve damage etc....".

The following statements from the questionnaires reinforce comments which have subsequently been obtained from various Physiotherapists. The purpose of these visits were to find out as much about electrotherapy as possible and its various modes of treatment and the equipment employed. These were critically examined to see where improvements could be achieved. The following list serves as a rough guideline for subsequent development:-

(a) Improving overall aesthetics of unit.
(b) Reducing size of unit to make it more portable and easier to store.
(c) Improving function and readability of control panel.
(d) Improving electrode attachments and leads.
(e) Providing storage space for attachments.

SECTION III

MEDICAL DATA

SECTION 3.1

From reading texts on the subject and from consultations with Phyiotherapists, the following current outputs were decided upon as being the most useful for a multi-treatment unit. Before a draft electrical specification for the new unit was drawn up, further literature searching into the Physiological effects of the different outputs was undertaken.

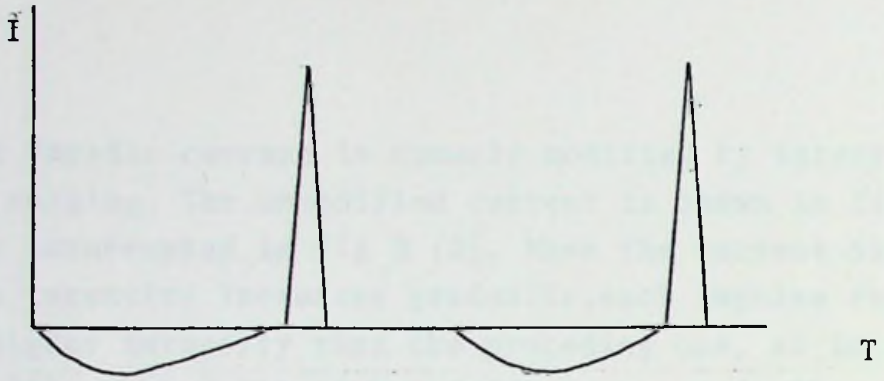
(Several other types of current and treatments were investigated; such as high-frequency currents, diadynamic currents and TENS (Trancuteneous Electrical nerve stimulation.) For the sake of clarity, only the currents that were extensively researched will be included in the report.)

There are basically three types of current commonly used in electrotherapy - thses are:-

(a) Faradic Current
(b) Galvanic (D.C.) Current
(c) Sinusoidal Current

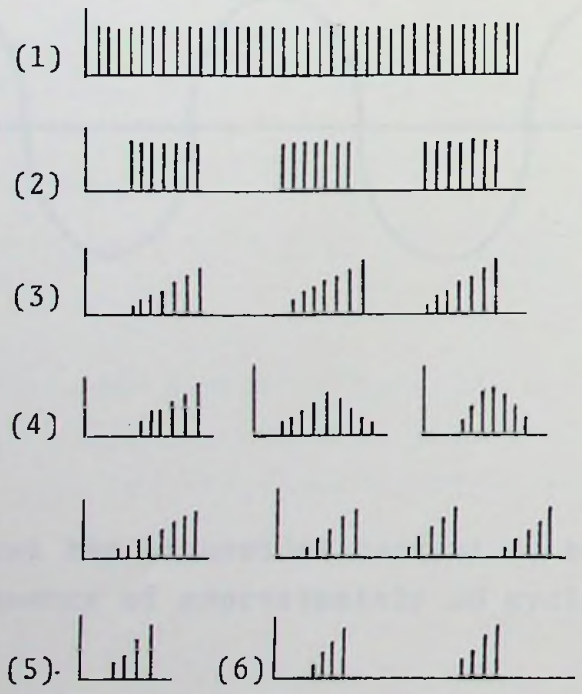
(a) FARADIC CURRENT

The term Faradism was originally used to signify the type of current produced by a faradic coil, which is a type of induction coil.



(fig 2.) ORIGINAL FARADIC CURRENT

Fig 2 shows the original faradic current which was an unevenly alternating current with two unequal phases; the first of low intensity and long duration and the second fo high intensity and short duration. The frequency was approximately 50 cycles/Second, and the duration of the second phases which was the effective one, about 1 millisecond. Faradic coils have now been superseded by electric stimulators which produce pulses of a similiar duration to the old Faradic currents and are therefore still called Faradic, although this is not strictly true.



The Faradic current is commoly modified by interrupting or surging. The unmodified current is shown in fig 2 (1). The interrupted in fig 3 (2). When the current is surged the intensity increases gradually,each impulse reaching a higher intensity than the preceding one, as in fig 3(3) to (6), then falls either suddenly or gradually. The curcuit can be modified to give surges of various durations (fig /(5)) frequencies (fig 3(6)) and wave forms (fig 3 (4)).

SECTION 3.2 SINUSOIDAL CURRENT

The sinusoidal current is an evenly alternating low frequency current .

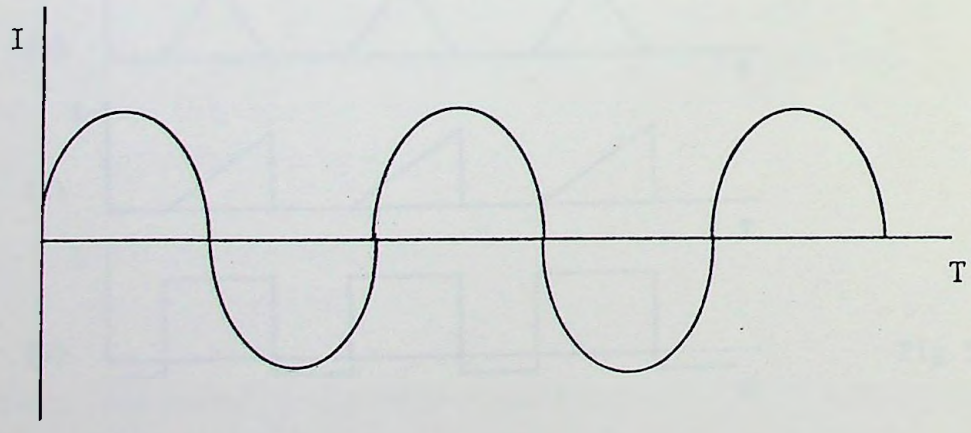


Fig (4) shows the sinusoidal current to be a sine curve with a frequency of approximately 50 cycles / Second.

SECTION 3.3 DIRECT CURRENT (GALVANIC)

Galvanic current can be similiar in form to Faradic, however, the range of durations are much different, ranging from 0.01 millisecond to 3 seconds. Constant D.C. is rarely used for treatment purposes, however, modified waveforms are in constant use.

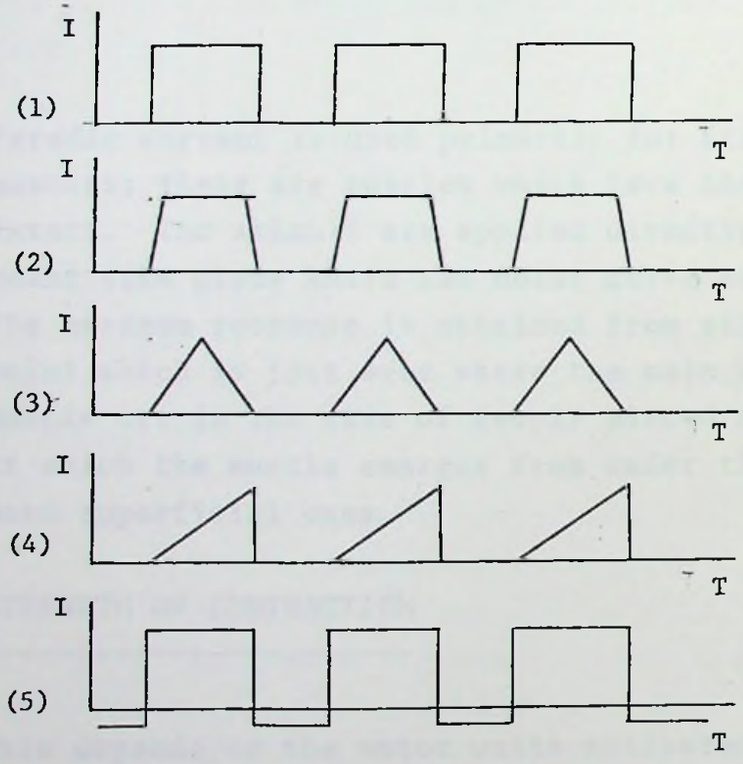


Fig 5.

Fig (5) shows the different forms of modification applied to Galvanic currents. In each case the important factor is the time needed for the current to reach its maximum

intensity, as this effects the response obtained when the current is applied to the body. Impulses with a gradual rise in intensity are ofer termed selective (the reason for this term is given in the following section on physiological effects.)

SECTION 3.4 PHYSIOLOGICAL EFFECTS OF FARADIC CURRENT

Faradic current is used primarily for stimulating innervated muscles; these are muscles which have their nerve supply intact. The stimuli are applied directly to the motor point (the place where the motor nerve enters the muscles). The maximum response is obtained from stimulation at this point which is just over where the main nerve enters the muscle or, in the case of deeply placed muscles, the point at which the muscle emerges from under the cover of the more superficial ones.

STRENGTH OF CONTRACTION

This depends on the motor units activated, which depends on the intensity of current applied; and on certain other factors which will now be considered.

RATE OF CHANGE OF CURRENT

A current, when raised suddenly in intensity is found to be more effective in producing a contraction of innervated muscles than one which charges gradually. The reason for this is with a gradually charging current the nerve adapts itself to the different conditions. This process of accomodation means that the potential difference resulting from current flow no longer affects the excitability of the nerve fibre which has adapted itself to the changing conditions.

THERAPEUTIC USES

The Faradic current is used to excercise muscles which have a normal nerve supply. The three main areas it is used in electrotherapy are: (a) painful conditions, (b) re-education of muscle action, and (c) education of new muscle action.

(a) PAINFUL CONDITIONS: This section is largely self-explanatory and refers to cases where movement is retarded by pain. Faradism is applied to reduce degeneration and wasting of the muscles.

(b) RE-EDUCATION OF OLD MUSCLE ACTION: This treatment is used when muscles are damaged and have not been exercised. In such a case the patient may have forgotton how to send voluntary impulses to the muscles. Faradic treatment can be used to demonstrate normality, produce the feeling associated with contraction and to re-educate the patient in how to re-establish voluntary contractions.

