EDDY CURRENT TESTING EQUIPMENT

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1975

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Eddy Current Testing Equipment

Diploma Project

Submitted in partial fulfillment for the requirements for the postgraduate diploma in industrial design.

by

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1975

Approval Sheet .

Diploma project entitled

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is approved for the Postgraduate Diploma

in Industrial Design.

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Examiners: :

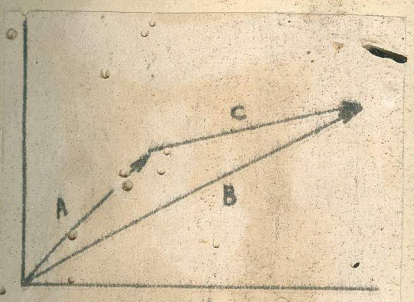
A.G. Jaishankar.

1. Introduction:

1.1

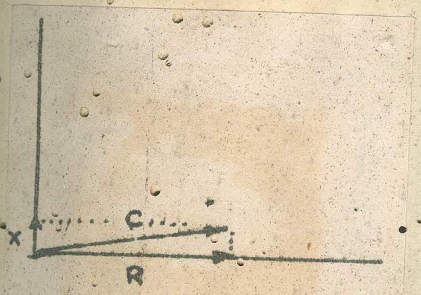
Eddy current tests provide a very importart testing technique for metals.

The technique is based on the principle that when a coil carrying A.C. is brought near or made to surround a metalic specimen, eddy currents are induced in that component, the magnitude and distribution of which depends on the geometry of the system and the conductivity of the specimen.



A - original coil impedence.
B - new impedence.
C - unbalanced change.

The coil impedence is affeted by the presence of eddy currents. The impedence change being resolvable to an inductive component which depends on the space relationship of the coil and specimen, and a resistive component depending on the conductivity of the specimen.

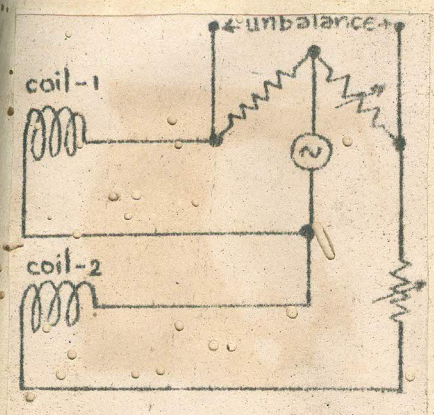


C - change
R - resistive component.
X - inductive component.

The conductivity is closely related to the metallurgical structure of the specimen and its state of heat treatment. Thus a seperation of these two effects gives a sensitive testing technique for the metals.

1.2

The use of eddy currents for nondestructive testing was pioneered by F. Forster and his associates in Germany and further development was made in Britain by E.G. Stanford and in U.S.A. by R. Hochschild and others.



1.3.

The 'Metallotest' instrument developed by Forster in 'forties consisted of a CRT display and other controls to give a simultaneous measurement of the inductive and resistive variables. The spot on the screen moves in different directions according to which variable is changing in what proportion. Each point on the screen thus corresponding to the definite value of the concerned variable. Screen scales can be calibrated to give direct reading.

2. Problem definition

2.1

To design the housing and panel for the multifrequency type eddy current testing equipment.

With emphasis on

1. Suitability for very low annual production.
2. Integration of function appearence and ease of operation.
3. Maintenance problems.
4. Durability.

2.2

Design of emblem for the manufacturers 'Technofour' has also been taken as a subproblem of graphic design.

3. Problem background.

3.1

Manufacture of Eddy current testing equipment is of recent origin in India, and multifrequency type eddy current testing equipment is being designed and manufactured for the first time, using Indian know-how.

3.2

The problem is unique in nature due to the fact that there is no similar equipment in operation at present and eventhough there is an eddy current tester of 50Hz available in the market, it has been introduced only two years ago and the users are still reluctant to give any information to anyone except the manufacturers. Hence the design will be based mainly on the information obtained from the manufacturers(Technofour) who are also the manufacturer of the new multifrequency type eddy current testing equipment.

As this equipment is used for testing metalic samples in the quality control departments of industries dealing in forging, casting and other types of basic metallurgical operations, it introduces some typical constraints on the design.

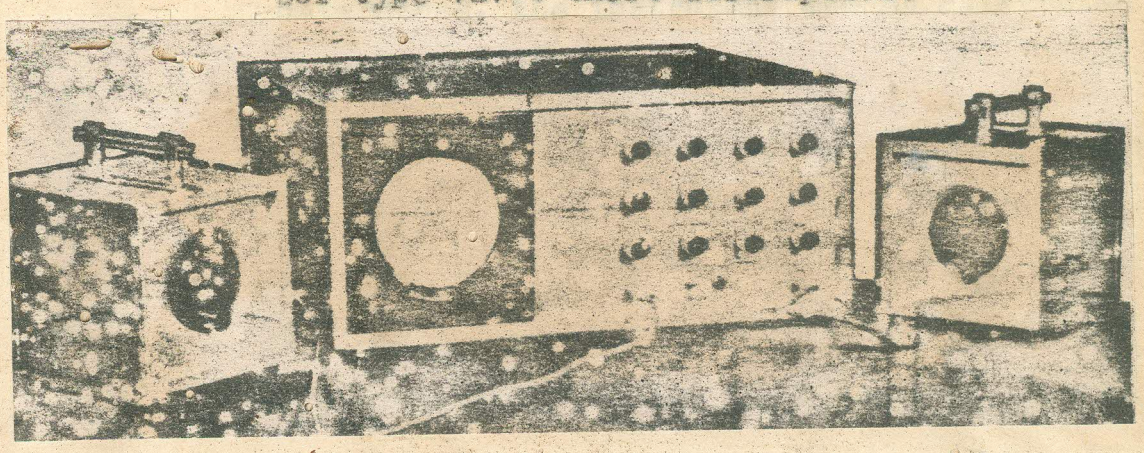
4. Information

4.1

Similar equipment : There is one similar equipment available,(Indian manufacture) but as it is of a much primitive type among eddy current testing equipment, information based on it will only serve as a few guiding points and not as a sound basis to be relied upon.

4.2

ECT type 727 : Short discription.



This consists of a main unit with cathode ray tube display and two coils made to specifications of the test specimens. The front panel of the main unit includes oscilloscope controls, coil balancing controls, phase shifting controls and a

switch to obtain either sine wave display or an ellipse display on CRT.

Overall size : 50 x 50 x 20 cms

Weight : 18 Kg aprox.

Material : Aluminium sheet & Channels.

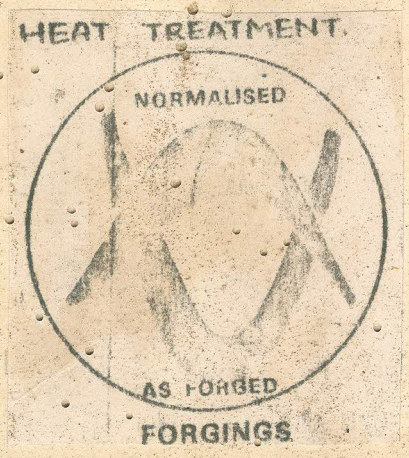
The equipment is used for comparing the physical and metallurgical properties of a test part with those of a reference part and to sort out the test parts accordingly. When there is only one prominent metallurgical variable and absolute values of the property under investigation are to be determined, the instrument can be calibrated to give direct reading.

