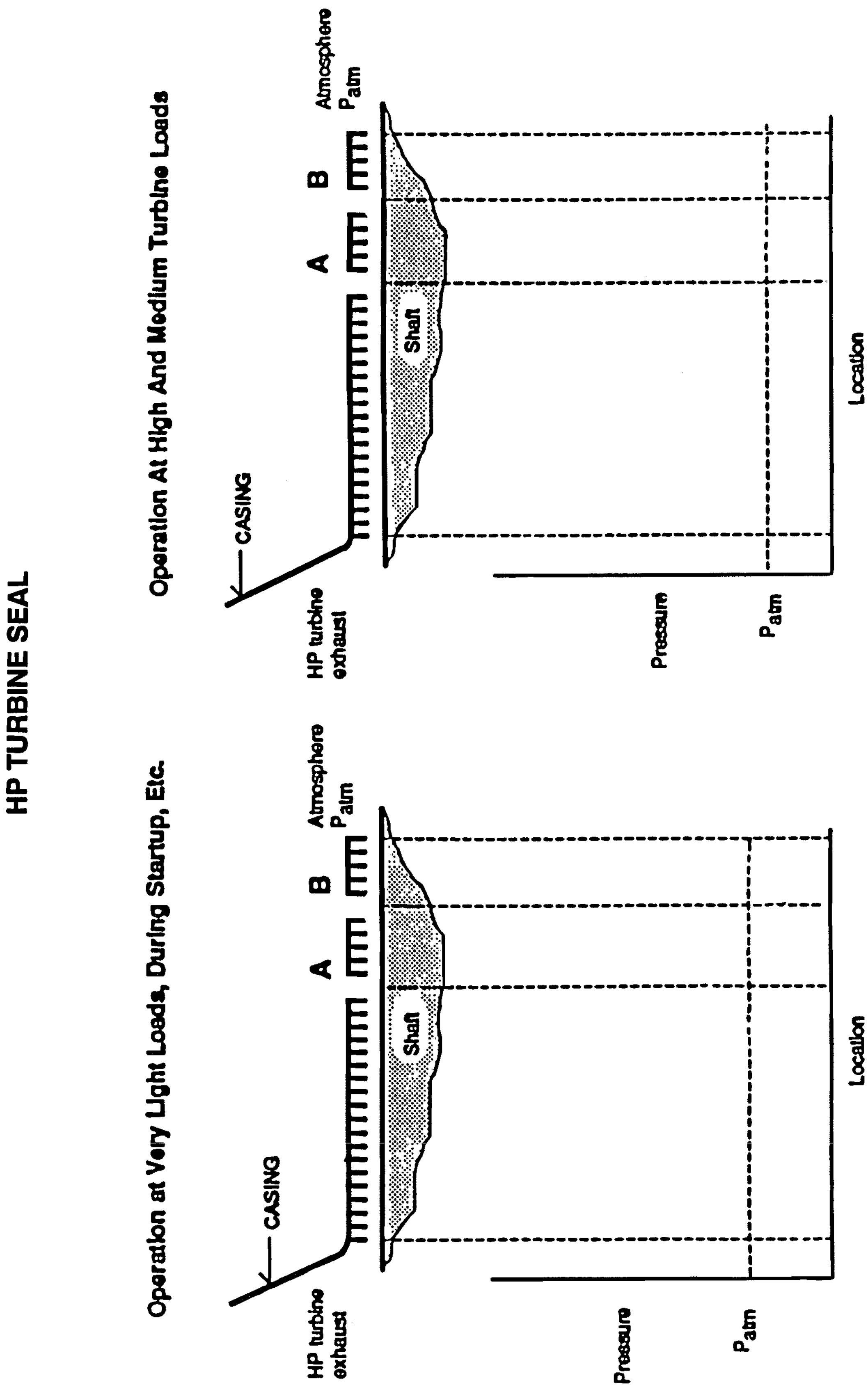
PROBLEM P-21   HP TURBINE SEAL



PROBLEM P-22

LABYRINTH SHAFT SEAL OPERATION

FINAL EXAM **DECEMBER 1993**

A labyrinth shaft seal is used to ensure proper sealing where the shaft passes through the casing of a low pressure steam turbine.

