A LOS ASISTENTES A LOS CURSOS DEL CENTRO DE EDUCACION CONTINUA

La Facultad de Ingeniería, por conducto del Centro de Educación Continua, otorga constancia de asistencia a quienes cumplan con los requisitos establecidos para cada curso. Las personas que deseen que aparezca su título profesional precediendo a su nombre en el diploma, deberán entregar copia del mismo o de su cédula profesional a más tardar el Segundo Día de Clases, en las oficinas del Centro, con la Señorita Barraza, de lo contrario no será posible.

El control de asistencia se efectuará a través de la persona encargada de entregar notas, en la mesa de entrega de material, mediante listas especiales. Las ausencias serán computadas por las autoridades del Centro.

Se recomienda a los asistentes participar activamente con sus ideas y experiencias, pues los cursos que ofrece el Centro están planeados para que los profesores expongan una tésis, pero sobre todo para que coordinen las opiniones de todos los interesados constituyendo verdaderos seminarios.

Al finalizar el curso se hará una evaluación del mismo a través de un cuestionario diseñado para emitir juicios anónimos por parte de los asistentes. Las personas comisionadas por alguna institución deberán pasar a inscribirse en las oficinas del Centro en la misma forma que los demás asistentes.

Con objeto de mejorar los servicios que el Centro de Educación Continua ofrece, es importante que todos los asistentes llenen y entreguen su hoja de inscripción con los datos que se les solicitan al iniciarse el curso.

ATENTAMENTE

ING. SALVADOR MEDINA RIVERO
COORDINADOR DE CURSOS.

DIVISION DE ESTUDIOS SUPERIORES
FACULTAD DE INGENIERIA, UNAM.

CURSOS DE MAESTRIA Y DOCTORADO

La División de Estudios Superiores de la Facultad de Ingeniería, UNAM, ofrece las siguientes Maestrías y Doctorados:

Maestrías

- Control
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- Hidráulica
- Investigación de Operaciones
- Mecánica teórica y Aplicada
- Mecánica
- Mecánica de Suelos
- Petrolera
- Potencia
- Planeación
- Sanitaria

Doctorados

- Estructuras
- Hidráulica
- Mecánica de Suelos
- Mecánica teórica y Aplicada
- Investigación de Operaciones

Programa de actividades para el segundo semestre de 1976

Exámenes de admisión: 10, 11 y 12 de mayo

Inscripciones: 31 de mayo al 4 de junio

Iniciación de clases: 7 de junio

Requisitos de admisión

a) Cumplir con una de las siguientes condiciones:

1. Poseer título profesional en Ingeniería o en alguna disciplina afín a las maestrías que se ofrecen en la División, otorgado por la UNAM o por cualquier institución nacional o extranjera.

2. Ser pasante de la Facultad de Ingeniería, UNAM

b) Aprobar los exámenes de admisión que se efectuarán en las fechas señaladas arriba.

c) Presentar, dentro del período de inscripciones arriba mencionado, la documentación que se indica en el folleto de Actividades Académicas 1975 de la DESFI

Mayores informes: División de Estudios Superiores de la Facultad de Ingeniería, Apartado Postal 70-256, Ciudad Universitaria, México 20, D. F. Tel.: 548-58-77

"POR MI RAZA HABLARA EL ESPIRITU"
Cd. Universitaria, febrero 3. 1976

EL DIRECTOR DE LA FACULTAD
M. en C. ENRIQUE DEL VALLE CALDERON

EL JEFE DE LA DIVISION
DR. OCTAVIO A. RASCON CHAVEZ

centro de educación continua
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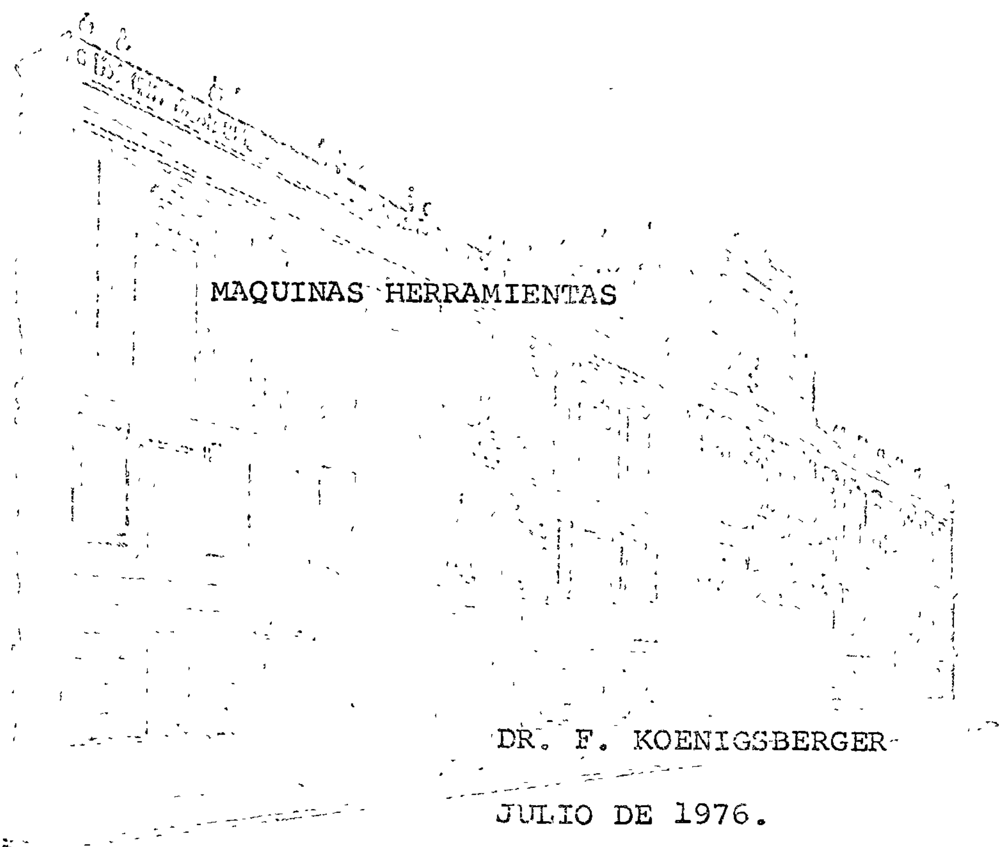
INGENIERIA DE MANUFACTURA



MAQUINAS HERRAMIENTAS

DR. F. KOENIGSBERGER

JULIO DE 1976.

Production Engineering in the Machine Shop

1. Metal Cutting Machine Tools

a) Metal Cutting Fundamentals

Parameters of metal cutting

depth of cut - a^{mm}

speed of cutting movement - $v^{m/min}$ (effect on tool life and surface finish)

in case of rotational movements: $v = \pi . d . n$
n = rev/min
d = rotational diameter

feed movement - rate s (measured either absolutely in mm/min or as a function of spindle rotation in mm/rev; effect on surface finish)

chip section - $a.s^{mm^2}$

Empirically devised specific cutting resistance - k_s (effect on chip thickness h and chip width b)

Cutting force - $P \approx a.s.k_s$

Net cutting power - $N_{net} = P.v$

Input power - $N_{input} = \frac{N_{net}}{\eta} = N_{idling} + \text{const.}\ N_{net}$

Cutting force components

Turning ; Tangential, radial, feed component

Drilling: Axial (thrust) force, torque

Milling : Instantaneous) Horizontal longitudinal horizontal axial vertical,

or) Tangential, radial, axial.

Variation of chip thickness during the cutting action and resulting variation of cutting force.

Instantaneous chip thickness $x = \frac{s}{n.n_t} . \sin \varphi$

(n_t = number of teeth)

Middle chip thickness ($\varphi_m = \frac{\varphi}{2}$)

$$h_m = \frac{s}{n.n_t} \sqrt{\frac{a}{d} - \frac{a^2}{d^2}}$$

$$\approx \frac{s}{n.n_t} \sqrt{\frac{a}{d}}$$

$$k_m = f(h_m)$$

Mean net Power $$N^{kW} = \frac{k_m^{N/mm^2} \cdot a^{mm} \cdot b^{mm} \cdot s^{mm/min}}{60 \cdot 10^6}$$

or $$N^{kW} = \frac{k_m^{kp/mm^2} \cdot a^{mm} \cdot b^{mm} \cdot s^{mm/min}}{60 \cdot 102000}$$

Conditions similar for face milling; slight difference between up and down milling.

Force pulsations determine ratio between maximum and mean force $\frac{P_{max}}{P_{mean}}$.

This is affected by the cutting conditions and the dimensions of cutter and workpiece viz.-: In the case of slab milling helix angle of the cutter as well as width and depth of cut; in the case of face milling the ratio between width of cut and cutter diameter and the position of the cutter axis relative to the surface to be milled.

b) Purpose of the machine tool

To obtain within permissible limits the specified accuracy of shape and dimensions as well as the surface finish of the workpiece produced on the machine, as far as possible independently of the operator's skill.

Available operational speeds and feeds must ensure high productivity and machine capacity utilization. Available power, strength and stiffness must allow rates of metal removal which ensure high productivity.

c) Speeds and feeds.

Stepped or infinitely variable

Required speed range (B) depends on

Maximum (d_{max}) and minimum (d_{min}) diameter of tool or workpiece.

Maximum (v_{max}) and minimum (v_{min}) cutting speed

$$B = \frac{v_{max}}{v_{min}} \cdot \frac{d_{max}}{d_{min}}$$

Step ratios (φ) in stepped gear boxes (preferrred numbers)

$$\varphi = \sqrt[z-1]{B} \qquad (z = \text{number of steps})$$

Infinitely variable speeds by means of hydraulic or electric d.c.drives.

Characteristics of hydraulic (pump-motor) and electric (Ward-Leonard) set.

Adjustability of hydraulic pump-motor set

$$n_2 = \frac{c_1 e_1 n_1 - Q_s}{c_2 e_2}$$

n_1 = pump speed; n_2 = motor speed; e_1 = pump adjustment; e_2 = motor adjustment; Q_s = leakage losses; c_1 and c_2 = design constants.

d) Strength and stiffness problems

Flow of forces in the structure
Centre lathe
Radial drilling machine
Milling machine
Grinding operation
Turning centre drive
Accuracy and cost
Open and closed frame design
Use of steel in machine tool structures
Combination of steel and cast iron

(example press frame)

$$\Delta l = l \cdot \frac{P}{A} \cdot \frac{1}{E}$$

slope of elongation curve

$$\tan\alpha = \frac{P}{\Delta l} = \frac{AE}{l}$$

Ratio between slope of steel (S_t) and cast iron (C_i)

$$R = \frac{A_{st} E_{st}}{l_{st}} \div \frac{A_{ci} \cdot E_{ci}}{l_{ci}} = \frac{A_{st}}{A_{ci}} \cdot \frac{E_{st}}{E_{ci}} \cdot \frac{l_{ci}}{l_{st}}$$

Load increase (P_{add}) over preload (P_p) in the steel anchor

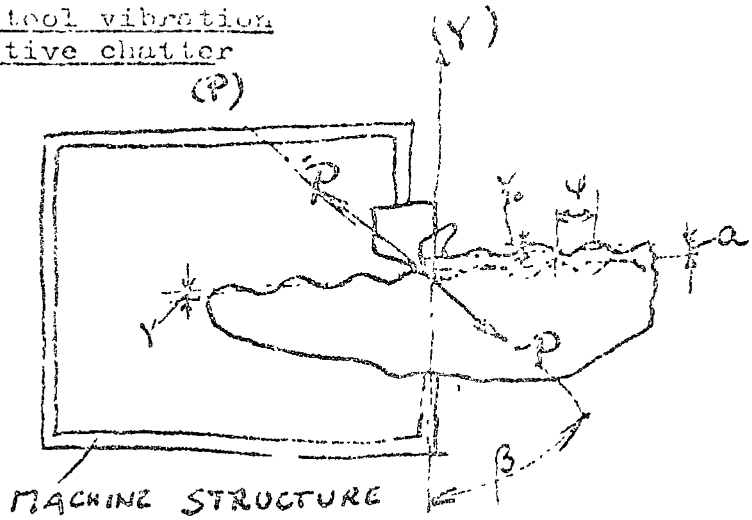
$$P_{add_{st}} = P_p \cdot \frac{\tan\alpha_{st}}{\tan\alpha_{ci}} = 0.34\ P_p \quad \text{in example}$$

where $\frac{A_{st}}{A_{c_i}} = 0.3$

$\frac{E_{st}}{E_{c_i}} = 2$

$\frac{l_{ci}}{l_{st}} = 0.56$

Machine tool vibration
Regenerative chatter



Tool-work deflections due to changing cutting force P (components P_x and P_y)

a) P_y causes deflection Y normal to the cut surface Y depends upon receptance of structure in Y - direction

b) P_x causes defelction X tangential to cut surface.

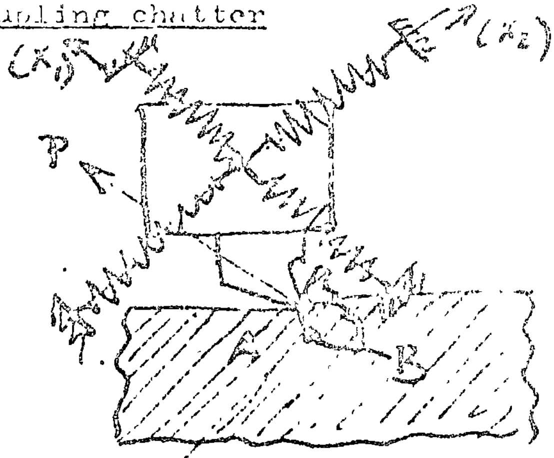
The deflection Y is of primary importance since it dictates the chip thickness (and thus force) variation.

If $Y < Y_o$ stable

if $Y > Y_o$ unstable

Limit of stability $|Y| = |Y_o|$

Mode coupling chatter



Two modes of vibration of close natural frequencies. Small transient change in P results in elliptical tool path.
Energy considerations show that anticlockwise movement is stable, clockwise movement unstable.
Examples of stiffness, stability and damping devices (Active and passive) will be shown.

e) Operation, utilisation and maintenance

Operation can be
- manual by skilled worker (e.g. centre lathe)
- manual by unskilled worker (e.g. capstan or turret lathe)
- automatic (mechanical) cam operated
- automatic (N.C.) i) by control tape
  - ii) DNC
  - iii) CNC

Machine tool utilization must be evaluated from several points of view, viz.-

Utilization of
- i) available time (machine loading)
- ii) available capacity (size, power, operational conditions)
- iii) obtainable quality.

i) depends on ii) and iii).

Example: Workpiece statistics in Germany in 1960s showed that centre lathes were utilized
- i) 26% overall (46% per shift)
- ii) for 90% of lathes, length capacity 2000-5000mm; diameter capacity up to 250 mm. actual diameters for 70% 200 mm and lengths 250 mm
- iii) quality requirements must be clearly stated (example Studer grinder).

Operational accuracy depends not only upon the accuracy with which the machine tool has been manufactured but also upon the operational method.
Errors can be corrected, but variations cannot.
Consistency more important than absolute accuracy (example: Morse taper)

Testing and planned maintenance essential.

Computer Control of Machine Tools

With computer numerical control (C.N.C.) a mini computer is permanently connected to the machine tool. This allows considerable flexibility because changes in operational conditions can be incorporated at will in the program which can thus be varied in accordance with specific requirements at any time.

The introduction of direct numerical control (DNC) leads to the possibility of controlling a group of machine tools from a central processor via an interface at each machine. The individual control equipment situated next to each machine also includes the power electronics for the feed drives, and in some cases a display terminal provided for maximising inter-active communication between the central processor and the operator. Alternatively, each machine tool can be controlled by a conventional NC or CNC controller in which case the DNC communication links operate behind the tape reader.

In order to study the problem as a whole it is perhaps appropriate to consider first the main advantage of using NC in general, be it CNC or DNC. Market research carried out in U.S.A., which has been reported and discussed in Germany, indicated that the obtainable workpiece quality, accuracy and surface finish are the deciding factors which influence the production engineer in favour of NC. Ease of programming, reliability and consistency are also important features. The ease of setting-up, the possibility of using standard cutting tools and of producing spare parts quickly from existing tapes as and when required are further advantages. The provision of large stores of work in progress can be replaced by programmed and tape-controlled intermediate storage. Modifications in the design of the product can be catered for by quick changes of programmes and tapes. Variations of the cutting tool dimensions due to wear and/or regrinding can be allowed for by means of simple manual input signals.

Testing of Machine Tools

First tests: Accuracy with which machine tools had been manufactured (Alignment tests, Schlesinger 1927). Salmon(1937) introduced the manufacture of test pieces. These tests are not sufficient, especially for conventional machines which have been adapted to modern methods such as NC or digital read out measurements. Here accuracy must be higher and more clearly defined because an operator's interference is undesirable and workpieces must be more accurate because of the needs in connection with subsequent operations. A typical example is the boring of two co-axial holes from both sides of a work-piece, which may be faster and requires a shorter boring bar than boring from one side only.

Modern measuring equipment (e.g. Laser-Interferometer) makes it possible to establish and record accurately and quickly many inaccuracies, displacements, deviations etc. They may either be geometric errors in the original machine configuration or they may occur during the operation of the machine under the effects of the forces acting on the structure (either cutting forces or changes in the distribution of masses due to the movements of the machine parts).

We must distinguish between:

a) prototype tests which help in establishing the capabilities of a machine and in improving future designs;
b) acceptance tests of machines which have been built to designs whose performance standards have been established and accepted.

If geometric errors are due to design weaknesses and not to inaccurate manufacture and assembly, they can sometimes be corrected by suitable steps during assembly but such corrections usually lead to other faults and difficulties. Errors can also be introduced by bad setting-up and these must be eliminated before the blame for bad machine performance can be put on the machine tool itself.

Examples of performance tests

1. Accuracy of working movements

Movement of a slide into a predetermined position. Comparison of actual position reached at end of movement and set "target" position. (Determination of "system errors"). Average error over some 20 target positions should be determined. On most machines "target" must always be approached in the same direction in order to avoid backlash or threshold errors. (Sometimes provided for on some numerically controlled machines). Two important methods laid down by N.M.T.B.A. (National Machine Tool Builders Association) and V.D.I.

Difference: N.M.T.B.A. determines repeatability for each target position.

V.D.I. defines average repeatability over whole length of movements along one axis.

Usually repeatability is uniform over the whole length of movement. If this is not the case then NMTBA method is preferable.

Example: Scatterband width ±3 σ of repeatability tolerance relatively large when table of horizontal borer is at the driving end of the leadscrew. With the VDI method this large scatter value would not be shown and the average scatter would appear at the position where $6\sigma = 5.7\mu m$. The choice of target positions is important if cyclic (periodic) errors have to be determined. Cyclic errors can often be greater than progressive errors. At UMIST we determine first the progressive error by choosing target positions which are spaced at intervals equal to the lead screw pitch or a multiple of it along the axis of movement. This eliminates any influence of cyclic errors. Then we choose some (say 50) equidistant target positions distributed over a length of at least two pitch lengths of the lead screw. These serve for determining cyclic errors.

Example: NC borer table moving along X-axis. Position feed back through synchros fitted directly to the lead screws. Cyclic errors of machines with incremental measuring equipment are usually smaller If an absolute rather than incremental measuring system is used the accuracy of setting it is vital if cyclic errors are to be avoided. Even on a measuring machine equipped with linear inductosyns we found a cyclic error (period of 1.25mm) of 175 μm(!).

The acceptance test had been carried out at targets which were spaced by multiples of 1.25 mm. The error was discovered when test pieces were found to be faulty.

For machines which are to produce profiles by continuous path control errors can be caused by threshold effect especially when the direction of movement along one axis has to be reversed. An American Standard (NAS) requires a circular test piece to be machined and measured, e.g. by Talyrond.

Example: Talyrond graph showing an error along one axis, which may have been caused by a "negative" loss of movement. (If such a loss is caused by backlash or strain in the lead screw drive, the position feed back being taken from the rotation of the lead screw, the loss would be considered positive).

Loss of movement can influence the repeatability of a system acting along a vertical axis to a relatively larger extent than in the case along horizontal axes because of possible creeping movements of the slides under their own weight. Errors so caused have been found to be up to 4 times those along horizontal axes.

Deformations under load

These depend greatly upon the design. They are caused by change of the forces acting on a structure. Internal and external factors can contribute to this.

a) Internal

The structure of the machine itself can vary through changes in position of table, ram, spindle head, etc.

b) External

Weight of workpieces which are moved, the application of heavy tool carriers or fixtures, cutting forces.

Some typical examples which we have found in our work:

Straightness of tool path (horizontal borer)
(Asquith ram droop compensation)
Example: horizontal borer with moving column
Measured deviation of ram with the head clamped to the column,
Diagnostic test with the help of a "pseudo-static" exciter (10 000 N at 4.5 Hz i.e. well below the machine's natural frequency)

No danger of resonance but the deformation follows also a sinusoidal law and can thus be determined by means of an accelerometer or similar dynamic measuring instrument. The result of our test was the fact that the major part of the deviation was due to the compliances at the joints between the different elements rather than the flexibility of the elements themselves.

Model:

Compliance of joints F_{hc} and F_{cb}

Moment W.Z. increases with protruding ram

Slope $\emptyset = W.Z.(F_{hc} + F_{cb})$

Vertical deviation

$$Y = -\emptyset(a+Z)$$
$$= -WZ(F_{hc} + F_{cb})(a+Z)$$
$$= -WaZ(F_{hc} + F_{cb}) - WZ^2(F_{hc} + F_{cb})$$

The path of the ram head is thus

$$Y = AZ + BZ^2$$

Coefficient of Z responsible for deviation from parallelism of path relative to its original position.

Coefficient of Z^2 responsible for straightness of movement.

$$\frac{Y}{Z} = A + BZ \text{ has been measured.}$$

Effect of the different elements found through test results.

It was found that F_{cb} was the weak spot. If with a NC machine the head cannot be clamped to the column then F_{hc} will be 5 times greater than with a clamped head and the ram droop increases accordingly.

The rotation of the column (F_{cb}) also affects the positioning accuracy of the ram along the Z-axis.

$$Z = W.Z.F_{cb}.h$$

As the measuring system is fixed at the height of the ram, the reference point on the column moves with the column rotation and the error is proportional to the height h and the ram movement Z. The influence can be determined by attaching a level to the column and measuring its deviation from the vertical during the ram movement. It is also possible to carry out two measurements at different heights h. The large error of 360µm was entirely due to the column rotation. (The machine had a measuring system for the ram movement, which has a [illegible] and worked within this tolerance!

Similarly for a machine whose table positioning was accurate when the table carried no load, under the permissible workpiece weight of 180 kg displacements took place.

Errors during table rotation (boring from two sides, table rotation 180°).

Table axis must coincide with vertical axis of spindle head movement, whether table is loaded or not.

4 cases are considered:

a) Table surface at right angle to axis of rotation which is not vertical (1-2 reading of level).
b) The same table as a) but axis of rotation vertical.
c) Table surface not at right angle to axis of rotation, and axis of rotation not vertical.
d) Table surface not at right angle to axis of rotation, but axis of rotation vertical.

By taking readings with a precision level it is possible to determine the position of table surface and axis of rotation. Measurements on a machine table with a load carrying capacity of 10,000 kg were carried out with the table without load, and excentrically loaded. In this case the accuracy was found to be better under load in that the slope of the axis of rotation was 0.018 mm/m whilst without load it was 0.032 mm/m. The model shows the reason for such variation.

$$(L+X)W = 2LK_2Y_2$$

$$Y_2 = \frac{W(L+X)}{2K_2L}$$

$$Y_1 = \frac{W(L-X)}{2K_1L}$$

When the table is rotated by 180° Y_2' (for point 1) and Y_1' (for point 2) can be found in the same manner

$$Y_1' = \frac{W(L+X)}{2K_1L}$$

$$Y_2' = \frac{W(L-X)}{2K_2L}$$

The readings from the level can then be used to determin K_1 and K_2 for a particular table.

If $K_1 = K_2 = K$, the table slope is

$$\frac{Y_2 - Y_1}{2L} = \frac{Y_1' - Y_2'}{2L} = \frac{WX}{2KL^2}$$

The orthogonality of table surface and axis of rotation is independent of the load or the excentricity of its centre of gravity. If, however, the stiffness $K_1 \neq K_2$ errors are bound to arise. In a machine which was load tested we found, e.g. $\frac{K_1}{K_2} = 1.67$ with resulting troubles.

Another error can be caused by the vertical displacement of the table under load.

This is

$$Y = \frac{WX}{2L} \left(\frac{1}{K_2} - \frac{1}{K_1}\right)$$

For the before mentioned example under a load of 3,000 kg and an excentricity of 100 mm the vertical error due to 180° rotation was 3.3 µm. For heavier workpieces and greater excentricities the error can become significant.

Heat effects

Effects may be due to temperature-changes in the workshop, but more serious errors are caused by internal heat sources in the machine such as spindle bearings, gear boxes, hydraulic drives, hydrostatic bearings, etc. They can be reduced by suitable provision in the design of the machines. Unfortunately heat distribution effects are not detected by the measuring system of the machine tool itself and their influence can perhaps best be compared with "drift" in measuring or setting devices.

The relative displacement between machine spindle and workpiece can be measured by means of instruments acting between them. By using two instruments in each of the axes (X and Y) it is possible to determine also angular displacements. The basic problem consists in establishing a heating cycle which represents typical working conditions, such as spindle speed, working time, rest time etc. We have chosen to use a "most unfavourable" cycle, putting the machine through two complete working cycles and measuring at top and bottom spindle speed. We measured horizontal spindle displacement of a lathe with transducers which were arranged at distances of 130 and 480 mm respectively from the spindle nose in both the horizontal (H_1 and H_2) and vertical (V_1 and V_2) planes.

Axial displacements of the spindle were measured by instrument A. The vertical displacement, which has little influence on the turning accuracy, increases with increasing speed. The horizontal displacement was less affected by the speed and soon approached asymptotically the value 12 µm.

An interesting example of heat distortion caused by hydrostatic slideway bearings occurred with a column of a horizontal borer which had to travel along the bed of the machine. The angular errors in the column position were measured. They were caused by the fact that the machine had two oil tanks which were connected by a pipe. The pump drew oil from tank 1 and pumped it to the bearings. In one position of the column no oil was either drawn from or returned to tank 2, so that the oil temperature in tank 1 was higher than that in tank 2 unless the column was traversed from right to left and low temperature oil supplied to tank 1. This resulted in deformations and an impossibility to obtain repeatable positioning of the column.

Difference between Laboratory and Workshop measurements

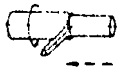
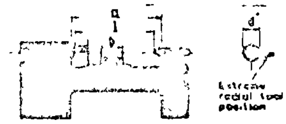
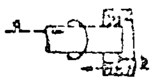
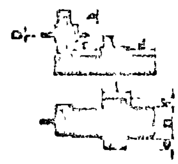
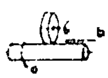
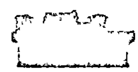
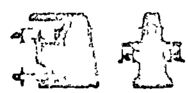
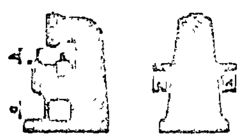
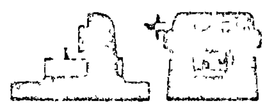
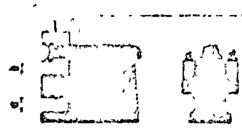
a) Temperature changes in the workshop may be excessive and overlooked.

b) In the workshop effects of neighbouring machines, cranes etc. may be transmitted to the foundations and affect the behaviour of a machine.

c) Vibrations caused by influences mentioned under b) may affect spirit level readings. Electronic levels which can be damped and whose sensibility is adjustable can overcome this problem.

d) It is important to employ experienced testers. Faulty conclusions caused by lack of basic knowledge and the inability of a sound analytical approach may prove costly in terms of money, time and effort.

TABLE 1

Type of Machining Operation		Cutting Movement	Feed Movement	Type of Machine Tool		Size Capacity
Turning		Workpiece	Tool	Centre Lathe (Similar for Capstan or Turret Lathe)		a = max. swing d = max. turning dia l = max. length between centres a - b = max. turning length
Drilling		Tool	Tool	Radial Drilling Machine		l = max. drilling length r = max. radial range h = max. height of workpiece
Boring		Tool	Tool (a) or Workpiece (b)	Horizontal Boring Machine		a+b = height range c+d = length range e+f = width range l+m = clamping area D bore spindle dia. } of acting apparatus
Cylindrical Grinding		Tool	Workpiece (a) and Tool (b) or Workpiece (a+b)	Cylindrical Grinding Machine		Similar to Centre Lathe
Slab Milling		Tool	Workpiece	Horizontal Knee - Type Milling Machine		a+b = height range c+d = length range e+f = width range } of cutting
Face Milling		Tool	Workpiece	Vertical Knee - Type Milling Machine		a+b = height range c+d = length range e+f = width range } of cutting
Planing (I) and Shaping (II)		Workpiece (I) Tool (II)	Tool (I) Workpiece (II)	Planing Machine		b = max. width c+d = max. height l = max. length } of workpiece
				Shaping Machine		a+b = max. height of workpiece c+d = width range of cut l = max. length of cut

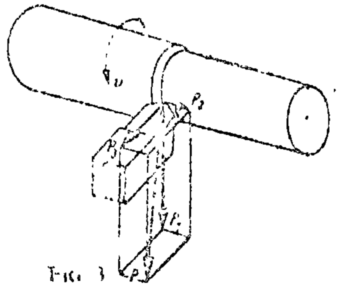


Fig. 3

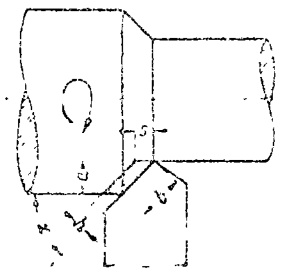


Fig. 6

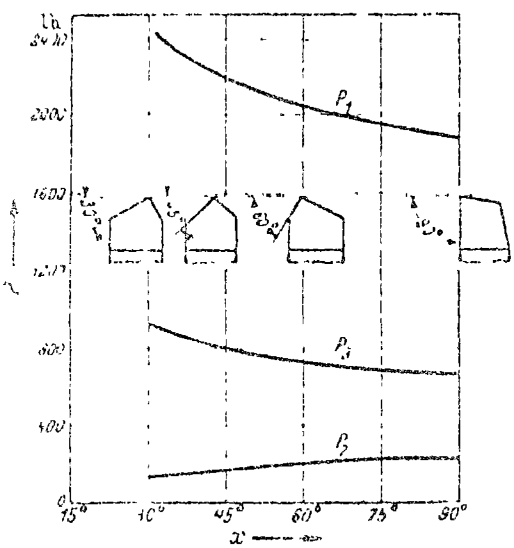


Fig. 7

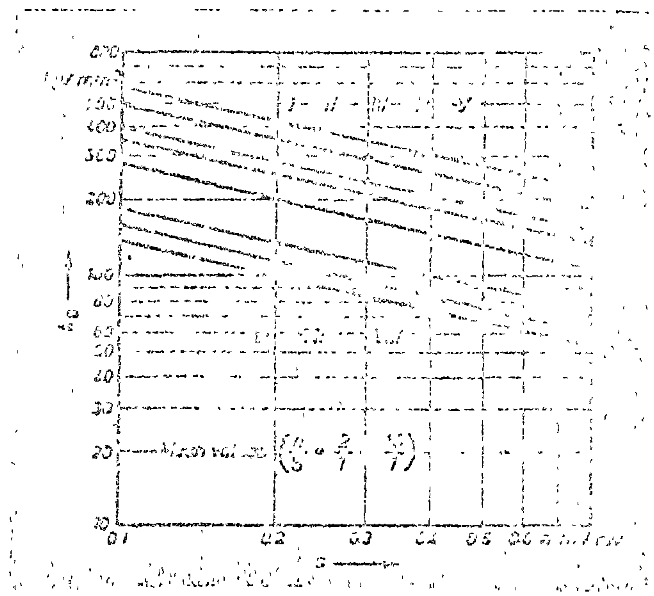
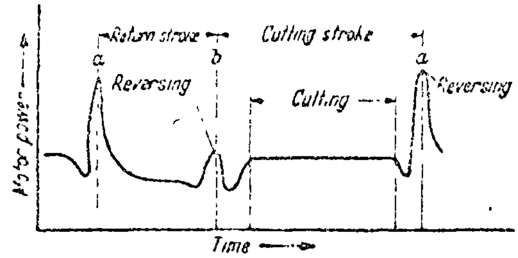
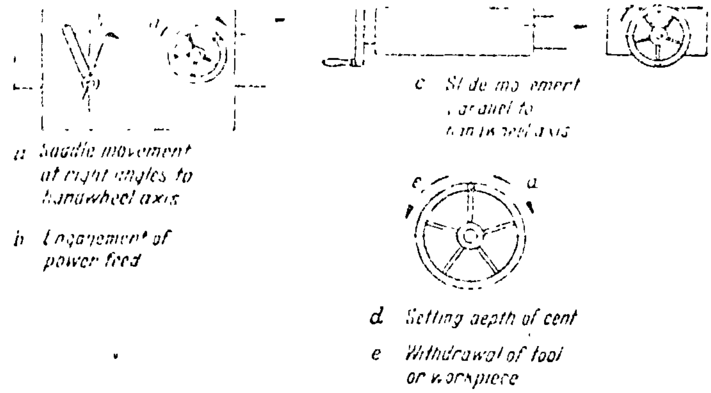


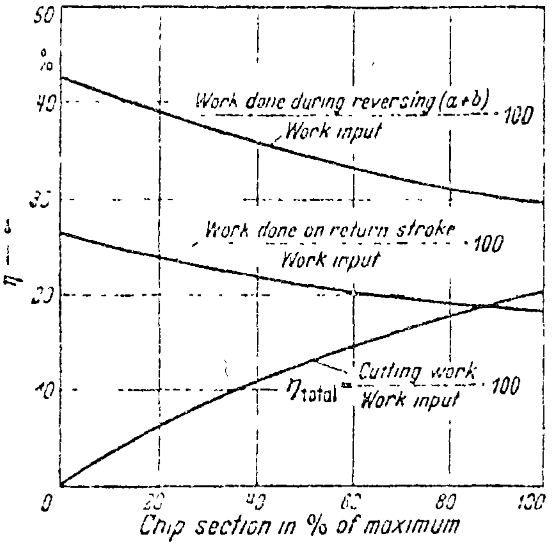
FIG. 5



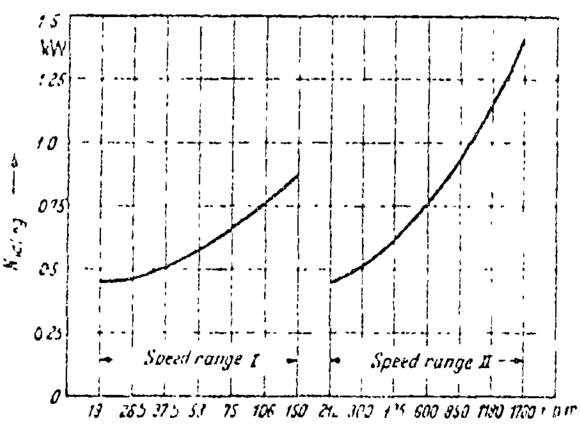
Return stroke
Cutting stroke
a
b
a
Reversing
Cutting
Reversing
Motor power
Time



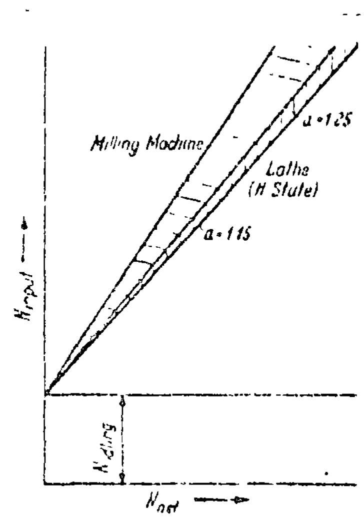
a Saddle movement at right angles to handwheel axis
b Engagement of power feed
c Slide movement parallel to handwheel axis
d Setting depth of cut
e Withdrawal of tool or workpiece



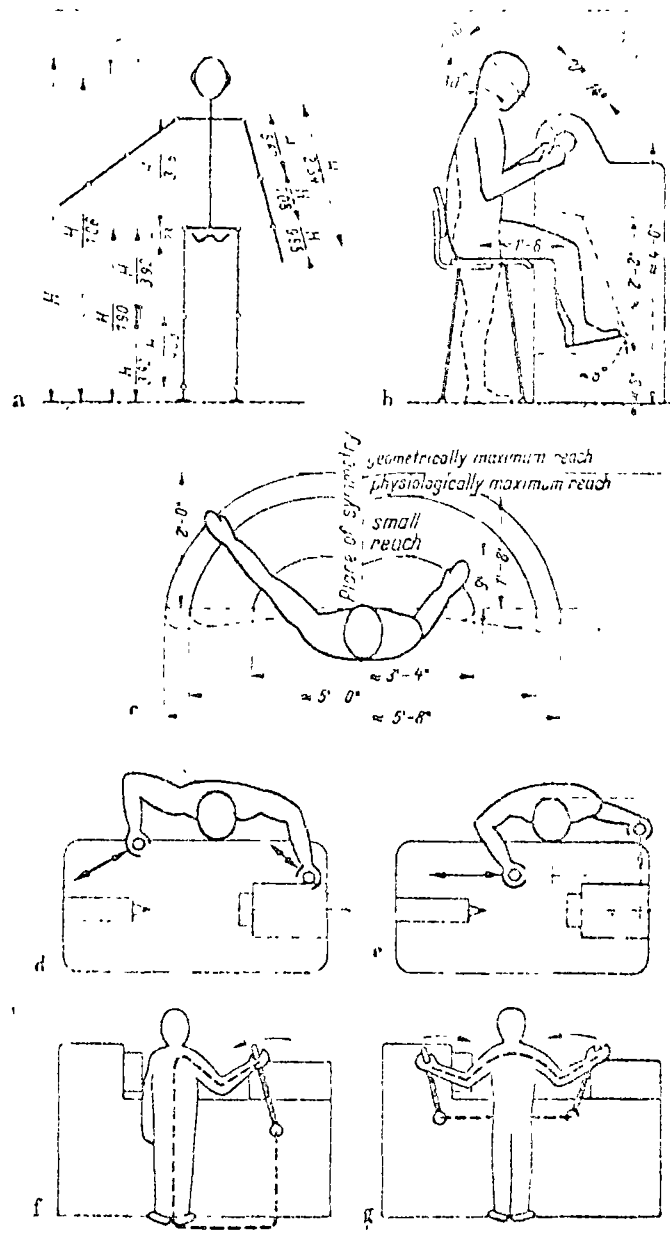
50
%
40
30
20
10
0
20
40
60
80
100
η
Work done during reversing (a+b) / Work input · 100
Work done on return stroke / Work input · 100
η_{total} = Cutting work / Work input · 100
Chip section in % of maximum



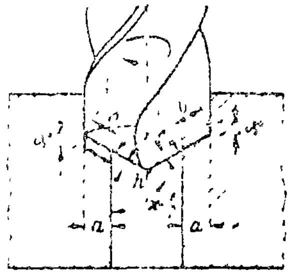
kW
1.25
1.0
0.75
0.5
0.25
0
Speed range I
Speed range II

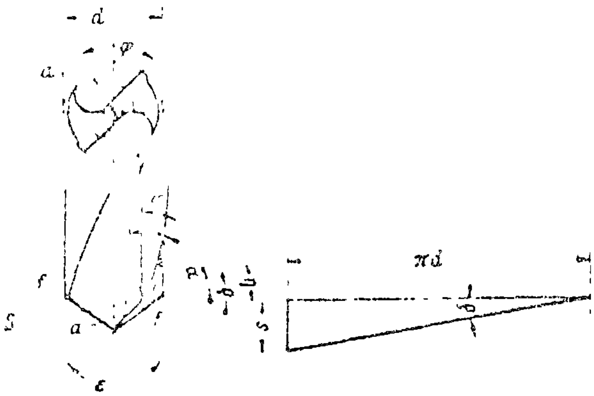


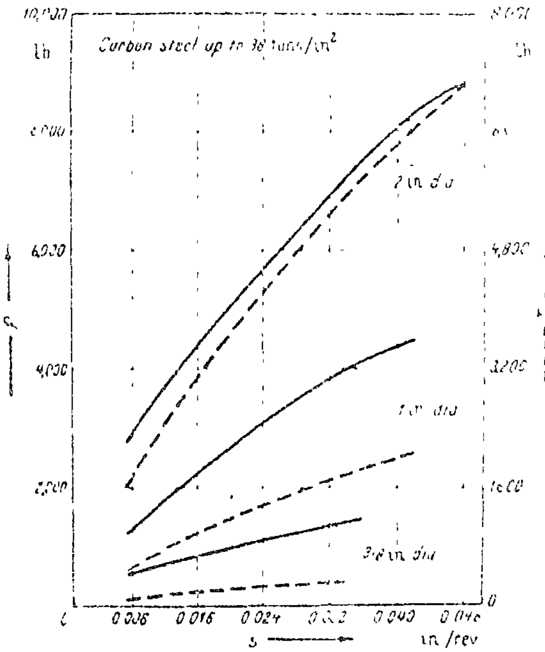
Milling Machine
Lathe
(H Stute)
N_{input}
N_{out}

