Facility for Endurance Tests of Thermal Insulations

R. Mauersberger

Hochtemperatur-Reaktorbau GmbH

Federal Republik of Germany

In the following report the design and construction of an experimental facility for endurance tests of thermal insulations is presented. It's name in abreviation is "ADI" standing for the German words "Anlage zum Dauertest von Isolierungen".

This test facility was build by HRB in order to investigate the performance of thermal insulation systems of hot gas ducts for the process heat-reactor-project. The tests are intended to simulate the conditions of reactor operation. They include short-time experiments for selection of insulation-concepts and in a second step long-time experiments as performance tests.

During these tests are measured

- the effective heat conductivity
- the local heat losses
- the temperatur profiles of the insulation, of the fixing elements and along the wall of the duct

The design-data required to perform all these tasks are shown in the first picture:

- The gas-atmosphere must be Helium in tests like in reactor with regared to the special thermal and hydraulic properties of Helium and to the influence of Helium on mechanicle friction and wear.

- The hot gas temperature in the PNP-reactor will be 950° C and should be equal in the experiments.

- The temperature on the cold side of the insulation has to be adjustable from 50° C up to 300° C.

- The Helium pressure in the hot gas ducts of a HTR-plant is about 42 bar. The ADI was layed out for 70 bar to cover the hole range of interest.

- A Helium mass flow has to stream through the insulated test duct in order to realize equal temperatures on the hot side of the insulation. A flow rate of 4,5 kg/s is sufficient for this requirement.

- The axial pressure gradient along the insulation must be the same as in the reactor, because this has an essential influence on the heat losses. This pressure gradient is about 40 Pa/m.

- An important part of the test programm is the realization of temperature cycles. The temperature transient should be approximately 3° C/min. This value is - however - depending on the quality of the test insulation. By temperature cycling the start-up and shut-down procedures and conditions of a PNP-reactor are simulated.

- Last not least the test of full scaled insulations must be possible.

A longitudinal section of the ADI-test-vessel is shown in fig. 2. It has an inner diameter of 2 m and a total length of 10 m.

- The test insulation is mounted in a tube, which is fastened to two special designed rings. On the outside of the tube is welded a cooling-system; it is divided into longitudinal sections and into circumferential segments in order to measure local heat losses. The cooling fluid is a special heat-transfer-oil which can be used up to 350° C.

- An electrical heater which is built in a tube, is inserted into the hot gas duct. Between this tube and the hot side of the test insulation is an annular space for the Helium flow.

- The hot gas Helium flow along the test insulation is circulated by an integrated blower. The blower has an electric motor drive with speed control. The shaft of this drive has magnetic bearings working without any friction. This special kind of bearings allow the endurance tests under Helium and at high temperature without interruption for changing the bearings. The axial wheel of the blower is working at full test temperature up to 950° C.

  The blower exhausts the heated Helium from the electrical heater and presses it into the annular space along the test insulation mentioned above. A ceramic guide for the Helium flow is placed behind the blower wheel. It protects the housing of the blower drive against high temperature and guides the Helium flow into the wanted direction. A similar ceramic guide is placed on the other side of test duct leading the Helium flow back to the heater.

- A Helium/water-heat-exchanger is integrated in the other cap of the pressure vessel. It is used for cooling the Helium purge flow to the gas-purification and for the Helium which has to be circulated if the test bench is performing temperature cycles.

- The empty volume in the pressure vessel is fulfilled with an auxiliary insulation of fibrous material.

A survey of the various systems for supply and control outside of the pressure vessel is given in fig. 3:

. The control system for the blower drive and the magnetic bearings.

. The oil-cooling system for the test duct.

. The measurement devices for the test-insulation.

. The water-cooling system for the whole pressure vessel.

. The energy supply and control for the electrical heater.

. The gas purification system including the analytical measurement of gas impurities.

All measured data from the test insulation and the operational components are collected by a data acquisition system. Then follows data processing and documentation.

The ADI can be driven automatically in normal operation and in cycling operation. In both cases all security precautions are taken into account. This self-controlled operation is a great advantage cause it decreases costs.

In the mean time the experiments with the first test insulation have been finished and some results are presented in the fig. 5 to 8.