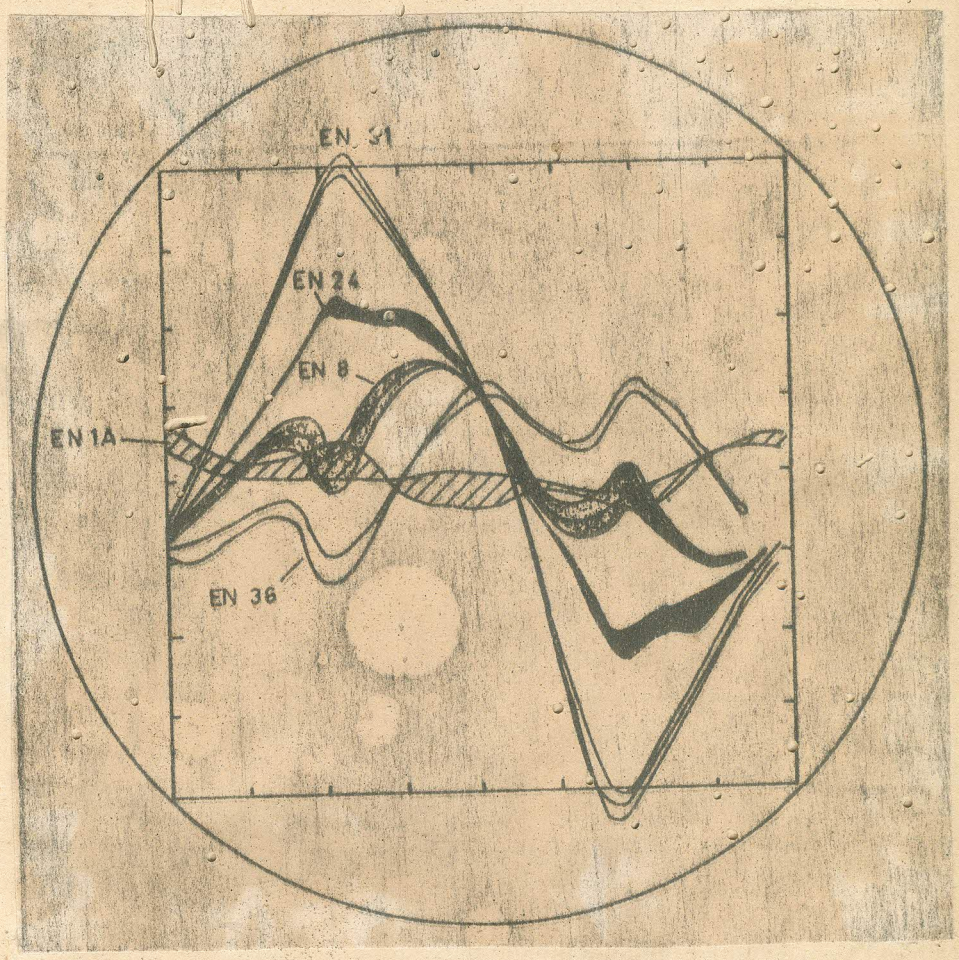
4.3

Variables of the test :

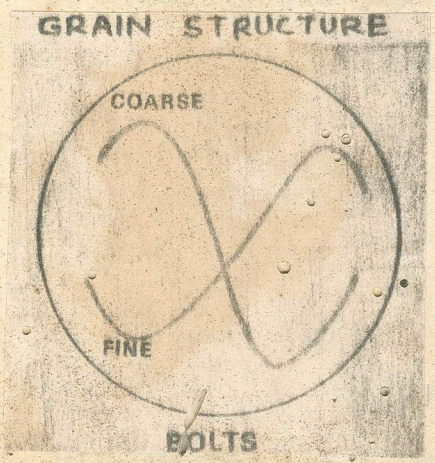
Eddy current tests can be carried out to compare or determine following variables.

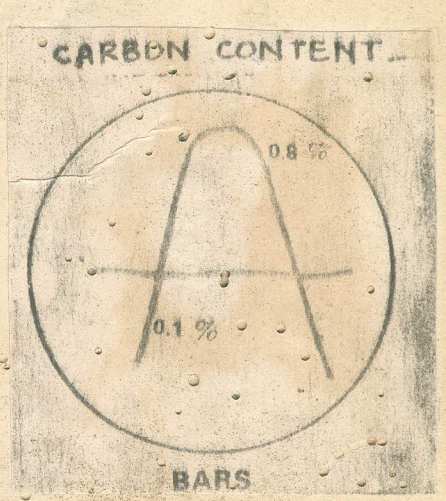
1. Alloy type
2. Heat treat condition
3. Grain structure
4. Hardness
5. Carbon content
6. Tensile strength
7. Brittleness.





Sorting of mixed bars with EN specifications by CRT traces.





Types of test components :

1. Castings
2. Forgings
3. Gears
4. Extrusions
5. Tubes, Bars
6. Nuts, Bolts
7. Other machined components.

4.4

Multifrequency type Eddy current testing equipment :

Expected overall size : 50 x 50 x 20 cms.

Front Panel elements :

1. Cathode ray tube
2. Intensity control
3. Focusadjustment
4. Position control
5. Astigmatism adjustment
6. Quality group indicater-1
7. Quality group indicater-2
8. Quality group indicater-3
9. Scale illumination
10. Power on/off
11. Mode selecter
12. Pilot lamp
13. Threshold control - upper level
14. Threshold control - Lower level
15. Trigger level control
16. Exciter

17. Sensitivity control
18. Equaliser
19. Compensator
20. Reset switch
21. Trigger slope selector
22. Frequency selector.

Rear Panel elements

1. Mains connector
2. 3 pin din socket - coil - 1
3. 3 pin din socket - coil - 2
4. Fuse
5. Relay output - 1
6. Relay output - 2
7. Counter output - 1
8. Counter output - 2
9. Counter output - 3
10. Earth connection

4.5

Use : This equipment will mainly be used in quality control departments of metallurgical industry.

4.6:

Steps in operation :

The metallurgist or quality control engineer or a similar highly qualified and responsible person sets up the equipment as follows :

1. Two test coils (which are specially made for the perticular component) are connected to the equipment.
2. Power supply is switched on
3. Since wave or ellipse display is obtained.
4. Sensityvity is selected
5. Two identical standerd reference parts are inserted in both coils.
6. Exciter is switched on.
7. Equaliser and compensator are adjusted simultaneously to obtain a balanced trace on the CRT screen.
8. Position of trace is adjusted to bring it in centre
9. Upper and lower threshold levels are adjusted according to the desired tolerances in sorting out the quality groups
10. Counter and relay outputs are properly connected to the corresponding equipments if desired.
11. Few specimen are tested as a trial run.

Then the equipment is ready for use and is handed over to the unskilled operator, for sorting out the parts given for test.

4.7

Constraints on design :

The most important constraint on design is imposed by the fact that expected annual production of the equipment is not more than 50 units. This being a specialised equipment of very high cost the sale is not expected to exceed this figure. (Cost estimated to be around 10 to 15 thousands rupees). This rules out the advantages of mass production.

The first element to be affected by this constraint is the knobs used on the panel. It is impossible to use specially designed knobs for all functions and only one type of knob has to serve all the functions that may be required to be satisfied.

The housing design is also affected by this constraint as methods of mass production are ruled out.

Only available methods of manufacturing the housing are using sheet metal and hand processing or using FRP and using hand processing.

