Survey on 20 Years of R&D on Nuclear Process Heat Applications in Germany

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IAEA Int. Conf. On Non-Electric Applications of Nuclear Power
April 16-19, 2007 Oarai, Japan

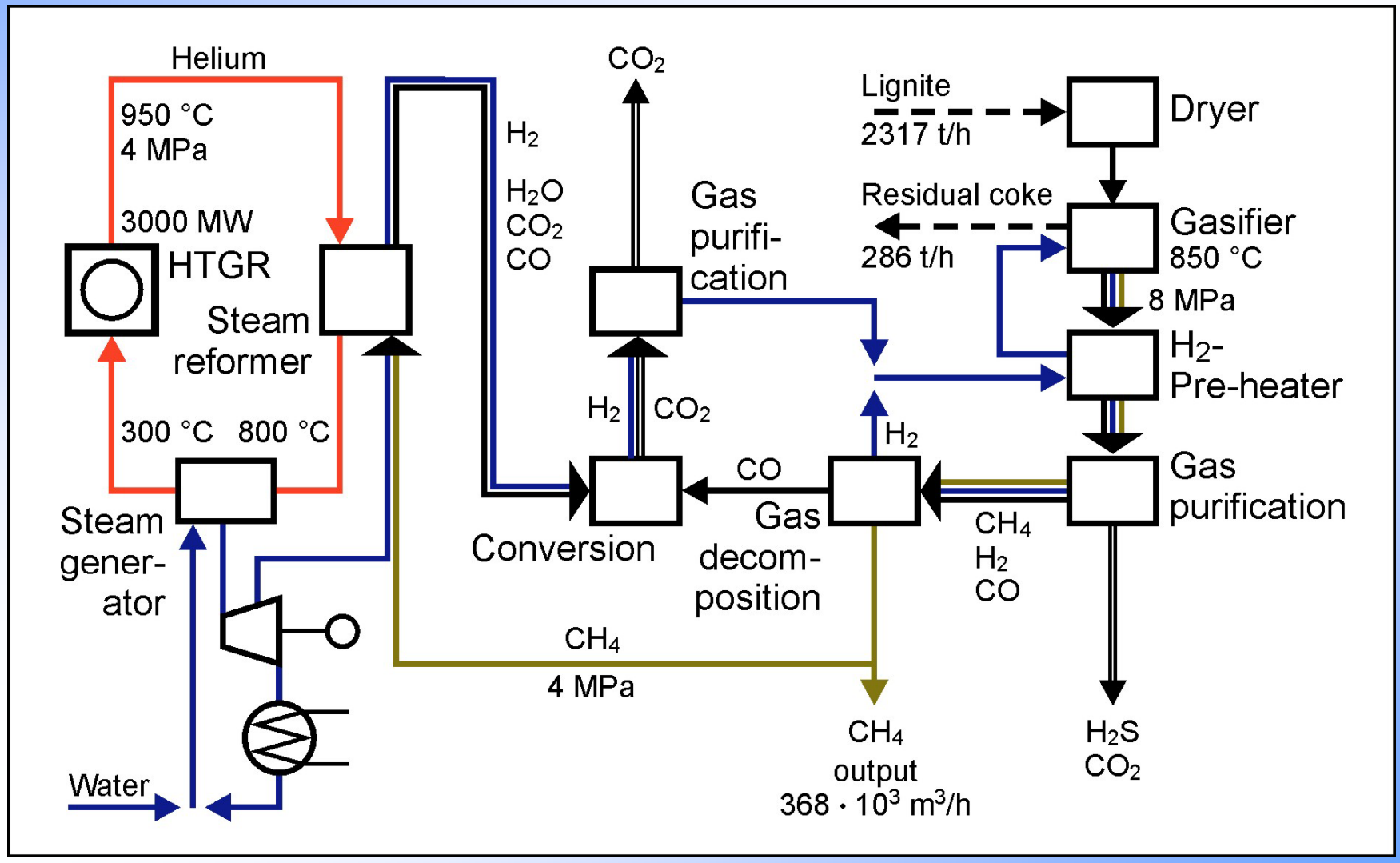
Objectives of the PNP-Project

- Develop, design, and construct an energy system based on the large resources of coal and uranium
- Reduce dependency on imports of fossil fuels
- Introduce nuclear energy into process heat market
- Reduce noxious gas emissions to environment by the nuclear production of SNG, synthesis gas, hydrogen, etc.

Development Steps of Nuclear Coal Gasification

- Identify appropriate gasification processes on lab scale
- Test selected processes on semi-technical scale
- Construct and operate pilot plants for selected processes
- Design large-scale nuclear plant for process heat prod.
- Construct and operate prototype nuclear coal gasification plant
- Construct and operate commercial nuclear coal gasification plant