(a) Explain briefly the philosophy of the design of such a seal. (3)

(b) Sketch a cross section of the shaft and seal showing labyrinths and external pipe connections. Show the flow of steam and air through the pipes and labyrinths in normal operation. (4)

(c) Sketch the pressure profile across the seal showing clearly the conditions inside and outside the turbine casing. (4)

(d) Explain what would happen to the pressure and flow in the seal if the external steam supply to it should fail. How would this affect the operation of the turbine. (4)

[15 marks]

TURBINE SEAL DESIGN

UNENE EXAM **MAY 2005**

Explain why seals are designed as non-contact devices, that is, with a leakage path. State what would happen if contact between the seal and the shaft did occur.

(3 marks)

PROBLEM P-23

TURBINE SEALING STEAM SYSTEM

SECOND TEST	**NOVEMBER 1987**
SECOND TEST	**NOVEMBER 1991**
SECOND TEST	**NOVEMBER 1993**
FINAL EXAM	**DECEMBER 1995**
SECOND TEST	**NOVEMBER 1999**
SECOND TEST	**NOVEMBER 2001**
UNENE EXAM	**MAY 2005**

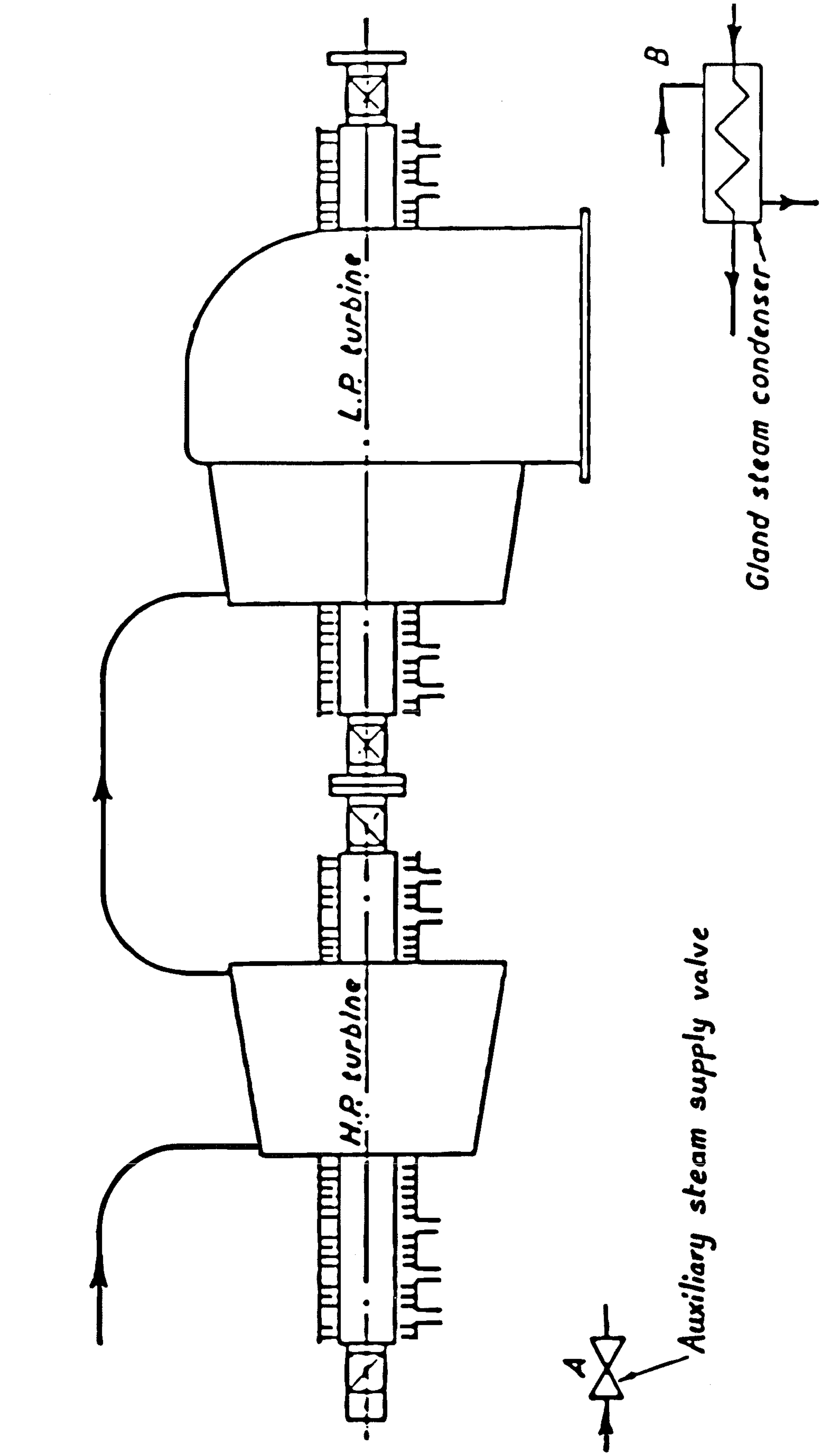
Refer to Examination Paper Attachments **Turbine Sealing System**

