UCRL--21296

DE90 009528

Final Report of Improved Crystal Bending Techniques

J.D. Silver
C.T. Chantler
Clarendon Laboratory

Lawrence Livermore National Laboratory

Final Report on Improved Crystal Bending Techniques Applied to the LLNL Dual-arm Johann mounting X-ray Spectrometer

Re: contract # P.O. 2142003

J.D.Silver, C.T.Chantler, Clarendon Laboratory, Oxford OX1 3PU

Introduction:

Earlier investigations using the LLNL Spectrometer have revealed several limitations to the resolution of observed spectral lines.

The first is the broadening due to the finite target source, together with secondary effects due to the bowing of the target. Other limitations relate to the target and spectrometer geometry, and in particular to the small (2R=30cm) Rowland Circle radius. At small radii the production of a 'perfect' curvature becomes increasingly difficult as distortions of the mosaic spread of crystallite angles are introduced by the stress. This is particularly true of lattice planes with three non-zero Miller indices (e.g. Si111 compared to Si220) and of stiff or thick crystals (e.g. silicon and quartz, which will shatter if $> 0.2mm$ crystals are bent to this radius), but small broadening and asymmetrical shifts are also introduced for other crystals. Conversely, soft crystals (such as thin PET) will bend readily to the radius but distort and relax in mountings with fixed bending forces.

This report addresses a set of improvements to the bending techniques for both soft and stiff crystals. The first and most important development is the use of parallel, vertical posts and (symmetrical) bending points driven by micrometers instead of the earlier formed (i.e. pressed) crystals. The primary advantage is that the curvature from a small number of stress points is calculable, reproducible and does not introduce random stresses and distortions over the surface. The major methods used include the 2-point,2-bar mount and the 4-point,4-bar method. Various 4-point,2-bar methods were also used.

The second development is the use of interferometric testing methods. The principle of interferometric measurement of surface profiles is well known in traditional optics, but does not appear to have been used in the present application before. This gives a precise evaluation of the distortions which each bending method gives to the crystals used, and shows the greater strain suffered by soft crystals. In particular, the improvement of the interference pattern after the other adjustments demonstrated that this new method is (i) superior to non-interferometric adjustment, and (ii) able to reduce the imperfection of the curvature to less than ca 6λ over the 2.5cm width of the useful region of the crystal. It also shows that the main effect with soft crystals is to reduce the stability of the fringe pattern in a vertical direction with a smaller and less significant distortion across the width. The latter effect reduces the range of Bragg angles and source locations which may be observed simultaneously (at the high resolution).

The final development deals with the problem of thermal drift in 'static' benders and the relaxation of relatively soft crystals. In particular, earlier experiments observed the relaxation of PET crystals bent under stress after a period of hours. Since typical high-resolution experiments can require 24 hours or so of exposure, a method was required which prevented or compensated for this effect. The method described below uses a capacitative feedback mechanism coupling the rear surface of the bent crystal to a piezo- electrically driven "Inchworm" device for the maintenance of a predefined curvature.

It should be noted that our improvements do not directly address other non-instrumental sources of error and broadening.

Design and Prototype:

Figures 1-4 show mounting arrangements implementing the first development described above. Figures 5-9 show design drawings for the prototype "active" bender. Figures 10-11 show typical optical (He-Ne laser) interferograms displaying the use & value of the interferometric testing methods. Figures 12-13 show a typical spectrum, from a contact print and an enlargement respectively (of hydrogenic iron using ADP crystals) showing the resolution obtained of ca 1600. This spectrum was taken with a non-feedback controlled 2-bar method which was interferometrically aligned. Finally, figures 14-15 show photographs of the prototype.

As in previous mounts, the new device is largely made from aluminium, with steel contacts and screws for the kinematic mount to the spectrometer baseplate. The two insulated posts or bars around which the crystals are bent are also steel, and the inserts and the contacts for the capacitative feedback are copper and insulated from the other contacts by araldite. This insulation is tested immediately after construction.

The screws for the contact points of the kinematic mount are 80TPI, as was used before, but due to the restricted access to these screws they have been shortened and a new tool has been made to manipulate them.

The rear of the mount is dominated by the two Burleigh IW-710 'Inchworm' motors, which are three-stage piezo-electric actuators allowing calibrated travel for 6.25mm to 0.5 micron precision. They are controlled by a 6005 handset for manual travel and adjustment, and by a 6100-2-2-2-2 controller connected to NIM units and electronic circuitry for the operation of the feedback mechanism.

Because of the size of the 'Inchworms', the '2-bar' mount was used in the prototype. This is adequate for relatively stiff crystals but not for thin, soft crystals, since the distortions introduced degrade the image. This method is nonetheless preferred due to the ability of the 'Inchworm' to cover the desired range precisely and to the closed loop display which is useful for testing and for the manual operation in bending the crystal. A subsequent prototype may deal with a method designed to optimise the bending of soft crystals.

The copper contacts slip in from the top of the mount and are fixed by screws pressing upon the edges against a front lip behind the crystal. The front of the inserted assembly is filed or smoothed to a flat surface, avoiding distortions of the signal. The 'Inchworms' are fixed in place by slotted, threaded rings which engage the thread of the 'Inchworms' and clamp them to the side of the aluminium block.

The crystal is supported by the ends of the 'Inchworms' pressing against the rear surface around the front steel bars. It is maintained above the conducting aluminium base largely by this pressure but an insulating insert additionally prevents the crystal from slipping onto the metal. This is done so that the conducting coated rear surface of the crystal is able to provide the capacitative feedback required to the copper insert.

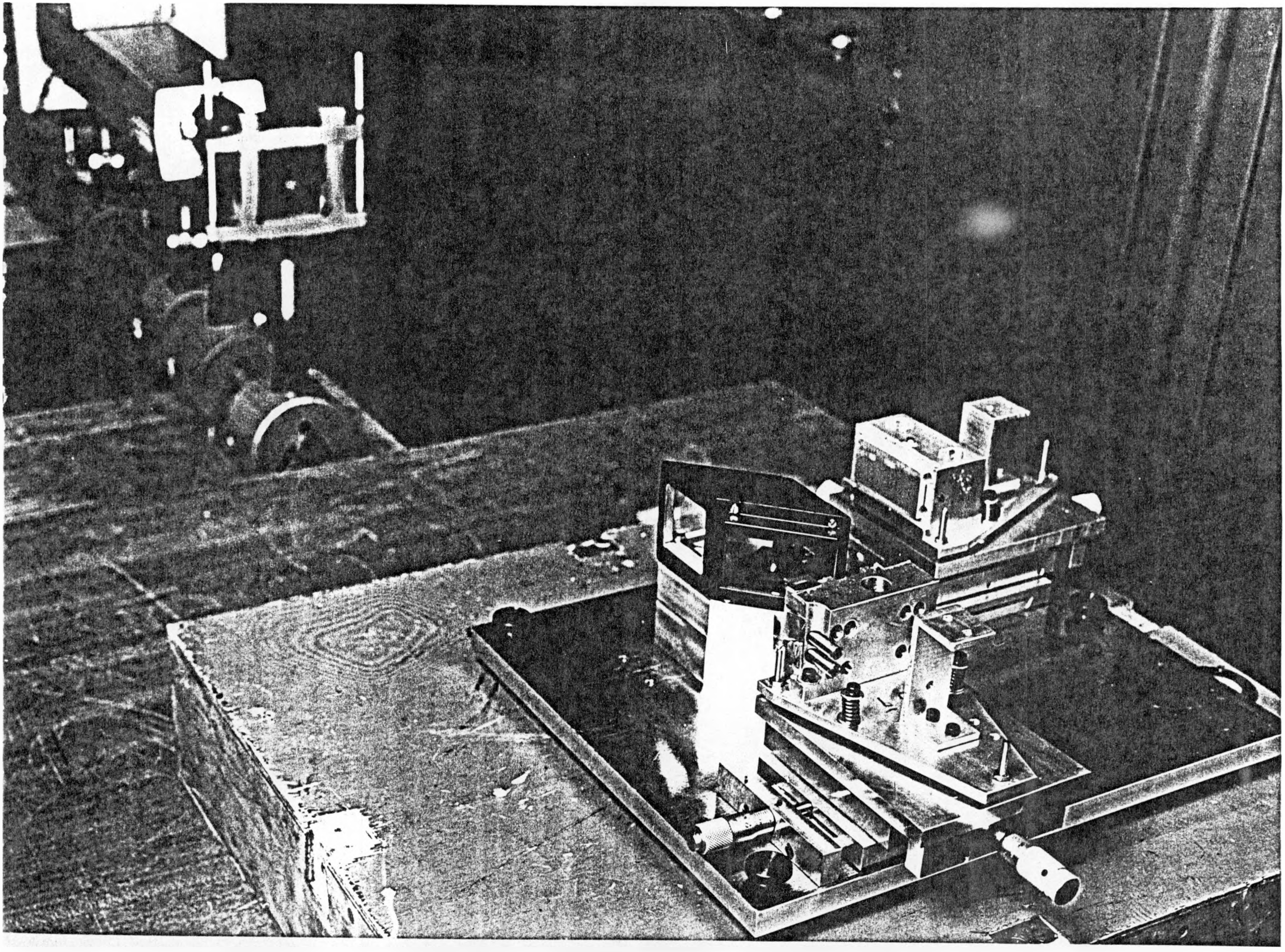
Operation of interferometric testing:

