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EVO design data and measurements for specified load cases

Günter Zahn

EVO

Germany

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**Compilation of Documentation
and
Publications about the
Helium-Turbine-Plant
of
Energieversorgung Oberhausen AG (EVO)**



Contents:

	<u>Page</u>
A. Report on Documentation concerning 50 MW-Helium-Plant Professor Dr. Ing. Karl Bammert (1988)	4
B. Possibilities to realize a Closed-Cycle-Helium-Turbine in a High Temperature-Reactor Professor R. Schulten (1989)	10
C. Documentation of the 50 MW-Heliumturbine of EVO and Consequences for further Developments and concerning stability of the Helium Turbine Professor H.J. Thomas (1987)	13
D. Documentation on Helium-Cleaning-System, Oil-Helium-Separation Equipment, Helium Storage - Helium Supply, University Dortmund, Professor Dr. Ing. P. M. Weinspach, Dipl.-Ing. M. Weber, Dr. Ing. A. Steiff (1988)	14
E. Documentation Helium-Turbine-Plant Oberhausen Technical Report of Kraftwerk Union AG	18
F. Details and Results of Testing at the Helium-Turbine-Plant Oberhausen Dr. W. Hensle EVO (1985)	21



	<u>Page</u>
G. Publications concerning the Helium-Turbine-Plant (1970 - 1983)	25
H. Collection of EVO-Research (1970 - 1983)	27
I. Documentation on Blade Damages EVO (1979)	32
J. Design Data and Description of the Turbogroups	33
K. Documentation Concerning Generator and Starting Device EVO (1980)	35
L. Insert of Mobil Oil DTE Medium in the Helium-Gasturbine-Plant	36
M. Concentric Pipe of the Helium-Turbine-Plant	37
N. Helium Sealing-Gas-Fan for the 50 MW Helium Turbine of EVO	38
O. Documentation Oil-Systems	39
P. Comprising Documentation over the 50 MW-Helium-Plant	40



**A. Report on Documentation concerning 50 MW-Helium-Plant
by Prof. Dr.-Ing. Karl Bammert
Institut of Turbomachinery University Hannover**

1. Goal of using a Helium-Turbine-Plant within the HHT-Program

- 1.1 Introduction
- 1.2 Helium as working fluid
- 1.3 The Helium-Circuit
- 1.4 German High-Temperature-Reactors
- 1.5 German closed-cycle Gasturbine-Plants
- 1.6 The High-Temperature-Helium-Turbine-Project (HHT)

**2. Description of the Plant Concept and basis of design
of the 50-MW-Helium-Turbine-Plant**

- 2.1 Heat Circuit
- 2.2 Total arrangement
- 2.3 Construction of the Turbo-Machines
 - 2.3.1 Comparison of Turbosets for the working fluids air and helium
 - 2.3.2 Turboset of the Hot-Air-Plant Gelsenkirchen
 - 2.3.3 Turboset of the Helium-Plant Oberhausen
- 2.4 Systems Sealing Gas, Cooling Gas, Sealings
 - 2.4.1 Sealing Gas System
 - 2.4.2 Cooling Gas System
 - 2.4.3 Sealings System



- 2.5 Construction of Heat Exchangers
 - 2.5.1 Heat Exchangers
 - 2.5.2 Pre- and intermediate Coolers
 - 2.5.3 Heliumheater
 - 2.5.4 Piping
- 2.6 Control equipment
 - 2.6.1 Circuit- and Control-Scheme
 - 2.6.2 Pressure Level Control
 - 2.6.3 Bypass-Control
 - 2.6.4 Safety System
 - 2.6.5 Speed Controller
 - 2.6.6 Hierarchy and Controlling

3. High-Temperature-Reactors in a closed Cycle

- 3.1 The HTR in the Helium-Turbine-Circuit
- 3.2 Built Gas-Cooled-Reactors

4. Hollow Radiation-Receivers in Gas-Turbines

- 4.1 Solar heated and fossil fired Radiation chambers
- 4.2 Air-Heaters of closed Gas-Turbines
- 4.3 Hollow-Radiation-Heaters of Solar Power-Plants