The attached diagram shows a typical configuration of a small steam turbine and its shaft seals. Sealing steam can be supplied through the auxiliary steam supply valve while excess steam is condensed in the gland steam condenser.

On the diagram draw in the appropriate connecting pipework between the steam supply valve, the turbine seal connections and the gland steam condenser. Indicate the direction of steam flow at both start-up and full load and identify different pressure levels.

[7 marks]

PROBLEM P-23 TURBINE SEALING SYSTEM



TURBINE SEALING SYSTEM

PROBLEM P-31

TURBINE LOSSES

SECOND TEST **OCTOBER 1987**
FINAL EXAM **DECEMBER 1997**

Consider the following four losses that occur within a steam turbine:

- Fluid Friction Loss
- Supersaturation Loss
- Moisture Loss
- Exit Kinetic Energy Loss

For each of these losses explain:

- Cause of the loss
- Influence of the loss on the turbine output (large or small)
- How the loss can be minimised
- Changes in the magnitude of the loss as turbine load varies (if applicable)

[15 marks]

PROBLEM P-35

WATER PASSAGE IN TURBINE BLADES

SECOND TEST **MARCH 1989**

Describe the passage of water drops through the latter stages of a low pressure turbine. Illustrate the effects with suitable velocity diagrams showing clearly the relative velocities of the steam and water with respect to the blades. Explain, with the aid of a suitable cross-sectional sketch of the relevant part of the turbine, how excess water may be removed from the latter stages of a low pressure turbine.

[15 marks]

PROBLEM P-36

WATER FORMATION AND REMOVAL

FINAL EXAM	**DECEMBER 1987**
FINAL EXAM	**DECEMBER 1991**
FINAL EXAM	**DECEMBER 1993**
UNENE EXAM	**MAY 2005**
FINAL EXAM	**DECEMBER 2005**

Consider a large low pressure steam turbine in which steam condenses in the latter stages.

(a) Describe the passage of primary and secondary water drops through the latter stages of the turbine. (5)

(b) Illustrate the effects above with suitable velocity diagrams for the steam and water showing clearly which parts of the blades are likely to be affected by water impingement. (5)

(c) Explain how excess water may be removed from the latter stages of a low pressure turbine. State which methods of water removal are most likely to be employed and why. (5)

(d) Explain how turbine blades can be protected against moisture erosion and state which parts of the blades require such protection. (5)

Support the above explanations with suitable sketches where appropriate.

[15 marks]

FINAL EXAM	**DECEMBER 1999**

Consider a large low pressure steam turbine in which steam condenses in the latter stages.

(a) Describe the passage of primary and secondary water drops through the latter stages of the turbine. (4)

(b) Explain how excess water may be removed from the latter stages of a low pressure turbine. State which methods of water removal are most likely to be employed and why. (5)

Support the above explanations with suitable sketches where appropriate.

[9 marks]

PROBLEM P-37

WATER FORMATION AND REMOVAL AND BLADE EROSION

SECOND TEST **NOVEMBER 2001**

Consider a large low pressure steam turbine in which steam condenses in the latter stages.

(a) Describe the passage of primary and secondary water drops through the latter stages of the turbine. (4)

(b) Explain how excess water may be removed from the latter stages of a low pressure turbine. State which methods of water removal are most likely to be employed and why. (4)

(e) Explain how turbine blades can be protected against moisture erosion and state which parts of which blades require such protection. (2)

Support the above explanations with suitable sketches where appropriate.