(c) EDUCATION OF NEW MUSCLE ACTION: The Faradic current is used to a lesser extent to train a muscle which has been transplanted. Sometimes this involves training a muscle in a new muscle action; probably one which opposes the original movement which the muscle performed. This process will obviously take longer and be much less effective than that of re-established it's normal function.

SECTION 3.5 SINUSOIDAL CURRENT

Physiological effects and therapeutic uses:-

3.5.1. - STIMULATION OF SENSORY NERVES:

When a sinusoidal current is applied, a marked prickling sensation is experienced on the skin. This is due to stimulation of the sensory nerves and is more marked than that produced by the Faradic type of current as the stimuli are of longer duration. Due to this stimulation of the superficial nerve endings, there is appreciable vasodilation and reddening of the skin, and it is assumed there is an increased blood flow through the underlaying tissues.

3.5.2. - STIMULATION OF MOTOR NERVES:

The sinusoidal current stimulates the motor nerves and provided it is of sufficient intensity, causes contraction of the muscles they supply. Owing to the marked sensory stimulation, the current is not as comfortable as the Faradic type. Also when applied locally, it is not always possible to tolerate a great enough intensity to produce a muscle contraction.

3.5.3. - EFFECTS OF MUSCLE CONTRACTION:

These are the same as the effects of the muscle contractions produced by the Faradic current.

3.5.4. - EFFECTS OF DENERVATED MUSCLE:

It is possible to obtain a contraction of denervated muscle with sinusoidal current, but the intensity required would be too uncomfortable for treatment.

3.5.5. - THERAPEUTIC USES:

The therapeutic uses of sinusoidal current is identical to those already discussed for Faradic treatment.

SECTION 3.6 GALVANIC (DIRECT CURRENT)

The interrupted D.C. is used for two purposes in the Physiotherapy department:-

(a) The stimulation of Denervated muscles
(b) Plotting of a strength/duration curve

3.6.1. - (a) THE STIMULATION OF DENERVATED MUSCLES

When the nerve supply to a muscle is damaged it is incapable of being contracted by Faradic or Sinusoidal currents; since these act on the motor points of the muscles. Interrupted direct current stimulates the muscle fibres directly and is capable of producing contractions of denervated muscle provided that the intensity of current and duration of impluses are adequate.

The contractions are sluggish in nature, the contraction and relaxation being slower then when the motor nerve is stimulated. As denervated tissue has not the same property of accomodation as the motor nerves, a current that raises fairly slowly in intensity is as effective as one which raises suddenly. With the slowly rising current a contraction of denervated muscle can often be produced with an intensity of current which is insufficient to stimulate the motor nerves; for this

reason these impulses are often termed selective. An impulse with a duration of 100 milliseconds is the shortest that is generally considered satisfactory for the treatment of denervated muscle, and it is often necessary to increase this in order to eliminate contraction of in-nervated muscle.

3.6.2. - (b) STRENGTH-DURATION CURVE

The plotting of a strength-duration curve is at present the most satisfactory method available for testing electrical reaction and degrees of nerve damage.

The apparatus (or portion of circuit in multi-treatment units) supplies rectangular impulses at different durations. Impulses of durations of 0.01, 0.03, 0.01, 0.3, 1, 3, 10, 30 and 100 milliseconds are required. Constant voltage or constant current may be used, these differences will be discussed later in this section.

PROCEDURE:

A small active electrode is used in order to isolate the muscles from each other. Current is applied using the longest stimulus first (100 msec), and increased until a minimal contraction is obtained. This may be assessed visually or by feeling the muscles being tested. The intensity of the current (or voltage) is noted and the duration of the impluses is shortened to the next increment.

This procedure is repeated with each duration in turn. The intensity of current being increased as required, to produce the same minimal contraction. A minimal contraction is used, as this makes it easy to detect any change in strength; it is important that the active electrode is held in the same point over the muscle through out the test.

With the duration of stimulus and its corresponding intensity noted for each increment, an intensity/time curve can be plotted for the results of the test.

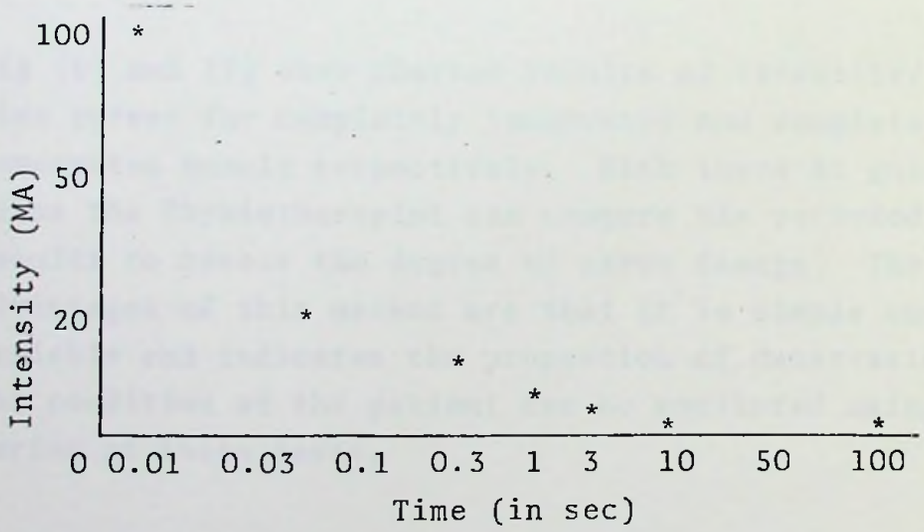


fig (6) INTENSITY/TIME CURVE OF NORMAL INNERVATED MUSCLE

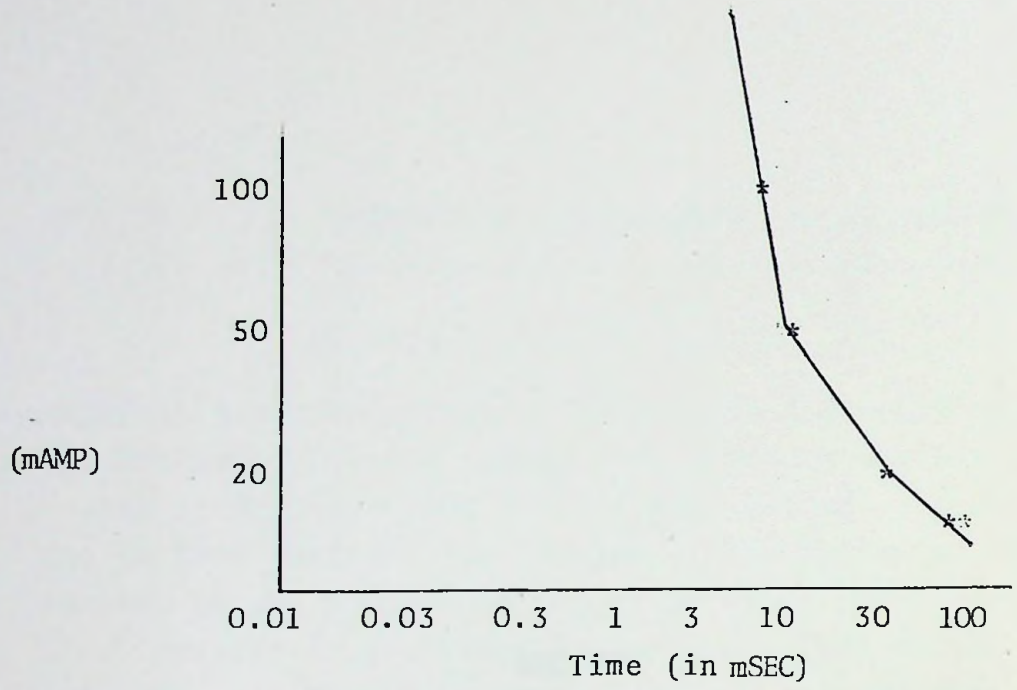


fig (7) INTENSITY TIME CURVE OF COMPLETE DENERVATED MUSCLE

Fig (6) and (7) show charted results of intensity/ time curves for completely innervated and completely denervated muscle respectively. With these as guide-lines the Physiotherapist can compare his recorded results to assess the degree of nerve damage. The advantages of this method are that it is simple and reliable and indicates the proportion of denervation. The condition of the patient can be monitored using a series of these tests.

SECTION IV

ELECTRICAL SPECIFICATION

SECTION 4.1 ELECTRICAL PROFORMANCE SPECIFICATION

Using information extracted from books and publications and discussing various ideas with Physiotherapists, an output proformance spec for the new unit was compiled. Due to time restrictions imposed by the author on this section of the project, a number of other possible electrical outputs (e.g. Transcutamous Electrical Nerve Stimulation), had to be shelved due to insufficient information.

The procedure for choosing the outputs was to establish which were the most commonly used, and to discuss with Physiotherapists the number of parameters, and their degree of variability.

SECTION 4.2 ELECTRICAL SPECIFICATION

What follows is the electrical spec for the unit. To aid clarity the reasons for choosing the various outputs will be given at the end of the section.

GALVANIC (D.C.) OUTPUT

(a) Output required for plotting of strength/duration curve:-

PULSE SHAPE:	Rectangular
PULSE DURATION:	100, 30, 10, 3, 1, 0.3, 0.1 and 0.03 milliseconds
INTENSITY RANGE:	0-20 MA

(b) Stimulation of Denervated Muscle:-

PULSE SHAPE:	Rectangular and Triangular
PULSE DURATIONS:	1,000, 600, 300, 100, 30 and 10 milliseconds

FARADIC CURRENT

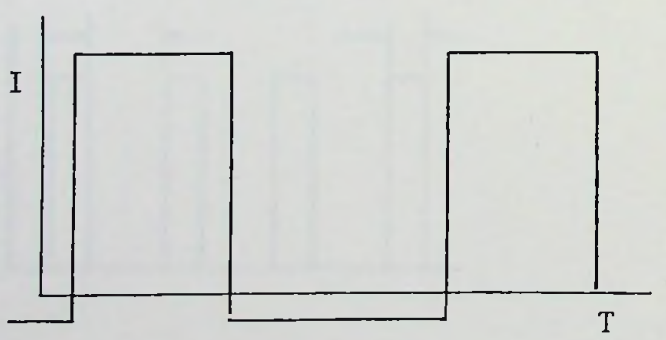


Fig 8

FARADIC CURRENT

(d)

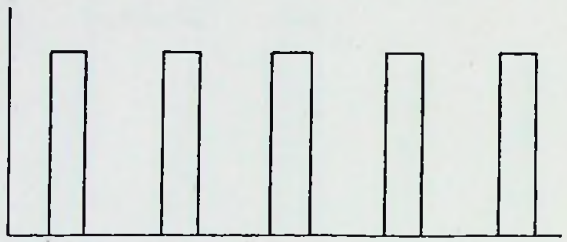


Fig 9

CONTINUOUS FARADIC CURRENT

Output consists of 1 millisecond pulses repeated 50 times/Sec to give a continuous smooth contraction of the muscle.

