SPECIAL PUBLICATION TH94e

from VGB Kraftwerkstechnik
No. 1/1991 • Page 33 to 39

PLANNING, CONSTRUCTION AND ERECTION EXPERIENCE WITH THE LOW-DUST "COMPACT DENOX PLANT"

by Dipl.-Ing. H.J. Eggers and H. Daschmann

Planning, Construction and Erection Experience with the Low-dust "Compact DENOX Plant"

By H.J. Eggers* and H. Daschmann**

* *Dipl.-Ing. H.J. Eggers, VEBA Kraftwerke Ruhr AG (VKR), Gelsenkirchen.*

** *H. Daschmann, Balcke-Dürr AG, Ratingen.*

Introduction

The task which faced us in 1988 can be described as follows: construction of a low-dust DENOX plant in the middle of a residential area for the Westerholt coal-fired power station 2 × 150 MW. The proposed solution was the compact DENOX plant (Figure 1) developed jointly by Balcke-Dürr and VEBA Kraftwerke Ruhr AG and for which a patent application has been filed. The technical solution chosen is presented below.

The section of the general layout (Figure 2) shows the compact DENOX plant, the existing 1 × 100% desulphurization plant, the flue gas ducts with the connection to the 300 m high chimney and the NH_3 unloading and storage facilities.

Objectives and Drawing-up of a Concept

In order to denitrate the flue gases it was necessary to find a technically good and economical concept as was the case with the desulphurization process, and achieve the following objectives:

- simple, compact plant construction with minimal space requirement,
- no direct contact between the gas flows, as far as possible,
- low investment and operating costs,
- easy to operate and with little maintenance required,
- low sound pressure level of 37 dB(A) at a distance of 60 m,
- short delivery and erection times.

The comparison of the processes offered, namely recuperative gas heater, heat displacement, heat tube or recuperator, showed that the compact DENOX system permits savings in the system and plant construction and offers the following advantages:

- no direct contact between the gases,
- minimal area requirement for the construction,
- relatively small construction volume,
- low power requirement,
- reduction in the scale of the flue gas ducts including expansion joints, insulation, steel support structure, facade, roofing as well as air supply and discharge systems.

For electrical load reasons, two units each with 50 % flue gas flow were selected.

The entire flue gas volume flow amounts to 1 421 000 m^3 (s.t.p., moist). The initial NO concentration in the range of 1900 to 1500 mg/m^3 is reduced to 200 mg.

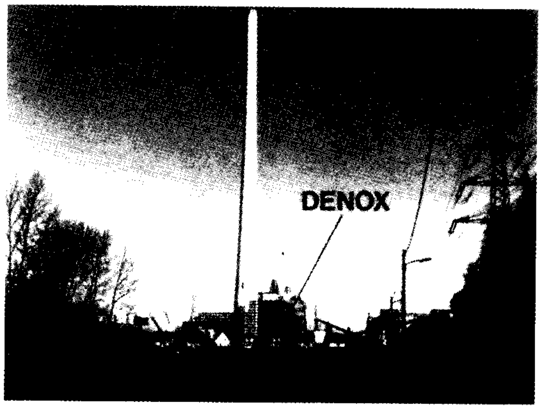


Fig. 1. View with chimney.