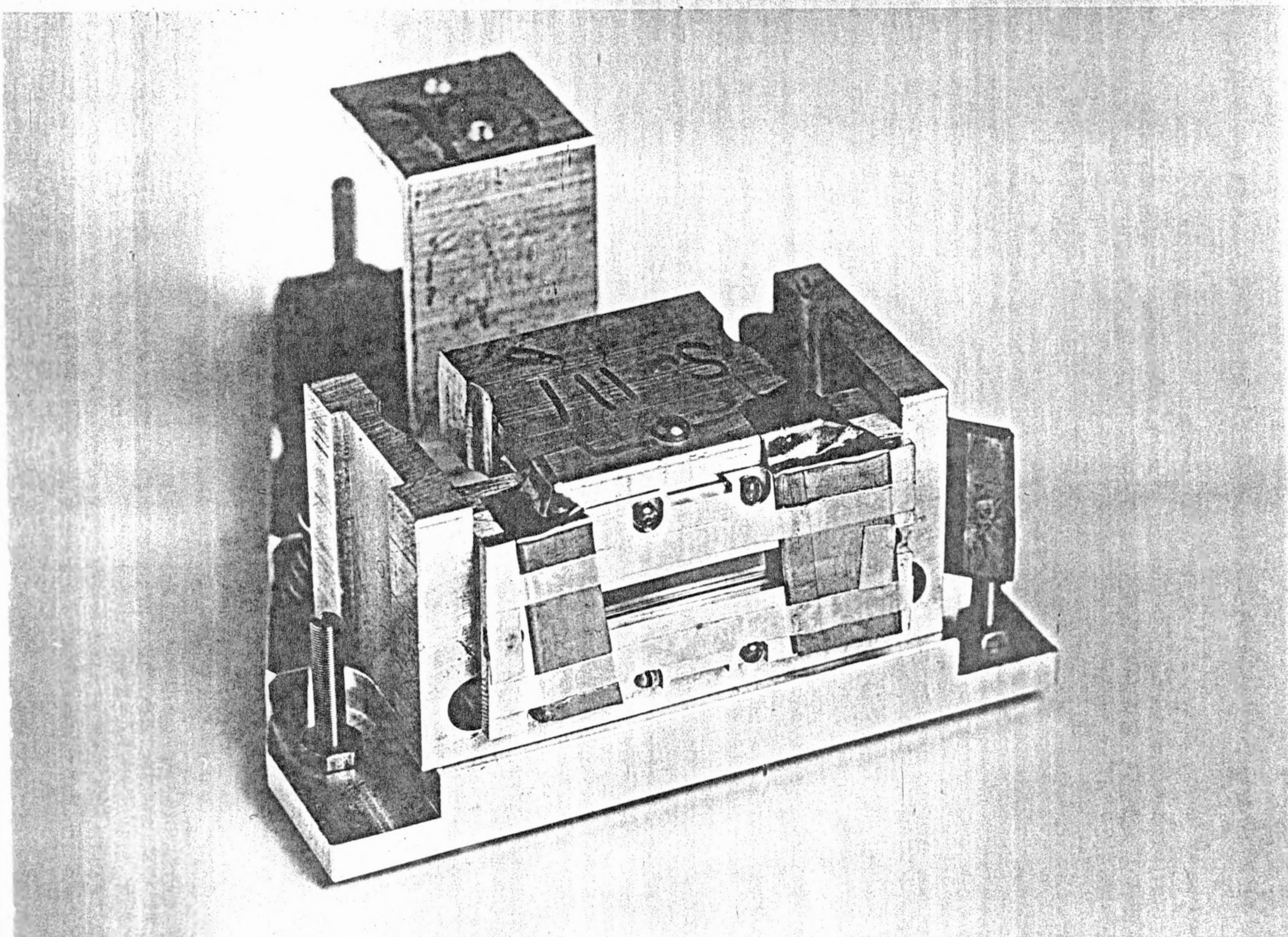
Note the improvement of the interferogram as shown from figures 10 and 11. The first shows a uniformity of the surface to $32\lambda/2$ over the central 20mm with approximately 42 fringes over the whole 25mm of the central region, while the latter shows only 7 fringes over the length of the 25mm central region, and only 1 fringe over the central 20mm. This improvement is replicated in the vertical direction, and is typical of the improvement gained with the interferometric testing.