4.8

Dimensional data :

1. CRT

diameter : 135 ± 5 mm

Length : 370 ± 10 mm

Thickness of glass : 5 mm aprox.

Shape : conical

2. Transformer :

Overall Size : 150 x 130 x height 180 mms

3. PCB:

Overall size : 150 x 180 mms.

Minimum spacing 20 mms center to center

Total 9 Boards to be used.

4. Potentiometers:

Sensistivity: potentiometers diameter 40 mms length 60 mm

equaliser potentiometer: length 60 mm diameter 40 mm

Compensator potentiometer: length 60 mm diameter 40 mm

All other remaining potentiometers

Diameter 25 mm

Length 13 mm.

5. Indicator lamps

Front : 12 x 18 mm

Depth : 14 + 32 mm

6. Exciter switch:

diameter : 40 mm

length : 30 mm

7. Frequency selector switch :

diameter 40 mm, length 80 mm.

5. Analysis

5.1

Materials

Although there are a large number of materials available for this type of requirements the constraint of low annual production and hand processing restricts the scope of selecting the materials.

There are only two possible alternatives

1. Aluminium or MS sheet and channels for structural framework.
2. FRP housing with Aluminium or MS frame for mounting the circuitry and CRT.

   The weight of the equipment is expected to be around 18 Kg and it will be most desirable to design the housing with minimum possible weight without sacrificing the requirement of strength.

5.2

Processes

1. If Aluminium or MS sheet and channels are to be selected as the meterials of production then the only process available being hand processing like cutting, bending, drilling, welding etc.

This restriction generates a very heavy drawback on the appearance of the equipment.

2. If FRP is selected as the material of production then the most suitable process will be hand moulding, using either wooden or plaster of paris moulds. This process does not have any drawbacks on the shape of the equipment housing and aesthetic requirements will not have to be sacrificed.

5.3

Functional Analysis : Electrical and ergonomical

The electrical and ergonomical functions of the panel elements can be analysed as follows:

1. CRT -

electrical : Display of unbalance in coil outputs on x-y coordinates relating directly to the resistive and inductive component of the unbalance in coil impedences.

ergonomical : display of the trace to the operator's eyes.

2. Quality group indicators (3 Lamps)

electrical : To indicate whether the test specimen is a) Superior b) Identical or c) Inferior to the reference.

ergonomical : display of quality group to the operator's eyes in a quick manner.

3. Pilot Lamp

electrical : To indicate the presence or absence of power supply.

ergonomical : visual indication.

4. Intensity control.

electrical : To adjust the intensity of electron beam on CRT screen.

ergonomical : continuous variation of knob through 270°

5. Focus adjustment.

electrical : To focus the electron beam on CRT screen into a sharp point.

ergonomical : Continuous variation of knob through 270°

6. Astigmatism adjustment.

electrical : To obtain a clear and steady beam.

ergonomical : Continuous variation of knob through 270°

7. Position control

electrical : Vertical variation in the position of electron beam spot on screen.

ergonomical : continuous variation of knob through 270°

8. Threshold control - 1

electrical : To fix the upper level of signal for group seperation.

ergonomical : continuous variation of knob through 270°

9. Threshold control - 2

electrical : To fix the lower level of signal for group seperation.

ergonomical : continuous variation of knob through 270°

10. Trigger level control

electrical : To obtain the required phase shift for stabilising the curve on screen.

ergonomical : Continuous variation of knob through 270°

11. Sensitivity control

electrical : Adjusting the proporation between coil output and beam deflection.

ergonomical : Continuous variation of knob through 360°x10 and give visual display of number of turns.

12. Equaliser

electrical : To obtain a balanced trace on CRT when both the coils have identical specimen.

ergonomical : Continuous variation of knob through $360^{\circ} \times 10$ and to give visual display of number of turns.

13. Compensator

electrical : to obtain a balanced trace on CRT when both the coils have identical specimen.

ergonomical : Continuous variation of knob through $360^{\circ} \times 10$ and to give visual display of number of turns.

14. Power on/off

electrical : To switch the power supply on or off

ergonomical : Up & down movement

15. Scale Illumination

electrical : To switch the scale lights on or off

ergonomical : Up & down movement

16. Mode selector

electrical : To select automatic or manual operation.

ergonomical : Up & down movement.

17. Exciter switch

electrical : To put the bridge power supply on or off

ergonomical : Up & down movement.

18. Reset

electrical : To reset the indicater lamps to original position.

ergonomical : Push movement

19. Trigger slope control

electrical : To select positive or negetive trigger slope.

ergonomical : Up & down movement

20. Frequency selector

electrical : To select the frequency of test current from the available set of frequencies.

ergonomical : Step rotary movement of knob through 8 steps spread over 210°

5.4

Classification of controls and other elements

1. Classification based on frequency of use

   A - high frequency of use

   B - medium frequency of use

   C - low frequency of use

2. Classification based on function.

   X - control of display or display

   Y - control of internal electrical parameters.

   Z - Control/selection of operation.

Classification

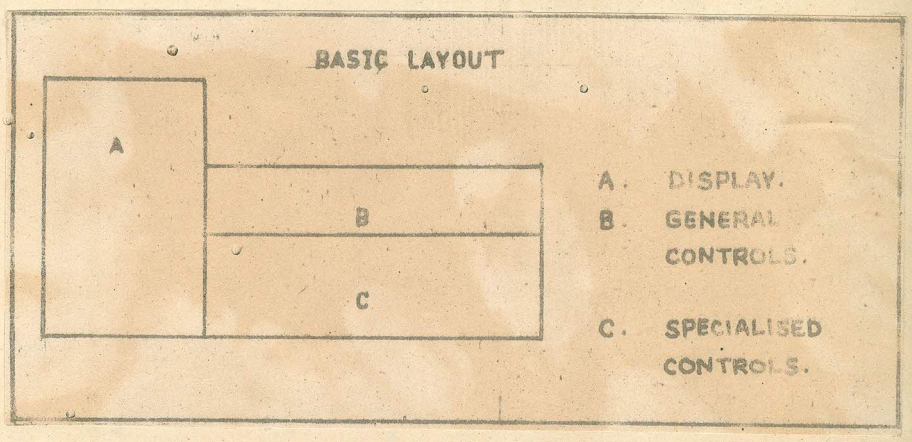
panel element		frequency	function
1.	CRT	A	X
2.	Quality group indicators	A	X
3.	Pilot lamp	A	X
4.	Intensity	B	X
5.	Focus	B	X
6.	Astigmatism	B	X
7.	Threshold control	C	X
8.	Trigger level	C	X
9.	Positioning	B	X
10.	Sensitivity	C	Y
11.	Equaliser	C	Y
12.	Compensator	C	Y
13.	Trigger slope	C	Y
14.	Power on/off	B	Y
15.	Scale illumination	B	X
16.	Mode selector	B	Z
17.	Exciter	B	Y
18.	Reset	B	X
19.	Frequency selector	C	Z

The classification also indicates that there are mainly three dominant groups of elements on the front panel with slight overlapping which can be ignored as it is of little importance. Both types of classifications cambined together suggest the three following groups of elements.

1. Visual display to be continuously observed by the operator.

2. Elements to be handled by the operator.

3. Elements to be used by the metallurgist, or quality control engineer.



6. Hypothesis

6.1

Concept.

As this design problem is directly related to very low production the solution should be of such nature that it takes full advantage of all the plus points of hand processing without geting afected by the drawbacks of the methods of hand processing.