(e)

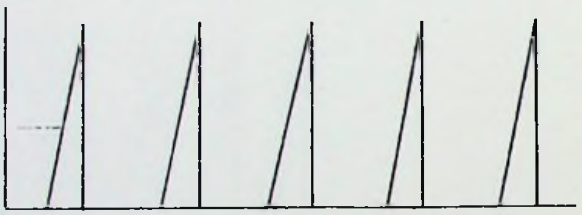


Fig 10

CONTINUOUS PROGRESSIVE FARADIC

Automatic duration of pulse is 1 millisecond repeated 50 times/Sec.

(f)

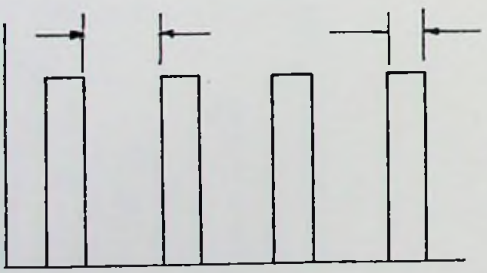
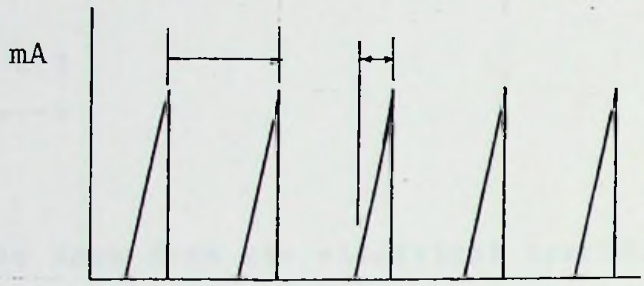


Fig 11

VARIABLES: Pulse Duration
Pulse Interval

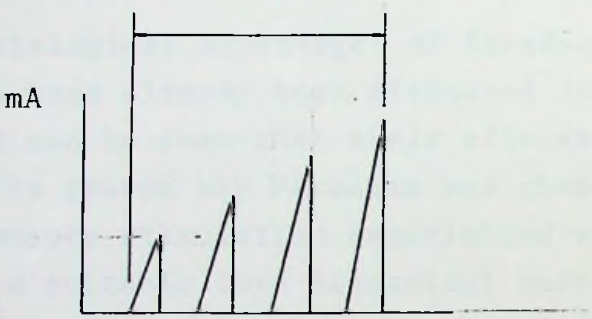
(g)



VARIABLES: Same as (f)

T Fig 12

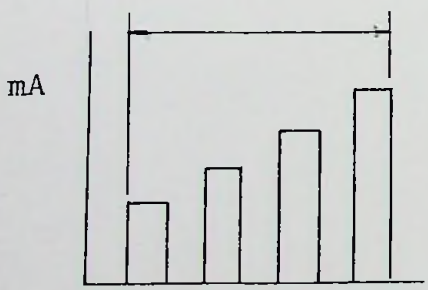
(h)



T Fig 13

SURGED PROGRESSIVE FARADIC

(i)



T Fig 14

SURGED FARADIC

SECTION 4.3

It can be seen from the electrical specification that Galvanic and Faradic currents were choosen for the unit. The reasons for choosing Galvanic is it's ability to stimulate damaged muscles and assess nerve damage during muscle testing.

The physiological advantages of Faradic and Sinusoidal currents have already been discussed in Section (3); from which it can be seen that their effects are almost identical. The reason why Faradism was choosen is that the small sensory stimulation experienced with it, makes it much more suitable than Sinusoidal current for localised muscle stimulation.

SECTION V

DESIGN OF UNIT AND ACCESSORIES

SECTION 5.1 UNIT DESIGN

The criteria for assessing the overall form of the instrument casing were as follows:-

(a) It must be as small and portable as possible.
(b) It must convey a scientific/electronic look.

The problems associated with the units on the market at the moment should be taken in a broader context than problems with just the housing for the electrodes. Treating the unit very generally as an intergrated piece, (e.g. - instrument, electrodes, leads etc), the problems encountered were:-

(1) Lack of general storage space for unit and accessories.
(2) Units made very heavy and mechanical looking.
(3) Units rendered non-portable by point 2 above and by the fact that no storage for accessories is available.

From these broad criteria and problem identification, it is clear that there is a wide variety of options still open for designing the instrument casing. Some examples of the various designs considered can be seen in the following sketch pages (the remainder of the sketches are available in the sketch book).

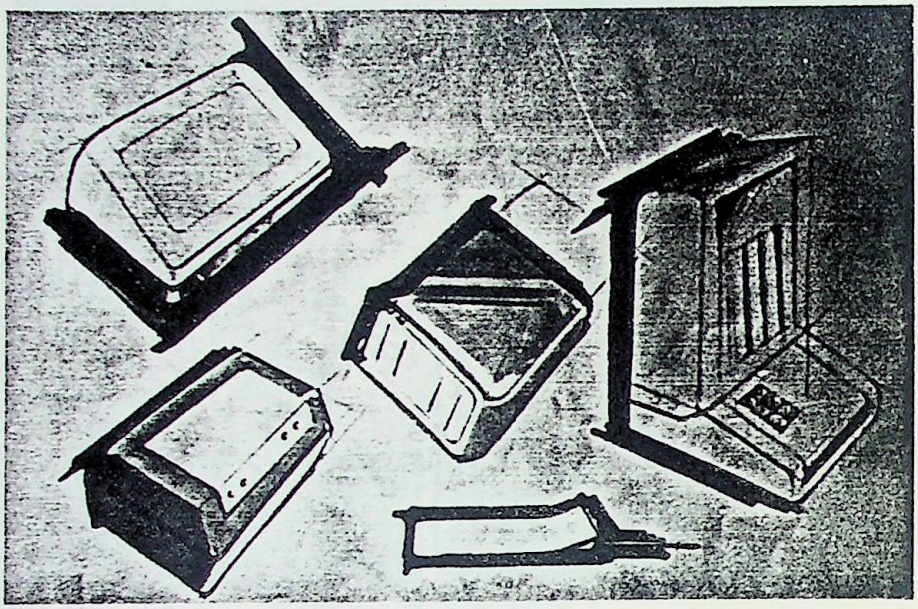


Fig 15.

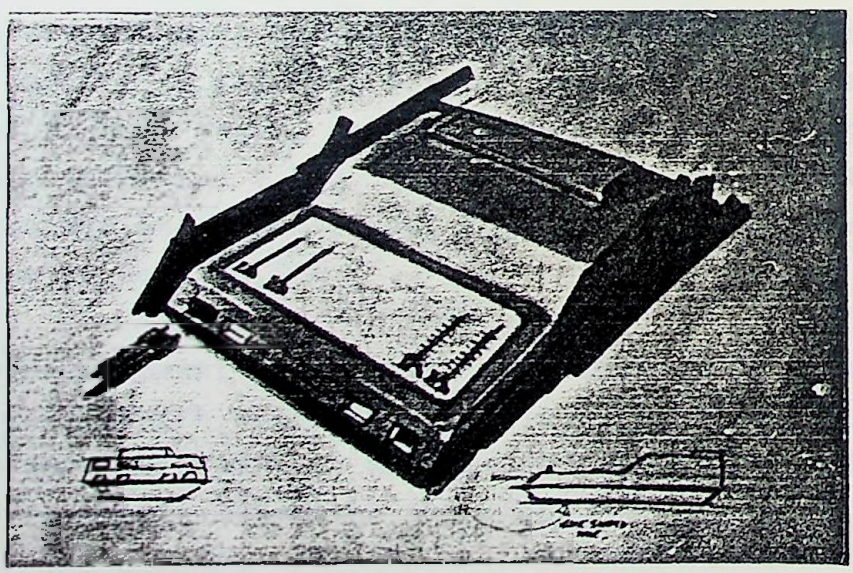


Fig 16.

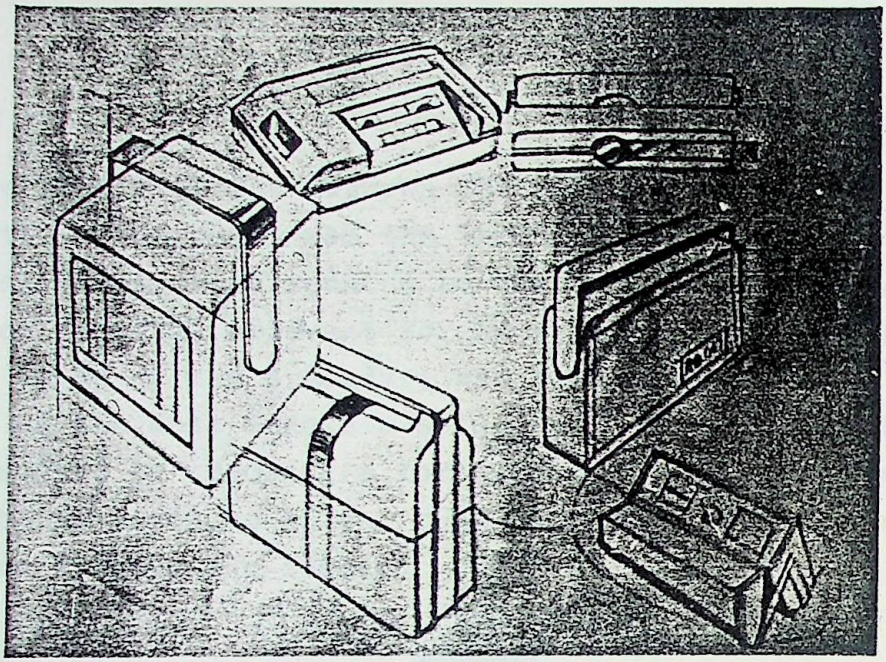


Fig 17

No attempt will be made to explain all the ideas considered, it should suffice to say that after a brainstorming for the various solutions, ranging from a hand-held single output unit to calculator and V.D.U. type cabinets, the most technically feasible and aestheticaly acceptable solutions were choosen to develop.

