OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D00522

Distr.
LIMITED

ID/WG.56/16
3 March 1970

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Expert Group Meeting on the Development of Engineering Design Capabilities in Developing Countries

Vienna, 11 - 15 May 1970

CENTRE FOR PRECISION MECHANICS 1/

by

A. Jentet
Head of Methods Control Department
S.A. Andre Citroen
Paris, France

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.70-1128

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.56/16/Add.1
20 March 1970
ORIGINAL: ENGLISH

Expert Group Meeting on the Development of Engineering Design Cap bilities in Developing Countries

Vienna, 11 - 15 May 1970

CENTRE FOR PRECISION MECHANICS

by

A. Jentet
Head of Methods Control Department
S.A. Andre Citroen
Paris, France

Addendum

Page 4 - The following should be added after the last paragraph of the Introduction:

This study gives the figures of the investment expenditures needed for setting up a mechanical precision center.

Of course these investments are justifiable only if their profit earning capacity can be guaranteed the producing industrial area to which such a center is attached must justify the investments.

id.70-1460

Distr.
LIMITED

ID/WG.56/16/Add.2
7 April 1970

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Expert Group Meeting on the Development of Engineering Design Capabilities in Developing Countries

Vienna, 11 - 15 May 1970

CENTRE FOR PRECISION MECHANICS

by

A. Jentet
Head of Methods Control Department
S.A. Andre Citroen
Paris, France

ADDENDUM

id.70-1802

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

CONTENT

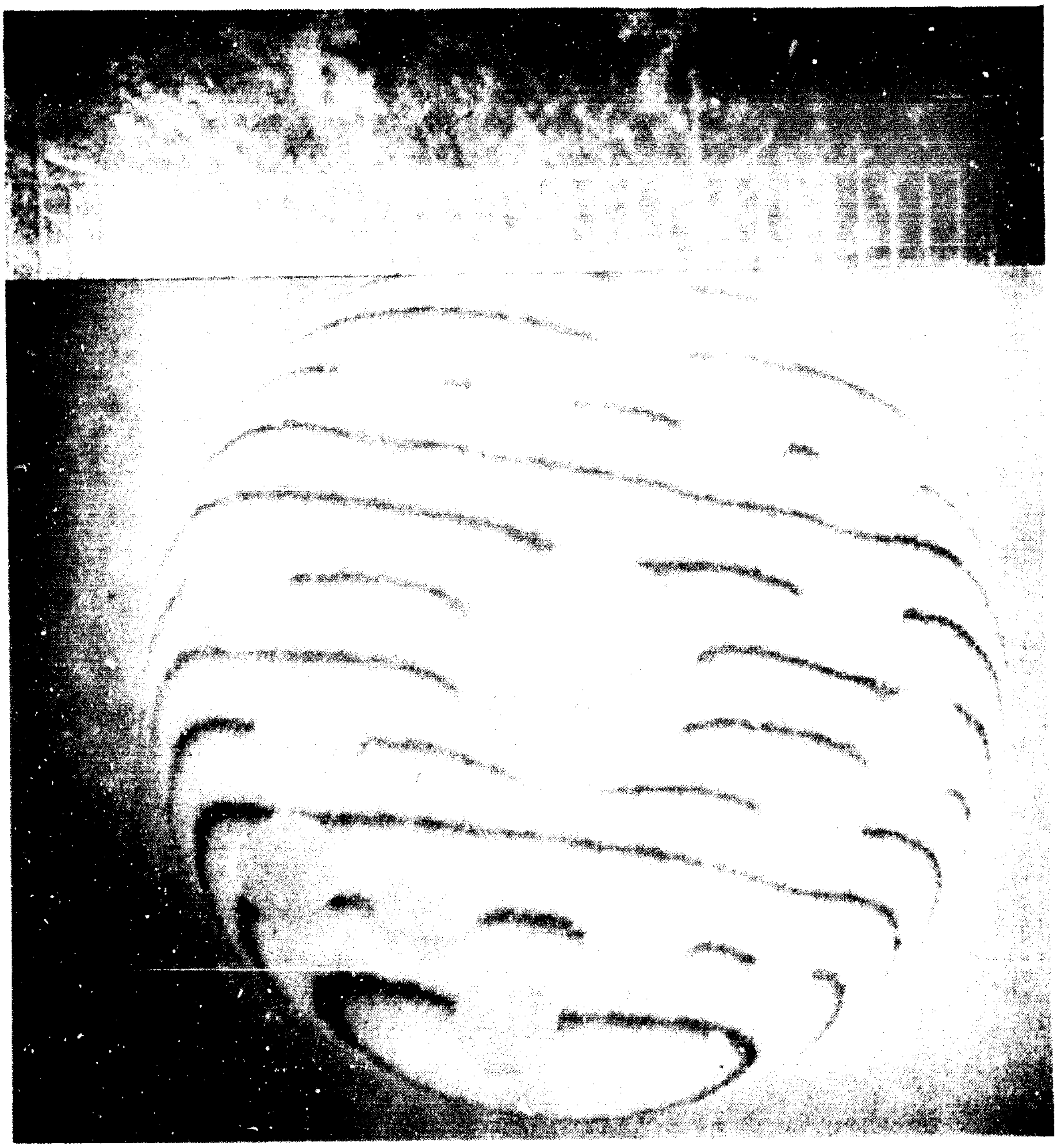


Fig 1 - Mesure de planéité d'une pièce d'organe hydraulique à l'aide du plan optique