6.2

Material

The best possible material must be selected to satisfy all the requirements of the problem, as the equipment is of a very specialised type. The equipment is mainly used in quality control departments or sometimes directly on the production line for sorting. Hence the material should be such that it will be strong enough to meet any unexpected impacts, also it should be durable as the equipment is very costly and must be protected efficiently against any damage.

6.3

Form

To combine function and appearance with ease of operation it must be taken as the basis of visualising the form of the housing.

6.4

Graphics and communication.

The form of the housing must be coherent with the graphic requirements of the panel so as to avoid any clash of the functional and aesthetic aspect of the three dimensional form, and two dimensional form. Also as the equipment is going to be used by two extreme classes of indivisuals, the graphic and communication solutions should take case of of both the requirements.

6.5

Maintenance

Maintenance is a major problem in all types of electrical equipment. The use of PCB system in this equipment with sockets for each plug in type PCB has somewhat reduced the maintenance difficulties and it is only necessary to provide an access for taking out the PCB easily from the socket.

6.6

Control elements.

Control elements should preferably designed seperately to serve each function, but the constraint of low production imposes a restriction on types of knobs used, hence a knob which can best serve all the expected functions must be designed or selected from existing designs.

7. Synthesis.

Principles of hypothesis cannot be directly brought into practice without working out a compromise between all the requirements and constraints.

Attempt is made to adhere to the requirements laid down by the hypothesis as far as possible.

The design of housing and panel will roughly be on the following basis.

1. Equipment housing and panel will be made in fiberglass reinforced plastic.
2. Design of test coils will not be considered here as it varies from component to component and the specifications of the customers. Also if the equipment is used in automatic mode, the coils become a part of the 'Autosort' attachment for automatic sorting which forms a seperate design problem in itself.
3. Panel will be a part of housing itself and anodised aluminium plates will be used for graphics, communication etc.
4. Housing will have a easily removable access for maintenance.
5. Basic framework for mounting the circuitry will be fabricated by using aluminium channels.

8. Preliminary design

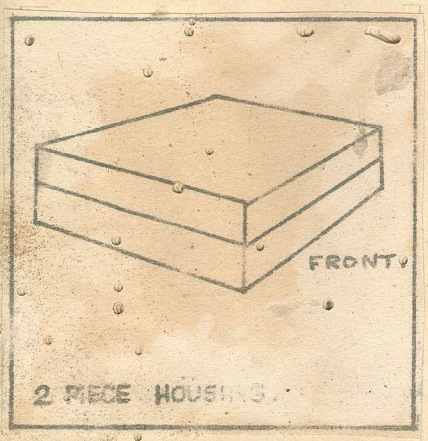
8.1

Housing

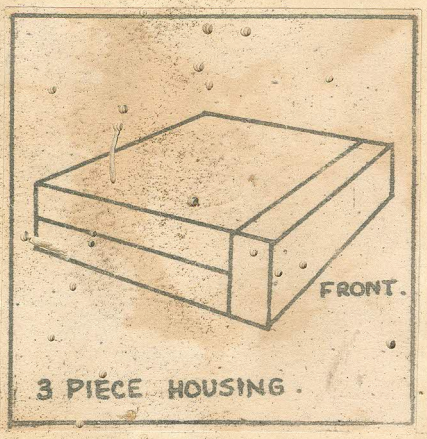
The analysis of materials and processes in the chapter on analysis suggest the use of FRP as the production material to be the best possible choice.

Although cost in high, reduction in weight and possibilities of evolving an attractive appearance without sacrificing strength compensate for high cost of production. Also percentagewise the cost of housing is very much smaller compared to total cost of the equipment, which is estimated to be around 10 to 15 thousands rupees.

Housing can be made in two pieces a) Top b) Bottom, but as the front panel will have a line of joint visible in the center and whenever the top protion is removed, the front panel will be split into two. Hence it is better to use 3 piece housing 1. Front 2. Top 3. Bottom, but this will still have a split in the rear panel.



2 PIECE HOUSING.



3 PIECE HOUSING.

From the chapter on data collection it becomes obvious that rear panel requires almost half the area of the front panel, hence even if

there is a split in the rear portion it will not divide the rear panel which can be fit into only bottom half or top half of the rear end.

This eliminates the necessity of having a four piece housing.

8.2

Maintenance

Maintenance requirements of this equipment are of the 'off the chasis' type, that is, as the circuit is divided on nine printed circuit boards, the boards have to be taken out from the sockets for repairs hence, access from top is sifficient for almost all purposes.

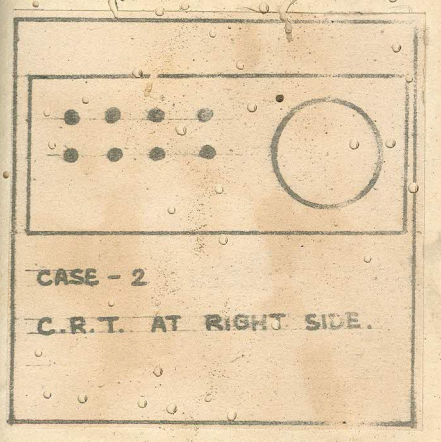
This requirement can be satisfied by joining the top and bottom portions by hinge at the back.

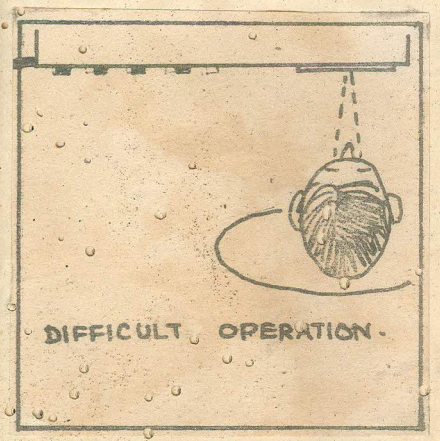
8.3

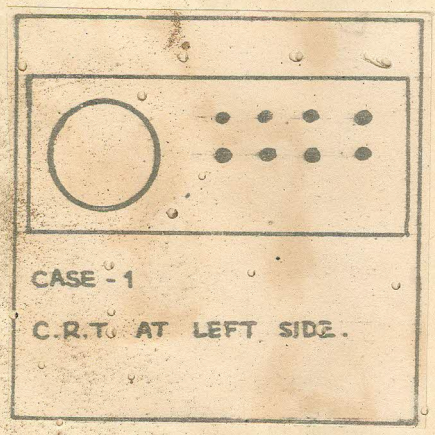
Front panel

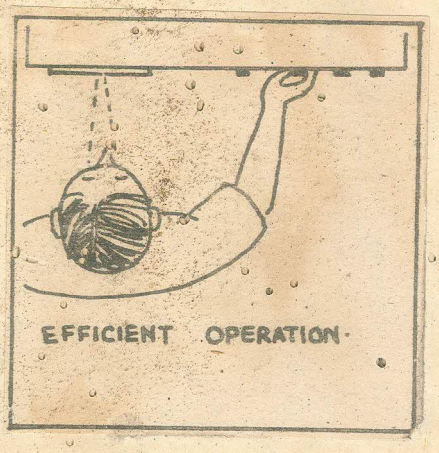
The most important elements on the front panel are the CRT and quality group indicator lamps. Hence, first design decision to be made about the front panel is the position of CRT.

The position of CRT can be either at left hand side, reighthand side or at the centre.









The overall size restriction and sizes of transformer and CRT eliminate the centre position.