- 4.4 Radiation Stress of Piped Cavities
 - 4.4.1 Transfer of Useable Heat to working fluid
 - 4.4.2 Heat Stress in a fossil fired Radiation Chambers
 - 4.4.3 Heat Stress in Solar Heated Radiation Chambers
 - 4.4.4 The local Radiation over the Pipe-Perimeter
 - 4.4.5 Highest Permitted Stresses in the Tube Cross-Sections
- 4.5 Solarreceiver in terrestrial and orbital Uses
 - 4.5.1 Concave Receiver in terrestrial Solar Power Plants
 - 4.5.2 Concave Receiver in Industrial Space Stations

5. Realisation of the Plant Concept 50 MW-Helium-Turbine

- 5.1 Adaption to new Construction Details
- 5.2 Final Heat Circuit (As Built)

6. Listing of measured Performance Data of the 50-MW-Helium-Turbine-Plant

- 6.1 Deviation from Reference Point
- 6.2 Stationary Measurements
 - 6.2.1 Measurements of Temperatures, pressures and pressure losses in the different components
 - 6.2.2 Accuracy of the IFS-Measurements
 - 6.2.3 Measurements of throughputs in the auxiliary Systems
- 6.3 Measurements Results
 - 6.3.1 Circuit Data measured by IFS and MAN/GHH
 - 6.3.2 Auxiliary Systems



7. Analysis of the three measured Operation Points

- 7.1 Input Data for the Evaluation Program
- 7.2 Description of the Evaluation
- 7.3 Survey of Performances and Efficiencies

8. Performance Reduction in the Reference Point

- 8.1 Difference of Design and Evaluation
- 8.2 Influence of Pressure Losses on the Power Output at Terminals
- 8.3 Summary of the Data in the Reference Point

9. Evaluation of the Different Components and Discussion of their Influence on the total Plant

- 9.1 The offered 50 MW -Helium-Turbine-Set
 - 9.1.1 Reduction of the Number of Stages in the HP-Turboset
 - 9.1.2 Turbine-Guide-Wheel
 - 9.1.3 HP-Turboset with Center Bearing
 - 9.1.4 Adjustable blades in the Compressor Guide Wheel
 - 9.1.5 Sealing-Gas-Bleeding in HP-Compressor
- 9.2 Division of the Discharge Heads of the Compressors
- 9.3 Modification of the HP-Turboset
- 9.4 Influence of the Turbo-Machine-Efficiencies on the Efficiency at Terminals



9.5 Design-Values and As-Built-Values of the Different Components

9.5.1 Design-Values and As-Built-Values of the Turbomachines

- 9.5.1.1 HP-Turbine
- 9.5.1.2 NP-Turbine
- 9.5.1.3 HP-Compressor
- 9.5.1.4 NP-Compressor

9.5.2 Design-Values of the Sealing- and Cooling-Gas-Throughputs

- 9.5.2.1 Extraction from the Maincircuit
- 9.5.2.2 Feeding into the Maincircuit
- 9.5.2.3 Correction of Sealing- and Cooling-Gas-Extraction

9.5.3 As-Built-Values of the Sealing- and cooling-Gas-Throughputs

- 9.5.3.1 Sealing-Gas-Throughput
- 9.5.3.2 Cooling-Gas-Throughput

9.5.4 Discrepancy of Design and As-Built-Values of Sealing- and Cooling gas

- 9.5.4.1 Justification of the Design-Values for the Cooling-Gas
- 9.5.4.2 Justification of the Design-Values for the Sealing-Gas
- 9.5.4.3 Differences of Design and As-Built-Values

9.5.5 Pressure losses and their Design and As-Built-Values

10. Measures to reach the Design-Data

- 10.1 Performance improvement by Modifications
- 10.2 Performance improvement by Partial Renewals



**11. Findings and Operation Experience with closed-cycle Gas-Turbines
and Outlook to further Development of such closed Power-Plants
within future HTR-Programs**

12. Literature



B. Possibilities to realize a Closed-Cycle-Helium-Turbine in an High-Temperatur-Reactor by Professor R. Schulten (1989)

1. Comparison of Concepts

2. The most Important Technical and Physical Means of the Plants

3. Description of the Plants

- 3.1 Reactor-Physical-Characteristics
- 3.2 Function of the Plant of the Gas-Turbines with High-Temperature-Reactor
- 3.3 The Nuclear Reactor as Helium Heater
- 3.4 The Fuel-Element of the High-Temperature-Reactor
- 3.5 Criteria for the mechanical Design of High-Temperature-Reactors
with directly Connected Gas-Turbine
- 3.6 Design of the Reactor with 200 MW_{th}
- 3.7 Design of the Reactor with 1200 MW_{th}