Fig 1 - Evenness test of a part of an hydraulic system made by optical flat

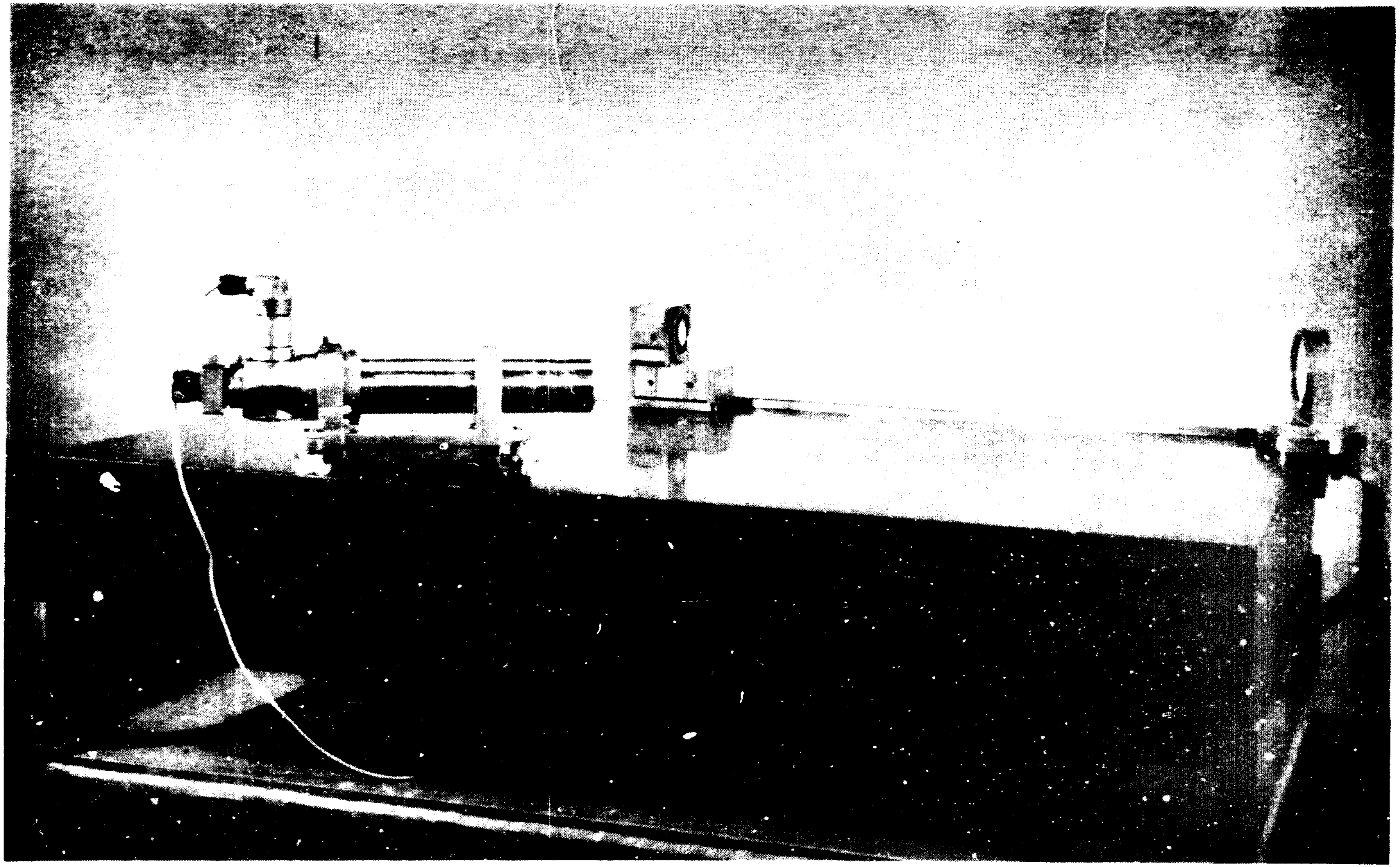


Fig 2 - Mesure de planéité d'un marbre en diabase à l'aide de l'autocollimateur

Fig 2 - Evenness test of a diabase bench face plate made by autocollimator

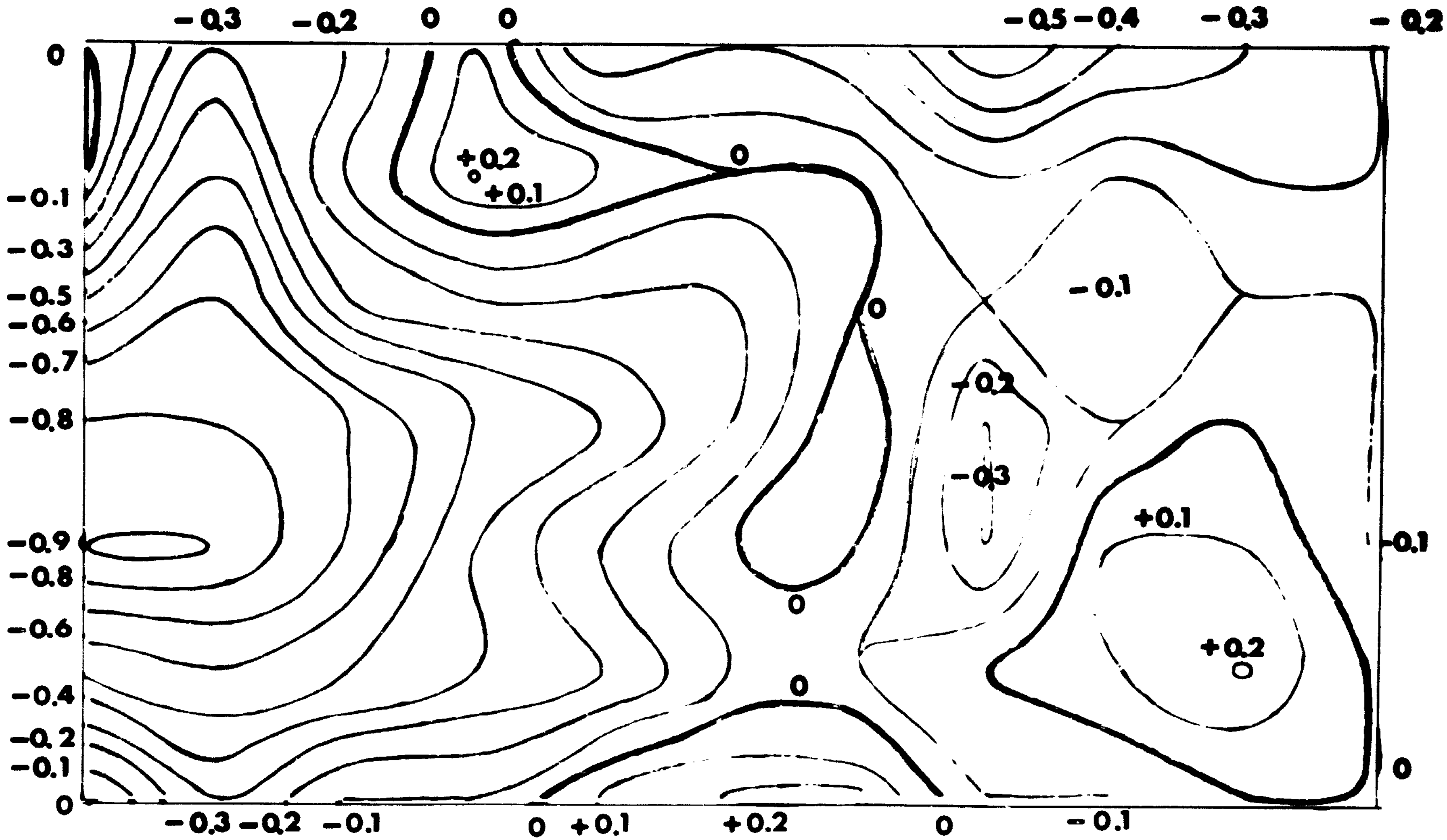


Fig 3 - Carte du marbre (cotes en µ)

Fig 3 - Map of the bench face plate (dimensions in µ)