The set-up construction of the test insulation is very similar to that one, which was explained in the report of Mr. Bröckerhoff, just before (fig. 5). Within a pressure tube is a inner liner tube made of graphite. This tube is supported by special spacer rings. Blanketts of fibrous insulation material are wrapped around the graphite tube. The density of the fibrous material is about 130 kg/m^3.

A temperature profile within the insulation is shown in fig. 6. It is remarkable that the temperatures near the duct decrease so steeply.

The temperature distribution along the wall of the pressure tube is given in fig. 7. There are remarkable temperature peaks in the neighbourhood of the spacers and the temperature differences between upper and lower side are sometimes considerable.

The heat losses as a function of gas temperature are shown in fig. 8.
The heat losses of section 2 are higher because this section includes two spacers.

At present experiments are running with another test insulation with spherical spacers of Interatom Company. Mr. Bröckerhoff has reported before on the experimental results of this insulation in the temperature range up to 400° C. In ADI the temperature range of the measurements will be extended up to 950° C.

The experiences with ADI gained over a period of more than one year have shown that the specifications and operational requirements have been fulfilled completely and very satisfactorily.

The erection of the test facility ADI and the performance of the tests were sponsored by "Minister für Wirtschaft, Mittelstand und Verkehr des Landes Nordrhein-Westfalen".

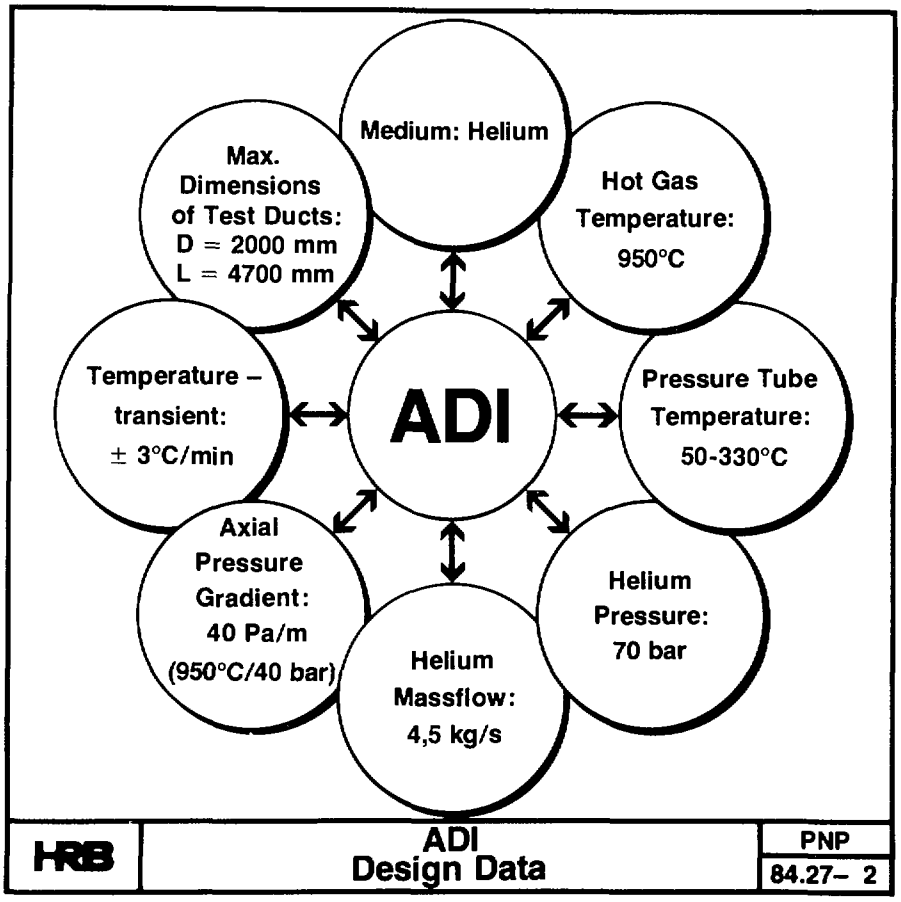
Medium: Helium
Max. Dimensions of Test Ducts: D = 2000 mm L = 4700 mm
Hot Gas Temperature: 950°C
Temperature – transient: ± 3°C/min
ADI
Pressure Tube Temperature: 50-330°C
Axial Pressure Gradient: 40 Pa/m (950°C/40 bar)
Helium Massflow: 4,5 kg/s
Helium Pressure: 70 bar
HRB
ADI
Design Data
PNP
84.27– 2