4. Auxiliaries

- 4.1 Handling of Fuel Elements
- 4.2 Helium-Purification
- 4.3 Surface Coolers
- 4.4 Devices to treat Radioactive waste
- 4.5 Ventilation equipment under Nuclear-Conditions



5. Fission Products, Radioactivity

- 5.1 Holding back of radioactive Fission Products
- 5.2 Contamination of Primary circuit
- 5.3 Activation of Circuit-Components

6. Safety Questions

- 6.1 Principals of Inherent Safety
- 6.2 Screening against direct Radiation
- 6.3 Means of Controlling malfunctions
- 6.4 Quality Management

7. Malfunctions

- 7.1 Means for Reactor Protection
- 7.2 Malfunctions based on reactivity
- 7.3 Break down of Reactor Cooling
- 7.4 Malfunctions of Turbine
- 7.5 Air- and Water-Leakage's in the primary circuit

8. Protection against Influences from outside

- 8.1 General
- 8.2 Earth quake
- 8.3 Plain crash
- 8.4 Shock wave due to Explosion
- 8.5 Influences by third Parties



9. Fuel Element disposal

9.1 Fuel Element Storage

9.2 Disposal

10. Shut down

10.1 Shut down by secured coverage

10.2 Total removal



C. Documentation of the 50-MW-Helium-Turbine of EVO and Consequences for further Developments and concerning stability of the Helium Turbine

by Professor Dr.-Ing. H.-J. Thomas

Institut of Thermal Power Plant, Technical Universität München

- 1. Introduction: Shaft oscillations of Turbo-Machines**
- 2. The Vibration behaviour of the EVO Helium-Turbine**
 - 2.1 Operation Experience
 - 2.2 Theoretical Investigations
 - 2.3 Results of Measurements
 - 2.4 Judgement from today's view
- 3. Further Development of the Helium-Turbine**
 - 3.1 Basic Considerations
 - 3.2 Judgement of Designs for High power outputs
- 4. Summary and consequences**
- 5. Quoted Literature or Reports**
- 6. Enclosure**
 - 6.1 Table 1
 - 6.2 Table 2 Rating deficiency of EVO-Helium Turbine



**D. Documentation on Helium-Cleaning-System,
Oil-Helium-Separation Equipment, Helium Storage - Helium Supply**

**by Prof. Dr.-Ing. P. M. Weinspach,
Dipl.-Ing. M. Weber,
Dr. Ing. A. Steif
University Dortmund, Abt. Chemietechnik
Institut for thermal Process Engineering**