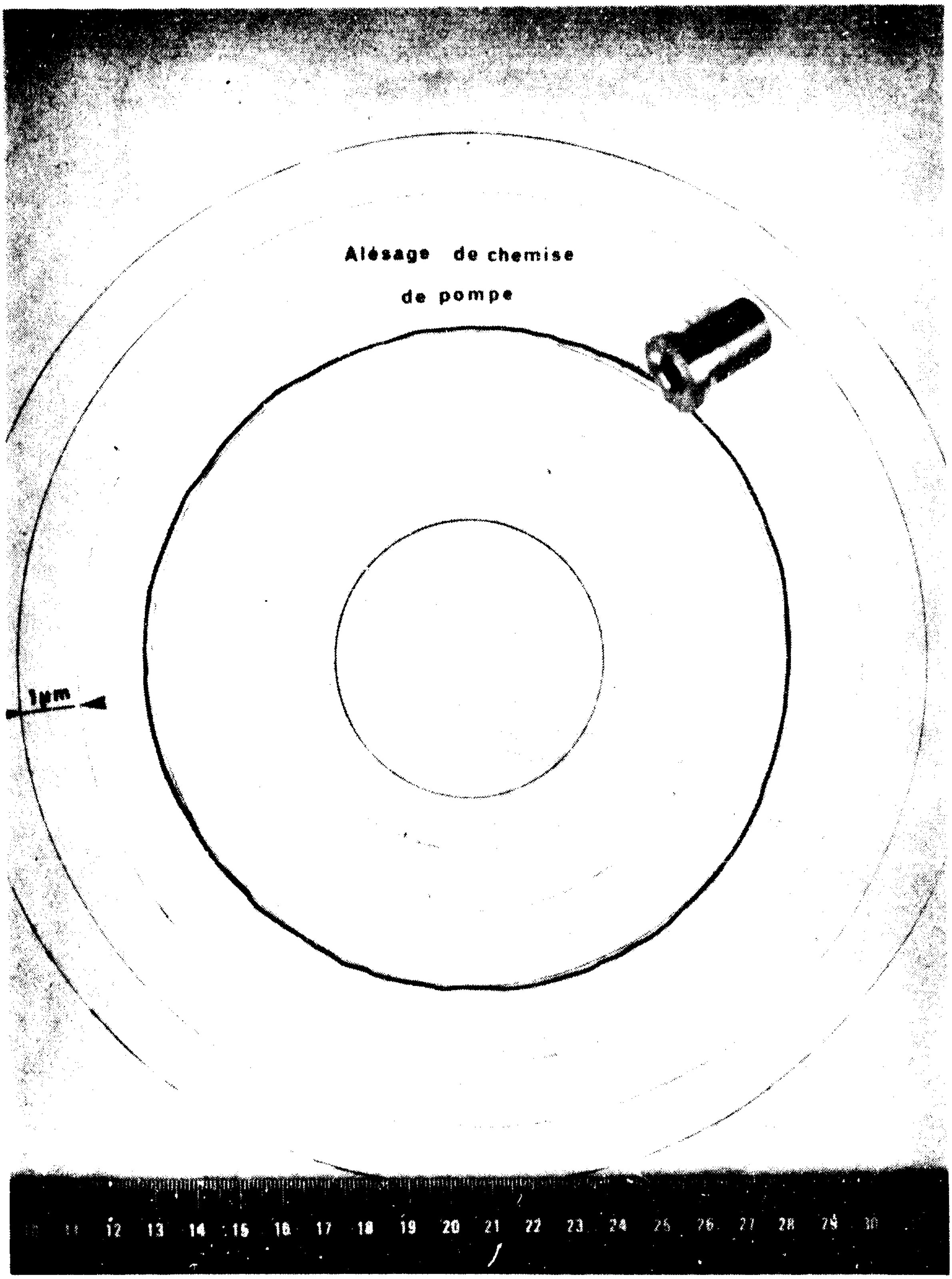


Fig 4 - Circularité d'une pièce d'organe hydraulique

Fig 4 - Circularity test of a part of an hydraulic system

Fig 5 - Contrôle d'une bille

Fig 5 - Inspection of a ball

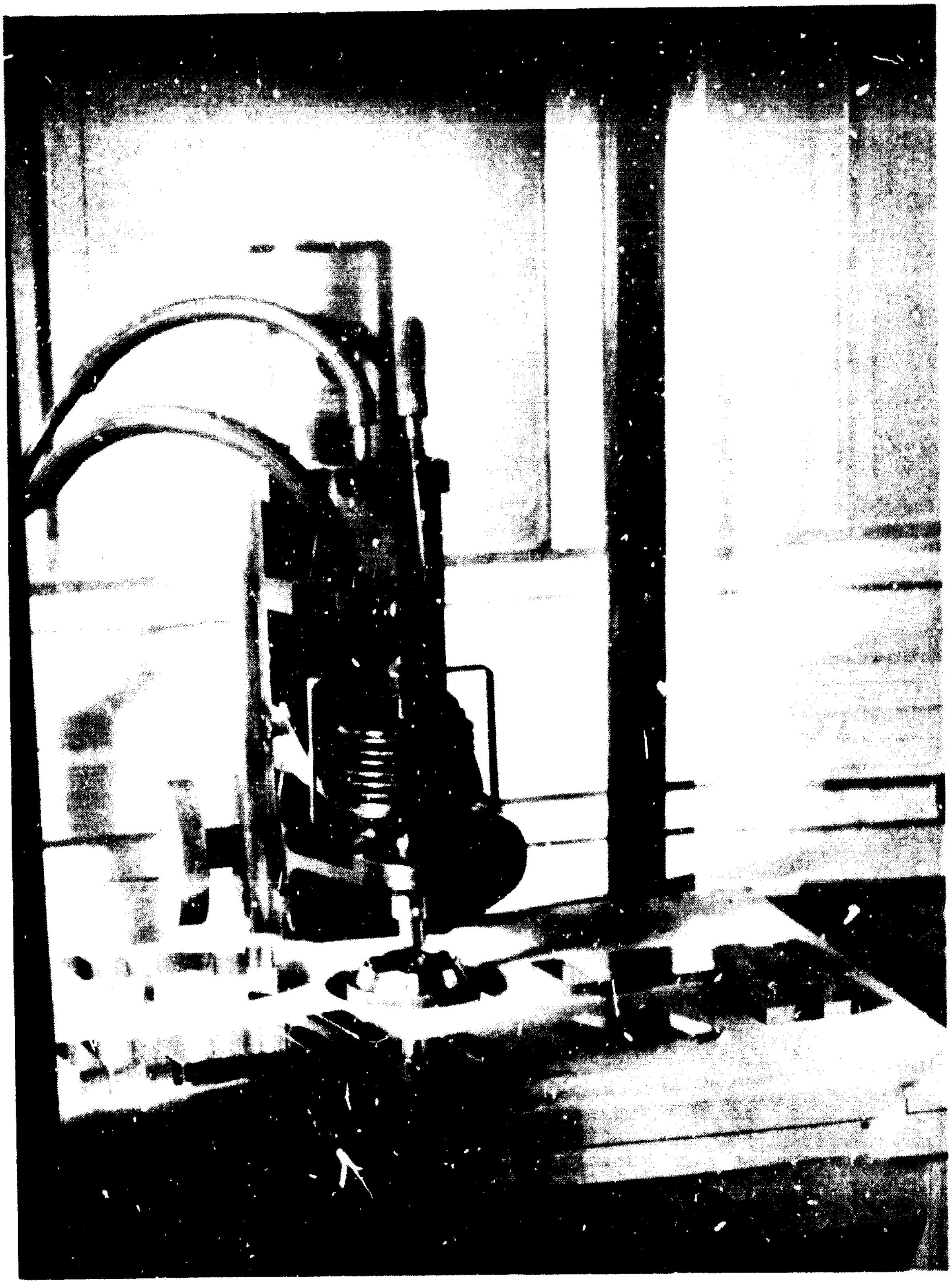


Fig 6 - Comparaison des cales étalons secondaires avec les cales étalons primaires
(Sensibilité 0,01 µ)

Fig 6 - Comparison of secondary standard gauge blocks with primary standard gauge blocks
(Sensitivity 0,01 µ)