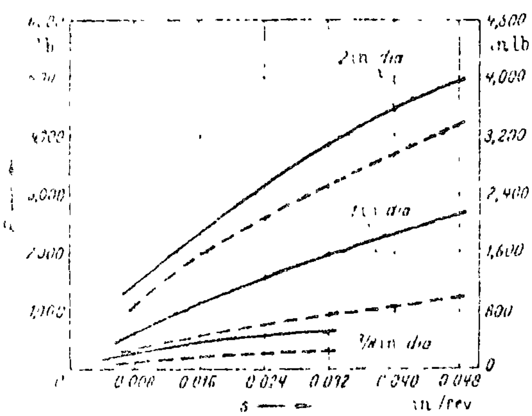


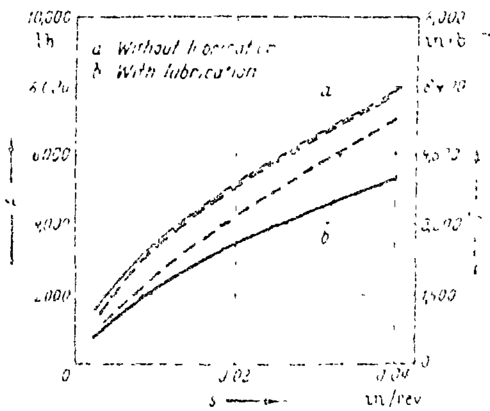
a
b
geometrically maximum reach
physiologically maximum reach
small reach
Plane of symmetry
2'-0"
≈ 5'-0"
≈ 5'-8"
c
d
e
f
g

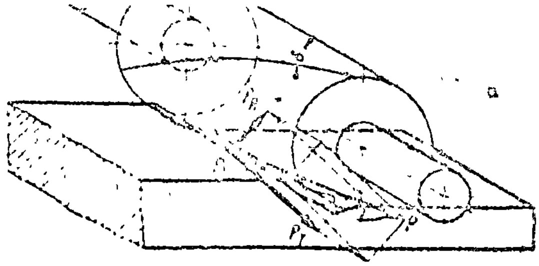


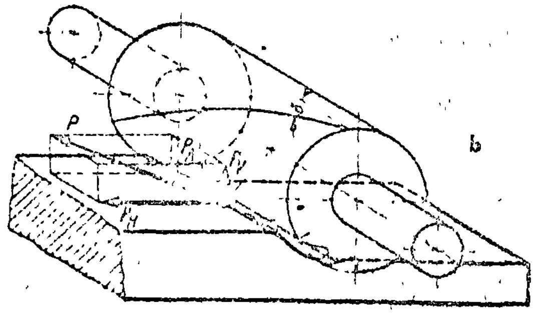

d
πd

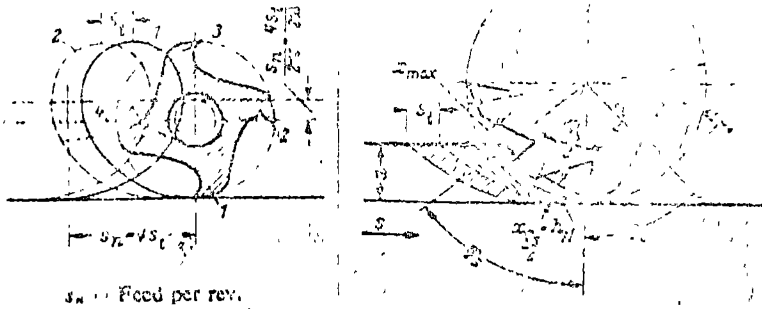

Carbon steel up to 38 tons/in²
2 in dia
1 in dia
3/4 in dia
in /rev


2 in dia
1 in dia
3/4 in dia
in lb
in /rev

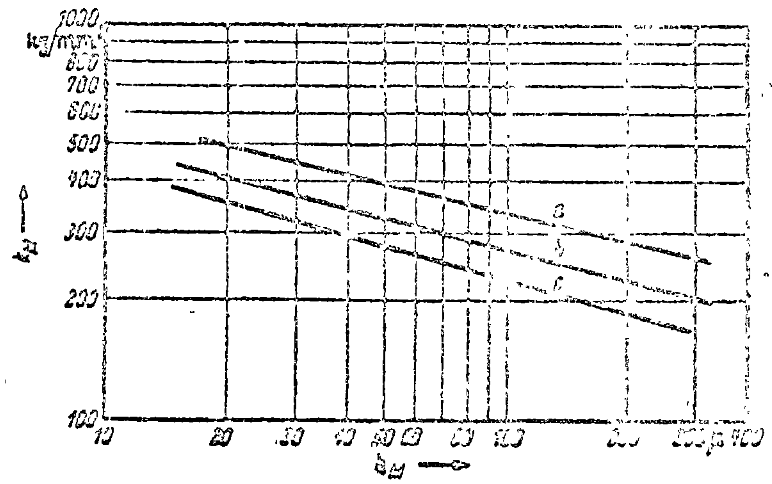

a Without lubrication
b With lubrication
in /rev

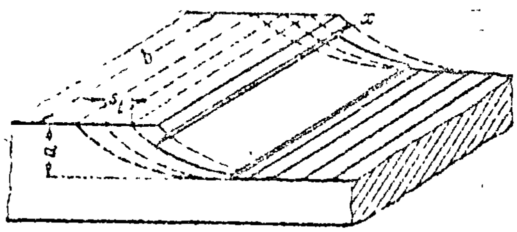


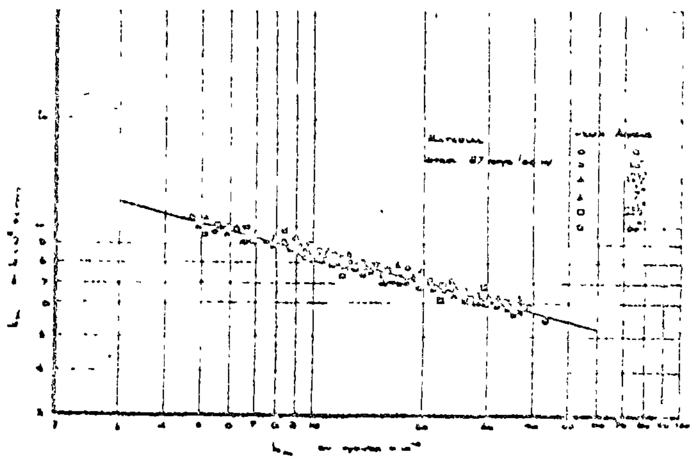


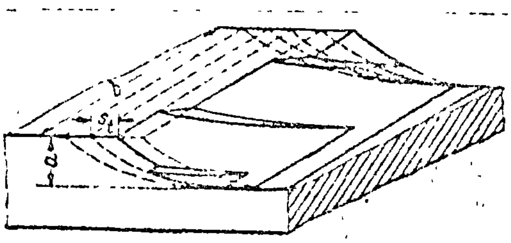


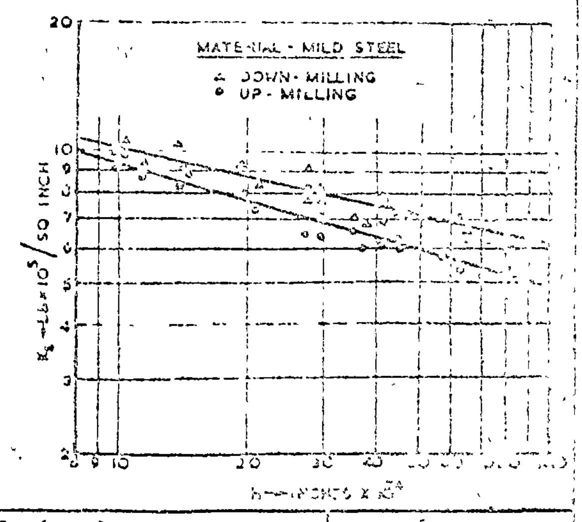
s_n — Feed per rev.
s_t — Feed per tooth.

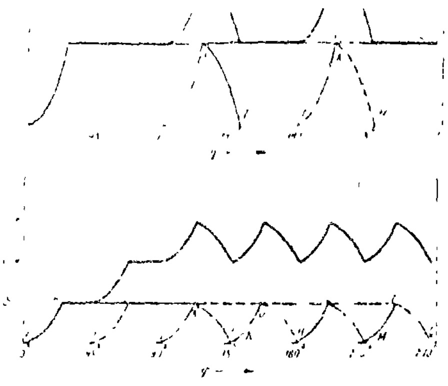


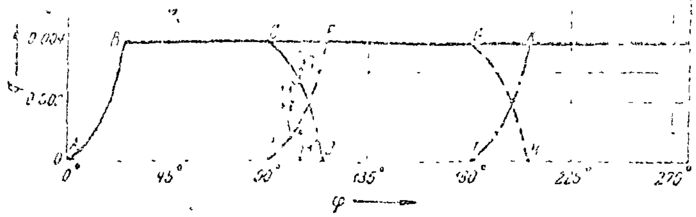




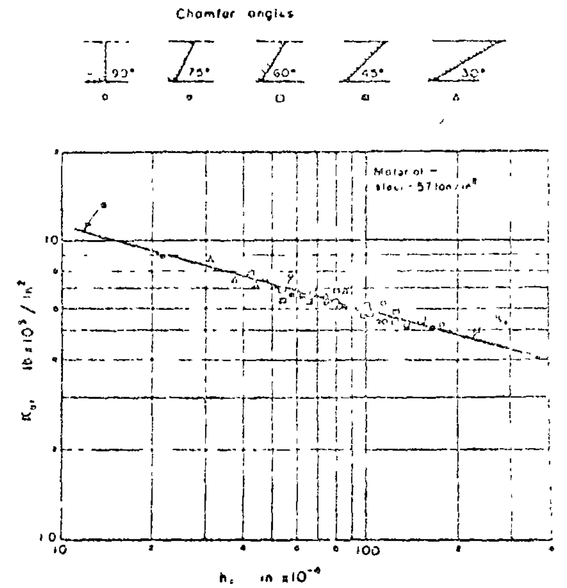




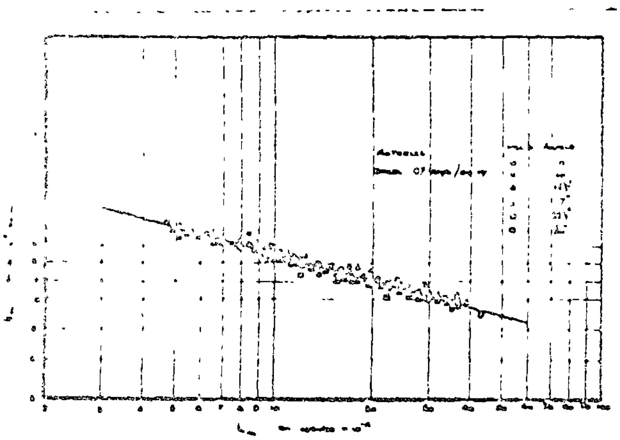


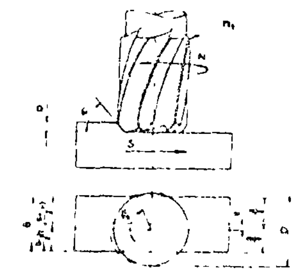


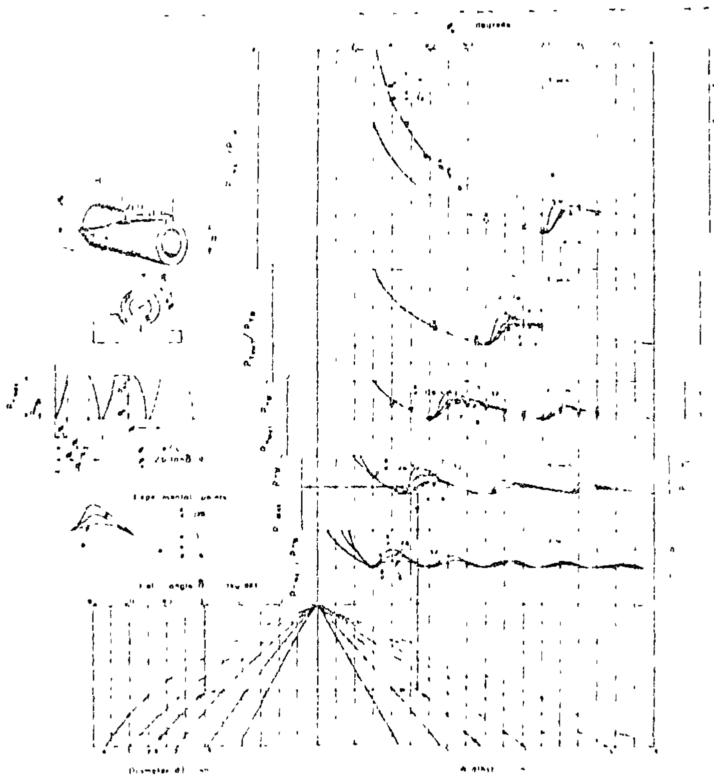
0.004
0.002
0
0°
45°
90°
135°
180°
225°
270°
φ

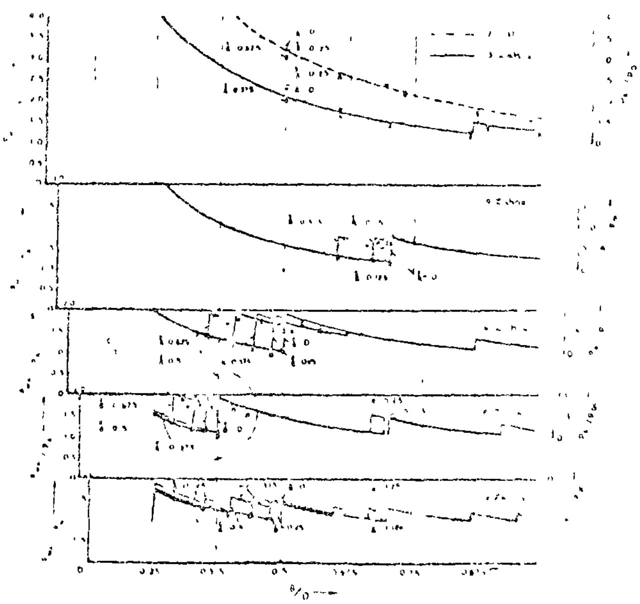


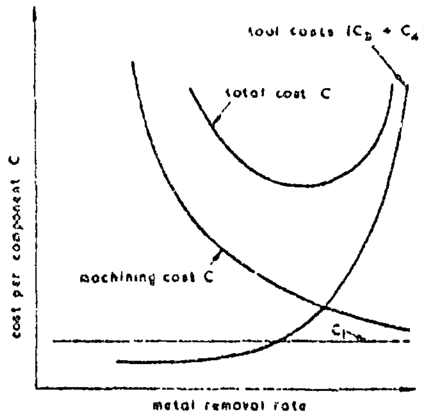
Chamfer angles
90°
75°
60°
45°
30°
10
100

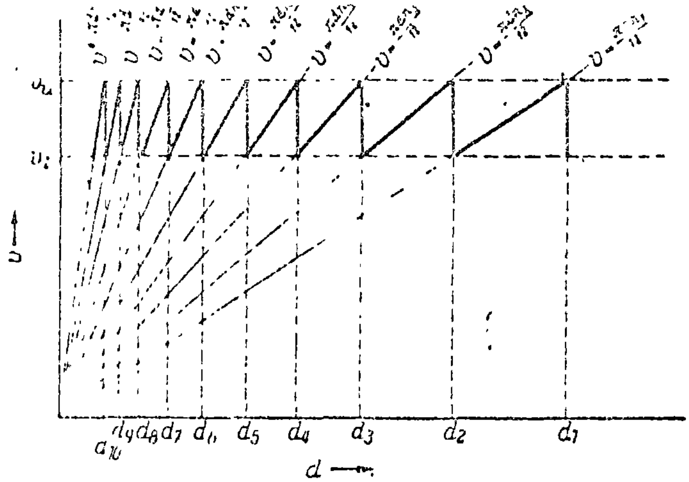


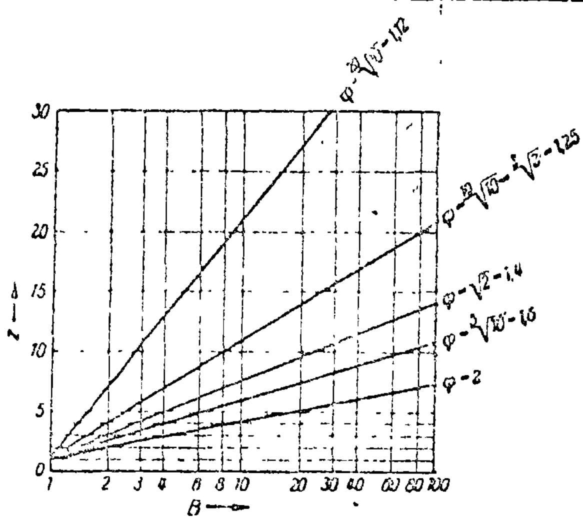






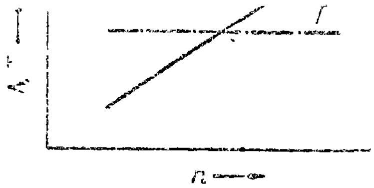


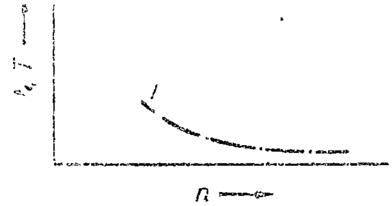


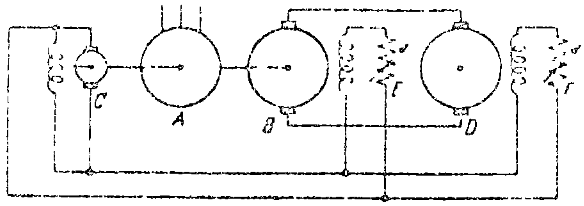


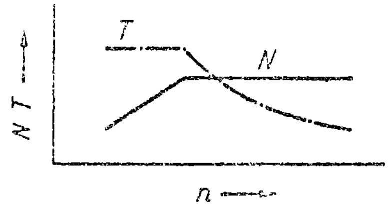
Standard Spindle Speeds Under Load According to DIN 804

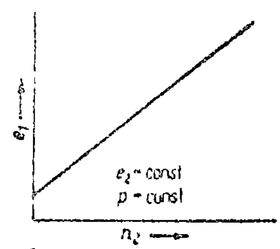
Basic Range R 20 φ = 1·12	Range R 20/2 φ = 1·25	Range R 20/3 φ = 1·4			Range R 20/4 φ = 1·6		Range R 20/6 φ = 2		
					(1400)	(2800)			
100				1000					
112	112	11·2				112	11·2		
125			125						
140	140			1400	140				1400
160		16							
180	180		180			180		180	
200				2000					
224	224	22·4			224		22·4		
250			250						
280	280			2800		280			2800
315		31·5							
355	355		355		355			355	
400				4000					
450	450	45				450	45		
500			500						
560	560			5600	560				5600
630		63							
710	710		710			710		710	
800				8000					
900	900	90			900		90		
1000			1000						


T
n

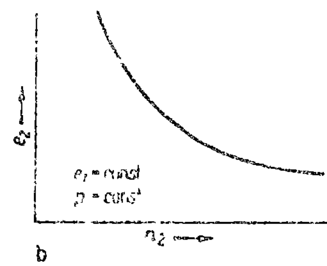

T
n


C
A
B
D
r

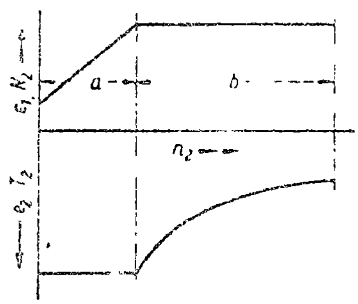

T
N
N T
n


e_1
e_2 = const
p = const
n_2

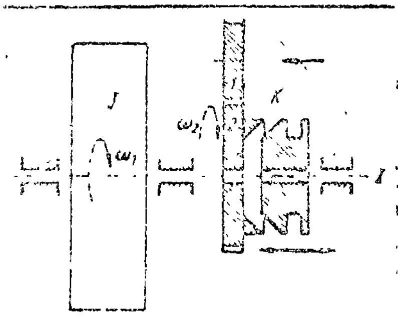
a

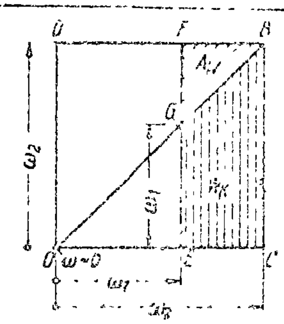

e_2
e_1 = const
p = const
n_2

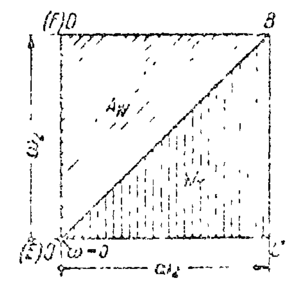
b

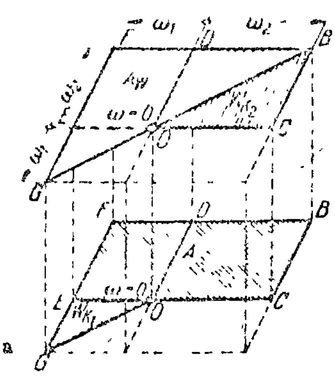

e_1 K_2
a
b
n_2
e_2 T_2

c

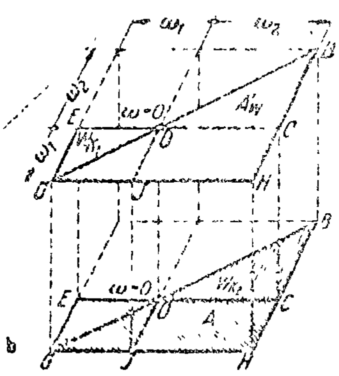

J
K
ω_1
ω_2


D
F
B
G
ω_2
ω_1
W_K
O
ω = 0
C

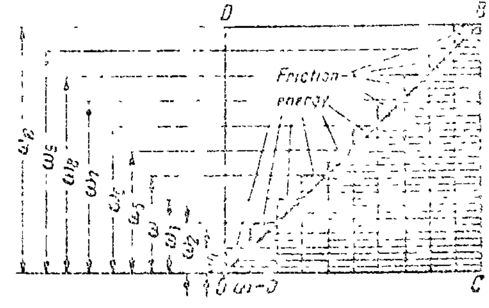

(F)D
B
A_W
W_K
ω = 0
C

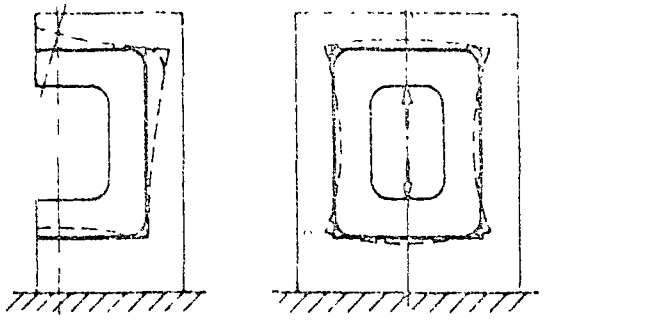

ω_1
ω_2
F
D
B
A_W
ω = 0
O
C
G
E
W_{K_1}

a

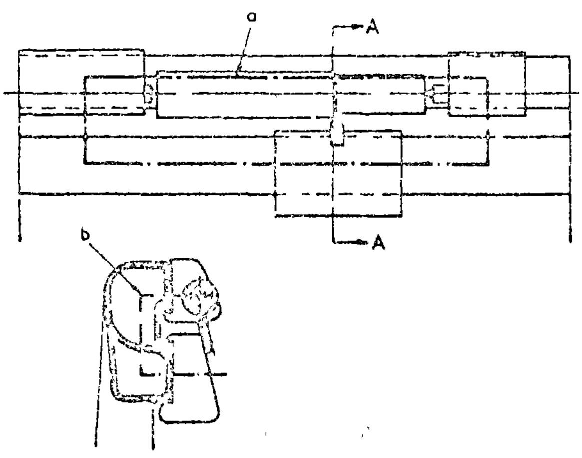

ω_1
ω_2
B
A'_W
ω = 0
O
C
E
W_{K_1}
G
H
J
W_{K_2}

b

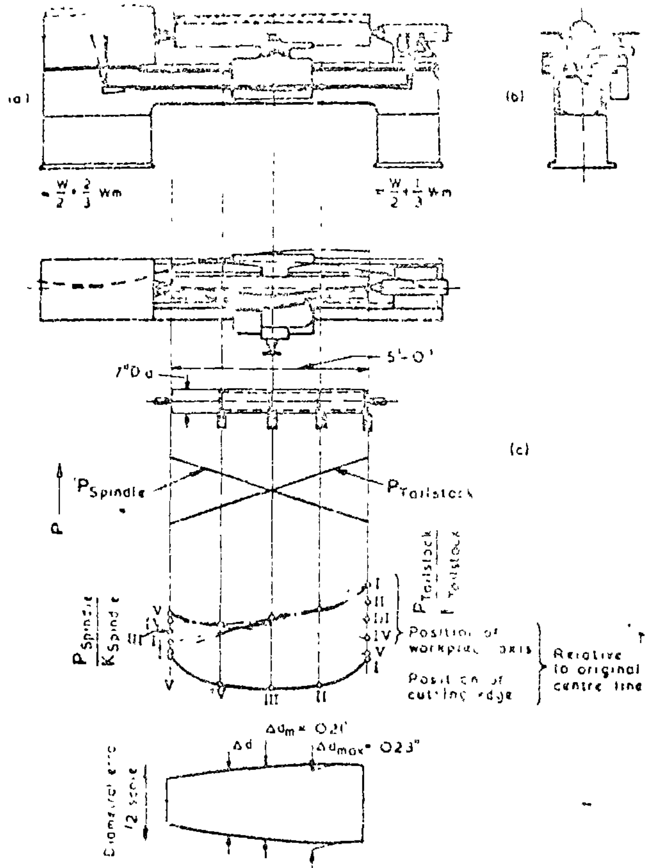

D
B
Friction-
energy
ω = 0
C

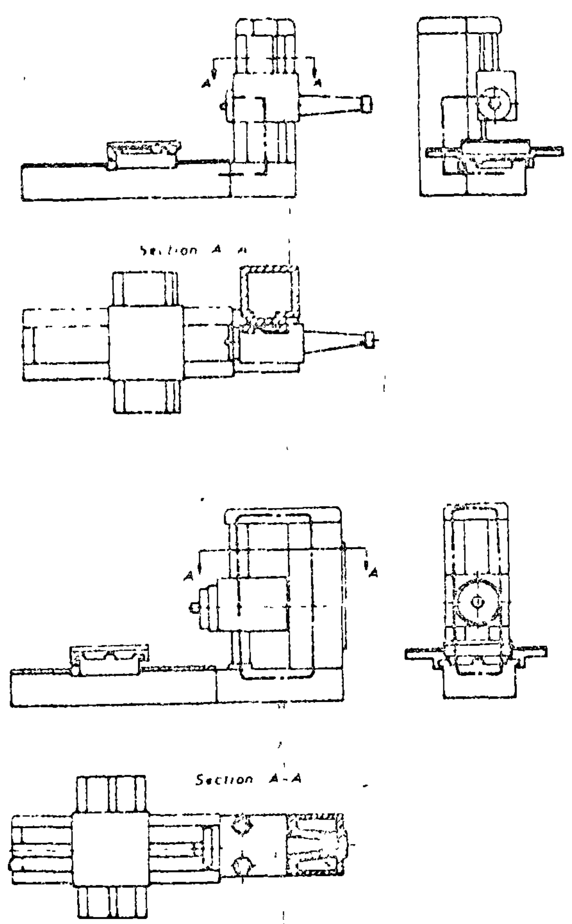


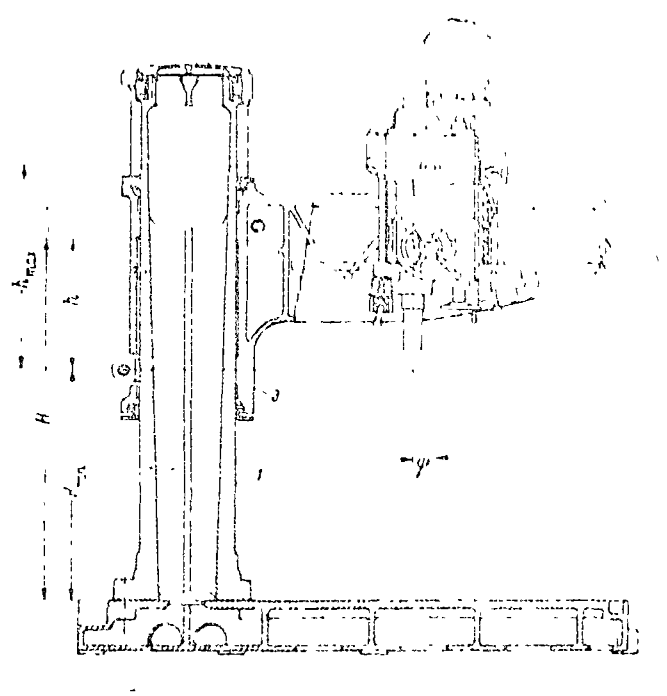
(a) (b)

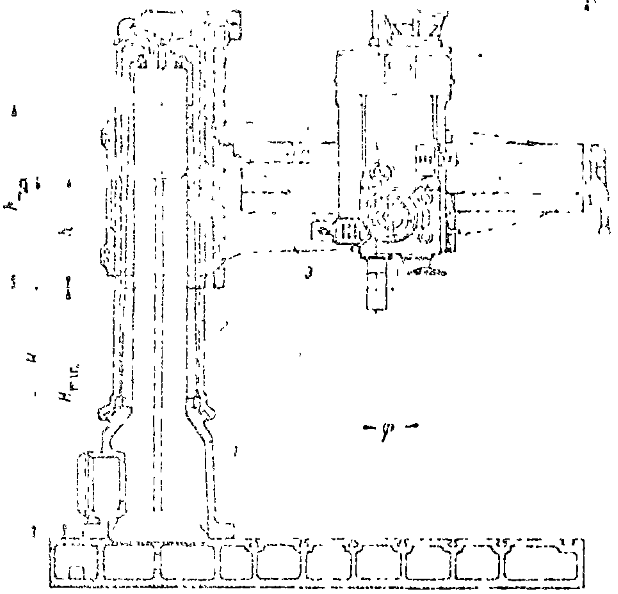


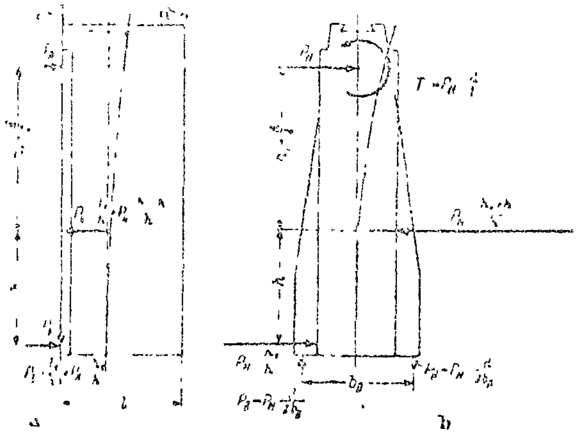
Section A-A

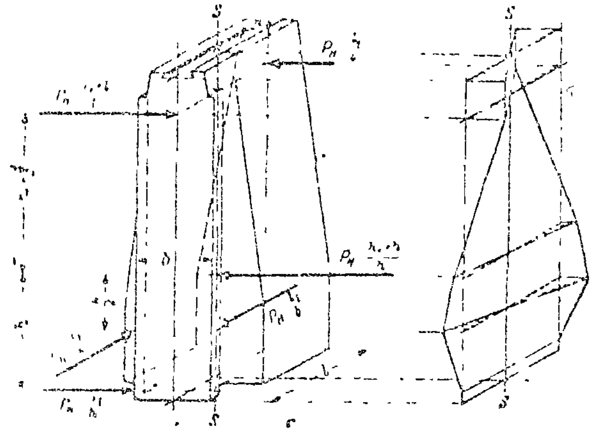


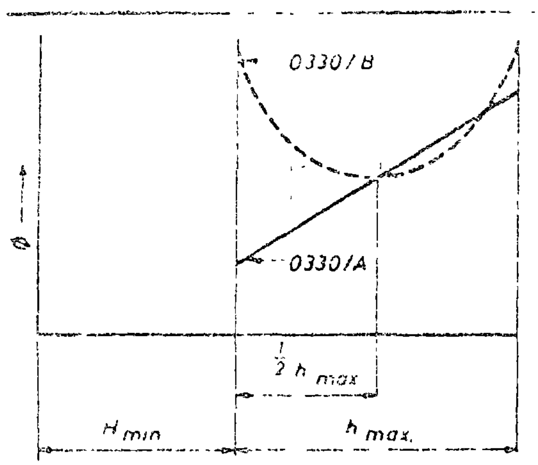












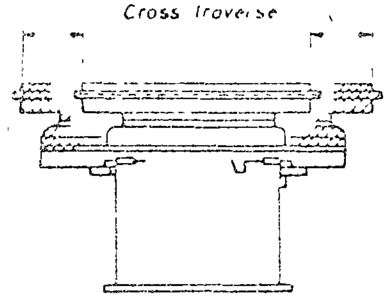
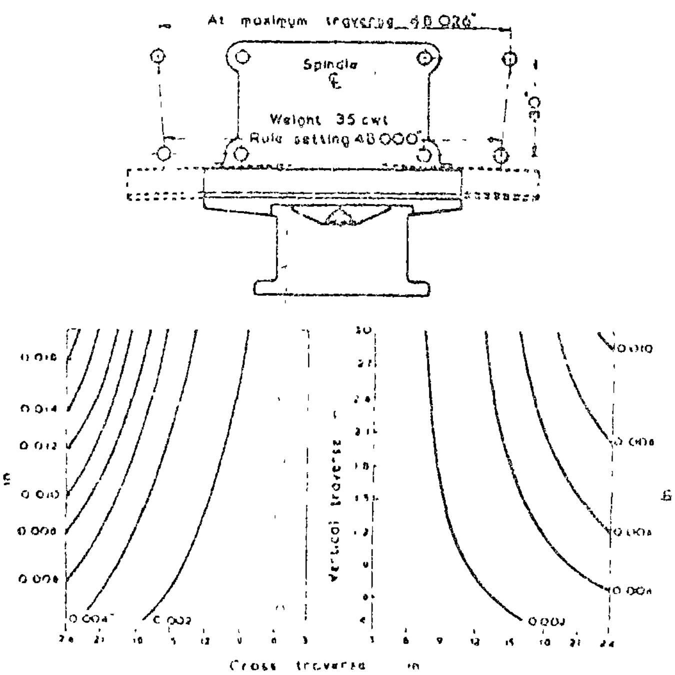


Table that is shorter than its slideway by an amount equal to the cross traverse of the table



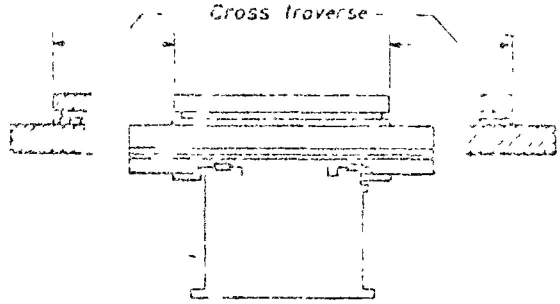
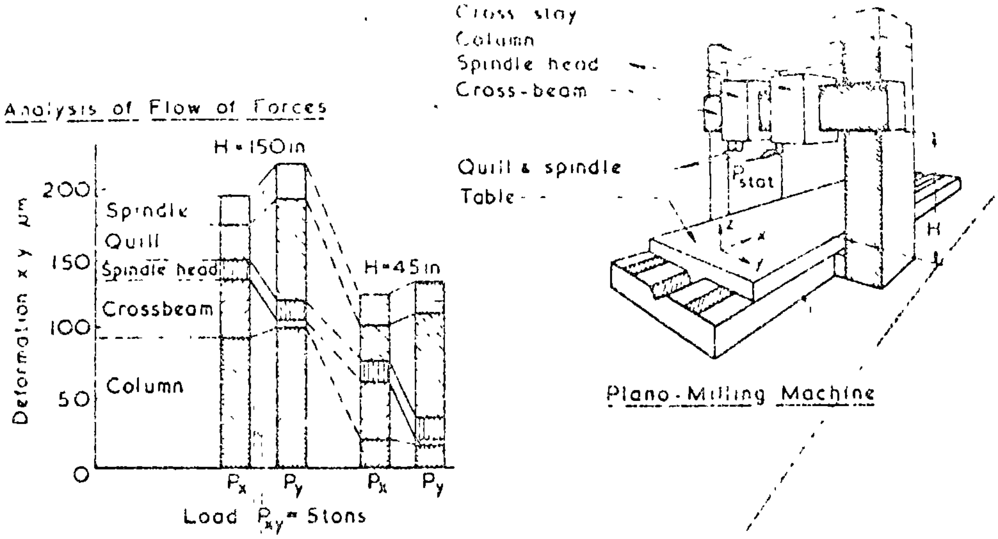
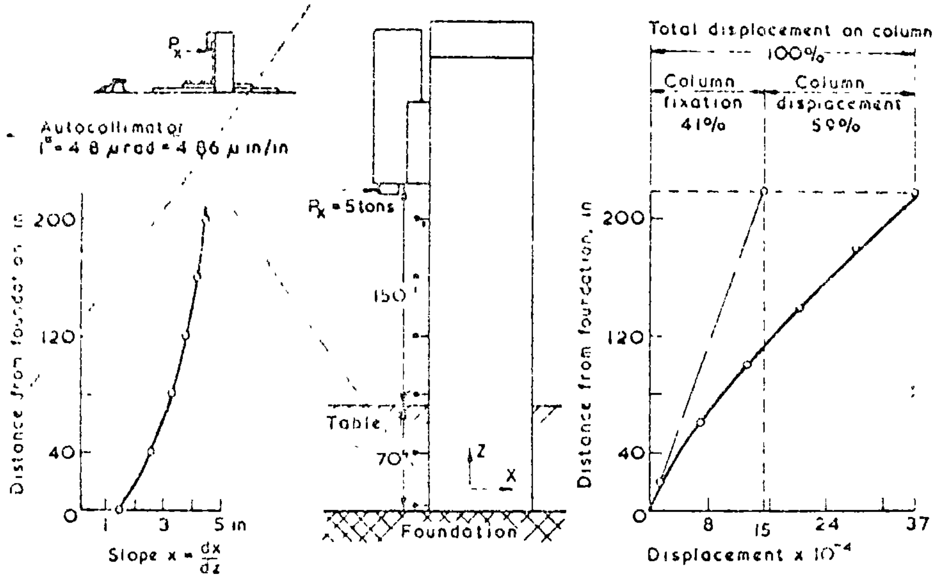


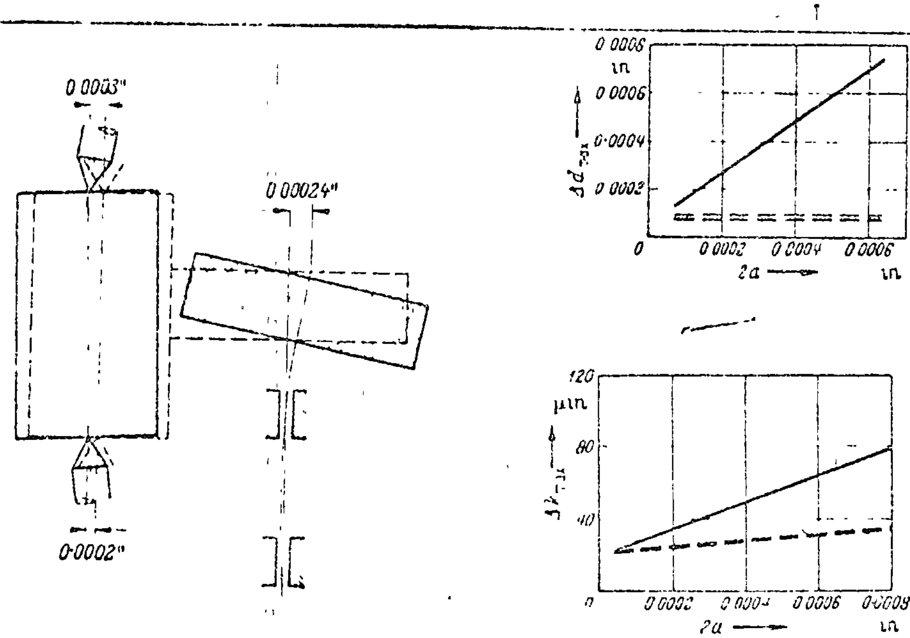
Table with length equal to that of its slideway

