INSTRUCTIONAL TURBINE
FOR
UNIVERSITIES
AND
TECHNICAL COLLEGES

BELLISS & MORCOM LIMITED,
BIRMINGHAM, 16,
ENGLAND

A 294

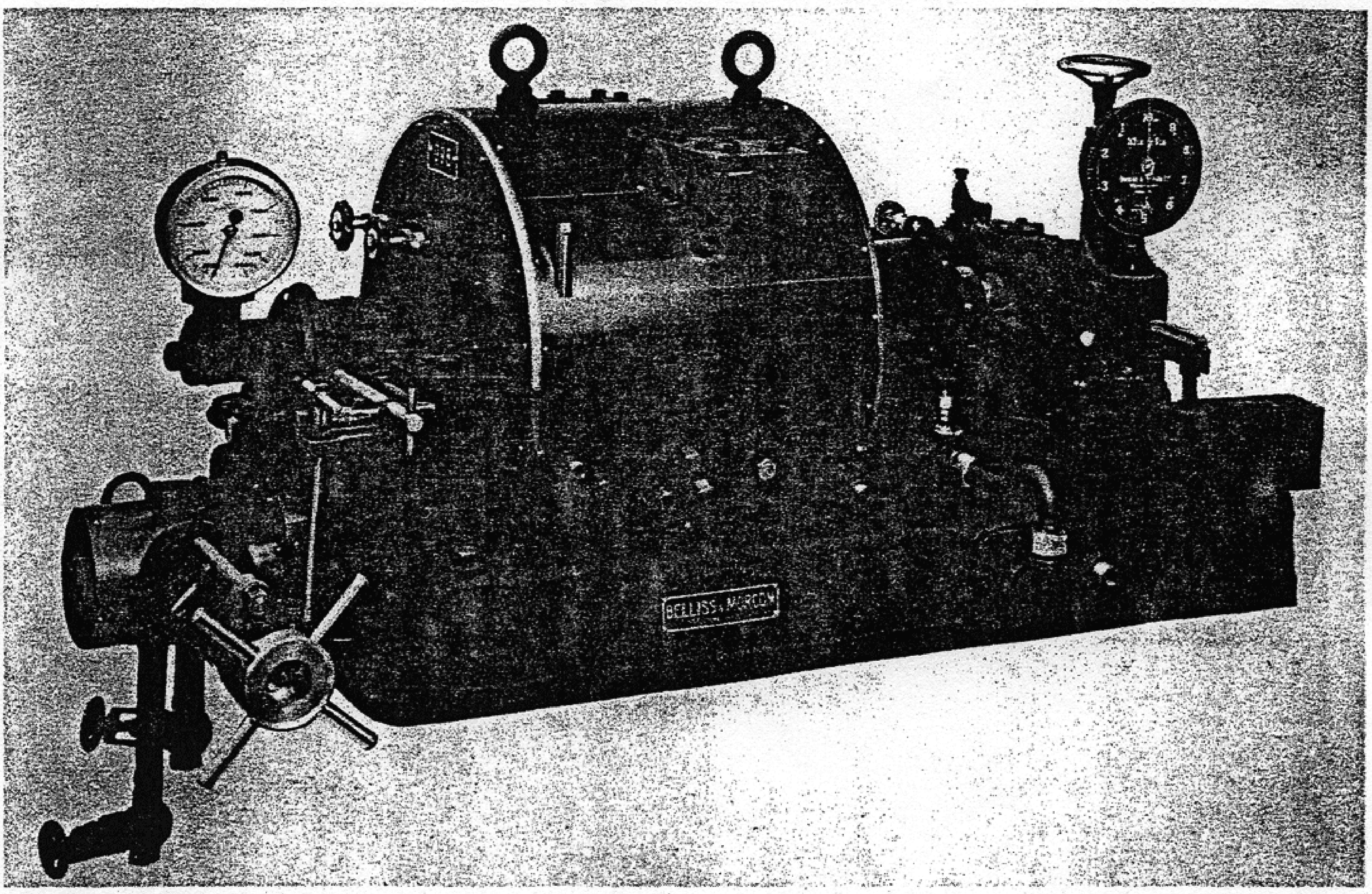

Fig. 1 Instructional Turbine.

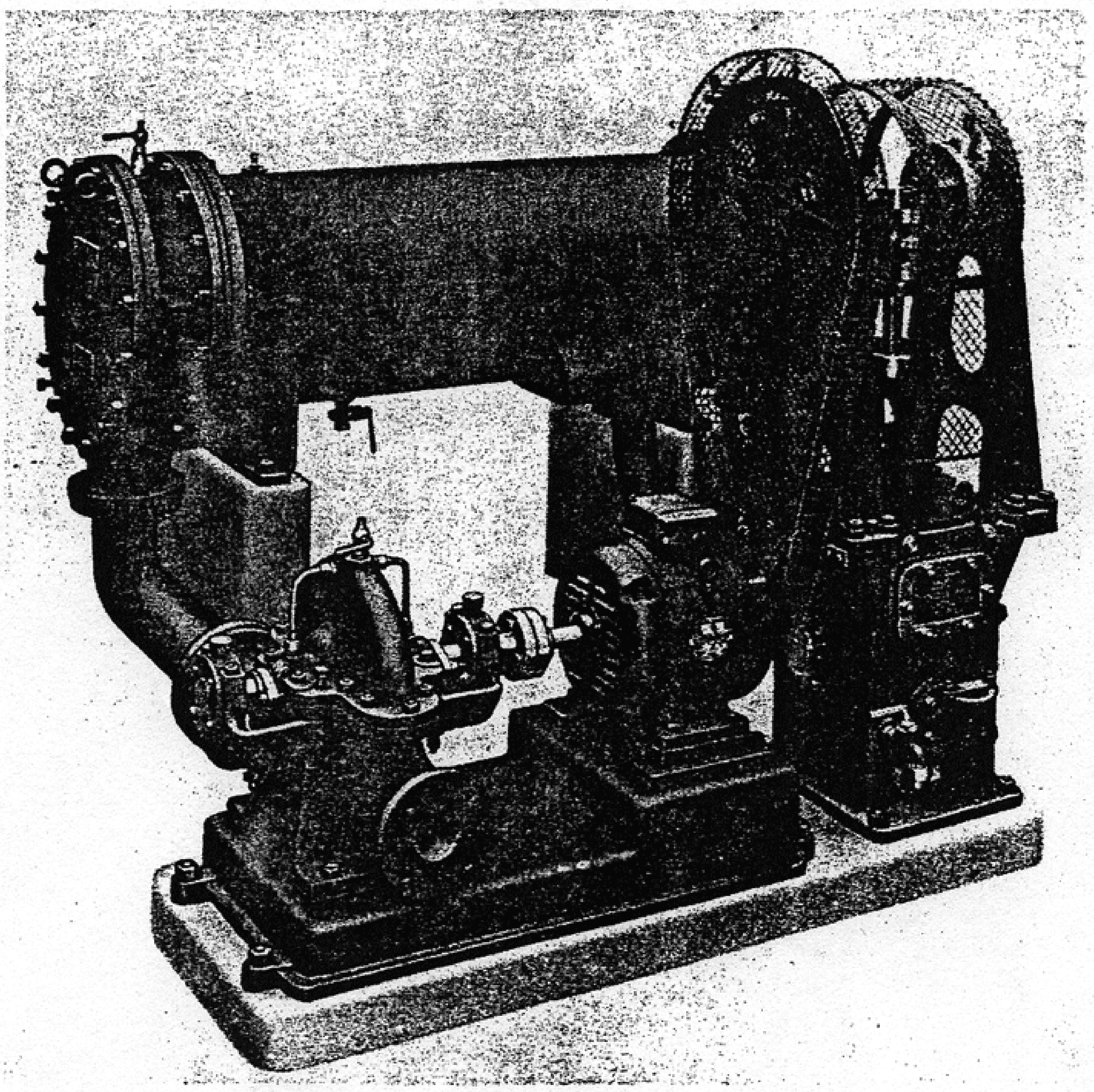

Fig. 2 Condensing Plant.

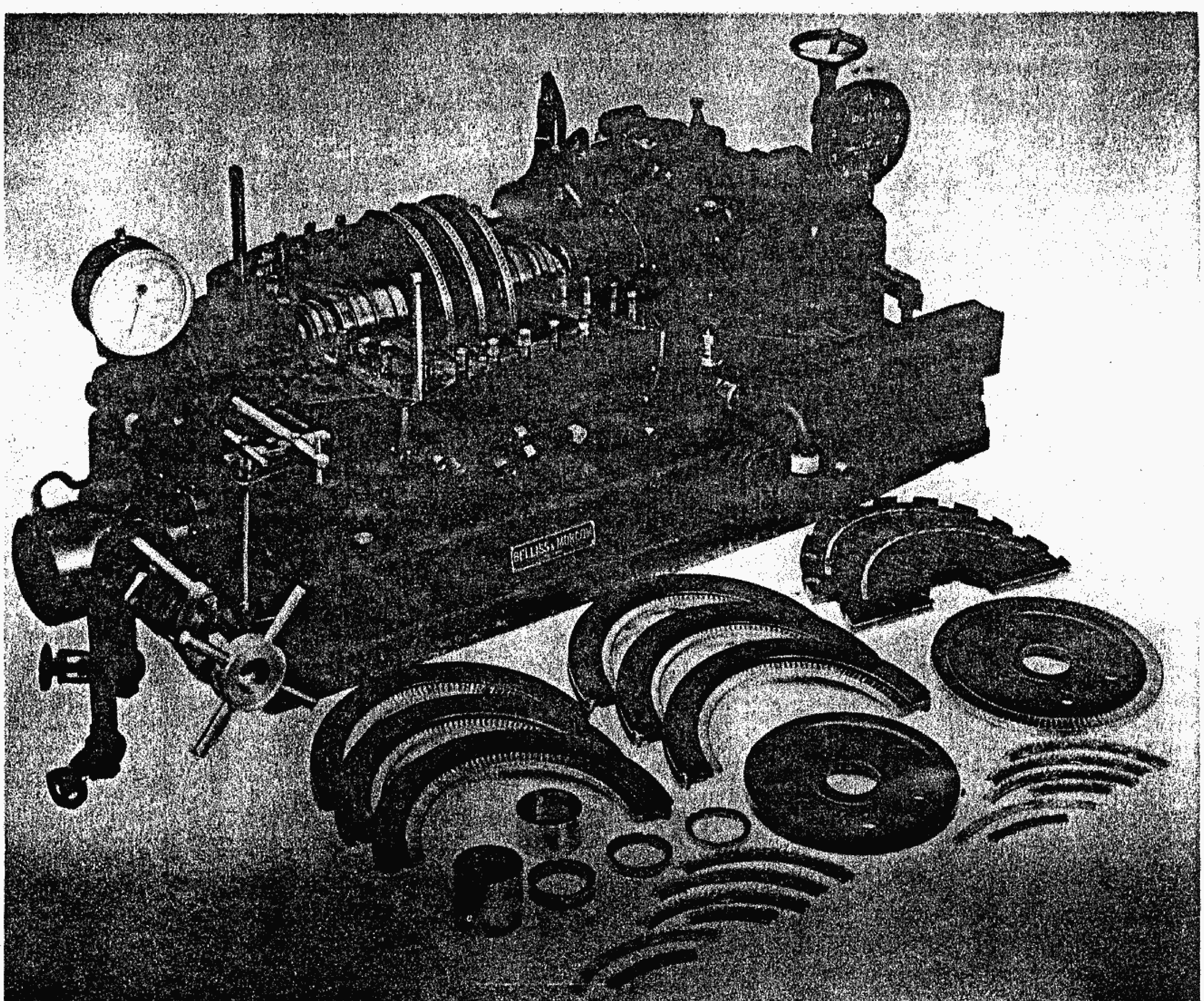

Fig. 3 Rotor and stator components for the Instructional Turbine.

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PART I

THE INSTRUCTIONAL TURBINE

Purpose and General Description

The Belliss & Morcom Instructional Turbine has been designed to meet the need of educational establishments for a multi-stage, demonstration steam turbine, with rotor and stator components which can be varied to give the usual arrangements mentioned in text books covering the theory and design of impulse steam turbines.

Design Limitations

The turbine scantlings have been decided by the following considerations:

1. The boiler capacity available in the average laboratory of an Engineering College.

2. Robust construction and eyeable proportions, bearing in mind the frequent stripping, rebuilding, and relatively inexperienced handling, which the unit may be expected to sustain in service.

3. The employment of stage heat drops which, at reasonable turbine speeds and good blade speed to steam speed ratios, would be measurable using standard gauges and instruments.

Compromise between these requirements has produced a small steam turbine in which a number of special features are incorporated to enable it to fulfil the various duties required.

The casing is of cast steel, designed to withstand pressures up to 200 p.s.i.g., and temperatures up to 500^{o}F.

Normal running speeds are 4000 r.p.m. to 8000 r.p.m. The emergency trip speed is 8800 r.p.m.

The stage mean diameter is constant at 12 inches.

Blade lengths vary between 1/4 inch and 7/8 inch. With these reasonably proportioned blades and the 12 inch mean diameter, the full annulus area would pass several times the available steam at all but sub-atmospheric inlet pressures.

To restrict the flow of steam, blanking strips are supplied to shorten the admission arcs of all stages. The flow areas can therefore be adjusted to suit the experimental conditions and to obtain the desired stage heat drops.

Two nozzle control valves are provided which make it possible to alter the first (control) stage nozzle areas while the turbine is running. The different characteristics associated with nozzle control and throttle control can thus be compared.

The internal parts of the turbine are interchangeable, so that a selection of wheels and diaphragms can be assembled to simulate any of the usual arrangements discussed in instructional courses in steam turbine theory and design.

The resort to partial admission to restrict steam flow, and other compromises, lower the thermal efficiency, so that the Instructional Turbine must not be expected to give Rankine cycle efficiencies comparable with a machine built for a specific duty.

The steam consumption figures must be regarded as illustrative, rather than as quantitative, compared with those obtained for commercial units.

Range of Experiments

It is considered that the most fruitful approach to steam turbine experimental work is to examine the turbine as a power unit, and to obtain overall characteristics for each type made available by changes in the internal arrangement of rotor and stator components.

An appreciation of turbine theory, and a discriminating judgement of the value of detailed experiment, can best be cultivated when the student is familiar with the characteristic behaviour of the steam turbine under varying conditions of steam speed and load.

The analysis of thermo-dynamic losses, with any degree of accuracy, is extremely difficult without a great deal of auxiliary apparatus, so that it is not thought desirable to introduce methods for separating losses which would be open to justifiable criticism on account of the wide assumptions which would have to be made.