fig. 1

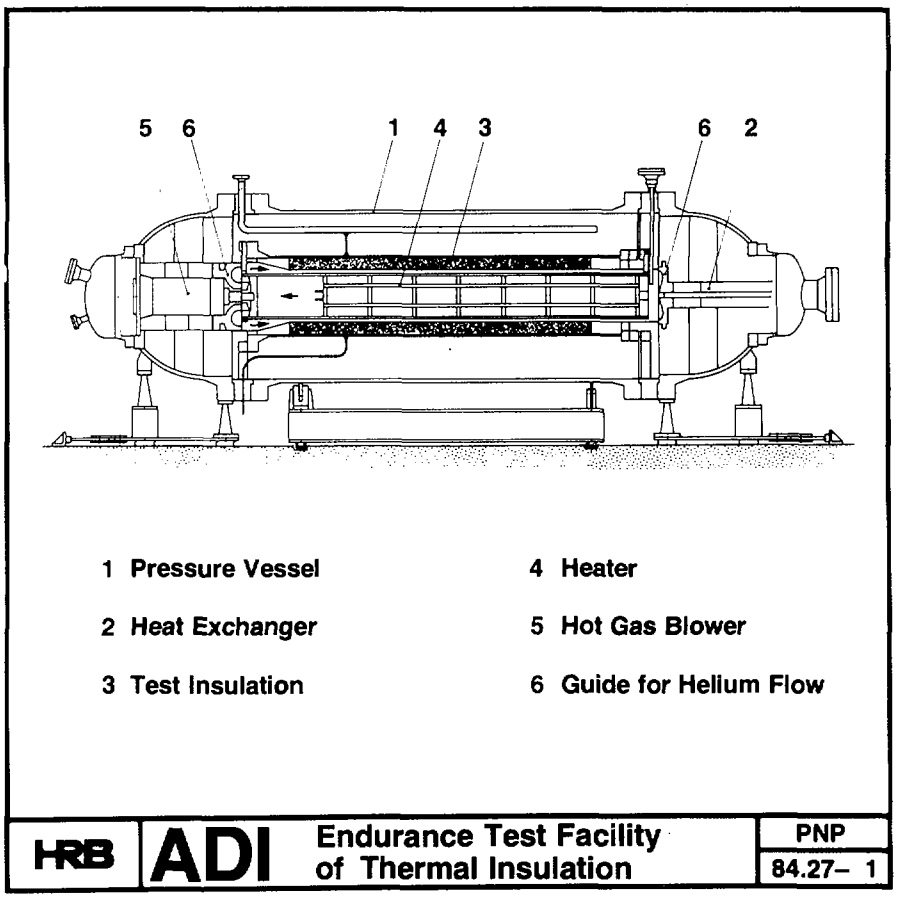
5 6
1 4 3
6 2
1 Pressure Vessel
2 Heat Exchanger
3 Test Insulation
4 Heater
5 Hot Gas Blower
6 Guide for Helium Flow
HRB
ADI
Endurance Test Facility of Thermal Insulation
PNP
84.27– 1