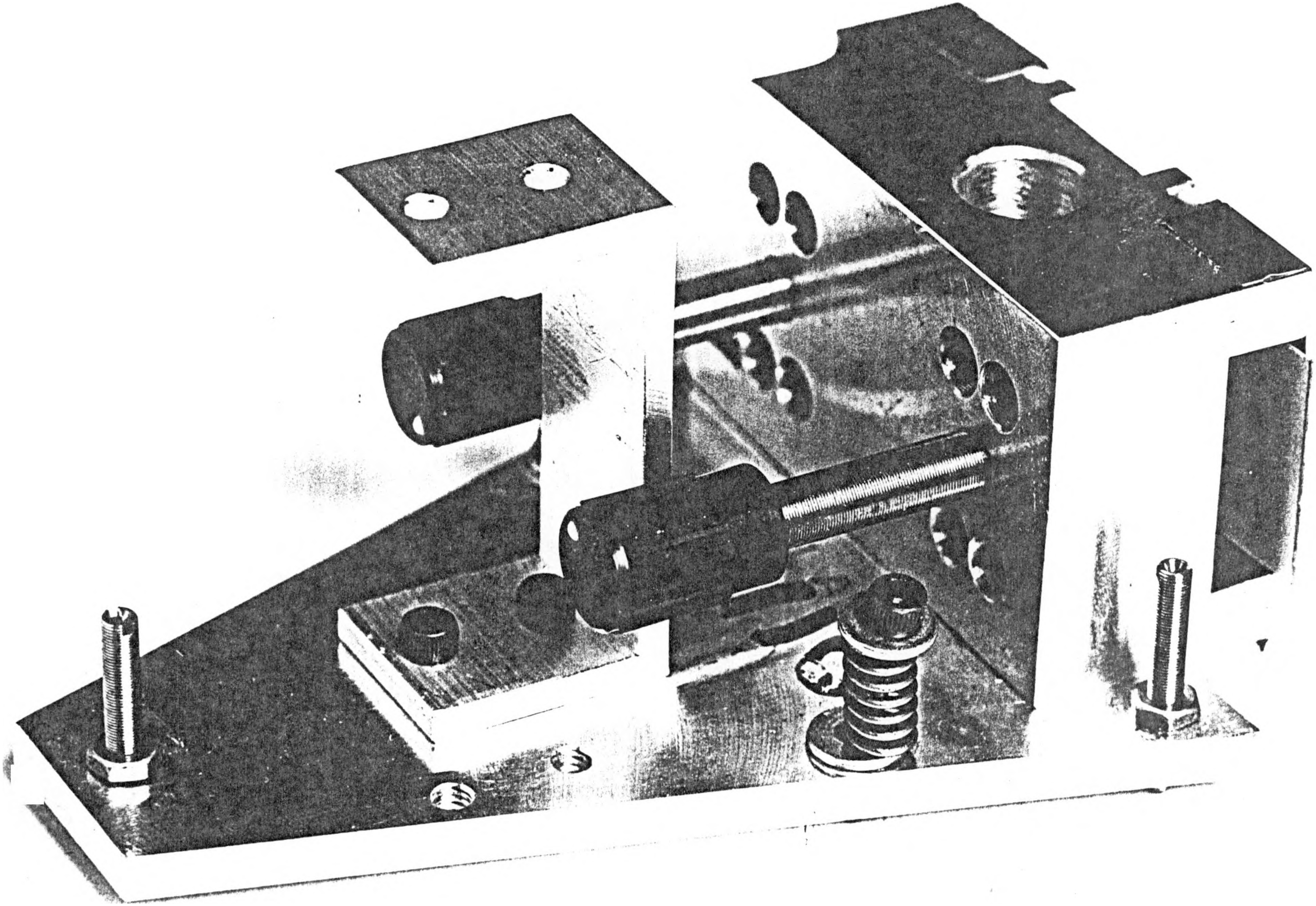
From figures 12 and 13 it may be calculated that the resolution achieved is typically 1600 and can be as high as 1900, compared to an estimate for the hydrogenic iron line of 3000. This estimate arises from the natural line width of 200 000, limited for a *flat* ADP crystal in first order diffraction at 7 Angstroms by the rocking curve to 7200, and broadened by the Johann width aberrations to approx. 3000. The result may also be compared to a previous experiment using the 'old' bending techniques which provided a resolution of only 930.

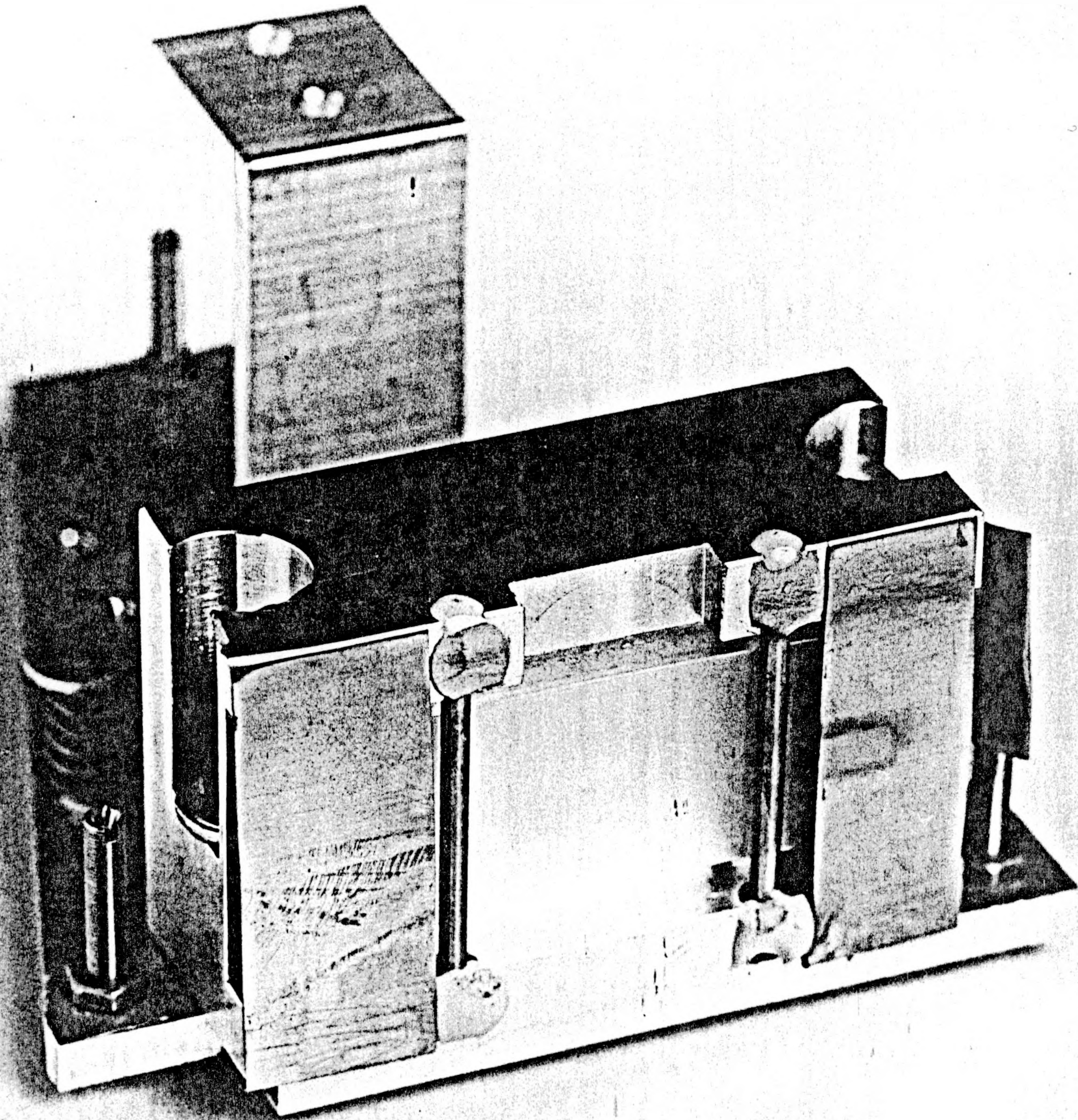
We are thus able to conclude that the developments have constituted a significant improvement upon the earlier bending and testing methods.