1. Introduction

2. Structure and function of the Helium-related auxiliaries

2.1 Auxiliaries of the Helium-Turbine

2.2 Sealing of rotating parts in the Helium circuit

2.2.1 Structure of a Labyrinth Sealing

2.2.2 Sealing Helium-, Bearing oil- and Sealing oil supply

2.2.2.1 Sealing Helium System

2.2.2.2 Bearing oil System

2.2.2.3 Sealing oil System

2.3 Oil-Helium-Separation device

2.4 Helium-Purification Plant



2.5 Helium-Storage and supply System

2.6 Devices to control the Helium purity

3. Handling and operation of the Helium-related auxiliaries

3.1 Regeneration and starting of the Helium Purification Plant

3.1.1 Changing of the Particle Filters

3.1.2 Regeneration of the H₂O/CO₂-Adsorber

3.1.3 Drying of the Helium-Purification Plant

3.1.4 Regeneration of the low Temperature Adsorber

3.1.5 Cooling down of the Helium-Purification Plant

3.2 Start up of the Helium Storage and supply Systems

3.3 Start up of the Turbine circuit

3.4 Cleaning of the Turbine circuit during Operation

3.5 Power Control of the Turbine Plant

3.6 Shut down of the Turbine circuit including auxiliaries

3.7 Handling and operation of the Oil-Helium-separation Plant



4. Documentation of operation results concerning Helium-purity and modelling of the main process units

- 4.1 Reasons for the occurrence of Impurities in the Helium circuit
- 4.2 Helium purity under continuous operation of the Purification Plant
- 4.3 Composition of the Helium after Shut down of the Purification Plant
- 4.4 Influence of Feeding of stored Helium on the purity in the Turbine circuit
- 4.5 For balancing the main Impurities in the separation devices of the Helium purification and Oil-Helium-Separation Plant during constant Turbine load
 - 4.5.1 Simplified mathematical total model for the Helium Turbine Plant
 - 4.5.2 Mathematical modelling of the Adsorption
 - 4.5.3 Comparison of the different operation modes and their Influence on the cycle time of the Adsorbers in the Helium Purification Plant
 - 4.5.3.1 Influence of different start concentrations
 - 4.5.3.2 Influence of instationary Helium mass flow
 - 4.5.3.3 Investigation of a Temporarily operation of the Helium Purification Plant
 - 4.5.3.4 Influence of the amount of desorption



5. Judgement of the existing Plant Concept and the transferability of the results to a high Temperature Reactor with Helium Turbine (HHT)

5.1 The HHT-Concept

- 5.1.1 Structure of a High Temperature Pebble bed Reactor with Turbine in the primary circuit
- 5.1.2 Criteria for the use of Helium as working medium
- 5.1.3 Consequences of the Impurities and the purity of the Helium to be guaranteed

5.2 Estimation of occurring Impurities for a 500 MW HHT-Plant

- 5.2.1 Extrapolation of the results of the existing Helium Turbine to a 500 MW -Plant
- 5.2.2 Additional Impurities because of the Nuclear Processes

5.3 Evaluation and possibilities of use of the existing auxiliaries in a HHT-Plant

- 5.3.1 Evaluation of the Effectivity of the Helium Purification Plant and the Oil-Helium-Separation Plant for the HHT-Project
- 5.3.2 Suggestion and means for use of the auxiliaries in a HHT-Plant

6. Symbols

7. Literature



E. Documentation Helium-Turbine-Plant Oberhausen

Technical Report of Kraftwerk Union AG

I. Recommendation for improvement of the 50 MW-Turbine Plant of EVO

1. Introduction

2. Operation experiences and Load measurements at the 50-MW-Turbine Plant

2.1 Operations experiences

2.2 Load measurements

3. Flow- and Blading-Losses in the Turbine Machine

4. Sealing and Cooling Gas Losses

5. Pressure Losses in the System

6. Recommendation

II. Layout of a Helium-Gasturbine with 50 MW Power Output for EVO-Cycle acc. To KWU-Layout

1. Checking the EVO-Machine Criterions

2. Layout acc. KWU-Criterions

2.1 Cycle data



2.2 Layout calculations

2.2.1 Standard Compressor and Turbine layout under use of Ferrite disk- and diagram Turbine Material and use of cooling gas

2.2.2 Standard compressor and Turbine layout under use of Austenite disk- and diagram material and reducing of the cooling gas mass flow rate

III. Layout and structure of Helium-Gas-Turbines acc. The KWU-concept for capacities between 100 and 1.000 MW at an example of a machine or 500 MW power output

1. Introduction

2. Thermodynamics Layout

2.1 Foundations

2.2 Layout calculations

2.3 Results

3. Description of the construction of the Turbo machine

3.1 General

3.2 Rotor and Bladings

3.3 Casing

3.4 Hot Gas Supply to the Turbine

3.5 Bearing- and Labrication System

3.6 Labyrinth System for packing the Shaft Bashing



4. Positioning, Foundation and Piping

5. Control System

IV. Enclosures to Point I to III



F. Details and Results of Testing at the Helium-Turbine Oberhausen

Dr. W. Hensle, EVO (1985)

1. Introduction

- 1.1 Description of the Cycle
- 1.2 Development of the different Layout Data
- 1.3 Determination of the Layout Data

2. Casing

- 2.1 Casing Materials
- 2.2 Guide Wheel Carrier

3. Rotors

- 3.1 Rotor Material
- 3.2 Geometrie of the Rotors

4. Blading Installation

- 4.1 Kind of the Blading Installation
- 4.2 Material of the Blading Installation and their Mounting Hardware
- 4.3 Clearing between Blades
- 4.4 Rotor- and Blade-Foot-Cooling

5. Bearing of the Rotors

- 5.1 Bearing Concept of Turbo Machine Section
- 5.2 Used Bearing Variantes and - Geometry

6. Gear



7. Generator/Motor

- 7.1 Design Layout of the Generator
- 7.2 Start up of the Turboset with the Generator and the Start up Device