[10 marks]

PROBLEM P-41

TURBINE OUTPUT AT REDUCED LOAD

SECOND TEST	**NOVEMBER 1987**
SECOND TEST	**MARCH 1989**
UNENE EXAM	**MAY 2005**

The following results were obtained on a full-load test of a steam turbine:

Output at turbine coupling	250 MW
Steam pressure before stop valve	5.0 MPa
Steam temperature before stop valve	500°C
Steam pressure at turbine inlet	4.6 MPa
Steam pressure at turbine exhaust	0.005 MPa
Steam consumption	240 kg/s

It is estimated that the power loss due to bearing friction, governor, and oil-pump drive, etc., amounts to 4 MW. Calculate the internal efficiency of the turbine at full load.

Calculate the output of the turbine when the steam consumption is 1/10 of that at full load. Assume that the turbine internal efficiency, the mechanical losses and the exhaust pressure are the same as at full load, and that the turbine is governed by throttling.

This question may be done by plotting on a Mollier Chart. If so the chart must be returned with the examination answer booklet.

[15 marks]

PROBLEM P-42

TURBINE ZERO LOAD CONDITIONS

FINAL EXAM	**APRIL 1989**
FINAL EXAM	**DECEMER 1993**
SECOND TEST	**NOVEMBER 1995**
FINAL EXAM	**DECEMBER 1999**

(a) The low pressure cylinders of a large steam turbine in a nuclear plant receive steam at 1.1 MPa and 250°C at full load conditions. If the internal efficiency of the low pressure turbines is 82% under these conditions, determine the exhaust steam temperature and wetness. The exhaust steam pressure is 0.005 MPa.

(5)

(b) If, under part load conditions, the steam temperature is maintained at 250°C by a reheater (heating steam not throttled) and the steam pressure changes according to the steam flow, determine the exhaust steam conditions at zero load. Assume that 10% of the steam flow at full load is required to maintain full speed at zero load and that the internal efficiency of the low pressure turbines drops to 70%. The new exhaust steam pressure is 0.004 MPa.

(5)

(c) Explain how the steam flow at the tips of the last stage blades is likely to change between full load and zero load conditions. State what consequences this is likely to have on the operation of the turbine.

(5)

[15 marks]

PROBLEM P-43

PART LOAD OPERATIONAL CONDITIONS

FIRST TEST **OCTOBER 1993**

Refer to the Examination Paper Attachment **Part Load Operation**

Steam is supplied to a turbine with an internal efficiency of 80% at 4 MPa and 400°C and exhausts at 0.005 MPa. At full load the steam flow is 24 kg/s.

(a) Calculate the power developed by the turbine at full load.

(b) Calculate the power developed by the turbine when the inlet steam is throttled to 1 MPa.

(c) Calculate the power developed by the turbine when the generator output is zero. Under these conditions the turbine power output is dissipated in friction in the bearings and windage in the generator. An inlet steam pressure of 0.1 MPa is required to maintain this condition.

(d) Determine the exhaust steam wetness and temperature under conditions (a), (b), (c) above and show graphically how exhaust steam wetness and temperature are likely to vary with turbine load.

Plot the processes on the attached Mollier Diagram but use Steam Tables to obtain improved accuracy in the calculations where appropriate.

Note that the steam flow is proportional to the inlet turbine pressure.

Assume that the internal efficiency is the same for all conditions.

[15 marks]

QUESTION P-43 Continued

FIRST TEST **OCTOBER 1999**

Steam is supplied to a turbine with an internal efficiency of 80% at 4 MPa and 400°C and exhausts at 0.005 MPa. At full load the steam flow is 100 kg/hr.

(a) Calculate the power developed at full load.

(b) Calculate the power developed when the inlet steam is throttled to 1 MPa.

Plot the process on a Mollier Diagram but use Steam Tables if necessary to obtain improved accuracy in the calculations.

Note that the steam flow is proportional to the inlet turbine pressure.

[7 marks]

PROBLEM P-45

TURBINE OPERATIONAL CONDITIONS

FINAL EXAM **DECEMBER 2001**

The efficiency of a steam turbine varies only slightly with load at medium and high loads but deteriorates significantly with decreasing load at low loads. It also varies with condenser pressure (turbine back pressure) which changes with cooling water temperature and flow.