After this development stage there was still quite a large number of units which would be suitable, therefore, to make the choice more objective it was decided to use the internal components to partly determine the shape.

For this purpose a number of mock-ups of the components were cut and re-arranged in different orders (see contact sheets in appendix). When each skeleton was established they were wrapped in tin foil to give an impression of the overall form.

It can be seen from the figures that the most dominent feature of the arrangement was the three 6V re-chargeable batteries, (these were reduced to one at a later stage, but the method is still relevant for determining the shape). The next stage of the procedure was to make polystrene mock-ups of the most feasible solutions. An evaluation of these resulted in choosing a form with a flat control panel and the battery placed at the rear to give a tilt for ease of viewing display and legends - (see fig 18)

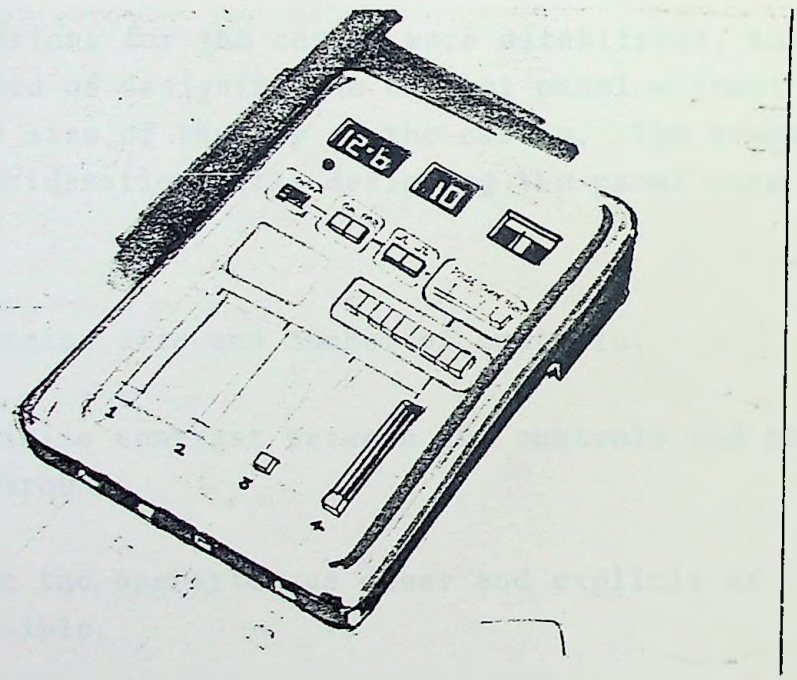


Fig 18.

The undercut in the base which is parallel to the top panel also provides a useful lifting recess.

SECTION 5.2 CONTROL PANEL

OVERALL FORM AND SHAPE

Once the dimensions for the casing were established, the problem remained of designing the control panel without increasing the size of the top of the casing. The areas taken into consideration while designing the panel were as follows:-

(a) Minimize size and number of controls.

(b) Maximize contrast between the controls and the backround.

(c) Make the operation as clear and explicit as possible.

(d) Relate size and placement of controls to frequency of use.

(e) Examine different possibilities for controls with regard to function and aesthetics.

The elements to be placed on the control panel are as follows:-

(1) Indicator for reading current (I/T Cruve).

(2) Treatment timer.

(3) Treatment timer re-set.

(4) Battery level indicator.

(5) Mains ON/OFF.

(6) Current (Galvanic/Faradic).

(7) Pulse type select.

(8) Pulse shape selector.

(9) Pulse durations.

(10) Pulse intervals.

(11) Current intensity controls.

Before designing the layout of the controls, the various options of form, dimension and colour for each was considered. The most important are listed as follows:-

5.2.1. TREATMENT TIMER

There are four basic options for current indicators on a control panel. These are (a) A Moving Coil Meter, (b) Bar Meter, (c) L E D Display, (d) L C D Display.

(a) MOVING COIL METER

The disadvantage of these are that after contacting a number of manufacturers, the smallest size which could be obtained was (45mm x 45mm). This was much too large for the size of panel considered. The overall shape of these meters did not suit the overall medical-scientific look which the author considered would suit the type of instrument. There is also the disadvantage that the character and markings are difficult to read when any distance is involved. Their advantage is that they are quite cheap and easy to connect.

(b) BAR METER

Bar meters can be obtained in samller dimensions than moving coil meters. However, when accurate readings are held (as in I/T testing), the legibility is very poor.

(c) L E D DISPLAY (LIGHT EMITTING DIODE)

The main advantage of numerical type of display is that it reduces risk of inaccurate readings. It is also moving more towards a modern scientific type of display. However, since the instrument is battery operated, there would be a considerable power drain from the illuminated type.

(d) L C D DISPLAY (LIQUID CRYSTAL DISPLAY)

The L C D indicator has all the advantages of (c) above, but with this type of display the power drain on the battery is considerably reduced.

5.2.2. SWITCHES

The switches choosen for the control panel must satisfy the following conditions:-

(a) Each switch must take up an area no larger than 10mm x 10mm on the panel.

(b) The depth of the switch, also height above panel must be optimised.

(c) When activated, it must show a position which is different to it's normal position.

Taking these factors into consideration, there are a number of switches which could satisfy the criteria. These included toggle switches, latching, push-button switches, momentary action push-button switches with seperate indicator lamp or illuminated switches. It was decided that since the panel had to retain a flat appearance, sub-miniature illuminated push-buttons were used because these gave the required action with only a protrusion of 4 mm above the panel surface.

5.2.3. INTENSITY CONTROLS

The intensity controls, potentiometers (pots), vary the intensity of current delivered at the outputs. This control is adjusted by the Physiotherapist and it's optimum level is usually as high as the patient can stand. In other words, the intensity level is increased and decreased under verbal command from the patient until the optimum level is reached. Therefore, the levels of operation occur over a range of values and not as one discrete one. It follows that pin-point accuracy, or very fine control is not needed here, so slider pots were choosen as opposed to the rotary or thumb wheel versions.

The other reason for choosing sliders was that they gave a direct linear relationship between the upward sliding motion of the pots and an increase in intensity; their shape and action were also more compatable with the form design choosen for the casing.

The rest of the controls on/off switch, battery-meter etc, were choosen using the same process, and to be compatable with the controls already mentioned.

5.2.4. CONTROL PANEL LAYOUT

With the elements for the panel choosen, it was important that they were laid out in as simple and concise a manner as possible. Because of the number of similiar switches on the panel it was important that these should be grouped somehow, so they are easy to scan. Various means can be used for the grouping, such as collecting them closer together or differentiating them by groups e.g. each group having it's own colour.

Grouping is also possible by dividing the area of the control panel into different sections with the aid of lines or colours (or a combination of both). It was decided that as many of these as possible would be used without increasing the potential manufacturers costs.

The elements which belonged in a functional unit were gathered together into one group. This was accomplished by placing the elements in the individual functional groups closely together, by making them similiar in form and colour and by dividing the panel into sections indicated by lines and one tone of gray.

When this was completed an operationally determined 'flowchart' layout of the control panel was used. With this type of layout there is zero-learning time between the actual treatment of the patient and understanding of the control panel.

SECTION 5.3 HANDLE EXPERIMENT

INTRODUCTION

From the data collected from Physiotherapists it was decided that two accessory electrodes would be made available with the unit; these were a roller and a point contact electrode. The roller is used to stimulate groups of muscles which are too closely packed to be stimulated seperately by pads, (e.g. some of the muscles of the back). The point contact electrode is used to locate motor points during the I/T test, (see section 3.6.2 (b)).

5.3.1. PURPOSE

The purpose of this experiment was to establish the most suitable length/ø to use for the handle of the point contact and roller electrode.

5.3.2. EQUIPMENT

The basic equipment for this experiment were wooden dowels cut to different diameters and lengths. Mild steel rods and smaller dowels were attached to these to stimulate roller electrodes. (see fig 19)

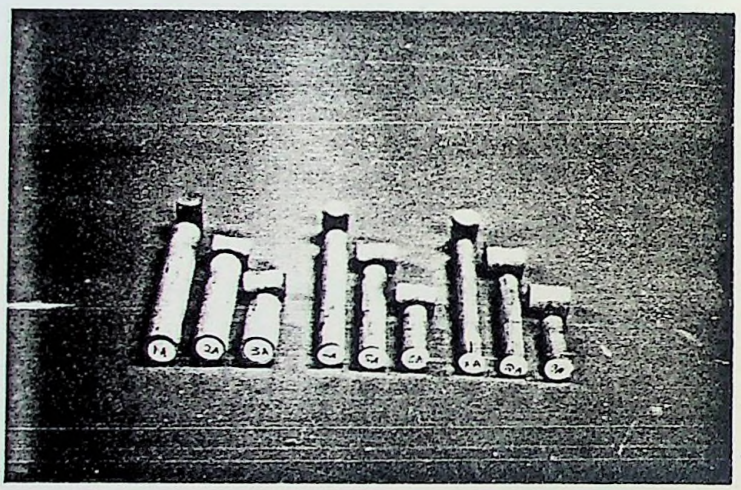


Fig 19.

The same handle and shaft, without the roller connection was used as an approximation to the point conduct electrode (see fig 20).

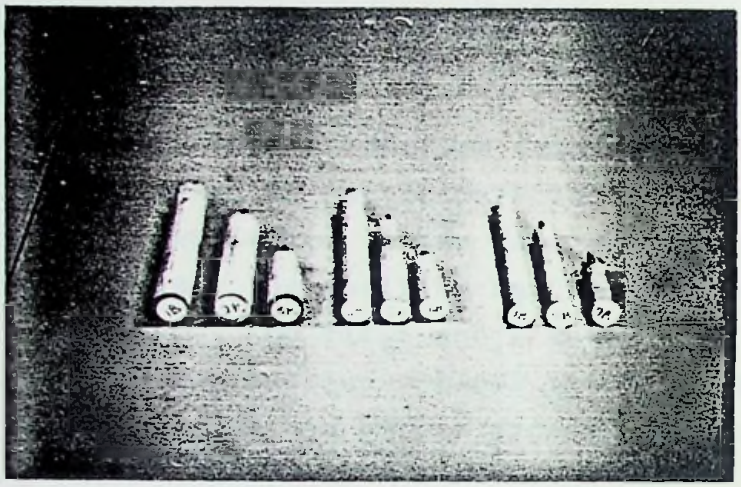


Fig 20.