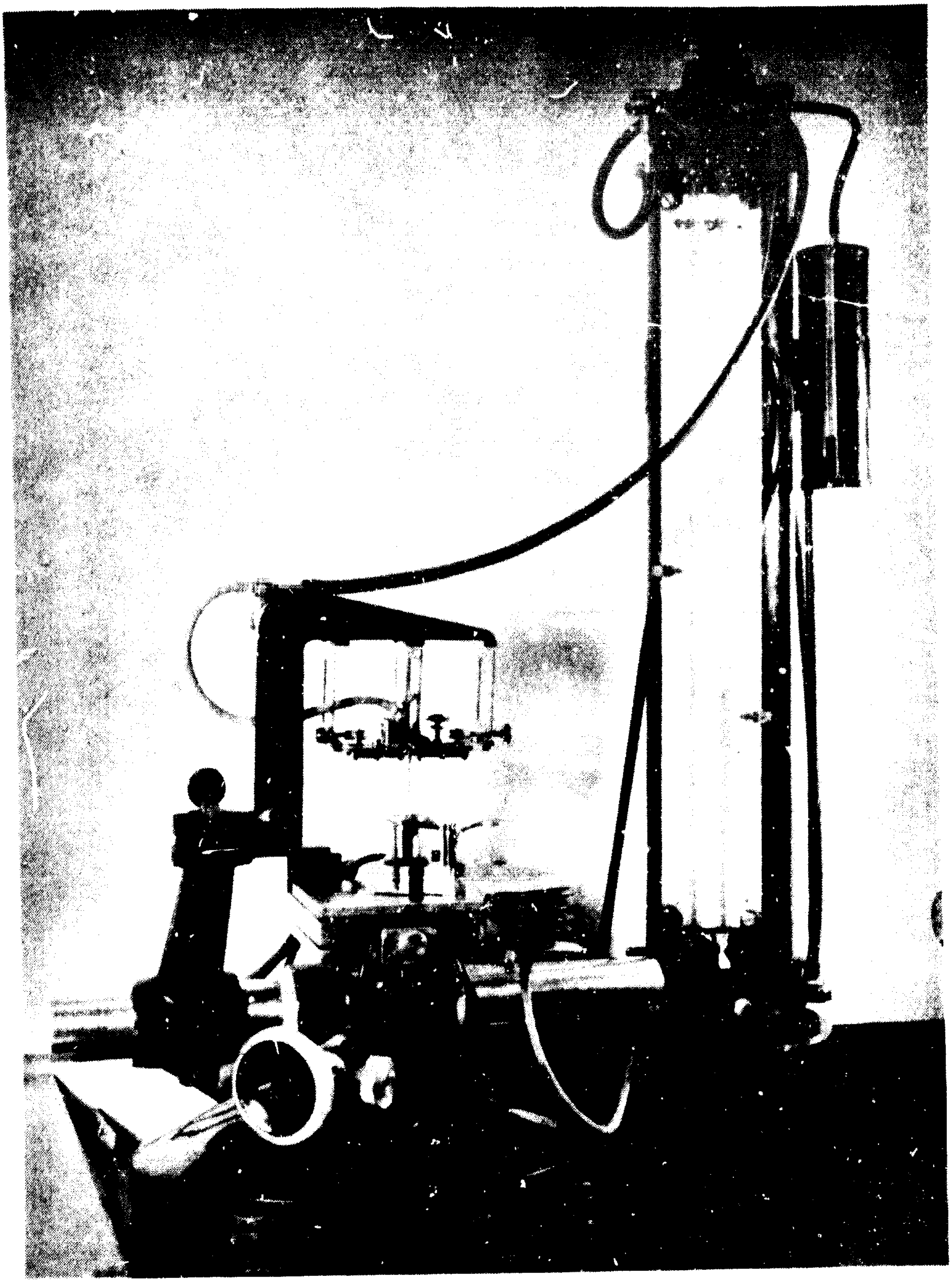


Fig 7 - Banc de mesure du diamètre des bagues étalons

Fig 7 - Diameter inspection bench of ring gauges

Fig 8 - Mesure du diamètre des bagues étalons. Précision 0,1 μ , Sensibilité 0,03 μ