8. Fossil fired Helium Heater

- 8.1 Design Layout of the Heater
- 8.2 Material

9. Heat Exchanger and Main-Cycle-Pipes

- 9.1 Helium-Water-Precooler
- 9.2 Helium-Water-Intercooler
- 9.3 Helium-Helium-Heat Exchanger
- 9.4 Connection Pipes of the Main Cycle

10. Helium Purification Plant

- 10.1 Demanded Purity Grade
- 10.2 Description of the Helium Purification Plant
- 10.3 Gas Analysis
- 10.4 Reached Purity Grades in the Main-Cycle
- 10.5 Break in at air in the Helium Cycle

11. Helium-Storage-System

12. Oil- and Helium-Sealing Systems

- 12.1 Labyrinth Sealing
- 12.2 Sealing oil gland
- 12.3 Stationary Seal
- 12.4 External Sealing Gas Fan
- 12.5 Sealing Gas System
- 12.6 Sealing Oil System



12.7 Oil Systems

- HP-Oil-Supply
- Closed LP-Oil System
- Jacking Oil System
- Control- and Stationary Oil Systems
- Open LP-Oil-System
- Cooling Oil System

13. **Safety Equipment of the Turboset**

- 13.1 Quick-Opening and Control-Valve
- 13.2 Speed Measurement and Control
- 13.3 Rotor Vibration-Measurements
- 13.4 Shut down of the Helium Plant during a Black Out

14. **Researches at the Helium-Turbine-Plant**

- 14.1 Investigation of the rotor vibration at the LP-Compressor and at the HP-Compressor
 - 14.1.1 Theoretical Investigations
 - 14.1.2 Measuring Point and Data Logging
 - 14.1.3 Analysis of the Measurements
- 14.2 Acoustic and Vibration Measurements at the Liner of the Helium Turbine Plant
 - 14.2.1 Acoustic Measurements at the concentric hot Gas Pipe
 - 14.2.2 Expansion Measurements of the inner turbos of the hot gas Pipe



- 14.3 Checking of the Pressure and Temperature Load of the Insulation
 - 14.3.1 Description of the Researching Measurements Points
 - 14.3.2 Data recording and Data evaluation
 - 14.3.3 Results of the Researches

- 14.4 Investigation of the dynamics of the Helium Turbine Plant
 - 14.4.1 Data Acquisition
 - 14.4.2 Carried out Measurements

- 14.5 Investigation of the dynamics of the auxiliary systems
 - 14.5.1 Measuring Point and Data Logging
 - 14.5.2 Behavior of the plant and the auxiliary system during quick opening case

- 14.6 Investigation of the Temperature profile in the heat exchanger, especially during the operation of bypass mixture



G. Publications concerning the Helium-Turbine-Plant (1970 - 1983)

- 1. Operation experience with hot air Powerstations and conclusions
for further development of helium powerstations**
Gerhard Deuster and Robert Plür, EVO (1970)
- 2. The 50-MW-Helium-Gasturbine-Plant in Oberhausen**
Robert Plür and Horst Wilzhoff, EVO (1976)
- 3. Some aspects for the construction of the
50-MW-Helium-Turbine-Plant at EVO Oberhausen AG**
Dr. Peter Zenker, EVO (1974)
- 4. The 50-MW-Helium-Turbine-Plant Oberhausen**
Dr. Peter Zenker, EVO (1975)
- 5. The closed cycle Gasturbine - historical development
and importance in future**
Gerhard Deuster, EVO (1978)
- 6. The high temperature reactor - Helium cycle,
Experience from 20.000 hours, experimental operation**
Walter Jansing and Herbert Teubner, Interatom GmbH (1990)
- 7. Helium-Turbines for nuclear powerstations**
Gutehoffnungshütte Sterkrade AG Oberhausen (1967)



8. The Helium-Turbine-Heatpower-Plant Oberhausen

Professor Karl Bammert (1974)

9. The Helium-Turbine-Powerstation Oberhausen

Layout and Design

Professor Karl Bammert und Gerhard Deuster (1974)

**10. Instrumentation and Procedures to the Measurement at the
Dynamic Behaviour at the Helium-Turbine-Plant Oberhausen**

Karl Bammert, Joachim Johanning, Erich Weidner (1983)



H. Collection of EVO-Research (1970 - 1983)

1. Investigation of shaftvibrations of the LP-Compressor and the HP-Parts of the Helium-Turbine of Energieversorgung Oberhausen

Report on experiment "A" (24.11.1978)

Prof. Dr. Ing. O. Mahrenholtz

Dr. Ing. B. Grabowski

Dipl.-Ing. V. Schlegel

Institut for mechanical engineering, Hannover University

2. Investigation of shaftvibrations of the LP-Compressor and the HP-Parts of the Helium-Turbine of Energieversorgung Oberhausen.