5.3.3. PROCEDURE

As can be seen from fig 19 and fig 20 each handle was given an appropriate code for ease of identification during the experiment.

PART I

Four randomly choosen volunteers (two male and two female), were asked to partisipate in the experiment. A male subject was asked to lie face downwards on a table to stimulate the position and height used in actual treatment. The first subject was then asked to use each of the mock-up rollers in an up-and-down motion on the muscles on either side of the back. (See fig 21).

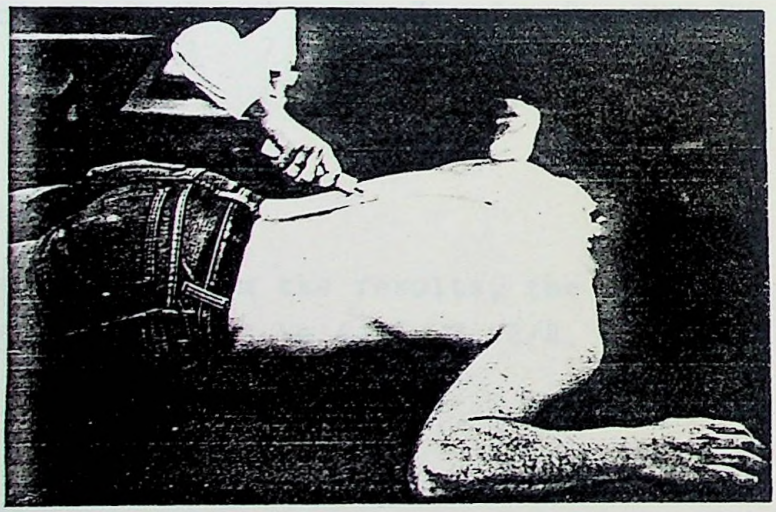


Fig 21

Each handle size was tested over the area for a number of minutes and the volunteer was asked to grade the handles from 1 - 9 with respect to comfort and ease of use. This process was repeated with each of the four subjects and the results of these finds are shown in table 4.

Roller Number		1	2	3	4	5	6	7	8	9
length (mm)		140	100	50	140	100	50	140	100	150
diameter (mm)		23	23	23	18	18	18	15	15	15
Preferances	A	7	4	5	8	2	1	9	3	6
Subject	B	2	1	5	4	7	8	9	6	3
	C	4	7	5	8	1	2	3	6	9
	D	4	5	8	7	2	1	3	6	9

Table 4.

It can be seen from the results, the order of preferance was as follows No 4, 5, 7, 2/8, 1, 3, 9, 6.

PART II

Using the same subjects a similiar type of procedure was adapted for the point contact electrode. The subjects

were asked to plot in a pre-determined sequence, a number of stickers which were placed on the volunteer's back (in the approximate location of motor nerves). (See fig 22).

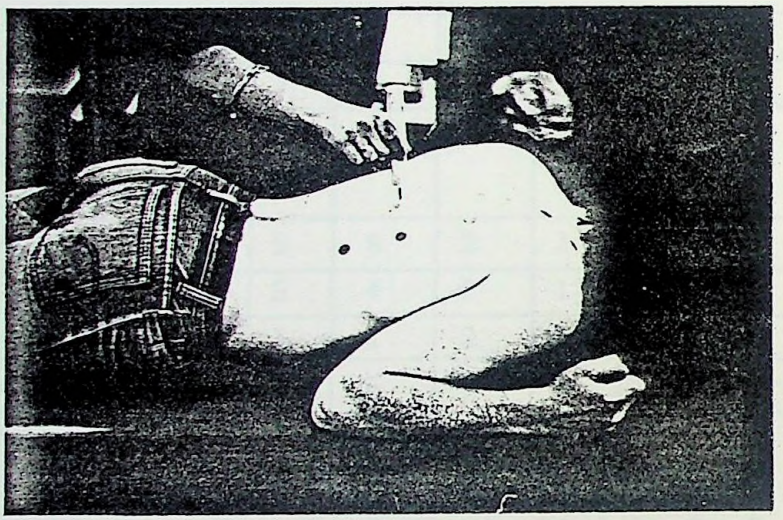


Fig 22.

This process was repeated and timed for the four subjects using each of the nine handles. They were again asked to grade the handles in order of preferance from 1 - 9. The results of these two stages are given in table 5.

Point Contact nos.	1	2	3	4	5	6	7	8	9
length (mm)	140	100	50	140	100	50	140	100	50
dia (mm)	23	23	23	18	18	18	15	15	15
Motor Point test time taken (sec)	6	5	4	5	4	4	4	3	3
	6	6	7	5	4	3	3	3	2
Preferance	7	4	5	8	2	1	6	3	9
	8	7	5	4	2	1	6	3	9
	8	5	7	4	2	1	6	9	3
	7	8	4	5	6	9	2	1	3

Table 5.

Order of preferance No: 7, 8, 5, 4, 2, 6/1, 9, 3.

Comparing the two sets of results gave the following sequence:

No: 7, 4, 5, 8, 1, 6, 9, 3.

The No 7 handle was 140 mm, ø 18
The No 4 handle was 140 mm, ø 15

The handle size which was choosen was 140 mm, ø 16.5

SECTION 5.4 PADS

The conductive pads are used to transmit the pulsed signals to the body. From the electrical spec (Section IV), it can be seen that there are basically two types of output generated. The first being Faradic pulses of duration 0.1 - 1 millisecond and the others being the longer duration Galvanic pulses. Due to the long durations of the latter, there is a danger of chemical burns at the interface, between the pad and the skin. For this reason the pads used for this treatment usually have a thick section of moist sponge under the active area to retard the chemical formations. The Faradic pads were thick sections and made of carbonized rubber.

5.4.1. PROBLEMS ASSOCIATED WITH GALVANIC PADS

1. High moisture content; due to the fact that the sponge section of the pad had to be wet. There was always a lot of water around the unit which could lead to damaged circuitary or corroded contacts.

2. Due to the fact that the pads were moulded with a hollow section to retain the sponge, they did not bend well in all directions (as with solid moulded pads).

5.4.2. OBJECTIVES

To standardise a pad which would be adaptable for both types of treatment.

5.4.3. MATERIAL

The first big area to be considered was the material used for the pads; at present there are two, the carbonized rubber and the sponge.

It was evident that if the pads were to be standarised, one type of meterial would have to be found which could be used for both appliances.

After some research and consultation with the Technical Manager of B.M.R. the material which was choosen to be tested was conductive rubber. The big advantage with this material is that it is available in a foamed section which is capable of replacing the sponge.

After initial testing by Personnel in B.M.R., a full testing programme was undertaken to assess the conductive rubber under full working conditions. The results of this programme have not been established; however, the initial tests were good enough to warrent the author continuning with this material as a feasible possibility.

5.4.4. DESIGN OF PADS

The first criteria to be considered was to establish the critical dimensions of the pads. For this purpose a number of full size drawings (5oth precentile male), were made with approximate sizes and locations of muscles and their motor points - (see figs 23 and 24).

Fig 23.

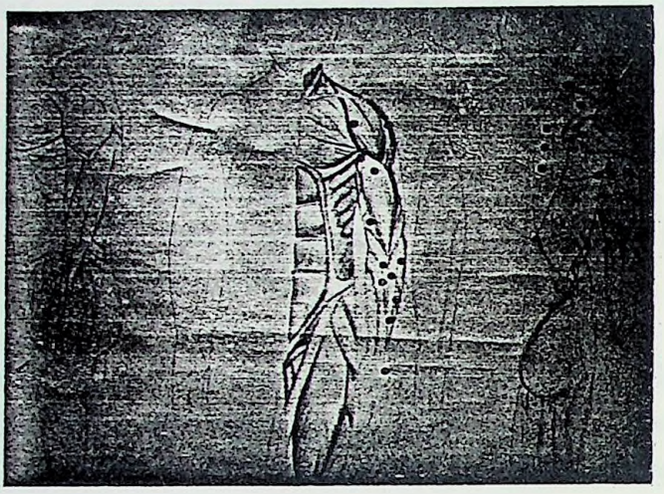


Fig 24.

As previously mentioned in Section 3.1., the Faradic pulses stimulate the motor points, while the longer duration Galvanic pulses stimulate the muscle fibres directly. The locations on the chart were used to establish the average size of pad needed for both treatments. Apart from the obvious functional requirements of the pads, there was a number of desirable features which the design should contain:-

(1) The pads must be as flexiable as possible to maintain good surface contact with the skin.
(2) They should convey a feeling of cleanliness.
(3) The should be as compatable as possible with the unit design and the rest of the accessories.

From the evaluation of sketch sheets for the pads, the form which was decided upon, was a solid moulded rectangular section. The dimensions which were choosen for the pads were (120mm x 180mm). This was a good approximation to the size that would suit most muscles. However, in retrospect it is considered that an additional pad size is needed which is half the dimensions of the above. These pads could be used to stimulate the smaller groups and could be an identical construction to the larger pads.

5.4.5. ATTACHMENT OF PADS

Numerous methods of attaching the pads to the patient were investigated, including adhesive gels, suction, rubber bands, straps etc. However, the most practical solution still remained - straps with 'velcro' at each end.

The construction of the straps was changed from different length sections to a modular length which could be attached together. The straps were also constructed wider than the pads so they would completely envelope them and eliminate any danger of slipping during treatment.

SECTION 5.5 LAYOUT OF COMPONENTS INSIDE UNIT

As previously mentioned in section 5.1., the overall form of the unit was established by considering the different possible layouts of the main components. When this was completed the mounting of the components inside the unit had to be considered. (details of the constructions described below can be found in the engineering drawing at the back of this report).

5.5.1. P C B (PRINTED CIRCUIT BOARD MOUNTINGS)

In order to keep the unit as flat as possible, the components on the control panel are mounted directly on to the top P.C.B. (due to small size of the unit and the complexity of the circuit, two P.C.B!s are needed; one for mounting the hardware and the other for the circuitry).

5.5.2. RECHARGEABLE BATTERY AND OUTPUT SOCKETS

The 'heel' shape at the back of the unit stops any longitudinal movement of the battery; (lateral movement being stopped by the P.C.B.). This means the battery is held in position without the addition of a battery holder.