Fig 8 - Diameter test of ring gauges. Precision : 0,1 μ ; Sensitivity : 0,03 μ

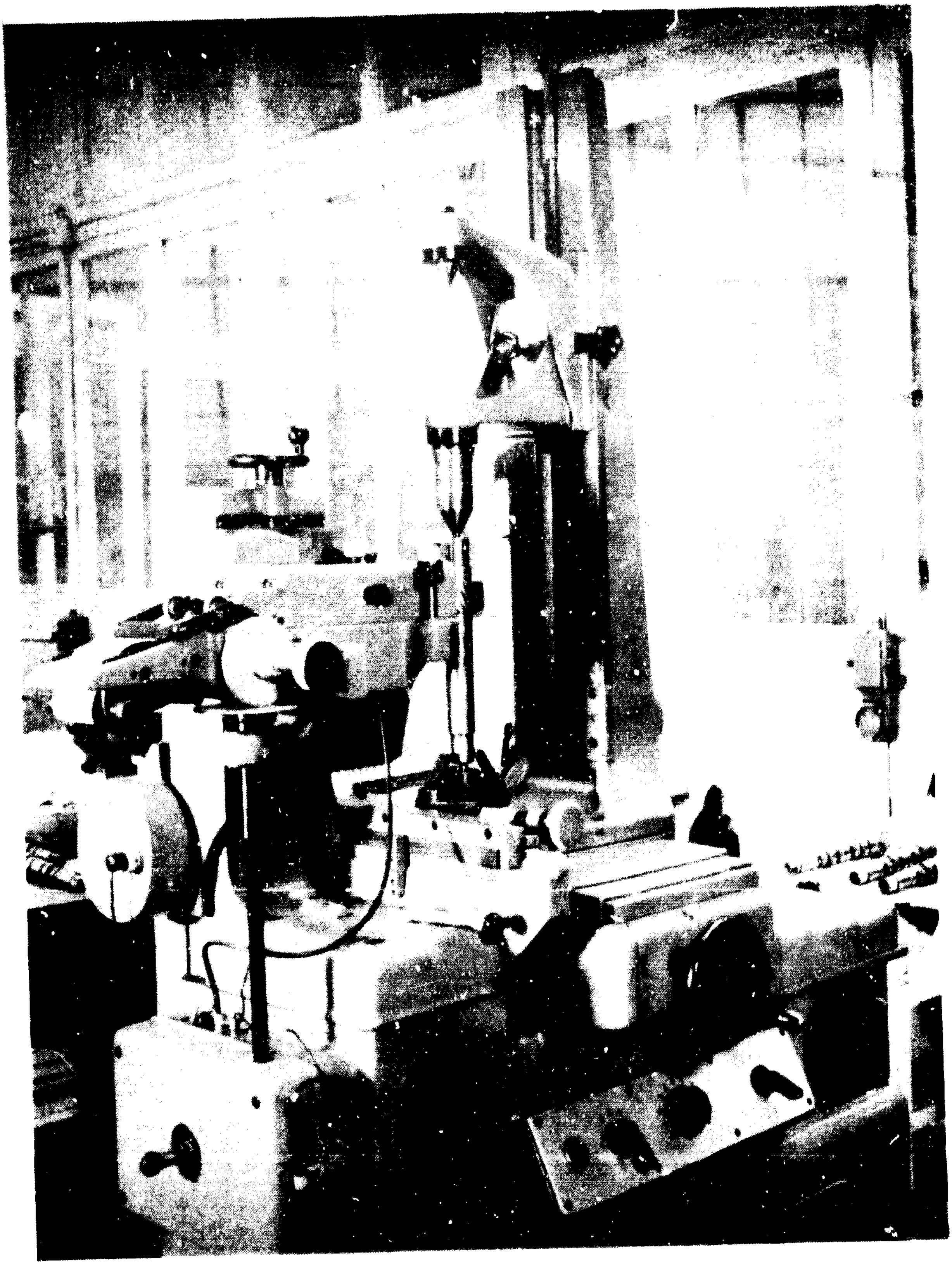


Fig 9 – Contrôle du profil et du pas de l'hélice d'un engrenage étalon

Fig 9 – Inspection of the profile and the helix pitch of a standard gear

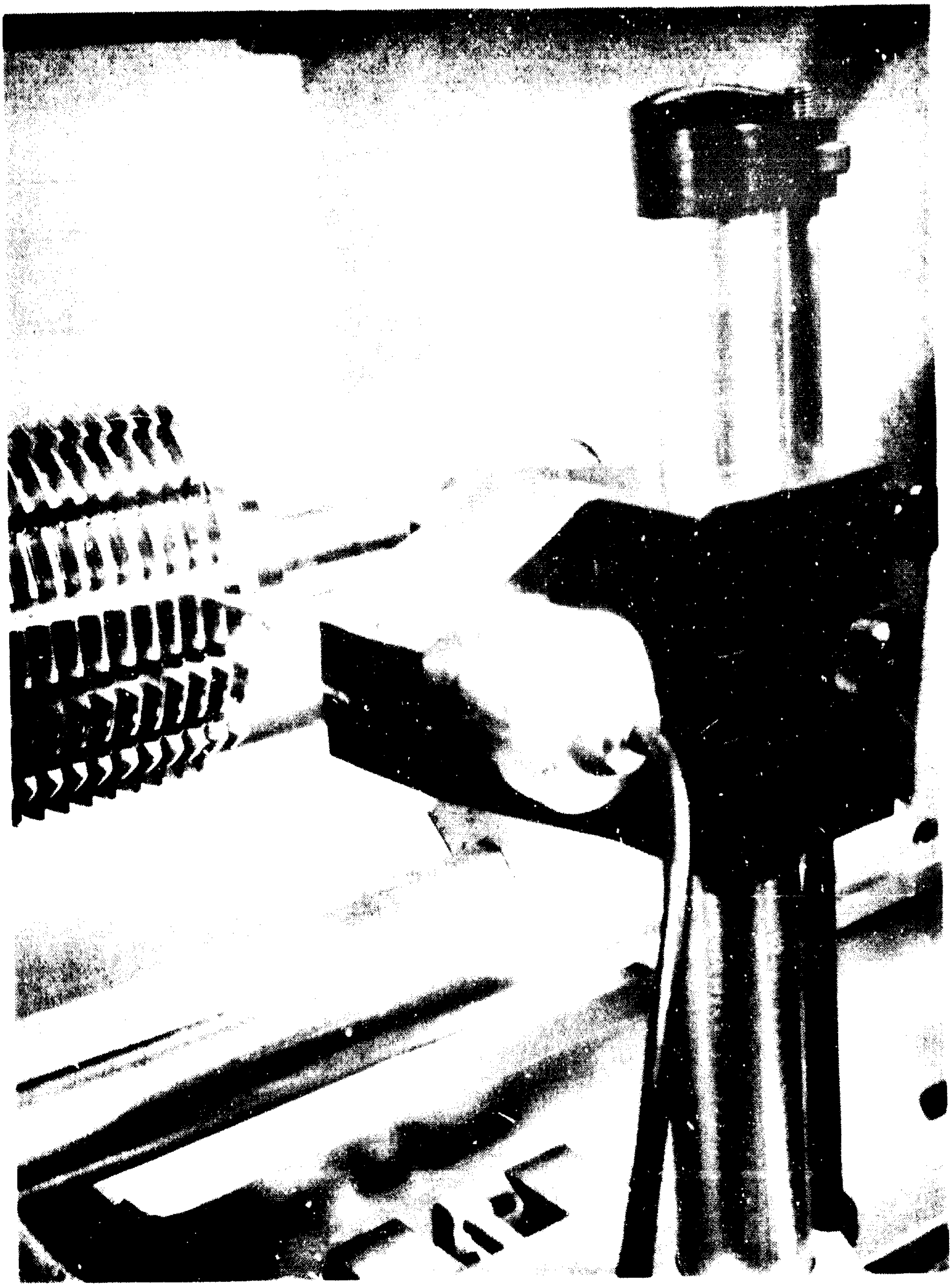
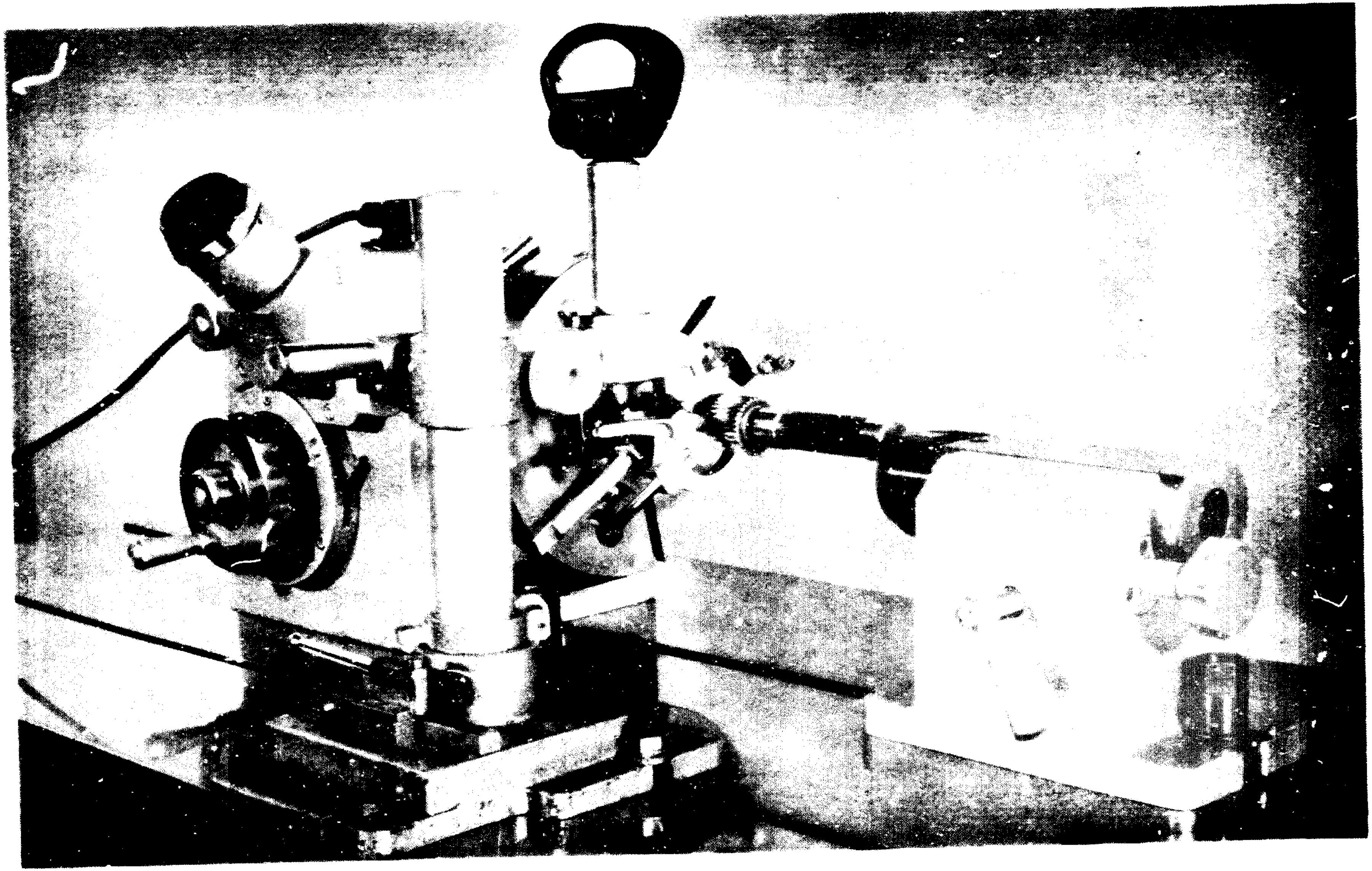