As a majority of operators is expected to use their right hand for operating the control knobs the righthand side position becomes inefficient.

Only choice left therefore is the lefthand side position for CRT and the quality group indicator lamps.

Psychological considerations also suggest the same position, as it is easier to keep an eye on the controls on rightside while observing the CRT on left side.

From the chapter on information it can be seen that the glass thickness of tube imposes as need for having the CRT screen axis parallel to the line of vision of the operator.

The operator is expected to work in sitting position, or sometimes standing position, an angle of around 30^{0} must be given to the screen surface. Also the height of equipment being 20 cms. it is necessary either to provide a tipstand for raising the front panel or to provide a raised portion on the panel itself for the CRT screen.

The placement of CRT and quality group indicators on lefthand side leave two groups of controls on the front panel.

One of them being frequently used and one rarely used. The group that is frequently used is mostly used by operator, and other group is used only by the metallurgist or quality control engineer.

8.4

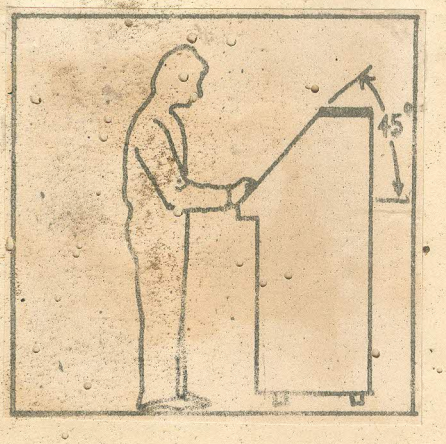
Knobs

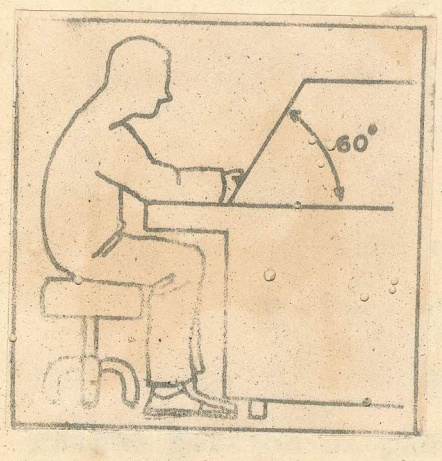
All knobs except one are to give continuous rotary movement through 270° or 360° x 10 or 210° only one knob gives step movement. Hence it is desirable to use only one type of knob for all controls as it makes production easy and also gives an integrated appearance on the panel.

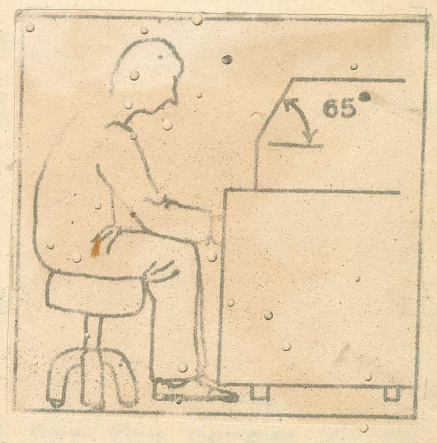
8.5

Rear panel

The panel elements which are used only before starting the operation and may not be disturbed again for a very long time will be placed on the rear panel.







9. Final design.

9.1
Housing

As seen in the previous chapter the best possible alternative for housing is the three piece model suggested.

This avoids the split in front panel and also provides for easy maintenance.

The form was designed as shown in the following drawing to meet three basic needs that were to be satisfied namely

1. Aesthetic needs
2. Integration of panel groupings into a coherent from with natural division of panel area into the desired groups.
3. Ease of maintenance.

The angle of inclination for the CRT screen was chosen to suit for an operation which includes sitting and slight bending of operator for placing the test parts into the coils which are kept at a lower level than the equipment.

The inclination of the CRT screen on panel also automatically divides the panel area into four seperate regious, combined with the raised portion of panel for the screen which is more convenient for the operator to observe.

Material chosen for manufacture of housing is FRP, for the reasons discussed in previous chapters. The process is hand moulding, using glassfiber mats and resin.

The form also suits this process because of the tapering surfaces and radii given at edges.

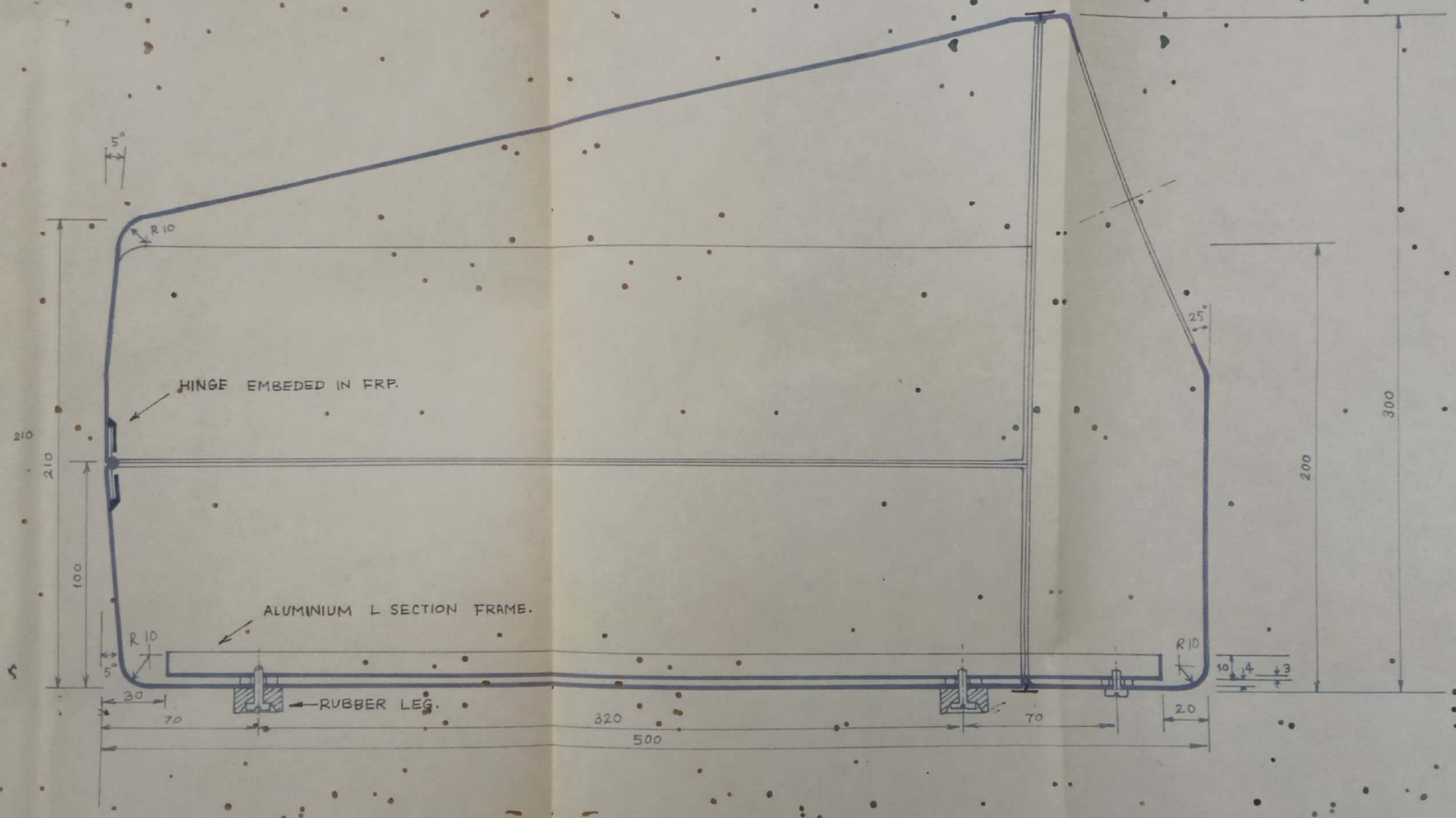
The joining details are shown in following drawings. An aluminium frame is used for holding the bottom & front piece together and for mounting of circuitry, the top piece is hinged to the bottom piece for ease of maintenance. The function of joining screws for frame, and bottom supports is combined together. Ventilation is provided at the top for the transformer heat.