Final report on experiment "A" (31.08.1981).

Prof. Dr.-Ing. O. Mahrenholtz, Institut for mechanical engineering,
Hannover Universität

3. Intermediate Report regarding Acoustic Measurements of the EVO-Plant (29.11.1978)

Prof. Dr.-Ing. G. Dibelius, Chair and institute for steam and gas turbines,
Rheinisch Westfälische Technische Hochschule RWTH Aachen
(Institute for Technology).



4. Acoustic and vibration measurement of the Helium Turbine of EVO

Technical report (January 1979)

K.H. Thode, Interatom

5. Acoustic and vibration measurement of the helium turbine of EVO

Final report on carried out measurements during experiment „B“
up to November 1980 (February 1982).

K.H. Thode, Interatom

**6. Intermediate report concerning the assessment of the
expansion of the inner tubes of the Helium Turbine of EVO**

(November 1978, replenished August 1979)

Prof. Dr.-Ing. H. Öry

Dipl.-Ing. H. Lahme

Institut for light construction Rhein.-Westf. Technische Hochschule Aachen.



7. Final report concerning the assessment of the expansion of the inner tubes of the Helium-Turbine, EVO (August 1981).

Part of Experiment "B"

Prof. Dr.-Ing. Öry

Dipl.-Ing. H. Köstner

Dipl.-Ing. H. Lahme

Dipl.-Ing. M. Wahle

Institut of light construction, Rhein.-Westf. Techn. Hochschule Aachen

8. Investigation of the Behaviour of the inner insulator of the coaxial tube of the Helium-Turbine, EVO

Final report on carried out measurements during experiment "C" from February 1977 to Dezember 1980 (Dezember 1981)

Ebers, Interatom

9. Investigation of the dynamism of the auxiliary systems Experiment "E" (October 1978).

GHH-Sterkrade AG



10. Temperature profile measurements in the heat exchanger of the helium turbine, especially the bypass mixer

Final report of the period 1979 - 1981

K. Freckmann, GHH-Sterkrade AG

11. Instrumentation of the coaxial tube experiments of the helium turbine, EVO

Technical report (11.02.1976)

H. Stehle, H.-H. Thode, J. Wolf, Interatom

12. Description of data recording and assessment software for the investigation under extreme pressure and Temperature conditions of the Helium Turbine, EVO

Technical Report (10.10.1978)

W. Nickel, R. Schmidt, Interatom



13. Investigation of the coaxial inner tube insulation and extreme pressure and temperature conditions.

Technical report on measurements up to May 1978 (06.04.1979)

14. Investigation of extreme force on the casing of the LP-Turbine due to the 50 MW-Helium Pant in Oberhausen

Report Nr. 8015 (18.03.1980)

Dipl.-Ing. K. Latsch,
Ingenieurbüro Dr.-Ing. K. Pitscheider

15. Report on the results of the stress investigation of the casing under different exhaust pipe conditions.

Report Nr. 8081 (16.12.1980)