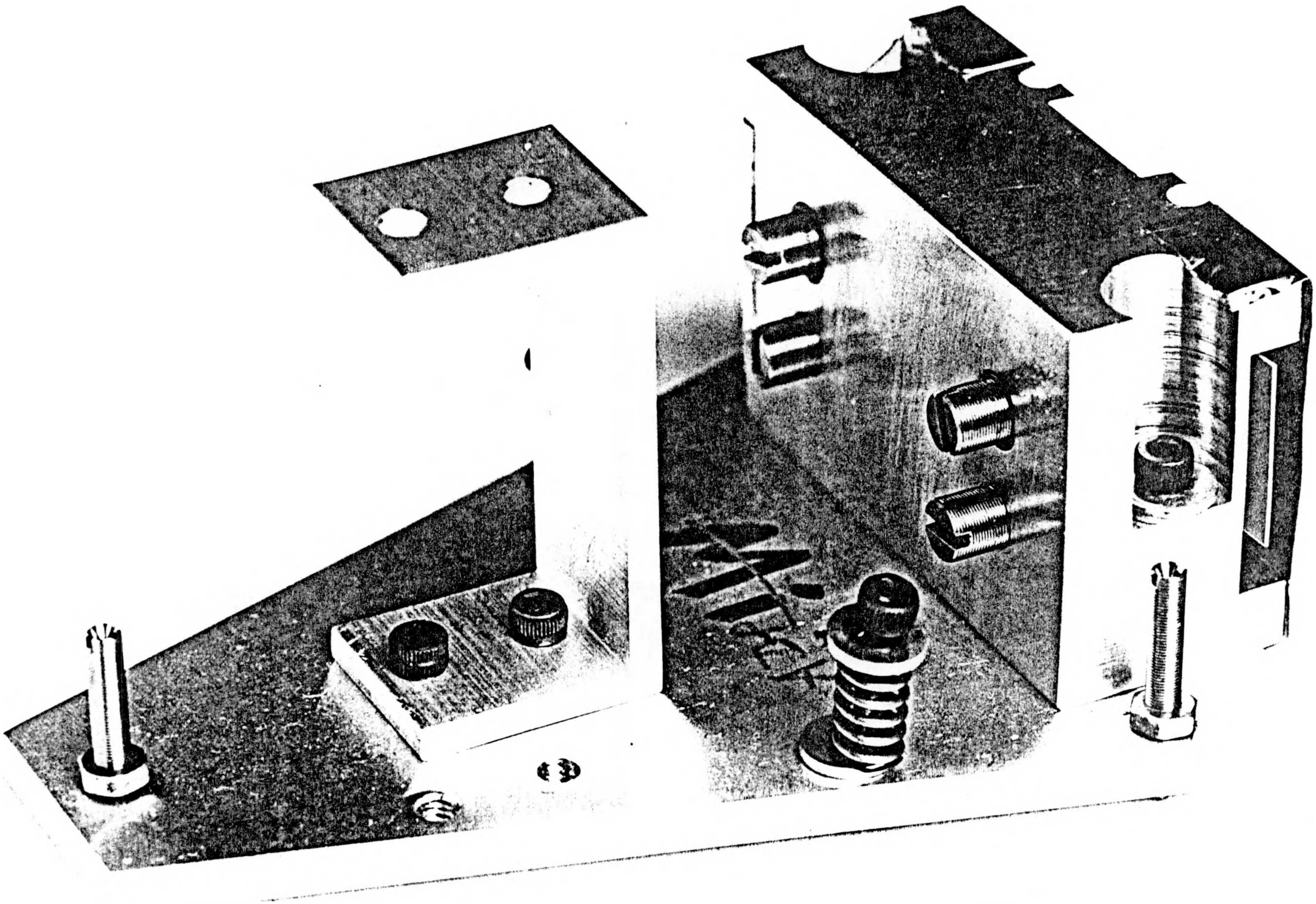
List of Figures:











Clarendon Laboratory · Parks Road · Oxford

Telephone: Switchboard (0865) 272200

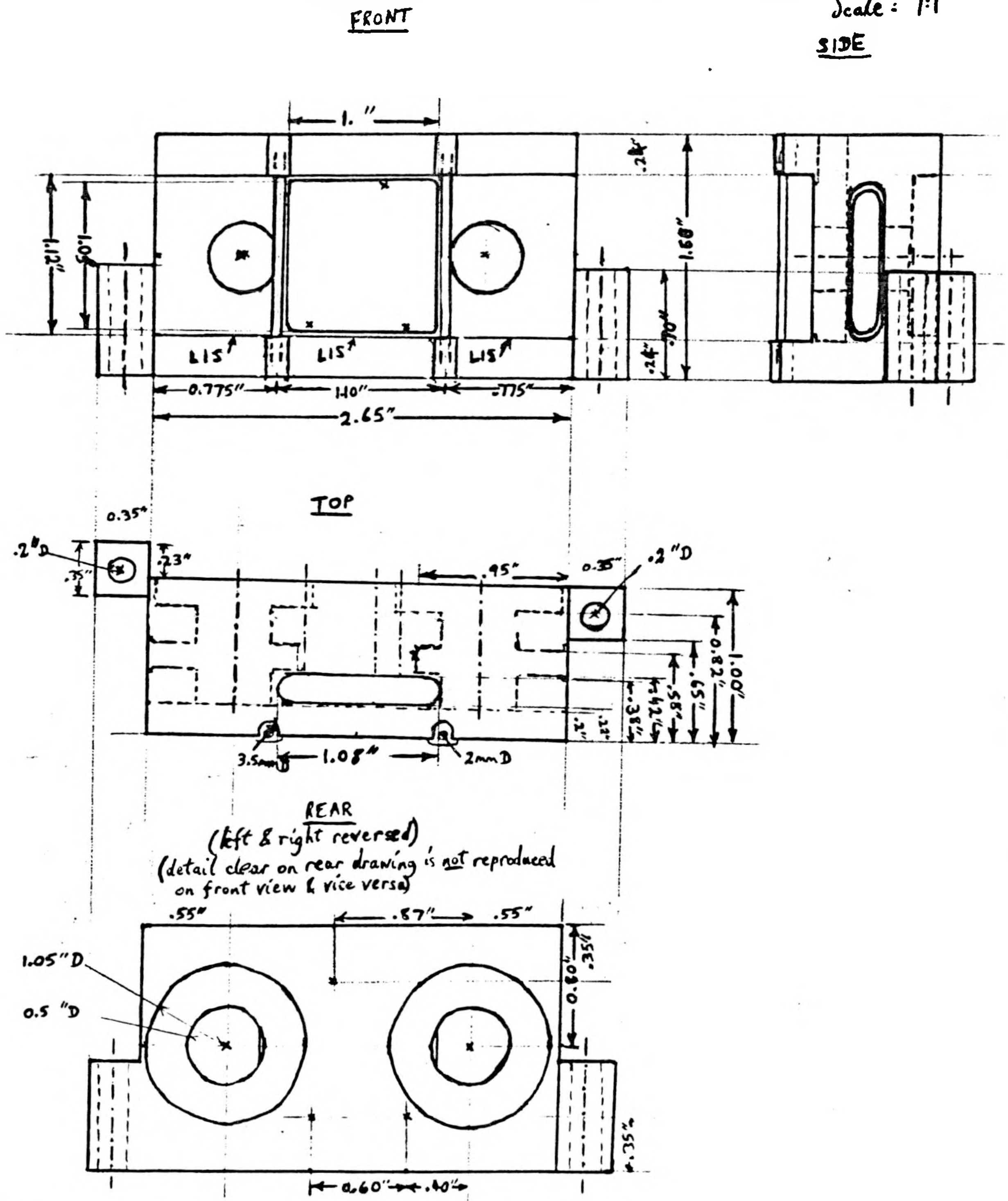
Direct Line (0865) 273348

Telex: 83154

Postal Address Clarendon Laboratory
Oxford
OX1 3PU

Figure 5: Prototype design. Holding Block of mount.