The Willans Line

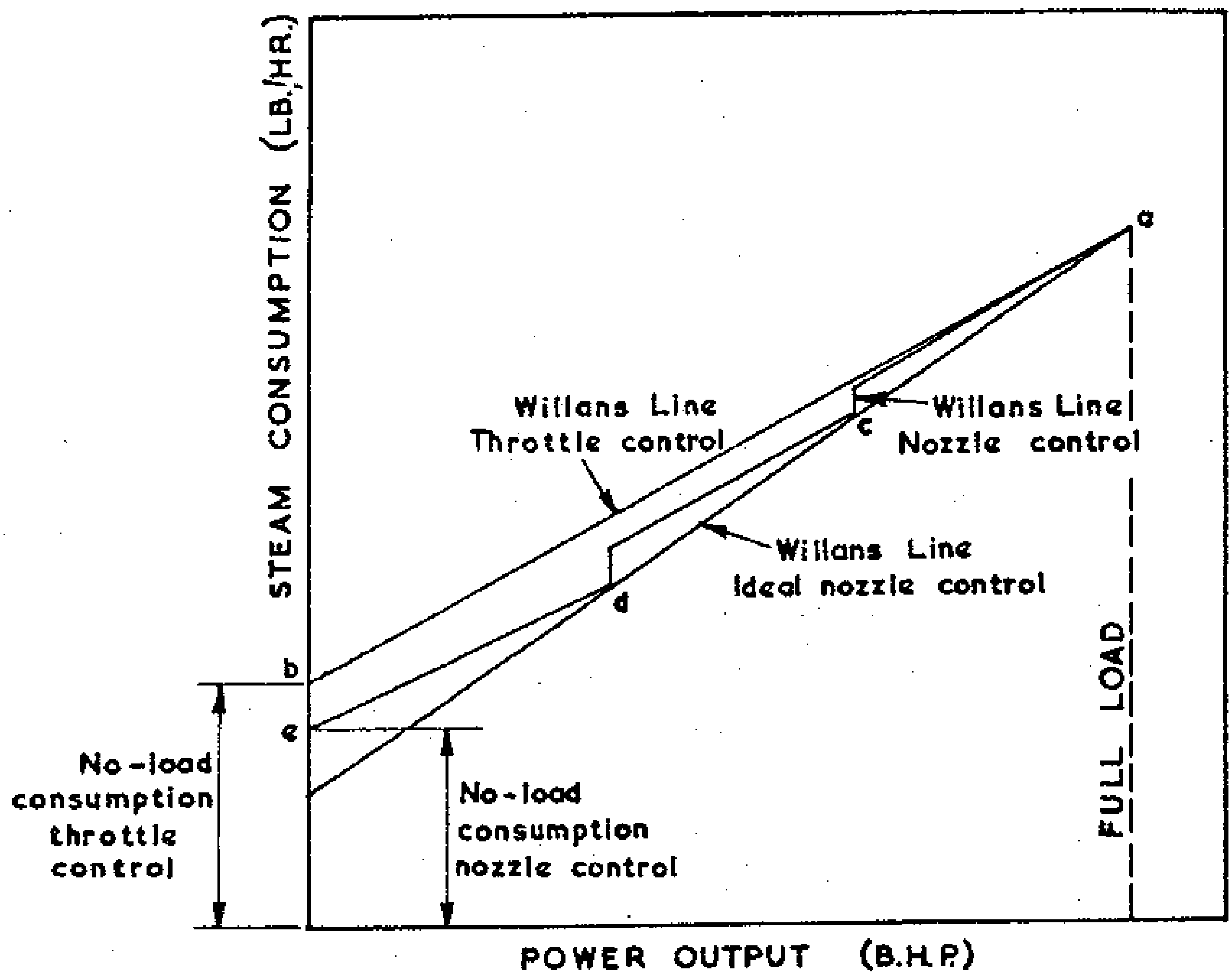

Fig. 4. Willans lines showing in exaggerated form the effect of nozzle control compared with throttle control.

The Willans line can be obtained using both throttle control (throttling the steam at the turbine inlet), and nozzle control (controlling steam by the nozzle valves provided), so that the effects on the slope of the line and on the no-load steam consumption can be made clear. The characteristics are shown greatly exaggerated in Fig. 4*

Here 'ab' shows the Willans line for throttle control. The line tends to become steeper as the no-load point is approached giving a slightly 'hogged' appearance, as shown in Fig. 5, an effect which becomes more marked as the back pressure is increased.

*Ref. H. G. Yates. 'The Engineer', Vol. 165, 28th Jan. 1938 et seq.

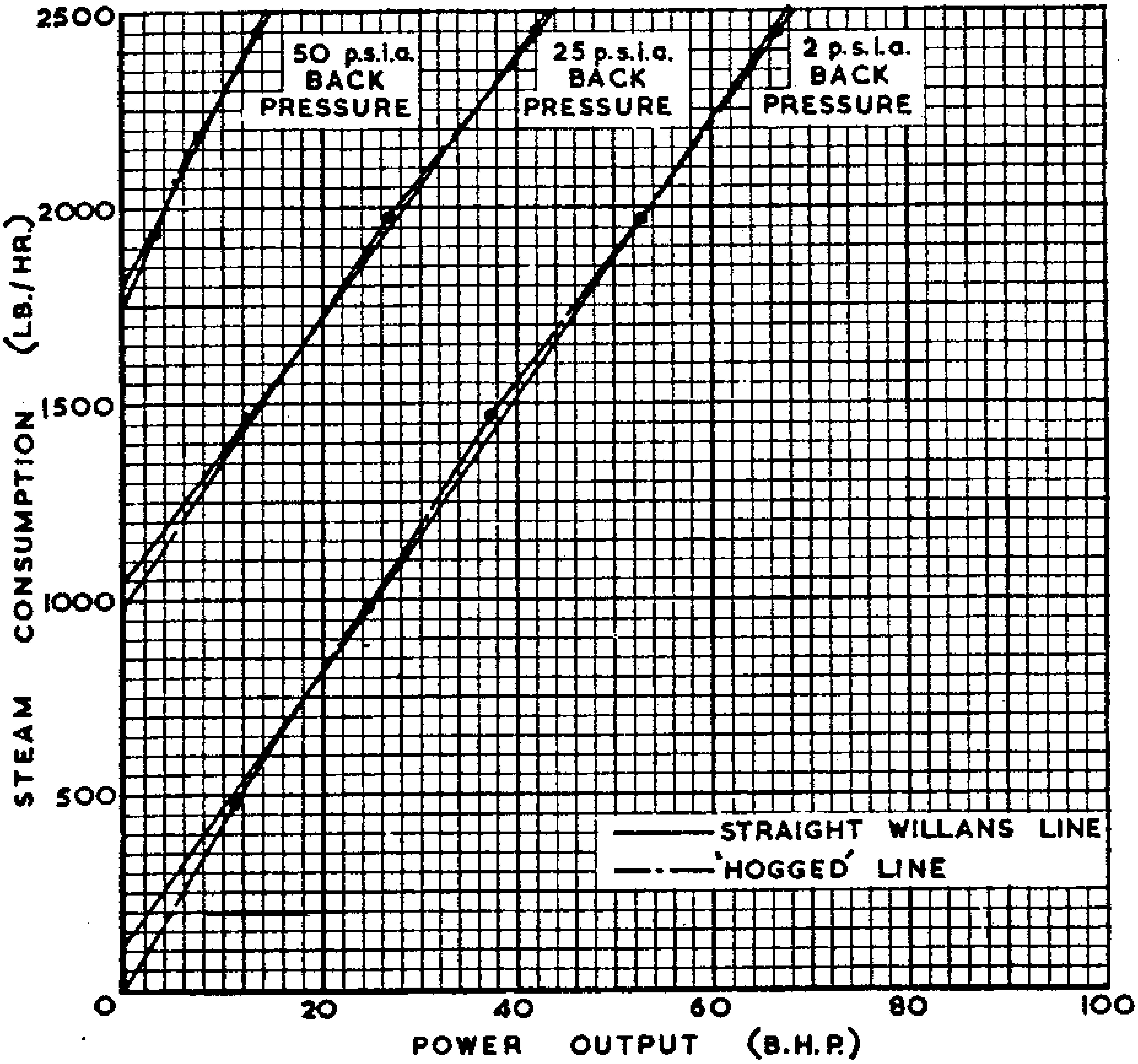

Fig. 5 Willans lines for a throttle controlled turbine showing slight "hogging" of the lines.

Arrangement: Three row Curtis.
Admission arc: One-quarter
Speed: 8000 r.p.m.

The Willans line for nozzle control is given by the stepped characteristic 'ae'. The ideal Willans line for nozzle control is obtained by joining the points 'c' and 'd'. The improvement in consumption at low loads by the use of nozzle control is most marked in the case of single wheel turbines. The relative improvement achieved decreases with increase in the number of stages.

The effect of speed, adiabatic heat drop and back pressure, on no-load consumption and line rate, can be examined for each type of turbine assembly.

Pressure-Steam Consumption Characteristics

In a multi-stage turbine the variation of pressure with steam quantity for constant inlet conditions is of paramount importance to the designer.

The pressure-steam consumption lines can be shown to be practically independent of turbine speed, but sensitive to back pressure. See Fig. 6, 20 and 21.

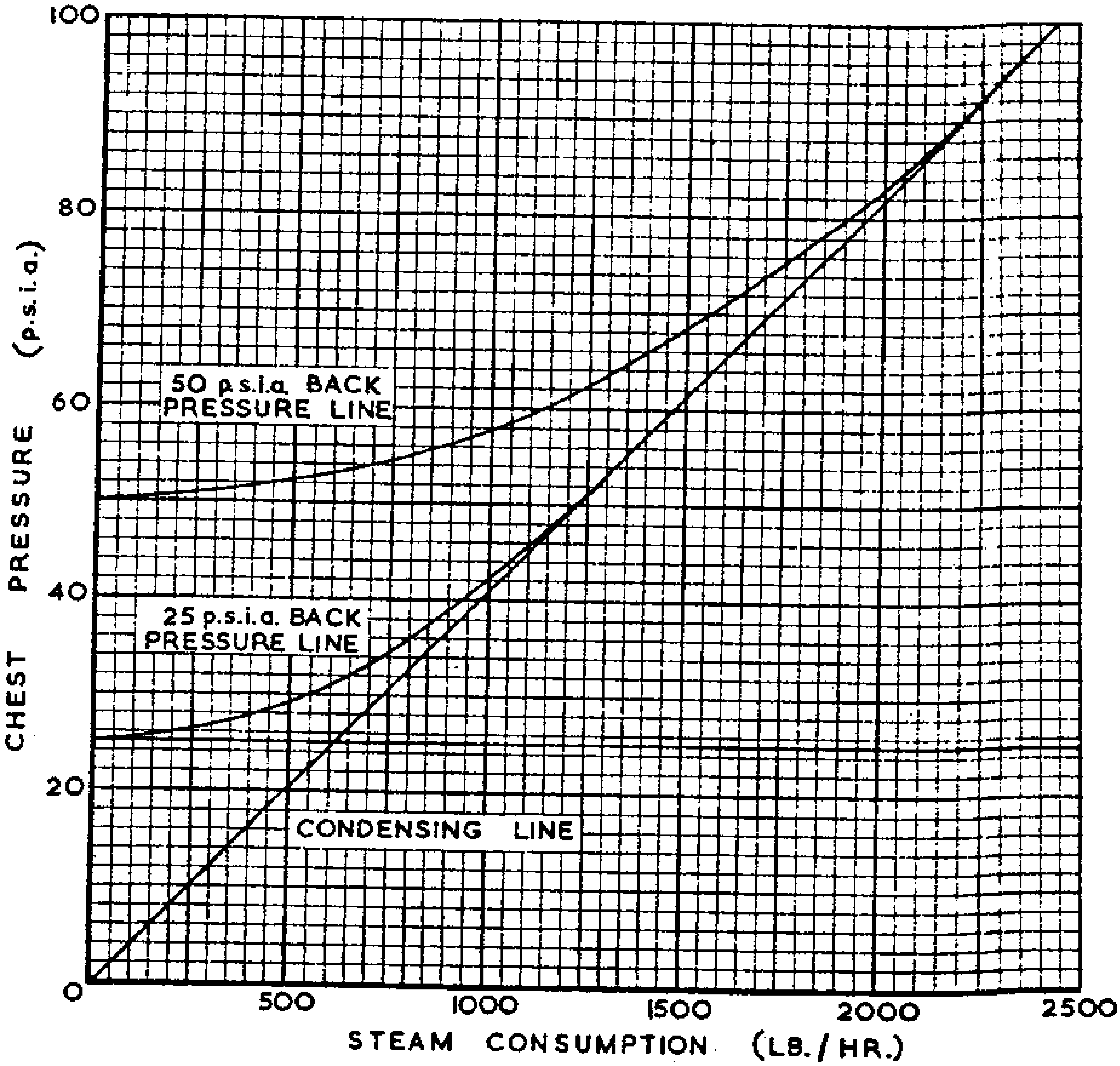

Fig. 6 Pressure-steam consumption curves for various back pressures.

Arrangement: Three row Curtis.
Admission arc: One-quarter.

The curves approximate to hyperbolae with the axis of pressure as major axis and touch tangentially the condensing line which passes through the origin.

A steam cone can be constructed and used to forecast results which can be checked by experiment.*

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*Ref. Stodola and Loewenstein. 'Steam and Gas Turbines', McGraw Hill, Vol.1, 1945, p.316.

Pressure-Power Output Characteristics

The curves of pressure plotted against power output are practically straight. The lines are of value in extrapolating to obtain power expectations from increased inlet pressure, or in forecasting from a part-load test the abilityof the turbine to give full load at design inlet pressure.

These characteristics can be shown to change with speed, see Fig. 7, but to be relatively insensitive to changes in inlet steam temperature.

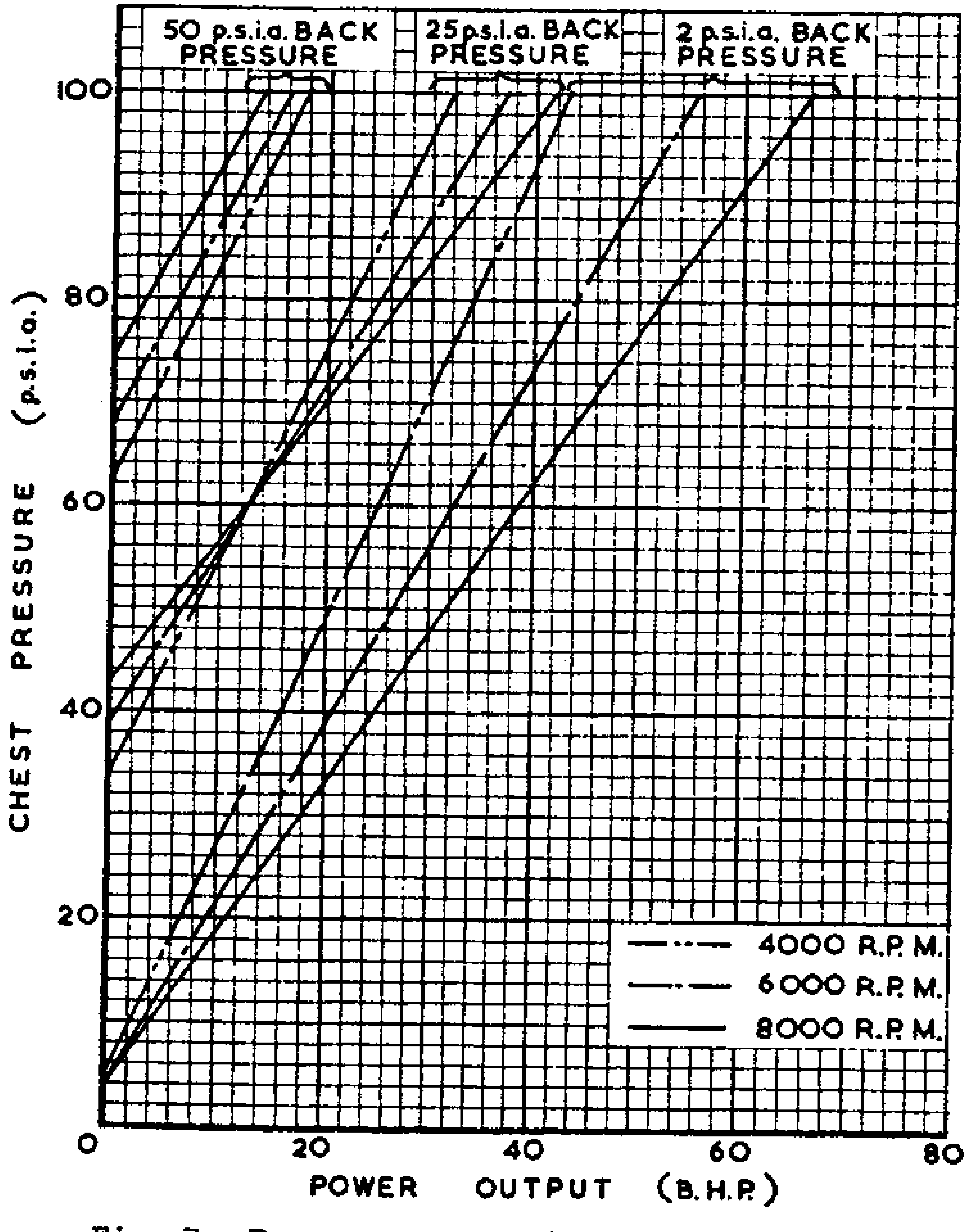


Fig. 7 Pressure-power output curves for various back pressures and running speeds.

Arrangement: Three row Curtis.
Admission arc: One-quarter.

Power Output-Speed Characteristics

By suitably varying the internal arrangements to give single Rateau, two and three row Curtis stages, a set of comparative power output-speed characteristics can be obtained, as shown in Fig. 8. Typical changes in the shape of these curves resulting from various back pressures and steam flows can be demonstrated.