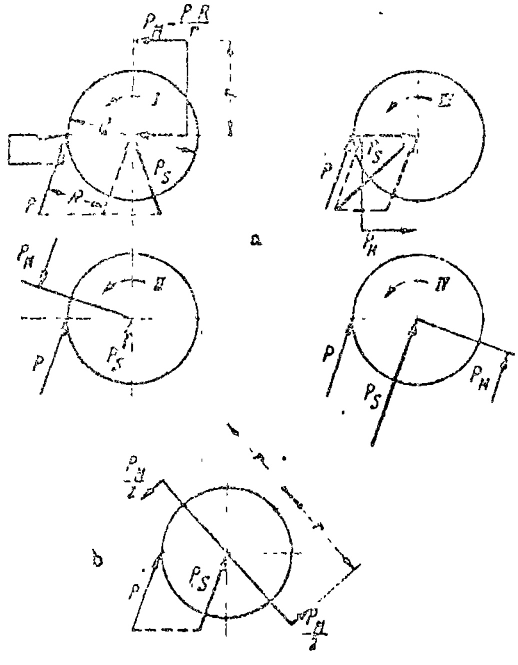


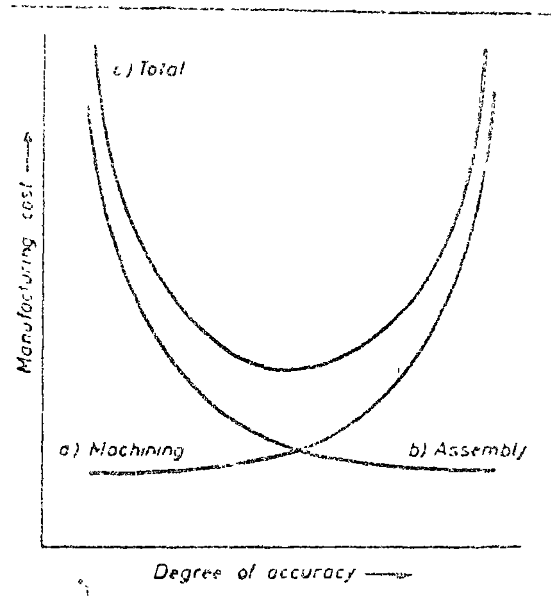
Ref 1 DEFORMATIONS OF A PLANO MILLING MACHINE

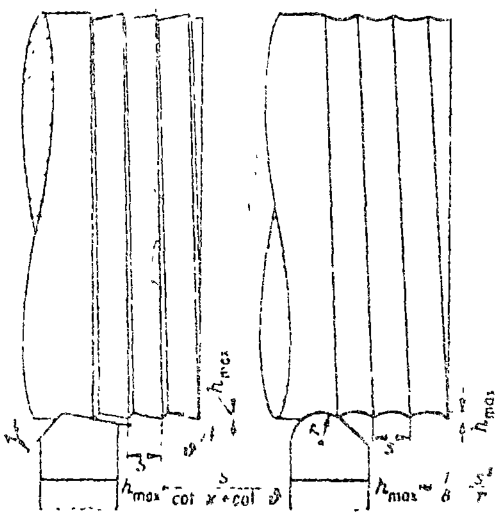


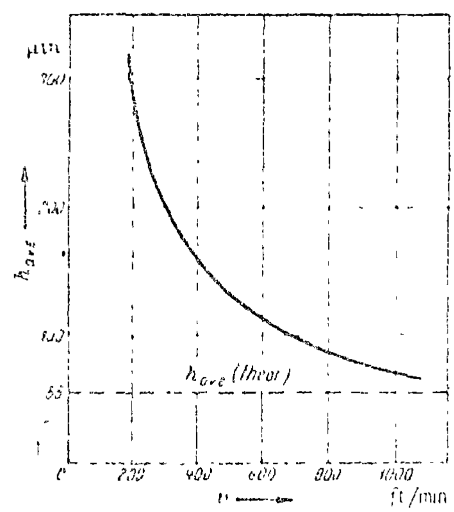
Ref 1 DISPLACEMENT OF THE SPINDLE AXIS OF A PLANO-MILLING MACHINE



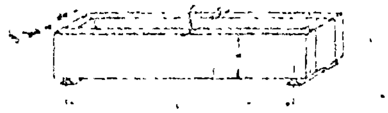








Effect of cutting speed upon surface finish (from Kumar) Tool—tungsten carbide, negative rake ( ), Material—mild steel (28 tons/in²), Depth of cut 0.002 in , Feed—0.00675 in./rev



δ Max deflection under load P

f_b Max bending stress under load P

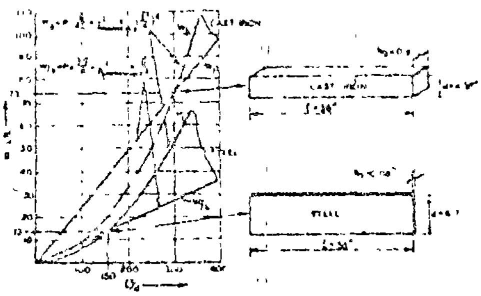
W Weight of beam (Volume V × Spec Gravity S)

W_b Weight required due to permissible deflection

W_f Weight required due to permissible bending stress

E Young's Modulus 30,000,000 lb/sq in for steel; 20,000,000 lb/sq in for cast iron

S Specific Gravity 0.282 lb/sq in for steel; 0.260 lb/sq in for cast iron



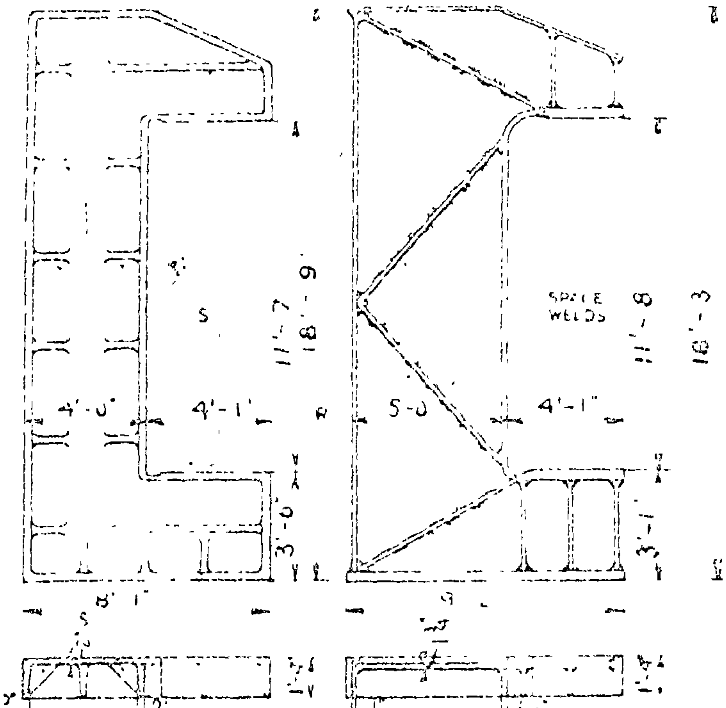
Example

P 2500 lb

l 30 in

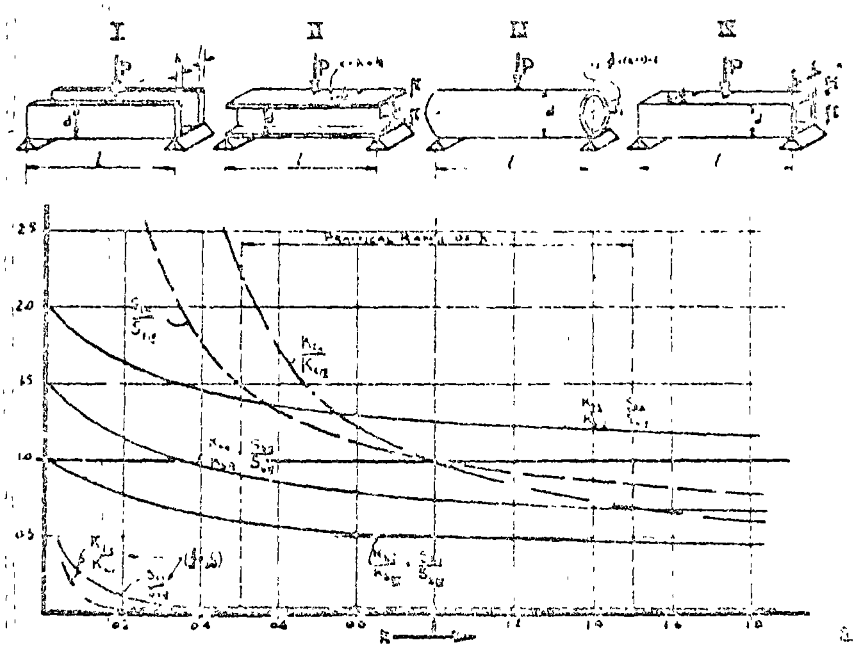
δ permissible 0.01 in

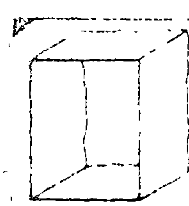
f_b permissible 12,000 lb/sq in (Steel); 4,000 lb/sq in (cast iron)



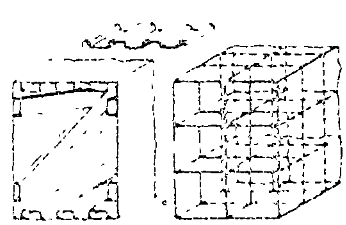
(a) CAST STEEL FRAME WEIGHT 7½ TONS

(b) FABRICATED FRAME WEIGHT 6½ TONS

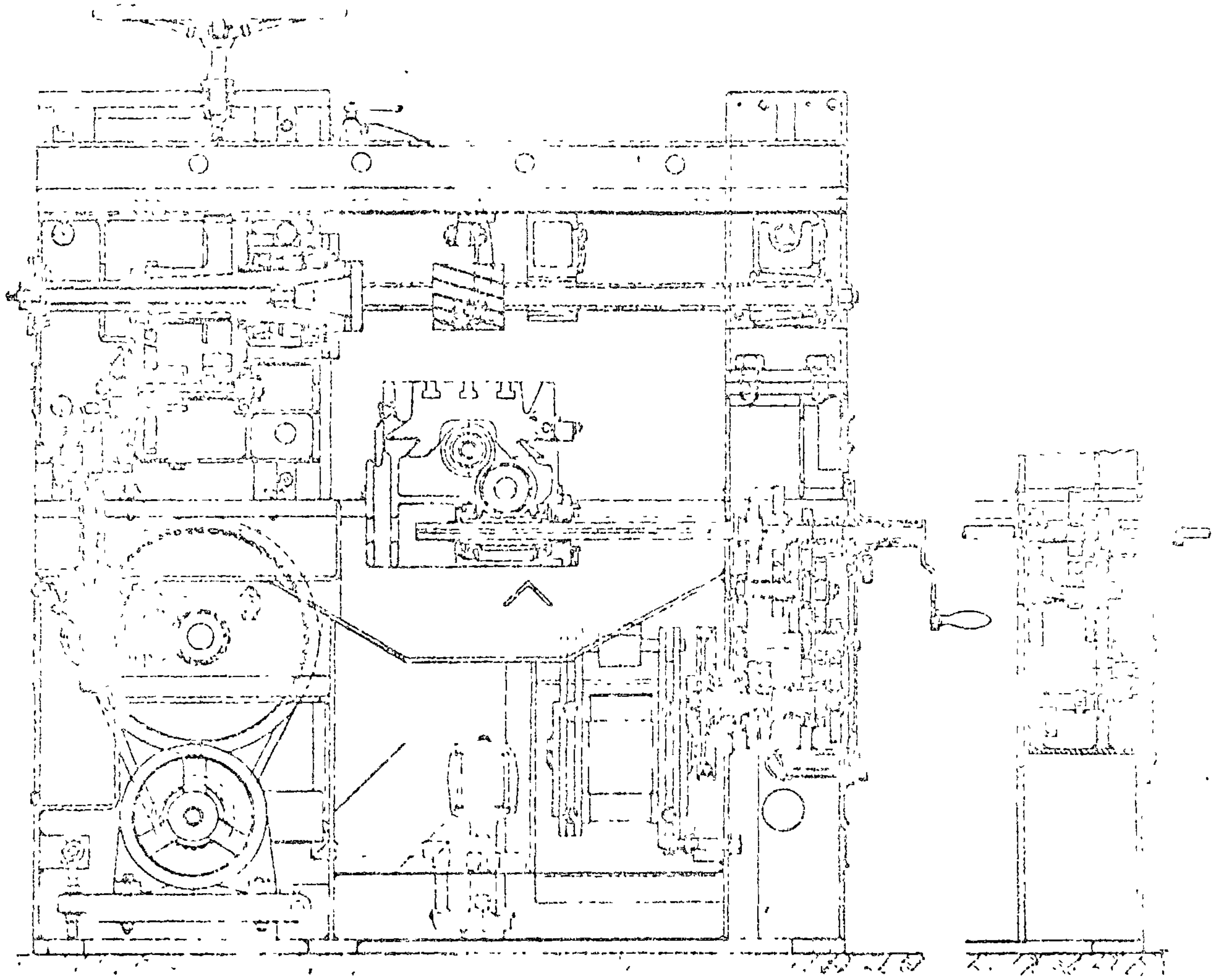


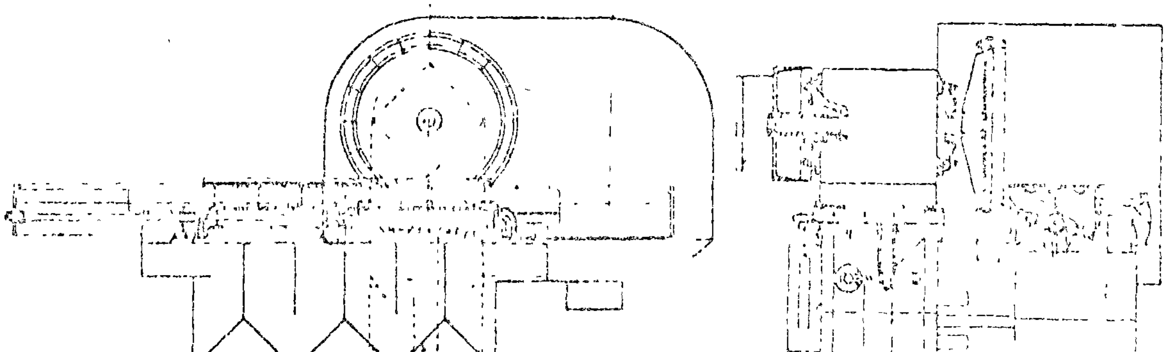


Required Section



Shell construction Cellular construction





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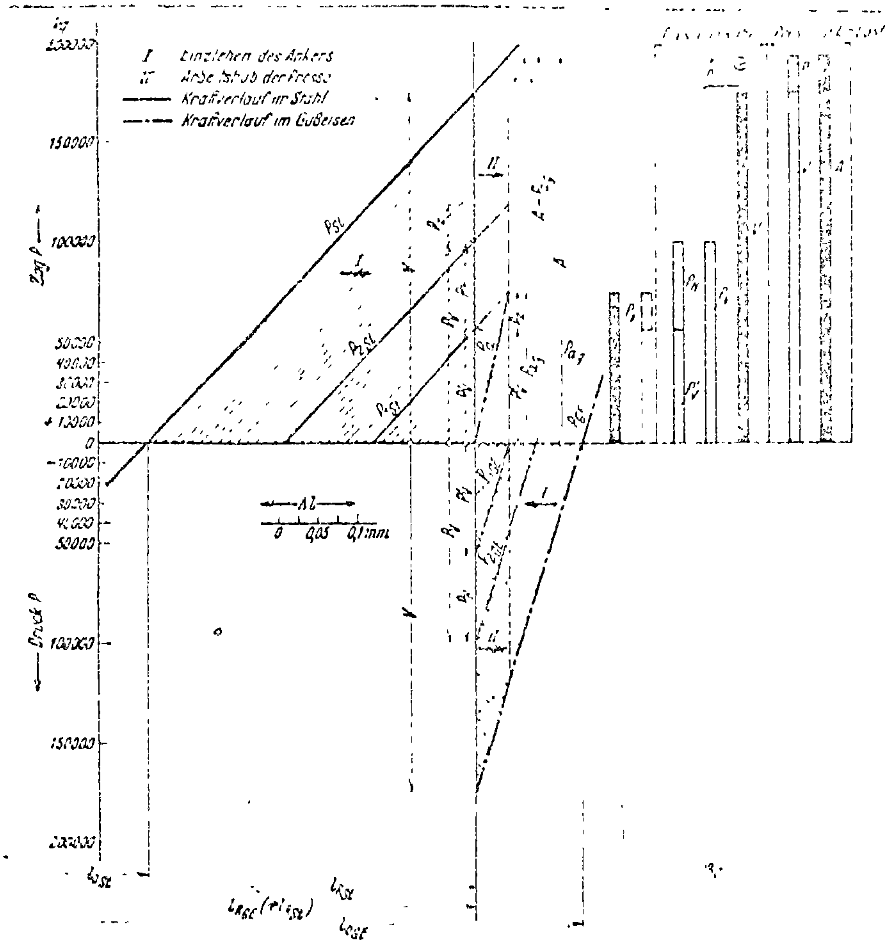
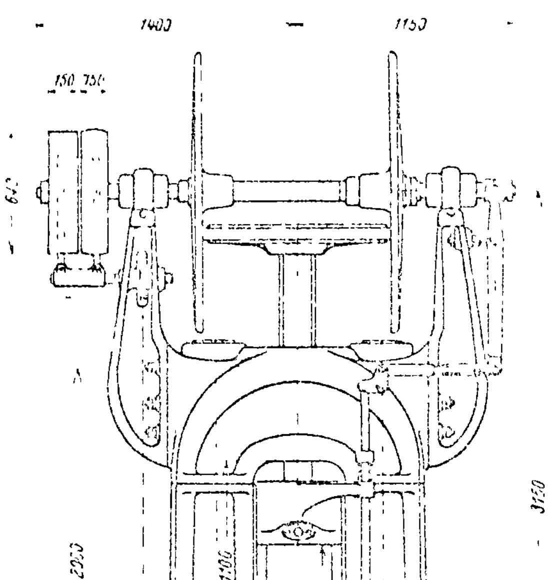
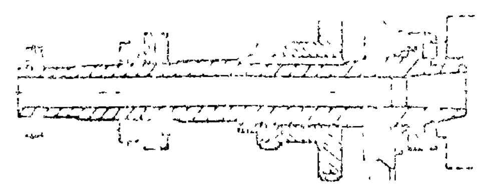
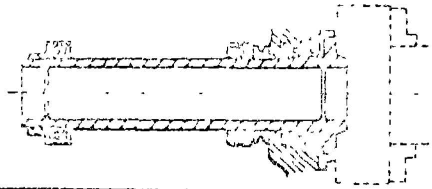
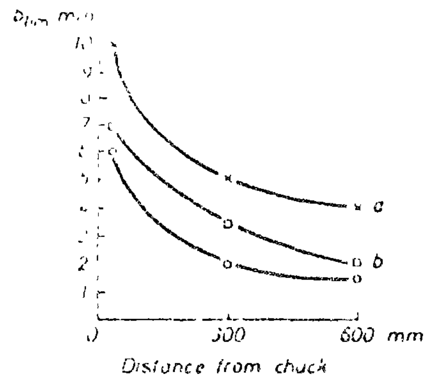
0374 / E | Professor F. Koenigsberger

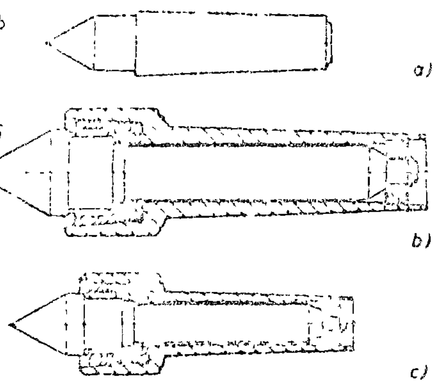

kg
I Einziehen des Ankers
II Arbeitshub der Presse
Kraftverlauf im Stahl
Kraftverlauf im Gußeisen
Zug P
Druck P
150000
100000
0
100000
150000
0,05
0,1 mm


1400
1150
3150
2000
1100
720
450
900

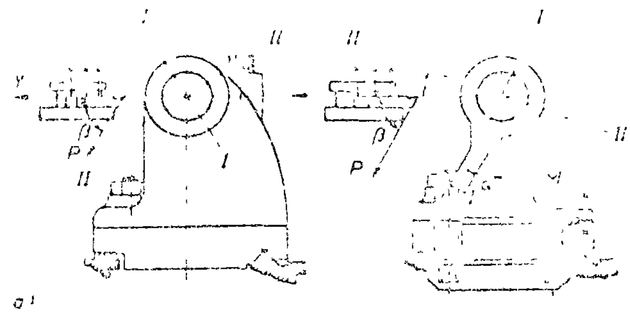
Lathe no	Drawing of the spindle and mounting	Swing over bed mm	Stat. stiffness of spindle end kg/μm	b_{lim} mm
A		630	15	2.5
B		750	71	15

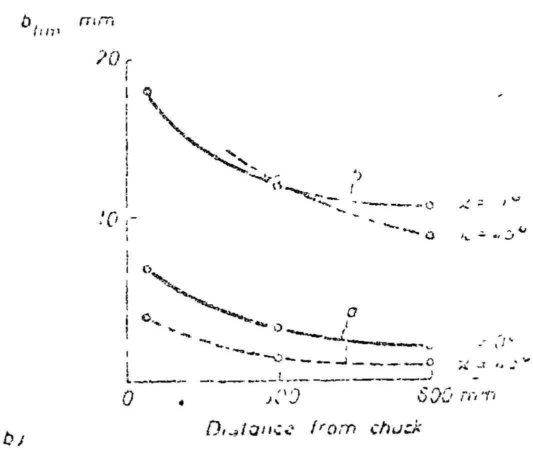
Effect of Headstock Design



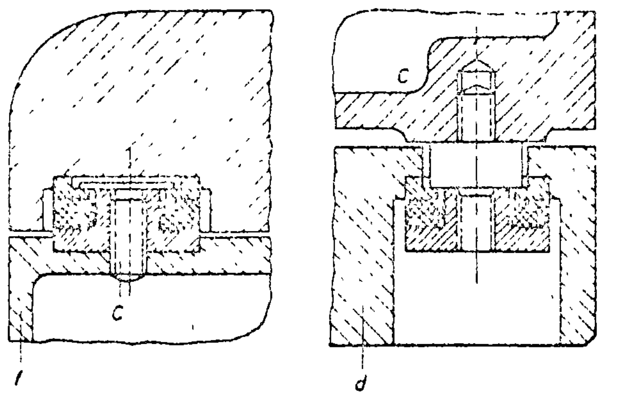


Effect of Stiffness of Centre

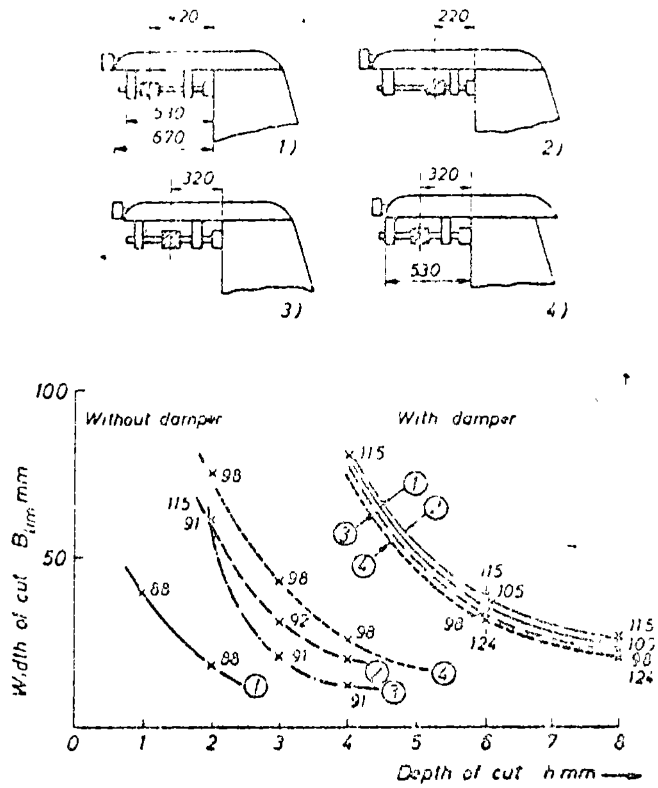




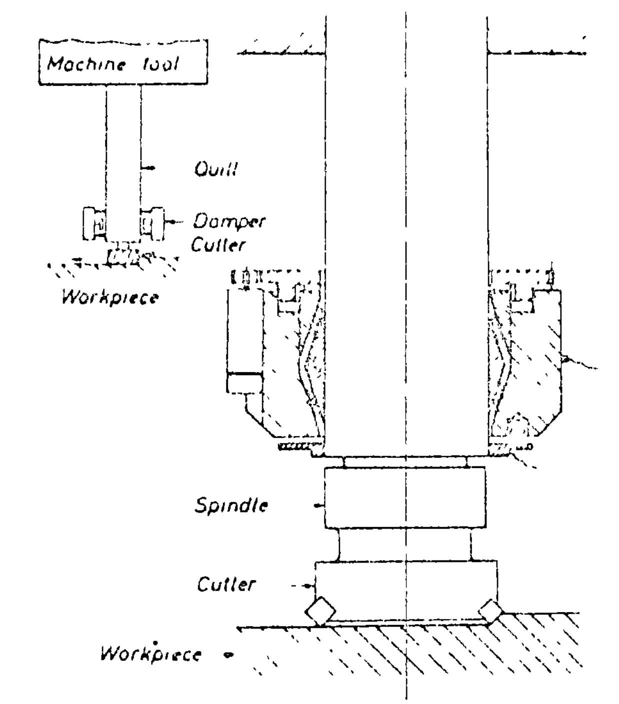
Effect of Mode Orientation



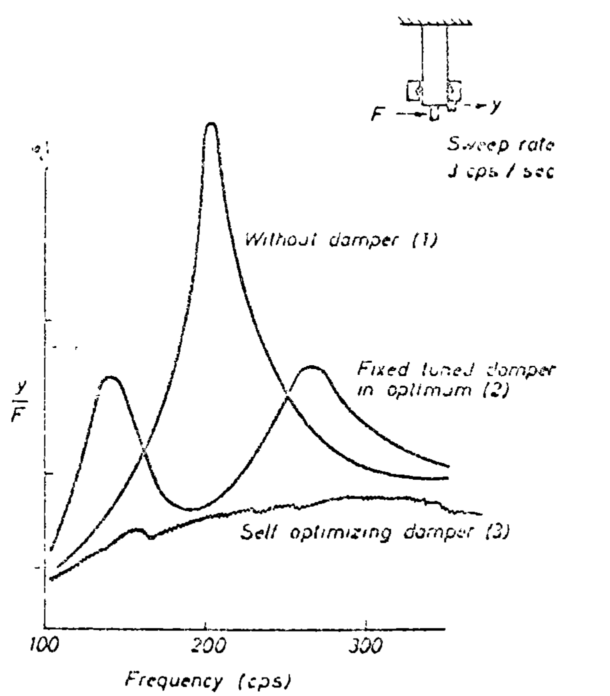
Practical Versions of the Damped Dynamic Vibration Absorber (Eisele and Lysen).

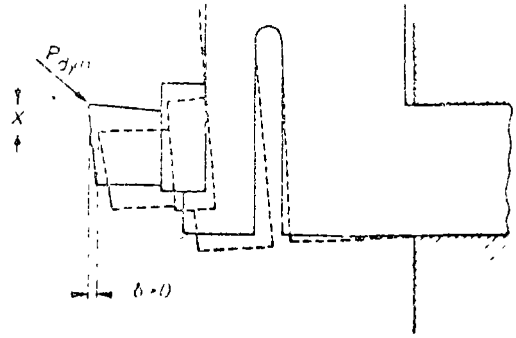


Effect of Damper

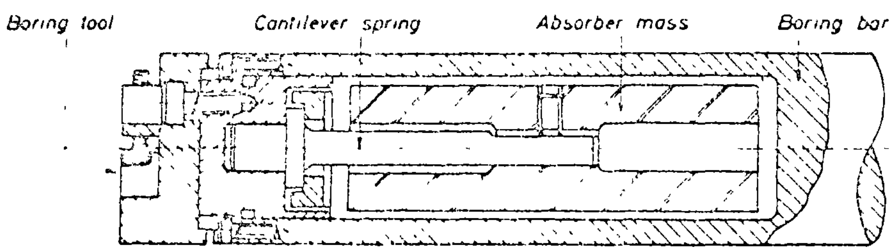


Active Damper
(Self Tuning)

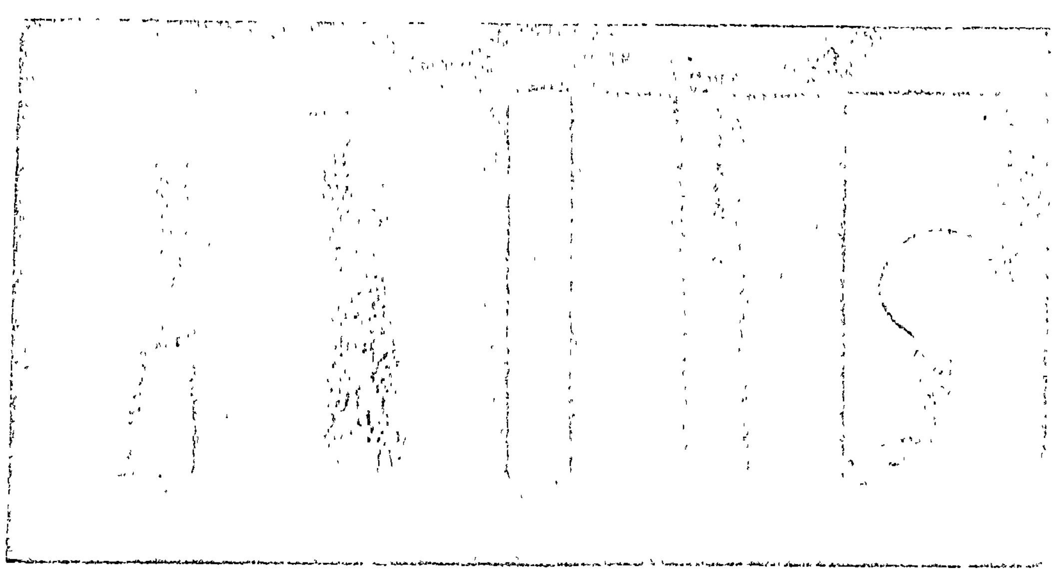




Parting Tool Holder (After Holken)



Overhang ratio	Solid bar c/c_c	Damped bar c/c_c
5/1	0 015	0 109
6/1	0 012	0 087
7/1	0 011	0 068
8/1	0 013	0 066



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INGENIERIA DE MANUFACTURA

UTILAJE DE SUJECION. CONTROL DE CALIDAD

DR. F. KOENIGSBERGER

JULIO DE 1976.

Palacio de Minería Calle de Tacuba 5, primer piso. México 1, D. F. Tels.: 521-40-23 521-73-35 5123-123

2. <u>Jigs, Fixtures, Quality Control.</u>

In the design, manufacture and application of equipment specially intended for producing a particular workpiece or type of workpiece certain considerations are important.

A specification must be established, which considers the ultimate purpose and tasks of the device in question. These must be reconciled with the available plant, the available power resources and the cost which can be carried by the project.

The purpose and tasks may cover one or several of the following: Workpiece or material handling, locating, clamping or producing (machining, pressing, forging, welding etc.) These tasks must be arranged in the required order of importance, so that it is possible to establish priorities. The necessary degree of accuracy, productivity etc. must be defined. The decision as to whether a single purpose type of equipment is essential or whether a more universal device can be employed will influence the cost considerations.

Simple cost calculation for special purpose device (FK.Roe, Mech. Eng. Feb.1941).
Questions:

1. How many components must be produced per annum to make the special device (jig, fixture, machine) pay?

2. If a certain saving in labour cost is required, what is the permissible cost of the special device?

3. How long will it take for the special device to pay for itself?

4. What will be the profit earned by the special device for a specific saving in labour cost and a given output?

The various items to be considered are:-

a = annual percentage allowance for "interest on investment";
b = annual percentage allowance for fixed charges, such as taxes, insurance etc.;
c = annual percentage allowance for maintenance;
h = number of years allowed for amortisation of investment

so that

$\frac{1}{h}$ = annual percentage allowance for depreciation and obsolescence based on uniform depreciation;

i = estimated total cost or purchasing price of the special device;

n = number of workpieces per batch;

u = number of batches per annum;

N = number of workpieces produced per annum;

N = u.n ;

y = cost of each setting-up operation including cost of dismantling (in the case of a special fixture) in order to restore normal condition of the plant for other operations;

Y = annual cost of setting-up;

$Y = y.u = y.\frac{N}{n}$;

s = saving in labour cost per workpiece;

S = annual total saving in direct labour cost;

S = N.s ;

t = overhead percentage of labour cost;

T = annual total saving in overheads;

T = S.t;

P = annual gross profit.

<u>Credit side per annum</u>

$S+T = Ns(1+t) = uns(1+t)$

<u>Debit side per annum</u>

$y.u+i(a+b+c+\frac{1}{h})$

<u>Answer to question 1.</u>

$$N \gtrless \frac{y.u + i(a+b+c+\frac{1}{h})}{s(1+t)}$$

<u>Answer to question 2.</u>

$$i \lesseqgtr \frac{Ns(1+t) - y.u}{a+b+c+\frac{1}{h}}$$

<u>Answer to question 3.</u>

$$h \gtrless \frac{i}{u\left[ns(1+t)-y\right] - i(a+b+c)}$$

$$\frac{1}{h} \gtrless \frac{u}{i}\left[ns(1+t)-y\right] -(a+b+c)$$

<u>Answer to question 4.</u>

$$P = uns(1+t) - yu - i(a+b+c-\frac{1}{h})$$

Quality control must be based on the requirements of the design as indicated on the production drawings. These requirements may be based on the product satisfying the conditions under which it is to be used, or on manufacturing needs, such as fitting into fixtures, providing reference faces, bores etc. for subsequent operations etc. Quality control can be effected by actual inspection operations, by self-checking fixtures, by in-process measurement etc.

Inspection equipment, gauges, comparators, surface finish and roundness measuring devices etc. are available. Advantages of "go" and "no go" equipment rather than measuring devices giving absolute readings. Selective and non-selective interchangeability.

	Concerned Department	Facilities Provided
1	Design	Variety reduction Recognition of repeat or similar parts
	Standards	Standard components easily identified Uniformity of characteristics
2	Production Planning	Use of repeat parts Grouping of parts requiring same machine Use of standard times
	Production Control	Suitability for Data processing
3	Production	Parts family manufacture
	Equipment	Adapting the machine tool to the work pieces required

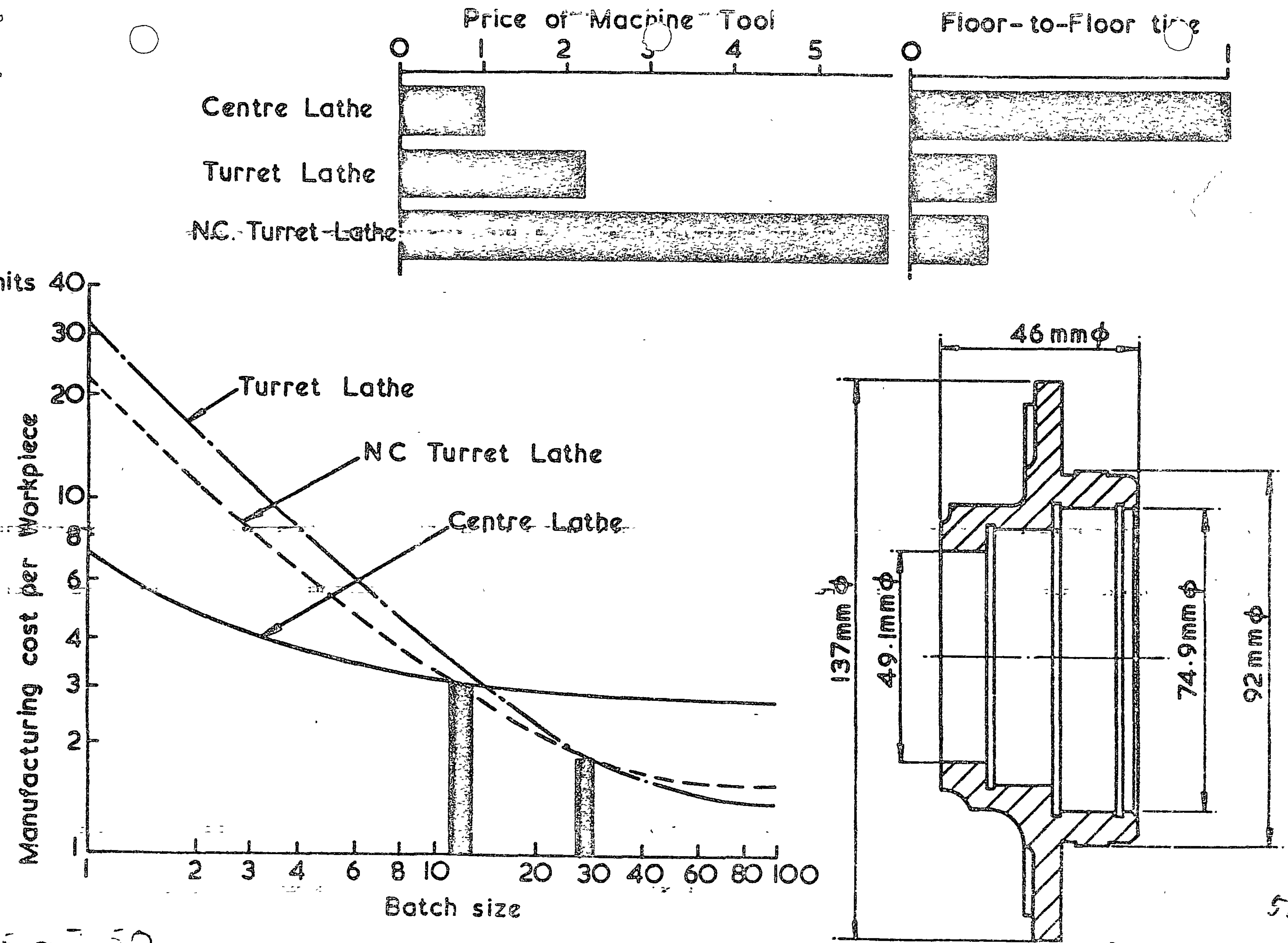

Fig 7.50

58

DB 0107

OPITZ CLASSIFICATION AND CODING SYSTEM

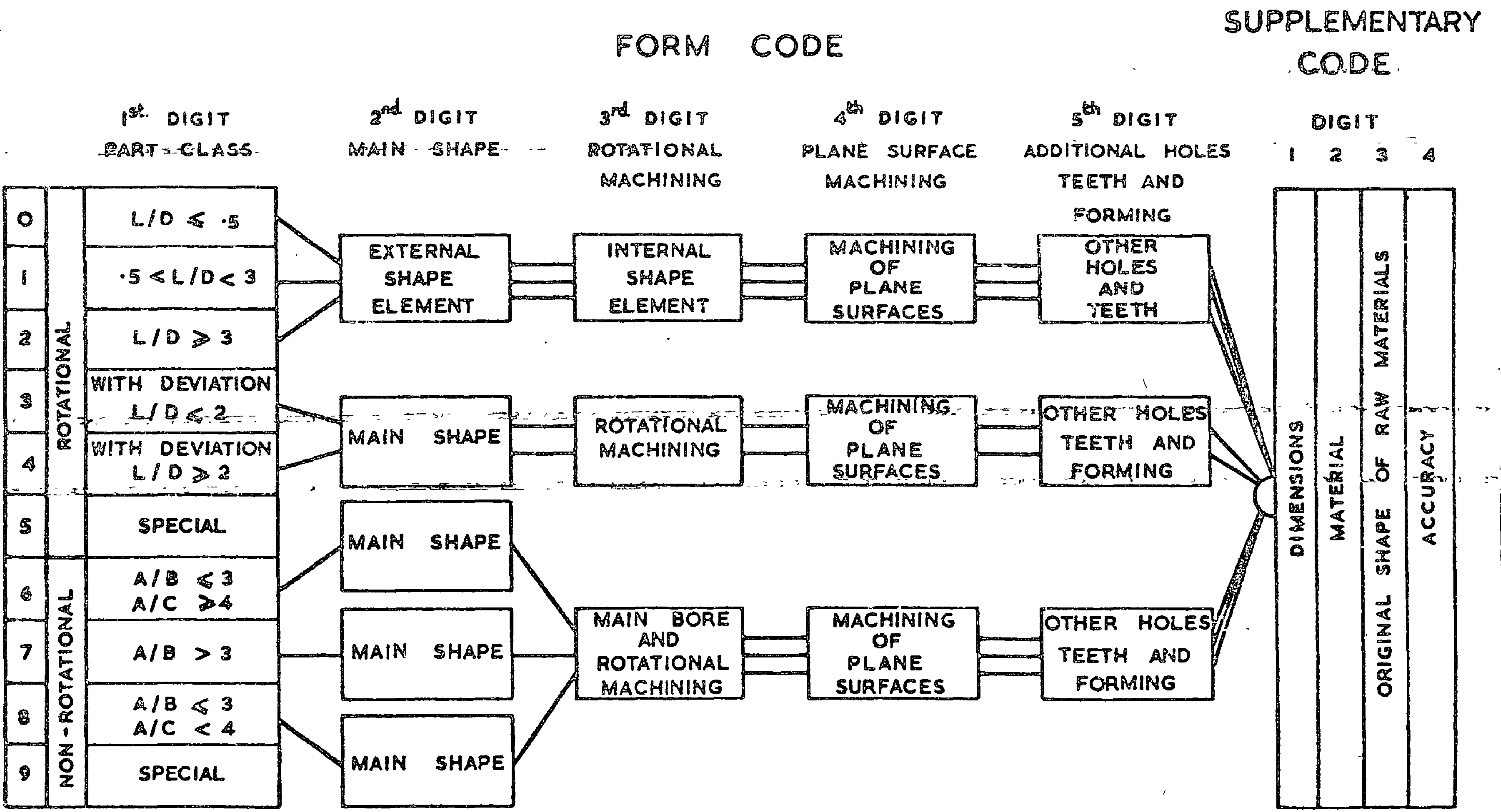

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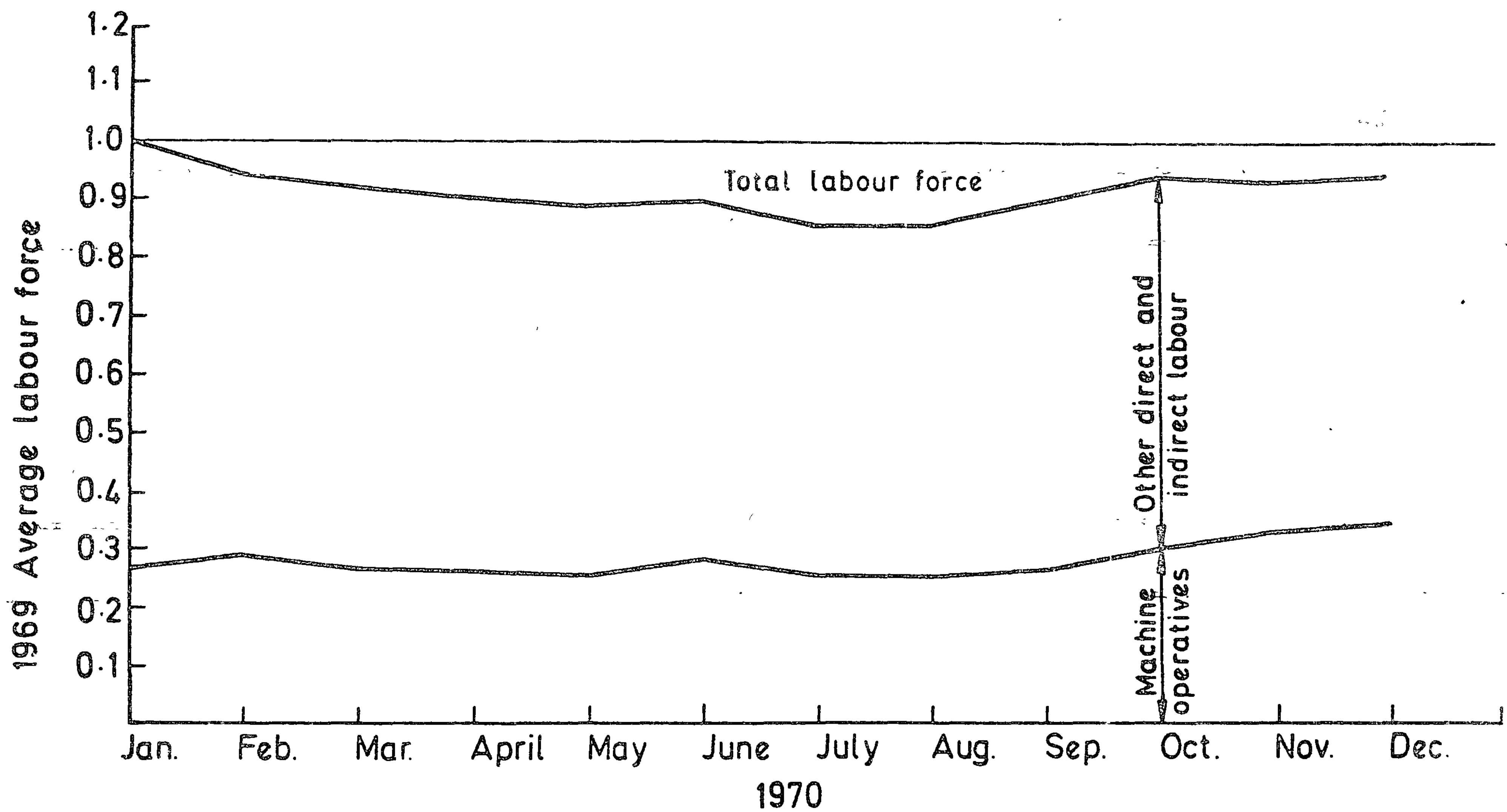
Fig 7 42 Drg 0177.CL