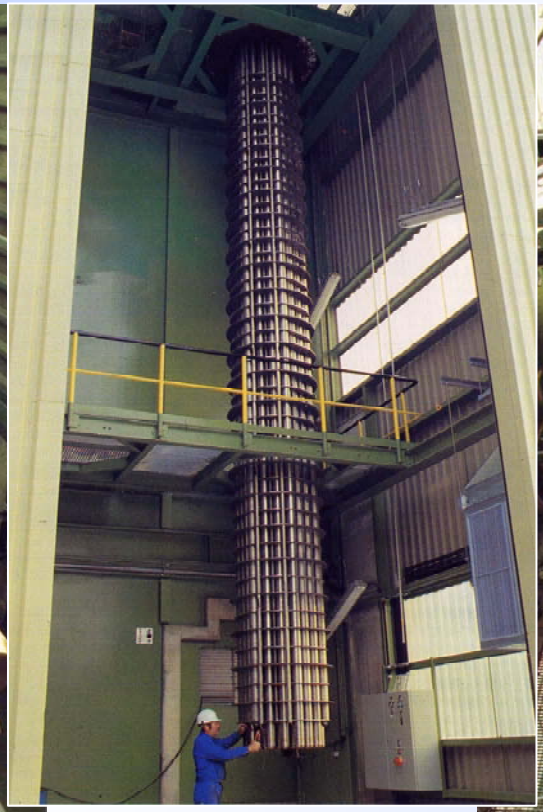
Nuclear Hydrogenating Coal Gasification

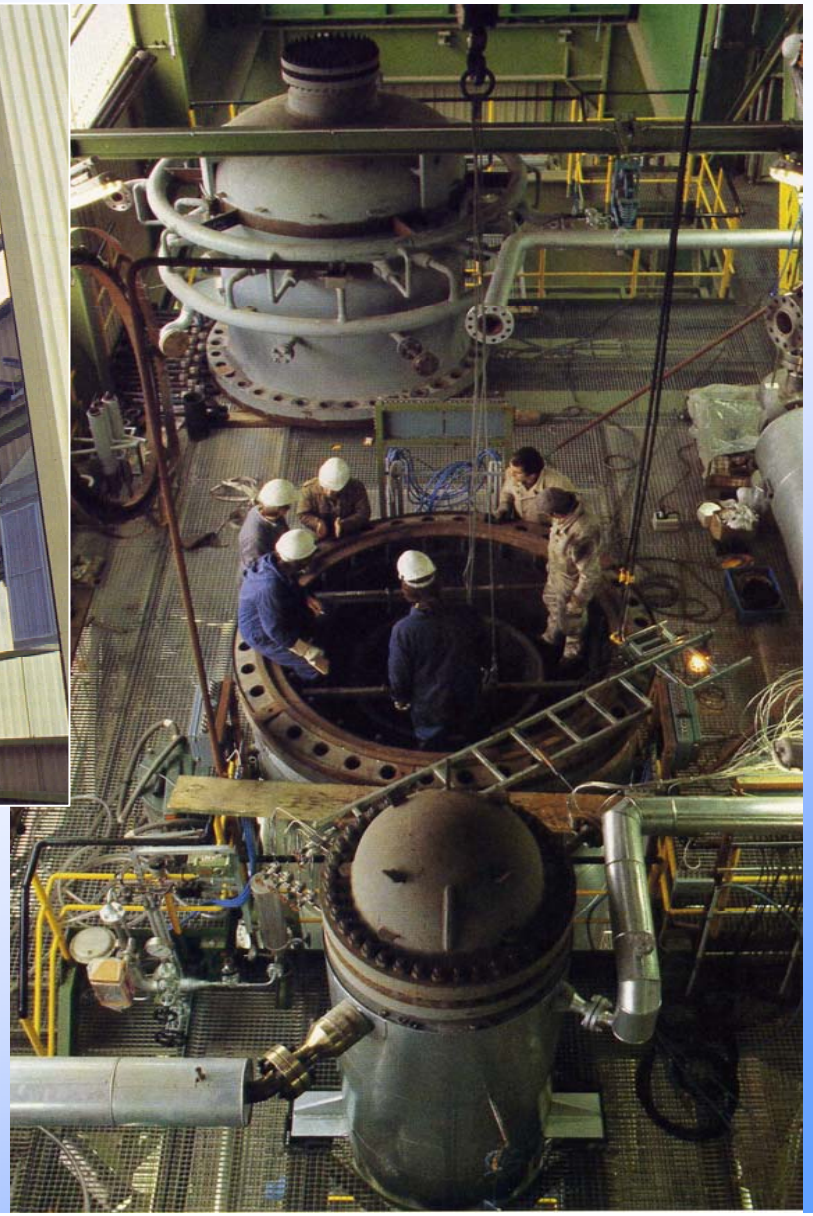


Pilot Plant for Hydro Coal Gasification

- Semi-technical scale testing 1975-1982 with 0.2 t/h
- Pilot plant scale testing 1983-1986 with 10.0 kg/h
- Gasification at 850-950°C and 6-12 MPa
- Coal throughput of ~40,000 t with up to 6400 Nm^3/h of SNG
- Operation time of ~8000 h

Steam Reformer





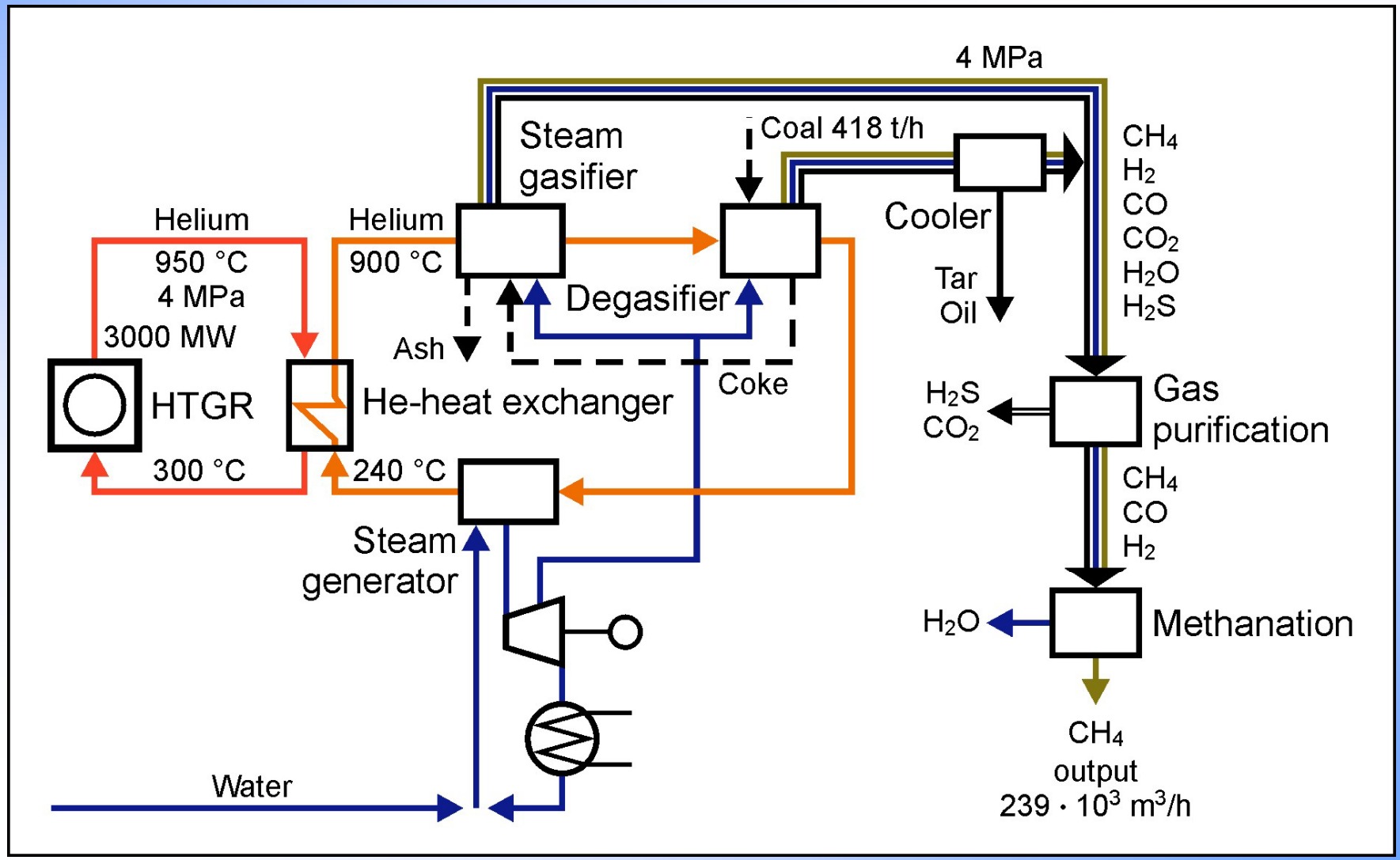
EVA-II reformer tube bundle
at the Research Center Jülich