fig. 2

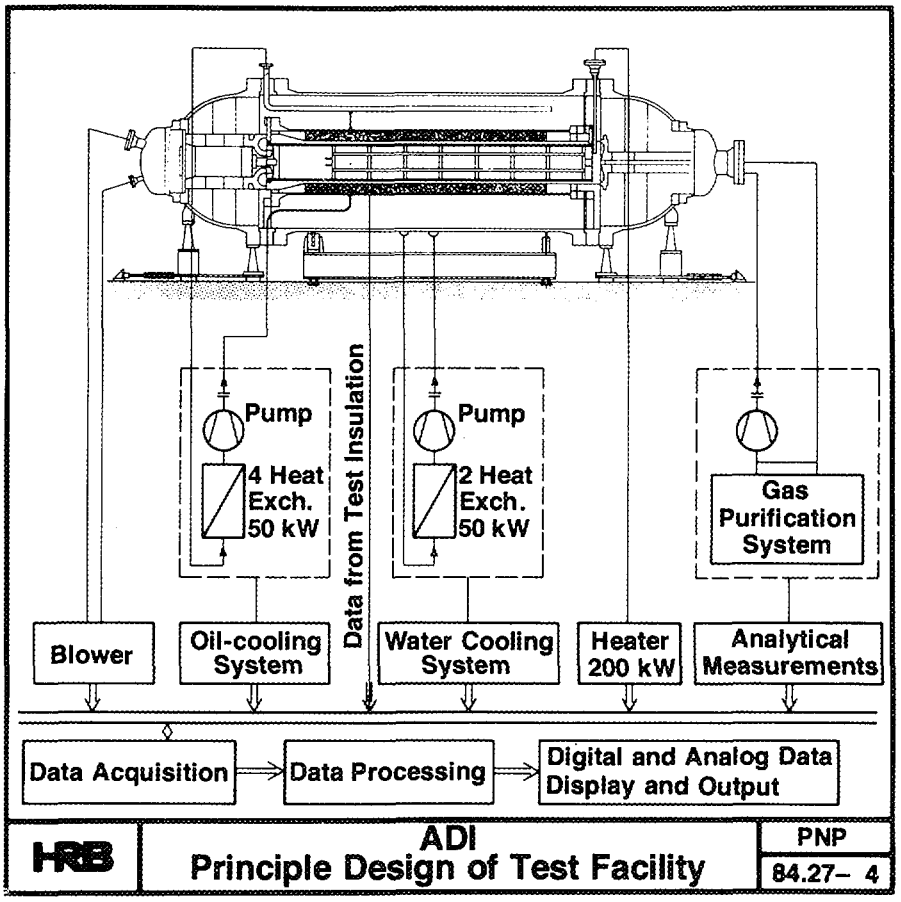
Pump
4 Heat Exch. 50 kW
Pump
2 Heat Exch. 50 kW
Gas Purification System
Data from Test Insulation
Blower
Oil-cooling System
Water Cooling System
Heater 200 kW
Analytical Measurements
Data Acquisition
Data Processing
Digital and Analog Data Display and Output
HRB
ADI
Principle Design of Test Facility
PNP
84.27- 4

fig. 3

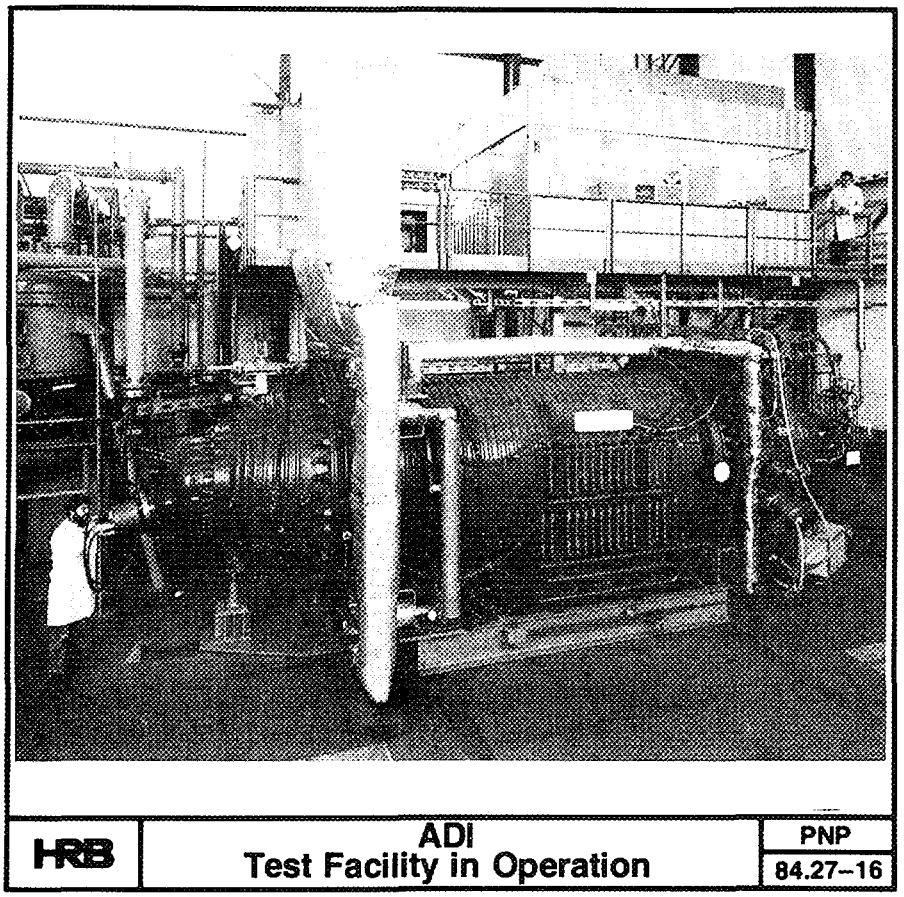
HRB
ADI
Test Facility in Operation
PNP
84.27-16