Fig 10 - Contrôle de l'hélice d'une fraise mère

Fig 10 - Inspection of the helix of a worm hob



[illegible] étal[illegible] [illegible]elé

Fig [illegible] grooved standard

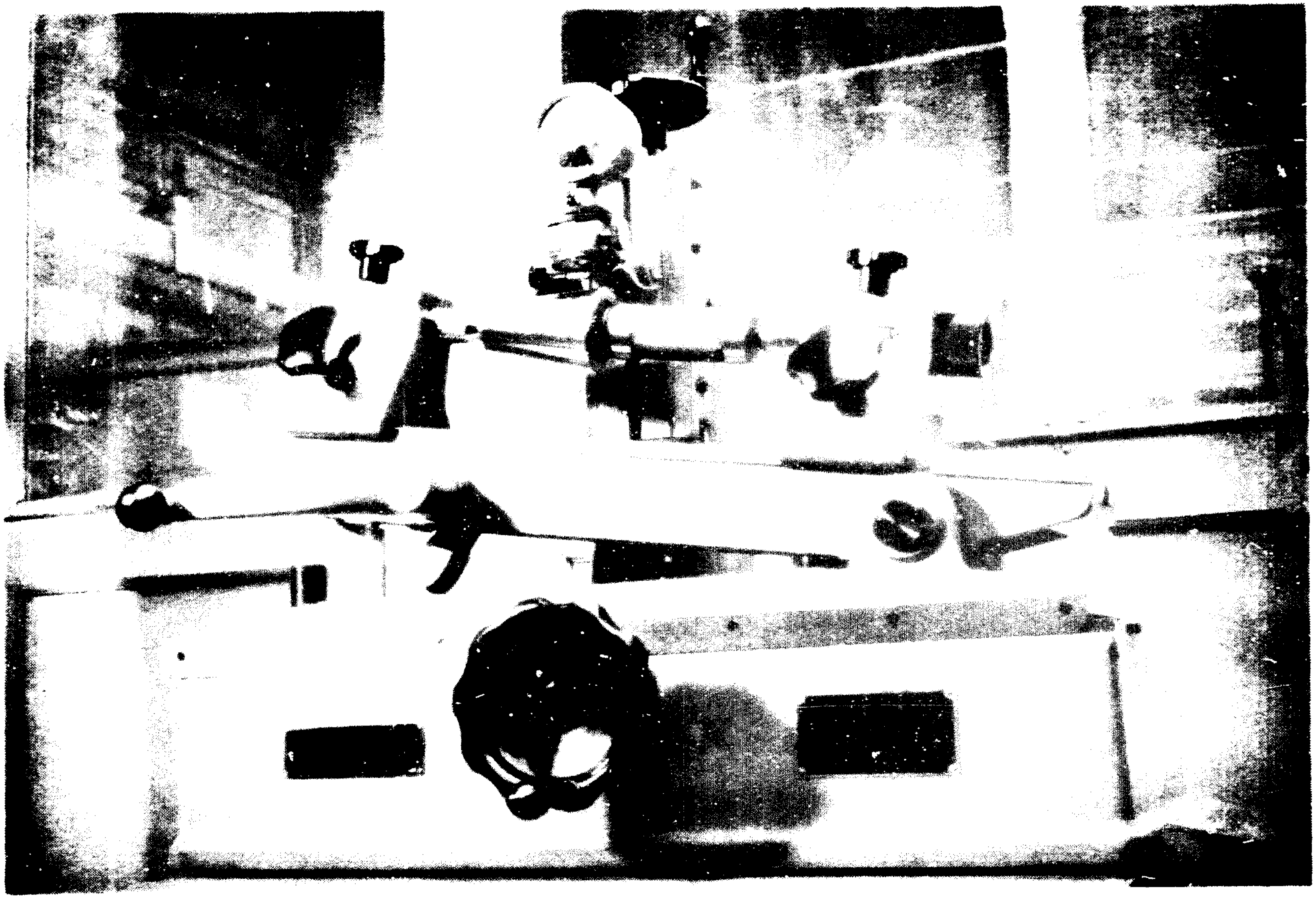


Fig 12 - Contrôle d'un cône étalon

Fig 12 - Inspection of a standard cone

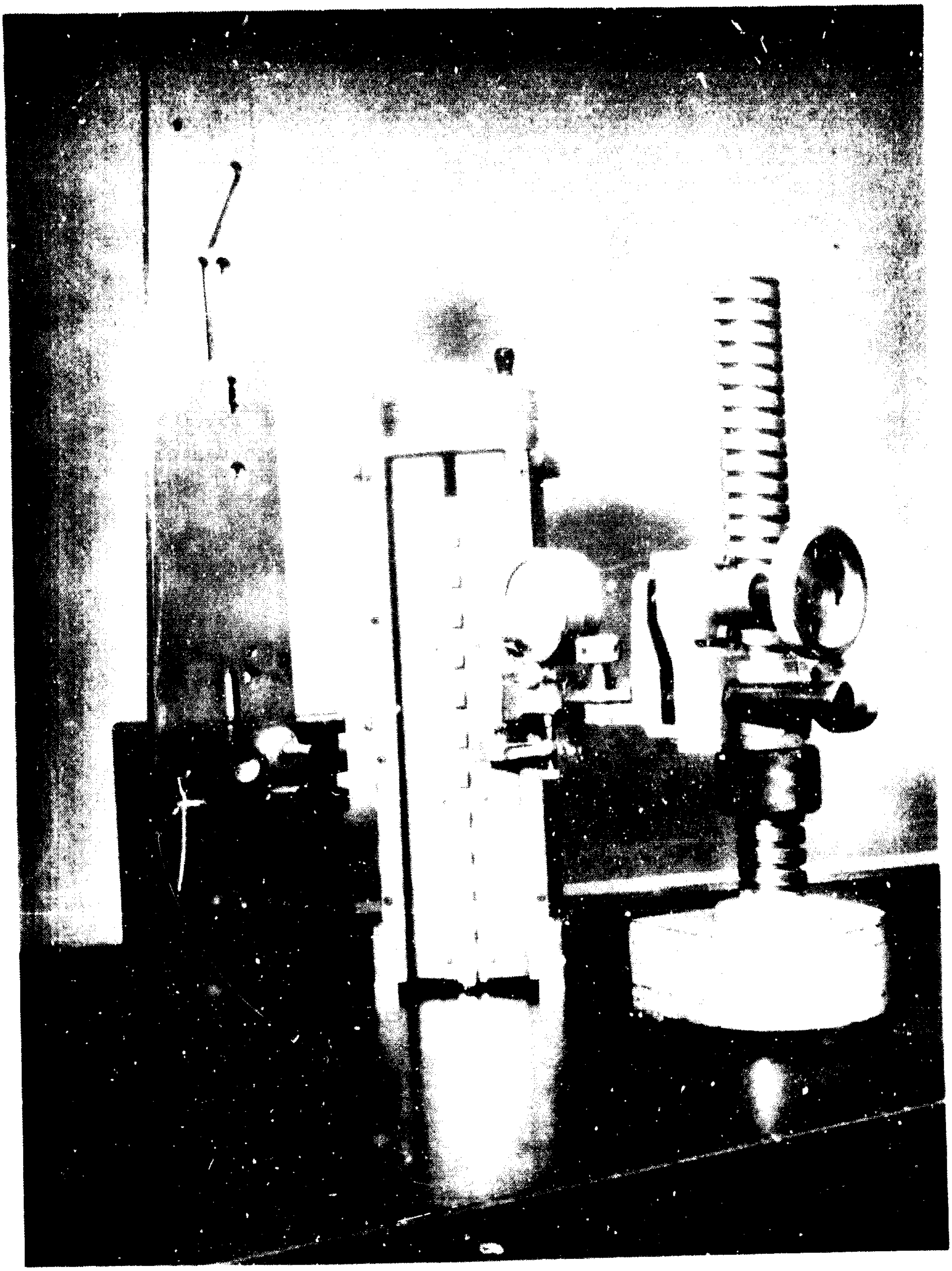


Fig 13 - Contrôle d'un calibre spécial

Fig 13 - Inspection of a special gauge

CONTENTS

I - INTRODUCTION

ORGANIZATION, FACILITIES AND METHODS OF AN INSPECTION METROLOGY DIVISION FOR PROTOTYPES, PRE-PRODUCTION AND TOOLING IN THE FRAMEWORK OF AN ENGINEERING CENTRE IN THE AUTOMOTIVE OR PRECISION MECHANICS INDUSTRIES

It is a well known fact that any implementation of new or adapted parts as defined by the designer should be carefully inspected and supported by accurate, written test reports.

It is also certain that ignoring this essential rule involves deviations up to and including a perfectly erroneous judgment of the performance of the proposed component. What will be blamed on design deficiencies is often a mere and unknown manufacturing deficiency.

It is therefore of the utmost importance, in a precision engineering Centre , to treat inspection metrology as an absolute must.

Quite obviously, later on, series production should be dealt with just as rigorously.

Meanwhile, the designer should state on his drawings, clearly and completely, in specifications and sets of tolerances, the requirements he intends to impose for the proper operation of the component he planned.

The inspection metrology division will be equipped accordingly, and we shall see that, in the framework of modern technology, such equipment requires a definite technical and economic effort.

Our present investigation is limited to the inspection metrology of dimensional characteristics in precision engineering production such as automotive and automotive tooling manufacture. it may readily apply to any other type of precision engineering such as that of machine tools, instruments and tooling.

A division of this type must necessarily include two departments :

- The first is <u>Basic Metrology</u> whose task is to preserve and certify basic standards of length, flatness, linearity and shape. Basic metrology may devote further expertise to certifications of weight, pressure, force, etc.

- The second is <u>Works Metrology</u> whose precision is guaranteed by Basic Metrology. Its purpose is to measure or test parts and tools submitted by the prototype or pre-production workshops.

II - BASIC METROLOGY

1 - PURPOSE :

The essential purpose of Basic Metrology is the inspection, preservation and supervision of basic or primary standards to be used in judging the practical or secondary standards put to work by the department of Works Metrology.

It is also natural to entrust Basic Metrology with testing inspection instruments used by other departments. By this we mean controlling the performance of commercially available measuring equipment.

Basic Metrology often checks and adjusts especially fine inspection rigs.

Finally, due to its powerful means, Basic Metrology is frequently called upon to settle disputes which arise between other departments.

Let us survey its major concerns :

2 - Measurement of lengths -

The starting point in the series of calibrations and transfers which winds up at the production shop inspection crib is the set of primary standard gauge blocks preserved at Basic Metrology.

The precision of such gauge blocks is specified in the supplier's itemized list (for example, .05 micron for block lengths under 30 mm).

Within the scope of average precision engineering (tolerances in the order of .01 mm), such specifications may be considered satisfactory and the set of gauge blocks may be used as a primary standard under the following prerequisites :

1) It shall be previously certified by an international measurement bureau and carry a measurement report.

2) It shall be checked at 2 or 3 years' interval by the same bureau.