Changes In Labour Force For 1970

57

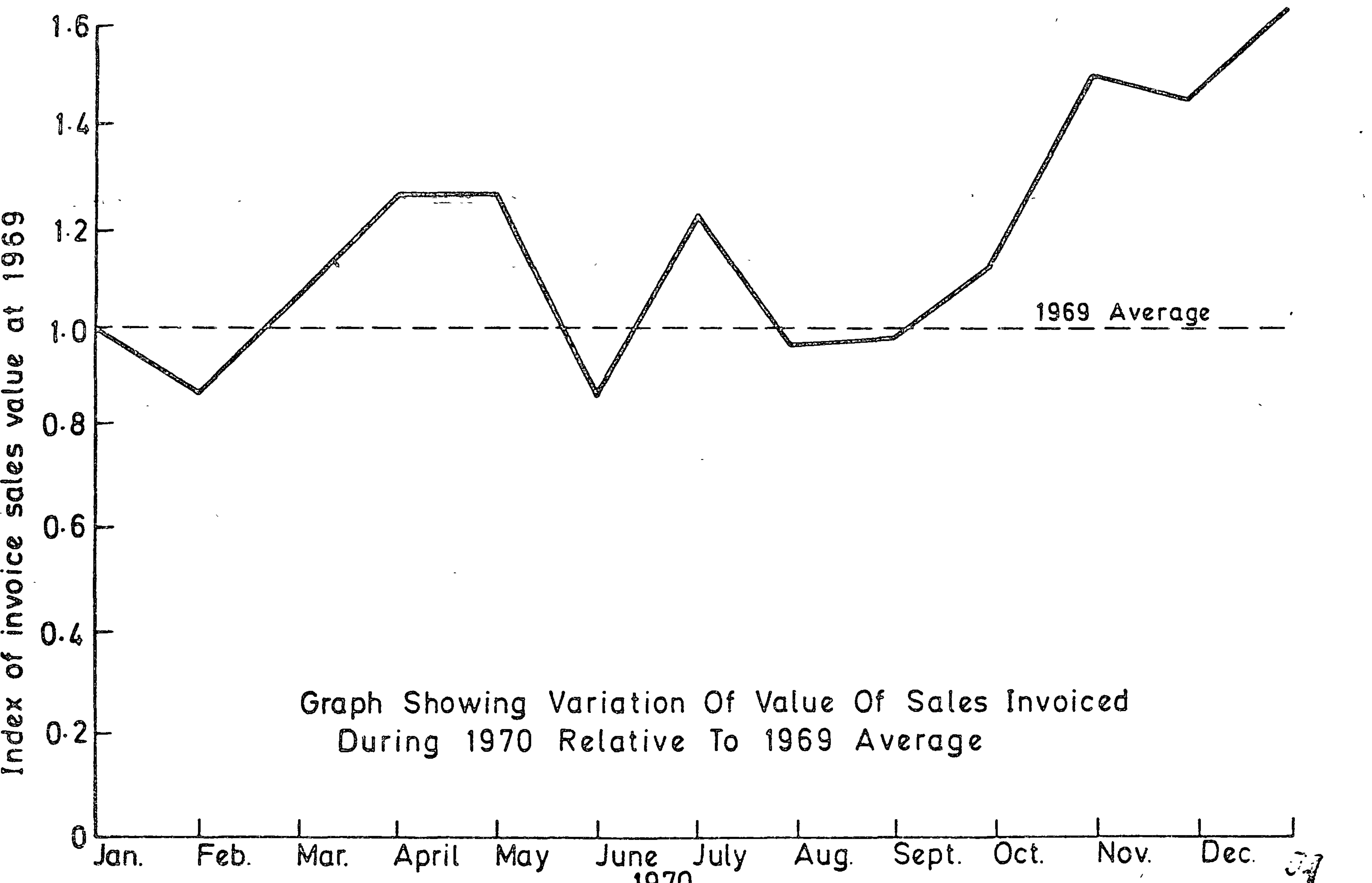
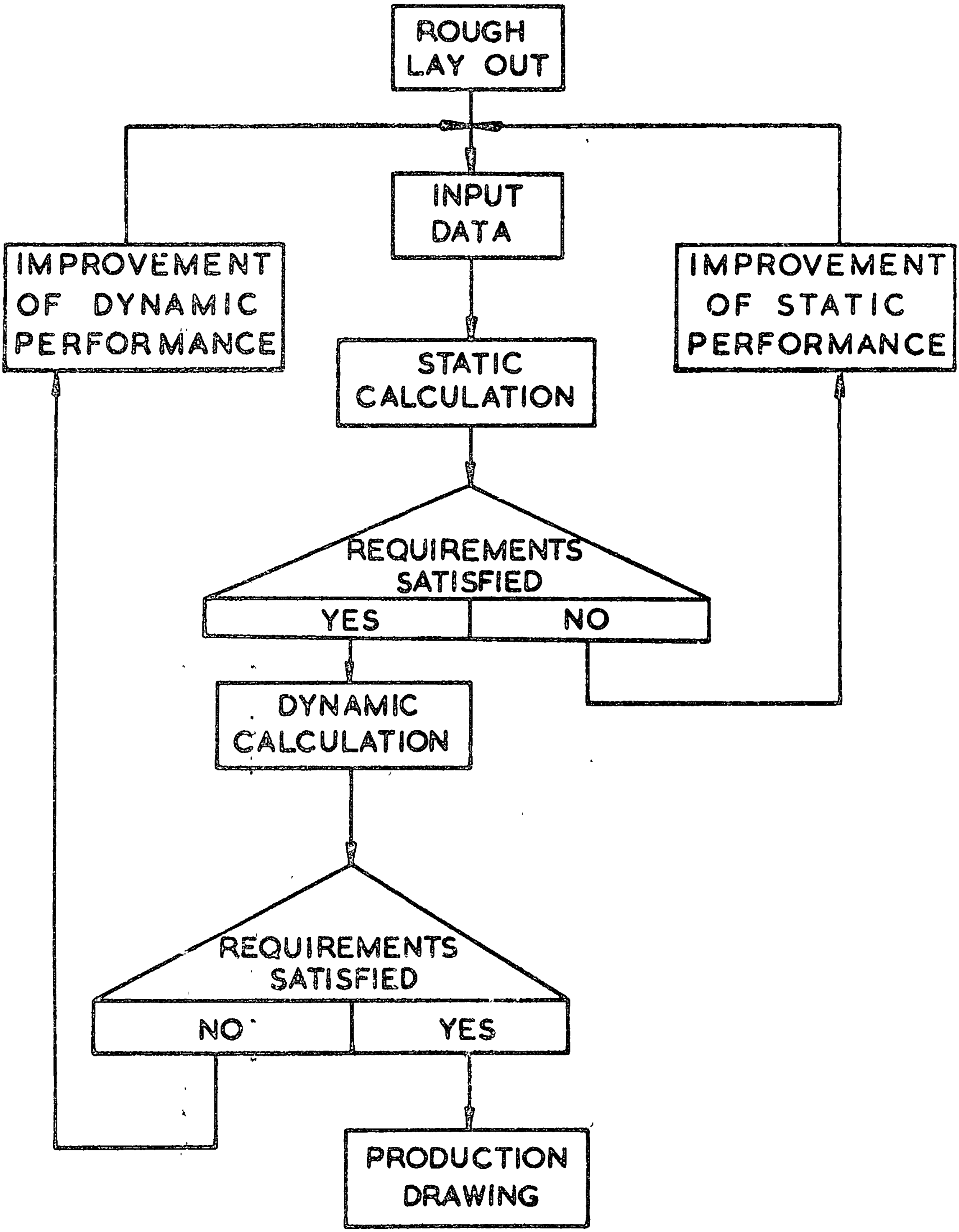


Fig 8	University of Manchester Institute of Science & Technology		0136/G

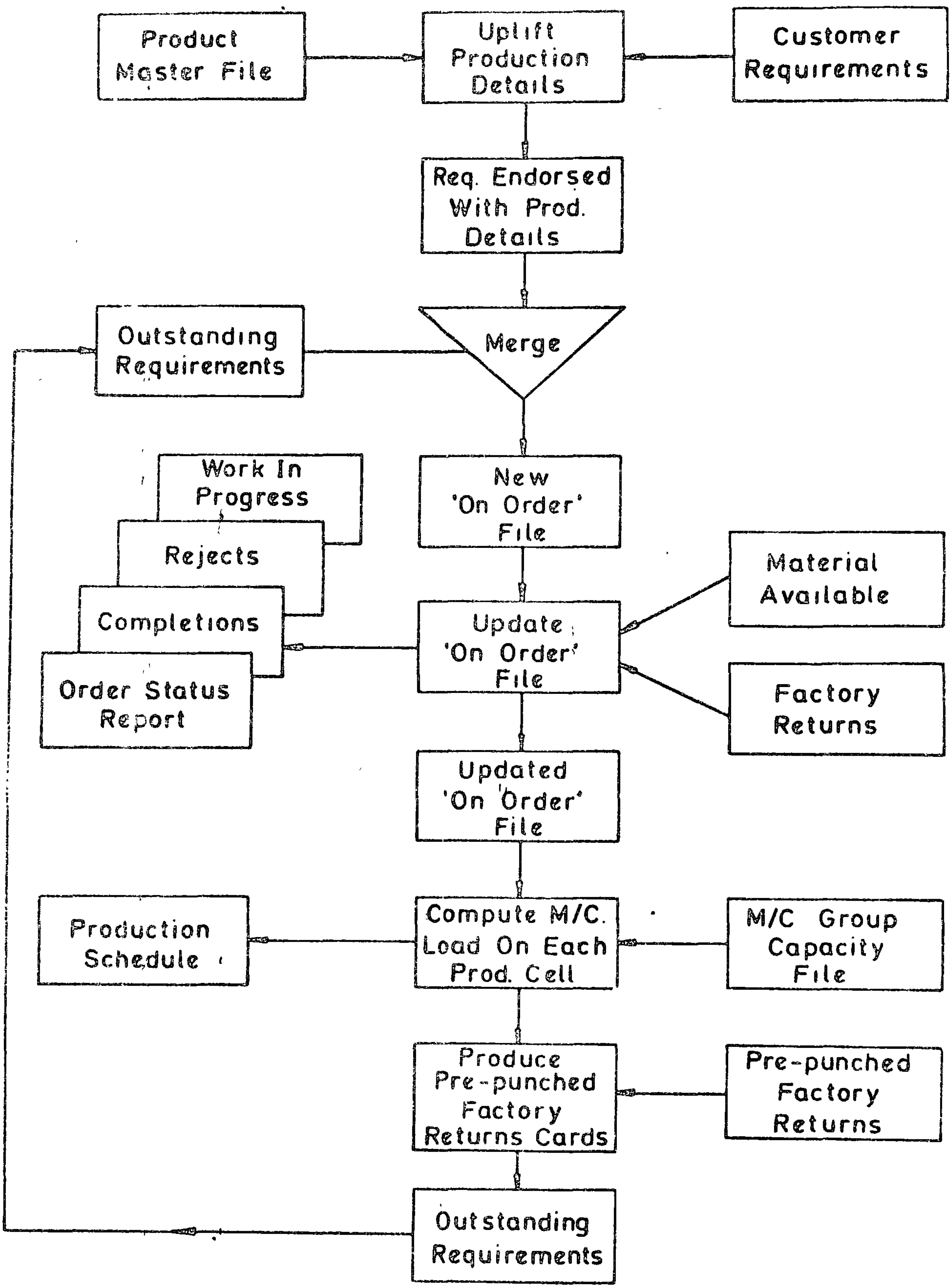
		Period		
		1969 Average	1970 Average	Oct., Nov., Dec. 1970 Average
Area Of Activity	Sales	1	1·19	1·54
	Total Labour	1	0·95	0·94
	Machine Labour	1	1·08	1·15
	Stock	1	1·16	1·60
	Work-in-Progress	1	0·81	0·74
	Stock + Work-in-Progress	1	0·91	0·95
	Ratios			
	Sales/Total Labour	1	1·25	1·64
	Sales/Machine Labour	1	1·11	1·34
	Sales/Stock	1	1·03	0·97
	Sales/Work-in-Progress	1	1·47	2·08
	Sales/Stock + W.I.P.	1	1·30	1·62

Performance Index Figures Relative To Unity In 1969 At The Start Of The Application Of Group Technology

ET 4 70

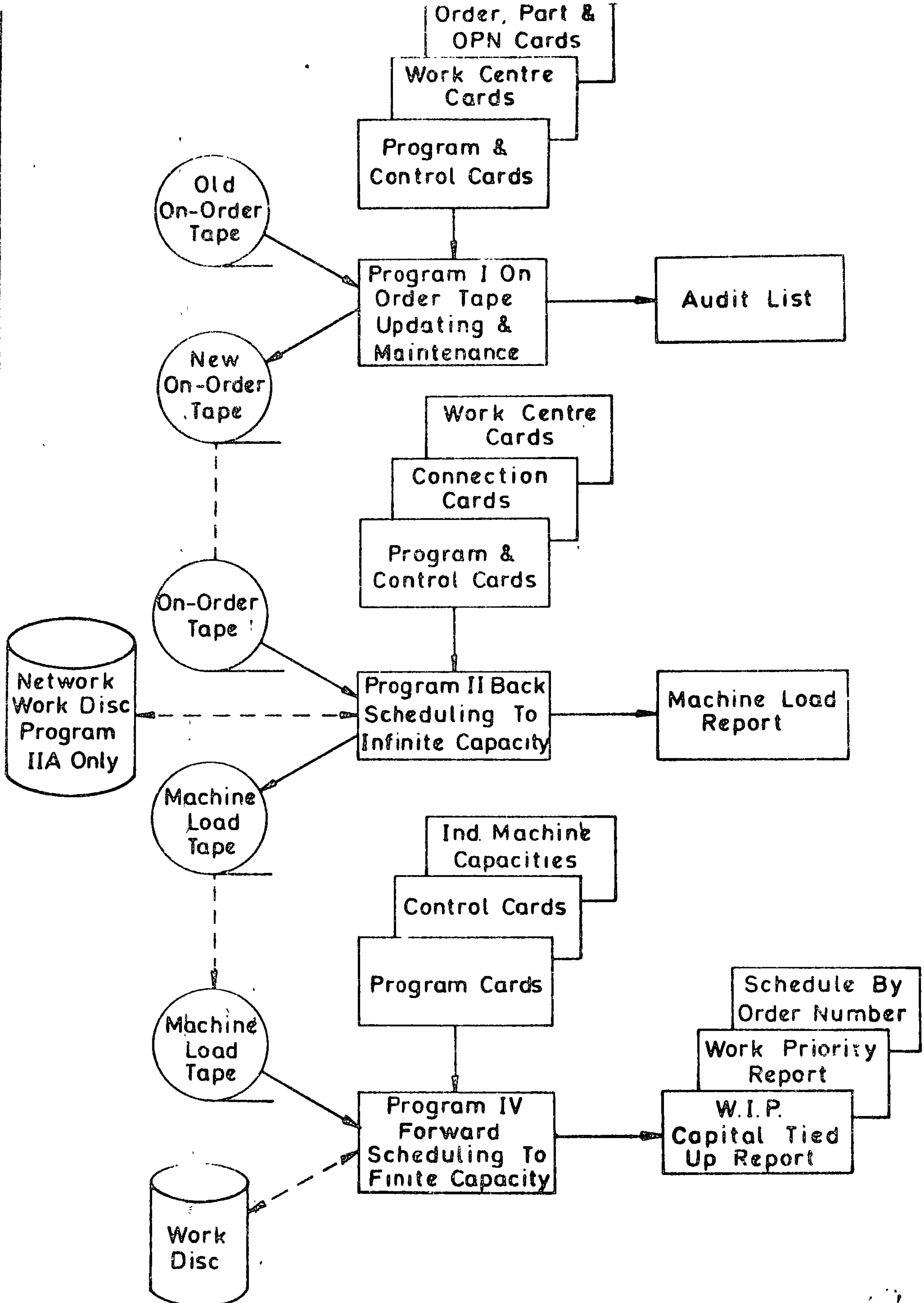


University of Manchester Institute of Science & Technology	Fig 4
0107/H	Prof. F. Koenigsberger.



Basic Principles And Concept Of Proposed Tailor Made System

University of Manchester Institute of Science & Technology	Fig. 3
0136/C	



Propriety Software Scheduling And Loading System

University of Manchester Institute of Science & Technology | Fig. 4

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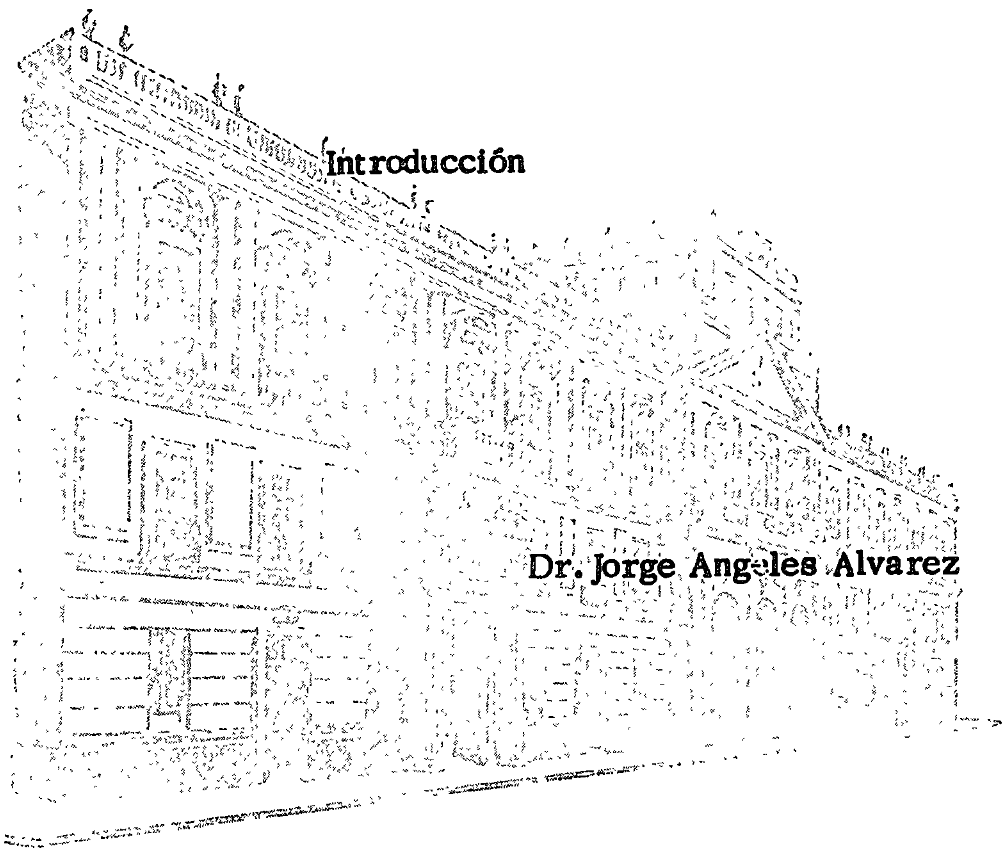
INGENIERIA DE MANUFACTURA

Introducción



Dr. Jorge Angeles Alvarez

DESFI- 1976.

"NECESIDAD DE FORMACION DE RECURSOS HUMANOS PARA LA INDUSTRIA DE BIENES DE CAPITAL"

Dr. Jorge Angeles Alvarez
Profesor,
División de Estudios Superiores
Facultad de Ingeniería
UNAM

"Machine tools are an international commodity"
United Nations Industrial Development Organization

En este trabajo se propone un programa para la formación de los recursos humanos que requiere el país en materia de producción de bienes de capital que consta de dos etapas:

En la primera, a tres años, se forman especialistas en las diversas áreas de Ingeniería de Manufactura, a nivel de Maestría, con la intervención de especialistas extranjeros en un 80%. En la segunda etapa, a cinco años se forman especialistas en esas áreas a nivel de doctorado, contando para esto con la intervención de especialistas extranjeros en un 50%. A partir de esos cinco años el país contará con el mínimo de especialistas a nivel de doctorado, requerido tanto para proyectos de investigación y desarrollo de la industria de bienes de capital como para la continua formación de recursos humanos para esa industria.

En la primera etapa se elabora el currículum académico, dentro de los programas de Maestría en Ingeniería Mecánica existentes en la DESFI*, que tiene tres objetivos principales, a saber,

i) Formar recursos humanos para satisfacer la demanda de personal docente en instituciones de educación superior, que ofrecen licenciaturas en Ingeniería Mecánica

*División de Estudios Superiores de la Facultad de Ingeniería, UNAM

ii) Formar recursos humanos para satisfacer la demanda de personal de investigación en los centros nacionales de investigación científica y tecnológica.

iii) Formar recursos humanos con un nivel de especialización a la altura de los que se encuentran en aquellos países industrializados productores de bienes de capital, para la producción de estos bienes con la calidad y costo requeridos para competir internacionalmente en este mercado.

NECESIDAD DE PRODUCCION DE MAQUINAS HERRAMIENTAS EN EL PAIS

La producción industrial de bienes de consumo, desde un bolígrafo hasta una flota de buques tanque petroleros, requiere el concurso de una amplia gama de procesos de corte y formado de metales.

Para la realización de estos procesos se necesita la utilización de diversas máquinas tales como: tornos, fresadoras, cepillos, taládros, brochadoras, rectificadoras, dobladoras y prensas. Las seis primeras, englobadas bajo el nombre genérico de máquinas herramientas (MH), son las que intervienen en el proceso productivo de bienes de consumo más notablemente, tanto por su número como por su costo. Por esta razón, la Organización de las Naciones Unidas para el Desarrollo Industrial (UNIDO) ha realizado investigaciones acerca de la demanda, a mediano plazo, de máquinas herramientas tanto en países desarrollados industrialmente como en aquellos en vías de desarrollo. En este sentido, UNIDO ha publicado las siguientes estimaciones para México en 1980 [1,p.67]

...

TABLA 1

Población (miles)	70,664
PNB per cápita (dólares)	751
Demanda anual de maquinaria industrial (miles de dólares)	998,500
Demanda anual de máquinas herramientas (miles de dólares)	83,310

Las estimaciones correspondientes a Brasil, que es el país latinoamericano con cifras más próximas a México son:

TABLA 2

Población (miles)	125,742
PNB per cápita (dólares)	389
Demanda anual de maquinaria industrial (miles de dólares)	490,540
Demanda anual de máquinas herramientas (miles de dólares)	66,590

De las estimaciones anteriores puede observarse la influencia que tendrá en los países en desarrollo el consumo de máquinas herramientas en las economías de esos países.

En México, el consumo predicho de MH para 1980 será del orden del 30% del presupuesto de la Federación para 1975, lo cual representará una fuga de divisas considerable si no se producen esas máquinas en México.

México está produciendo máquinas herramientas; pero el consumo de las mismas excede desproporcionadamente la producción, pues mientras que en 1970 exportó 100,000 dólares en MH, tuvo importaciones, por este concepto, de 65 millones

...

de dólares, en el mismo año. En ese mismo año, México ocupó el 29° lugar en la producción mundial de MH, y el 3o en Latinoamérica, después de Brasil y Argentina, como se muestra en la Tabla 3 [2,pp-16 y 17]

TABLA 3

País	1970				1971 (estimado)			
	Total	Corte de metales	Formado de metales	Participación en la prod. mundial (%)	Total	Corte de metales	Formado de metales	Participación en la producción mundial (%)
	(millones de dólares)				(millones de dólares)			
República Federal de Alemania	1,479.0	1,018.4	460.6	18.9	1,820.0	1,230.0	590.0	23.4
Estados Unidos	1,443.1	992.9	450.2	18.5	980.0	662.0	318.0	12.6
Japón	1,109.4	867.4	242.0	14.2	912.0	722.0	190.0	11.7
U. R. S. S.	1,073.0	803.0	270.0	13.7	1,160.0	865.0	295.0	14.9
Gran Bretaña	476.9	378.5	98.4	6.2	465.0	367.0	98.0	6.0
Italia	433.6	346.9	86.7	5.6	423.0	338.0	85.0	5.4
Francia	316.5	240.5	76.0	4.1	387.0	273.0	114.0	5.0
República Democrática Alemana	252.3	185.7	66.6	3.3	260.0	193.0	67.0	3.3
Checoslovaquia	250.0	210.0	40.0	3.2	275.0	230.0	45.0	3.5
Suiza	242.0	206.0	36.0	3.1	266.0	226.0	40.0	3.4
Polonia	123.0	112.0	11.0	1.6	145.0	132.0	13.0	1.9
España	88.6	77.5	11.1	1.0	98.0	83.0	15.0	1.2
Suecia	66.0	43.0	23.0	0.8	79.0	51.0	28.0	1.0
China	53.0	31.0	22.0	0.6	58.0	43.0	15.0	0.9
Hungría	44.7	41.6	3.1	0.5	47.3	44.3	3.0	0.6
Canadá	34.9	21.1	13.8	0.4	37.0	22.0	15.0	0.5
Bélgica	33.9	16.3	17.6	0.4	37.4	17.7	19.7	0.5
Brasil	33.8	19.6	14.2	0.4	34.4	20.0	14.4	0.4
Argentina	33.4	19.0	14.4	0.4	34.3	19.1	15.2	0.4
India	31.2	29.3	1.9	0.4	45.0	42.5	2.5	0.6
Holanda	29.7	18.5	11.2	0.4	33.7	21.1	12.6	0.4
Yugoslavia	26.0	22.5	3.5	0.3	36.2	29.0	7.3	0.5
Austria	25.4	11.6	13.8	0.3	28.1	12.9	15.2	0.1
Bulgaria	23.0	21.0	2.0	0.3	26.9	24.6	2.3	0.3
Australia	22.5	6.2	16.3	0.3	23.9	6.8	17.1	0.3
Rumanía	17.0	15.5	1.5	0.2	22.8	20.8	2.0	0.2
Dinamarca	14.7	9.1	5.6	0.2	15.3	10.1	5.2	0.2
Sudáfrica	7.2	3.3	3.9		7.0	3.0	4.0	0.1
México	5.0	2.0	3.0		5.0	3.0	2.0	0.1
Turquía	4.9	2.9	2.0		...	...	...	
Portugal	2.8	1.5	1.3	0.5	3.1	1.7	1.4	
Egipto	1.7	0.7	1.0		...	...	...	0.3
Israel	1.3	1.0	0.3		...	...	...	
Chile	0.9	0.5	0.4		...	...	...	
Otros países	1.0	0.6	0.4		...	...	...	
Total mundial	7,801.0	5,776.6	2,024.6		7,765.5	5,713.6	2,051.9	

Se puede obtener una idea más precisa sobre los tipos de MH de más consumo en México con la siguiente información [2, p. 42]

TABLA 4

Porcentaje entre manufactura nacional y consumo, por tipo de máquinas herramientas, en 1969.

Tornos	15.6
Taladros	12.5
Rectificadoras	7.9
Prensas y cortadoras	19.4
Forjas	5.2
Máquinas para corte de madera	17.5

En la tabla 5 se muestra estimaciones de importación, por tipos de MH, hasta 1980 [2, p. 42]

TABLA 5

(Unidades)

	1967	1968	1969	1970	1975	1980
Tornos	1,362	1,685	1,903	1,500	2,028	3,051
Fresadoras	390	400	526	365	500	734
Taladros	929	957	835	993	2,020	3,070
Rectificadoras	643	819	872	954	945	1,450
Prensas	540	601	790	543	1,105	1,555
Otras máquinas para procesos de metal	1,873	2,282	2,242	2,406	3,040	3,840
Máquinas para corte de madera	1,560	1,195	1,586	2,127	1,770	2,260

Fuente: Foreign Trade Statistical Yearbooks, General Office of Statistics.

Según estudios de la propia UNIDO, ningún país satisface totalmente su consumo de MH. No se puede esperar, por lo tanto, que México llegue a ser la excepción.

...

Lo que sí se puede conseguir es abatir el volumen de importaciones, al mismo tiempo que incrementar el de exportaciones, con el objeto de obtener una mejoría en la balanza de pagos del país.

Las alternativas que se presentan para satisfacer la demanda en MH son:

1. Importar
2. Producir bajo contrato
3. Explotar una patente extranjera
4. Producir a partir de diseños propios
5. Reconstruir máquinas obsoletas

Desde luego que de estas alternativas la más sencilla de realizar es la primera, que requiere una inversión inicial mínima y no requiere técnicos especializados. Tiene el grave inconveniente de que, en primer lugar, propicia la dependencia tecnológica del país y, en segundo, desequilibra desfavorablemente la balanza de pagos del mismo.

La segunda alternativa solo requiere la existencia de mano de obra b arata, pues la participación técnica del país es mínima. Deja dividendos al país solo por concepto de mano de obra y, en grado mucho menor, por concepto de administración.

En cuanto a la tercera alternativa, se requiere contar con técnicos experimentados en procesos de manufactura y control de calidad adecuados para que la compañía concedente de la licencia confíe en que el producto que aparecerá con su marca sea de la confiabilidad de aquel que ella misma produce. Implica la fuga de divisas por concepto de regalías pagadas por la explotación de la patente extranjera.

Respecto a la cuarta alternativa, producir MH a partir de diseños propios, es la más difícil y más costosa, inicialmente, de realizar, pues el proceso que comprende desde la conceptualización de la máquina hasta el desarrollo de un diseño particular es tardado y requiere del concurso de expertos con los que no se cuenta, al menos en número suficiente, dentro del país. Tiene la ventaja de que, una vez iniciada la producción, el país comienza a recibir no sólo la utilidad que la producción implica, sino además, abate la fuga de divisas porque no hay que pagar regalías por ningún concepto.

La última alternativa desde luego que también debe considerarse, aunque no puede esperarse que por sí sola satisfaga una demanda cada vez mayor. En efecto, dada la longevidad de las MH, las máquinas inútiles, accesibles para reconstrucción, no abundan. La tabla 6 [1, p. 42] muestra la distribución de MH en la Gran Bretaña, por edades, en 1970.

TABLA 6

Edad (años)	Porcentaje
5 ó menos	19
6 - 9	23
10-20	37
más de 20	21

Excepto la primera de las alternativas anteriores, todas requieren del concurso del personal con diversos grados de capacitación y especialización, aumentando la demanda de personal técnico especializado en la tercera con relación a la segunda. La cuarta requiere, además, de la participación de expertos en diseño, investigación y desarrollo de MH, con los que el país no cuenta actualmente en número suficiente, como ya se apuntó

...

ESTRATEGIA PARA LA FORMACION DE RECURSOS HUMANOS

Como ya se expuso antes en este trabajo, la industria de bienes de capital requiere personal capacitado a diversos niveles, desde obreros especialistas hasta ingenieros investigadores y diseñadores. Aquí se trata solamente de la preparación de estos últimos.

Los ingenieros especialistas en utilización y diseño de MH deben contar con los antecedentes académicos de una licenciatura en Ingeniería Mecánica. La especialidad que sigan será de posgrado, a nivel de Maestría por lo menos.

El entrenamiento que se propone de este personal es a base de un programa de Maestría que consiste en:

1. Cursos de formación básica: modelos matemáticos, teoría del corte de metales (mecánica de la formación de viruta, temperaturas de corte, potencia requerida en el proceso de corte de metales), vibración en sistemas mecánicos, análisis de cargas en estructuras, métodos numéricos de tratamiento de modelos matemáticos y simulación.
2. Experimentación: Determinación de fuerzas y temperaturas de corte, deflexiones estructurales y desgaste de herramientas.
3. Investigación: Desarrollo de proyectos originales sobre problemas no resueltos en las áreas de: procesos de formación y de corte de metales y diseño de MH.

El proyecto definitivo de estos programas se espera realizar con el concurso de expertos en esta industria, procedentes de países con tradición en producción de MH.

...

REFERENCIAS

1. UNIDO, The Machine Tool Industry, Publicación de la Organización de las Naciones Unidas, N. York, 1974.

2. UNIDO, Machine Tools in Latin America, Publicación de la Organización de las Naciones Unidas, N. York, 1974.

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INGENIERIA DE MANUFACTURA

DISEÑO PARA LA PRODUCCION

DR. F. KOENIGSBERGER

JULIO DE 1976.

3. Design for Production

Design involves:

a) To establish a specification which takes into consideration the purpose and function of the product, performance requirements, the environment of its operation, service and maintenance conditions production rates and cost estimates.

b) To explore those details which may determine not only the technical performance and reliability but also the competitive value of the product.

c) To produce the manufacturing specifications which-in the form of drawings, planning instructions, control tapes, punched cards etc. - form the basis for making the design a practical proposition.

Design is not invention!

The basic principle of a designer's work is, therefore, to allow for and make use of all those facilities which are available both for carrying out the design process and the actual manufacture of the product.

The task of the designer lies thus in converting ideas into technological realities, and he must, therefore, consider

i) Material selection (technical and economic considerations)

Examples:- Shear pin

$$\text{Torque} = P \cdot R$$

$$P = \frac{\pi d^2}{4} \cdot \tau_{ult}$$

$$d^2 \cdot \tau_{ult} = \text{const.} = \frac{4P}{\pi}$$

Either small d and high τ or vice versa.

Welded bosses

Steel Plate with spotfaced holes

Copy of casting with bosses weight	20kg
Steel plate alone	25kg

increase in cost for 5kg of steel about £1.00

Labour + overhead cost for preparing bosses and welding (1 hour)=£3.00

C.I. versus steel (strength and stiffness)

ii) the manufacturing process and procedure are affected to a certain extent by i) in that the state and properties of the raw material may have a considerable influence on the manner in which it can be treated during manufacture. For example in the design of cast iron parts the moulding procedure and the complexity of patterns has to be considered whilst in the design of forgings or drop stampings batch size enters into the considerations. When considering the design of machined components the available facilities, capacities and possibilities of location, resistance to clamping and cutting forces (spot welded bed plate), inspecting (jig bored plate) must be borne in mind.

iii) An important aspect is the fullest utilization and exploitation of the advantages offered by standardisation both in the design of assemblies and of components.

The importance of variety reduction as an aid to improving the economics of production has long been recognised. From the extreme application of the principles involved, e.g. when Henry Ford offered "any colour as long as it was black", to the introduction of wide ranges of industrial, national and international standards for elements, components and units, which could be applied to a variety of products, designers and production engineers have endeavoured to reduce the times and efforts needed for special set-up requirements of machine tools and equipment and to increase the quantities of products which could be manufactured in batches, preferably in specially laid out workshops. However, inspite of the undoubted economic advantages which can be obtained, one often finds either open or at least sub-conscious opposition to standardisation on the part of designers who feel that it cramps their style. They do not realise that by making the fullest possible use of the available standardisation they can concentrate all their energy on the solution of new design problems, without having to waste time and effort on those problems for which solutions are known or which can be more efficiently dealt with by specialists. Where would machine design and construction be if, for example, each designer had to design, and each factory to manufacture, its own ball and roller bearings?

The standardisation of parts used in small quantities for different applications, and in different industries, enables manufacturers who specialise in the manufacture of such parts to produce them in larger batches than would otherwise be possible.

Whilst standardisation of time, money, weights and measures has existed for many years in various countries, the beginnings of standardisation in engineering date back to the middle of the nineteenth century. The most common element of machinery, the screw thread, was standardised by Sir Joseph Whitworth in 1841 and was followed by the standardisation of material specifications, wire and sheet metal sizes, rolled sections, keys, screws and nuts, rivets, etc.

The term standardisation is commonly applied to materials, parts or mechanisms. A very important application, however, is in the use of dimensions and other numerical values, where standardisation can reduce design work and tooling and manufacturing cost very considerably. The standardisation of material specifications covering compositions, mechanical properties, sizes and shapes results in simplified purchasing, testing, inspection and storage procedures. Together with the standardisation of limits and fits, the standardisation of diameters and tapers leads to a reduction in the necessary stocks of such tools as drills, reamers and gauges. The standardisation of radii in machined items and castings reduces the required number of profile tools for machining operations and blending tools used by pattern makers. The standardisation of machine tool spindle speeds and of gear reduction ratios helps not only to simplify the designer's work but also to facilitate and to speed up production planning and progressing.

The purpose of standardisation is, therefore, on the one hand efficiency and economy in the use of human time and effort, on the other hand economy of material varieties and stock quantities and, therefore, reduction of capital outlay and increase of turnover.

Standardisation can be divided into:

(a) Basic standardisation

Preferred numbers, preferred sizes, scales and weights, voltages, air pressures in factory pipe lines, screw thread profiles, limits and fits, surface texture, testing procedures, drawing and writing paper sizes, etc.; in other words, standardisation of items which are applied in all fields of industrial life.

(b) Dimensional standardisation of engineering components: Screws, nuts, rivets, dowels, keys, gear tooth pitches, etc.