Technical Data of EVA-II / ADAM-II

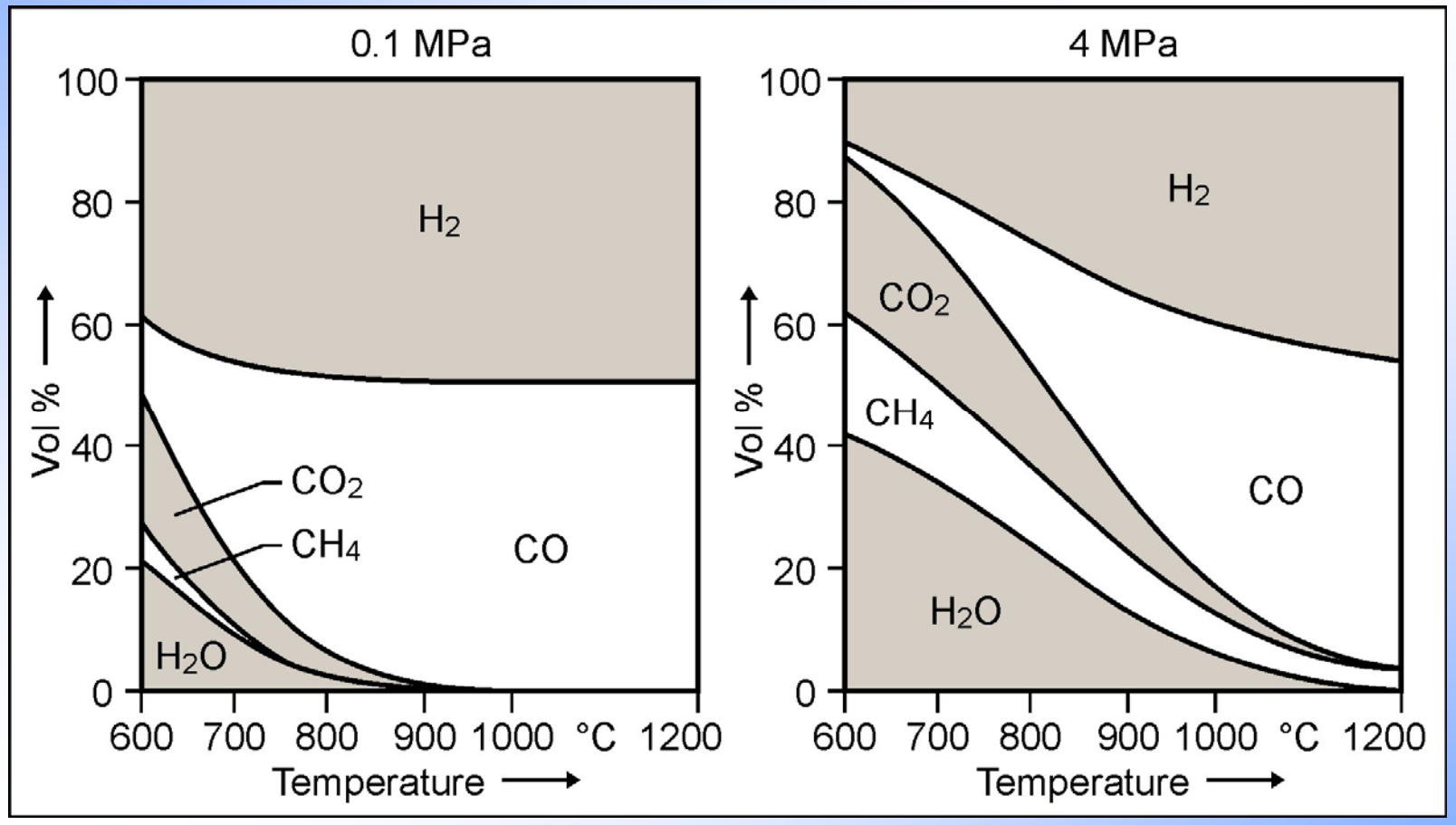
Power Input	10 MW(e)
Cooling gas flow rate	4 kg/s of helium
Pressure	4 MPa
Temperature max/min	950/350 °C
SG temperature/pressure	700 °C / 5.5 MPa
Methane input	0.6 kg/s
Steam reforming temp. max	820 °C
Methanation temp. max	650 °C
ADAM-II heat release rate	5.3 MW(th)

From 1981 - 1986: **13,000** hours of operation, of which **7750** h at 900 °C and **10,150** h as complete process