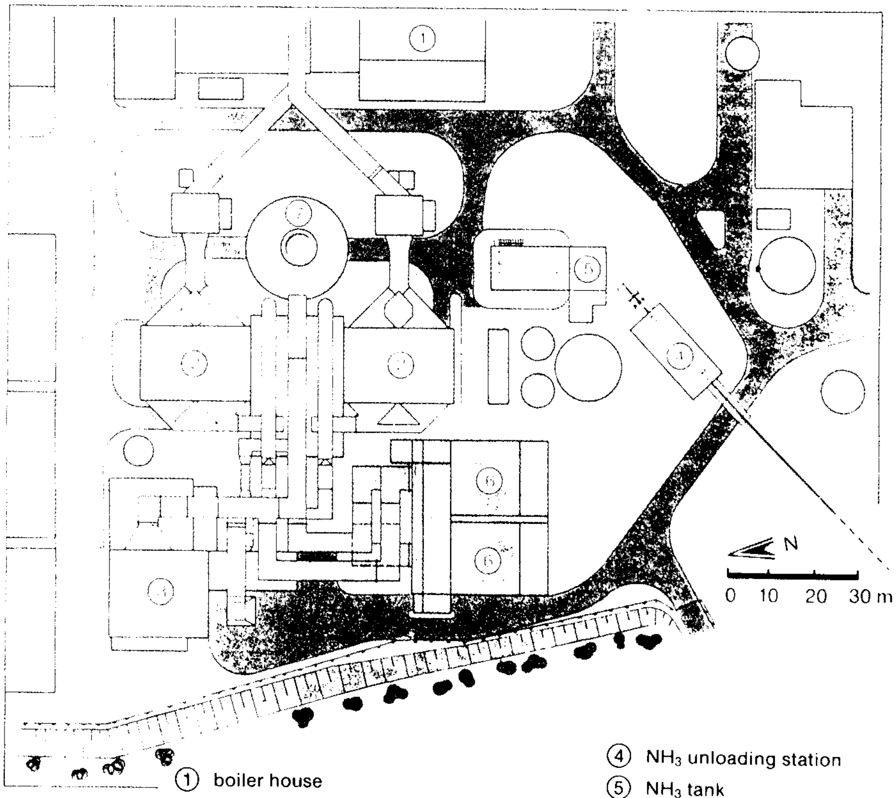
Diagram of Construction

Figure 3 is a diagram of the construction of the compact DENOX plant showing the mass flows

- flue gas with NO_x,
- denitrated flue gas,
- NH_3/air mixture,
- steam,
- condensate.

A washing system is provided which can be used when necessary.

When the sulphur and dust has been removed from the flue gases they are heated to 78 °C and conveyed to the recuperator where they are heated to 290 °C. The subsequent heating of the flue gases by 30 K is achieved using a DAGAVO (steam-heated gas preheater), a fin tube heat exchanger.



① boiler house
② el. precipitator connected downstream
③ flue gas denitrification plant
④ NH_3 unloading station
⑤ NH_3 tank
⑥ DENOX unit 2 × 50 %
⑦ stack

Fig. 2. Section — General layout.

The NH_3/air mixture is then injected via a static mixing system. This ensures thorough mixing with an even temperature profile upstream of the catalyst. After the denitration process in the catalyst, the treated flue gas flows through the recuperator in cross-counterflow to the untreated gas, cools to 110 °C and is then discharged via the chimney.

The total recuperator output amounts to 119 MW. At a steam pressure of 145 bar and a steam temperature of 515 °C the DAGAVO has an output of 19 MW and a steam rate of 40 t/h. The total flue gas-side pressure drop, including catalyst, amounts to a maximum of 35 mbar.

Construction of the Plant

As can be seen from the cross-section (Figure 4), the compact DENOX plant was constructed by direct inter-arrangement of the components

- recuperator,
- reheating system,
- NH_3/air mixture injection system,
- catalyst.

The total weight of the steel incorporated in a unit amounts to approx. 1900 tonnes, the building volume to 16 500 m^3 including two stairway systems, passenger elevator and erection shaft.

Compared to the low values specified in the preliminary planning, a further reduction of 6.5 % was achieved plus the savings with respect to the amount of casing required, still conforming to the noise regulations.

The cold end support structure (Figure 5) transfers the load from the hot supporting steelwork into the foundation.

The recuperator is suspended in the supporting steelwork and can expand freely downwards and sidewards. The DENOX plant rests on the support structure. Each half of the plant has a fixed point. The other bearing points between the supporting steelwork and the supporting structure are constructed as multiple ball bearings with thermal barrier.

The front-cased section permits direct access

- below + 18 m to the recuperator for the installation of heat exchanger plates and the washing equipment,
- above + 18 m to the DAGAVO, to the NH_3/air injection system with the static mixers, the rectifier and catalyst levels.