Scale: 1:1



Composition: Aluminium; stainless steel bars and screws;
1mm thick lowe insulating support (LIS)
fixed in 3 sections with araldite to base of crystal platforms;
Bars held in place (& parallel) with insulating ARALDITE System 2004
(linear coefficient of expansion $(90-105)\times10^{-6}/^{\circ}C$)

Clarendon Laboratory · Parks Road · Oxford

Telephone: Switchboard (0865) 272200

Direct Line (0865) 273348

Postal Address Clarendon Laboratory
Oxford
OX1 3PU

Telex: 83154

Figure 6: Prototype design: Holding plate

TOP VIEW

Scale: 1:1
Dimensions: mm

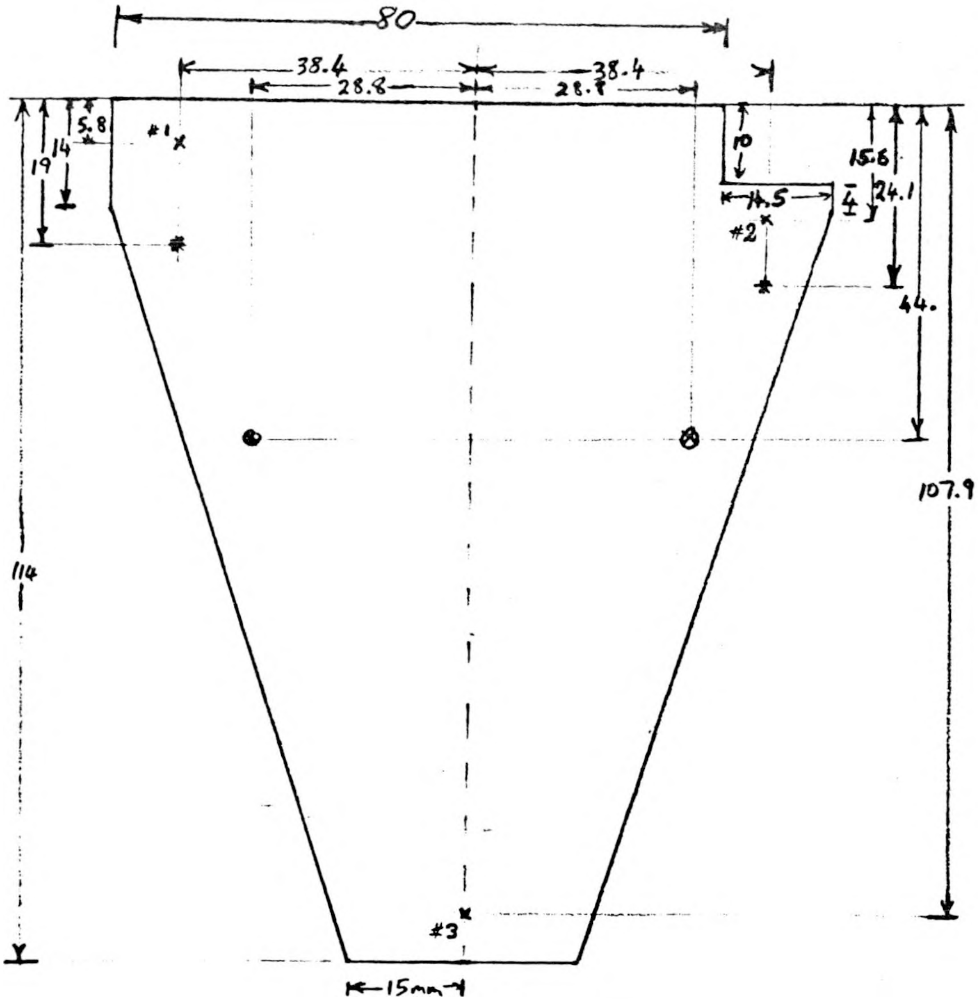
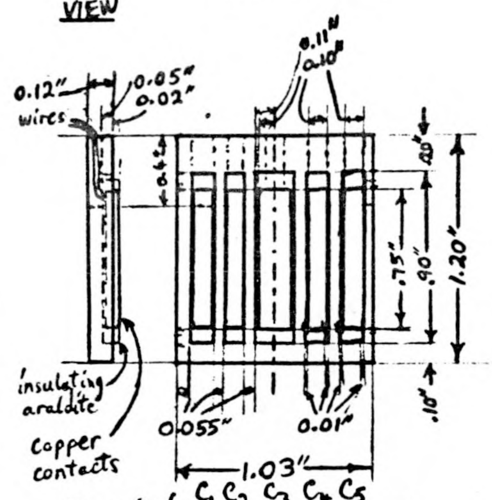


Figure 7: Prototype design: Copper insert

SIDE VIEW

FRONT VIEW



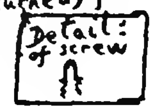
The set of 5 coaxial wires leads to each copper contact, insulated from the base of the insert by araldite:
A7103 + CIBA H7956 Resin System
(linear coefficient of expansion $(95\text{-}100) \times 10^{-6}/C$

For a flat (non-bent) crystal, the resulting capacitances C_1 to C_5 from the contacts would obey $C_1 \sim C_2 \sim C_4 \sim C_5 \sim \frac{1}{2} C_3$.

Composition: Aluminium

×: 6-80 TPI D&T through (needs special tap)

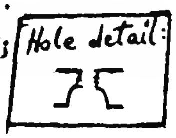
#1 & 2: 25mm steel screw with slotted head & round (turned) foot for kinematic mount + brass fixing nut.



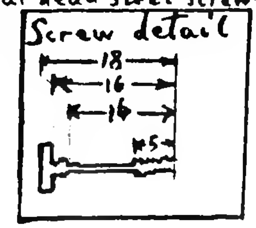
#3: 17mm "

✱: 6-32 TPI D&T through for Holding block.

⊗: 6-32 TPI D&T through for fixing screws; 'C-bore' for captured screws.



Hexagonal head steel screw + spring + washer:



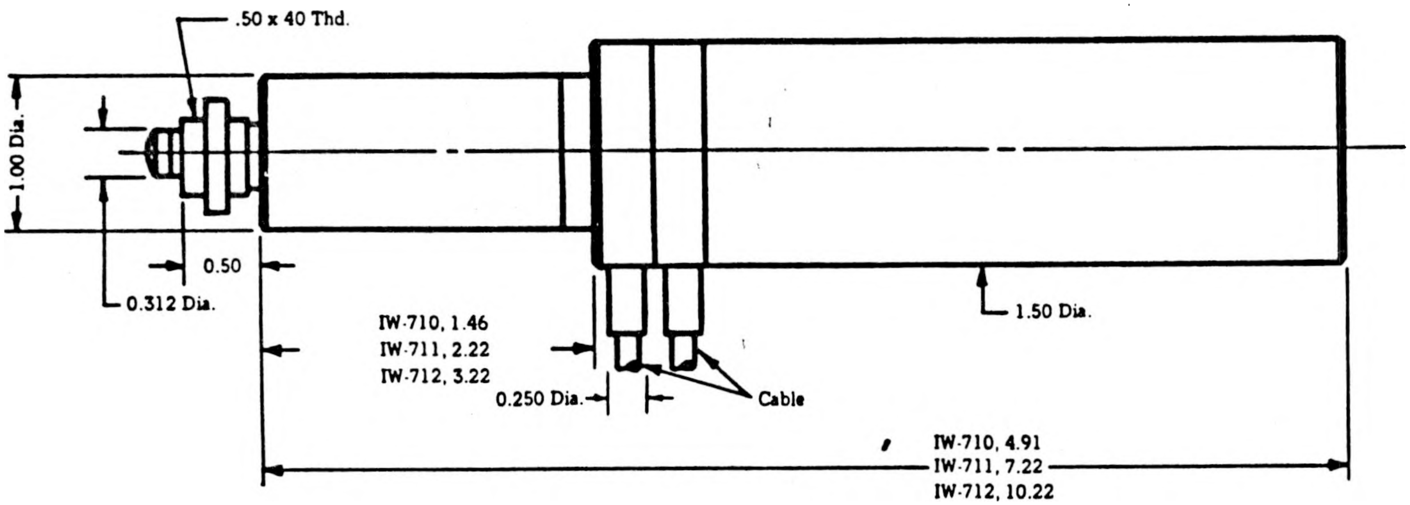
Clarendon Laboratory · Parks Road · Oxford

Telephone: Switchboard (0865) 272200
Direct Line (0865) 273348
Telex: 83154

Postal Address Clarendon Laboratory
Oxford
OX1 3PU

OUTLINE DIMENSIONS

This model: IW-710



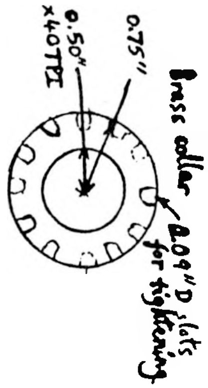


Figure 8: Burleigh Inchworm & collar.