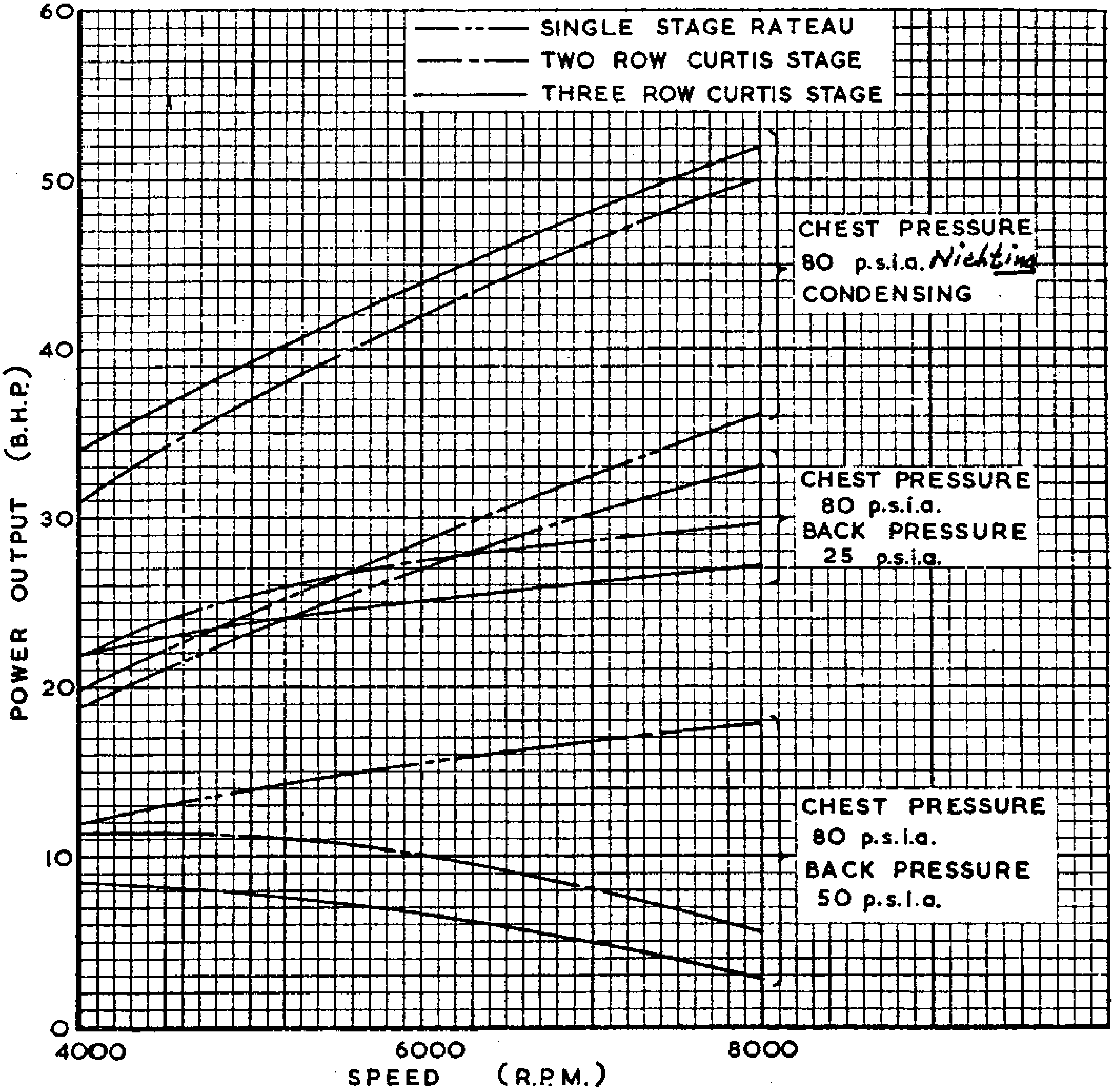


Fig. 8 Typical power output-speed characteristics for:
(a) Single Rateau stage.
(b) Two row Curtis stage.
(c) Three row Curtis stage.
Admission arc: One-quarter for each arrangement.

TECHNICAL DATA

Steam Conditions

Inlet pressures higher than 100 p.s.i.g. are not usually necessary. For consistent results it is advisable to work with a minimum of 50°F superheat at the stop valve.

Gland leakage at pressures above 5 p.s.i.g. should be allowed for when analysing test results.

Blading

All blading employed in the turbine is made from rolled or drawn strip. Drawings giving nominal dimensions are shown in Fig. 9, 10 and 11.

The fixed nozzle rings are divided into short arcs in order to assist in choosing the most appropriate areas of flow.

The arcs of fixed blades are formed by riveting blading sections between shroud sections.

Variation of Admission Arc

The sets of blanking strip provided are arranged to vary the admission arc from one-eighth full circle, in eighths, to "full circle" or all round admission, as illustrated in Fig. 12a, 12b, 13a and 13b. The method of changing the length of admission arc is detailed in Part II page 32.

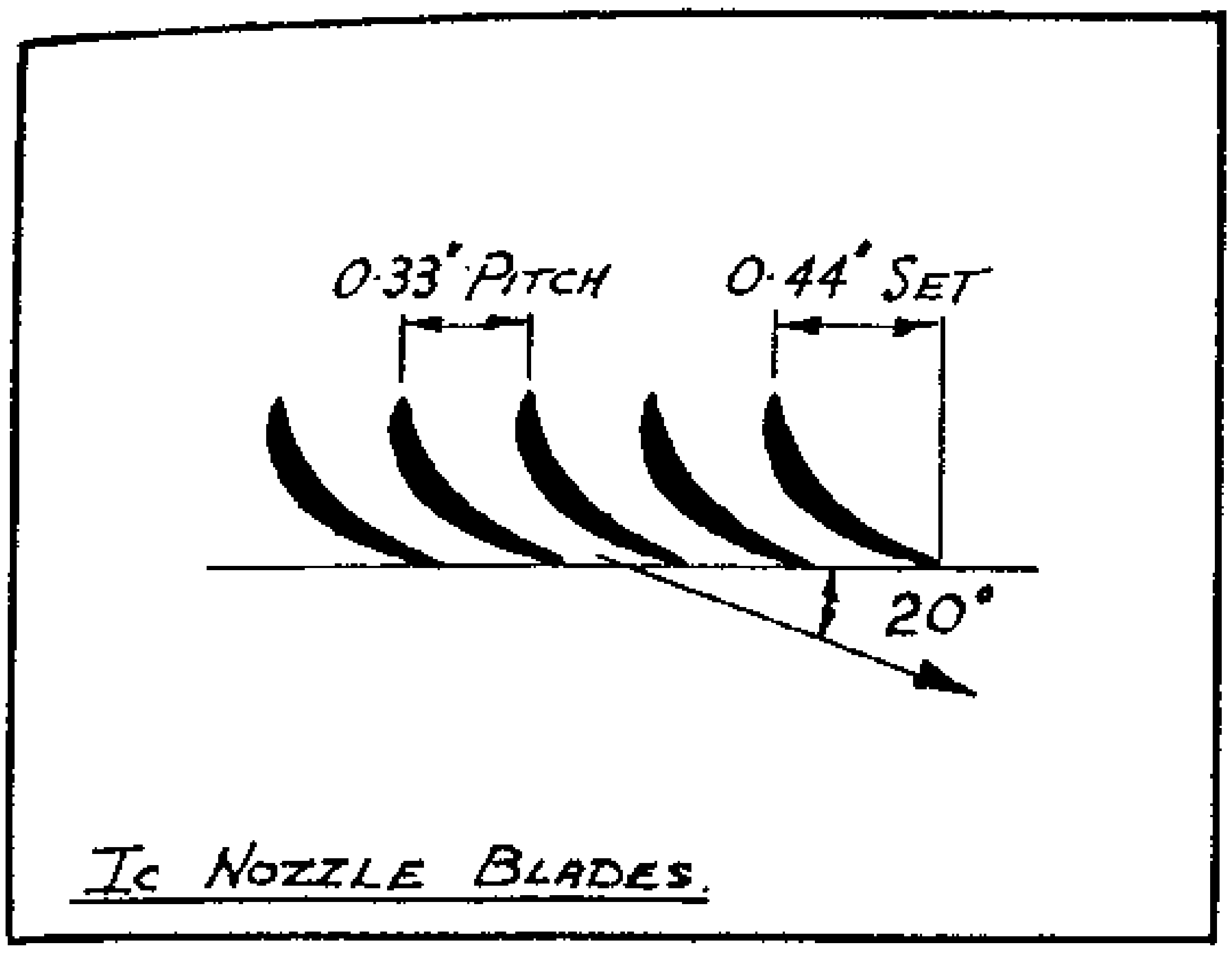


Fig. 9. Ic Nozzle blade.

Effective throat area of one nozzle
0·113L sq.in
where L = blade length in inches

Pitch 0·33") on inner shroud
Set 0·44") diameter

Nominal steam discharge angle 20°

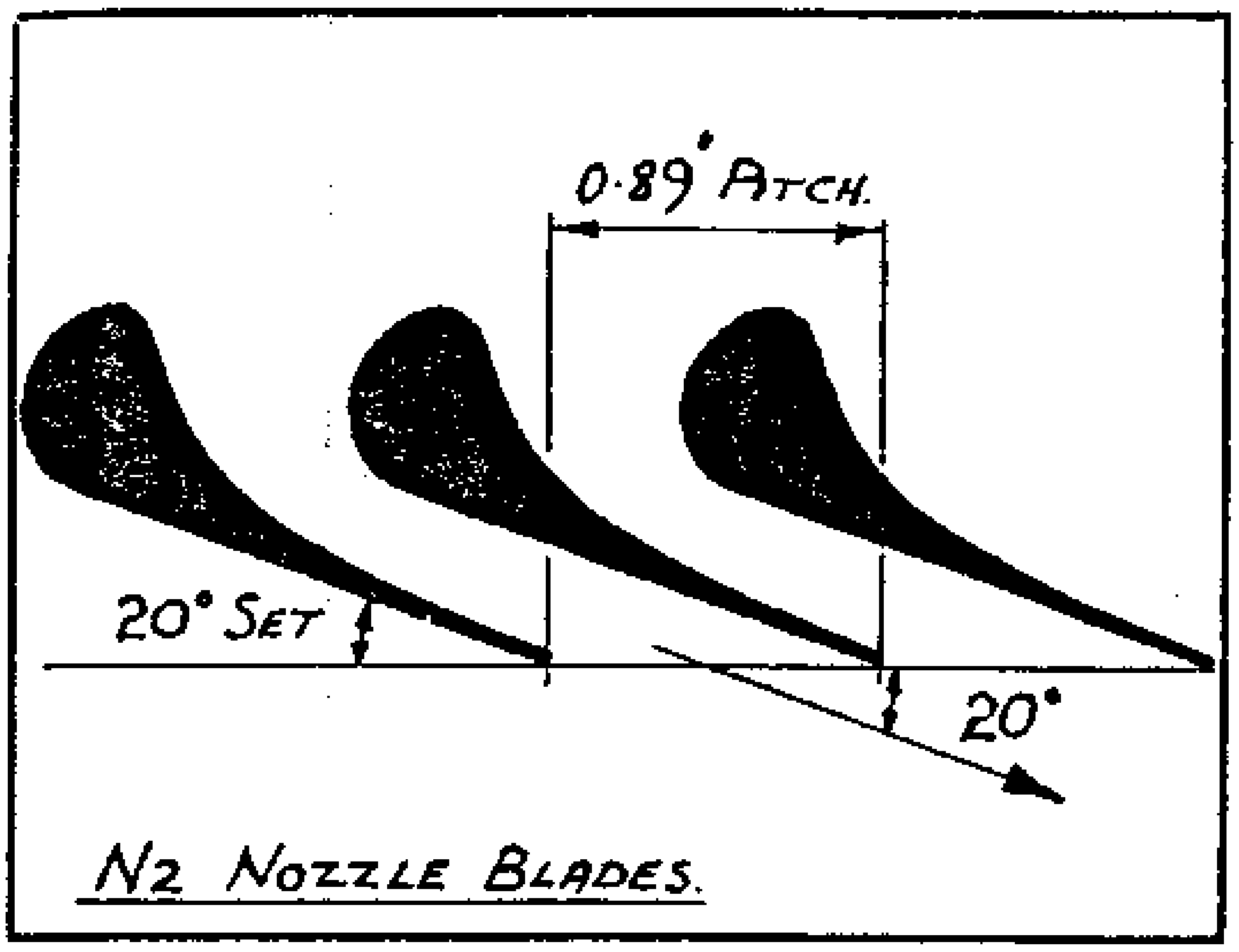


Fig. 10. N2 Nozzle blade.

Effective throat area of one nozzle
0·064 sq.in.

Ratio: $\frac{\text{Effective Outlet Area}}{\text{Effective Throat Area}} = 1{\cdot}07$

Pitch 0·89" on inner shroud diameter
Set 20° to back of the blade

Nominal steam discharge angle 20°

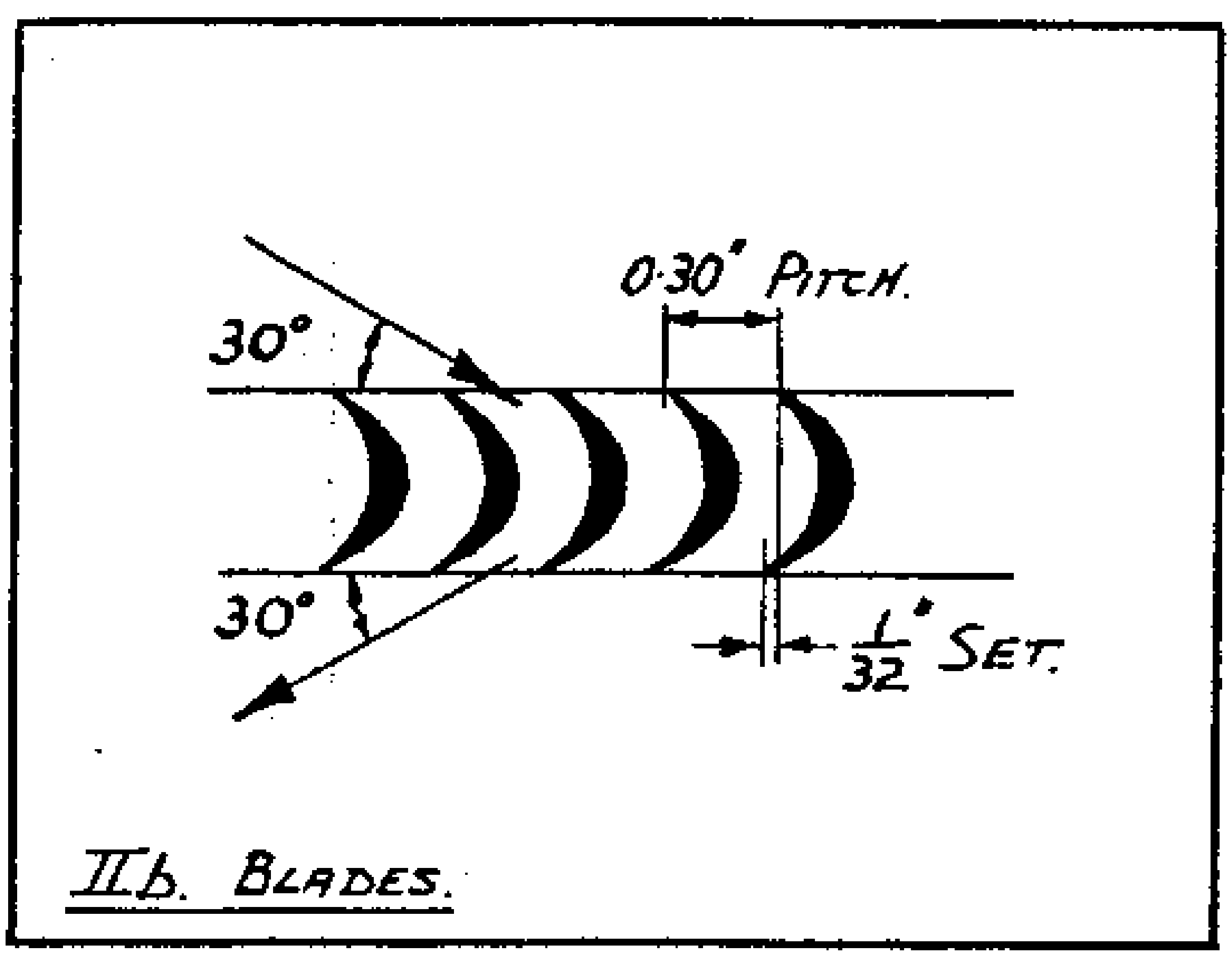


Fig. 11. IIb Moving and guide blades.