Nuclear Steam Coal Gasification

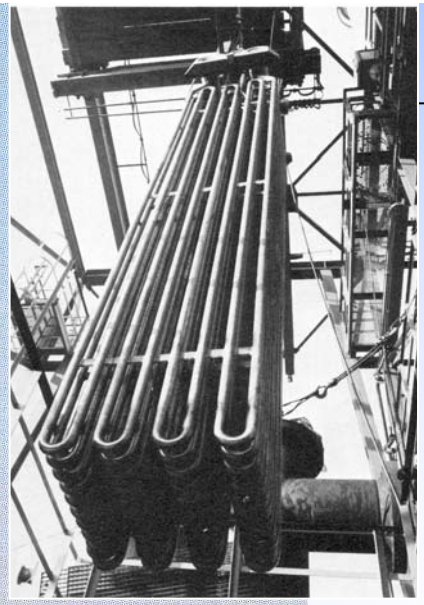


Gas Composition after Steam Coal Gasification



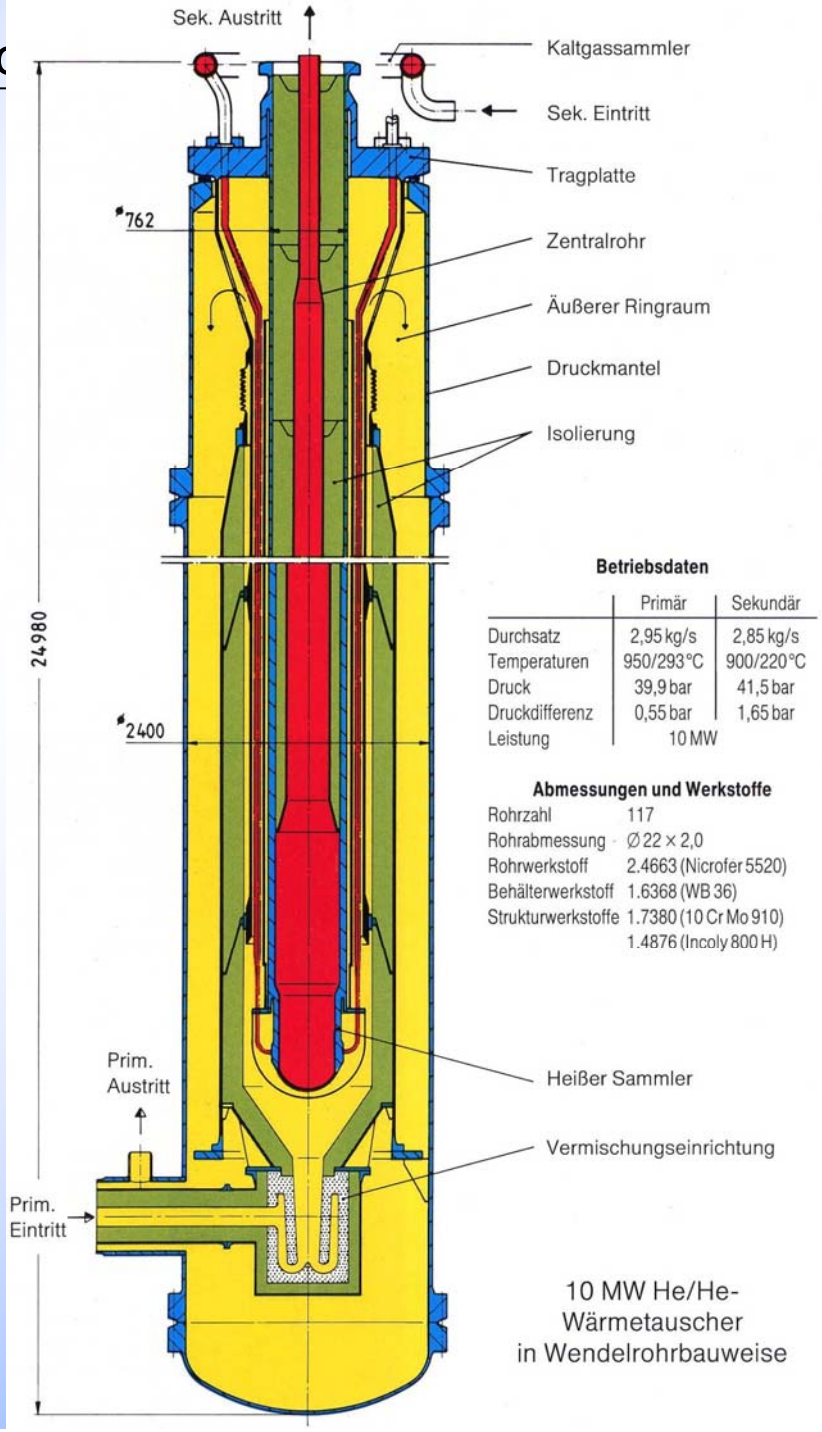
High pressure increases methane content → good for SNG production
High temperature increases hydrogen content → good for syngas production

Nuclear Simulated Steam Coal Gasification



- Lab scale testing
  1973-1980 with 5.0 kg/h
- Semi-technical scale testing
  1976-1984 with 0.5 t/h
- Gasification at 750-850°C and 2-4 MPa
- Total coal gasified: 2413 t
- Operation time of ~26,600 h with
  ~13,600 h under gasification conditions

10 MW(th) Helical IHX



Betriebsdaten

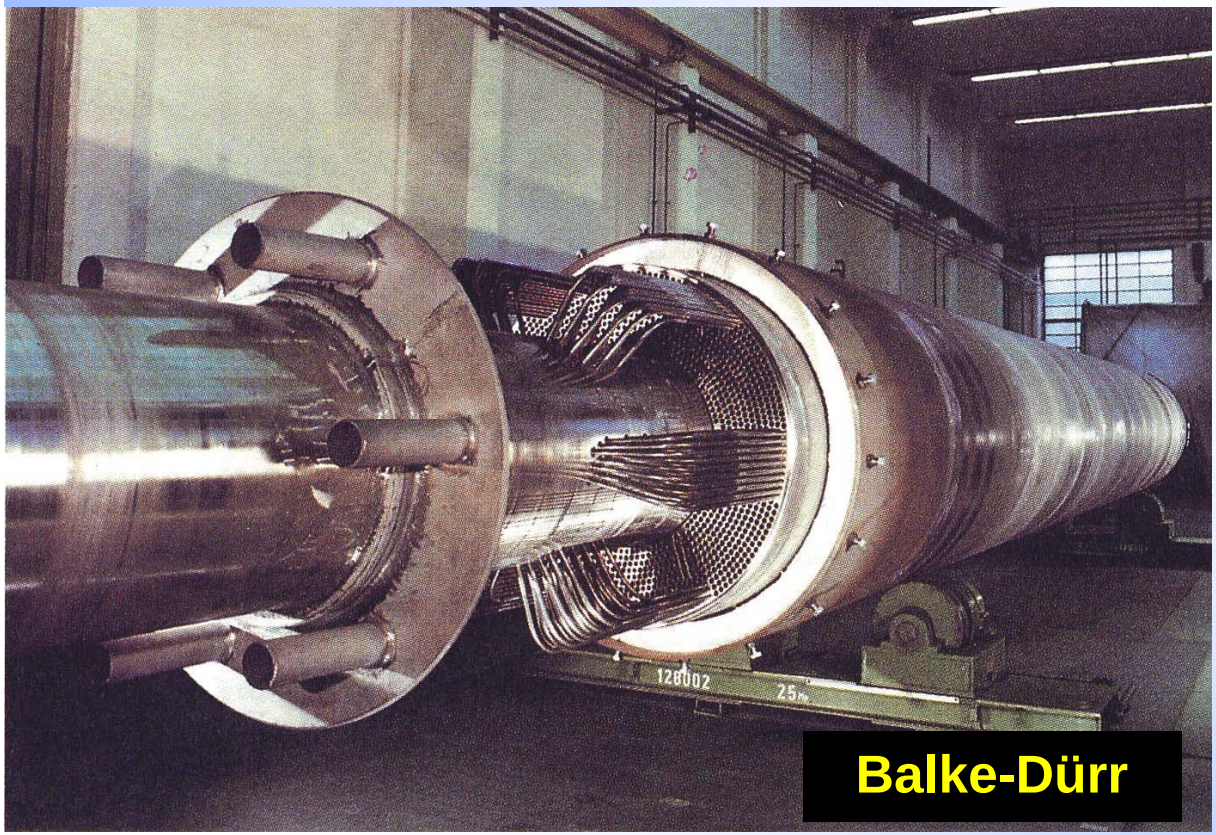
	Primär	Sekundär
Durchsatz	2,95 kg/s	2,85 kg/s
Temperaturen	950/293 °C	900/220 °C
Druck	39,9 bar	41,5 bar
Druckdifferenz	0,55 bar	1,65 bar
Leistung	10 MW	