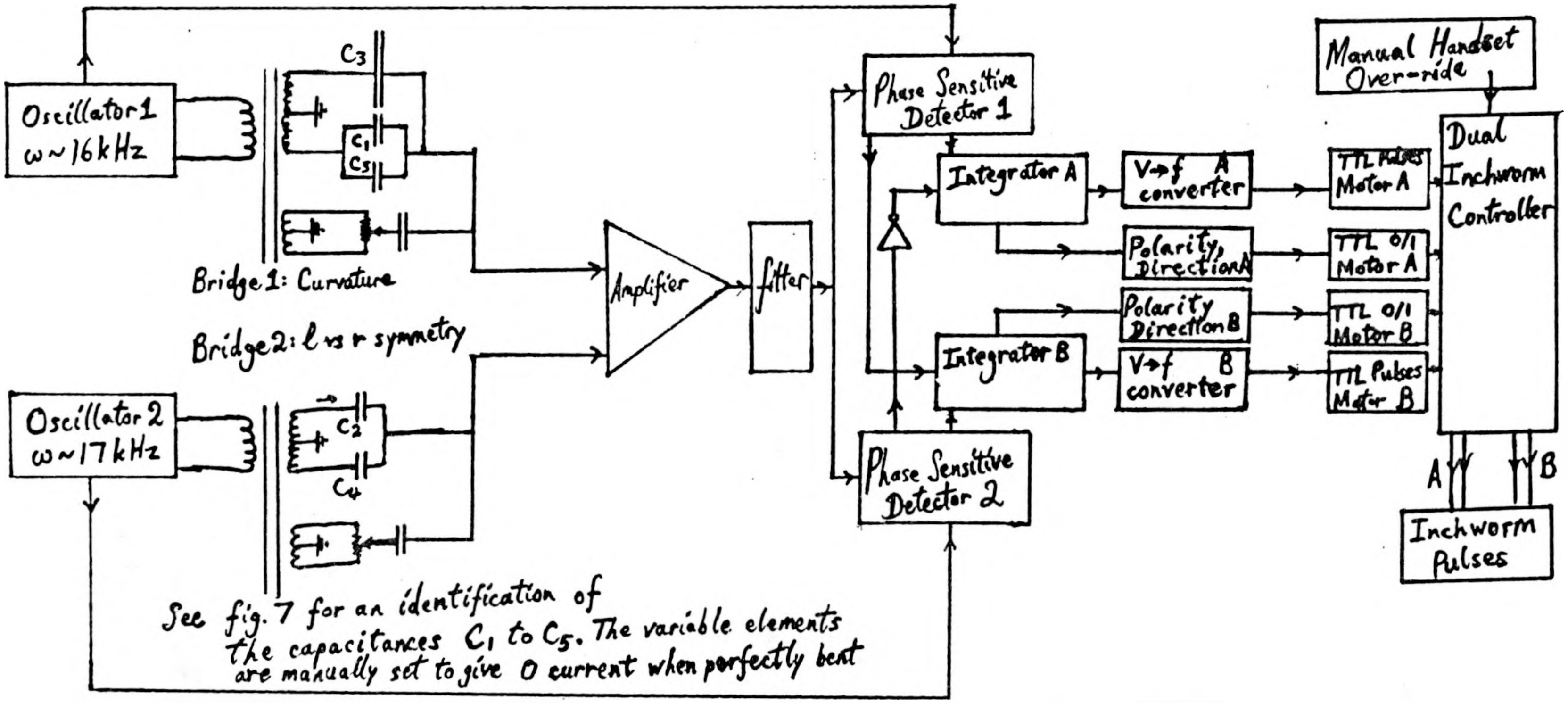
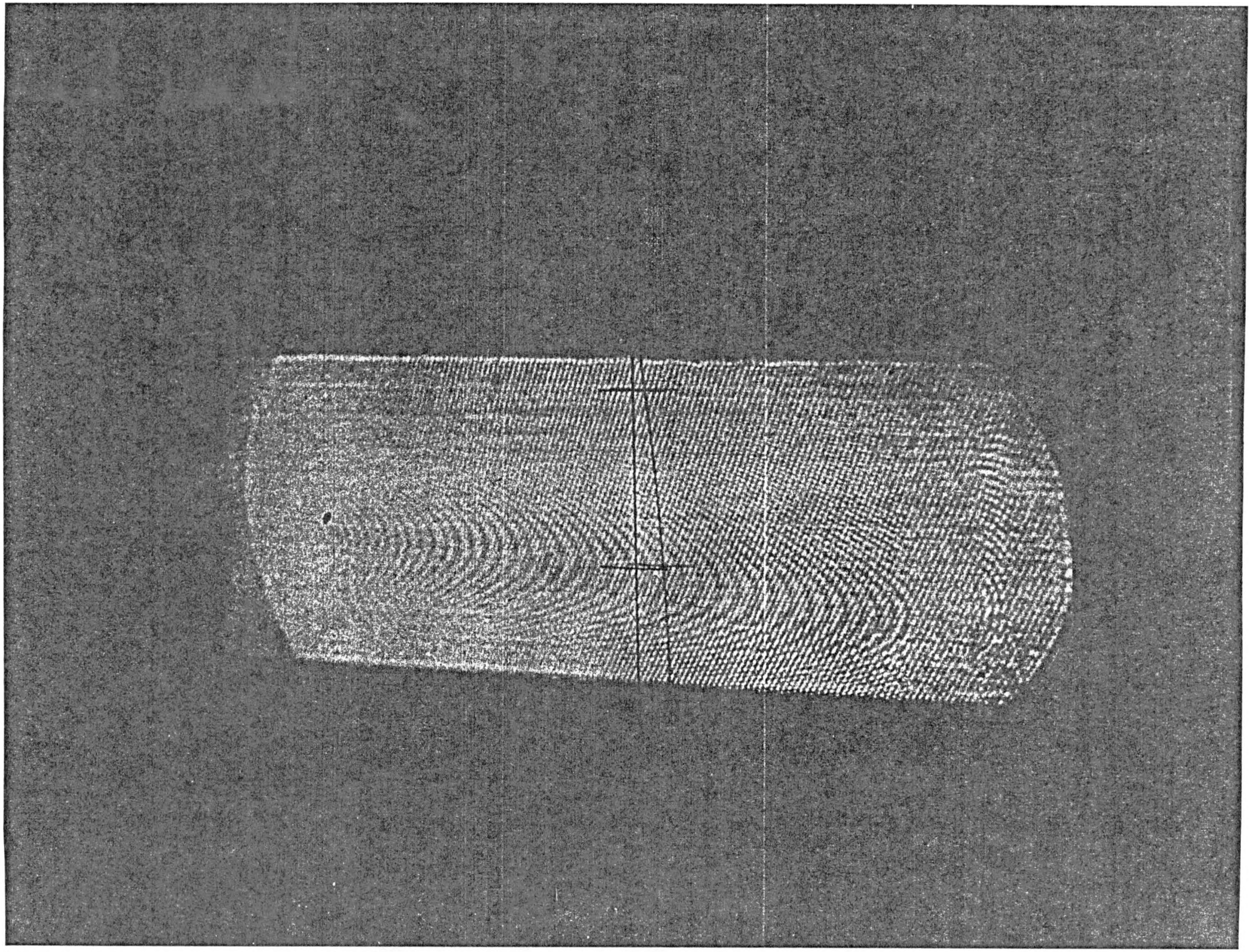
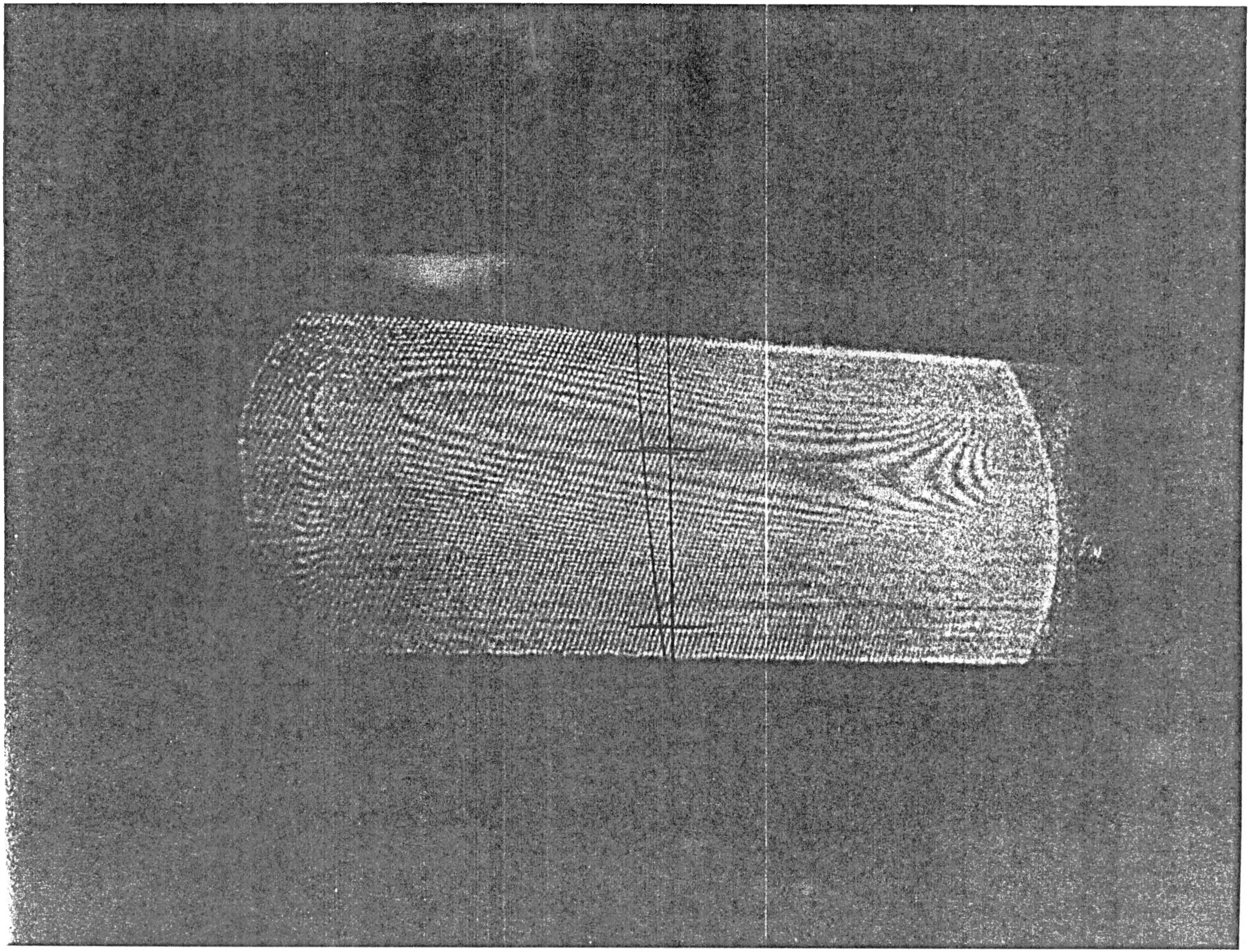