The four output sockets are placed to one side at the back of the unit, (the reason for this is that they will be out of the operator's way while the equipment is in use). Placing them to one side means that any 'pull' on the unit by the patient will be counteracted by the weight of the battery. Placing the outputs all on one side also means that it is easier for the operator to relate the intensity controls to their corresponding outputs.

5.5.3 FIXING OF TOP AND BOTTOM CASINGS

The top and bottom sections of the casing are held together by retaining screws which are countersunk in the base of the unit. These screws are located on to mounting brackets fixed on the underside of the top panel.

SECTION 5.6 COLOUR

The colours which were choosen for the unit and accessories were used to give an impression of a scientific-medical piece of instrumentation. An attempt has been made to ease away from the monochromatic colour scheme which is used on a great deal of medical instruments. This was achieved by adding blue, (which gives an impression of cleanliness), into some of the accessories. The remainder of the instrument and accessories being polished metal, black and gray.

SECTION VI

MATERIALS AND MANUFACTURING PROCESSES

SECTION 6.1

The choice of materials and manufacturing processes have been an integral part of the design thought, throughout this project; even though they are treated here as a seperate section.

To aid clarity, the different parts of the design have been split-up into sub-sections and the materials and manufacturing processes for each have been considered seperately. It should be noted here that the manufacturing runs for the total package is estimated at between 1,000 and 1,500 per annum, for a period of three years.

SECTION 6.2 UNIT DESIGN

From the proposed production runs and low cost of the unit, it is obvious that processes such as injection moulding which involves a high initial tooling cost are not economically feasible.

From the size and shape of the unit under consideration, (see engineering drawings), the most suitable methods of production are:-

(a) Sheet-metal fabrication

(b) Drawing or pressing

(c) Thermo-forming

6.2.1. (a) SHEET-METAL FABRICATION

Making the unit from sheet-metal could be seen as a feasible solution, however, this method of fabrication does not lend itself very readily to the small dimensions of the unit. There would also be a number of problems associated with fixing, since it is desired that the unit retains as smooth an appearance as possible.

6.2.2. (b) DRAWING OR PRESSING

This method is considered feasible for manufacturing the top panel of the unit. The depth of draw needed for the bottom section would make the tooling costs too high.

6.2.3. (c) THERMO-FORMING

This process is considered the most suitable method of manufacture due to:-

(a) It's suitability for low production runs.

(b) Low initial tooling costs.

(c) Ease of fabrication.

6.2.4. CHOICE OF PROCESS

It was finally decided that to achieve a medical-scientific look, a combination of shallow drawing for the top and a thermo-forming base would be used for the unit. The top control panel to be a shallow drawn metal 'cover' and the unit bottom to be vacuum-formed, each being surrounded by an aluminium extrusion.

6.2.5. VACUUM-FORMING

This process is applied to plastics which have already been made into sheet form. The method discribed below is thought the most suitable for producing the required shape:-

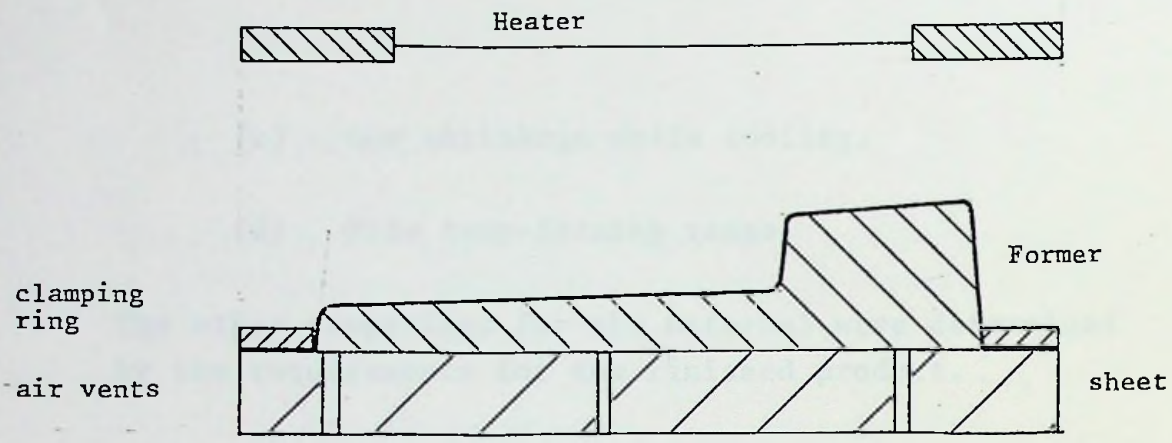


Fig 25.

Fig 25 illustrates the process of vacuum forming. The sheet is heated and drawn over the shape while a vacuum is applied to suck it around the former. This method gives a good material distribution, even though there is a slight thinning over the drawn section.

6.2.6. MATERIAL REQUIREMENTS

The manufacturing requirements for a sheet material for vac-forming are as follows:-

(a) Adequate tear strength while hot

(b) Reasonable strength to allow it to be shaped at low pressures and prevent excessive sagging.

(c) Low shrinkage while cooling.

(d) Wide temp-forming range.

The other properties for the material were determined by the requirements for the finished product.

6.2.7. MATERIAL REQUIREMENTS FOR UNIT

(a) The finished forming should have adequate strength and rigidity, with good impact strength to withstand common encounters. (Such as hitting a hard surface from 4/5 feet or being cast around during transportation).

(b) Adequate resistance to scratching.

(c) Chemical resistance. The material should have a 'reasonably' good chemical resistance.

(d) Resistant to scratching. (Scratch Resistant).

(e) Resistant to corrosion.

(f) Should be non-permeable to liquids.

(g) Should have adequate colourability.

6.2.8. MATERIALS AVAILABLE

There are quite a number of polymeric materials which meet the above requirements to varying degrees and are capable of being thermo formed. These include:-

(a) Polypropylene

(b) Polyethlene

(c) A.B.S.

(d) Polyvinyl Chloride (P.V.C.)

(e) Polsytrene

(f) Acrylic

The various attributes which constitute a good material are ranked in order of relevance to the project:-

(1) Mouldability

(2) Impact strength

(3) Resistance to chemicals

(4) Colourability

(5) Non-permeability to liquids

(6) Tensile strength

(7) Compression strength

6.2.9. MATERIAL COST

The cost of the various materials was then considered.

MATERIAL COST	1980 PRICES
A.B.S.	£750/tonne
Polyamide	£1,610/tonne
Polycarbonate	£3,500/tonne
Polyethylene	£910/tonne
P.V.C.	£510/tonne
Polystrene	£575/tonne

Table

When the benefit/cost analysis was carried out on the possible solutions, the material which was choosen was A.B.S. due to it's excellent combination of mechanical, thermal, electrical properties, and reasonable price.

SECTION 6.3 UNIT TOP-CASING

It was decided to use a shallow drawn aluminium sheet for the top section of the unit for a number of reasons.

(a) The combination of the aluminium and the A.B.S. would help give the unit a more technical image.

(b) If aluminium is used, the legions and characters on the control panel could be etched, mechanically engraved, or photographically fixed on to the surface which give a more permanent surface than screen-printing.

6.3.1. SHALLOW DRAWING

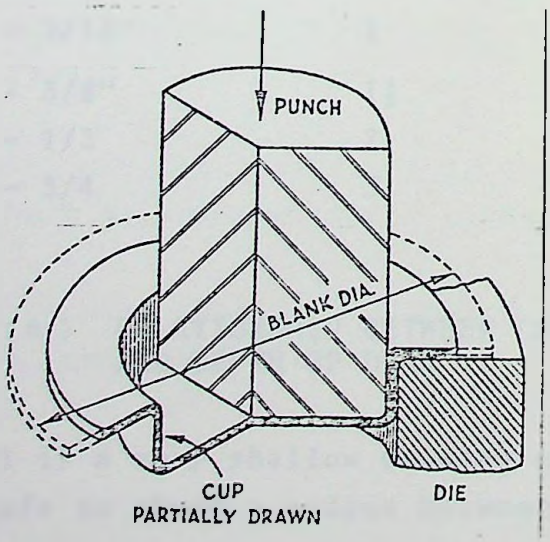


Fig 26

Fig (26) shows the essential features of a drawing process. The illustration shows the drawing of a cup shape, but the basic elements remain the same for drawing the top panel.

As the punch decends, material from the flange is drawn over the die radius and into the wall of the cup.

In drawing there is a direct relationship between the corner radius and the depth of draw which can be achieved.

6.3.2.

RADIUS	DRAW
3/32" - 3/16"	1
3/16" - 3/8"	1½
3/8" - 1/2	2
1/2" - 3/4	3

Table (6) RELATIONSHIP BETWEEN CORNER RADIUS AND DEPTH OF DRAW

The top panel is a very shallow drawing of 7 mm. Therefore it is safe to chose a radius between 3/16" and 3/8".

6.3.3. PRINTING OF INFORMATION GRAPHICS ON PANEL

As previously mentioned there are a number of processes which can be used for printing the panel. These include

(a) Screen printing

(b) Chemical etching

(c) Mechanical engraving

(d) Printed photographically

The process which was eventually choosen was the photographic process due to:-

(a) The scratch resistance of the finished panel.

(b) The ease which colours may be applied to the panel.

(c) The unexposed sections of the panel have a hard scratch-resistant coating.

(d) Finished panels are completely resistant to solvents and oils.

6.3.4. PROCESSING

The entire process is illustrated graphically in the following illustration.