(a) Explain, with the aid of sketches of last stage blade profiles and velocity diagrams as appropriate, why efficiency deteriorates under low load operating conditions.

(b) Explain the consequences of the steam velocity changes experienced under low load conditions. State what corrective action may be taken to alleviate these consequences.

(c) State three factors that affect turbine efficiency when turbine back pressure is varied under constant load conditions. For each explain how the efficiency is affected.

[15 marks]

PROBLEM P-48

AIR EXTRACTION AND CONDENSER PERFORMANCE

FINAL EXAM	**DECEMBER 1995**
SECOND TEST	**NOVEMBER 1997**
UNENE EXAM	**May 2005**

Note: Detailed explanations supported by appropriate diagrams are required for this question. Marks will only be given for specific facts.

(a) Explain how air is extracted from a condenser and what parameters govern the effectiveness of air removal. Clarify any design requirements.

(5)

(b) Explain how and why condenser pressure varies with the following parameters:

- (i) cooling water flow rate
- (ii) cooling water temperature
- (iii) turbine load (steam flow rate)

Assume that only one parameter changes at a time. If appropriate sketch the temperature profiles along the length of the condenser.

(5)

(c) Explain the effect on turbine operation of varying the condenser pressure above and below the design value when the turbine is operating under full load conditions. Show the change in efficiency with respect to condenser pressure on a suitable graphical sketch. Clarify why the curve has the shape as shown.

(5)

[15 marks]

PROBLEM P-52

CONDENSER OPERATION

SECOND TEST **NOVEMBER 1999**
UNENE EXAM **MAY 2005**

Consider a condenser operating under the following conditions:

Cooling water inlet temperature	10°C
Cooling water outlet temperature	20°C
Steam inlet (saturation) temperature	30°C

Sketch the anticipated temperature profiles for both cooling water and steam across the condenser for each of the following conditions:

(a) Cooling water inlet temperature increased to 16°C.

(b) Cooling water flow reduced to one half of its original value.

(c) Turbine load reduced to one half of its original value.

[6 marks]

PROBLEM P-53

AIR EXTRACTION

SECOND TEST	**NOVEMBER 1991**
FINAL EXAM	**DECEMBER 2005**

Air is extracted from the condenser of a large steam turbine using air pumps of fixed volumetric capacity. The prevailing temperature within the steam space of the condenser is 30°C. The temperature at the point of air extraction however is lowered to 24°C by means of an air cooling section.

(a) Calculate the ratio of the mass of air extracted to the mass of steam extracted in a given volume of mixture. (6)

(b) If the temperature at the point of air extraction were reduced state how this would affect the ratio calculated in (a) above. (1)

For air R = 0.287 kJ/kg°K

PROBLEM P-54

CONDENSER PERFORMANCE

SECOND TEST **NOVEMBER 1991**
FINAL EXAM **DECEMBER 2005**

The condenser of a large steam turbine receives exhaust steam at varying flows depending upon the prevailing turbine output. On axes of condenser pressure versus condenser steam flow sketch the following:

(a) Variation in condenser pressure with steam flow into the condenser (due to variation in turbine output). (3)

(b) Variation in condenser pressure with steam flow into the condenser at a cooling water temperature higher than that in (a) above. (2)

Explain why the condenser performance curve has the shape shown and why the variation shown in (b) is different from that shown in (a). (3)

[15 marks]

PROBLEM P-55

AIR EXTRACTION AND CONDENSER PERFORMANCE

FINAL EXAM **DECEMBER 1995**
SECOND TEST **NOVEMBER 1997**
UNENE EXAM **May 2005**

Note: Detailed explanations supported by appropriate diagrams are required for this question. Marks will only be given for specific facts.

(a) Explain how air is extracted from a condenser and what parameters govern the effectiveness of air removal. Clarify any design requirements.

(5)

(b) Explain how and why condenser pressure varies with the following parameters:

(i) cooling water flow rate
(ii) cooling water temperature
(iii) turbine load (steam flow rate)

Assume that only one parameter changes at a time. If appropriate sketch the temperature profiles along the length of the condenser.

(5)

(c) Explain the effect on turbine operation of varying the condenser pressure above and below the design value when the turbine is operating under full load conditions. Show the change in efficiency with respect to condenser pressure on a suitable graphical sketch. Clarify why the curve has the shape as shown.

(5)

[15 marks]