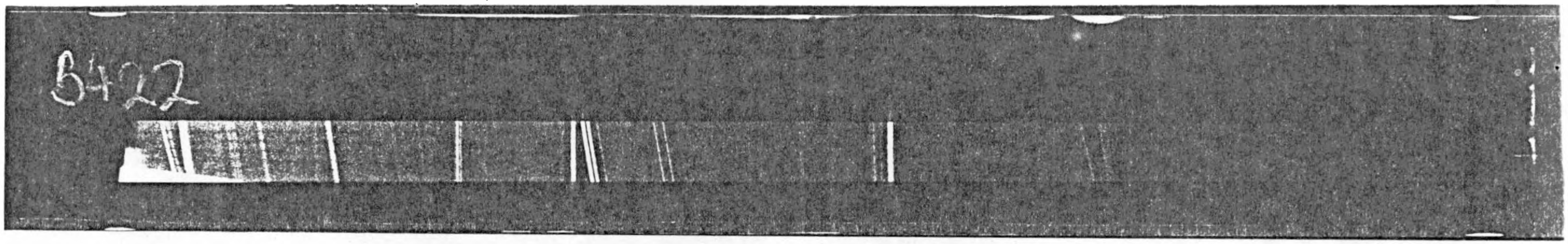
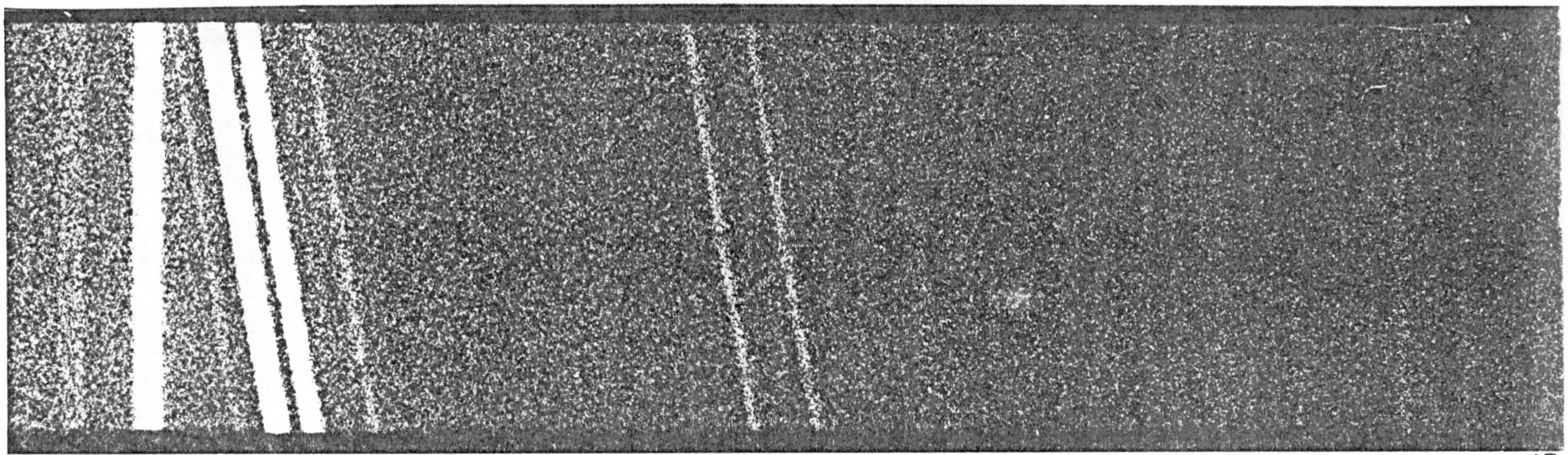