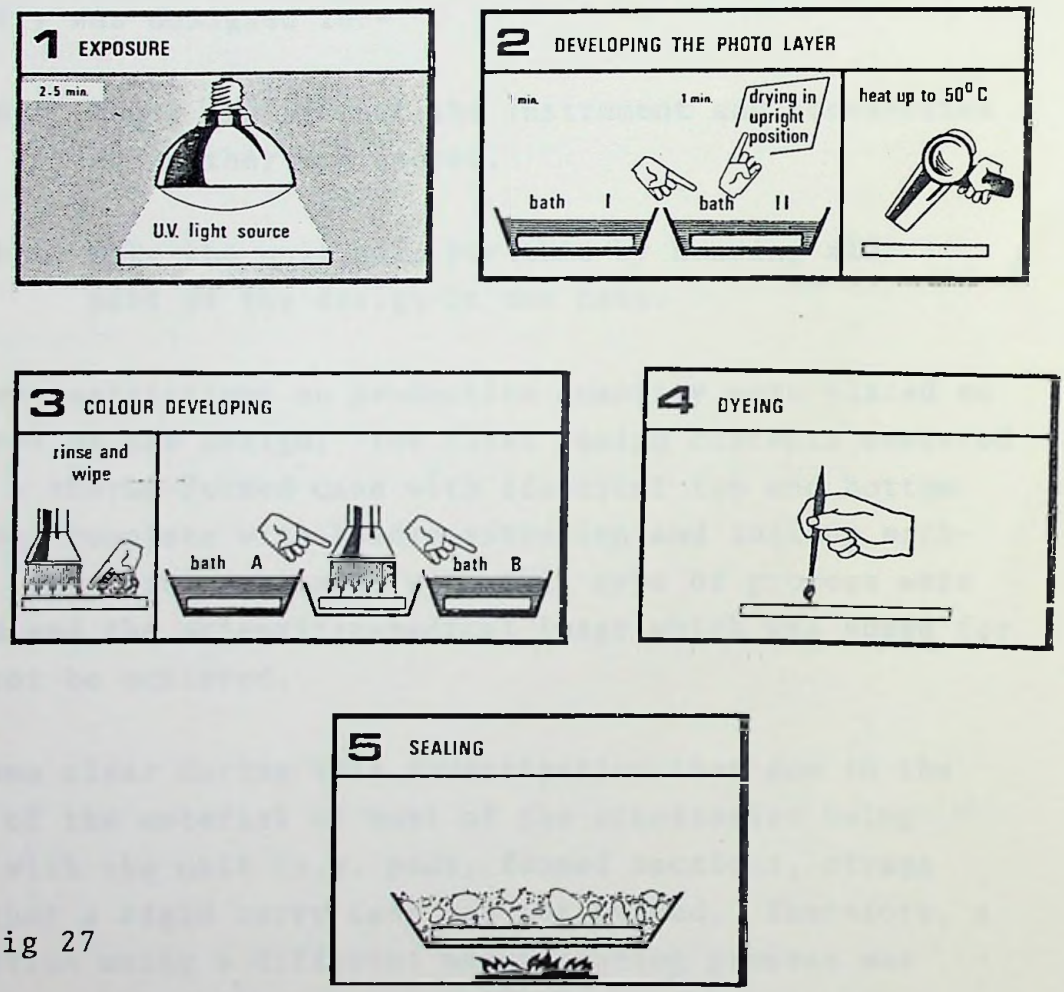


Fig 27

Fig (27) illustrates the procedure in the processing of polychromal sheets (anodised aluminium sheets with a fotoresist).

SECTION 6.4 CARRY CASE

The carry was designed to:-

(a) House and protect the instrument and accessories while they are stored.

(b) Make the unit more portable by housing all part of the design in one case.

The same restrictions on production quantity were placed on this area of the design. The first design concepts centered around a thermo-formed case with identical top and bottom sections, complete with handle extrusion and locking mechanism. The forms available with this type of process were limited and the scientific-medical image which was hoped for could not be achieved.

It became clear during this investigation that due to the nature of the material of most of the accessories being stored with the unit (e.g. pads, foamed sections, straps etc), that a rigid carry case was not needed. Therefore, a soft option using a different manufacturing process was choosen.

6.4.1. MATERIAL AND MANUFACTURING PROCESS

The process which was choosen to manufacture the case was a technique of high-frequency welding sheets of P.V.C. around cardboard inserts. Using this, a box construction could be built up using some of the weld lines as integral hinges.

To this construction a length of webbing was attached to act as a carry strap. This is to be adjusted so a carry handle option may be used. The other advantage of a strap is that the instrument can also be hung when not in use.

SECTION 6.5 ROLLER AND POINT CONTACT ELECTRODE

6.5.1. HANDLE MATERIAL

Due again to the small production runs, it was decided that tooling up to mould the handles would not be economically feasible.

Using the same procedure of material selection as with the bottom casing of the unit, it was decided that nylon would be used, due to it's good machining characteristcs and wear resistance.

6.5.2. MANUFACTURING PROCESSES

Since moulding the handle was not feasible, the next most practical solution would be to form the handles on a lathe. Using the critical parameters of length and diamater as indicated by the Handle Experiment (Section 5.3), the handles were designed. A textured surface was left over the length to stop it slipping during use.

SECTION 6.6 ROLLER AND PROBE-TIP

The roller and probe-tip which is used on the 'Slendertone' SL 20 is suitable for use with this project.

SECTION 6.7 PADS

As previously mentioned in Section 5.4.3., the material choosen for the base conductive section of the pads was conductive rubber. Nitrile rubber was choosen as the top section, due to it's very good insulating, moulding and tensile properties.

6.7.1. MANUFACTURING PROCESS

Compression moudling was choosen as the most suitable method of manufacture for the pads. (A moulding process is feasible here since there are eight pads sold with each unit).

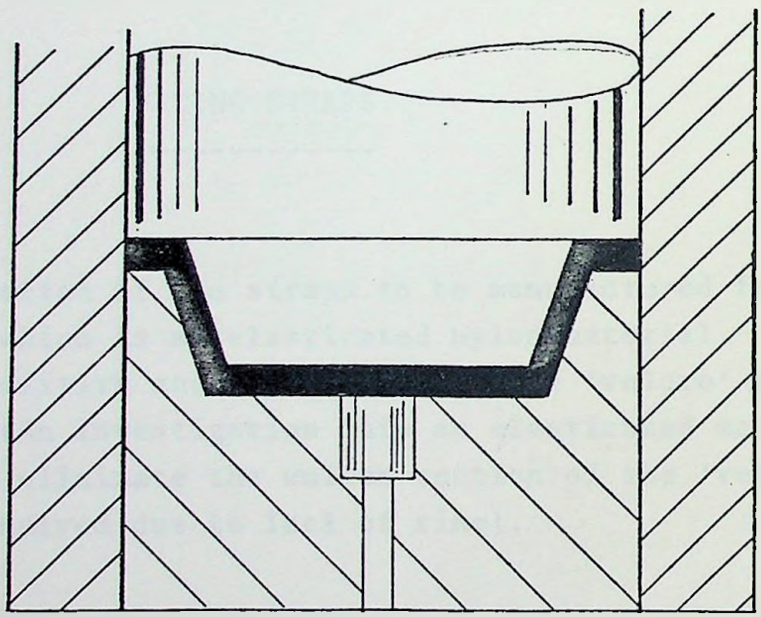


Fig 28

Fig (28) shows the positive mould method of compression moulding. The equipment consists of a press with two heated platens carrying the punch and die units. The raw material in the form of

powder or granules is subjected to heating and pressure during the forming process.

Using a modified form of the above method a two piece mould with different materials can be produced by firstly moulding the top section of the pad, changing one of the platens and moulding the conductive area.

SECTION 6.8 FIXING STRAPS

The main section of the straps to be manufactured from polyester, which is an elasticated nylon material. On to these, positive and negative pieces of 'velcro' are stitched. (An investigation into an elasticated material which would eliminate the wollen section of the 'velcro' had to be shelved due to lack of time).

SECTION 6.9 LEADS

The leads and plug assemblies to be used are standard 'Slendertone' equipment.

SECTION VII

OPERATING INSTRUCTIONS

SECTION 7.1 INTRODUCTION

These outline operating instructions are based on the assumption that the person using the equipment has some understanding of the use of similar types of units.

This unit is designed to give the Physiotherapist a comprehensive range of electronic waveforms for therapeutic purposes. This range has already been explained in Section 4.

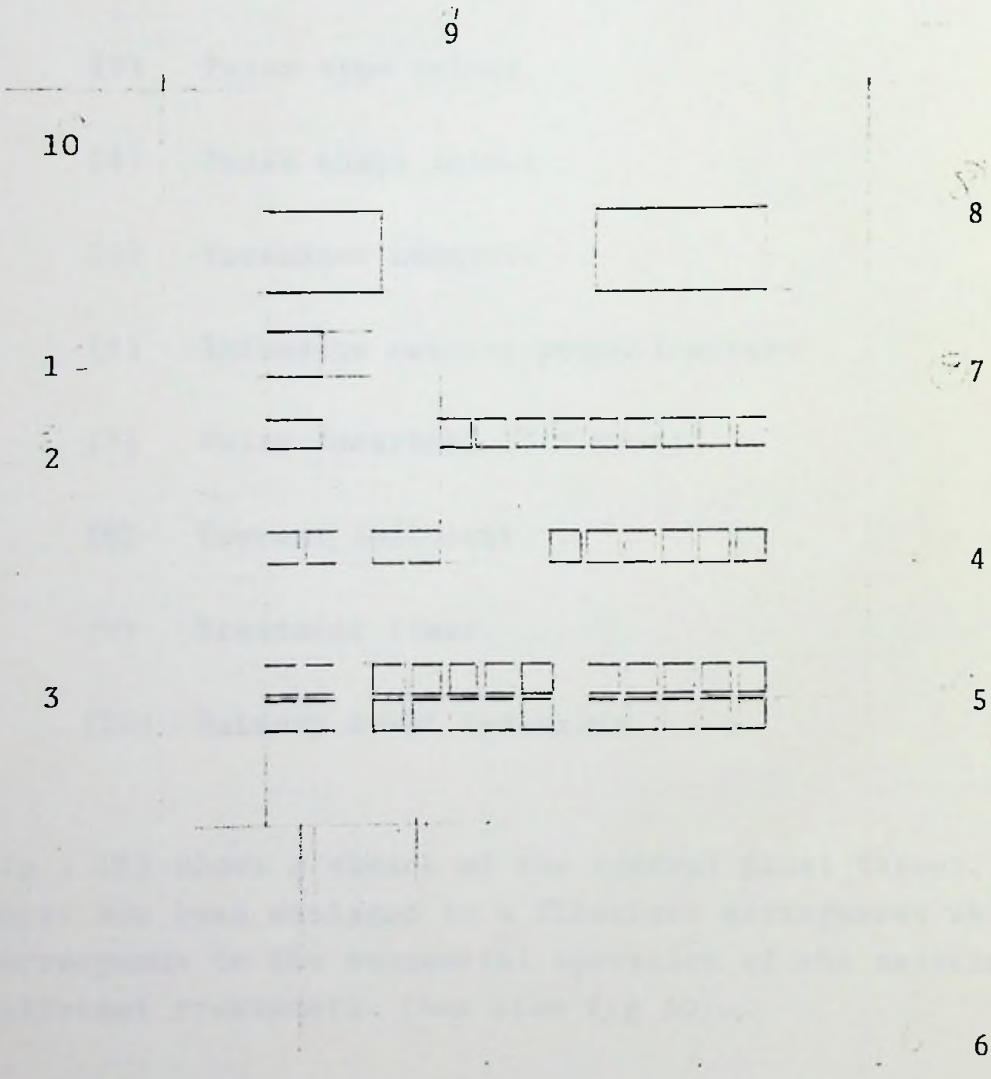


Fig 29.