fig. 4

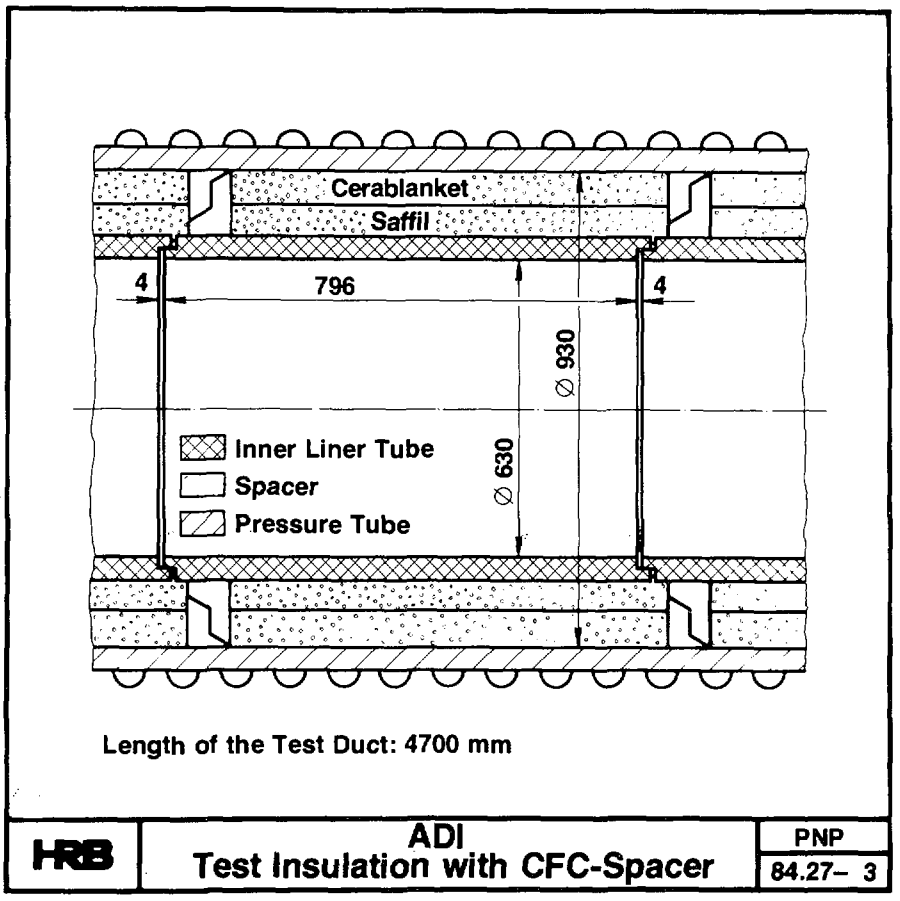
Cerablanket
Saffil
4
796
4
930
630
Inner Liner Tube
Spacer
Pressure Tube
Length of the Test Duct: 4700 mm
HRB
ADI
Test Insulation with CFC-Spacer
PNP
84.27– 3