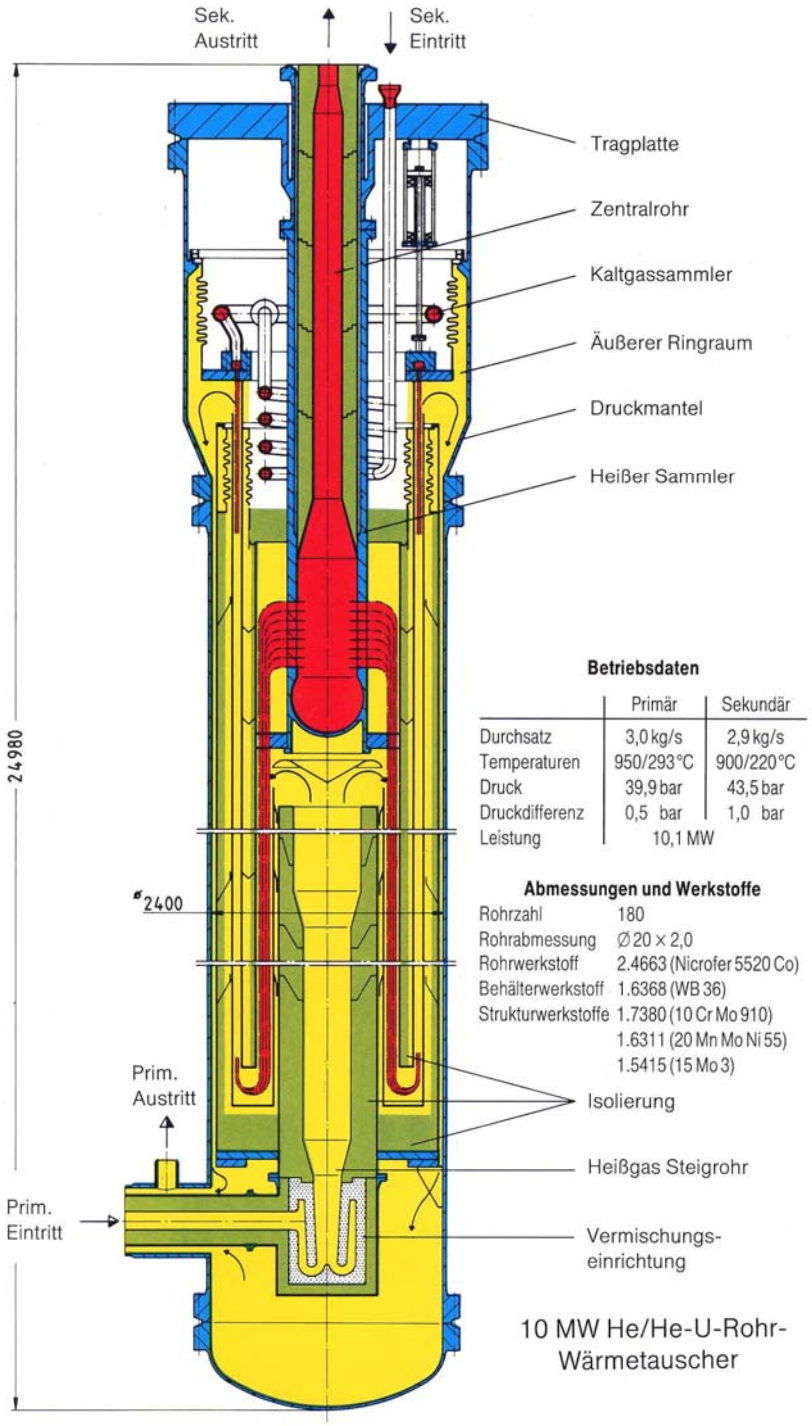
Abmessungen und Werkstoffe

Rohrzahl	117
Rohrabmessung	Ø 22 × 2,0
Rohrwerkstoff	2.4663 (Nicrofer 5520)
Behälterwerkstoff	1.6368 (WB 36)
Strukturwerkstoffe	1.7380 (10 Cr Mo 910) 1.4876 (Incoly 800 H)

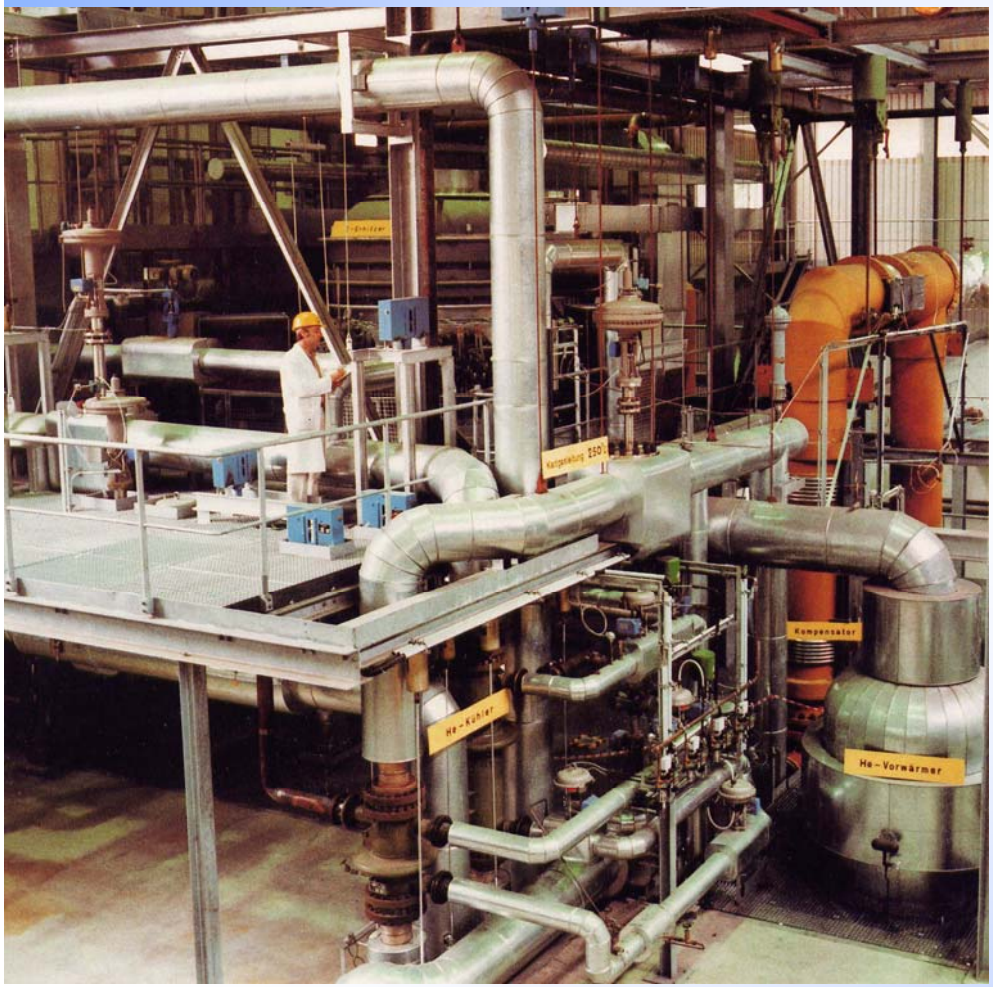
10 MW He/He-Wärmetauscher in Wendelrohrbauweise