Pitch 0·30") on inner
Set 1/32") diameter

Nominal inlet angle 30°) With plane
Nominal outlet angle 30°) of wheel

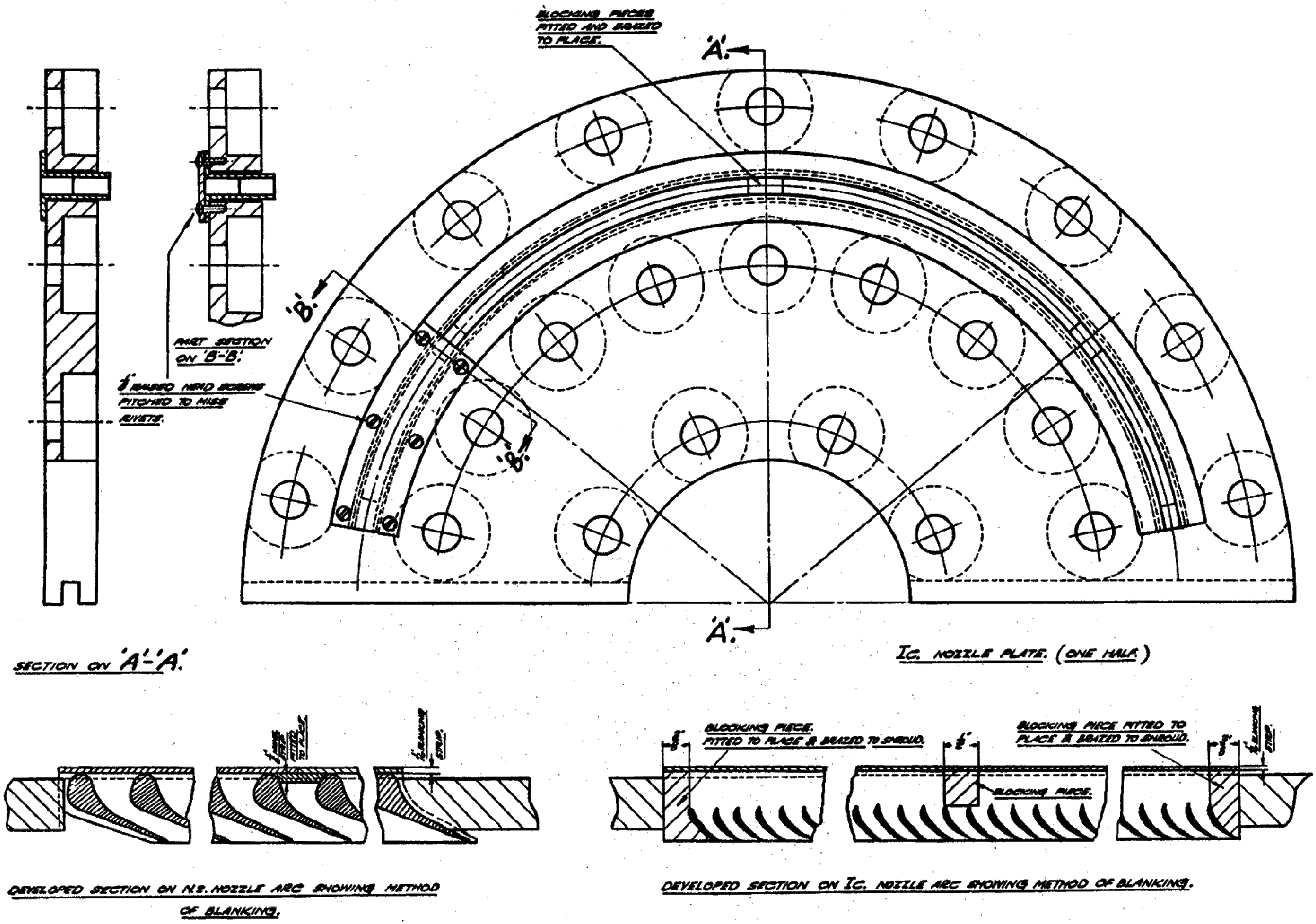


Fig. 12a Method of blanking nozzles for stage I.

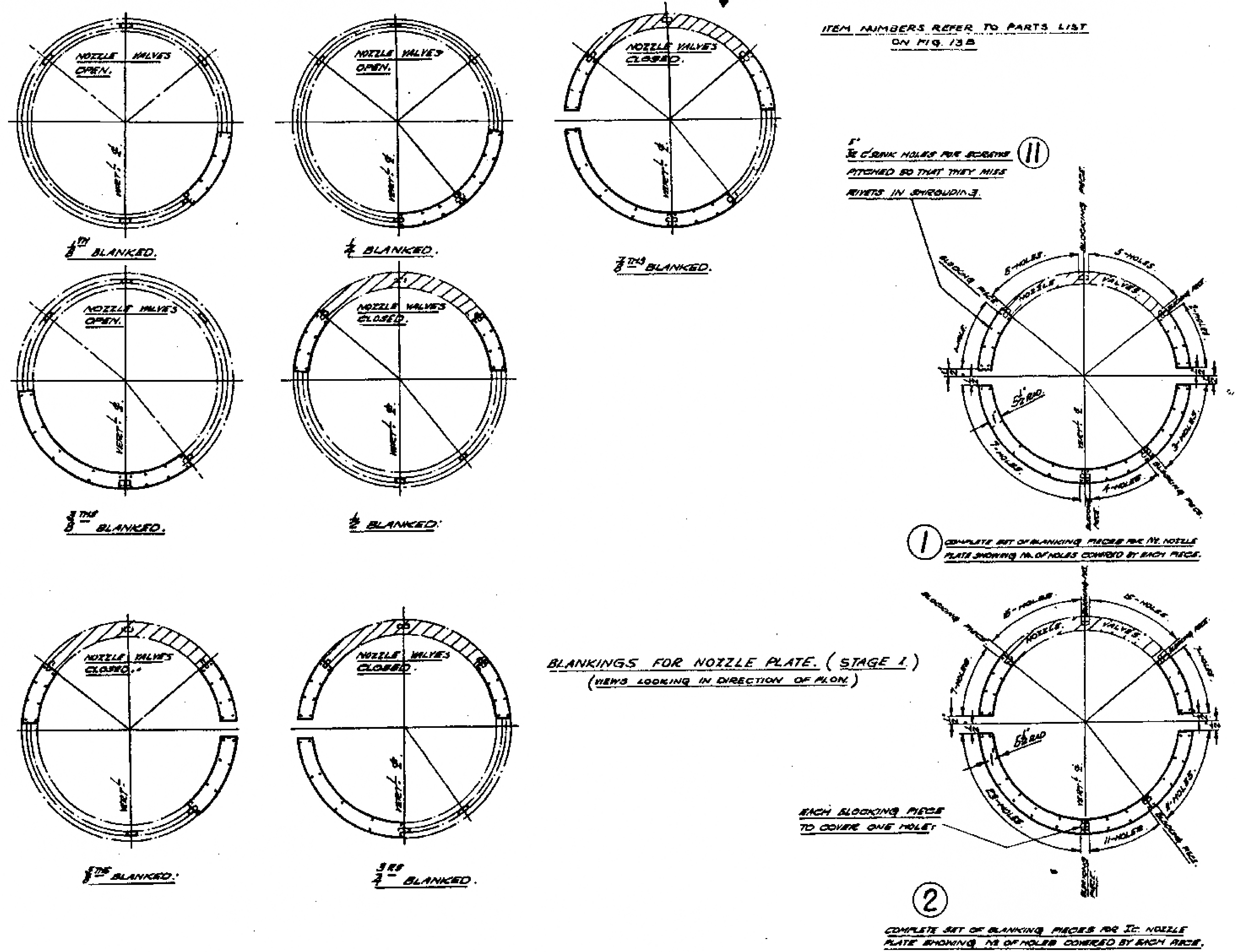


Fig. 12b Blankings for stage I nozzle plates.

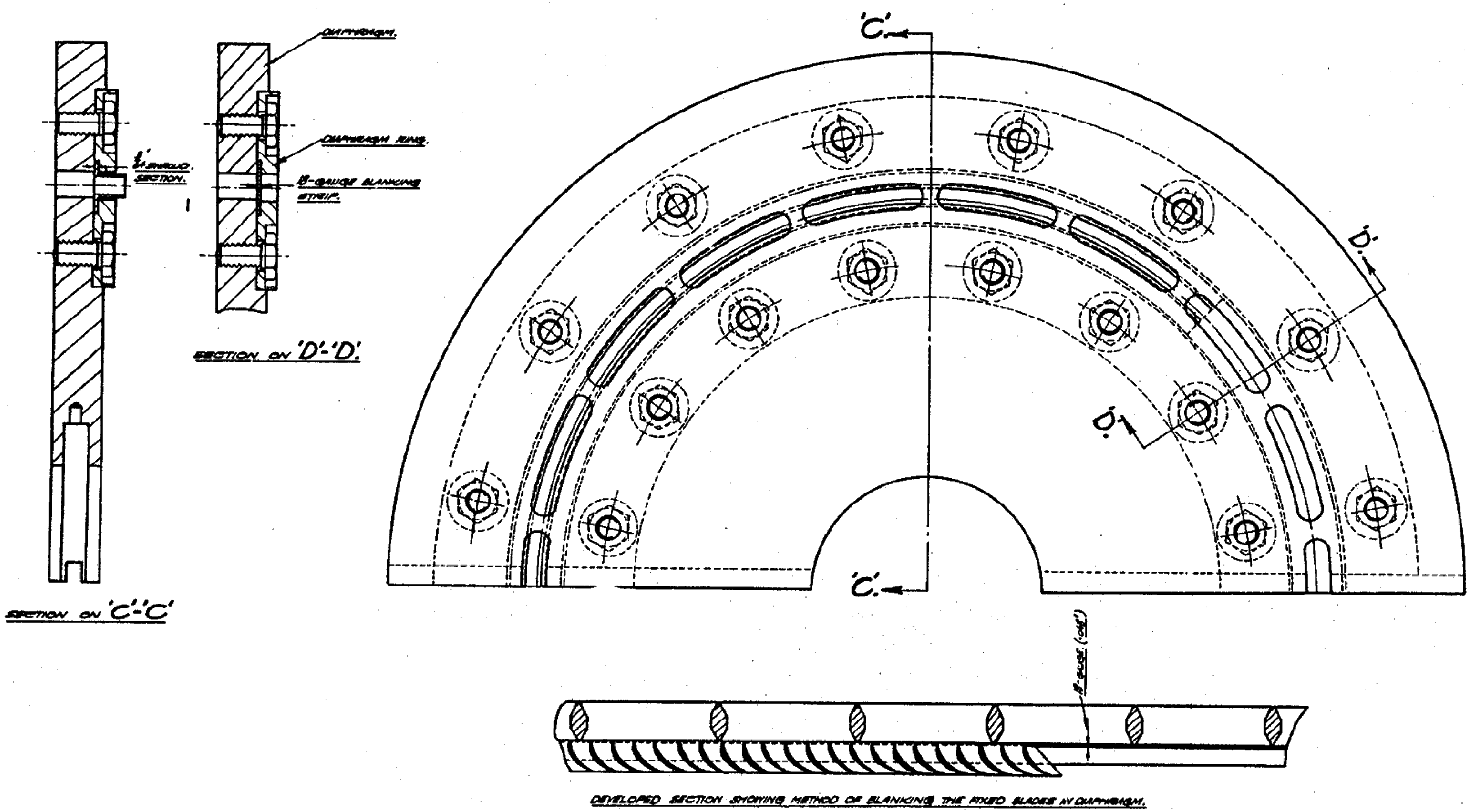
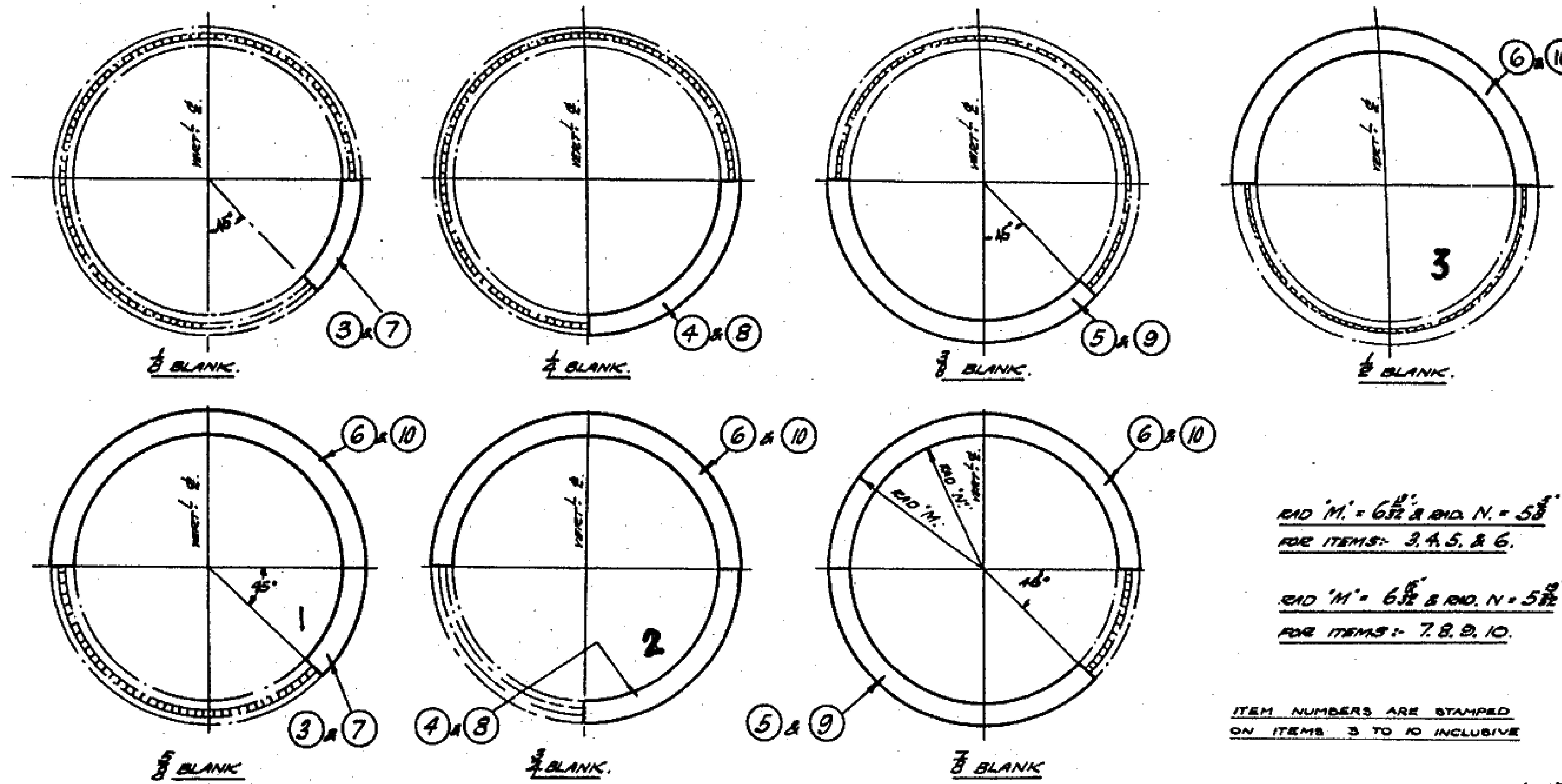


Fig. 13a Method of blanking fixed blades for stages II and III.



RAD 'M' = $6\frac{11}{32}$ & RAD. N = $5\frac{3}{8}$
FOR ITEMS:- 3, 4, 5, & 6.

RAD 'M' = $6\frac{15}{32}$ & RAD. N = $5\frac{19}{32}$
FOR ITEMS:- 7, 8, 9, 10.