The flue gas inlet and outlet had to be arranged on one side due to the location. It would be better to arrange them on opposite sides as the overall height could then be reduced from 31 to 27 m with the corresponding cost saving.

Construction

Recuperator

The recuperator consists of the casing with deflection chambers, the supporting structure, the plate-type heat exchanger and the mounting and sealing elements. The total heat exchange surface amounts to 2 × 130 000 m^2.

The heat transfer in connection with the pressure drop is optimized by shaping the plate surface (Figure 6). The thermal and flow design was tested using an original construction under comparable conditions in the laboratory at Balcke-Dürr AG and also at the Institut für Technische Thermodynamik, Rheinisch-Westfälische Hochschule, Aachen.

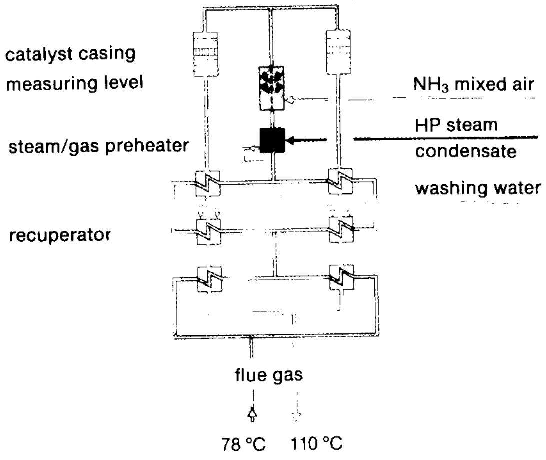


Fig. 3. Diagram of construction.

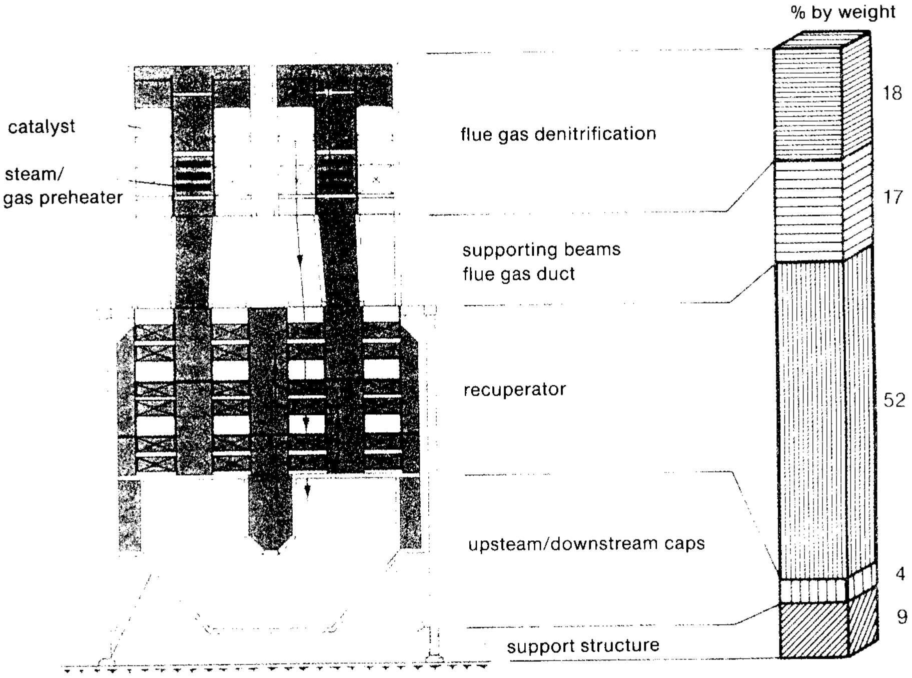


Fig. 4. Cross-section.