(c) Material standardisation

Types and qualities, sizes and shapes of materials used for the manufacture of various products, as well as tools, lubricants and other consumable goods.

Group (a) is based on general considerations of numerical theories. An example is the use of geometrical progressions for preferred numbers with ratios based on $\sqrt[5]{10}$, $\sqrt[10]{10}$, $\sqrt[20]{10}$ and $\sqrt[40]{10}$.

Another example is the standardisation of paper sizes in which the length-to-width ratios are $\sqrt{2}:1$. This results not only in the same length-to-width ratio of the various sizes but also in standard sheets folded in half, quarters, etc., always remaining of standard sizes. It also makes possible the photo-copying of any sheet size on the same films and printing papers, thus assisting filing procedures.

Groups (b) and (c) really represent the result of a suitable selection from the full range of approved quantities and qualities, such as the International Standards in which all theoretically justified and practically suitable items are represented. An example is the I.S.O. standard of limits and fits, which allows for any appropriate combination of allowances and tolerances to be selected. From this large group of international standards, national standards are selected for those items which are considered essential and suitable from the point of view of the industrial and economic requirements of a particular country; and from the national standardisation the selection can proceed to even smaller and less varied groupings in different industries or other ways of life. Thus standardisation need not even be limited to parts in common use in all fields of engineering. Groups of industries or even single firms can find great advantages in introducing their own standards if and when required.

A fundamental condition of technically and economically efficient manufacture and of the effective use of standard components and modules is interchangeability; or better, non-selective interchangeability. This involves accuracy requirements in production, which the designer must specify. It must be stressed again in this connection that accuracy for its own sake must be avoided, and that each part should be produced to the lowest and cheapest quality requirements which produce a satisfactory performance. On the other hand the final cost depends not only on the cost of the detail parts but also on that of the complete assembly and if the saving in assembly cost, due to more accurate though more costly machining, results in lower total cost, high accuracy is not only justified but economically essential.

The degree of accuracy can be defined by the 'tolerance' which is the difference between the upper and lower permissible 'limit' of a given dimension. The tolerance values depend upon the task of the component in question and the required 'fit' with the mating part. This may be either a 'clearance fit' (a) when the mating parts have to move easily in relation to each other, an interference fit when the two parts must be rigidly connected or a 'transition fit' between (a) and (c).

The basis for achieving a particular fit between mating parts may be either the hole or the shaft, different fits being obtained either by keeping the limits for the hole diameter constant and varying those for the shaft diameter ('hole basis') or vice versa ('shaft basis'). The tooling cost is usually lower for the 'hole basis' system because, for example, only one size of reamer is required for finishing each diameter and the various sizes of shafts can be produced by controlling the infeed of a grinding machine, whilst the shaft basis system requires a number of reamer sizes per diameter equal to the number of fits used. The shaft basis system is, however, applicable in the manufacture of transmission shafts, or in other operations where large quantities of bright drawn material can be used without further machining operations. It is important to be aware of the influence which the use of either the 'hole basis' or the 'shaft basis" exerts upon design details.

An example is a shaft which is supported by two plain bearings (running fit) and carries a gear block (keying fit).

The actual values of tolerances and limits can be found in the relevant standard specifications. The application of the various fits which result from the use of these tolerances can be based on the following considerations:

Clearance fits are used between parts which in service must move more or less easily in relation to each other, such as rotating or sliding shafts in their bearings e.g.:

a slack running fit for mechanism levers and pins, long shafts running in more than two bearings;

a normal running fit for crankshafts and similar parts;

a close running fit for main spindles of machine tools and other cases where minimum play is important;

a sliding fit for parts which can slide without being actually loose, such as clutch members or sliding gears on shafts.

Transition fits are used between parts which do not necessarily move in service and when assembly should require a certain amount of force, e.g. for a

push fit: heavy manual pressure;

light keying fit: use of a mallet;

heavy keying fit: light hammer blows.

Interference fits are used between parts which must be rigidly joined so that loads can be transmitted. The force required for joining such parts may be considerable, e.g. for a

drive fit: heavy hammer blows;

force fit: pressure exerted by a hydraulic or screw press or by shrinking.

The force fit can generally be relied upon to transmit axial forces and torques. The drive and keying fits resist axial displacement but rotation must be prevented by suitable key arrangements if torques are likely to be considerable.

Apart from the actual function of the parts concerned the problem of assembly must be considered. A sliding fit is easy to assemble, even in a restricted space, e.g. inside a machine body or in a gearbox. A push fit or a keying fit present little difficulty when assembled on the bench but may be awkward when the parts must be assembled in a space of restricted accessibility. The assembly of a driving fit represents heavy fitting work, whether inside or outside a machine part, and the assembly of force fits can only be carried out under a press or by a shrinking operation. Whilst force fits should be tight enough to transmit torsional loads they must not result in the material being overstressed when the two parts are being connected. The wall thickness and length of the male and female parts, the surface conditions of the parts to be joined, temperature variations in service and the choice of lubricant used for pressing the parts together must be considered carefully.

Machining accuracies obtainable by present day 'commercial' standards are of the order of ISO qualities IT 5-7. About 80% of workpieces manufactured to this accuracy satisfy the conditions of interchangeability. For non-selective interchangeability to be achieved, i.e. when no skilled fitting operations are required, machining accuracies to higher ISO qualities are necessary.

Dimensional tolerancing for obtaining the required fits is only one aspect of ensuring accuracy of manufacture. The whole geometry of the design detail must be analysed carefully in this respect. Shape, flatness and alignment accuracies must be specified and checked, in particular cylindrical shapes measured axially (irregularity or taper) and radially (ovalness), steepness of tapers, symmetry and concentricity of cylindrical parts, parallelism or perpendicularity between axes and faces or between two or more faces, etc.

Whilst the errors in circular shape of a cylinder may be within the dimensional tolerances, the resulting irregularity may not be permissible and may have to be limited independently; a shaft which is very accurate as far as the circular shape of its cross section is concerned may have a curved axis; centreless grinding may produce lobed shapes, etc.

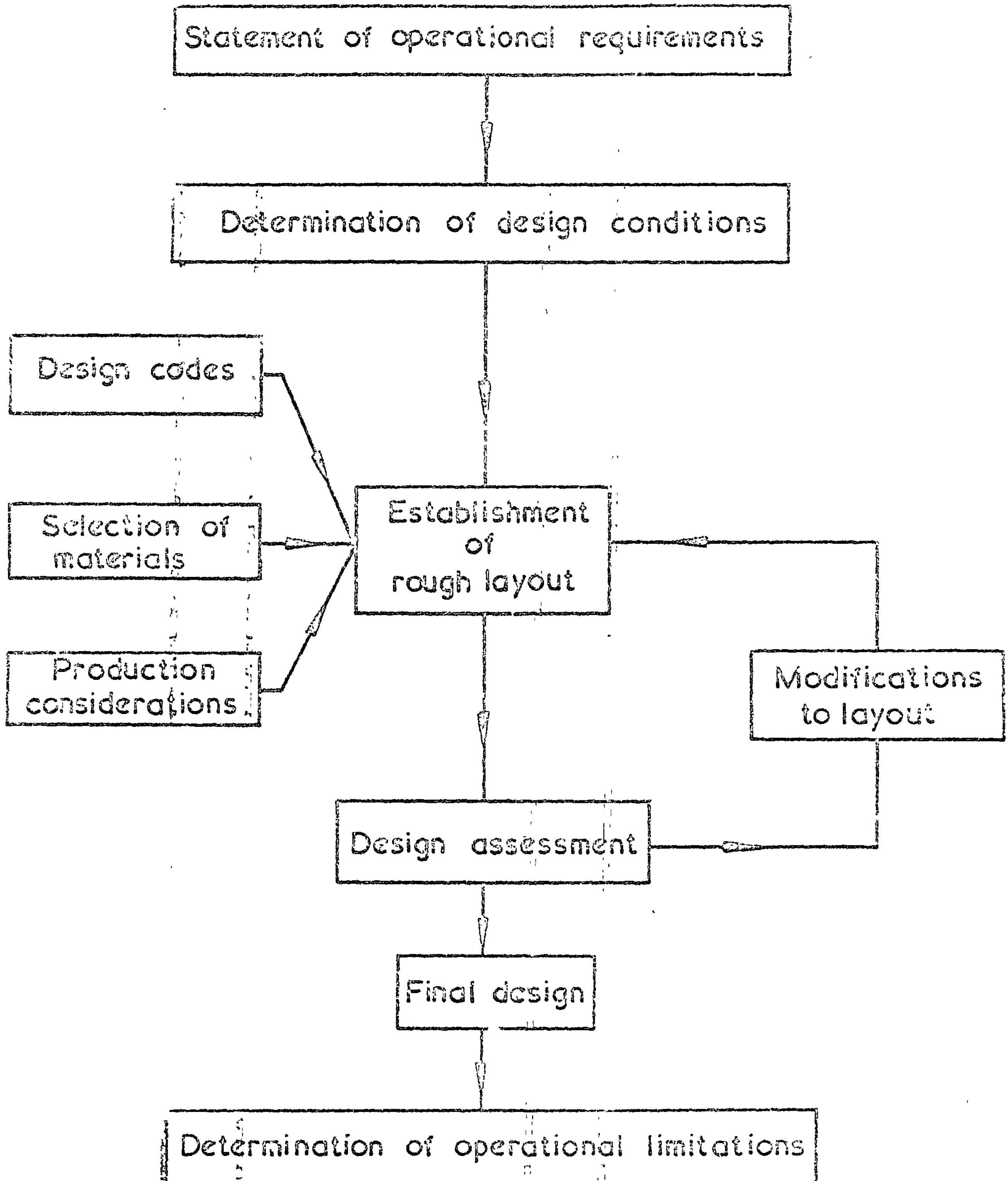

Fig 1.7

35
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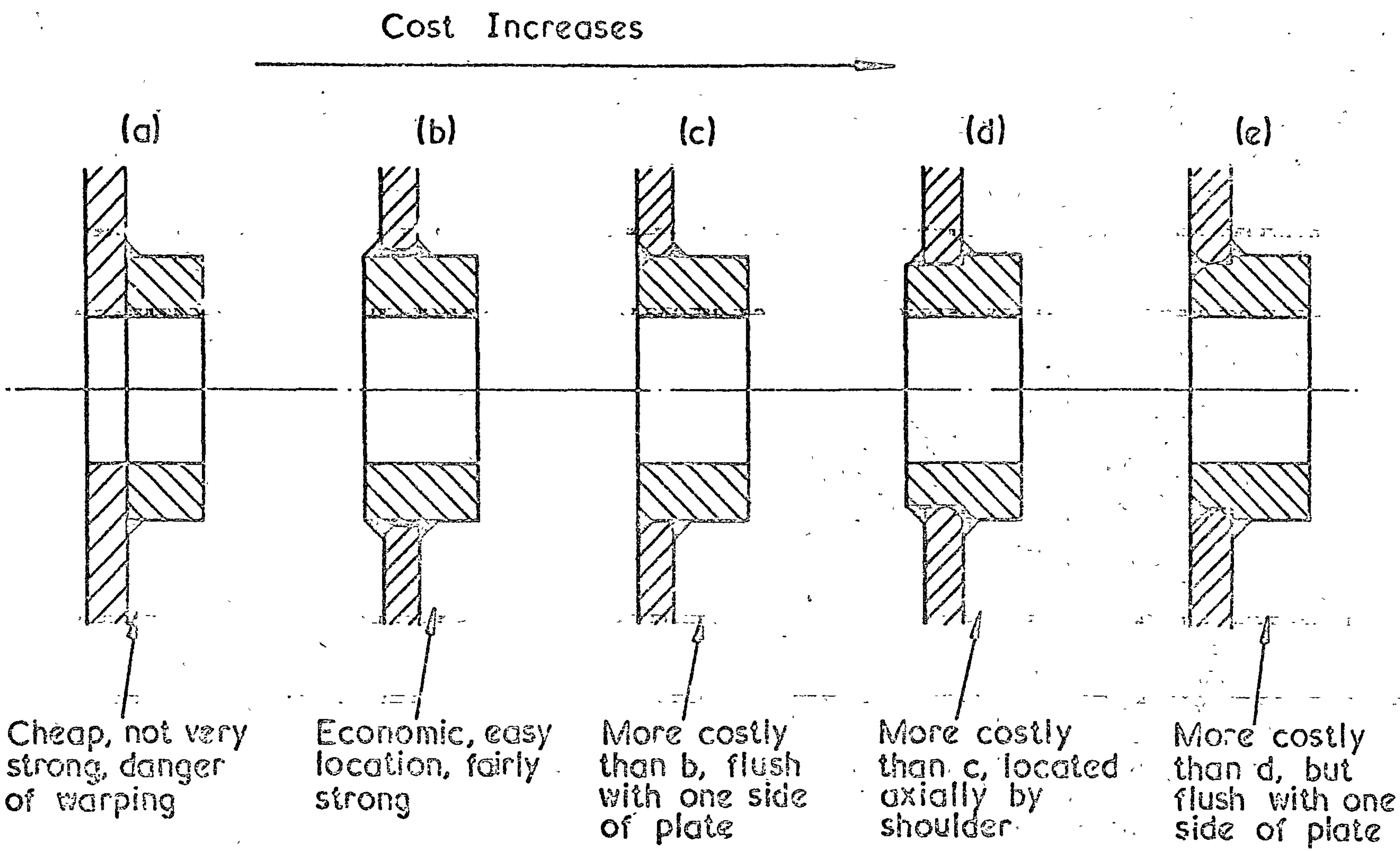

Fig 7.3

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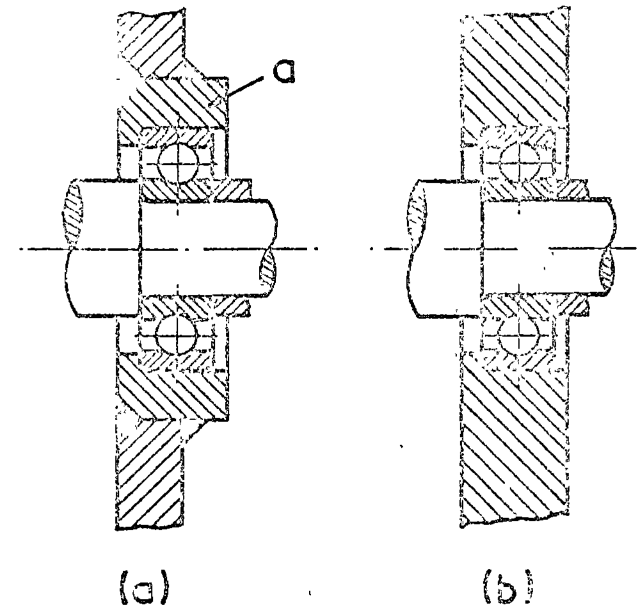

Fig 7.14

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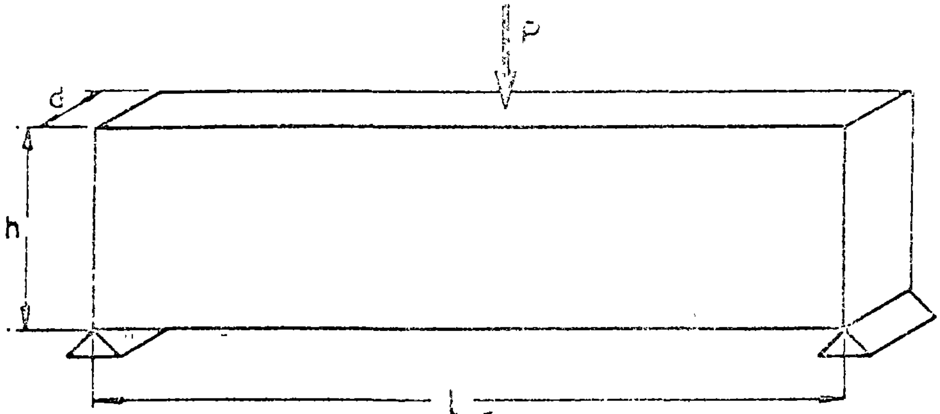


E = Young's modulus { 20×10^4 MN/m² for steel; 10×10^4 MN/m² for cast iron } assumed

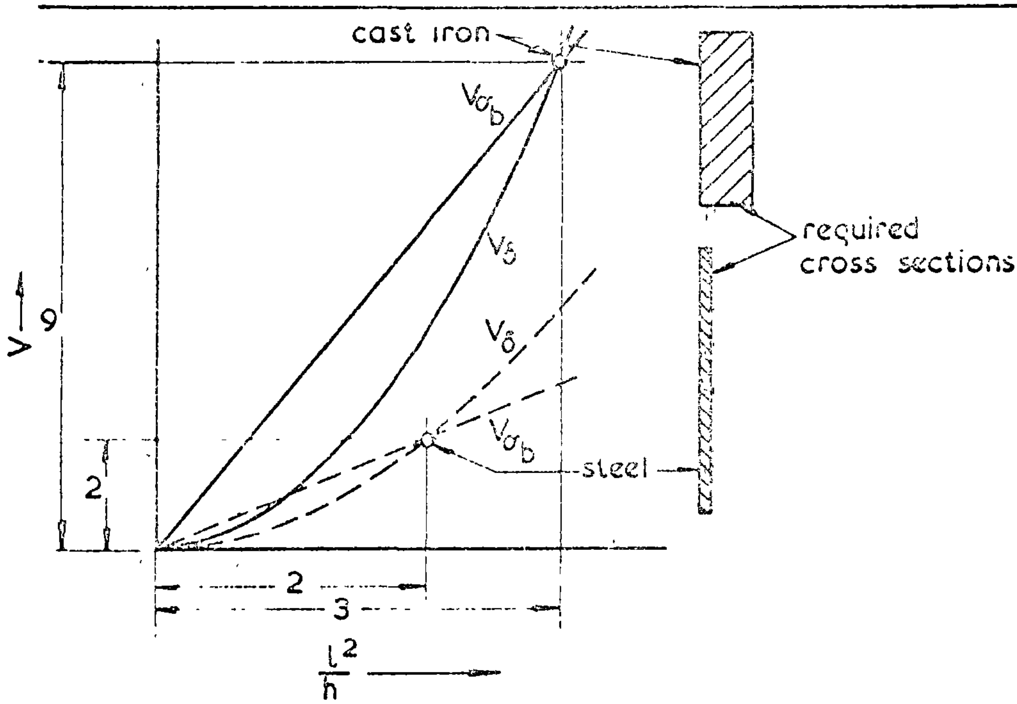
$\sigma_{b\,perm}$ = Permissible bending stress { 45 MN/m² for steel; 15 MN/m² for cast iron } assumed

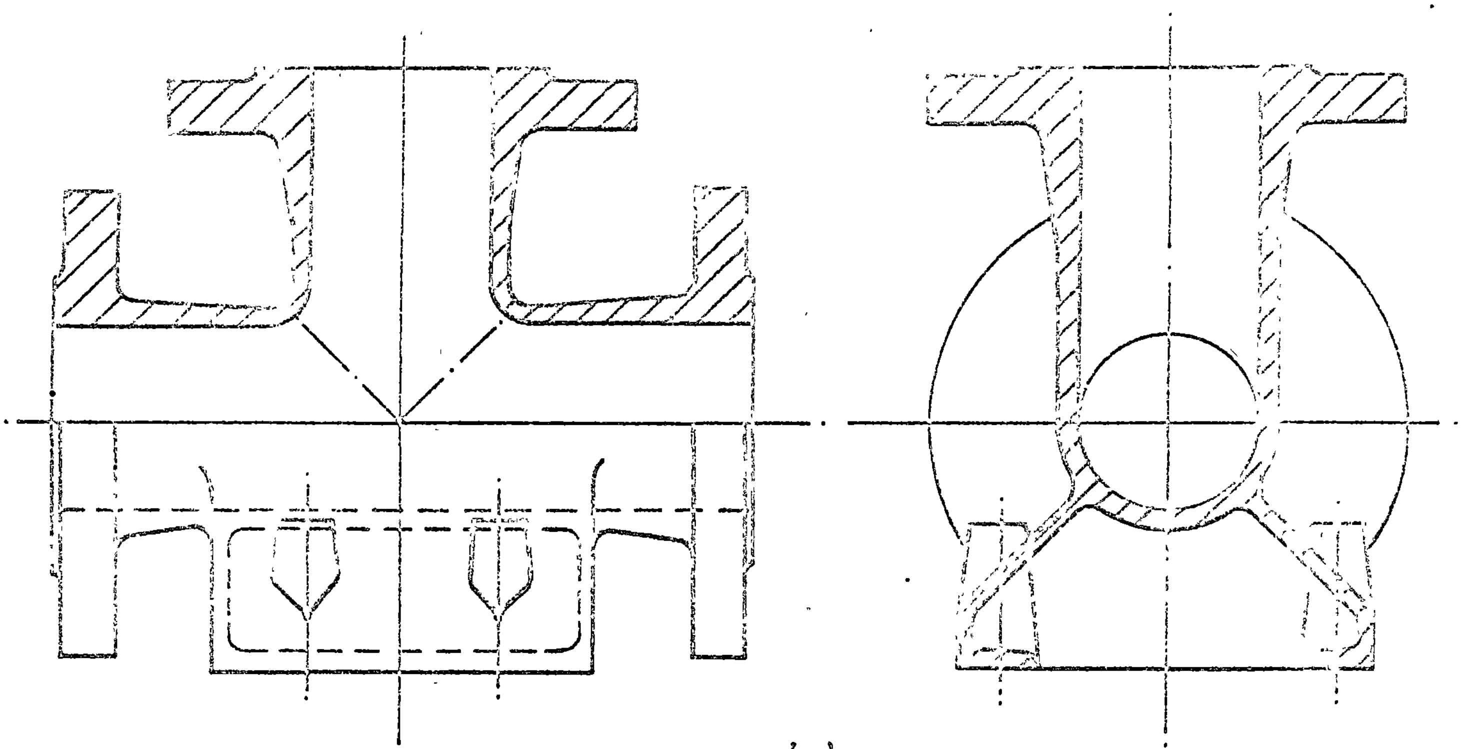
δ_{perm} = Permissible deflection of the beam

V = Volume of beam material $V = d \cdot h \cdot l$

Deflection	Stress
$\delta = \frac{Pl^3}{4Edh^3} = \frac{P}{4EV} \cdot \frac{l^4}{h^2}$	$\sigma_b = \frac{Pl}{4} \cdot \frac{6}{dh^2} = \frac{3}{2} \cdot \frac{P}{V} \cdot \frac{l^2}{h}$
$V_\delta = \frac{P}{4} \cdot \frac{1}{E} \cdot \frac{1}{\delta_{perm}} \left(\frac{l^2}{h}\right)^2$	$V_{\sigma_b} = \frac{3P}{2} \cdot \frac{1}{\sigma_{b\,perm}} \cdot \frac{l^2}{h}$

For given values of P and l different combinations of d and h can be used.




(a)

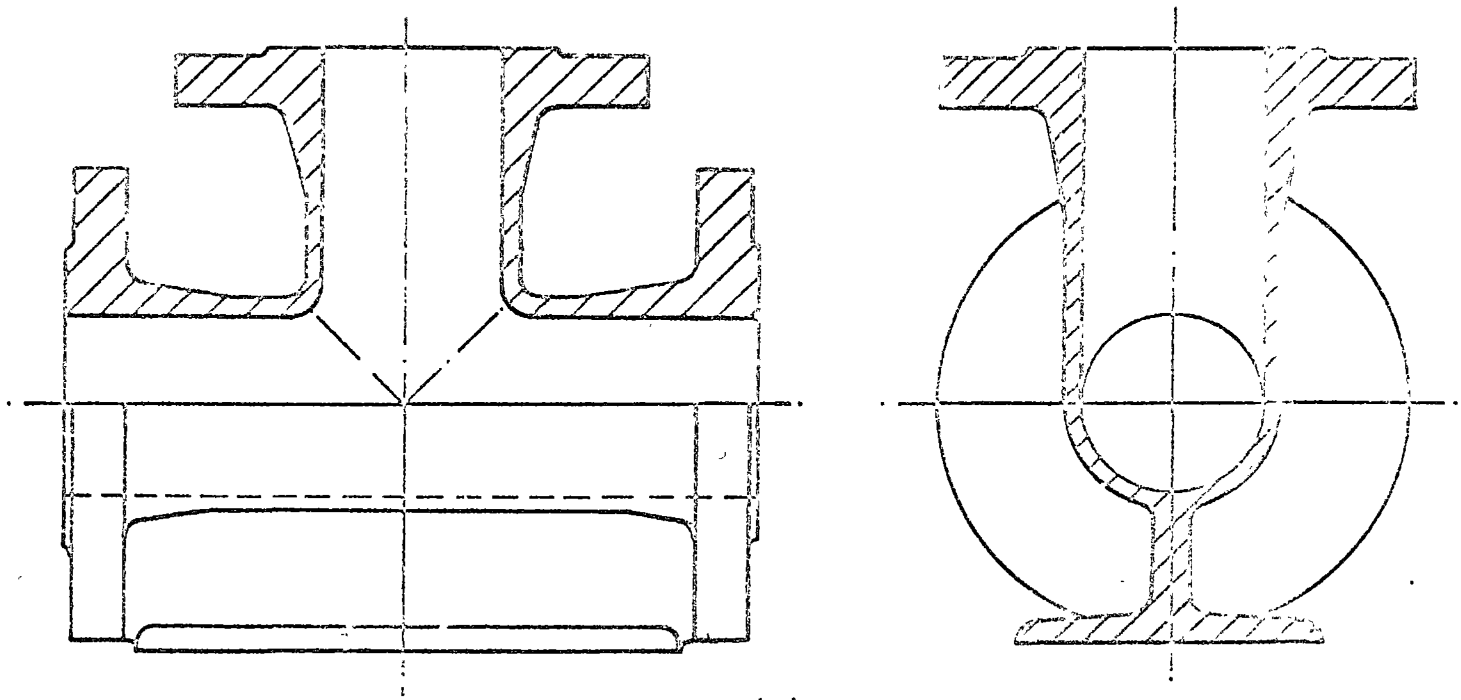

(b)

Fig 7.22

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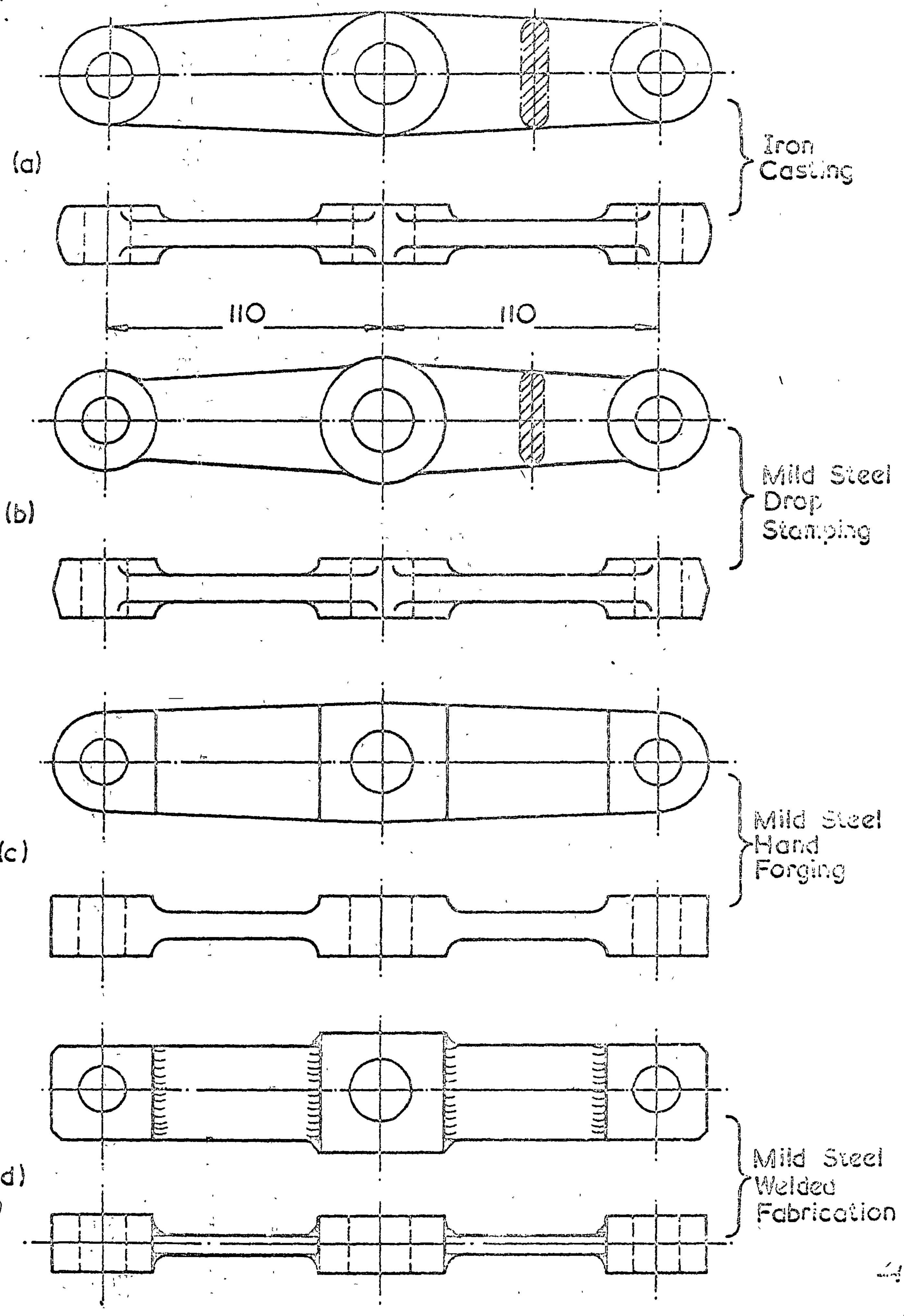
(a)
Iron Casting
110
110
(b)
Mild Steel Drop Stamping
(c)
Mild Steel Hand Forging
(d)
Mild Steel Welded Fabrication

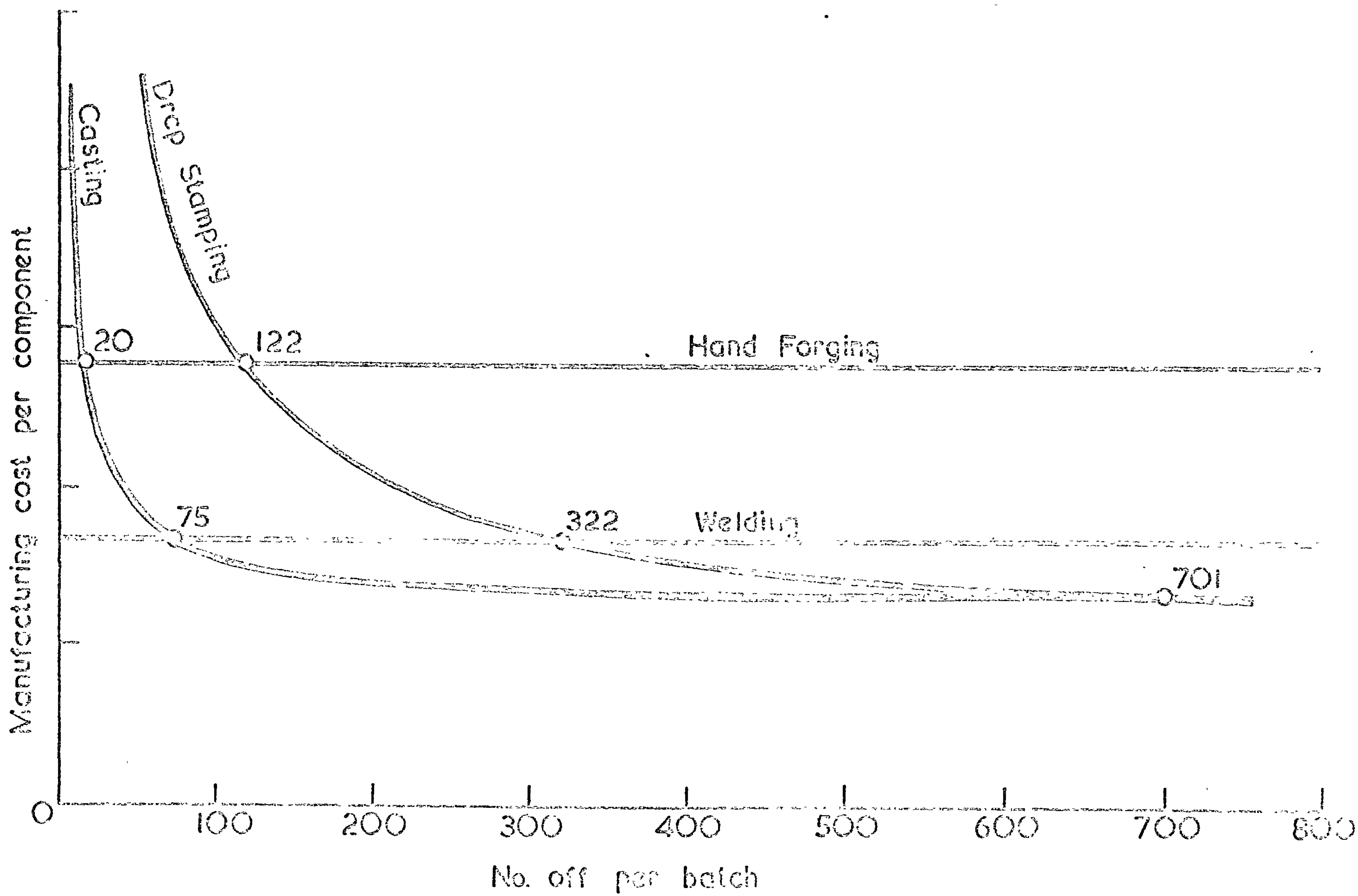

Fig 7.2.4

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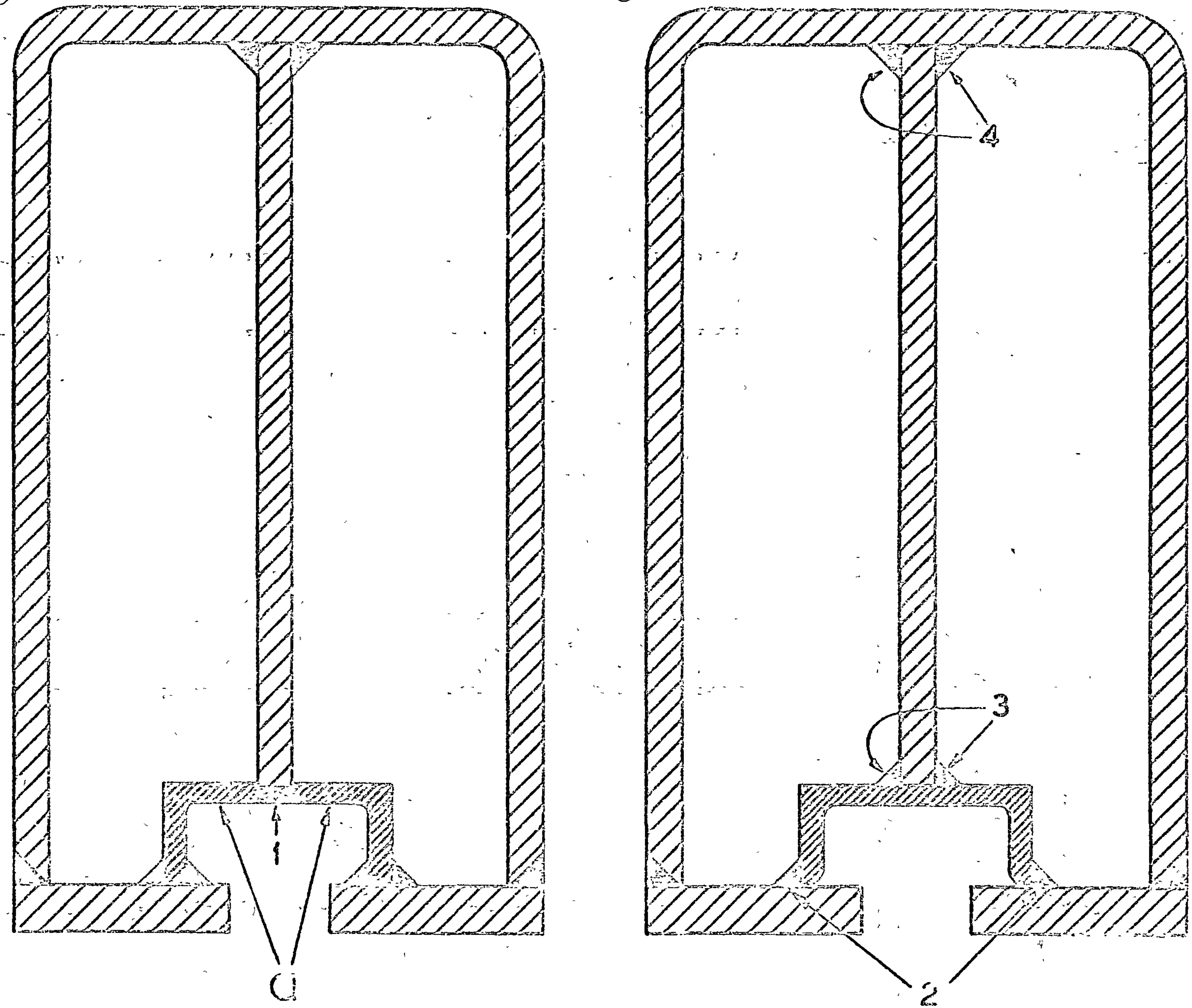
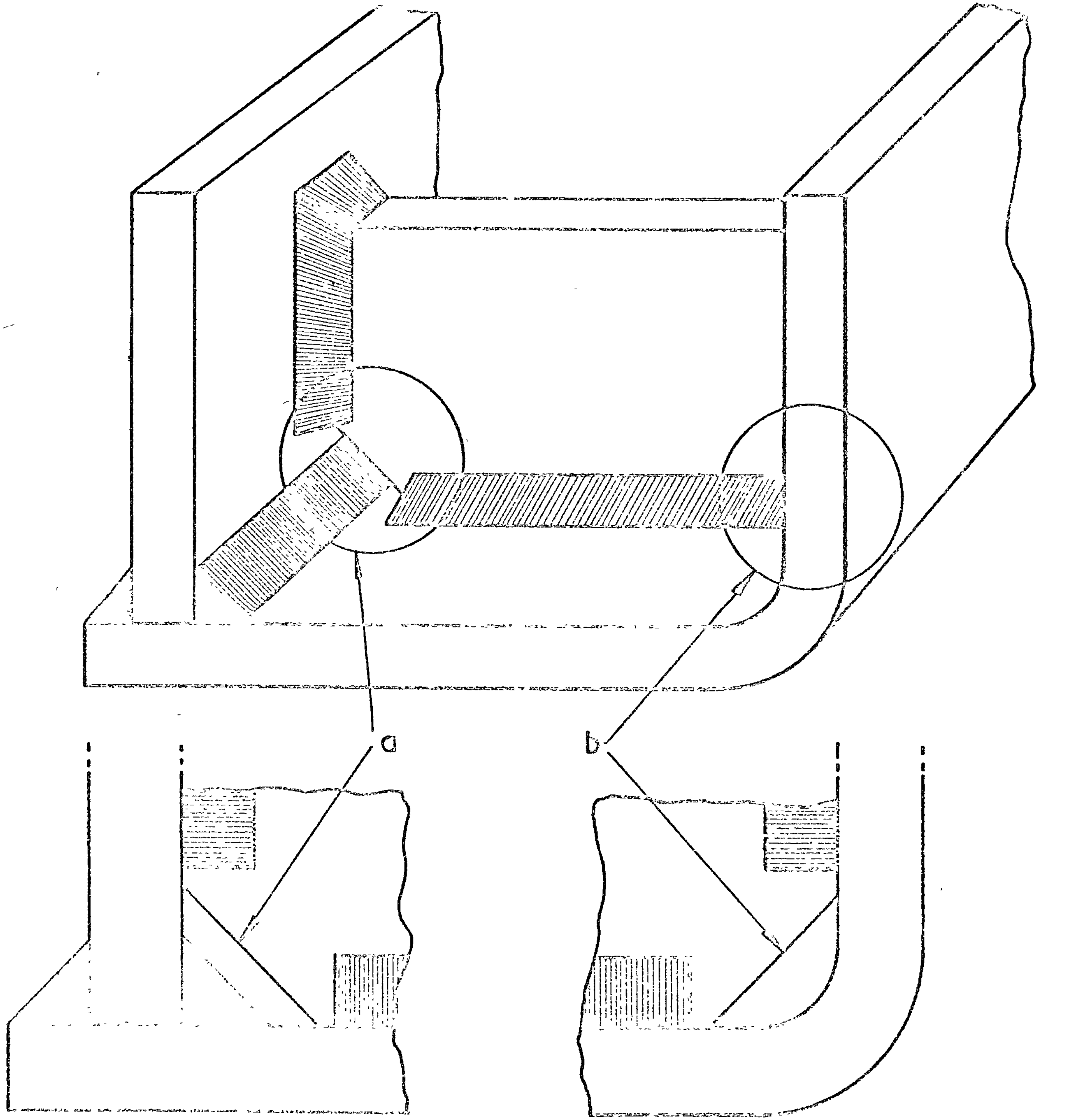


(A) (B)


a
b

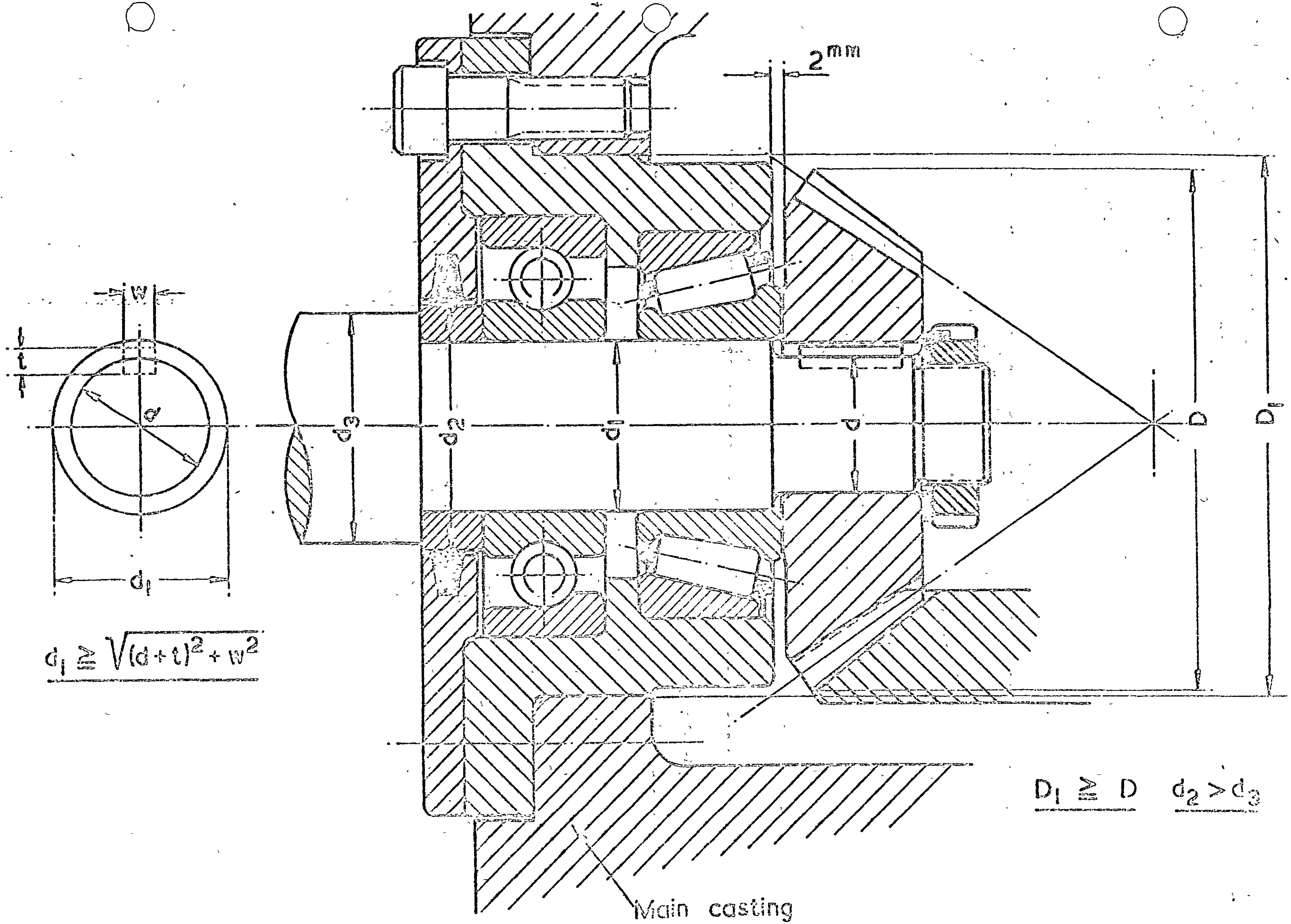


Fig 7.2.