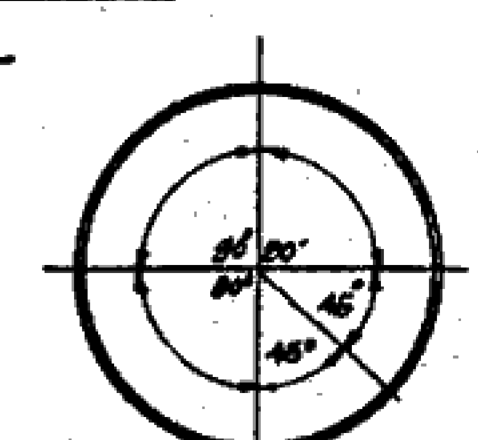
ITEM NUMBERS ARE STAMPED ON ITEMS 3 TO 10 INCLUSIVE

BLANKINGS FOR DIAPHRAGMS.

(STAGES II & III.)

(VIEWS LOOKING IN DIRECTION OF FLOW.)

THE VARIOUS DEGREES OF BLANKING (AS ABOVE) WHICH ARE POSSIBLE NECESSITATE THAT THE FIXED BLADING SECTIONS IN DIAPHRAGM SUBTEND ANGLES OF 90°, 90° 90° 45° & 45° AT CENTRE THUS:-



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ITEM.	DESCRIPTION.	No. OFF	MAT.L	N.S.B. PAGE.	N.S.B. No.	PINLIST. PAGE.	PINLIST. No.	AMT.	REMARKS.
1.	NOZZLE ARC BLANKING STRIPS.	1.SET.	MONEL						1/16" THICK SHEET.
2.	NOZZLE ARC BLANKING STRIPS.	1.SET.	MONEL						1/16" " "
3.	1/8 DIAPHRAGM BLANKING STRIP.	1.	ST. ST.						18. GAUGE SHEET.
4.	1/4 " " "	1.	ST. ST.						" " "
5.	3/8 " " "	1.	ST. ST.						" " "
6.	1/2 " " "	1.	ST. ST.						" " "
7.	1/8 DIAPHRAGM BLANKING STRIP.	1.	ST. ST.						" " "
8.	1/4 " " "	1.	ST. ST.						" " "
9.	3/8 " " "	1.	ST. ST.						" " "
10.	1/2 " " "	1.	ST. ST.						" " "
11.	RAISED HEAD SCREWS.	45 REQ'D	ST. ST.						1/8" WHIT. x 5/8" LONG.

Fig. 13b Blankings for stage II and III diaphragm plates.

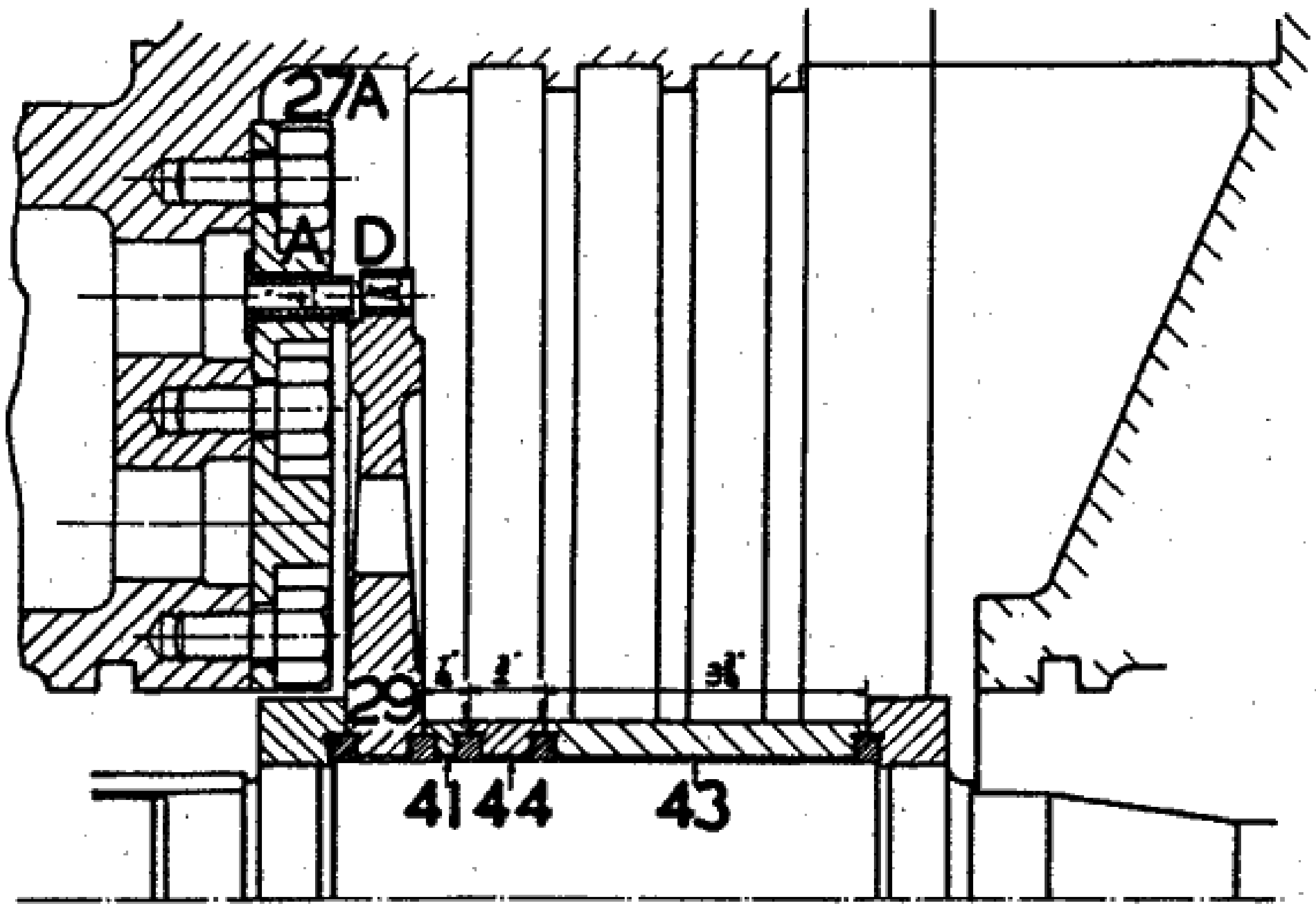


Fig. 14 Simple impulse assembly.

Single Stage Turbine
Simple Impulse
or Single Stage Rateau

The maximum stage efficiency will occur with heat drops of the order of:

5 B.Th.U./lb. at 4000 r.p.m.
20 B.Th.U./lb. at 8000 r.p.m.

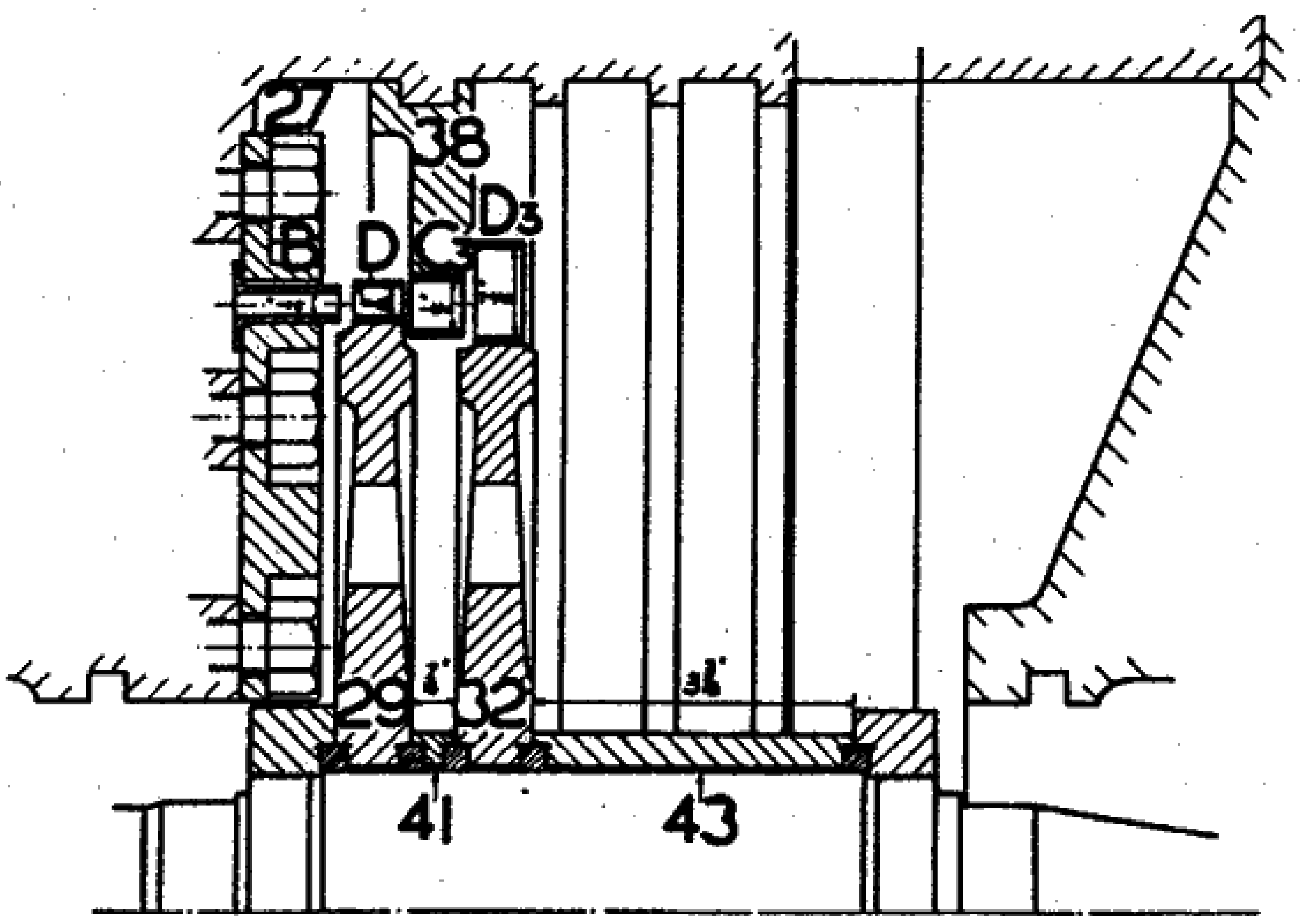


Fig. 15 Two row Curtis assembly.

Single Stage Turbine
Two Row Velocity Compound
or Two Row Curtis Stage

The maximum stage efficiency will occur with heat drops of the order of:

20 B.Th.U./lb. at 4000 r.p.m.
80 B.Th.U./lb. at 8000 r.p.m.

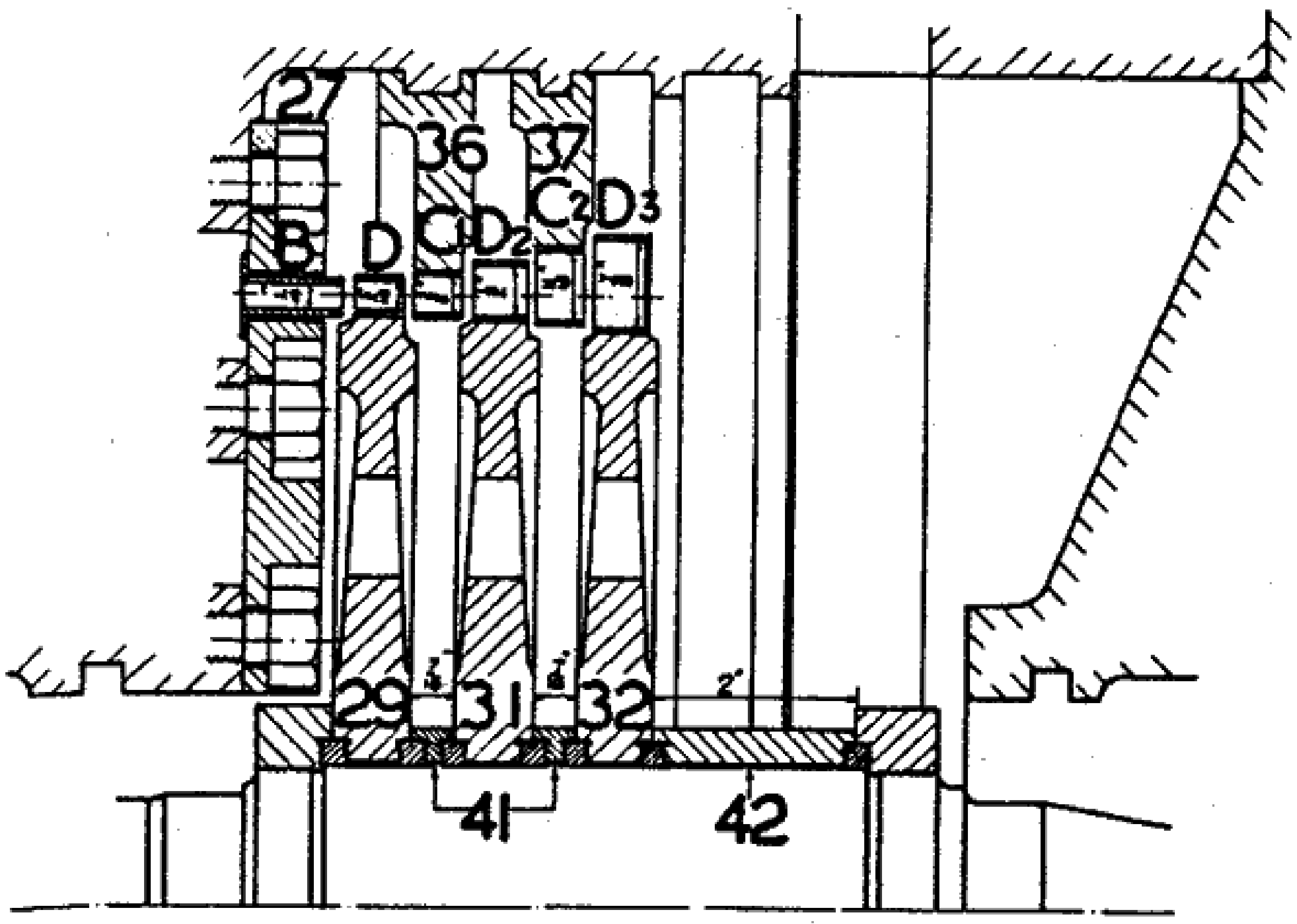


Fig. 16 Three row Curtis assembly.

Single Stage Turbine

Three Row Velocity Compound

or Three Row Curtis Stage

The convergent-divergent nozzles are used with advantage in this arrangement.

The maximum stage efficiency will occur with heat drops of the order of:
40 B.Th.U./lb. at 4000 r.p.m.
150 B.Th.U./lb. at 8000 r.p.m.

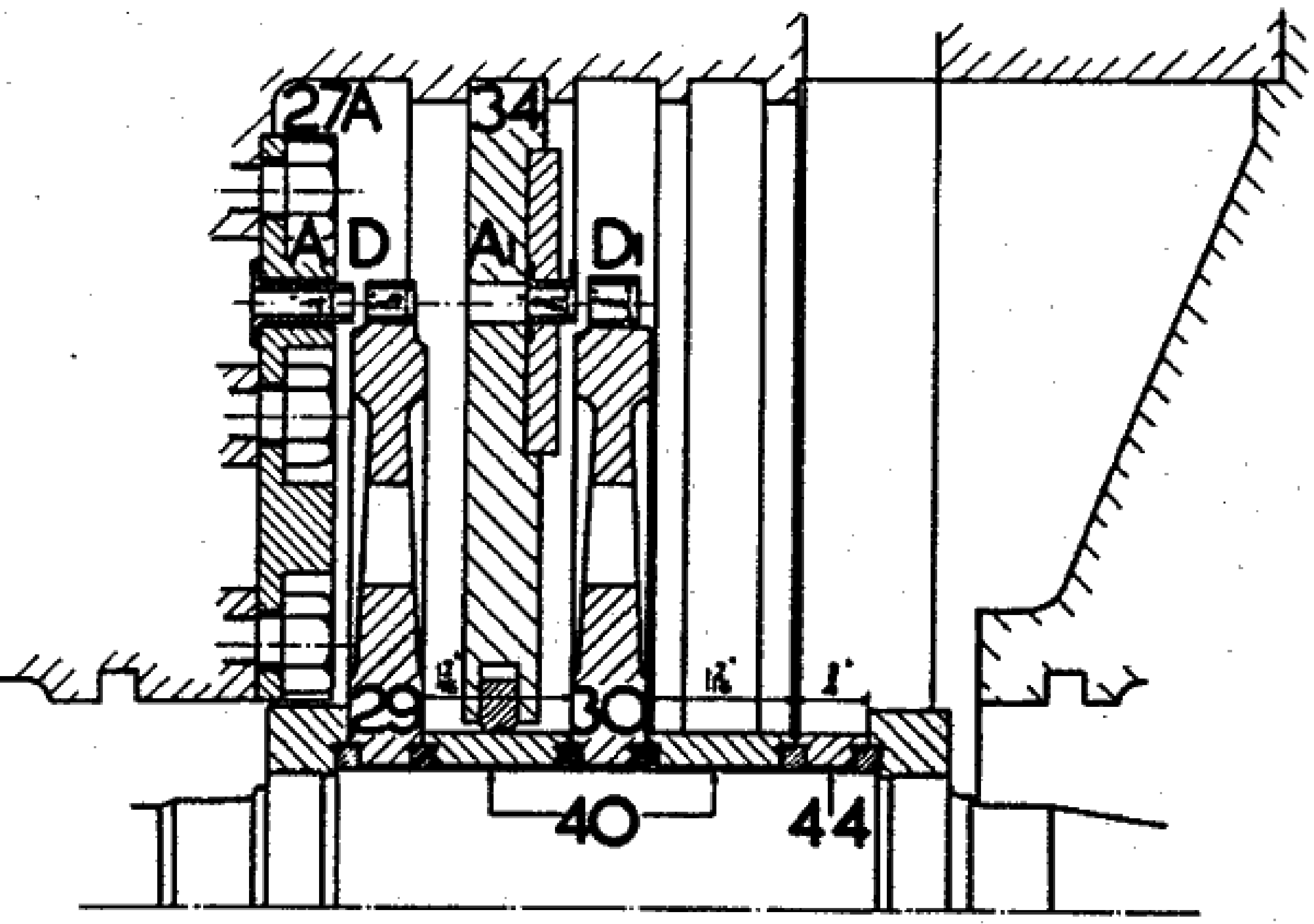


Fig. 17 Two stage Rateau assembly.