(1) On/Off Switch

(2) Current select GAL or FAR

(3) Pulse type select

(4) Pulse shape select

(5) Paramater controls

(6) Intensity control potentiometers

(7) Pulse Durations (I/T Test)

(8) Current Indicator

(9) Treatment Timer

(10) Battery level indicator

Fig (29) shows a sketch of the control panel layout. The panel has been designed in a flowchart arrangement which corresponds to the sequential operation of the switches for different treatments. (See also fig 30).

SECTION 7.2 TREATMENT FLOWCHART

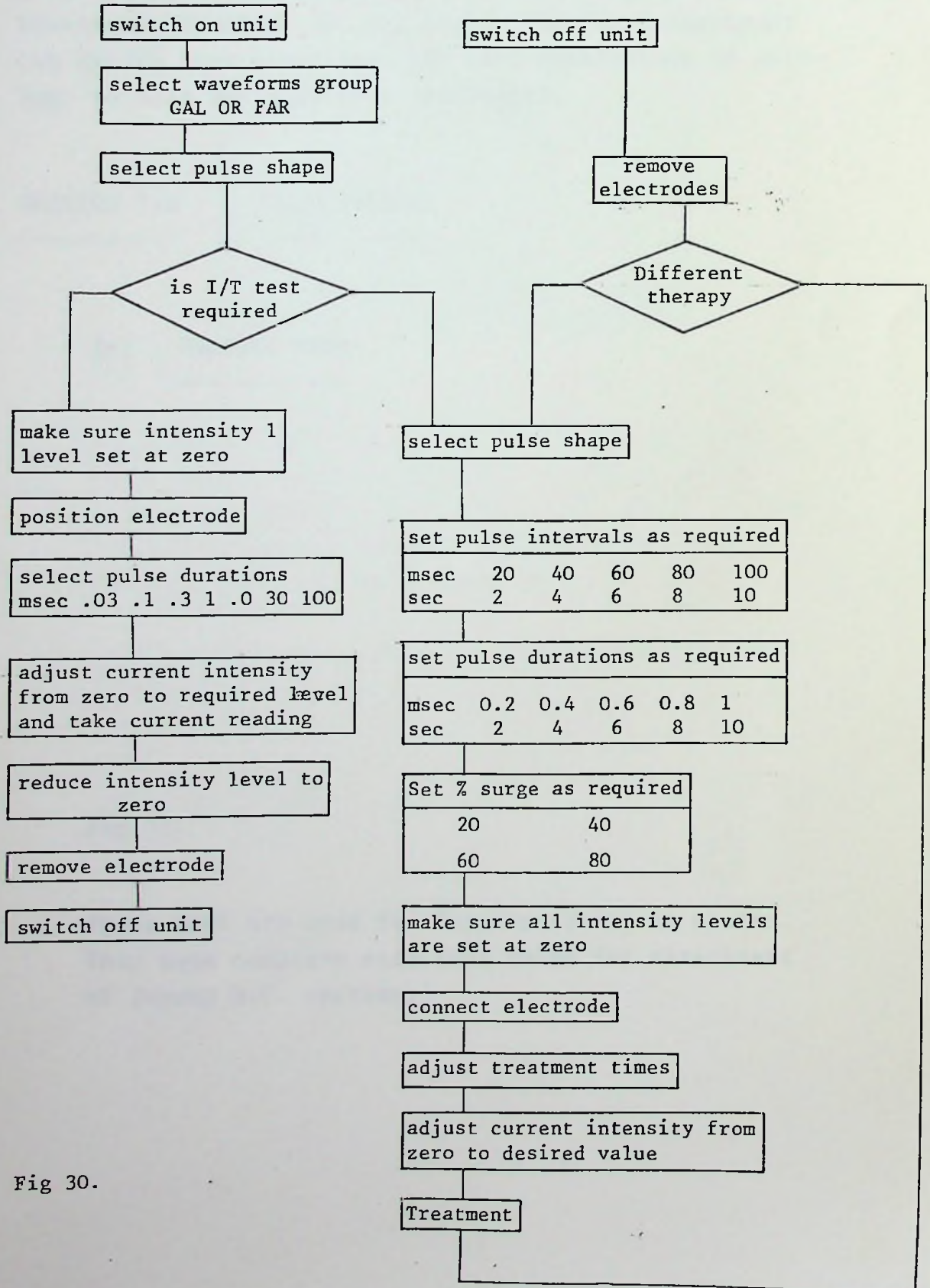


Fig 30.

It can be seen from figs (29) and (30), that there is a direct relationship between the control panel and the treatment flowchart for the unit. The Physiotherapist can decide from experience the best combination of settings to suit for different treatments.

SECTION 7.3 ACCESSORIES

(a) FARADIC PADS

Fig 31.

These pads are used for Faradic treatment cycles. They come complete with four holes for attachment of foamed D.C. section.

(b) D.C. SECTION

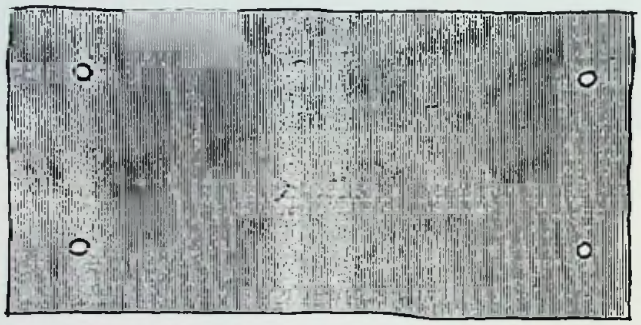


Fig 32.

The Faradic pads can only be used with the long duration D.C. pulses, with the addition of the foamed conductive rubber sheet. The sheet is positioned by pressing the four nylon studs into the locating holes in the Faradic pad.

(*note: there is no need to moisten the conductive rubber).

(c) BODY STRAP

These straps are designed to hold the pads firmly during treatment

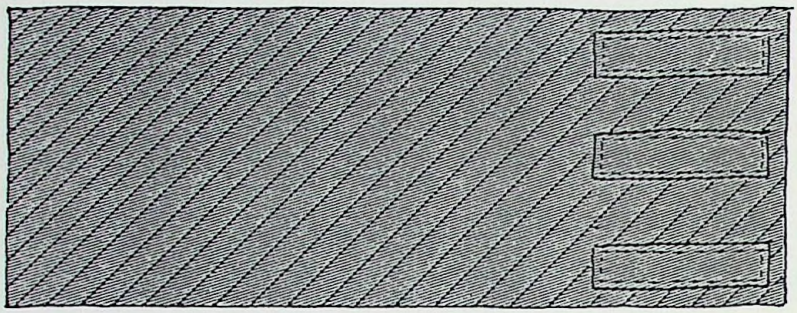


Fig 33.

The pads are slipped under the straps and placed over the points on the body to be treated. They are designed on a modular basis, i.e. a number of straps can be fixed together to encircle a large area.

(d) The roller and point contact electrodes are used in a similar way to those available with other units.

SECTION VIII

COSTING

SECTION 8.1 INTRODUCTION

The following section does not cover all the areas of costing; it is intended as an approximate cost analysis of the new unit.

SECTION 8.2 ANALYSIS

On investigation of the present units produced by BIO-MEDICAL RESEARCH LIMITED, it was found that the cost of the units can be devided into two main areas:-

(a) Material Costs

(b) Labour Costs

(a) Material costs are straighforward as they consist of all the component costs.

(b) Labour costs are divided into sub-sections which consist of:-

(1) Direct Labour costs.

(2) Direct production costs.
(which are a % of No 1)

(3) Indirect Overheads.
Including costs of marketing and sales promotions etc, again a % of No 1.

For the purposes of this project sub-section (1) and (2) have been estimated by comparison with present 'Slendertone' units.

SECTION 8.3 COST BREAKDOWN

As previously mentioned Section 8.1., this costing only serves as an indication of the cost of the unit. Various approximations have had to be made e.g. in the costing of the printed circuit board the components have not been listed as the full board has not as yet been designed.

SECTION 8.4 PARTS LIST AND COSTING

(a) INSTRUMENT CASE

Case base moulding	£1.20 x 1	=	£1.20
Case top	£1.80 x 1	=	£1.80
Printing on top panel	£0.40 x 1	=	£0.40
Case extrusion	£1.10 x 1	=	£1.10

(b) P C B's

Total cost of assembled P C B's	£6.00 x 1	=	£6.00

(c) CONTROL PANEL

Illuminated push-button switches	£0.06 x 42	=	£2.52
On/Off switch	£0.15 x 1	=	£0.15
Slider pots and actuators	£0.12 x 4	=	£0.48
L C D Display	£1.30 x 2	=	£2.60

(d) ACCESSORIES

Roller electrode	£0.92 x 1	=	£0.92
Point contact electrode	£1.00 x 1	=	£1.00
Coiled leads	£0.20 x 2	=	£0.40
Body strap	£0.32 x 10	=	£3.20
Pads	£0.36 x 8	=	£2.88
Foamed sections	£0.15 x 8	=	£1.20
Stud fasteners	£0.02 x 16	=	£0.32
Lead assembly gray	£0.32 x 8	=	£2.56

(e) CARRY CASE

Main case	£4.00 x 1	=	£4.00
Carry strap	£1.00 x 1	=	£1.00
Buckle	£0.10 x 1	=	£0.10
Strap retainers	£0.07 x 4	=	£0.28

(a)	TOTAL COST OF COMPONENTS	=	£34.11
(b)	COST OF LABOUR		
	1 hour @ £2.00 per hour	=	£ 2.00
(c)	PRODUCTION OVERHEADS		
	3.0 x (b)	=	£ 6.00
(d)	INDIRECT OVERHEADS		
	2.0 x (b)	=	£ 4.00
	TOTAL COST	=	£46.11
	PROFITY @ 30%	=	£15.36
	COST OF UNIT	=	£61.46

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APPENDIX