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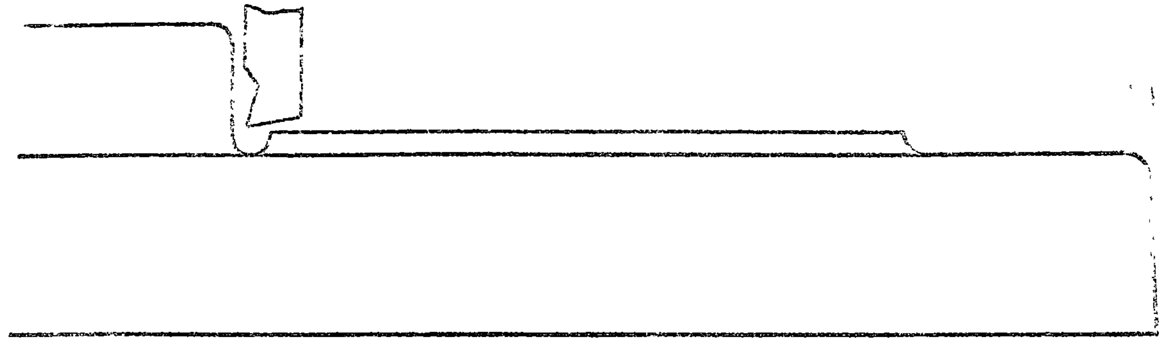

Fig 7.28

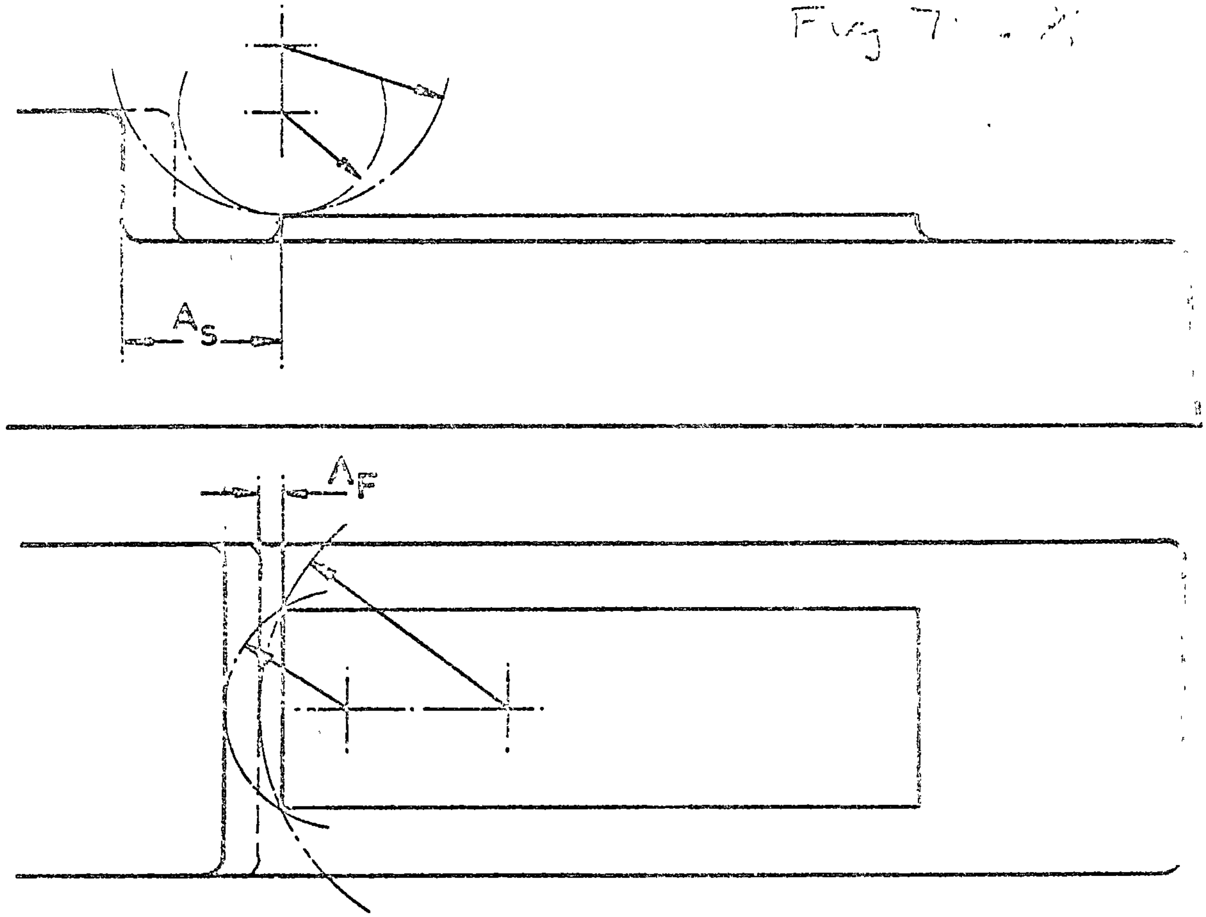

Fig 7.29

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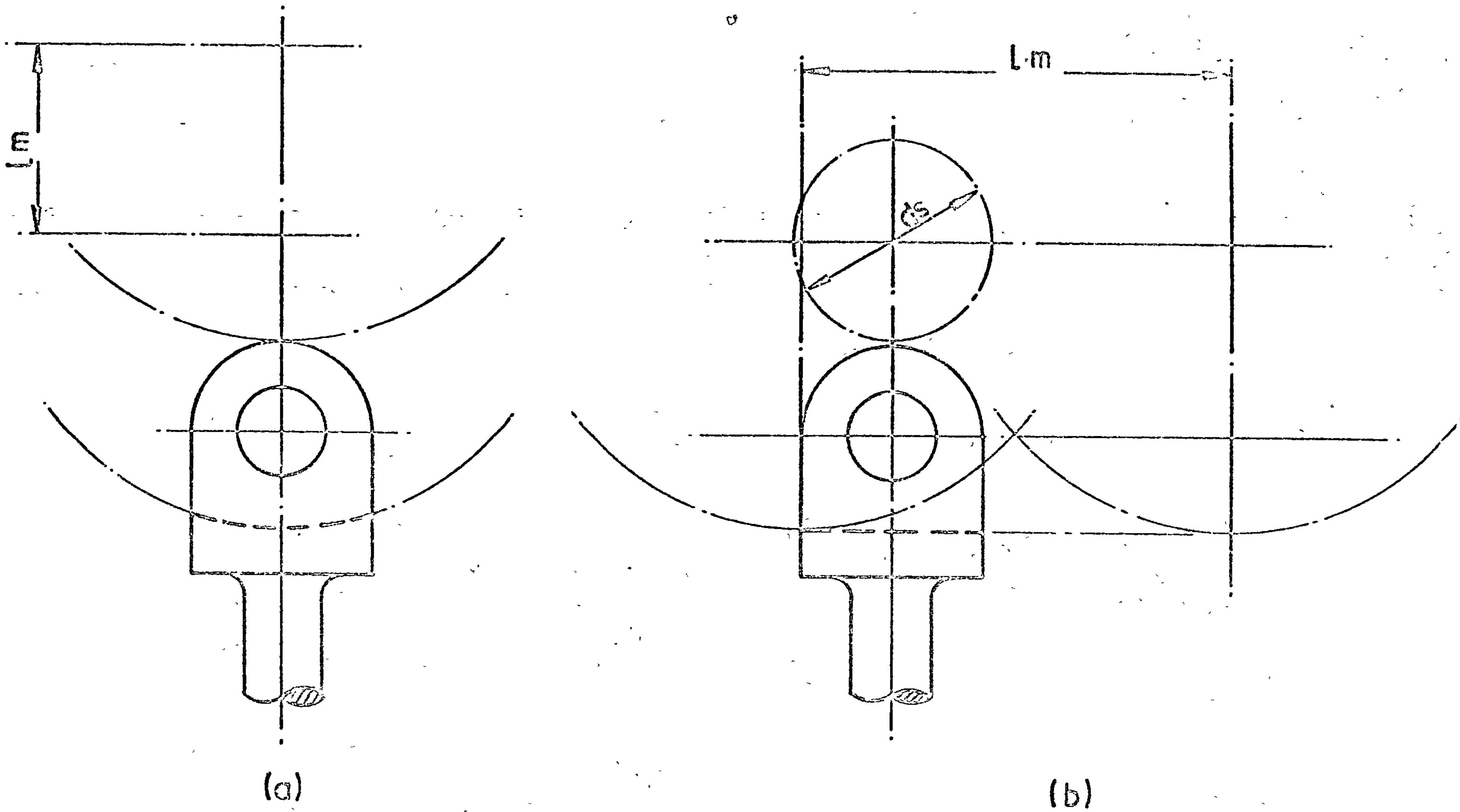

Fig 7.27

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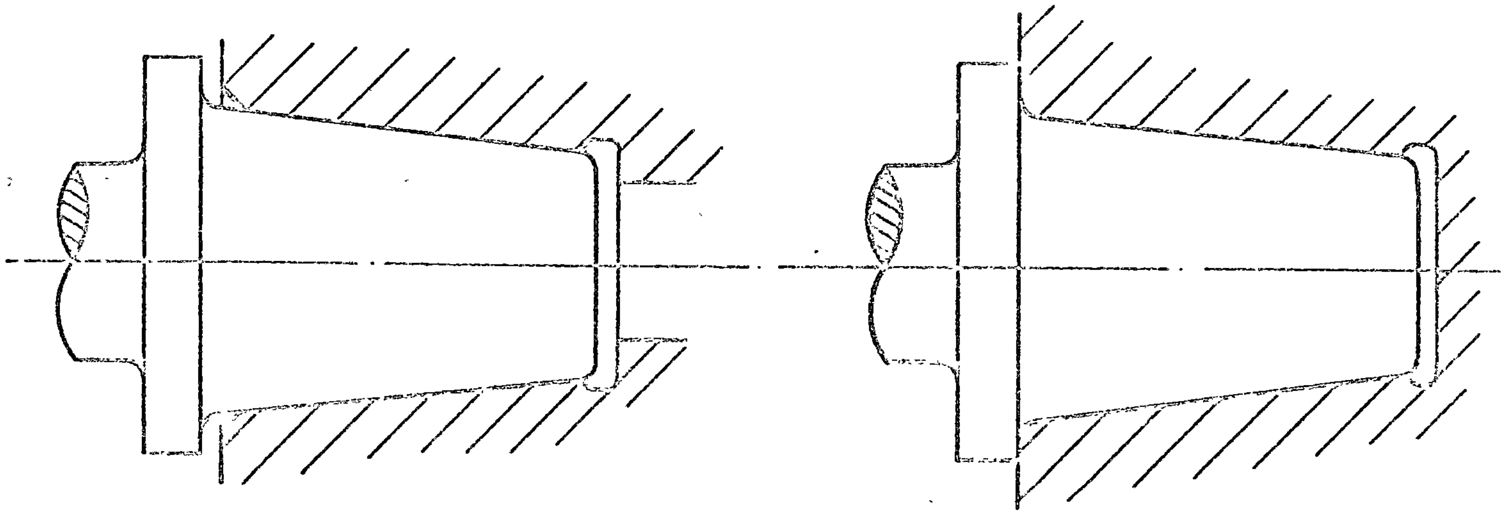
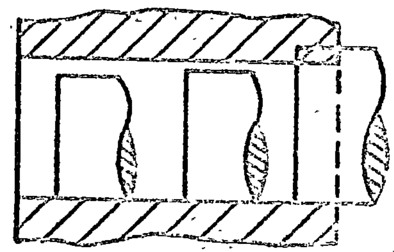
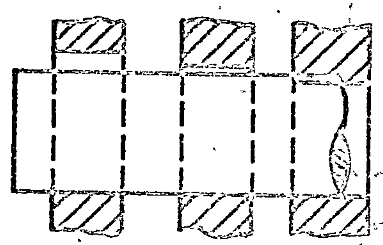


(a) Right

(b) Wrong



Hole Basis



Shaft Basis

Fig 7.4.8

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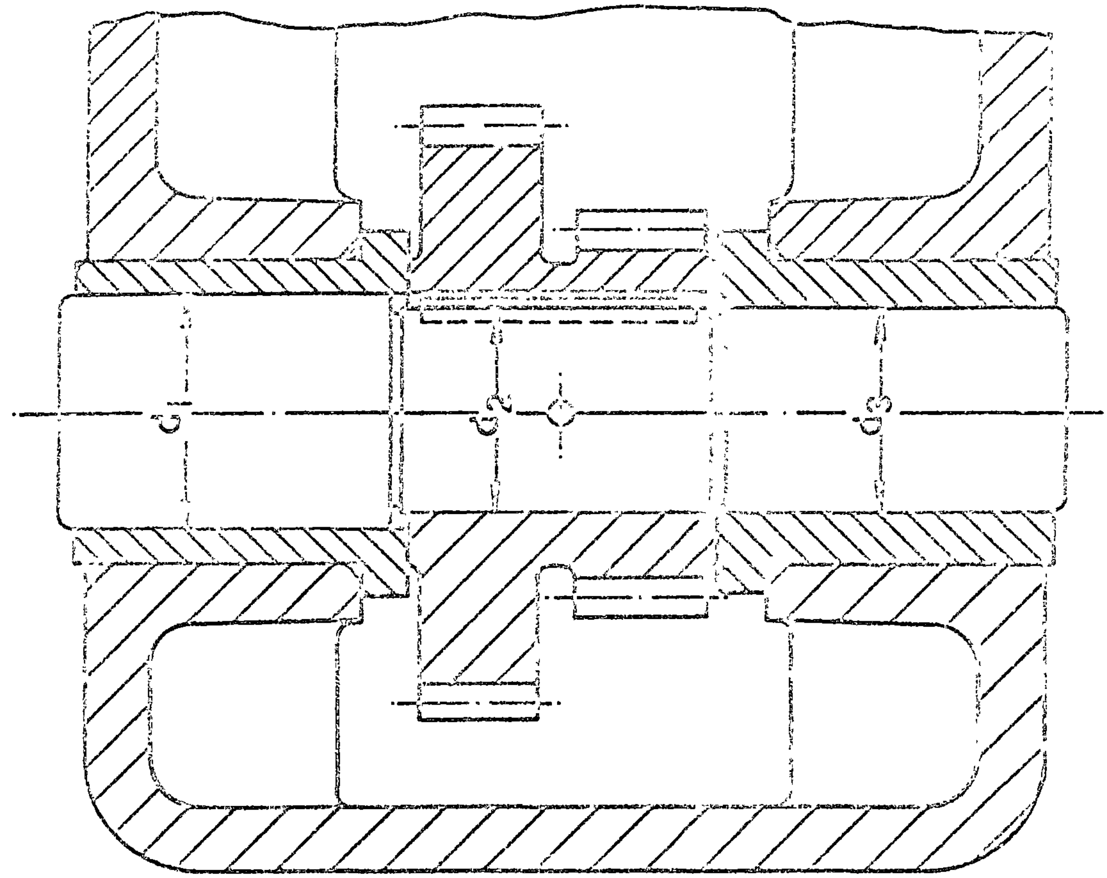
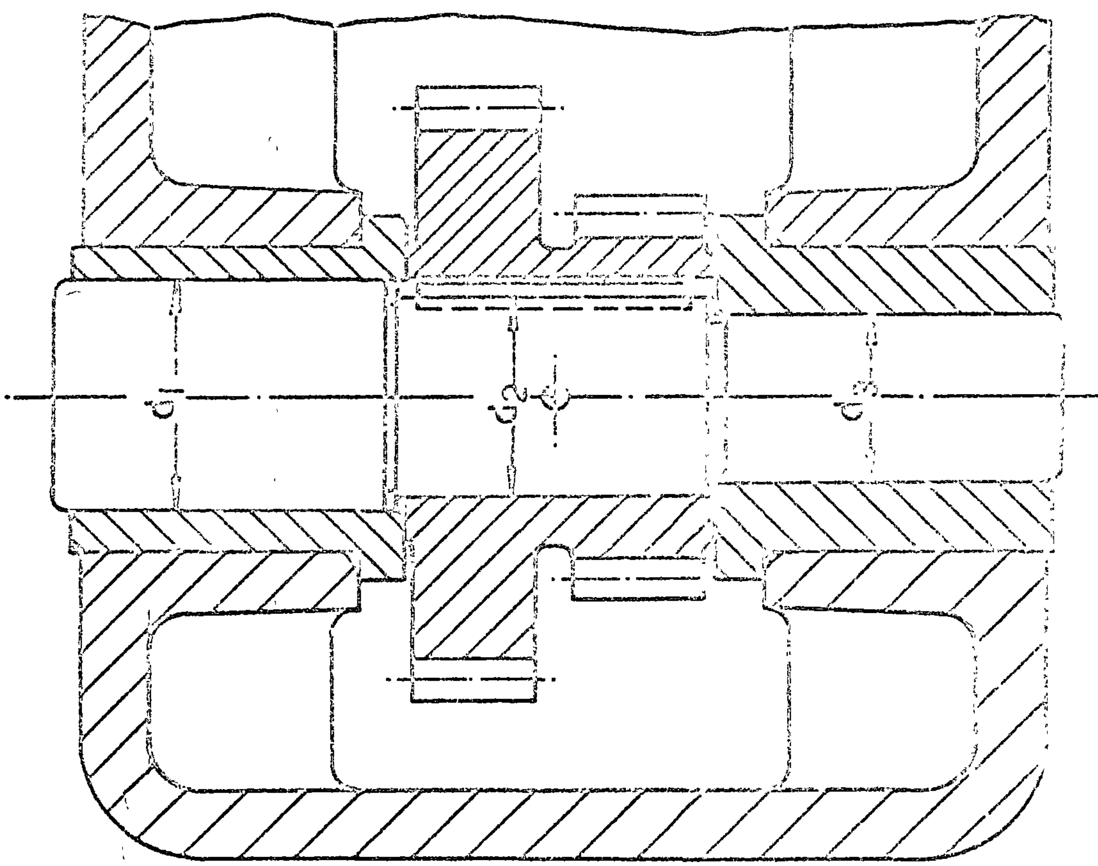
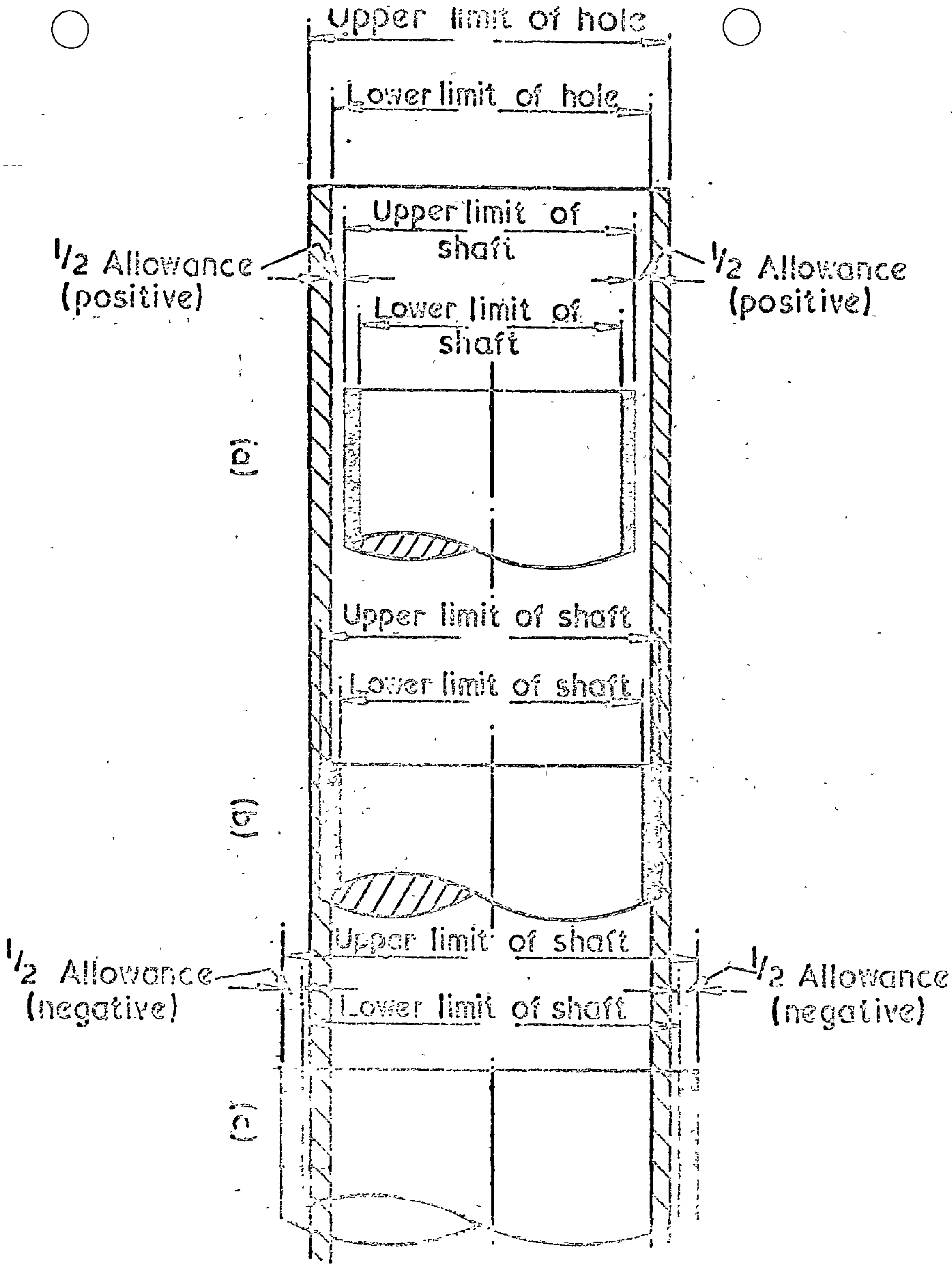
Drg 0107

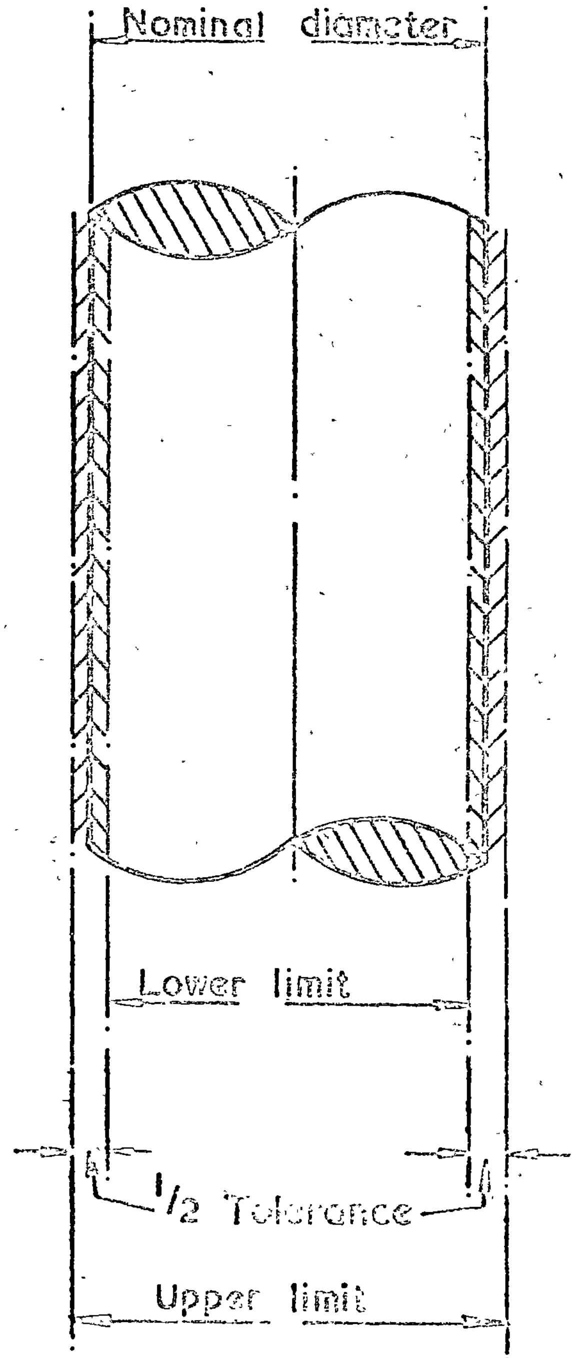


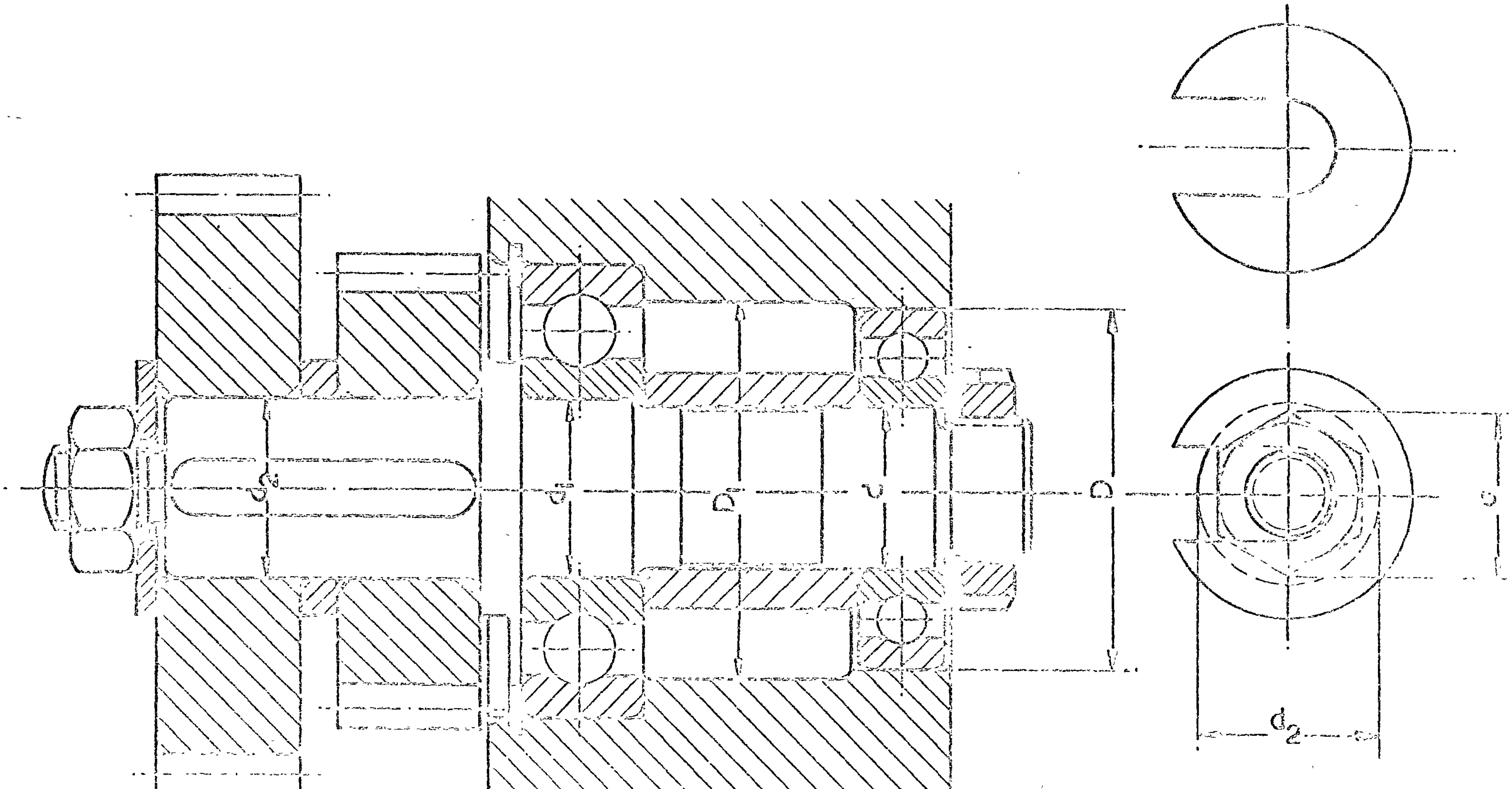
Hole basis



Shaft basis

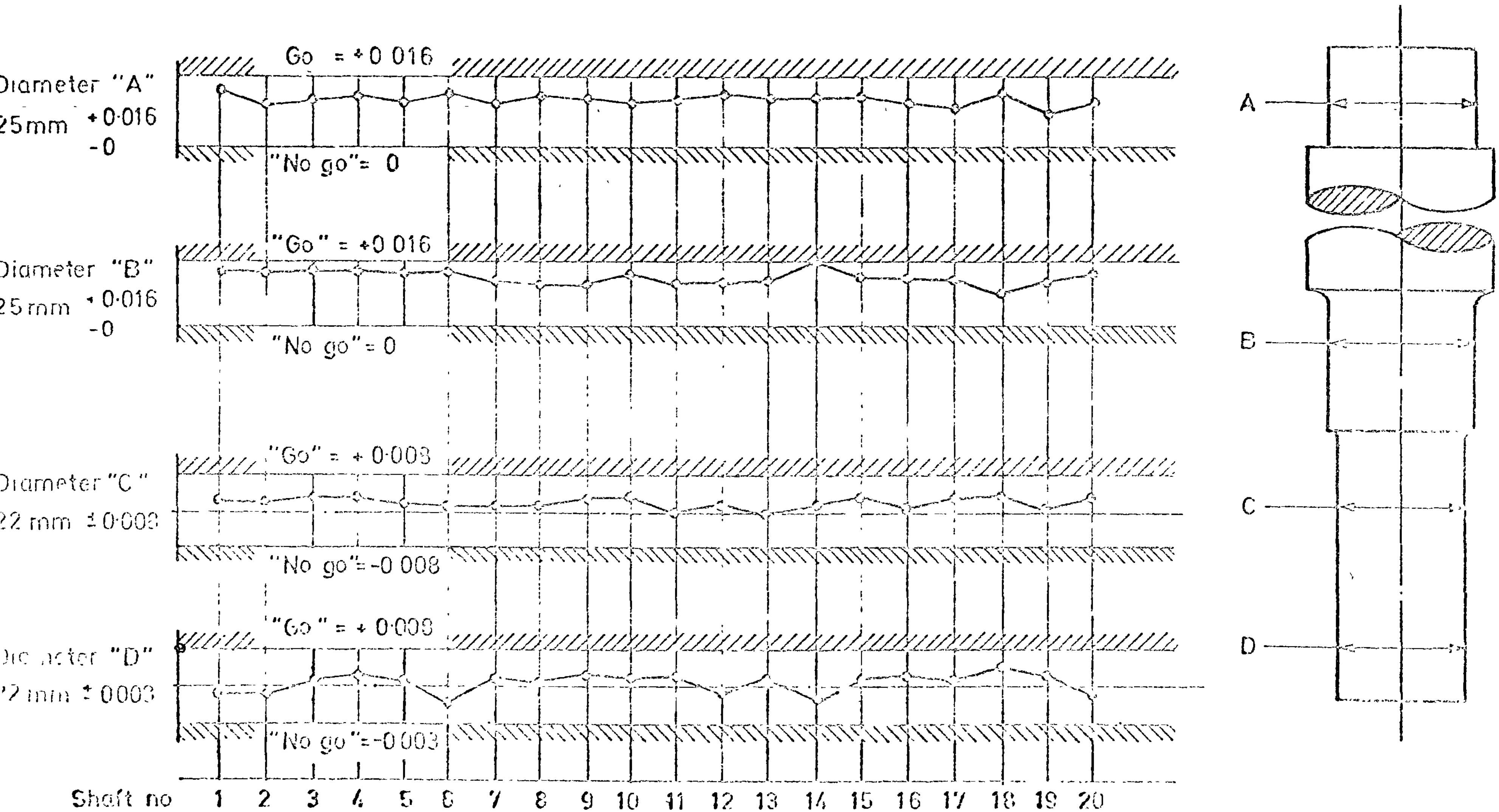

Upper limit of hole
Lower limit of hole
Upper limit of shaft
Lower limit of shaft
1/2 Allowance (positive)
1/2 Allowance (positive)
(a)
Upper limit of shaft
Lower limit of shaft
(b)
Upper limit of shaft
Lower limit of shaft
1/2 Allowance (negative)
1/2 Allowance (negative)
(c)


Nominal diameter
Lower limit
1/2 Tolerance
Upper limit



$d_1 > d \qquad D_1 > D$

$d_2 \geq s$



Go = +0 016
Diameter "A"
25mm +0·016
-0
"No go"= 0
"Go" = +0 016
Diameter "B"
25 mm +0·016
-0
"No go"= 0
"Go" = +0·008
Diameter "C"
22 mm ±0·008
"No go"=-0 008
"Go" = +0·008
Diameter "D"
22 mm ±0·008
"No go"=-0·008
Shaft no 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
A
B
C
D

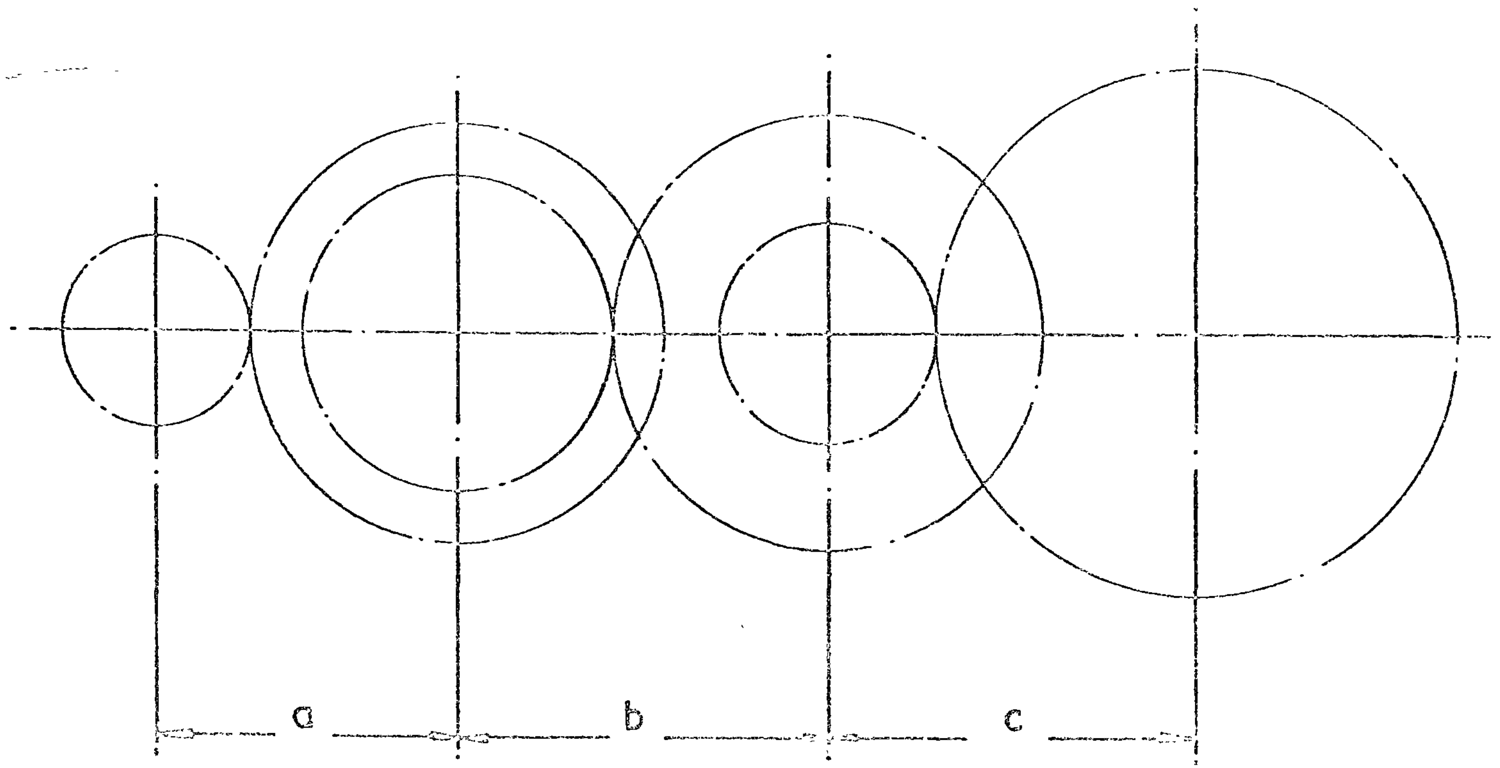


Fig 740

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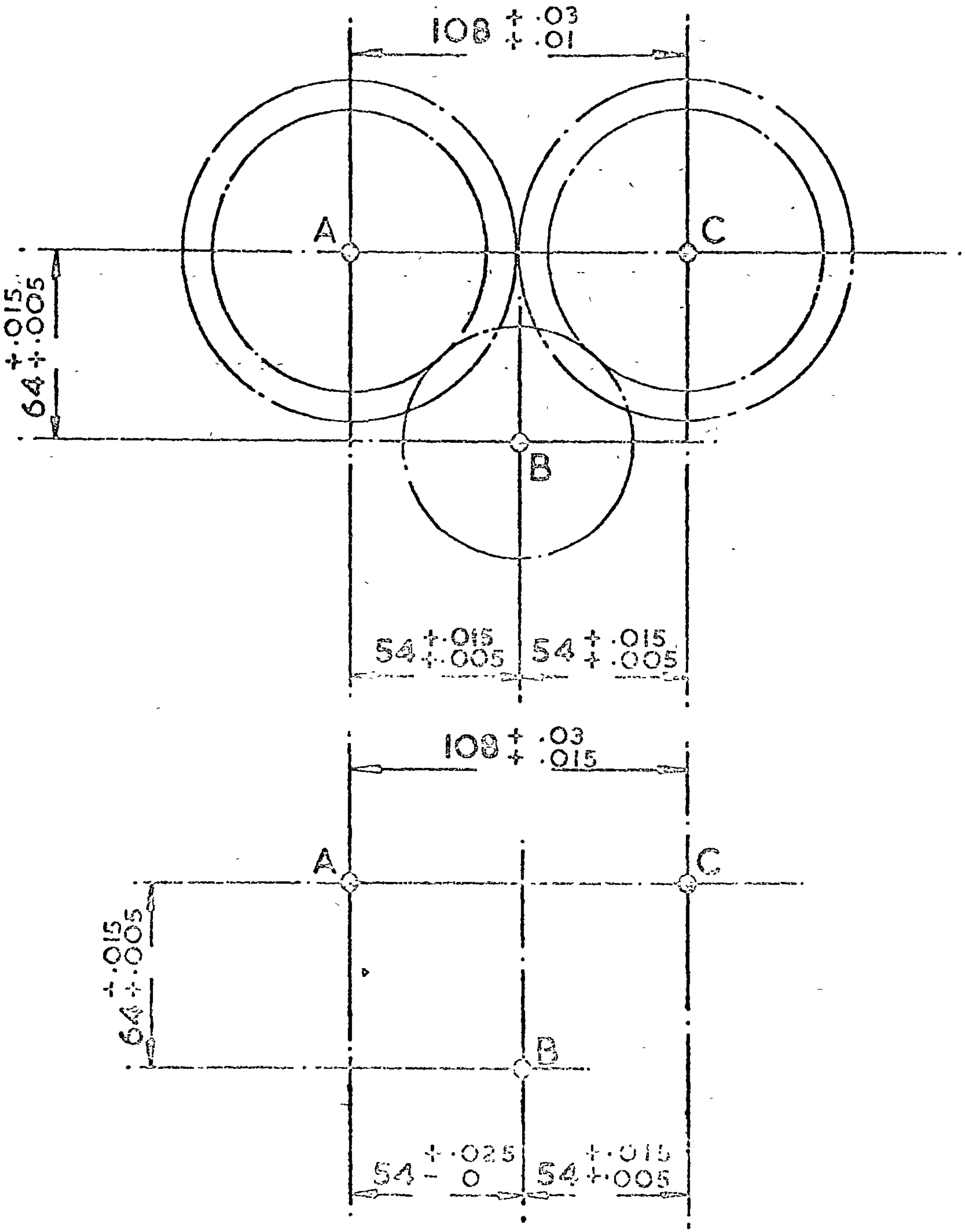

Fig 7.41

DS 0107 / A1

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INGENIERIA DE MANUFACTURA

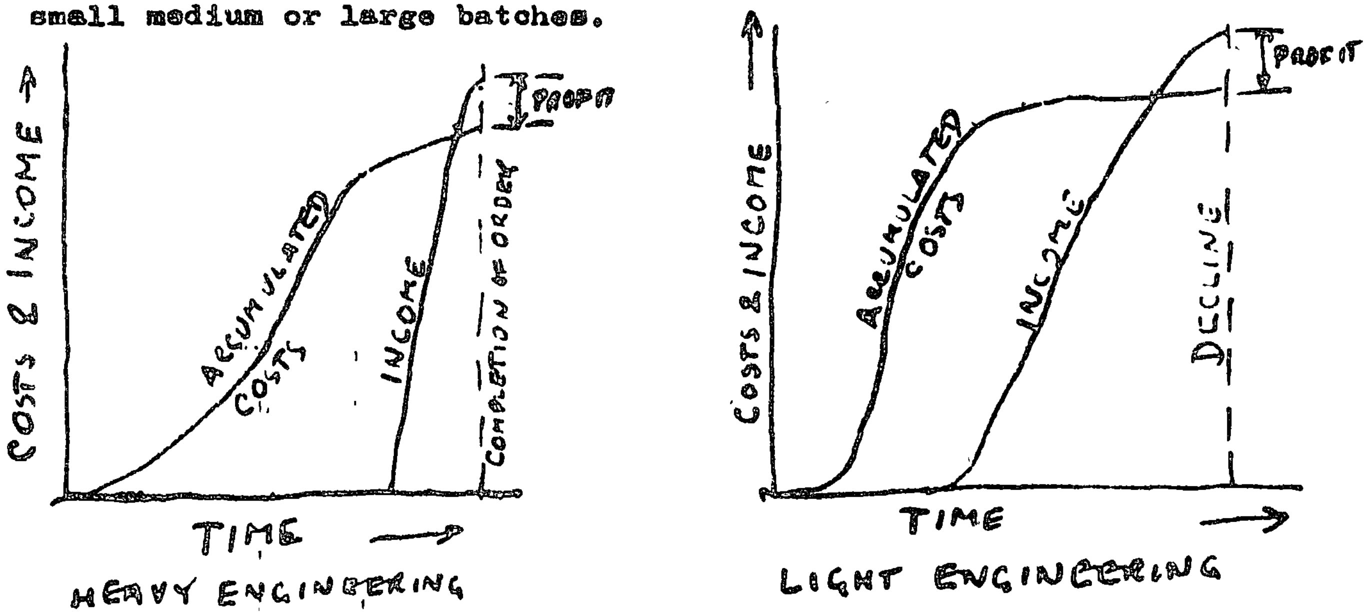
SELECCION Y DISTRIBUCION DE EQUIPO

DR. F.KOENIGSBERGER

JULIO DE 1976.