Two Stage Turbine

Two Rateau Stages

The ideal heat drops for this arrangement will be about double those advised for the single stage Rateau turbine.

i.e. 10 B.Th.U./lb. at 4000 r.p.m.
40 B.Th.U./lb. at 8000 r.p.m.

25 BTU/lbs = 5,815 kJ/kg
100 BTU/lbs = 23,26 kJ/kg

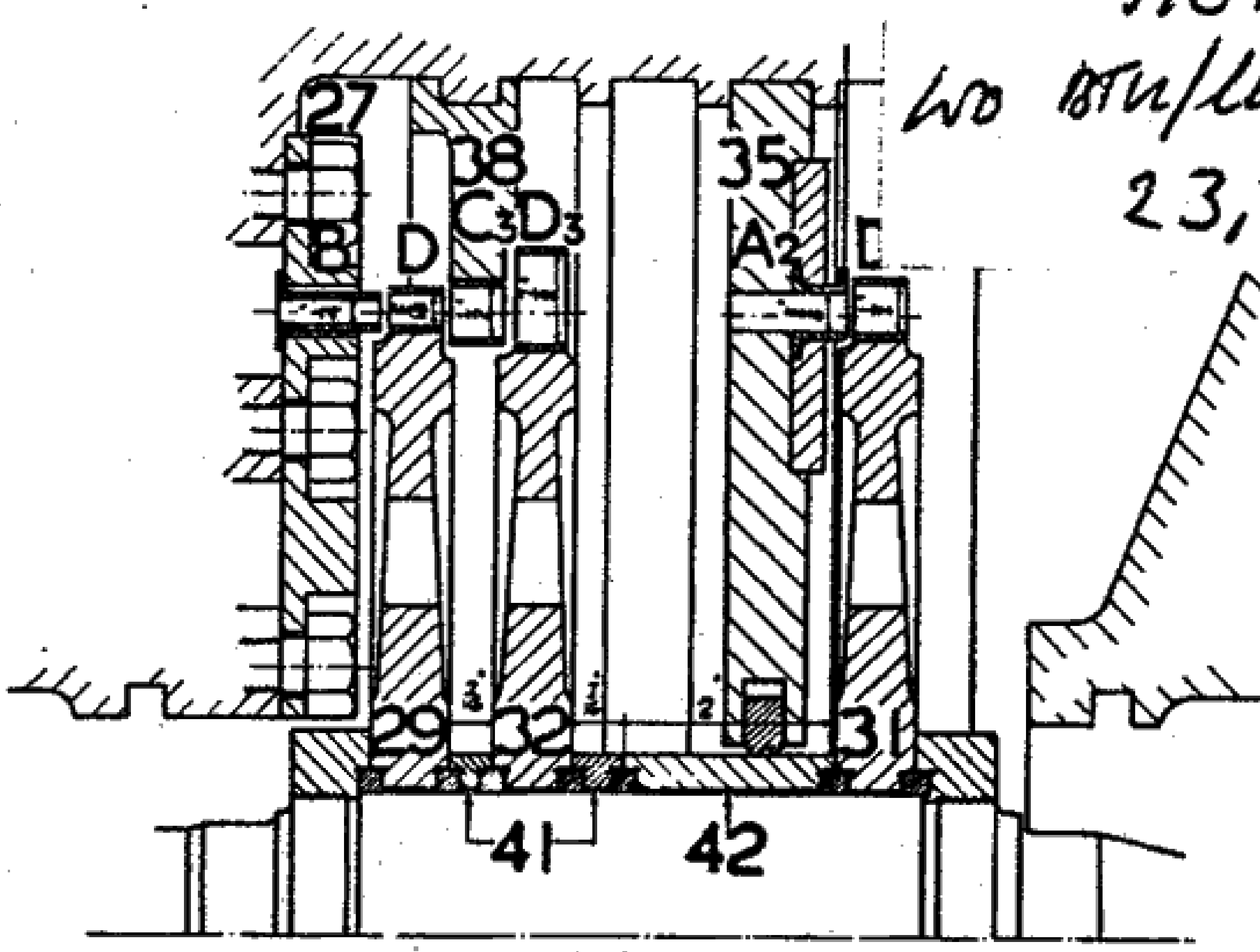


Fig. 18 Two row Curtis stage and single stage Rateau assembly.

<u>Two Stage Turbine</u>

<u>Two Row Curtis Stage followed by Single Rateau Stage</u>

This is a very common arrangement used in commercial turbines, the Curtis stage being used as the control stage.

Ideal heat drops:

25 B.Th.U./lb. at 4000 r.p.m.

100 B.Th.U./lb. at 8000 r.p.m.

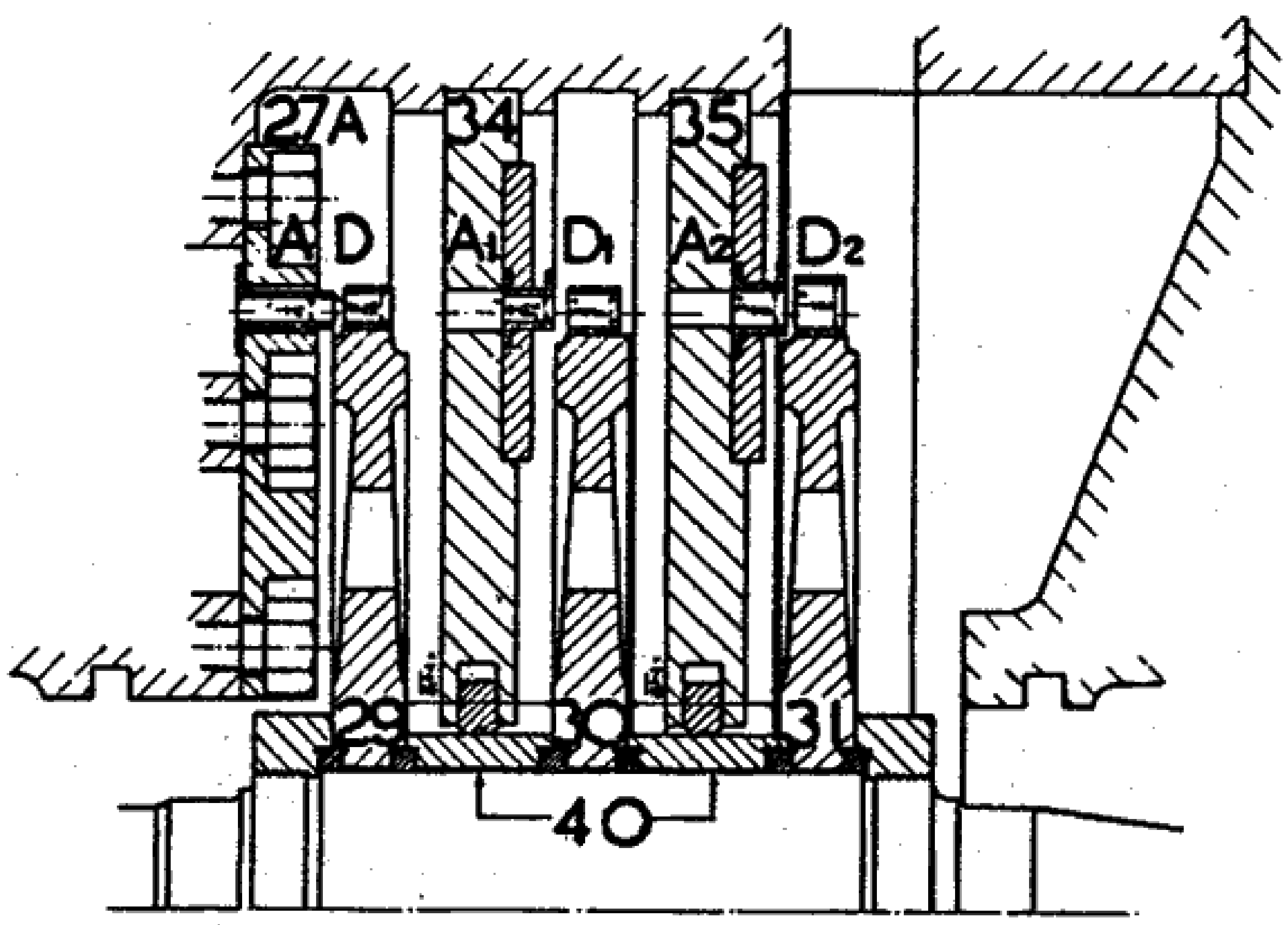


Fig. (19) Three stage Rateau assembly.

<u>Three Stage Turbine</u>

<u>Three Rateau Stages</u>

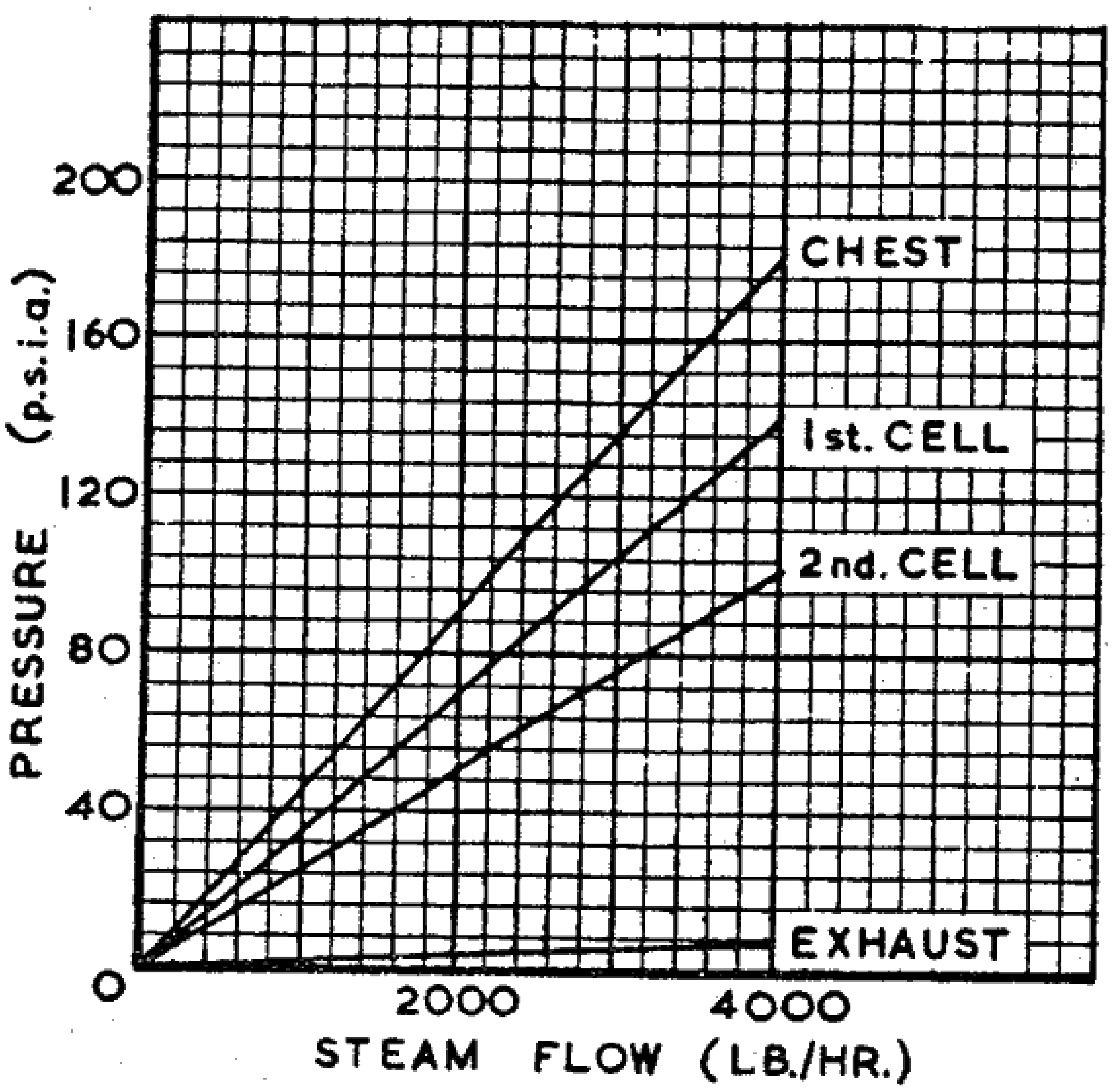
The ideal heat drops for this arrangement will be three times those advised for the single stage Rateau turbine.

i.e. 15 B.Th.U./lb. at 4000 r.p.m.

60 B.TH.U./lb. at 8000 r.p.m.

15 BTU/lb = 3,49 kJ/kg Joule

60 BTU/lb = 13,96 kJ/kg



80 psig ⇒ 5,516 ba.
120 psig ⇒ 8,274 "
40 psig ⇒ 2,7 bar
2000 = 0,252 kg/s
4000 = 0,504 kg/s

Fig. 20 Pressure-steam flow curves for condensing turbine.

Arrangement: Three stage Rateau.
Admission arc: One-eighth on all stages.