fig. 5

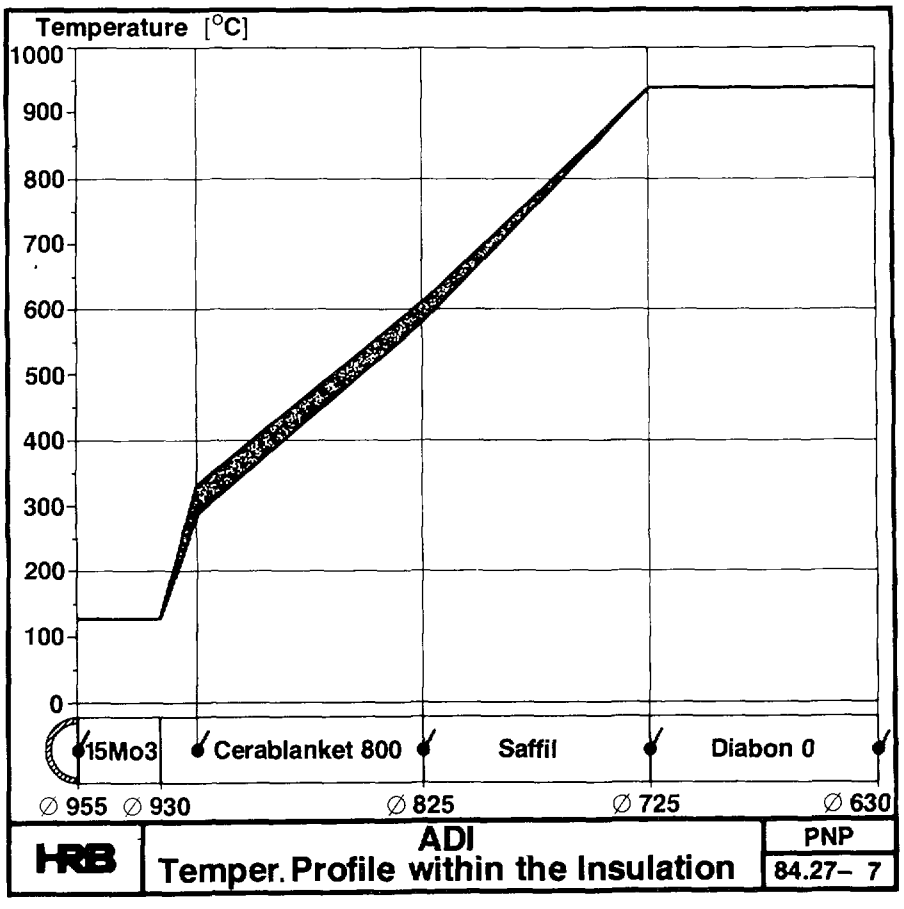
Temperature [°C]
1000
900
800
700
600
500
400
300
200
100
0
15Mo3
Cerablanket 800
Saffil
Diabon 0
∅ 955
∅ 930
∅ 825
∅ 725
∅ 630
HRB
ADI
Temper. Profile within the Insulation
PNP
84.27– 7

fig. 6

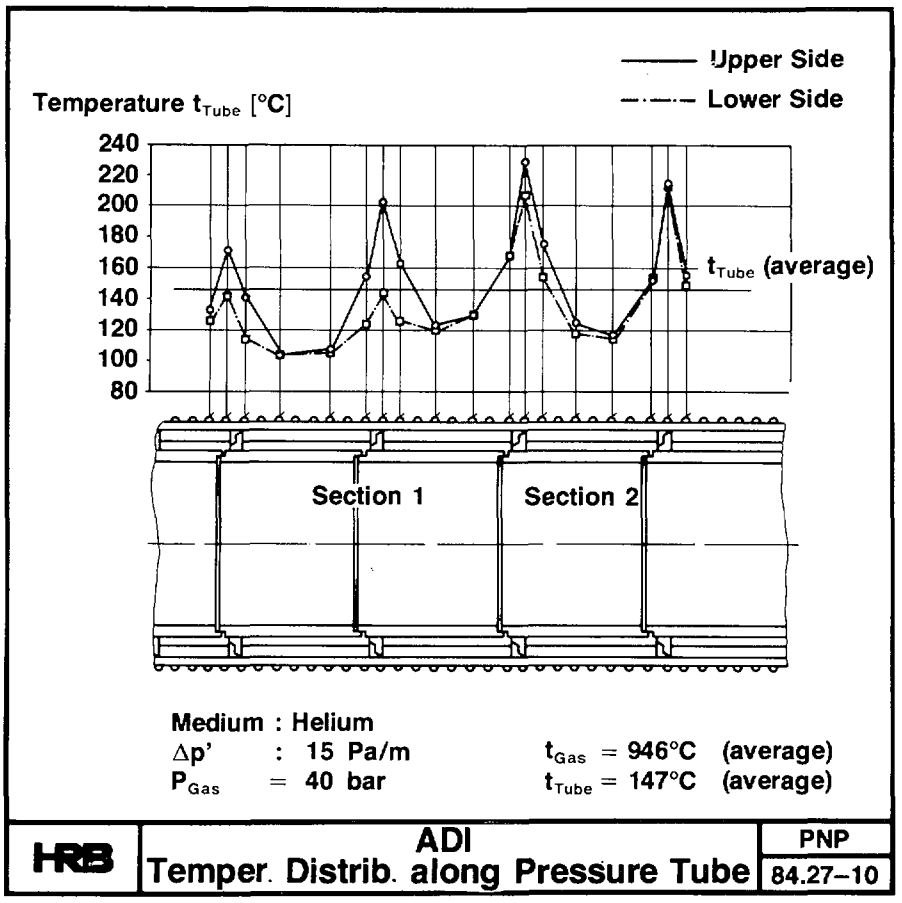
Upper Side
Lower Side
Temperature t_{Tube} [°C]
240
220
200
180
160
140
120
100
80
t_{Tube} (average)
Section 1
Section 2
Medium : Helium
Δp' : 15 Pa/m
P_{Gas} = 40 bar
t_{Gas} = 946°C (average)
t_{Tube} = 147°C (average)
HRB
ADI
Temper. Distrib. along Pressure Tube
PNP
84.27–10