Dipl.-Ing. K. Latsch,
Ingenieurbüro Dr.-Ing. K. Pitscheider



I. Documentation of Blade Damages EVO (1979)

1. Introduction

2. Blade Material

3. Blade Damages

3.1 Blade damages from 05.02.1979

3.1.1 Course of damage

3.1.2 Examination of the damaged blade

3.1.3 Further damages

3.1.3.1 Damages on the HP-blading

3.1.3.2 Damages on the LP-Turbine blading

3.1.4 Steps of Repair

3.1.4.1 HP-Turbine

3.1.4.2 LP-Turbine

3.1.5 Further steps

3.2 Blade damage from 07.05.1985

3.2.1 Blade rubbing damage

3.2.2 Damages on the sealing elements

3.2.3 Damages at the moving blades at the sealing groove

3.2.4 Discussion concerning the origin of chlorides at the external platings



J. Design Data and Description of the Turbogroups

1. Introduction

2. LP-Compressor

2.1 Casing

2.1.1 Guide Blade Carrier

2.2 Rotor

2.3 Blading Installation

2.3.1 Kind of the Blading Installation

2.3.2 Material of the Blading Installation

2.3.3 Clearance between Blades

2.4 Bearing Pedestal of the Rotors

3. HP-Compressor and Turbine

3.1 Casing

3.1.1 Guide Blade Carrier

3.2 Rotor

3.3 Blading Installation

3.3.1 Material of the Blading Installation

3.3.2 Clearance between Blades

3.3.3 Rotor- and Blade-Root-Cooling

3.4 Bearing Pedestal of the Rotors



4. LP-Turbine

4.1 Casing

4.1.1 Guide Blade Carrier

4.2 Rotor

4.3 Blading Installation

4.3.1 Material of the Blading Installation

4.4 Bearing Pedestal of the Rotors



K. Documentation Concerning Generator and Starting Device EVO (1980)

1. Generator

2. Starting device

2 a) Principle of choice of starting device

2 b) Description of starting device

2 c) Start- and shut down of the Helium Turbine with starting device

3. Operating experience

3 a) Start- and shut down the plant with starting converter

3 b) Operating hours

3 c) Current consumption

3 d) Trouble in the start up device



L. Insert of Mobil Oil DTE Medium in the Helium-Gasturbine-Plant

- 1. General Description of the Oil-Systems**
- 2. Quality Requirements for Turbine Oils**
- 3. Important technical Data of the used Oils**
- 4. Emergency Lubrication Property of Oil in Helium Atmosphere**
- 5. Documents about Solubility of Gases in Lubricants**
- 6. Operating Experience**



M. Concentric Pipe of the Helium-Turbine-Plant

1. Description

1.1 Materials

- 1.1.1 Kaowool
- 1.1.2 Welmonil 43
- 1.1.3 Heat resistant austenitic steel
- 1.1.4 High temperature resistant austenitic steel

2. Structural point of view

3. Damages at the concentric Pipe

4. Experiments

- 4.1 Sound and Vibration Measurement
- 4.2 Investigation of the Behaviour of the Insulation
at the inside insulation of the concentric Pipe

5. Literature



N. Helium Sealing-Gas-Fan for the 50 MW-Helium-Turbine of EVO

- 1. Introductory remarks**
- 2. Layout of the Sealing-Gas-Fan**
- 3. Details of the design of the Sealing-Gas-Turbine**
 - 3 a) Fan
 - 3 b) Driver of the Sealing-Gas-Fan
 - 3 c) Helium Tightness for passage of Power and control Cable and Installation of a Inspection Glass
 - 3 d) Lubrication of the Bearings
- 4. Operating Experience**
 - 4 a) Collector Coal for the Motor
 - 4 b) Further Operating Experience



O. Documentation Oil-Systems

1. Introduction

2. Description of the Oil Systems

2.1 Control Oil System

2.1.1 Stationary Seal

2.2 HP Oil-System

2.3 Lifting Oil System

2.4 Closed LP-Oil-System

2.5 Seal Oil system

2.6 Open LP-Oil-System

2.7 Cooling Oil System



P. Comprising Documentation over the 50 MW-Helium-Plant

by Prof. Thomas Bohn

Essen, University

1. Background and possibilities of development of the Helium-Turbine-Project

- 1.1 Development of gas cooled reactors
- 1.2 Possibilities of development of the HTR-Project
- 1.3 Hotair-Turbines in Germany and the Concept of the Helium-Turbine Plant in Oberhausen

2. Design of the Helium-Turbine-Plant in Oberhausen

- 2.1 Total concept
- 2.2 Heliumheater
- 2.3 Turbine
- 2.4 Heat exchanger and coolers
- 2.5 Piping
- 2.6 Helium, sealing and cooling cycles
- 2.7 control



3. Results of operation and experiences

- 3.1 Survey on operation
- 3.2 Control equipment's
- 3.3 Main results
- 3.4 Comparison concerning design data
- 3.5 Causes of Underperformance
- 3.6 Consequences for major plants

4. Classification and result from the actual point of view

- 4.1 Nuclear crisis and the HTR
- 4.2 Concepts of HTR plants and their classification
- 4.3 Results