Nichting

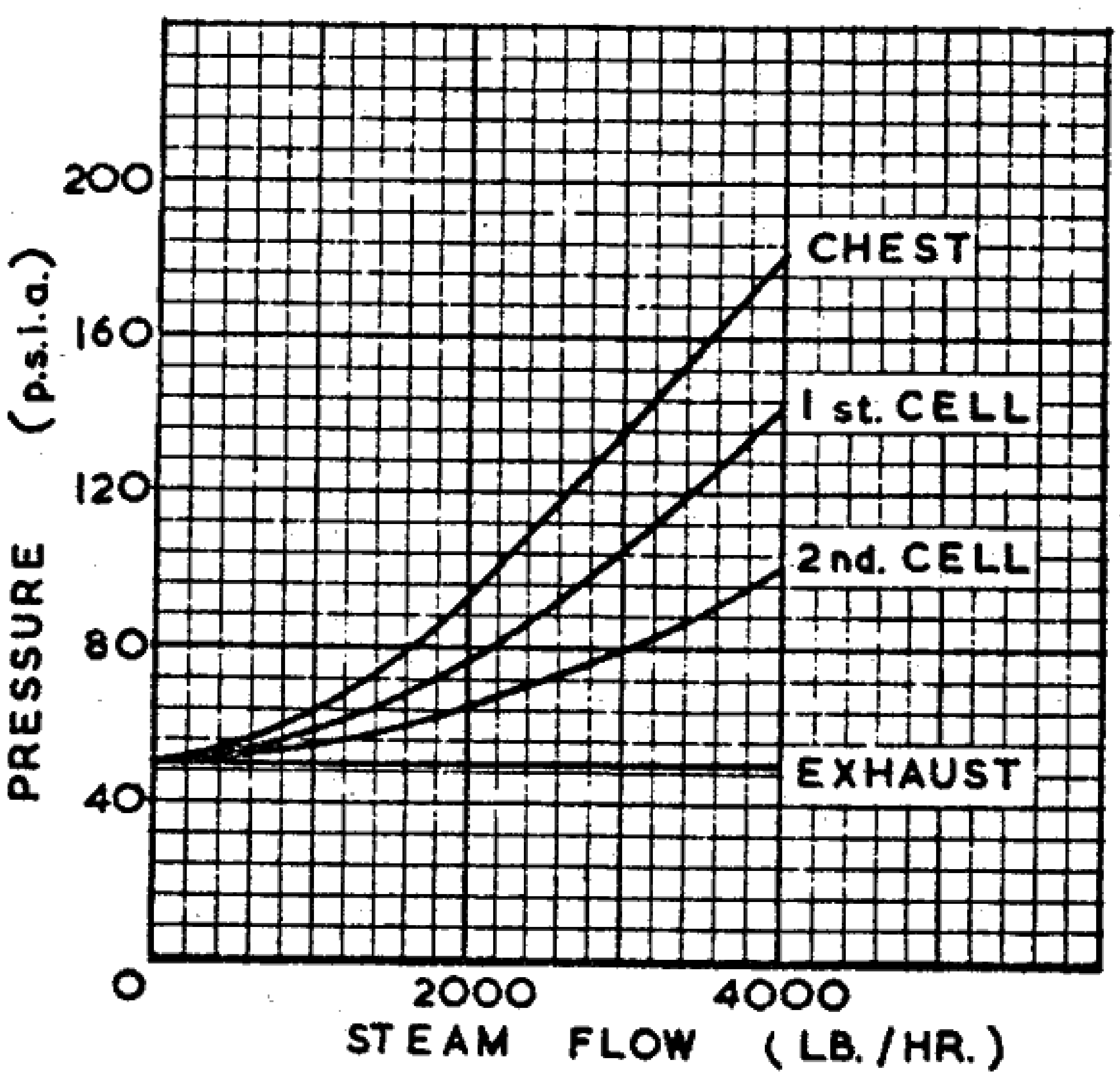


Fig. 21 Pressure-steam flow curves for back pressure turbine.

Arrangement: Three stage Rateau.
Admission arc: One-eighth on all stages.

It is emphasised that the experiments listed to illustrate the uses of various rbine arrangements do not exhaust the possibilities of the unit as a piece of perimental apparatus.

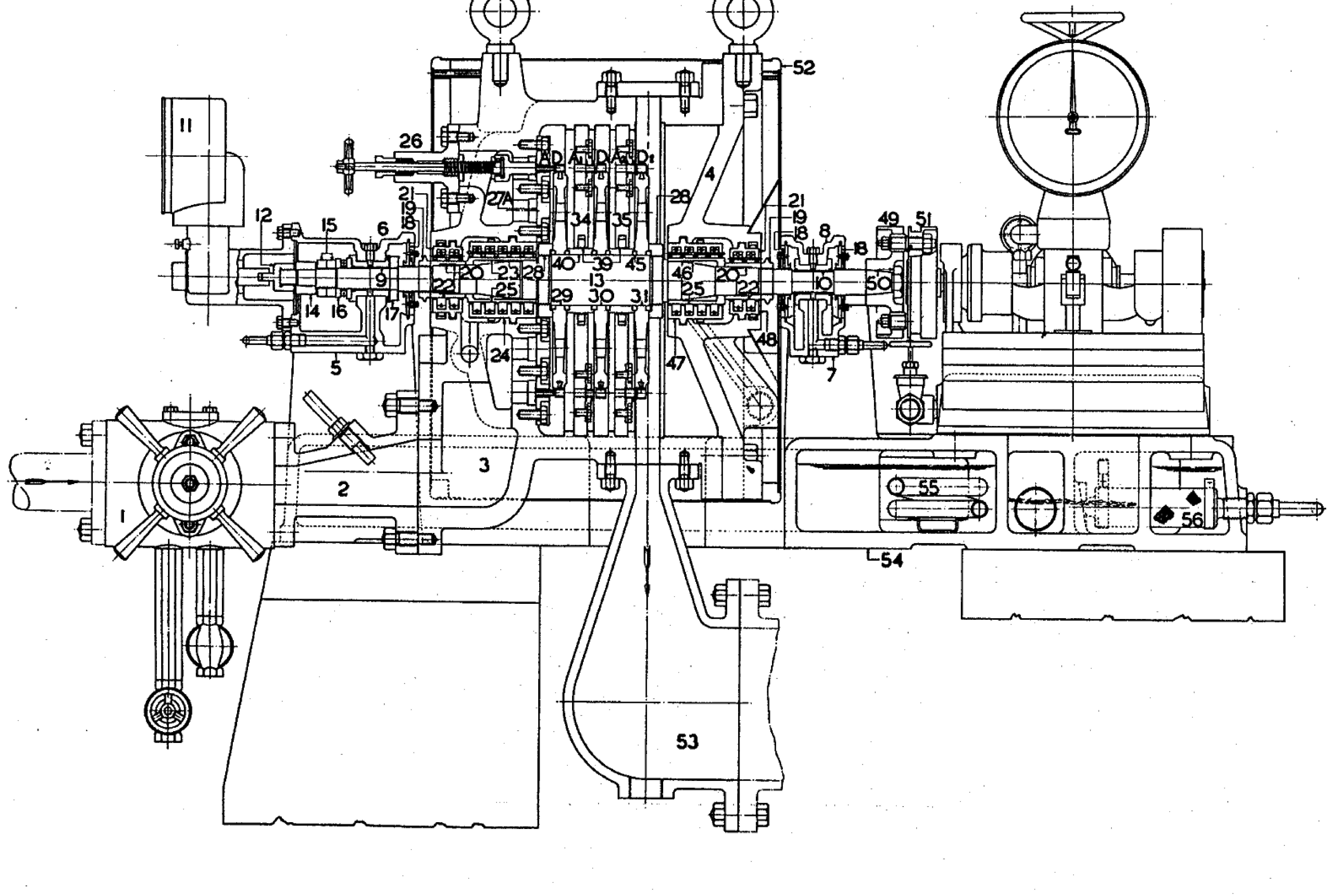


Fig. 22 Sectional arrangement of Instructional Turbine, set up with three Rateau stages.

MECHANICAL DETAILS.

NAMES OF PRINCIPAL PARTS SHOWN ON SECTIONAL ARRANGEMENT & ALTERNATIVE ASSEMBLIES.

1.	STEAM INLET STOP VALVE.	21.	H.P. & L.P. GLAND OUTER BOXES.	40.	DIAPHRAGM SLEEVES. (1 3/4" LONG).
2.	STEAM INLET BRANCH.	22.	" " " " PACKING RINGS - 2" DIA.	41.	" " (AS ITEM 40 7/16" LONG).
3.	STEAM CASING.	23.	H.P. GLAND INNER SLEEVE.	42.	" " (" " " 2" LONG).
4.	CASING COVER.	24.	" " " BOX.	43.	" " (" " " 3 5/16" LONG).
5.	'A' BEARING PEDESTAL.	25.	H.P. & L.P. GLAND PACKING RINGS - 2 1/2" DIA.	44.	WHEEL DISTANCE PIECE. (3/4" LONG).
6.	'A' BEARING CAP.	26.	NOZZLE VALVE.	45.	SPIGOT RINGS.
7.	'B' BEARING PEDESTAL.	27.	STEAM CHEST FACEPLATE - CURTIS.	46.	L.P. GLAND INNER SLEEVE.
8.	'B' BEARING CAP.	27A.	" " " - RATEAU.	47.	" " " BOX.
9.	'A' BEARING SHELL.	28.	WHEEL NUT.	48.	" " OUTER " .
10.	'B' BEARING SHELL.	29.	1ST WHEEL.	49.	TURBINE HALF COUPLING.
11.	TACHOMETER.	30.	2ND " .	50.	TURBINE NUT.
12.	" DRIVER.	31.	3RD " .	51.	DYNAMOMETER HALF COUPLING.
13.	MAIN SHAFT.	32.	4TH " .	52.	LAGGING MOULDING.
14.	EMERGENCY GOVERNOR.	33.	FRICTION DISC.	53.	EXHAUST BRANCH.
15.	THRUST NUTS.	34.	1ST DIAPHRAGM } USED FOR RATEAU ASSEMBLY	54.	BEDPLATE.
16.	" BALL RACE.	35.	2ND " } USED FOR RATEAU ASSEMBLY	55.	COOLING COIL.
17.	BACK THRUST COLLAR.	36.	GUIDE RING. } USED FOR CURTIS ASSEMBLY.	56.	OIL FILTER.
18.	OIL CATCHERS.	37.	" " } USED FOR CURTIS ASSEMBLY.		
19.	H.P. & L.P. GLAND SLEEVE NUTS.	38.	" " } USED FOR CURTIS ASSEMBLY.		
20.	" " " " OUTER SLEEVES.	39.	DIAPHRAGM PACKING RINGS.		

BLADING PARTICULARS.

COMBINATION.	ROW	FIXED BLADES.		MOVING BLADES.	
		DISTINGUISHING LETTER	DESCRIPTIVE NAME	DISTINGUISHING LETTER	DESCRIPTIVE NAME
3 STAGE RATEAU.	1.	A 1)	CONVERGENT NOZZLE SEGMENTS	D.	SINGLE IMPULSE BLADES.
	2.	A1 2)	" "	D1.	" " "
	3.	A2 3)	" "	D2	" " "
3 ROW CURTIS.	1.	B	CONVERGENT - DIVERGENT NOZZLE SEGMENTS.	D	1ST COMPOUND VELOCITY BLADES.
	2.	C1	1ST GUIDE.	D2	2ND " " "
	3.	C2	2ND GUIDE.	D3	3RD " " "
2 ROW CURTIS, 1 STAGE RATEAU.	1.	B	CONVERGENT - DIVERGENT NOZZLE SEGMENTS.	D	1ST " " "
	2.	C3	1ST GUIDE.	D3	2ND " " "
	3.	A2	CONVERGENT NOZZLE SEGMENTS.	D2	SINGLE IMPULSE BLADES.

WHEN REFERRING TO ANY PARTICULAR ROW OF BLADING, PLEASE ALWAYS GIVE THE WORKING LENGTH OF BLADES AS A CHECK. THE WORKING LENGTH IS MEASURED FROM THE TOP OF THE INNER SHROUD, TO THE UNDERSIDE OF THE OUTER SHROUD.

Ordering Spare or Replacement Parts

Part numbers shown on the cross-sectional arrangement, Fig. 22, and the assembly arrangements, Fig. 14, 15, 16, 17, 18 and 19, refer to the schedule of principal parts given above.

When ordering spares or replacements please quote the part name and number from the schedule, and give the number of the figure in which it is illustrated. When ordering new blading it is wise to give the working length of the blading as a check.

1) schoeplengte 7.8 mm

2) —"— 9.5 mm

3) —"— 12,5 mm.

PART II

INSTALLATION

Alignment

The turbine and dynamometer are mounted on a common bedplate (Fig. 22), and the set has been aligned and dowelled by the manufacturer. Provided that instructions for mounting and grouting in the bedplate have been followed, so that the bedplate is not distorted, there should be no further need to adjust the turbine and dynamometer alignment.

Steam Pipes & Boiler Installation

Fittings and steam pipes must be clean inside, free from scale, sand, bits of jointing, loose weld beads and other foreign matter. Immense damage can be caused to blading by solid matter blown into the turbine.

If the boiler installation is new, the steam pipe should be disconnected close to the stop valve, and the steam blown "full blast" through the erected pipe line to the turbine and thence to a safe place by means of a temporary pipe. This will clear most of the dirt and odd assortment of rubbish which always seems to be left in new boiler and pipework installations.

<u>N.B.</u> It is imperative that the temporary pipe be securely anchored in order to prevent any accident due to the jet effect of the issuing steam creating whip and possible fracture.

Steam Supply

Clean steam is the pre-requisite of a clean turbine and the best insurance against corrosion troubles.

The presence of water vapour in the casing while the turbine is standing causes serious corrosion. It is important therefore that the steam inlet valves be maintained in first class condition. If the turbine is to stand for long periods some protective treatment should be applied to inhibit chemical attack.

Forcing boiler plant, resulting in priming and carry-over of chemical substances and precipitates associated with water treatment, can be serious for the turbine. Deposits can be built up on the blading, which adversely affect experimental results.

High Pressure Steam Separator

A steam separator, although very desirable, is not absolutely essential if super-heated steam is used. Super-heated steam is recommended in order that experimental work may be consistent.

For wet steam a separator is most desirable, not so much to trap flushes of water, as to reduce the constant stream of minute drops of water which erode the turbine blading.

Combined Stop and Emergency Valve

A single valve functions as turbine stop valve and emergency valve. The design incorporates a spring loaded spindle nut which has sufficient freedom of movement to move the valve from the 'full open' to the 'closed' position.

With the valve nut in the forward 'tripped' position, and the valve held on its seat by the spring pressure, the handwheel is first turned in the 'close' direction. As the valve is already on its seat, the nut moves up the spindle until it can be retained in the withdrawn 'set' position, by rotating a clutch plate so that the dogs engage the spline lands on the outside of the nut. By reversing the rotation of the handwheel and turning in the 'open' direction, the valve is then lifted from the seat.

If the emergency gear rotates the clutch plate so that the clutch dogs engage the splines, the nut, spindle and valve are driven forward by the spring, and the valve is closed. Valve travel and spindle nut travel are so proportioned that it is necessary to follow the resetting procedure before the valve can be opened to steam.

The operating gear should be kept clean, and it is good practice to trip the emergency valve by hand occasionally to ensure that the mechanism is in order.

When repacking the gland, the packing must not be pulled down too tightly, or the valve spindle will be restrained when the emergency trip operates, so that the valve may not close fully.

Use only best quality lubricant and graphite impregnated 3/8 inch steam packing.

Turbine Drains & Steam to Gland Cocks

The greater part of the turbine is self draining towards the exhaust. The two drain valves are situated before and after the steam inlet stop valve. These and the steam to gland cocks must be kept clean and in good mechanical condition.

Hand Nozzle Control Valves

Two nozzle arc control valves are fitted, each covering about a quarter of the full circle of high pressure nozzles. The design is simple, and when closed the valve blanks off a section of the nozzle blading on the steam inlet side.

These valves must be either fully open or fully closed when the turbine is in operation.

When repacking the stuffing box use 1/4 inch graphite impregnated steam packing.

Emergency Governor

The emergency governor consists of a spring loaded unbalanced ring mounted on the main shaft. After a period of time the internal spring may take a small permanent set and, if this is within allowable limits, adjustment should be made using the plugs fitted in the ring for this purpose. No attempt should be made to put packing under the spring. The standard setting gives a trip speed 10% above normal running speed.

It is good practice to test the overspeed device occasionally by allowing the turbine to run up to trip speed. This ensures that all is in working order and that the trip operates in the correct speed range.

Speed Control

A speed control governor is not fitted. The dynamometer provides a stabilising load which allows the speed to be controlled easily by the stop valve.

Turbine Glands

H.P. and L.P. glands are of a segmental carbon type which have proved to give long life in commercial service and require minimum adjustment.

When adjustment is needed, the radial clearance can be closed by reducing the circumference of the assembled ring. This is accomplished by rubbing away carbon from the end of a segment on a sheet of fine emery cloth placed on a surface plate.

Radial clearances between gland sleeve and carbons when assembled should be between 0·002 inch and 0·003 inch.

Diaphragm Packings

Floating ring type diaphragm packings are used. The rings are in halves, each half being restrained at the horns and loaded by a wave spring. They give little trouble and do not usually call for adjustment. Ensure that they are free to move and not stuck in the grooves.

When new diaphragm packing has been fitted, the turbine will need a run to 'break-in' the packing. On the first run up the turbine will probably show some vibration owing to the packing rings bearing hard on the diaphragm sleeves. If vibration starts shut the turbine down and allow it to cool for ten minutes. On the second run up vibration should be delayed until a higher speed is reached. Repeat the cycle until full speed is attained without vibration. Three or four cycles are usually required.

Note that steam should not be admitted to the glands while the rotor is at rest - see Starting and Running Instructions on page 33.