fig. 7

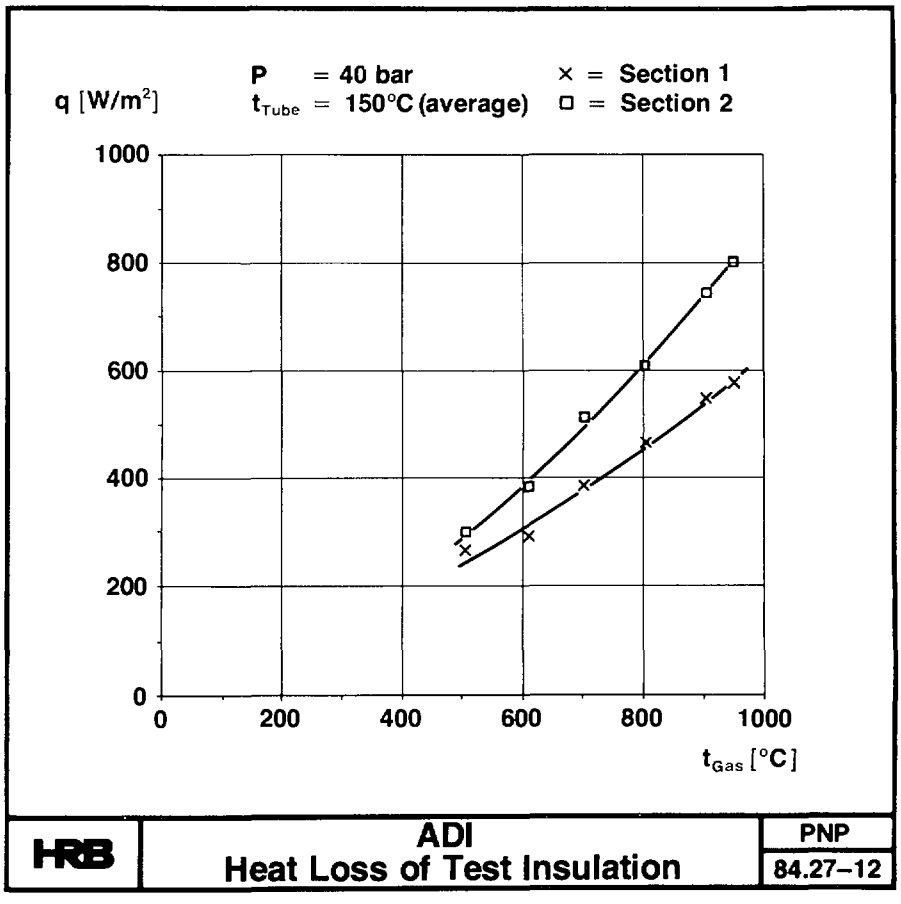
q [W/m²]
P = 40 bar
t_{Tube} = 150°C (average)
× = Section 1
□ = Section 2
1000
800
600
400
200
0
0
200
400
600
800
1000
t_{Gas} [°C]
HRB
ADI
Heat Loss of Test Insulation
PNP
84.27–12

fig. 8