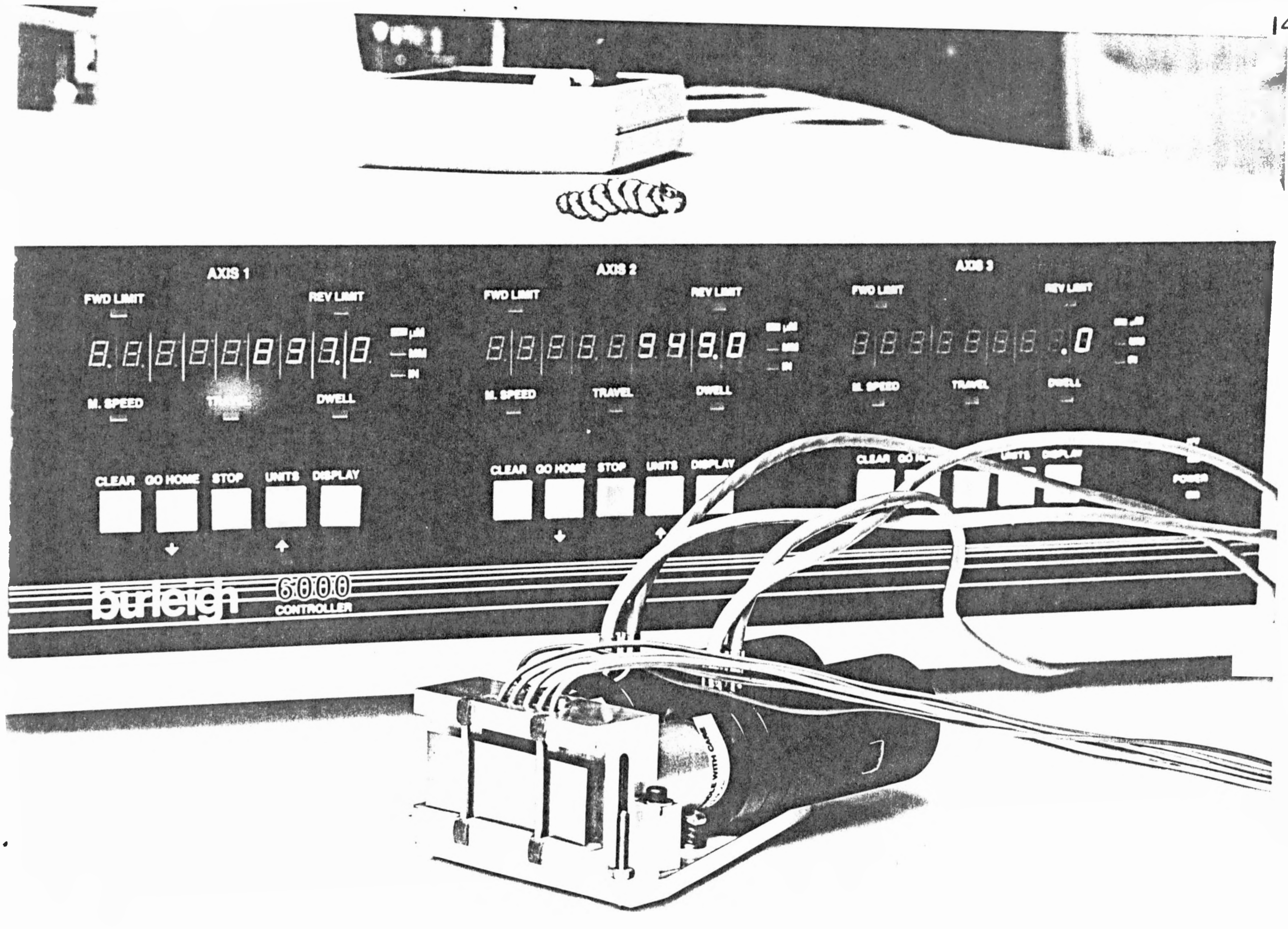
Figure 9: Schematic of electronics

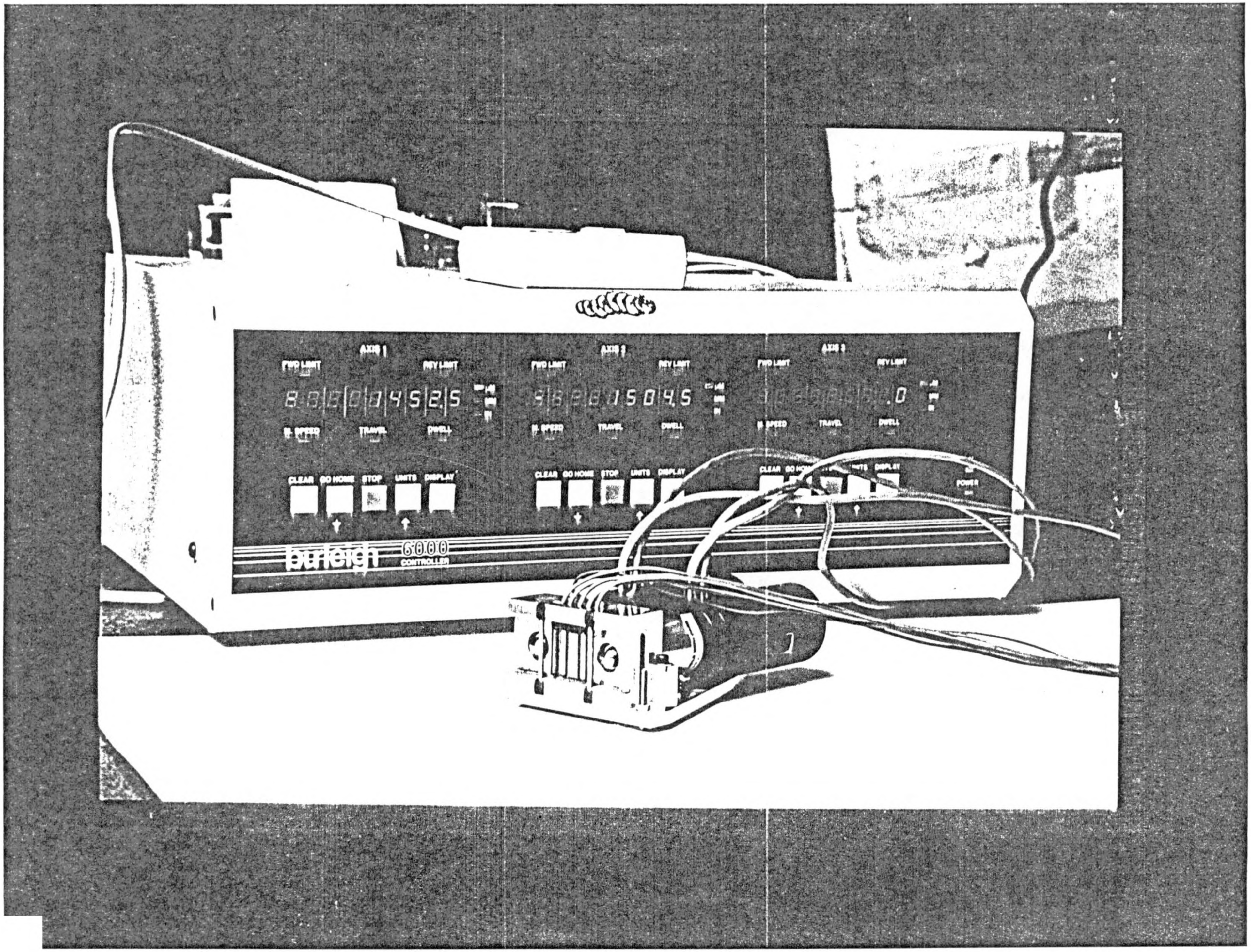





B422




AXIS 1
FWD LIMIT
REV LIMIT
M. SPEED
DWELL
CLEAR
GO HOME
STOP
UNITS
DISPLAY
AXIS 2
TRAVEL
AXIS 3
burleigh
6000
CONTROLLER


AXIS 1
FWD LIMIT
REV LIMIT
M. SPEED
TRAVEL
DWELL
CLEAR
GO HOME
STOP
UNITS
DISPLAY
POWER
burleigh
6000
CONTROLLER