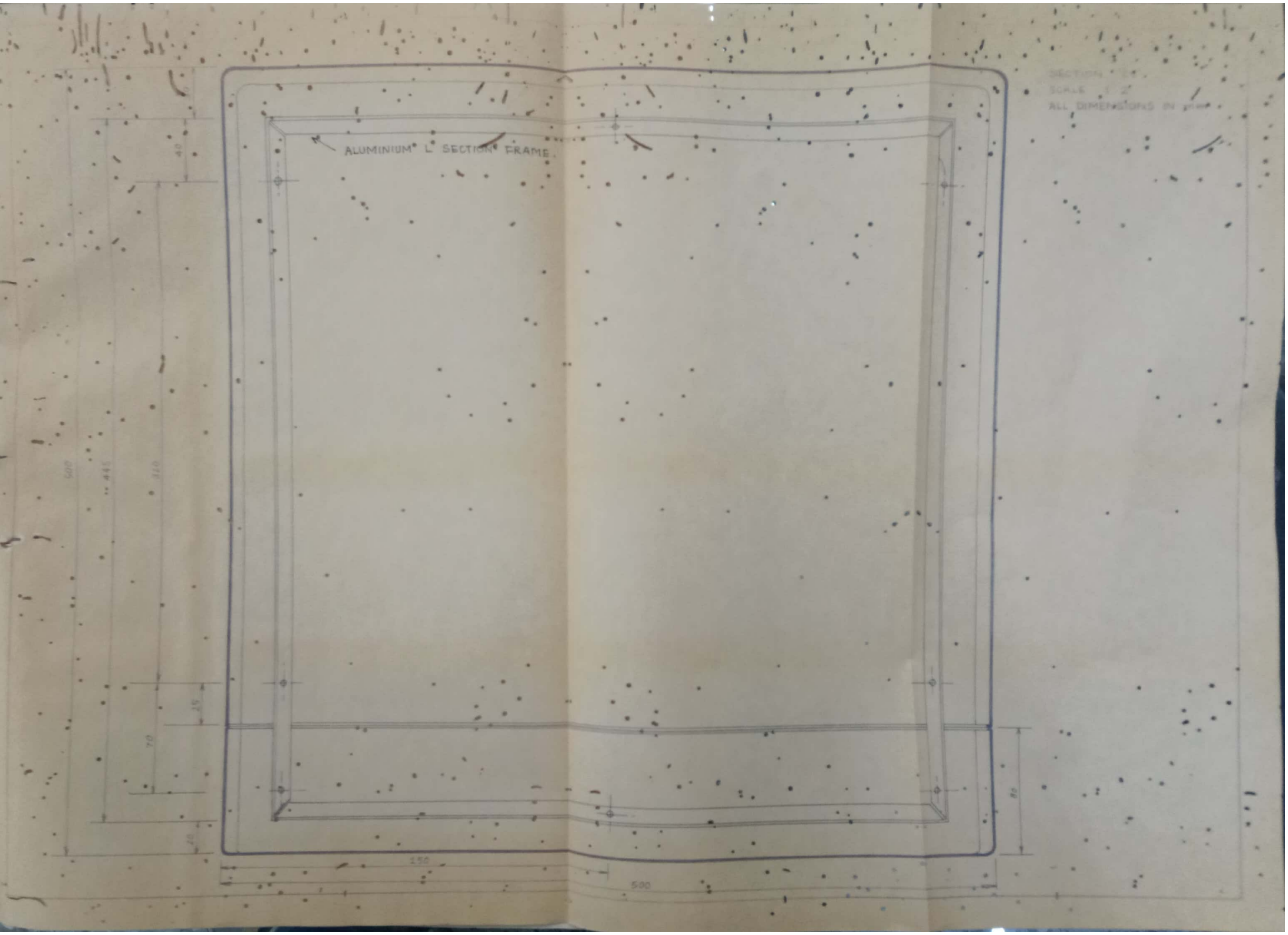
Need for a tracing attachment was considered but it was realised that the equipment will mostly be used by large industries in their quality control departments or directly on production line for sorting or testing and the provision of quality group indicators will be extensirely used instead, of comparing the actual curve on screen for each test part. Hence no provision is made in the original housing for tracing attachment, but the front panel is made plane without any projecting

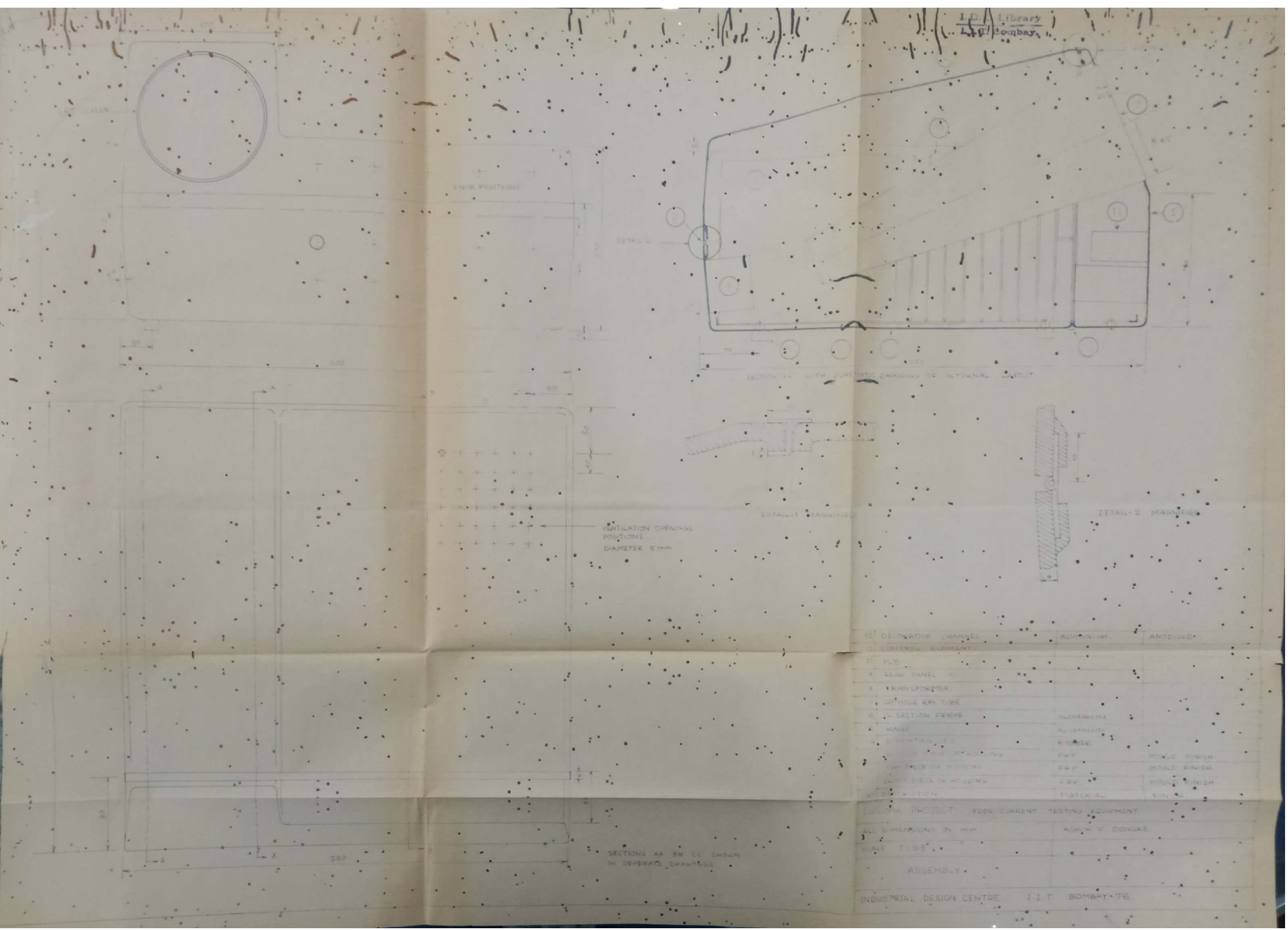
SECTION 'AA'