10 MW(th) U-Tube IHX



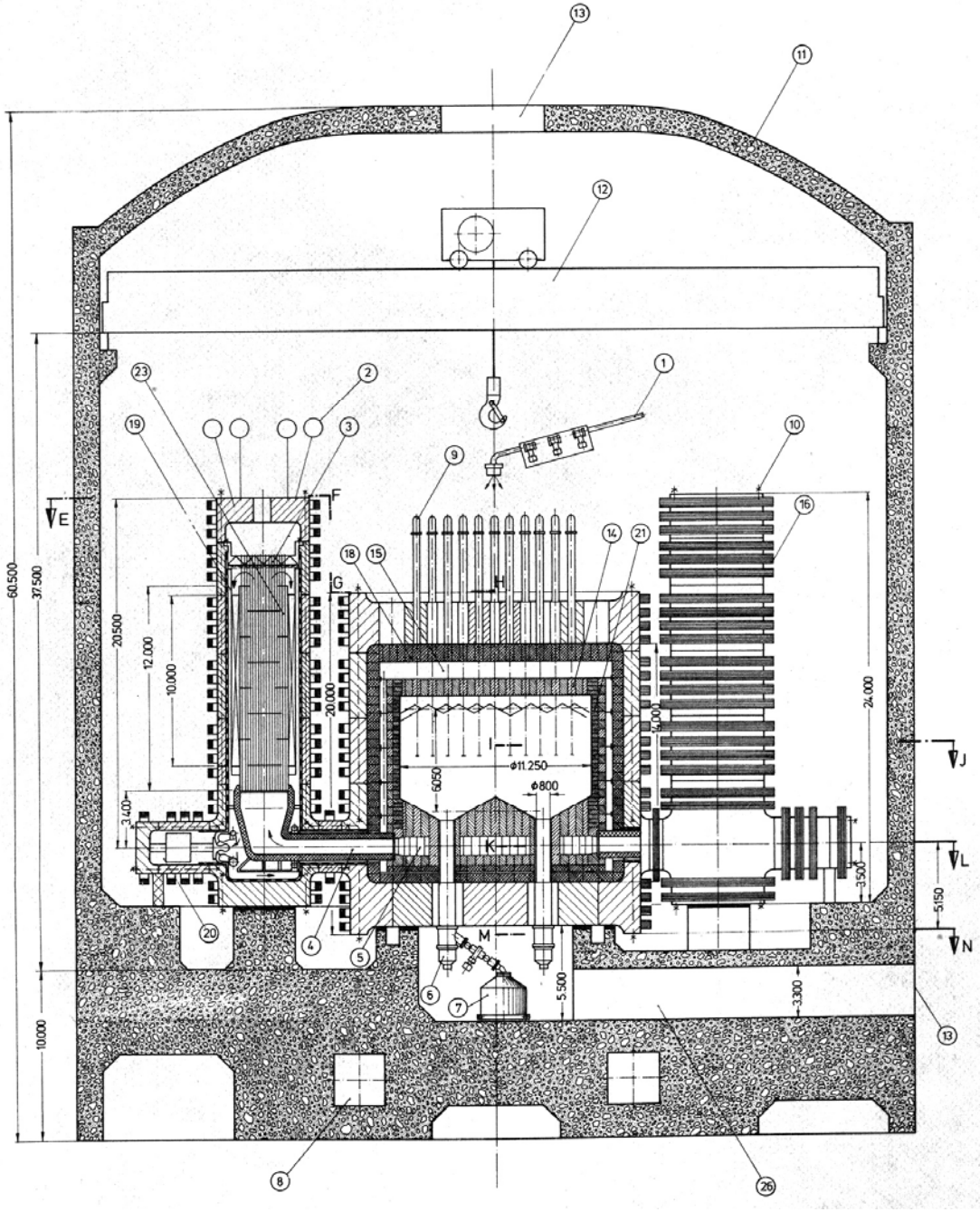


10 MW(th) Component Test Loop (KVK)



Hot gas duct

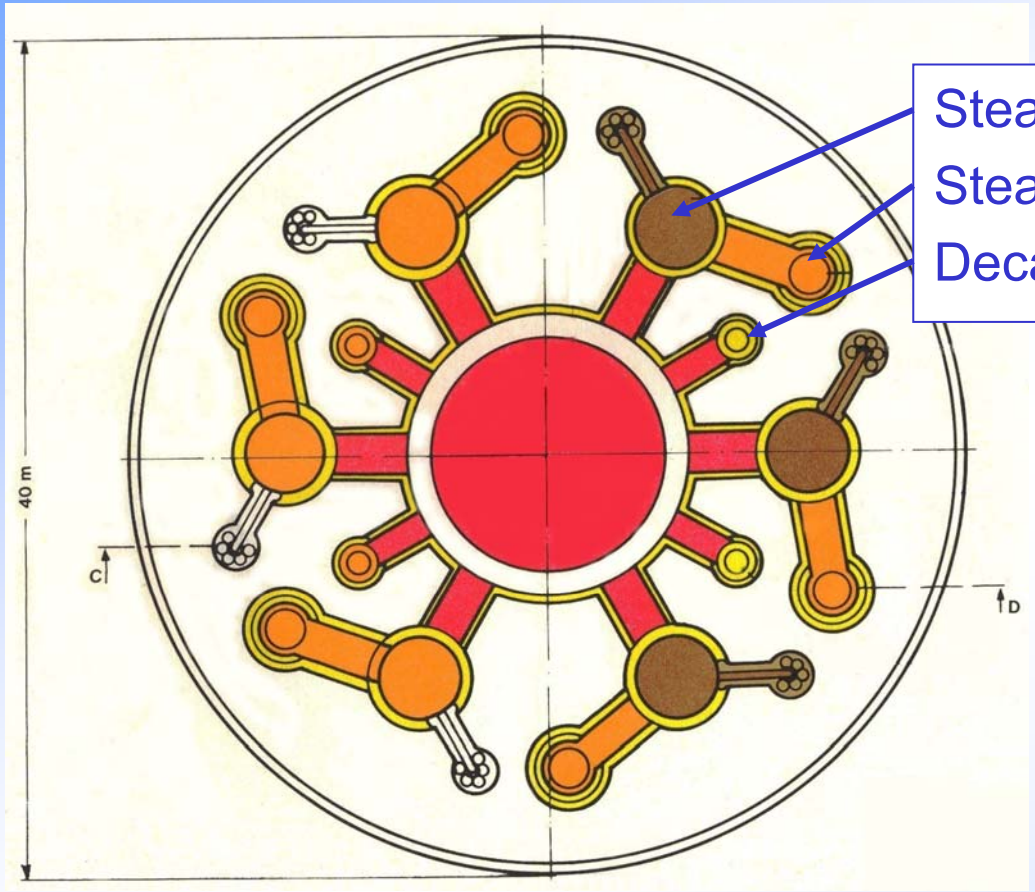
- **Thermal Power:** **10 MW(th)**
- **Helium flow:** **3.2 kg/s**
- **Max. He temp. prim/sec:** **950/900°C**
- **System pressure:** **4 MPa**
- **Operation time:** **~13,000 h**