4. Equipment Selection and Lay-out," Planning and Progress Control

In the establishment of a manufacturing organisation the type and marketing conditions concerning the product must be considered. Whilst many heavy engineering products are produced against a specific order and in more or less small quantities (often one off) light engineering products may be produced in small medium or large batches.



COSTS AND INCOME VS. TIME
(FROM C. RUIZ)

For the purpose of our discussion we shall deal with the more general case of light engineering. In light engineering, particularly in the manufacture of consumer goods the problems encountered today are two-fold:-

a) If a standard product can be marketed for a considerable time mass production methods can be used, resulting in considerble economic advantages.

b) The time when standard products could be easily marketed (Ford's famous statement that the customer could have the model-T car in any colour or shade, provided it was black) is passed.

In other words in most lines of consumer goods the demand for specialised products and for limited life consumer goods is on the increase.

This demand must ultimately be satisfied at the assembly stage when the whole product is completed. In the preparation of the components, however, a certain variety reduction can lead to considerable economies. This preparation, the manufacture of detail components will now be discussed. Cost is the deciding factor, unless - as in some cases - safety, reliability or other necessities override cost considerations (e.g. space travel, nuclear energy, mining machinery, transport equipment, etc.). Design of the product must make possible low-cost manufacture.

Apart from well known principles concerning quite generally simplification of manufacture, the correct selection of materials, the design to suit easy and low cost machining etc. are important points. Based on the design drawings the planning of the manufacturing processes must include the selection of the most suitable machine tools and the determination of their availability and operation at the right time. (Gantt chart). In order to determine the manufacturing cost it is necessary to consider not only the raw materials used but also the cost of labour for setting up and running the machine tools and the overheads which depend upon investment cost, running cost of the factory, special tooling equipment etc. If we take for a given component to be machined the direct labour and tooling cost this consists of the share of labour costs for setting up the machines (C_s), the labour costs per component for operating the machines (C_o), the share of the cost of changing tools (C_{ct}) and of special tooling equipment (C_t). C_o can be subdivided into actual machining cost (C_m) and handling cost (C_h).

$$C_o = C_m + C_h = \text{labour cost of floor-to-floor time}$$

The cost of setting-up occurs only once per batch (batch size A) whilst the changing of tools may have to take place after a certain number of components (B) has been completed. The cost per machined component depends then, apart from the cost of raw material and the overheads, especially the investment and maintenace cost of the manufacturing plant as a whole, upon the cost of special tools

Example from Brommer-Holste, Forschung, Entwicklung und Konstruktion im Maschinenbau VDMA, 9.5.1968, Hamburg.

$$T = T_P + T_{NP}$$

$T_{s\ell}$ = slacktime due to
No parts
No material
No tools or instructions
Machine faults
Planning faults

The floor-to-floor time

$$\tau_P = T_P + T_{s\ell}$$

and the time utilisation factor (efficiency)

$$\eta_a = \frac{T_P}{\tau_P}$$

Cost $Q = Q_P + Q_{NP}$

Cost per unit time at labour + overheads = P_L

machine depreciation = P_M

$$P_P = \frac{P_L + P_M}{\eta_a}$$

With multi-shift production P_M would be reduced in proportion to the number of shifts whilst P_L would tend to increase because hourly wages would probably be increased. Discussion of principle of preset tools which are either positioned ready for action in the tool carrier

a) multi-tool lathe
b) milling machine

or ready to be put into position in a rotating multi-tool holder fixed to the tool carrier, turret lathe or available in a tool magazine from which they can be transferred to the tool carrier, machining centre.

Advantages can be obtained by combining the need for small quantity or batch manufacture with the economic benefits obtainable from large quantity production, if the "group technology" concept is applied. Workpiece statistics have shown that there is a certain regularity in the distribution of shapes and sizes of workpieces which have to be produced in the machine shops of the engineering industry, and how these occupy the available time capacity of the machine tools. For the example of turned components the ratio between time occupied as a function of the total time available on all turning machines in a factory has been plotted. If one can bring similar components together, taking also into account other operations, it is possible to group small batches of components which are similar either by virtue of their shape and sometimes size or technologically by virtue of the machining operations necessary for their manufacture, and thus to form larger batches with resulting technological and economic benefits.

As an example, the basic elements which occur in turned components have been defined and combined in an artificial "complex" part.

If equal or similar elements of this complex part occur in different components these can be grouped together into batches which can then be produced on corresponding groups of machine tools. In order to identify the similarity of existing parts and to assist the design office in making use in their new design of those elements which already occur in existing components, classification systems are often used.

Here it appears necessary to stress the following: the fact that the classification and coding of workpieces was considered a prerequisite for implementing group technology methods in production resulted in many people concentrating all their efforts on problems connected with the coding system which after all is only a means to an end and not the end in itself. Arguments arose as to whether the shape of components or the processes involved in their manufacture should provide the overriding considerations, or whether a system that was tailor-made for each specific case was preferable to a universal one which covered, say, 80% of the requirements.

All systems have their pros and cons and must be judged in connection with the needs for each specific application.

However, whilst the capacity and quality of this important tool have been extensively studied, progress in the practical implementation and application of the whole concept of group technology in full scale manufacture appears to have been much slower. The criticisms of individual coding systems, which have been ventilated in the technical press, have diverted the attention from the value of the whole concept to the detail of one means of achieving it.

According to the requirements of group manufacture machines can be arranged either in flow lines or in cells.

The flow line layout is advantageous if the sequences of machining do not make it necessary to send components forward and backwards, whilst the cellular layout can be more flexible both in the planning and progressing of component manufacture.

The benefits of group technology methods can best be demonstrated by the results of introducing them into two factories.

In order to control the production system as a whole, from customer's order via design, manufacture, inspection to despatch, the computer has been playing an ever increasing role, as a few examples will now show.

Computer aided design and planning

This term is used rather loosely in that it is applied not only to the actual design activity, i.e. the conversion of ideas into feasible realities, but also to the checking by calculation and, if necessary, modification of existing components and structures. The former is based mainly on a store of available data concerning detail elements ("Menu" system) which are selected and combined by the computer (often in a dialogue with the designer) in such a manner as to satisfy the specified requirements of the product that is to be designed, whether it is a complete assembly or a separate, more or less complex component.

The first example concerns the design of a motor shaft by putting together three elements, driving end, middle (torque transmitting) portion and fan drive end, from a store containing all possible shapes and sizes, which has been established for these purposes.

The result is a working drawing and a planning sheet. The storage capcity which is needed in order to provide the means for a search on which the combination of suitable elements can be based, and the logic required for automatically preparing the production plans necessitate the use of a very large and expensive computer. However, by means of limiting these tasks through variety reduction and a less ambitious approach, e.g. by omitting the automatic preparation of a planning sheet, manufacturing drawings have been successfully produced with relatively small and economically viable computers.

As far as the computer operations for establishing the geometry of the drawing are concerned it is necessary to distinguish between the descriptive input and the processing effort. If the information describing the geometric shape is provided in the form of co-ordinates the input effort is high whilst the processing effort is relatively low. If on the other hand the input consists of a performance specification, such as for the example of a gear drive, power capacity and speed, the complete correlating logic must be available in the computer; in other words the necessary input effort decreases whilst the processing effort increases. In practice there will be many cases between these two extremes.

The design function is not concerned merely with the determination of geometric shapes and sizes. It may also involve the optimisation of functional layouts for combining a variety of elements and components.

In contrast to a real design function as described above the computer can also be used for carrying out a checking and correcting function. This is of considerable importance when complex structural designs are to be optimised and when conventional calculation methods would be so involved that the time and effort required would make them impracticable.

This is the case in machine tool design, where static computations are used for calculating the static flexibility of an existing design for a structure, whilst dynamic computations are applied when not only the natural frequencies and modal shapes but also the tool/workpiece dynamic characteristics must be determined.

In comparison with the three-dimensional design requirements for mechanical parts the design of electronic circuits and layouts is generally a two-dimensional exercise and as such more easily planned, programmed and transferred to a two-dimensional drawing. This is perhaps one reason for electronics companies being in the forefront of those who use CAD in their everyday work.

The computer aided design centre of Siemens in Germany employ the "menu and dialogue" system together with a light pen technique as well as a cheaper version which uses a digital plotter. It was interesting to note that although the light pen technique indicated the latest developments in this field the cost of its use amounted to about £200 per hour, against £80 per hour with the digital plotter. The results of both could be transferred to punched tape and utilised accordingly.

It is of interest to note that the philosophy of the Siemens engineers concerning the introduction and application of CAD appears to differ from that encountered with engineers in Great Britain where the first steps are usually taken by manual design and work is then transferred to computer assisted drawing and programming. Siemens engineers believe in starting with the computer assisted design and filling in by hand those gaps which cannot be covered easily by the computer. When the computer is to be used for controlling production the planning and programming of the whole process must be even more accurate than it has to be with manual production control.

For a given design of a product the various operations must of course first be planned, the most suitable machines selected and the manufacturing cost estimated.

If new plant and equipment is to be installed to suit the requirements of a specific product the establishment of group technology cells, flow lines or other systems may be considered most appropriate. For the case of machine shop processes, i.e. the manufacture of detail components prior to assembly of the finished product, the times required for cutting or forming the various pieces on different machine tools, the setting-up, handling and inspection times, etc. must be calculated or estimated and the machine loading must be determined, taking into account the batch sizes of each part as well as the total quantity to be produced per annum.

These calculations are usually based on an estimate of an expected sales demand and it is part of the task of production control to be sufficiently flexible for adjusting these to suit any developments or changes in demand for the product. At the same time the ordering of raw materials, special tools, jigs and fixtures etc. must ensure that the workshops are enabled to work to the planned time schedule.

When the progress control is to be carried out by human operators, clerks etc. apparent emergencies may lead to panic activities. One of these may be seen in the appointment of "progress chasers" who - whilst temporarily solving difficulties by pushing a "desperately urgent" job ahead of an "urgent" one may create further trouble and greater chaos later on.

In the case of computer control, eventualities and emergencies must be taken into account when the general programme is developed. As an example in the manufacture of electric motors and pumps the usual manual system failed to provide a clear appreciation of the basic problem of relating production commitments for a given period of time to the production capacity that was available. Consequently the available capacity was not allocated to the jobs in hand in such a manner as to maximise the completion of finished products in order of priority or to provide for the frequent and accurate feed-back of information, concerning for example overdue orders, to the commercial departments. It was decided, therefore, to introduce production control by computer. Two solutions were possible:-

1. The development of a production control system that was tailor-made for the job in hand.
2. The use of a proprietary software package.

Whilst the former would have been as near as possible to an ideal solution it would have required lengthy development work which is unavoidable in the implementation of a new and as yet untried system. A proprietary software package which was not only available but also already used in another factory of the Company concerned, was therefore accepted.

The package comprises a suite of computer programs which can be split into three main programs denoted by I, II and IV. Program IIA is optional and provides a network scheduling facility, where-by, tools, parts, sub-assemblies and assemblies are linked together so that their availability at the estimated times is ascertained.

Program I is the maintenance procedure of the system, by which an "On Order" file is updated with the addition of new incoming items and deletions of complete operations. The input to the system is in punched card form, detailing control parameters, work centre data and 'order' production data. When all parts in an order have been finished, the complete order, including part control records, is erased. The output from this section is an audit list of the input, to facilitate correction of errors.

Program II' is the scheduling procedure whereby the latest start and finish dates for every operation on file are determined. This computation assumes an infinite resource availability, and the output report is a statement of the weekly machining load demand on each work centre, indicating any overloads by comparison with the actual capacity. A further print-out is also obtained listing the file content by order number sequence. Thus a visual record of the order status is provided. Program IIA may be run in this section if required, to check the status of any batch in an order using "PERT" analysis techniques, but the network for each assembly must be provided. This computer run also creates a copy tape, on which the detail requirements of the short term loading period are recorded. The period can be varied as required but, for economic considerations, is normally limited to 2-3 weeks.

The copy tape provides the data for the Program IV scheduling run. The program schedules each operation record on this file, taking into account a number of parameters such as: work centre capacity, tool availability, and order priority. There are a host of priority rules, some simple, some complex, which relate to the degree of lateness, order due date, number of operations to be completed, director priority, added value, machining time, length of queue etc. In between operations, the program automatically adds transit time, which is governed by another set of rules. If the batch is late, the transit time is reduced by stages to bring the work back on schedule. This is sometimes further complicated if the batch splitting and operation overlapping faciltities are exercised. The main output of this run is a list, in priority sequence, of work to be processed at each work station. Other optional and supplementary reports are provided, such as a statement of capital tied in work-in-progress, and a priority listing of orders on file. If an underload occurs, the program also provides the facility of bringing work forward, provided it is on the short term machine load tape.

To improve control further, preparations were put in hand to introduce an additional computer program which provides ready access to data of stock levels, gross and nett requirements of parts required to meet order commitments or market forecasts, production costs and engineering data. This allows the manufacturing management to modify plans quickly in response to changes of design, market policy or out of pattern demands of sales.

Computer Control of Machine Tools

With computer numerical control (C.N.C.) a mini computer is permanently connected to the machine tool. This allows considerable flexibility because changes in operational conditions can be incorporated at will in the program which can thus be varied in accordance with specific requirements at any time.

The introduction of direct numerical control (DNC) leads to the possibility of controlling a group of machine tools from a central processor via an interface at each machine. The individual control equipment situated next to each machine also includes the power electronics for the feed drives, and in some cases a display terminal provided for maximising inter-active communication between the central processor and the operator. Alternatively, each machine tool can be controlled by a conventional NC or CNC controller in which case the DNC communication links operate behind the tape reader.

In order to study the problem as a whole it is perhaps appropriate to consider first the main advantage of using NC in general, be it CNC or DNC. Market research carried out in U.S.A., which has been reported and discussed in Germany, indicated that the obtainable workpiece quality, accuracy and surface finish are the deciding factors which influence the production engineer in favour of NC. Ease of programming, reliability and consistency are also important features. The ease of setting-up, the possibility of using standard cutting tools and of producing spare parts quickly from existing tapes as and when required are further advantages. The provision of large stores of work in progress can be replaced by programmed and tape-controlled intermediate storage. Modifications in the design of the product can be catered for by quick changes of programmes and tapes. Variations of the cutting tool dimensions due to wear and/or regrinding can be allowed for by means of simple manual input signals.

Although some experts have stated that CNC is more versatile and cheaper than a hard-wired system, the Japanese Company Fujitsu-Fanuc appear to consider a DNC installation more economical than a number of CNC machines. Siemens have extended this concept by creating a system in which working and performance data of different workshops and machines can be not only distributed but also monitored, using manual or computer-assisted distribution, administration and control. Their system can be applied to workshops equipped with both NC and conventional, manually operated machine tools.

Moreover, Siemens have carried out a very thorough study of DNC economics. An important point in this connection is their distinction between quantifiable and non-quantifiable benefits. As far as the former are concerned it has been shown that an investment of about DM1,000,000 can lead to savings of about DM250,000 per annum; amongst the latter they count better deliveries, variability of control information, accurate control of machine loading, variability of information concerning progress in the factory, elimination of manual information which can lead to human errors, and others.

Two interesting applications of DNC, in which the human operator is practically needed only if something should go wrong, are worth mentioning.

The first is the control of 8NC lathes to which workpieces are supplied by a robot travelling along the whole line of the machines. The robot picks up the raw material from conveyor belts, locates it in the chucks and after completion of the operation withdraws the finished workpiece from the chuck and places it back on the conveyor belt. One operator looks after the whole layout and supplies the conveyor loading station with the raw material (castings or forgings) as and when required. The second example is in the Diesel-Engine Factory of Yanmar (Japan) where five machining centres and their materials handling and transport equipment (conveyors, etc.) are controlled by one central computer. The workpieces are located on platens, allotted and directed by the computer to the most suitable machine which becomes available at the right time. The programming effort covering a variety of workpieces is claimed to have amounted to one man year (actually 2 men working for six months).

The economics of NC systems can be greatly affected by low utilisation caused either by single shift work or by down time due to lack of reliability, breakdowns, etc. The former is a serious problem because both in Europe and in Japan there is considerable reluctance amongst operators to work outside the period of a day shift. It would appear that the best which can be achieved is two shift work. It is thus even more important to keep the non-productive time during the available shifts down to a minimum. At the DNC plant of Yanmar (Japan), down time for maintenance during the two shifts (20 hours) per day is reckoned to be 8 to 10% of the available time. In order to maintain such a very good record the maintenance staff must be highly competent and efficient. In one particular case it was mentioned that the supplier had a resident service engineer permanently stationed in the customer's works.

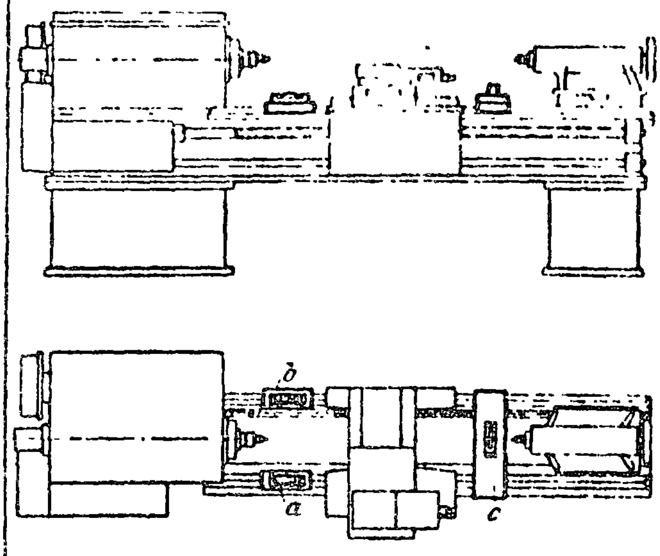


Fig 1

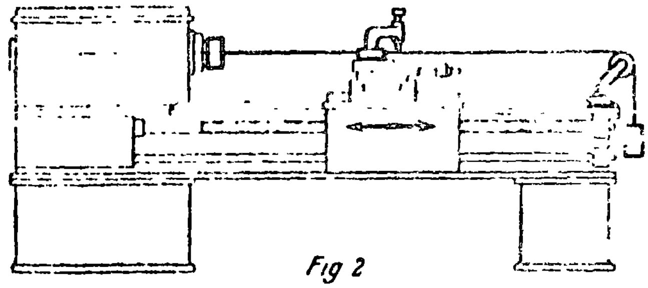


Fig 2

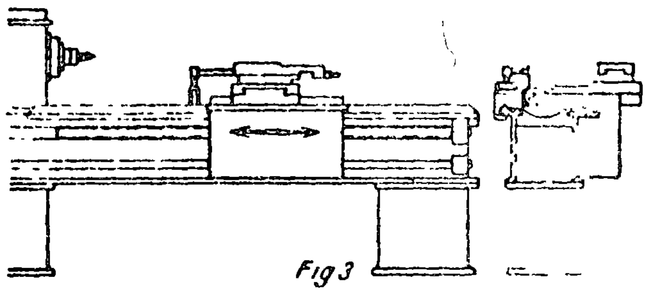


Fig 3

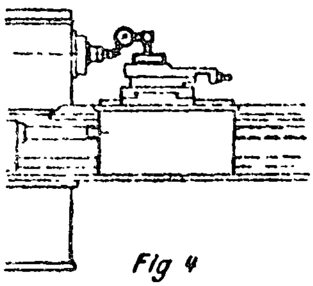


Fig 4

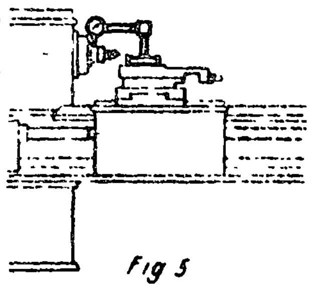


Fig 5

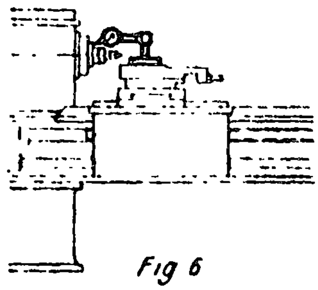


Fig 6

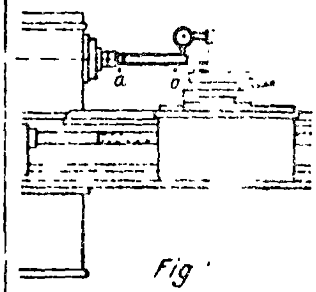


Fig '

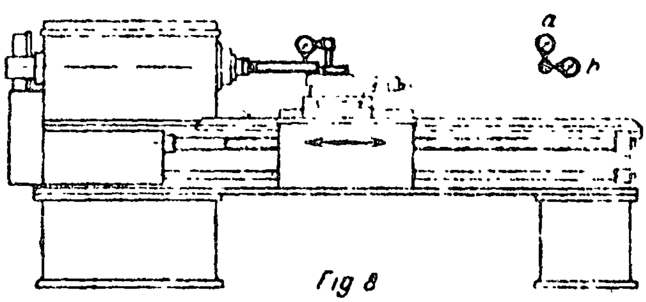


Fig 8

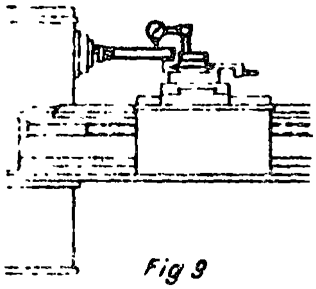


Fig 9

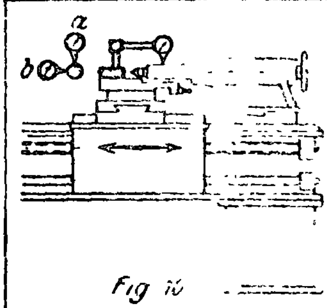


Fig 10

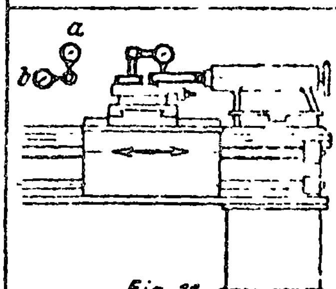


Fig 11

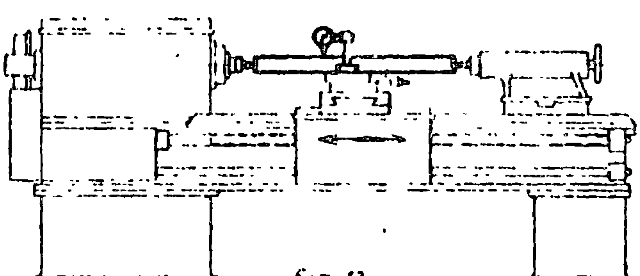


Fig 12

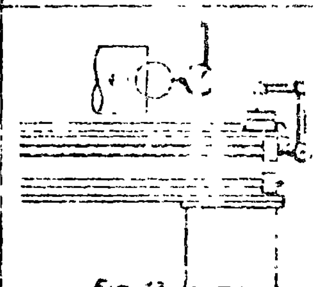


Fig 13

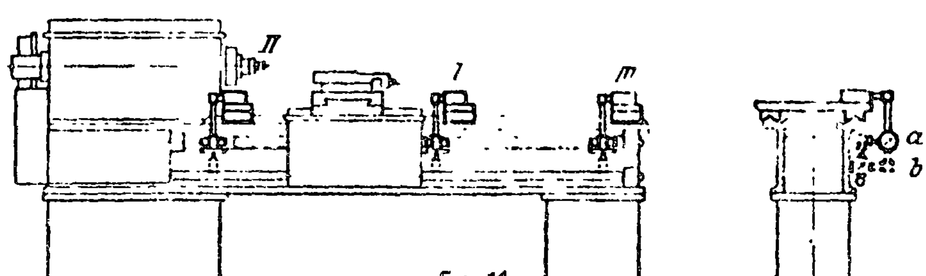


Fig 14

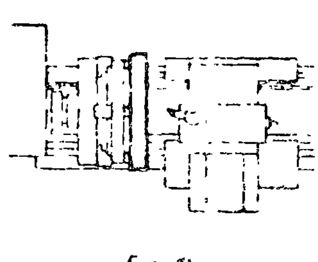
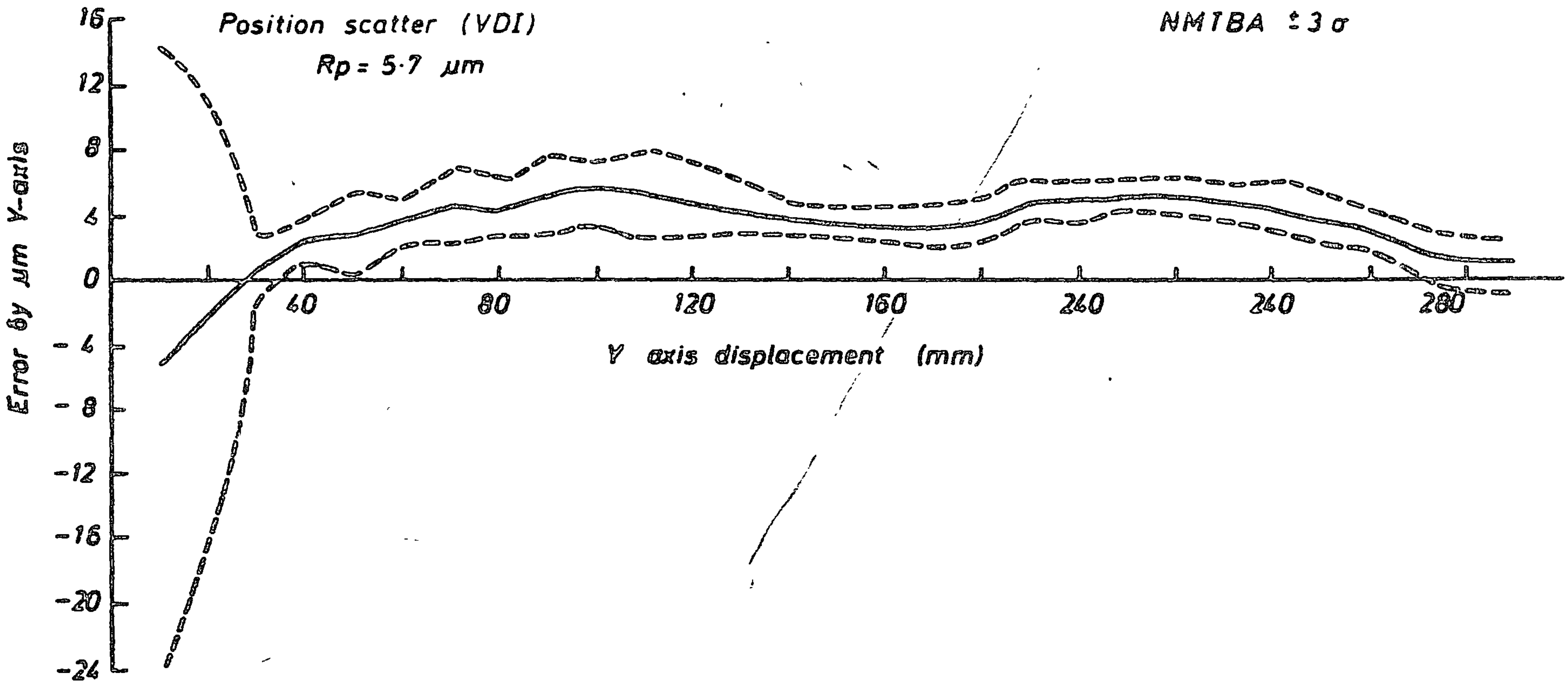


Fig 15

University of Manchester Institute of Science & Technology

0221 / E1 | Professor F. Koenigsberger



Displacement Accuracy of Y Axis of Drilling Machine.

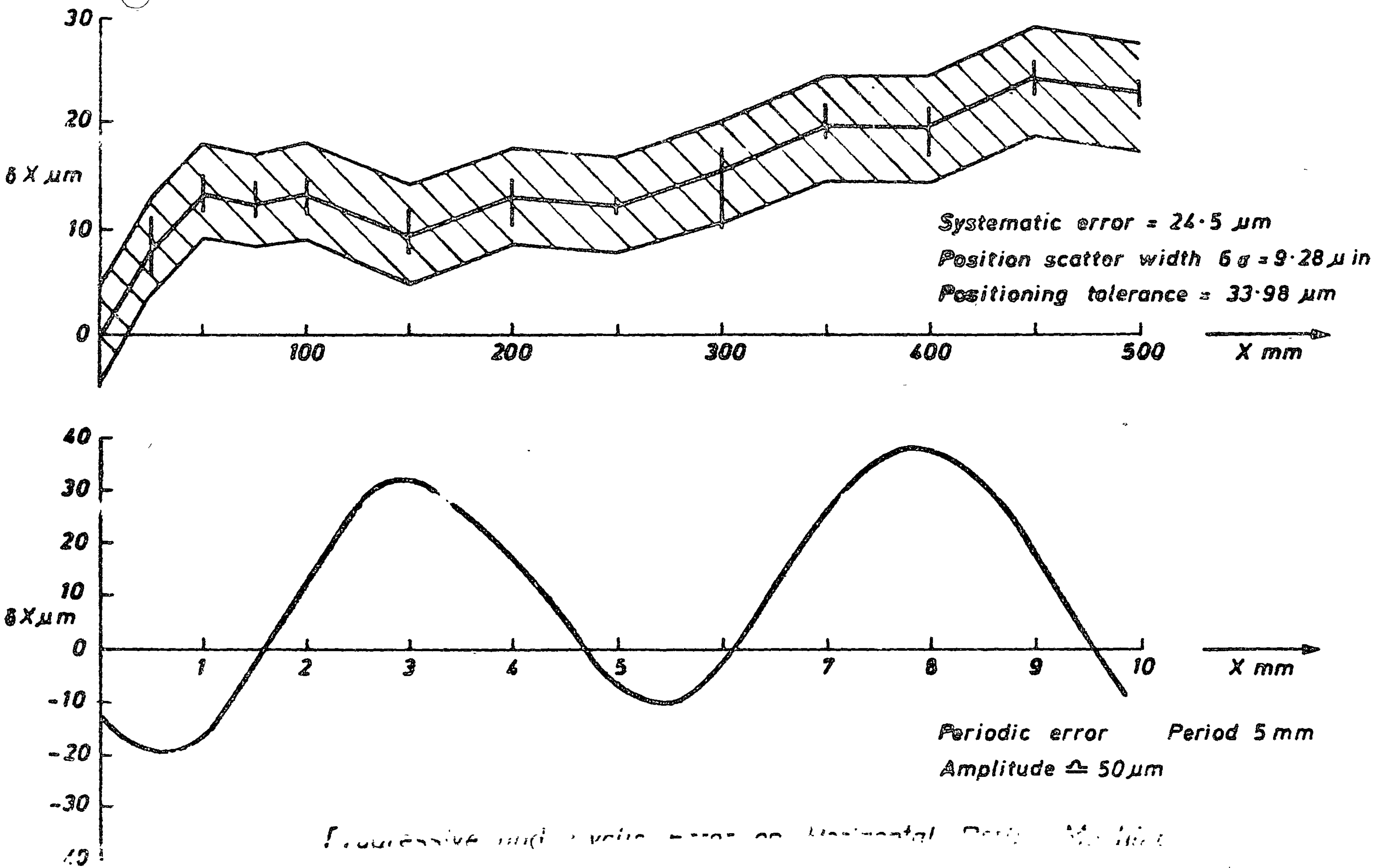
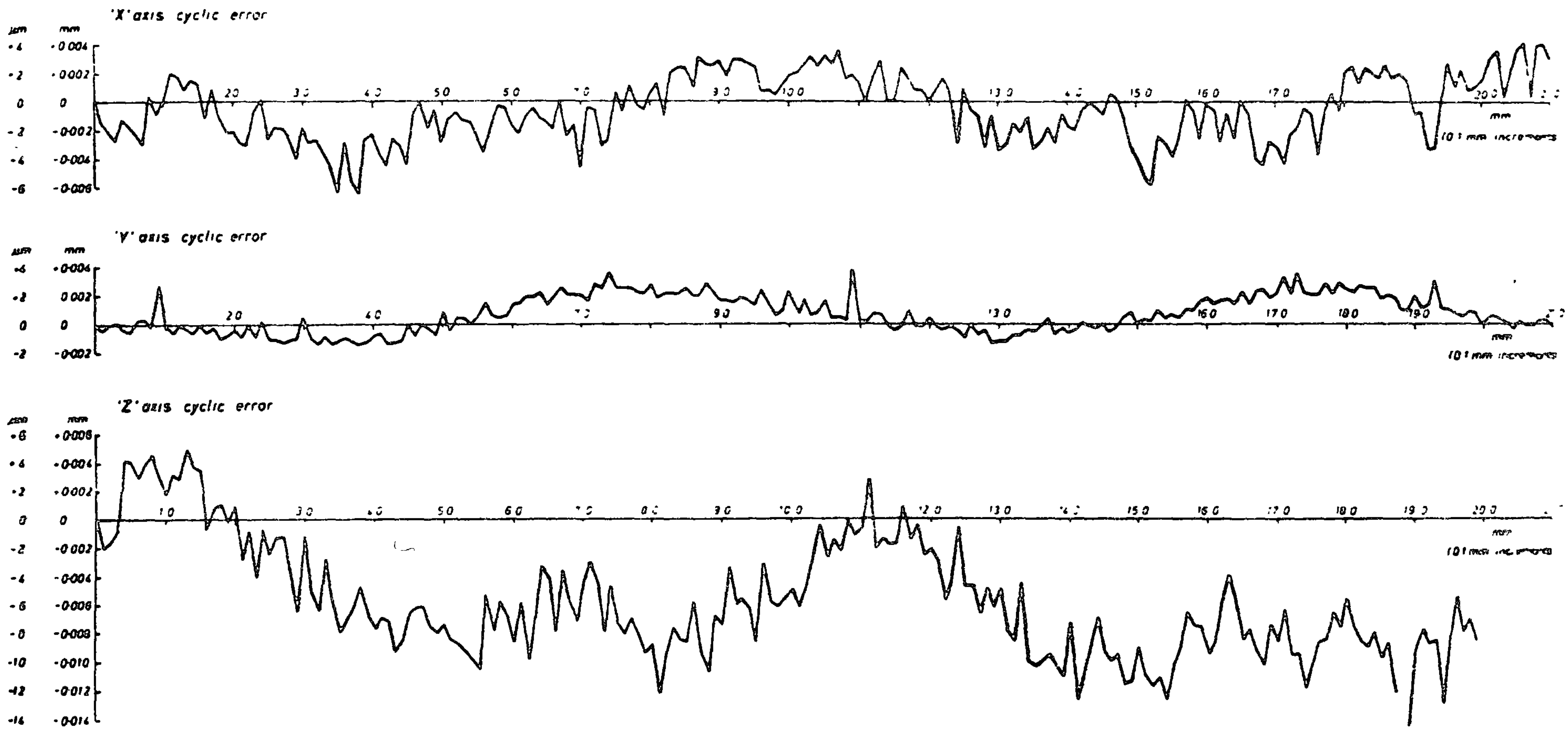
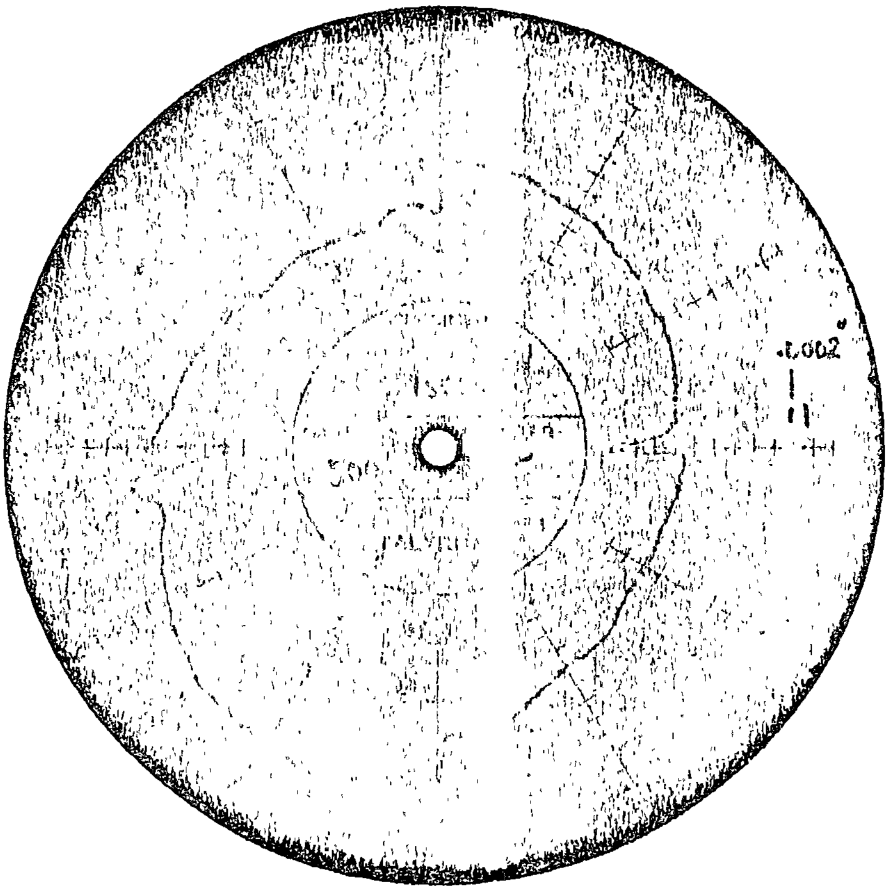