SCALE 1:2

ALL DIMENSIONS IN mm.







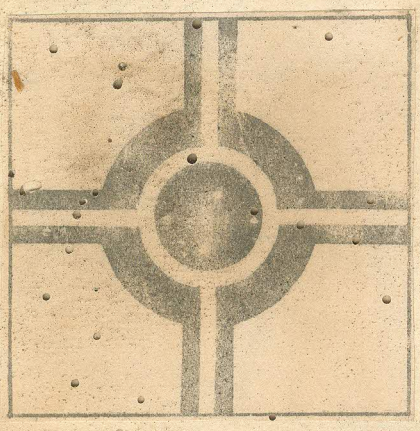
border so that sufficient place is left for fixing the tracing on to the screen for comparison by using adhesive tape whenever the need is felt.

The weight of equipment makes portability impossible and hence no handle is provided as the equipment will either be stationary or on a trolly when being moved. Lifting is needed only when it is being placed on a trolly or being transferred from the trolly to the work table. For this, it can be lifted directly by hands inserted below the bottom part which is raised by the supporting legs from the surface below. The tapering shape also provides for easy grip.

9.2

Panels.

Grouping of panel elements was done based on principle discussed in the chapters on analysis and preliminary design. The layout is shown in following drawing. The panel is made of anodised aluminium plate for ease of communicati

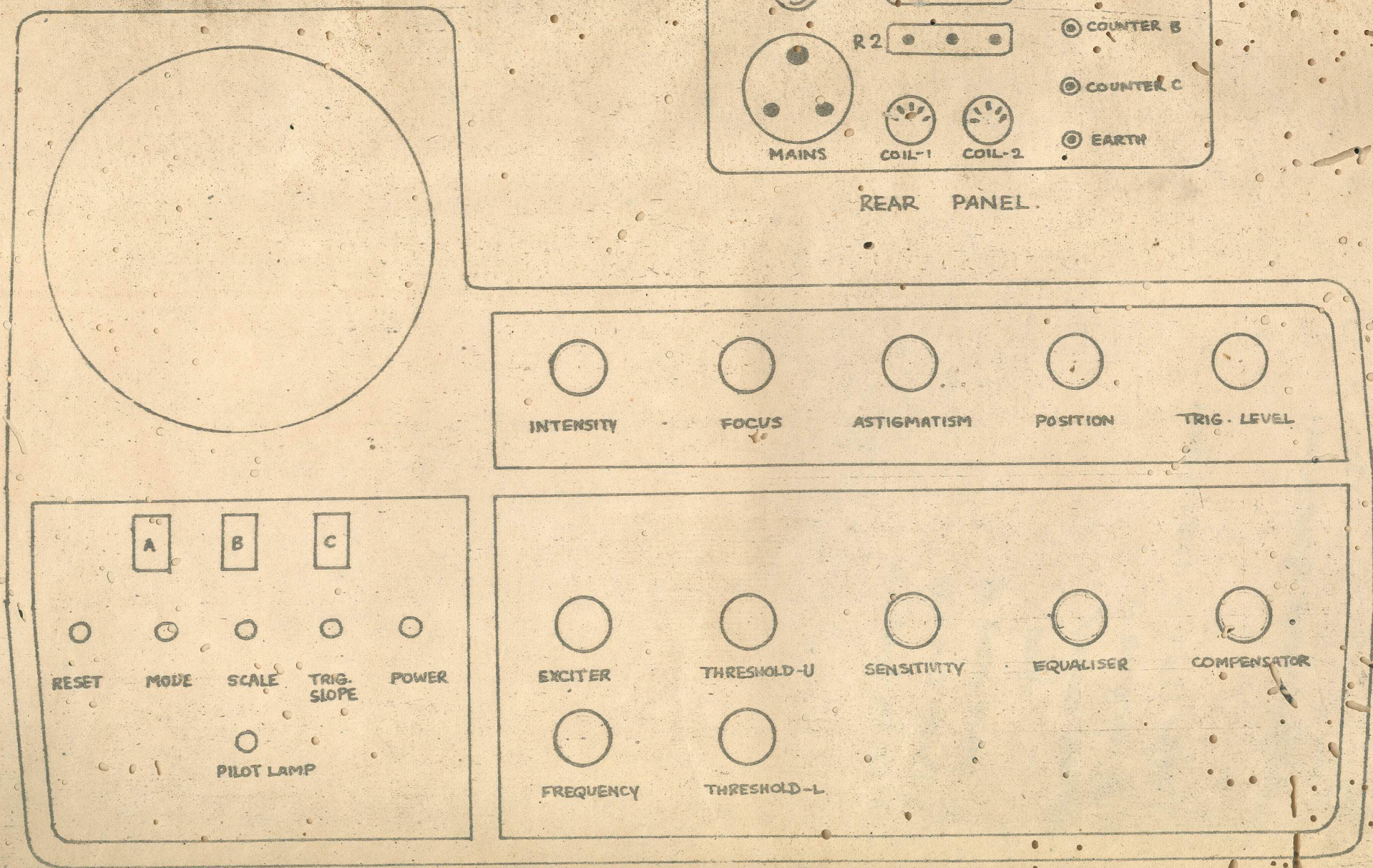


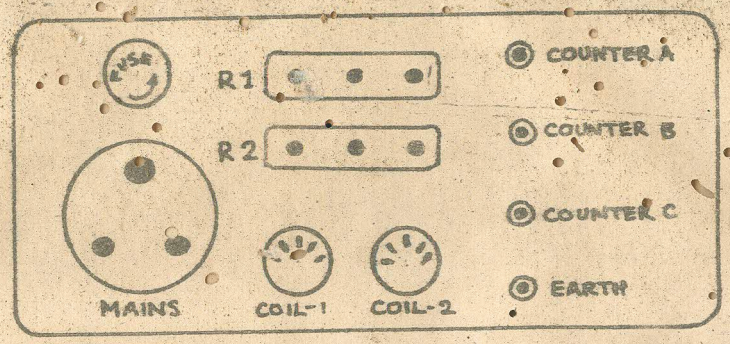
9.3

Emblem

The emblem for manufactures was designed considering the history of their organisation and the desired image to be projected.