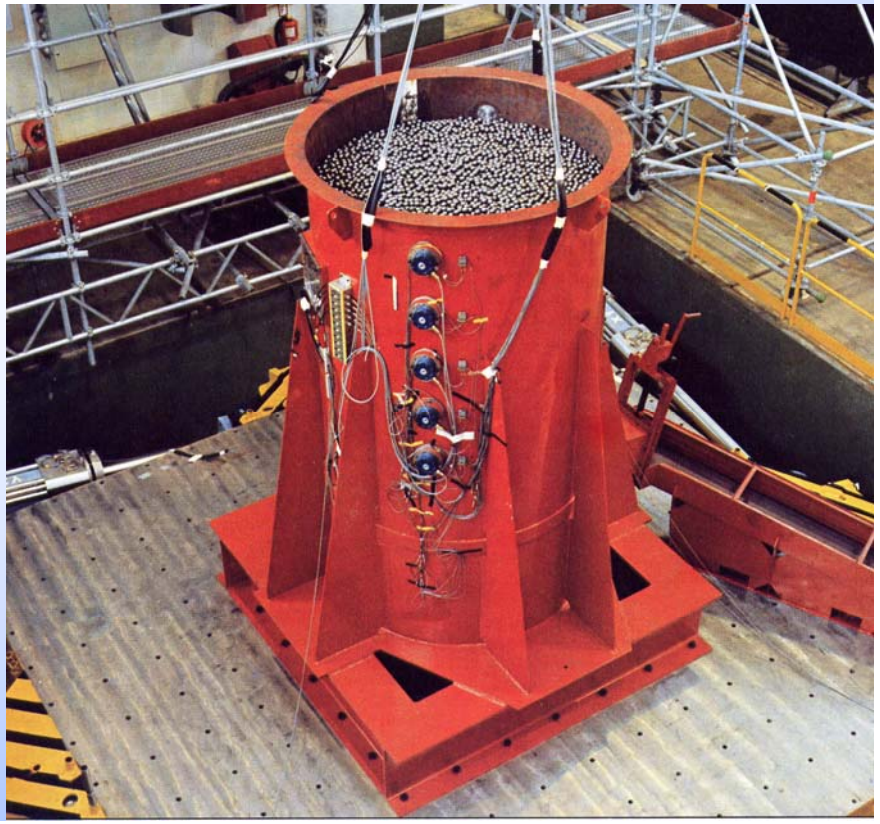
Design of PNP-3000 Nuclear Process Heat Plant

- Thermal Power: 3000 MW(th)
- Power Density: 5 MW/m^3
- He inlet/outlet: 300/950°C
- OTTO fuel loading scheme
- 6 main loops with SR+SG or IHX
- 4 decay heat removal systems
- Prestressed concrete pressure v.

PNP-3000

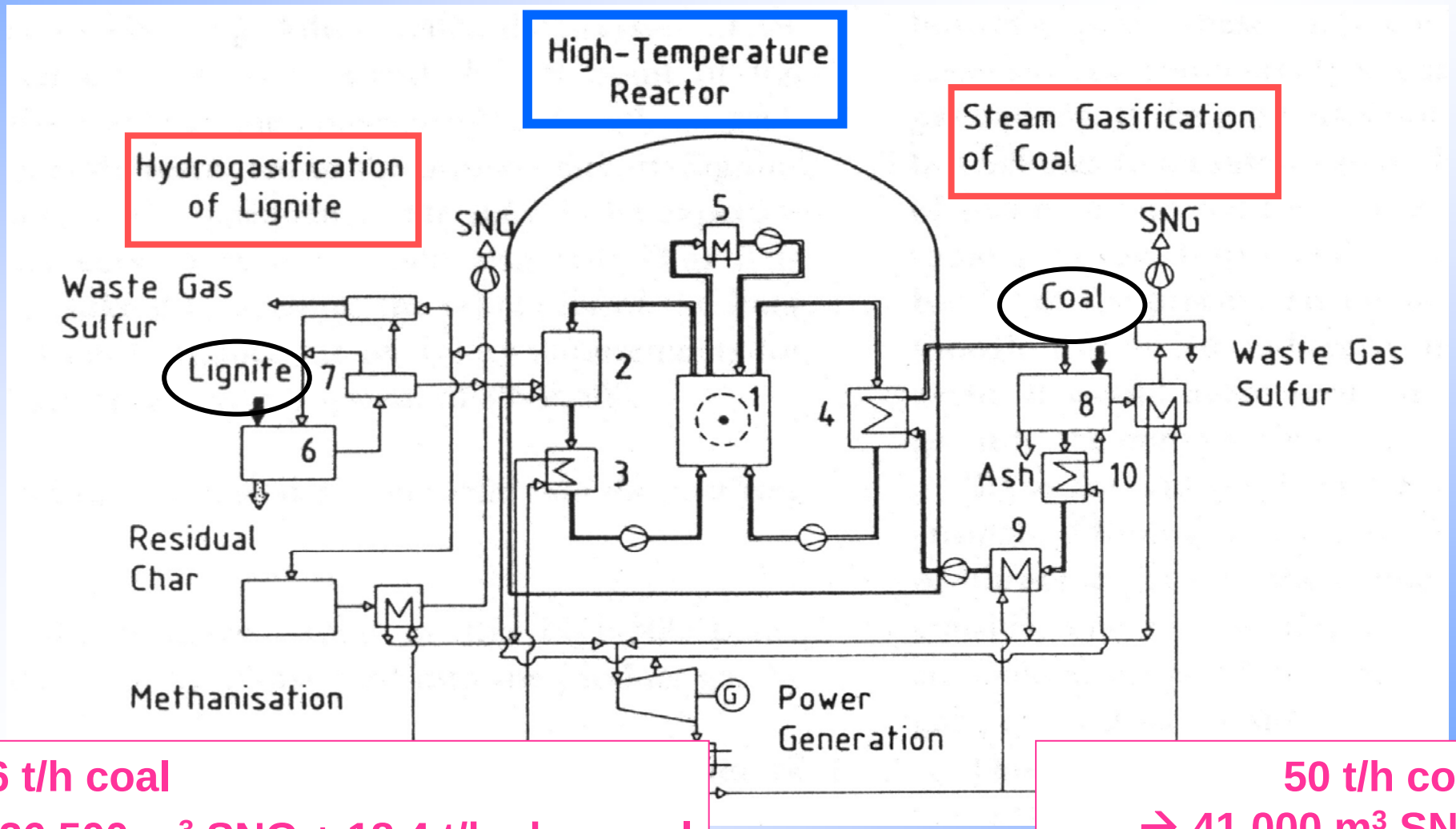


Steam reformer (950 → 800°C)
Steam generator (800 → 250°C)
Decay heat removal system