In high precision production like that of hydraulic systems mass produced in the CITROEN plants with tolerances under 1 micron, the general information supplied by the block manufacturer is insufficient, even though certified by an international bureau, as surface unevenness and face parallelism error as well as the accurate size of each block should be known within at least .03 micron. .

In addition, it is mandatory to check yearly the stability of primary standards.

The linear interferometer need not be described - it is well known. Let it be simply stated that its usual light sources are cadmium, mercury, helium or neon tubes.

It is nevertheless extremely interesting to use a stabilized laser which generates finer interferences and allows the measurement of much more considerable lengths. The method to be evolved is then the direct measurement of lengths by fringe counting. We must say that this technology is not yet fully developed.

Consequently, we have to stay temporarily with conventional illumination, and most centres currently use it with the method of fractional overshoots.

However, the legal definition of one metre being the wavelength of the green radiation 2 P 10/5 D 5 of krypton 86, the krypton lamp is practically a must with its cryostat which increases beam fineness, and thereby beam range..Gauge blocks up to 100 mm can be measured with a cadmium lamp. A crypton lamp and associated cryostat readily enhance this range to 200 mm.

This equipment provides us with a knowledge of gauge blocks with an accuracy of .03 micron.

Basic Metrology will now turn to the measurement and certification of the secondary standard gauge blocks for Works Metrology. The topography of block ends must be known in order to frequently delineate restricted areas which will be the only ones used for transfers. We use a highly contrasted FIZEAU interferometer with associated camera which gives us a direct image and provides us with a map of the useful area.

As a matter of fact, the size of secondary gauge blocks must be known within .05 micron for lengths under 30 mm. This takes us to :

the comparator interferometer, the essential purpose of which is to measure secondary gauge blocks by comparison with primary ones.

Nearly all we previously wrote about the linear interferometer applies to the comparator interferometer.

It should be kept in mind that all this optical equipment requires very well kept premises of special design :

The room should be immune to ground vibrations.

It should be very carefully air conditioned and temperature stabilized.

Room temperature should not vary by more than .2°K during measurements.

The interferometer proper should be stabilized within .05ºK during measurements.

The temperature of the gauge block to be measured should be the same as interferometer temperature and known within .01ºK, which supposes a thermometer calibrated in steps of .005ºK.

Finally, to perform air index corrections, we must know :

- barometric pressure : a mercury barometer is sufficient, readings within .1 mm, with usual latitude and altitude trim;

- moisture : a conventional hygrometer;

- CO2 content : may be ignored most of the time.

3 - Gauge measurement - general

Although form gauges are mostly used for series production, even in a prototype-oriented Centre like the Works Metrology we shall come to needs ring, cylinder, taper and threaded plug gauges of perfectly known shape.

Knowing a gauge always starts with investigations of flatness, linearity, circularity and surface condition. It is perfectly useless to measure a ring gauge along one of its diameters without knowing its bore distortions. This is made particularly obvious at the CITROEN hydraulic production line where ring gauges must be known within .1 micron, as for example a taper defect of more than .1 micron would deprive them of any practical value.

Let us look into this in a little more detail :

a) Evenness test : This is a very frequent test on some parts of precision inspection tooling when two such parts have to be matched in perfect true.

A bench face plate should also be checked regularly to know whether it can still be used as a base for measurements.