Fig. 2	University of Manchester Institute of Science & Technology	M. Burdekin	~~0315/A~~

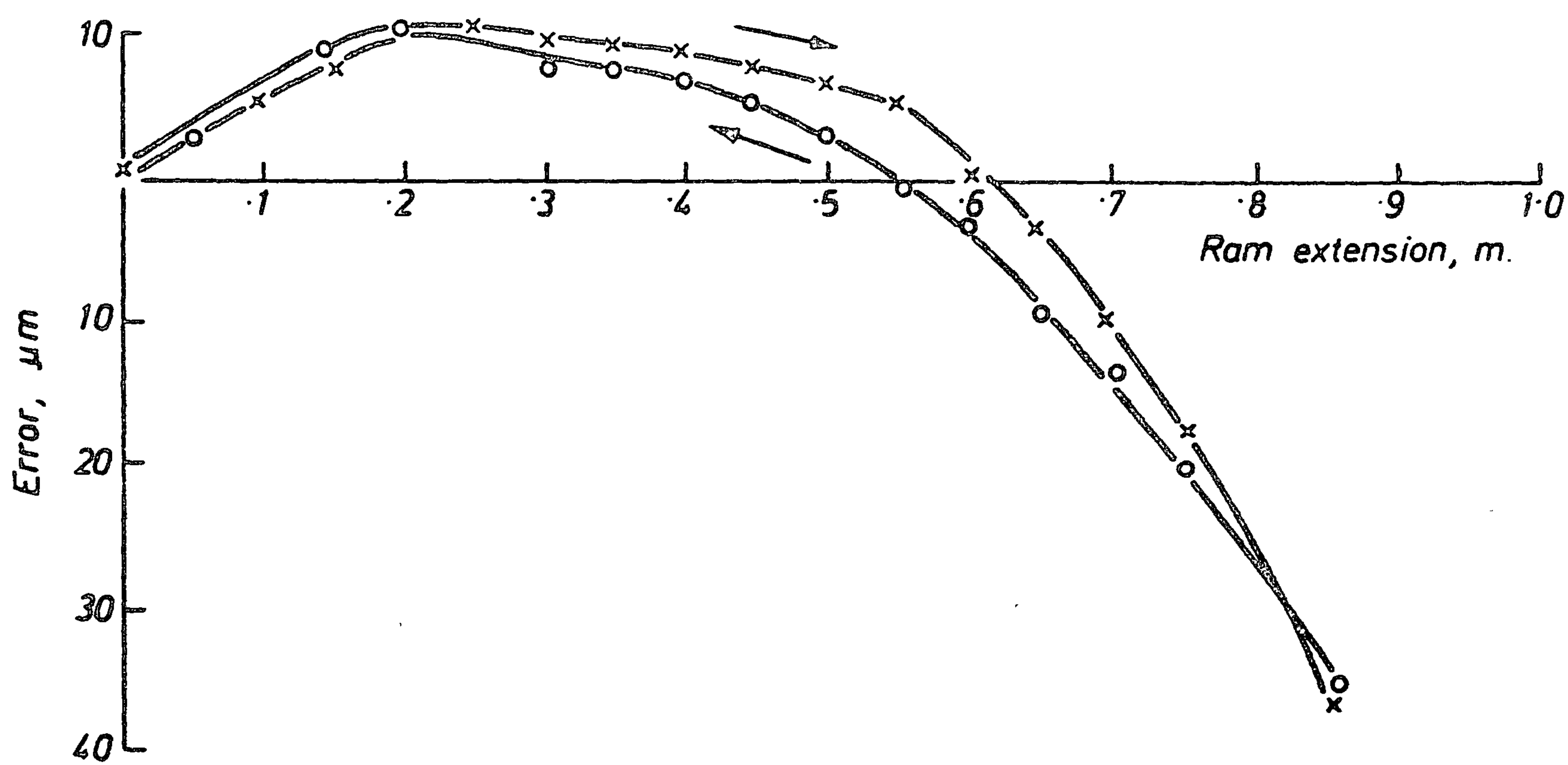
21



University of Manchester Institute of Science & Technology

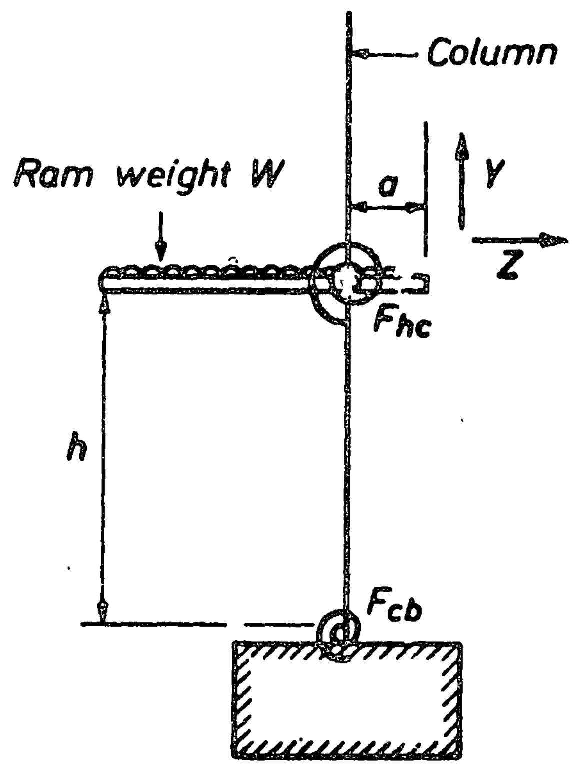


Profile Roundness Test or. a NAS979 Specimen



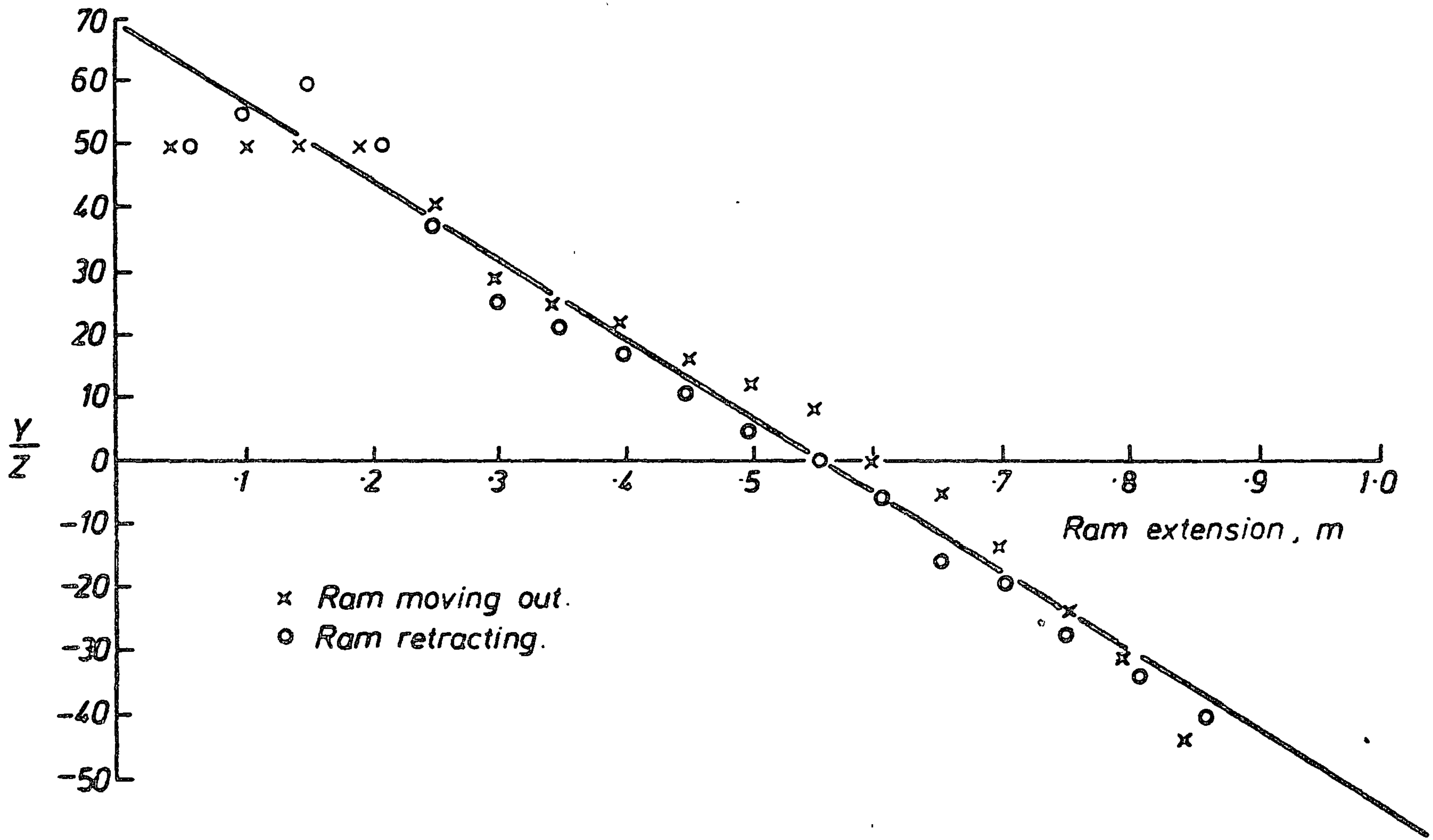
Alignment of Ram with Headstock Locked

Fig. 5	University of Manchester Institute of Science & Technology	M. Burdekin	0391/F



Simple Structural Model.

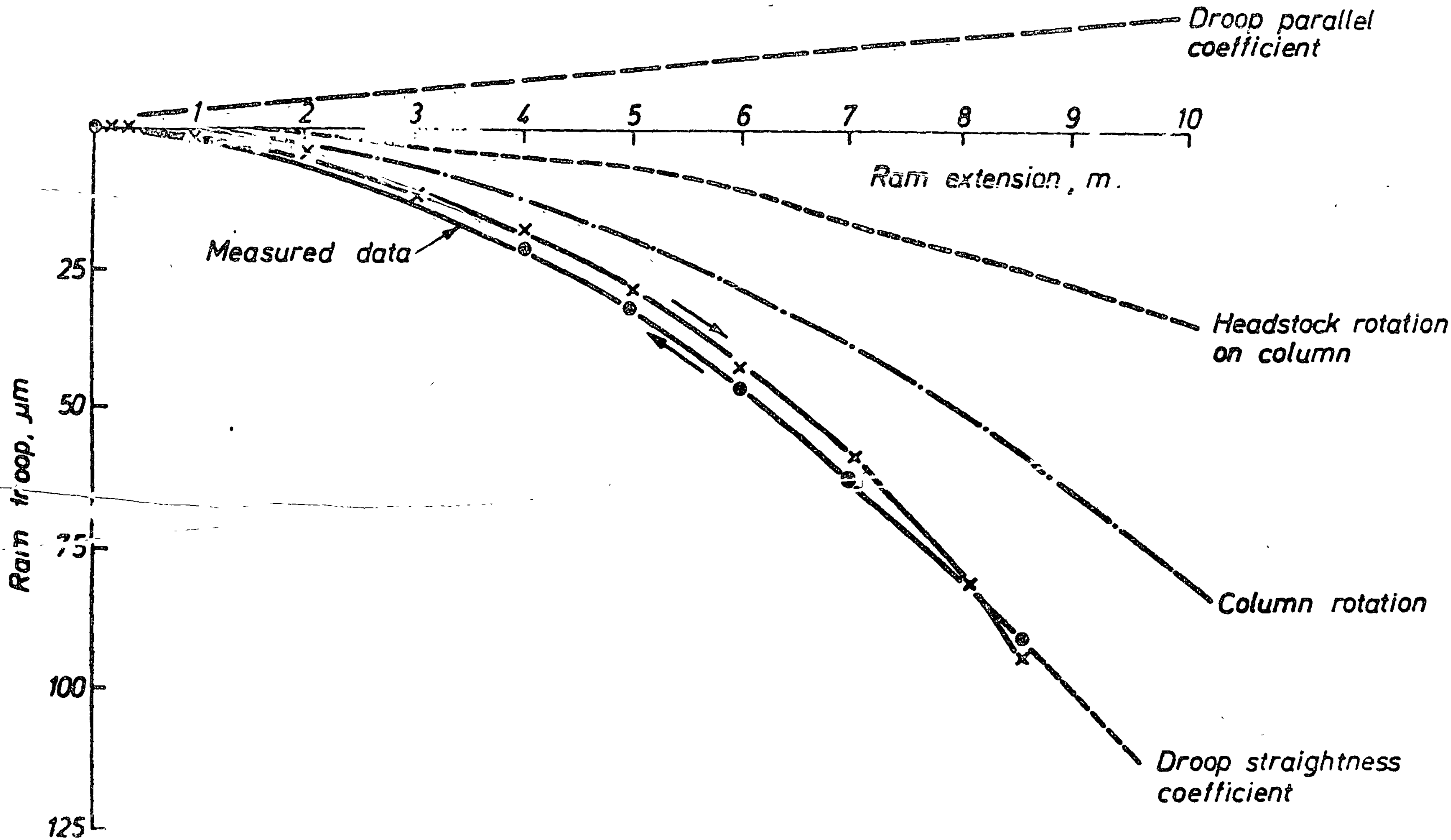
University of Manchester Institute of Science & Technology	Fig 6
0342/F	M. Burdekin



Experimental Straightness Errors with Headstock Locked.

26

Fig. 7	University of Manchester Institute of Science & Technology	M. Burdekin	0391 /E



Influence of the Various Elements on the Magnitude of the Ram Droop

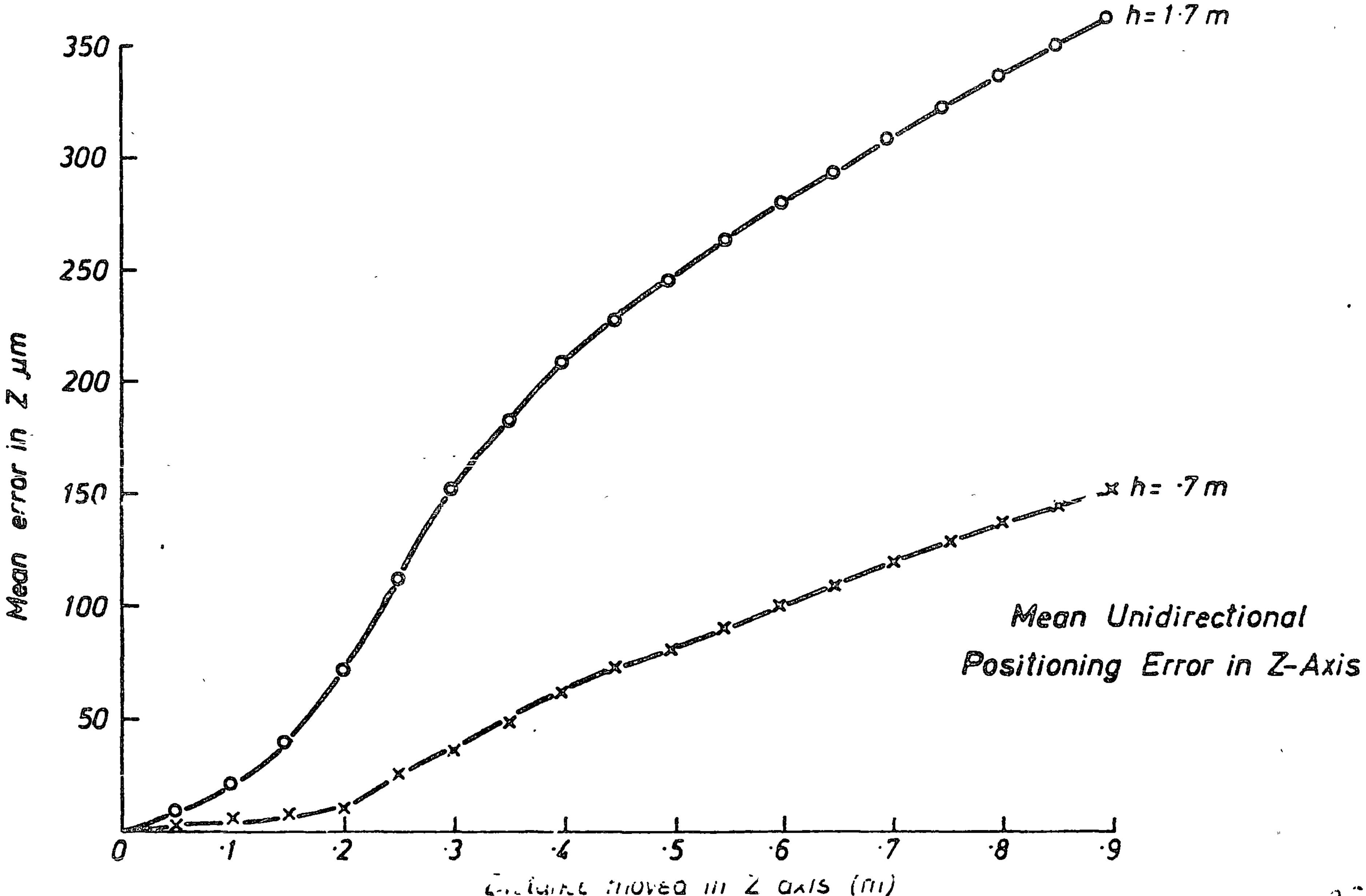
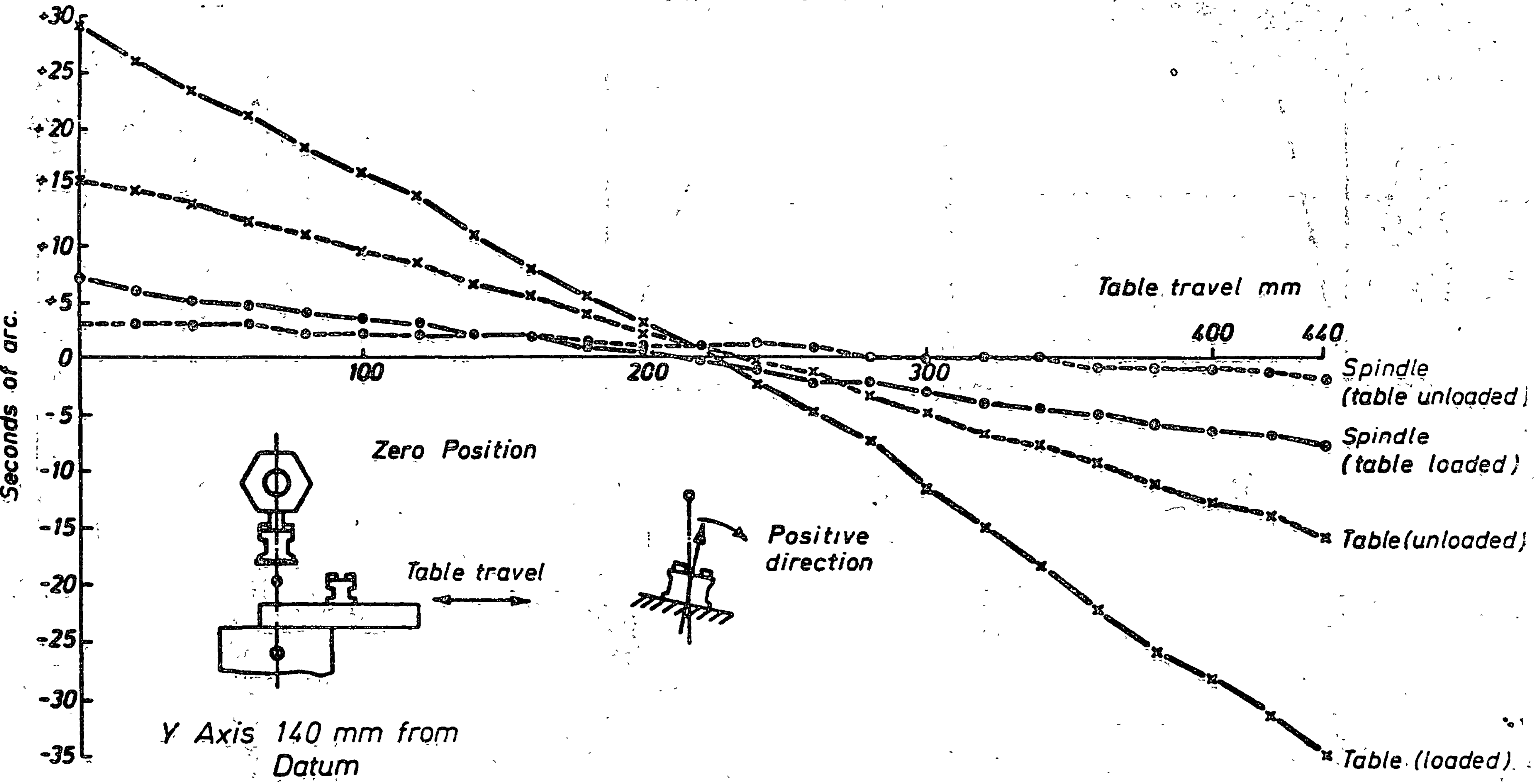
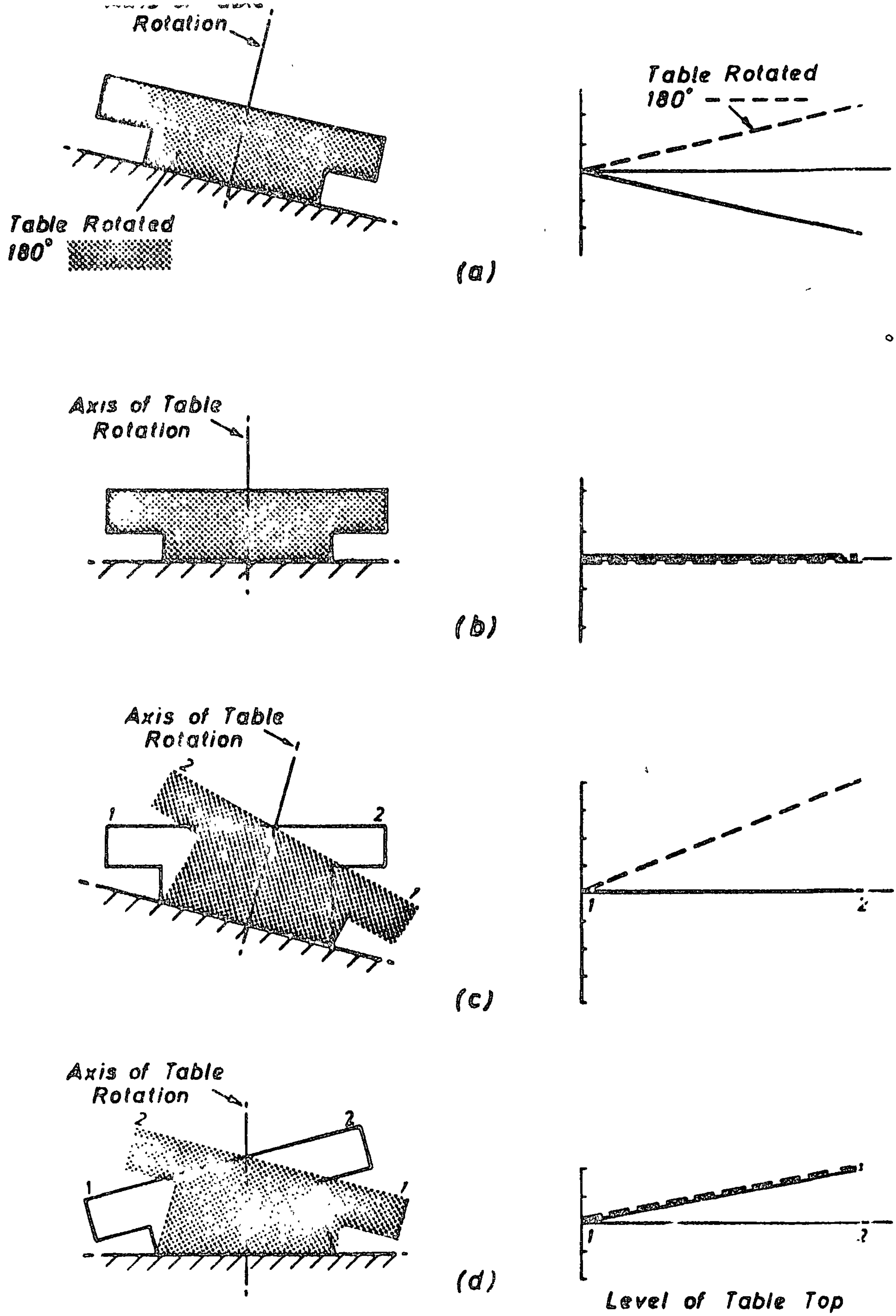


Fig. 9 | University of Manchester Institute of Science & Technology | M. Burdekin | 0391/C

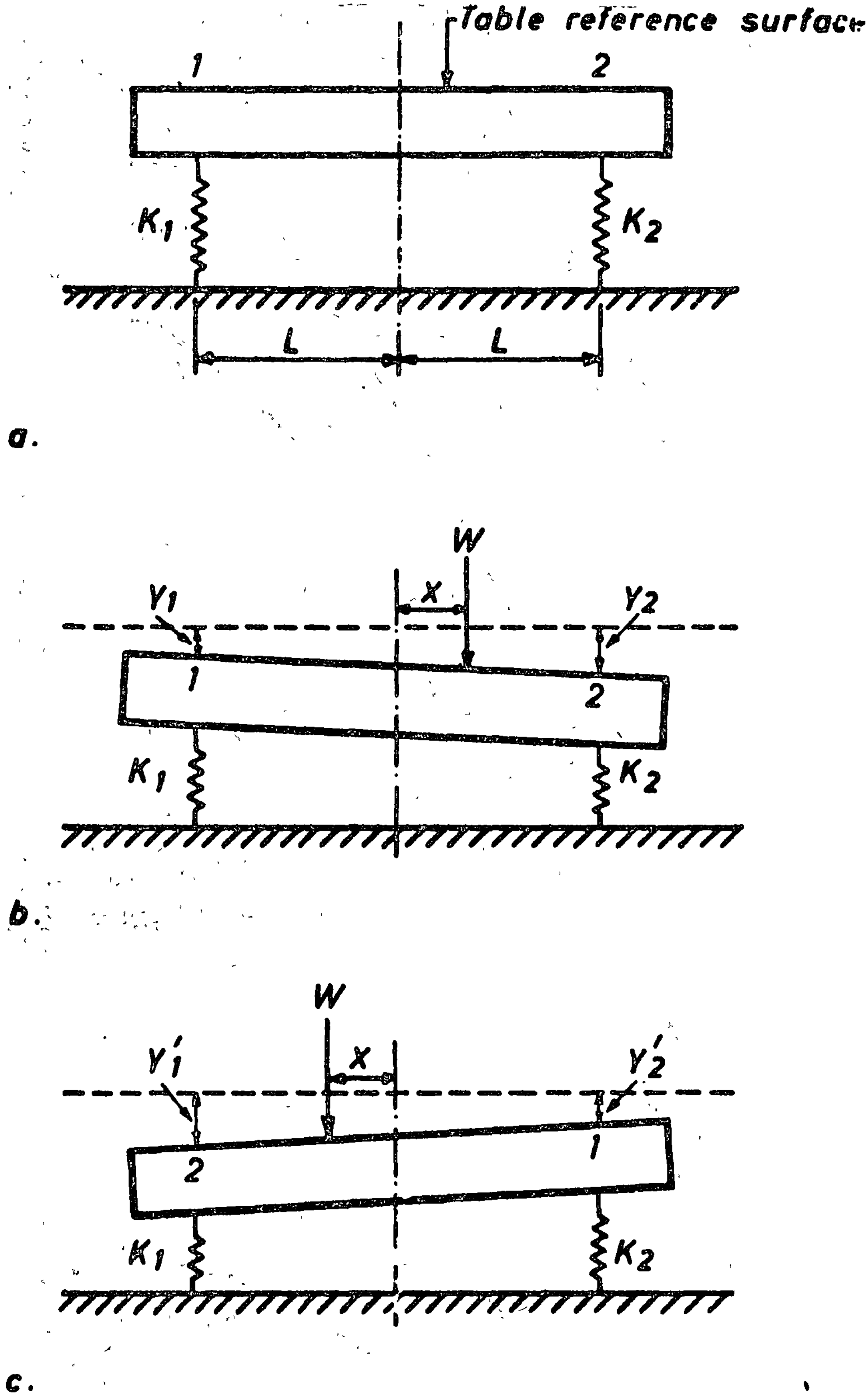


True Weight Deformation on NC Drilling Machine



Schematic Representation of Reference Surface Level and Axis of Rotation

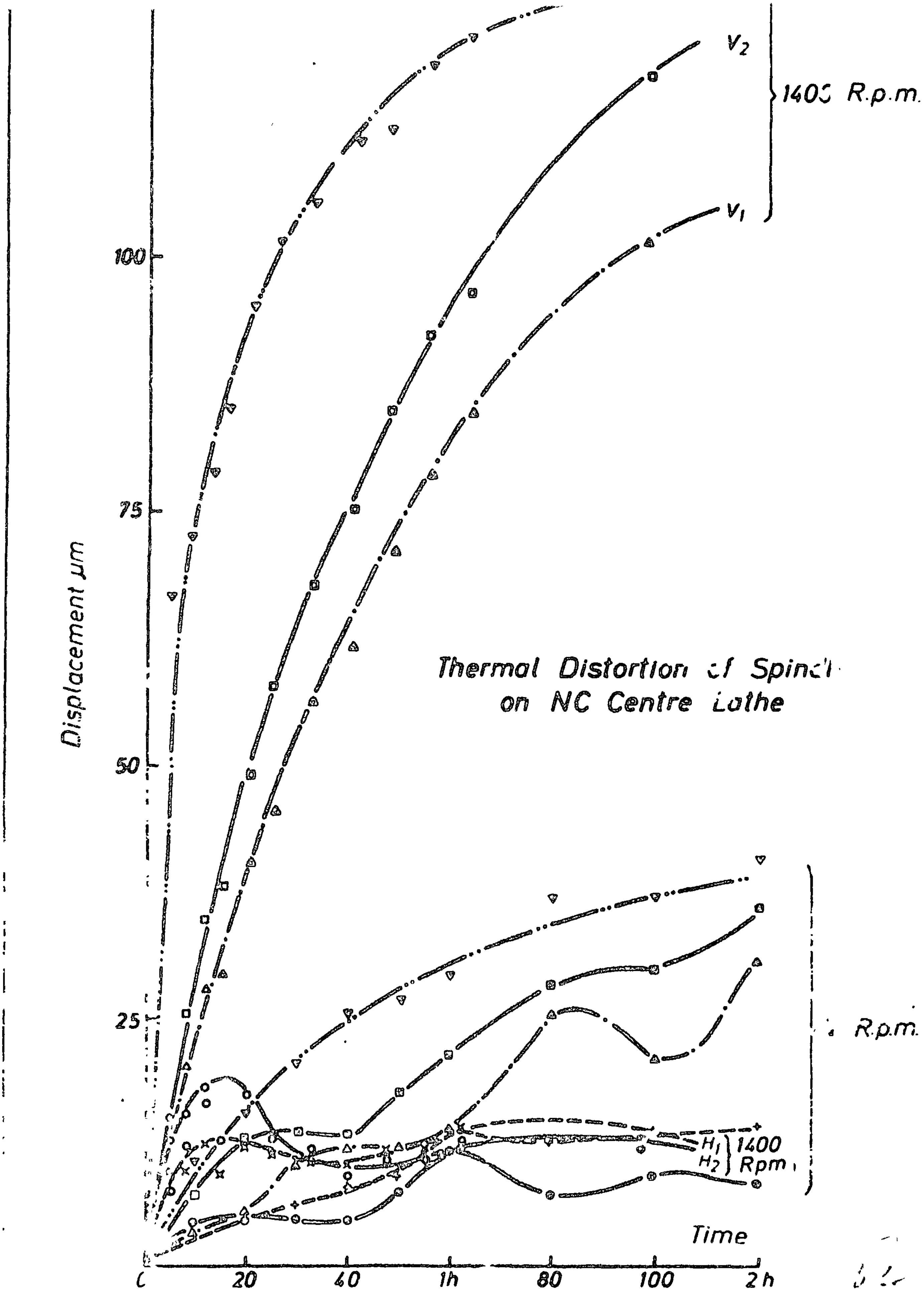
University of Manchester Institute of Science & Technology	Fig.
0284/G	M. Burdekin



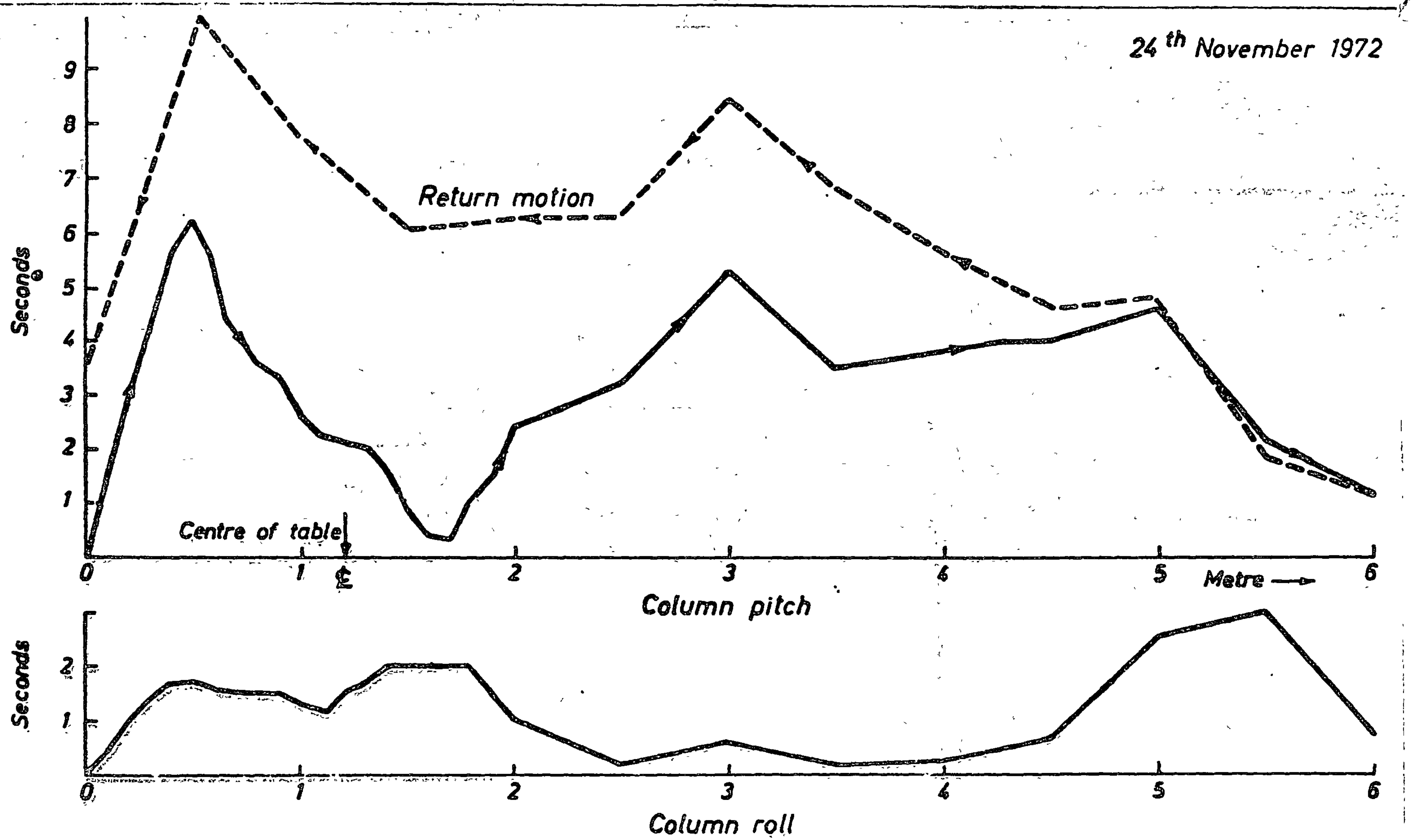
Weight Deformations of Rotary Index Table

(31)

University of Manchester Institute of Science & Technology	Fig. 11
0284 / S	M. Burdekin



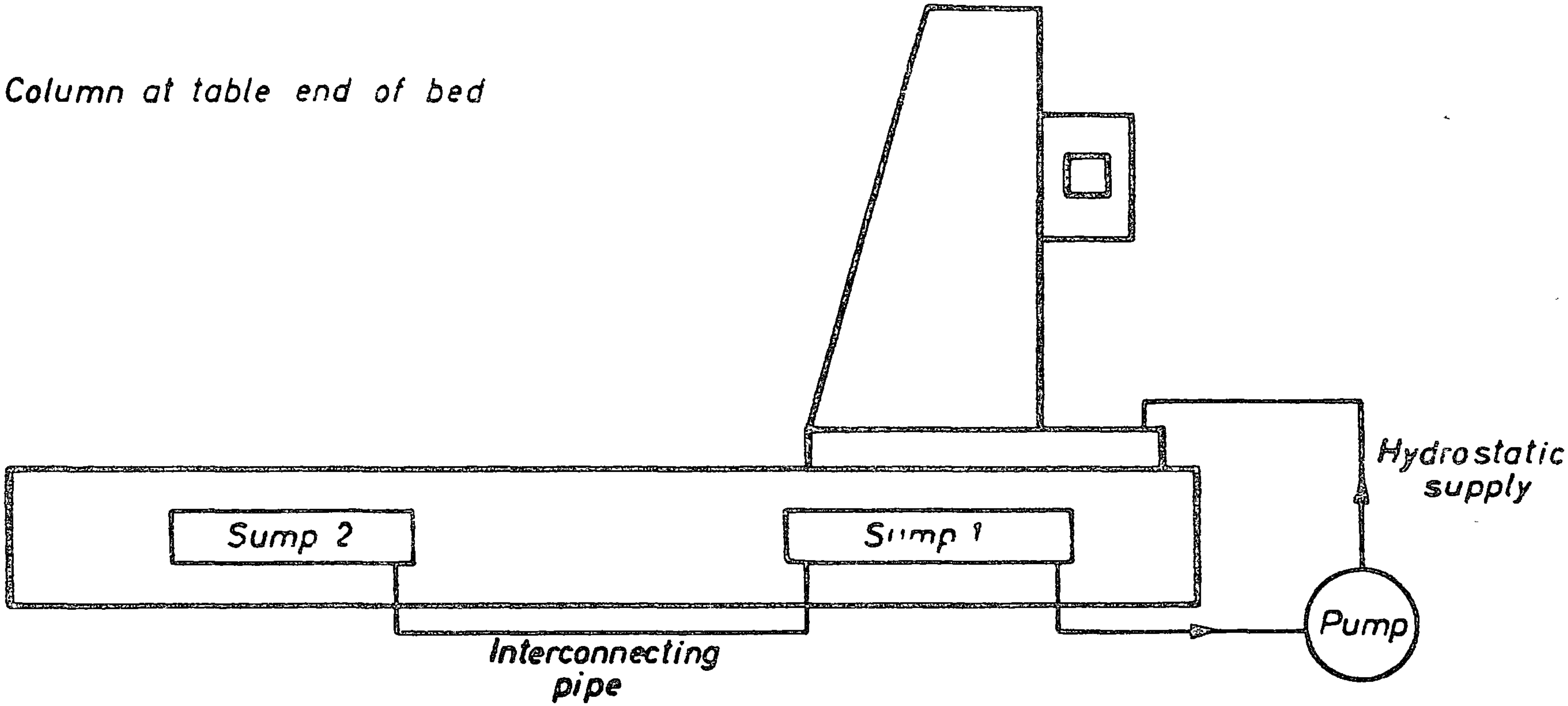
University of Manchester Institute of Science & Technology	Fig 12
0342/M	M. Burdekin



Pitch and Roll of Column

33

Column at table end of bed



Hydrostatic Oil Supply and Collection System

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