Earth quake simulation testing facility SAMSON

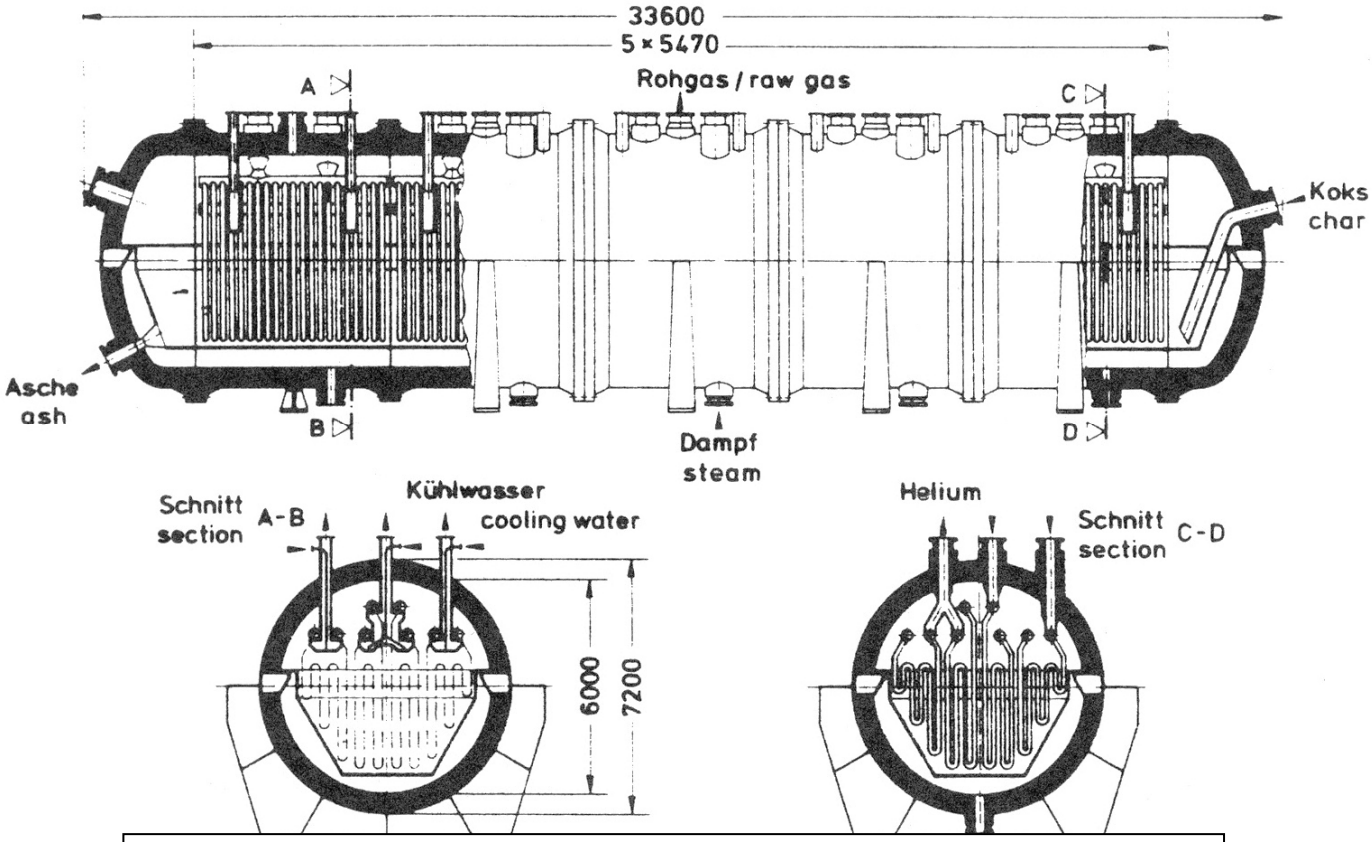
Prototype Plant PNP-500

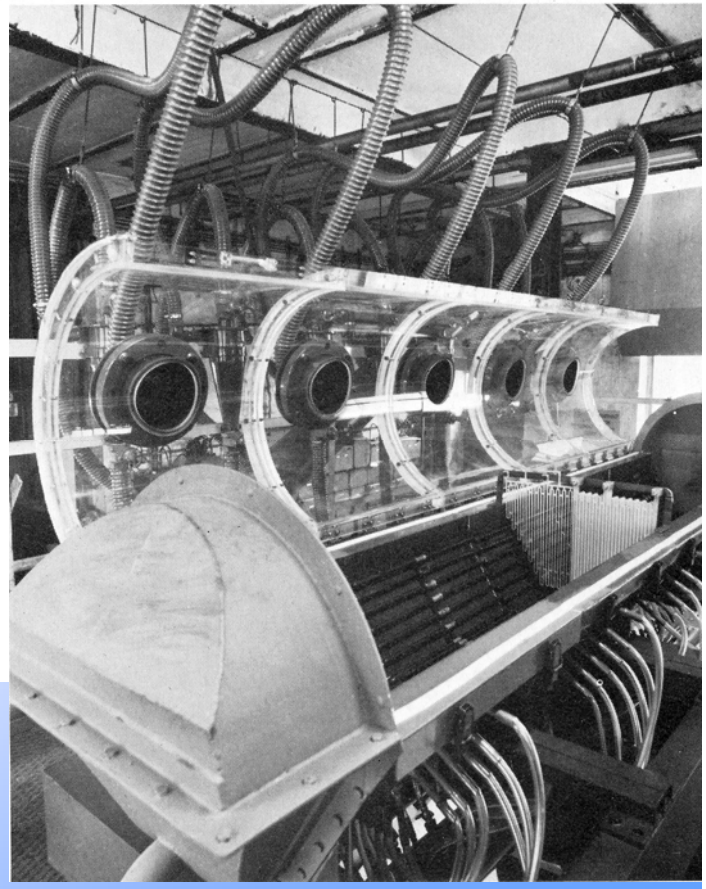


166 t/h coal
→ 26,500 m³ SNG + 18.4 t/h char coal

50 t/h coal
→ 41,000 m³ SNG

Steam Coal Gasifier Design for Prototype Plant





- Coal throughput: 50 t/h
- Effective volume: 318 m^3
- Heat exchanging area: 4000 m^2

PNP-Related Safety Research

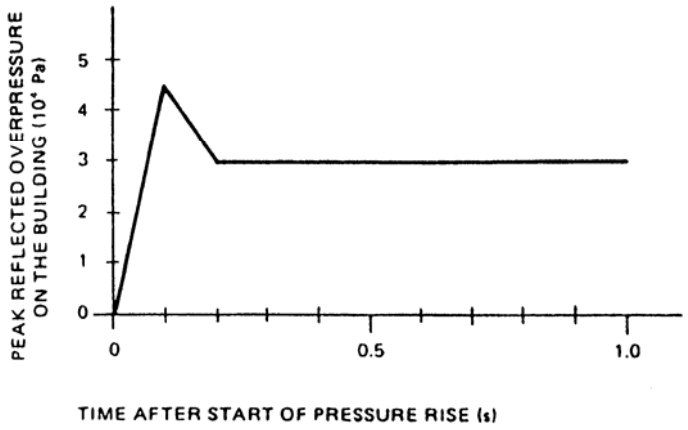
- Permeation of tritium/hydrogen through heat exchanging walls;

  Germany: T limit for any fabricated product: < 500 mBq/g;
  using fossils refined by nuclear: < 5 Bq/g.

- PNP gas cloud program;

  Germany: Safety distance: $R = 8 * M^{1/3}$, ≥ 100 m

  Pressure wave



Achievements of PNP Project

- Confirmation of technical feasibility of allothermal, continuous coal gasification
- Manufacture and successful operation of high temperature heat-exchanging components
- Demonstration of licensing capability of a nuclear process heat HTGR by resp. safety research

But under the given conditions at that time, the nuclear process was not competitive with the conventional process!

Future Work

Re-evaluation of nuclear process heat studies

- to compare against present technologies/markets;
- to select promising applications within existing and evolving markets.

Thank you
for your kind attention !

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