Oil System & Lubrication

The turbine has an integral oil system consisting of an oil well, strainer, and motor driven oil pump. The oil is drawn through the strainer, pumped to the bearings at a pressure of approximately 25 p.s.i.g., and then drained back to the tank.

In the pre-1955 design, the oil well consists of a separate galvanised steel tank, mounting a motor driven oil pump and containing the strainer. The strainer can be removed for cleaning. [In the present design, the oil well is formed in the bedplate under the dynamometer.] A copper pipe oil cooler is built into the bedplate oil well, which can be supplied with water as a separate circuit, but it is suggested that it should be connected in series with the dynamometer, the cold water passing to the oil cooler first. The cooling element is carried from a door in the side of the bedplate. When the oil well is cleaned it is recommended that the cooling element is withdrawn and cleaned at the same time.

Oil

B.S.S.489/1955 medium grade turbine oil is recommended.

Oil must be kept clean and in first class condition. The many undesirable consequences of poor or dirty oil include overheated bearings, 'run' white metal, and thrust bearing troubles.

The oil strainer should be inspected regularly and any deposits clinging to the gauze should be washed off carefully, not rubbed through the gauze.

Only one strainer is fitted, which means that it must be cleaned only when the turbine is standing, so that no dirty oil can be drawn into the pump.

In damp atmospheres the oil well should be inspected regularly for water, and any accumulation drained off. The oil tank should be topped up with clean oil if necessary.

The oil strainer must be well covered with oil when the oil pump is running to avoid the intake of air. When standing, the strainer should be covered by at least 1 inch of oil.

The oil well should be cleaned out when the oil has been drained for filtering or renewal. Use only clean rag free from loose threads. Never use cotton waste.

Bearings

The turbine has been given a test run by the manufacturer and bearing temperatures have been passed as satisfactory.

It is always advisable to check bearing temperatures, and a ready method is by feeling the warmth of the bearing by hand. If the fingers can be kept on the bearing cap the bearing temperature is probably less than 130°F 54° If they can be kept on the cap for only two or three seconds, the temperature will be of the order of 140°F. 60° If the bearing can only be touched, the temperature is probably of the order of 150°F and is getting into the zone where special attention should be given it.

High bearing temperatures can usually be associated with one of the following conditions:

Stoppage or restriction of oil supply.
Poor quality or dirty oil.
Hot lubricating oil.
Insufficient bearing clearance.
Dirt accumulations on edges of oil grooves.
Very high temperature steam.

To Lift the Top Half Casing

The glands will not be disturbed when the top half casing is lifted, even though the gland boxes are in halves, since they are held together by means of steel retaining rings. The gland boxes lift out with the rotor assembly.

Always have the guide pillars in place when lifting or lowering the casing. Proceed with great care. If the blade shrouding catches, or any fouling takes place, severe damage may result.

It is good practice to turn the rotor slowly, in the direction of rotation, when lifting or lowering the top half casing. If this is done any fouling is made evident at once.

N.B. Never turn the rotor against the direction of rotation. Any obstruction which has lodged in or between the fixed and moving blades tends to clear itself, when the rotor is turned in the direction of normal rotation, but can cause damage. If the rotor is turned against the normal direction serious damage will certainly be caused.

To Lift the Rotor

Take a double turn round the shaft with wire rope slings when lifting the rotor, This is a safety precaution to prevent the shaft slipping through the slings. Lifting gear is not supplied.

When the rotor is out of the turbine, it should be placed on two trestles and supported as close to the wheels as possible. If the rotor is removed by hand, special care should be taken. The shaft is relatively slender, and can be damaged by a blow or fall.

To Change the Rotor Assembly

The wheels and diaphragm sleeves are carried on spigot rings - see Fig. 22. The spigot rings are a tight fit between the shaft and the bore of the recess in the flank of the wheel. This method of construction allows quick assembly changes, and any wear or damage, consequent upon removing wheels, is confined to the spigot rings which are inexpensive and easily replaced.

To remove a wheel, slack off and remove the L.P. end wheel nut (N.B. right hand thread). Do not disturb the H.P. end wheel nut. Place two pieces of wood, of thickness which will just allow them to pass between the wheel being removed and the adjacent one, one piece on each side of the shaft, and gently prise off the wheel. It will be found helpful to tap the flank of the wheel with a lead hammer, but in no circumstances should the blading be caught by the pieces of wood or the lead hammer.

Diaphragm sleeves can be prised off using the tools provided, which fit into the slots machined in the sleeves.

Spigot rings must be handled with great care. It is worth remembering, that if a wheel has to be moved far along the shaft it should be moved about 3/16 inch forward to clear the back spigot ring, the front spigot ring being carried forward with the wheel. The wheel can then be tapped gently backward off the front spigot ring, and the components removed separately with ease.

Whenever the rotor is dismantled, the shaft, spigot rings, recesses and bores of wheels, and diaphragm sleeves, should be well rubbed with best dry graphite until the surfaces present an "ebony" finish. This is best accomplished using a piece of dry cloth or a short bristled stencil brush.

To Remove Diaphragms

It is advisable to remove diaphragms at intervals of not more than twelve months or they may get stuck in the casing grooves.

Remove the hexagon headed screws and keep plates at the horizontal joint, and tap the half diaphragm on its horizontal joint close to the casing joint, moving it from side to side to release it. When it is free, either tap the half diaphragm round so that it slides round out of the groove, or affix a clip in the centre of the diaphragm and lift it out.

Before replacing the diaphragm treat the edge of the diaphragm and the groove in the casing with graphite as prescribed for the rotor assembly.

To Change Fixed Blading Arrangement

The fixed blading is clipped to the diaphragm by outer and inner annular rings secured by set pins.

To remove a section of blades, slacken off the set pins and slide out the section of blades.

To fit blanking pieces, slacken off the set pins, slide out the arc of blading to be removed, slide in a suitable blanking plate and re-tighten set pins. Fit blanking pieces carefully or steam leakage may spoil experimental results.

Reassembly

Always take bearing, oil catcher and gland clearances after the rotor has been disturbed. Glands and oil catchers should have uniform clearance all round between the rotating part and the gland box or cover.

Do not make thick casing joints. Proceed as follows:

Clean the surface of the horizontal joint thoroughly, and paint evenly with fine powdered graphite mixed with a little cylinder oil, or with a ready mixed graphite jointing.

Replace the top half and tighten down the joint evenly commencing from the middle and working to the ends.

Vertical casing joints are "permanent" inasmuch that there is no need to disturb them, but if for any reason they have to be remade it would be wise to obtain advice from the manufacturer.

Warming up instructions (see page 33) should be observed carefully after making joints, since they are easily spoiled by too rapid heating.

STARTING & RUNNING INSTRUCTIONS

Before Starting

(1) Make sure that:

(a) The oil well is filled with the recommended grade of oil to the correct level (see page 29).

(b) The dynamometer bearings are filled with grease.

(c) There is a flow of water through the dynamometer.

(2) Oil the tachometer.

(3) Drain all steam inlet and exhaust pipes (and separator if fitted).

(4) Open steam range and chest drains.

(5) Start the oil pump.

(6) Turn on water supply to oil cooling coil if in separate circuit from the dynamometer water supply.

(7) Start the Turbine.

Follow the starting instructions carefully.

Starting Procedure

Start, by a sharp blast of steam, i.e. open the stop valve smartly until the rotor begins to rotate, then close the stop valve quickly and re-open gently to a point which will control the turbine at the correct speed.

Turn on sealing steam to glands when turbine is rotating, not before, and adjust steam to glands so that there is a slight "show" of vapour blowing from the glands.

Warm up, by allowing the turbine to run slowly for about ten minutes. Then if no vibration or other indications of trouble are evident, steadily increase the speed to just over 4000 r.p.m., and hold this speed constant for about five minutes. If all is well, gently increase the speed until 8000 r.p.m. is reached.

The total time to bring the turbine up to full speed, from cold, should be about twenty minutes.

Running

At full speed, with oil temperature up to normal (about 105°F) the oil pressure should not fall below 20 p.s.i.g.

The drains, before and after the stop valve, can be closed by degrees as the turbine heats up and the rate of discharge of water decreases. They should be closed when the turbine is hot.

Keep superheat temperatures steady, since rapid fluctuations of temperature can be dangerous.

Keep dynamometer water glands just tight enough to avoid spray, but do not over-tighten them.

Investigate any unusual noise immediately. A "rub" inside the casing makes a distinct noise and is usually, although not always, accompanied by vibration. If a "rub" in the turbine or dynamometer is suspected, shut down at once. Damage from rubbing at high speed is cumulative on account of local temperature rise and consequent distortion of affected parts.

Smooth running and lack of unusual noise is not an absolute guarantee that all is well inside the plant, therefore regular examination is recommended.

Post the framed copy of starting and running instruction in a position close to the turbine so that all who operate the turbine can read it easily.

Shutting down

Close the stop valve and bring the turbine to rest. Allow the turbine to cool for a quarter of an hour before shutting down the oil system.

Open the turbine drains in order to keep the internal parts of the turbine dry, and free from corrosion.

PART III

CONDENSING PLANT

Description

The condensing plant consists of a surface condenser, an Edwards type Air Pump, and a centrifugal cooling water pump, both pumps being driven by a single electric motor.

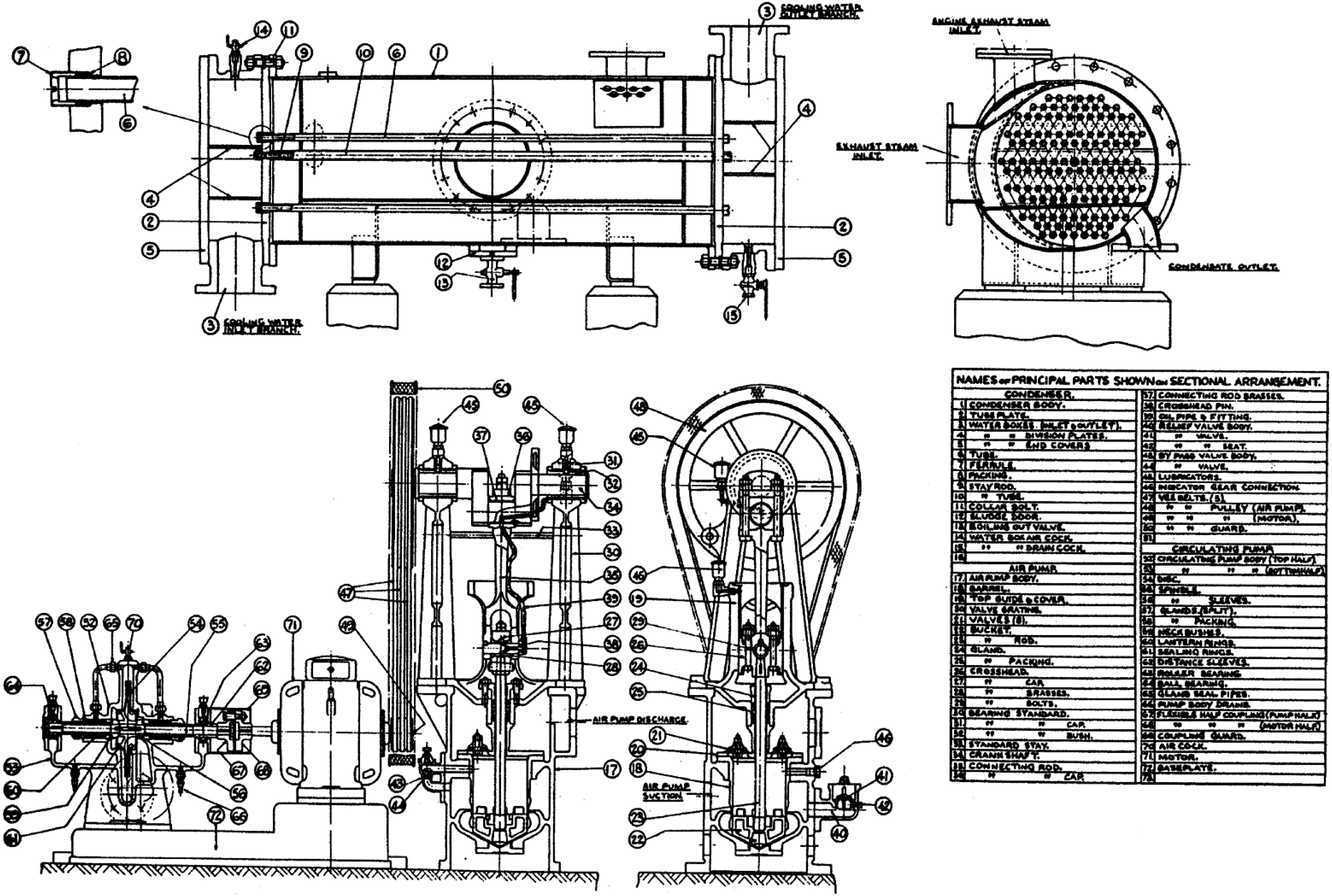
Design Considerations

The condensing plant is not designed primarily as an experimental unit, although much useful information can be obtained from it. For example, heat transmission rates can be determined with various water flows and possibly temperatures, or by alteration to the cooling surface and tube arrangement by removing tubes and plugging the tube plate.

This information can be obtained either during the turbine tests, or preferably by isolating the condenser from the turbine and admitting steam through the separate branch provided on the condenser body. In the latter case the vacuum can be adjusted by admission of air through the cock on top of the condenser body, or alternatively the air-steam mixture can be controlled by replacing the cock with calibrated nozzles. These nozzles are not supplied as part of the standard equipment.

The Edwards type Air Pump has been practically superseded in commercial power plant, but has been chosen for this application mainly because separate extraction of the air and condensate is difficult on so small a plant, and also the measurement of the turbine steam consumption is less complicated. The reciprocating wet vacuum pump is still found in some branches of engineering, and in order that the performance of this type of pump may be demonstrated, a plugged connection is provided on the air pump body for fitting indicator gear.

A separate booklet gives details of the condensing plant design, and also useful information on care and management.



NAMES OF PRINCIPAL PARTS SHOWN ON SECTIONAL ARRANGEMENT.			
	CONDENSER.	37	CONNECTING ROD BRASSES.
1	CONDENSER BODY.	38	CROSSHEAD PIN.
2	TUBE PLATE.	39	OIL PIPE & FITTING.
3	WATER BOXES. (INLET & OUTLET).	40	RELIEF VALVE BODY.
4	" " DIVISION PLATES.	41	" VALVE.
5	" " END COVERS	42	" " SEAT.
6	TUBE.	43	BY PASS VALVE BODY.
7	FERRULE.	44	" VALVE.
8	PACKING.	45	LUBRICATORS.
9	STAY ROD.	46	INDICATOR GEAR CONNECTION.
10	" TUBE.	47	VEE BELTS. (5).
11	COLLAR BOLT.	48	" " PULLEY (AIR PUMP).
12	SLUDGE DOOR.	49	" " " (MOTOR).
13	BOILING OUT VALVE.	50	" " GUARD.
14	WATER BOX AIR COCK.	51	
15	" " DRAIN COCK.		CIRCULATING PUMP.
16		52	CIRCULATING PUMP BODY (TOP HALF).
	AIR PUMP.	53	" " " (BOTTOM HALF)
17	AIR PUMP BODY.	54	DISC.
18	BARREL.	55	SPINDLE.
19	TOP GUIDE & COVER.	56	" SLEEVES.
20	VALVE GRATING.	57	GLANDS (SPLIT).
21	VALVES (8).	58	" PACKING.
22	BUCKET.	59	NECK BUSHES.
23	" ROD.	60	LANTERN RINGS.
24	GLAND.	61	SEALING RINGS.
25	" PACKING.	62	DISTANCE SLEEVES.
26	CROSSHEAD.	63	ROLLER BEARING.
27	" CAP.	64	BALL BEARING.
28	" BRASSES.	65	GLAND SEAL PIPES.
29	" BOLTS.	66	PUMP BODY DRAINS.
30	BEARING STANDARD.	67	FLEXIBLE HALF COUPLING (PUMP HALF)
31	" " CAP.	68	" " " (MOTOR HALF)
32	" " BUSH.	69	COUPLING GUARD.
33	STANDARD STAY.	70	AIR COCK.
34	CRANK SHAFT.	71	MOTOR.
35	CONNECTING ROD.	72	BASEPLATE.
36	" " CAP.	73	

Fig. 23 Sectional arrangements of condenser, air and circulating pumps.