FRONT PANEL.



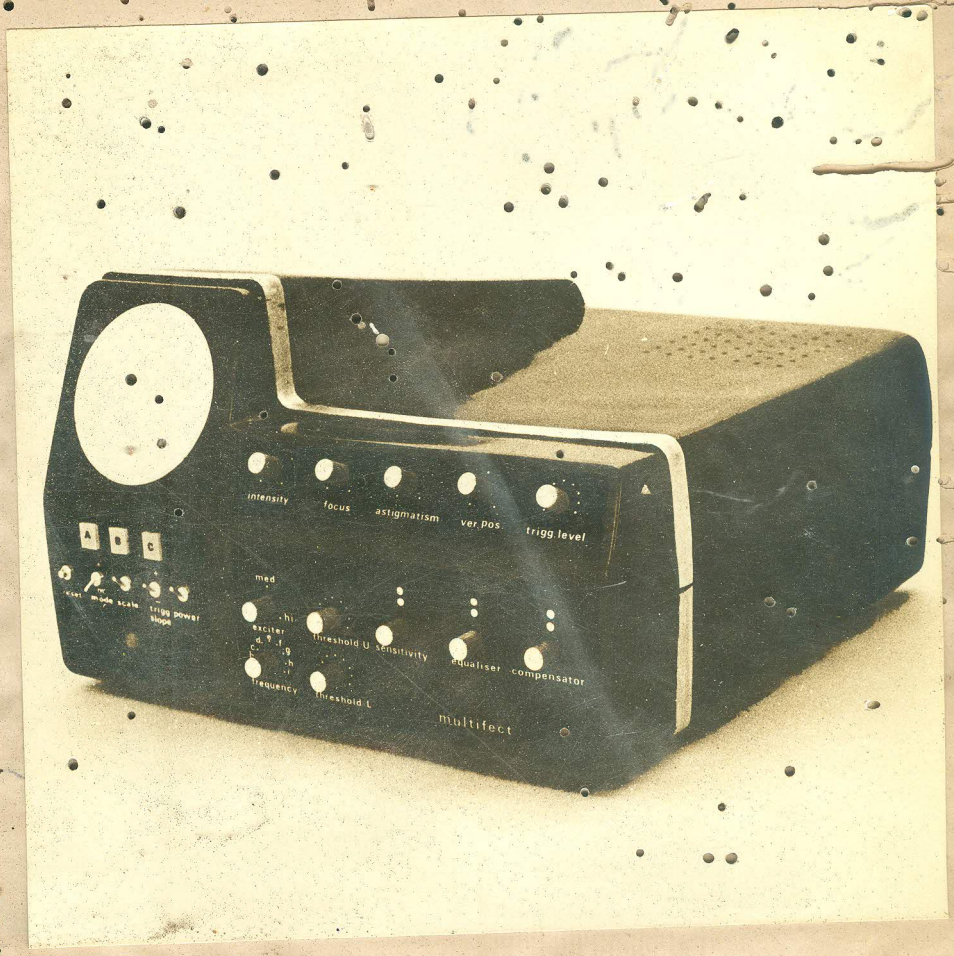


REAR PANEL.

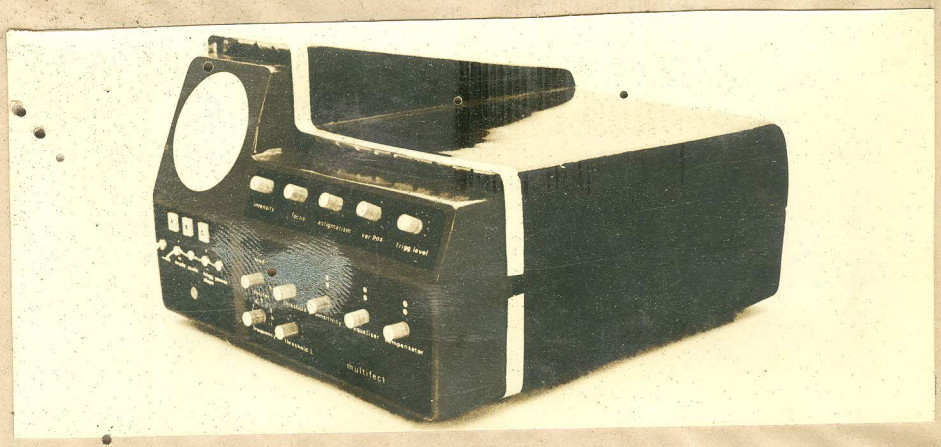
Photographic Documentation.

Photographs:

1. Scale model (Scale 1:2)
2. Top piece being opened around the hinge at the back.
3. Front view.
4. Panel detail - 1.
5. Panel detail - 2.



1



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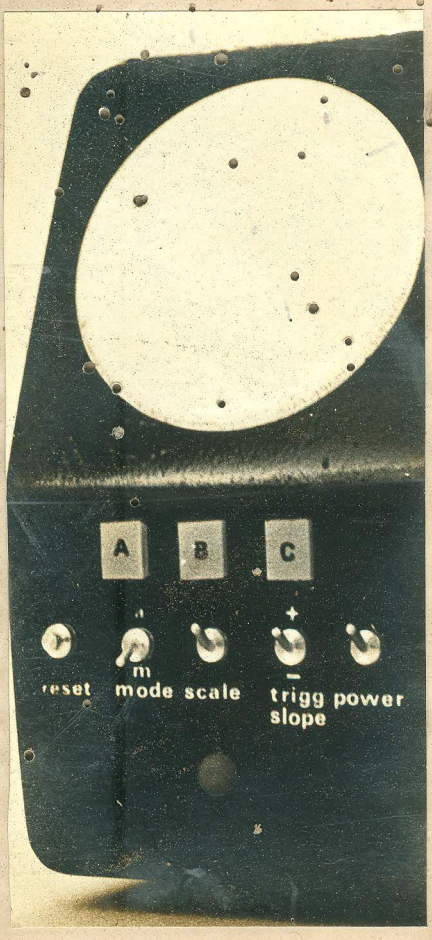
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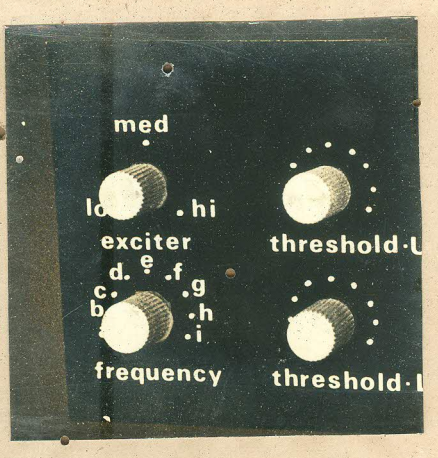
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threshold

5

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Acknowledgements.

My sincere thanks are due to
Prof. S. Nadkarni
Shri M. Chattopadhyay
Shri A. G. Rao

for their able guidance.

and I.D.C. staff and students for their friendly help.

Special acknowledgements are due to
Shri Godbole
Shri Dhole
Shri Kudekar
Shri Kulkarni
of Technofour, for suggesting the problem and providing all the information.