A number of items, such as the faces of water pump sealing rings or of crankcases assembled without gaskets, should also be perfectly flat.

Such measurements are made with optical flats, spirit levels or autocollimators.

- Optical flats are parallel faced quartz discs, the face(s) of which are optically controlled and guarantee a flatness within $\frac{\lambda}{40} \approx$ .0015 micron, but their diameter seldom exceeds 300 mm.

- The air or spirit level is a dependable instrument which can reach a fair accuracy, but its use requires time and great care. Maximum accuracy : 1 second of an arc.

- The autocollimator is a must in flatness and alignment tests. Its accuracy is about .1 second of an arc. It is used particularly to define the linearity of machine beds and to control diabase inspection benches.

All diabase face plates in Basic and Works Metrology must be inspected and tested regularly. At the same time, their contour map is drawn. The point of this operation is to ascertain the capabilities of a face plate (a bench of 1 sq.m. should be flat within 2 microns). It also reveals the best areas to be reserved for finer measurements. Of course, as soon as the bench shows excessive wear, it is downgraded or repaired.

b) Linearity tests : Most often, they consist in checking a generatrix on a standard gauge or a cylindrical part, or the linearity of a machine bed or of an inspection bench. Problems are akin to those of flatness.

For example, a generatrix under 100 mm is normally checked with a profilometer whose feeler is supported by a guided linear bar. The bar is ckecked first by means of the optical flat.

The precision to be aimed at is .1 micron over 100 mm.

c) Perpendicularity tests : They are derived from the same concepts. Standard squares or optical squares with an accuracy of about 2 seconds of an arc are normally used.

d) Circularity tests : They are essential in precision engineering, as knowing a diameter gives no information on the actual "bulk" of the workpiece : circumscribed cylinder in the case of a male part, inscribed cylinder in the case of a female part. Quite often, a piston designed to travel in a cylinder with a clearance of a few microns seizes or even acts as a "no go" whereas both piston diameter and cylinder bore seem correct.

The instrument most often used is an air pressure or electric feeler with a recording unit, carried on a rotating spindle, which revolves around a vertical axis. The whole accuracy of the system depends on the spindle. The stated requirement must be .05 micron. The part to be measured must be aligned with the spindle, which is quite feasible for trained operators.

More sophisticated instruments with electronic feelers and electronic circular compensation supply centred diagrams of non-centred parts.

Note that, for high precision production, the amplification should rate 10 000 to 20 000, whereas in routine production an amplification of 1 000 is permissible.

e) Surface condition : Commercially available profilometers are well known and their operating principles need no description. Let us note however that attempts at international standardization are still highly controversial, which is conceivable as one cannot characterize something as complex as roughness by one single parameter.

Our opinion is that the best appreciation of surface condition to be obtained, according to stated objectives, is through direct reading of the recorded trace. In measurements of fine surface finish, the feeler should be kept to a straight course with appropriate followers, which supposes a linear base. Therefore the profilometer at Basic Metrology will necessarily operate by linear guided movement of the feeler, as opposed to usual equipment where the feeler is maintained by a shoe sliding on the workpiece. The adjustable amplification ratio should reach 100 000.

To measure balls, an interference microscope is a must, inasmuch as balls are a major item in engineering.

The above equipment being installed, all that is now required to measure standard gauges is :

f) The inspection bench : It is used to measure the ID, OD, thickness or taper of standard gauges destined to Works Metrology or to the production workshops. The dimensioning of a standard is generally valid only over a determined area of its surface. This area is limited by a peripheral line engraved by the metrologist, and the assessed dimension is also engraved on a visible face of the gauge.

Measurements are performed by comparison with a bridge of gauge blocks.

The equipment is conventional, but measurement frictions and stresses have to be eliminated, and another fact to be reckoned with is the shift from feeling two planes on the bridge of gauges to feeling (most often) a cylinder on the standard. This requires careful and trained operators.

III - WORKS METROLOGY

1 - PURPOSE AND ORGANIZATION :

Works metrology measures parts manufactured according to drawings issued by the designer (prototypes or pre-production). Such inspection often requires special tooling which is designed, built and tested by Works Metrology.

This department also checks the conformity of production tools (broaches, hobs, etc.) and of machines as well as that of production or inspection rigs.

In order to relieve Basic Metrology, Works Metrology has sufficient facilities to test standard gauges with a tolerance of 1 micron or more as well as thread gauges.

Works Metrology is also entrusted with the regular inspection, against the secondary gauge blocks supplied by Basic Metrology, of all the gauges used in the various workshops.

These last three activities become quite cumbersome in a mass production plant like CITROEN, but they remain manageable in a Centre dealing with adaptation, prototype or pre-production work.

STAFFING

The staff will be composed of month-rate technicians in preparation or supervision functions, and of qualified operators and some specialized workers for current work.

FACILITIES

Test equipments will be direct reading instruments available on the market or special rigs designed by Work Preparation.

BASIC OPERATING PRINCIPLE

The Design Office supplies accurate drawings and specifications of equipments to be tested. Works Metrology replies in a test report. This report stresses in particular dimensions falling outside specified tolerances. It will be up to the designer to accept or refuse the component. Works Metrology may guide him in his decision by stating an opinion.

Works Metrology comprises :

- the office for Work Preparation;
- various workshops.

2 - OFFICE FOR WORK PREPARATION

The Centre's measurement operations should be planned in view of :

- adhering to the requirements of drawings and specifications;
- minimizing the cost of special tooling required;
- avoiding improvisation and loss of time during measurements;
- making judicial use of workshop personnel while avoiding an excessive burden to Supervision;
- avoiding delays in implementing tooling.

All test instruments used by the Centre should carry a follower issued by Work Preparation and stating :

- measurement accuracy;
- meqsurement capability;
- instrument capability;
- type of calibration.

Such followers may be supplemented by a process sheet.

Typical setup of an office for Work Preparation :

1) Preparators specialized in the inspection of mechanical automotive parts.

2) Preparators specialized in the inspection of bodywork automotive parts.

3) Preparators specialized in the inspection of tooling.

4) Designers engaged in special inspection tooling, as all measurements cannot be made with commercially available equipment or with the Centre's existing facilities only.

5) Loft tracers to produce the drawings required for inspection on profile projectors.

6) Personnel taking care of printed standards, filing and circulating papers to the inspection workshop.

Quite obviously, the importance of Work Preparation will depend on the bulk and nature of the workload at Works Metrology.

In the simplest case, supervisors of the inspection workshop will be able to cope with its various functions.

However, it appears fairly essential to provide at least one draftsman to design or order complementary inspection tools : smooth, cylindrical or tapered chucks with or without shoulders, templates, drawings for the picture projectors.

Note : Forgings and castings are inspected by loft tracers; this operation requires no preparation. The specialist lofts the part according to drawings and specifications.

3 - PRECISION MEASUREMENT WORKSHOP

a) All lengths shall be measured according to the secondary standards checked by Basic Metrology. The dimensions of these reference gauges are guaranteed within .05 micron.

Works Metrolo
sets used in lengt
is given within .1
specialists. Test
mechanical, air pr
accuracy of .02 mi

The facilitie
station can be app

In the course
degree of wear, th

The precision
accordance with th
Centre.

b) Works Metrolo
measurements of ri
more inspection be

- Approximate c

In this works
precision instrume

- Instruments t
at values ranging

- Instruments t
faults in circula

- One or two b
with optical or d
accuracy 1 second