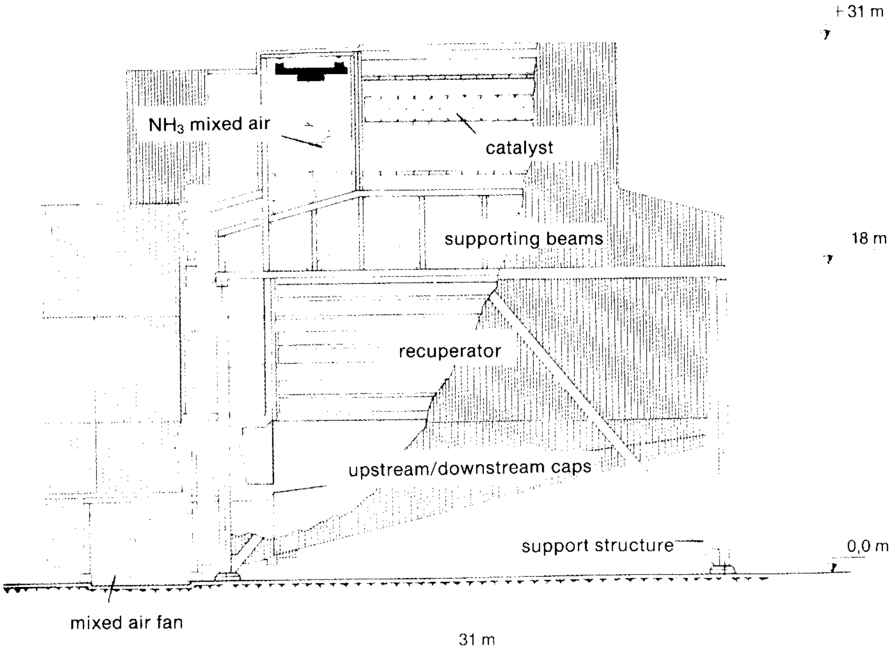


Fig. 5. Longitudinal section.

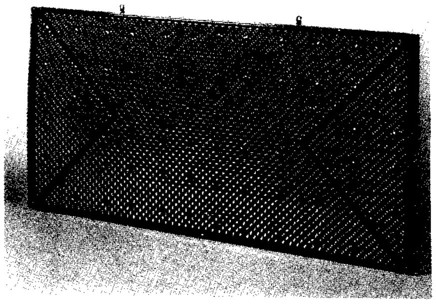


Fig. 6. Plate section.

A new production line had to be developed to manufacture a total of 180 000 shaped plates and 1248 heat exchanger modules. A multi-stage pressing tool (Figure 7) was used to manufacture the plates so that faults due to cold forming are avoided as far as possible and the pre-fabricated metal blanks could be machined without waste.

In order to avoid a residual gap all weld joints were carried out using the TIG process. Special machines with several welding torches operating in parallel, as a result of which economic welding times were achieved, had to be used to manufacture the twin plates and heat exchanger modules. It was therefore necessary to weld the twin plate using 2 × 3 and the modules using 2 × 4 TIG torches. Figure 8 shows the manufacture of a twin plate and Figure 9 the welding to form modules.

Another economic effect was achieved by assembling the next heat exchanger module in the same machine (Figure 10) during the welding process. The welding was therefore carried out practically without interruption.

The twin plates to be enamelled are pickled and dipped into a nickel bath to permit better enamel adhesion. The enamel was applied to the plate surface using the electrostatic spraying process and baked in the continuous furnace (Figure 11) at a temperature of 850 °C. The enamel coating is 150 µm thick. After the baking process, examinations were carried out to check the enamel thickness, number of pores and adhesion.

Upon completion of manufacture each module is tested for leaks using compressed air. Leakages are determined on the basis of measurements (Figure 12).

The plate-type heat exchanger (Figures 13a and b) consists of three twin layers.

52 individual modules measuring 1700 × 850 × 1000 mm and weighing approx. 1200 kg are used in each layer. The upper and lower plate-type heat exchangers are manufactured from Corten sheets 0.8 mm thick. As deposits of ammonium hydrogen sulphate are to be expected in the middle layer section at a surface temperature of between 250 and 180 °C, these plates are enamelled on the treated gas side. The heat exchanger modules were welded to the support structure and casing to achieve a gastight joint. The enamelled modules were sealed with high-quality silicone to prevent mass exchange between the treated and un-

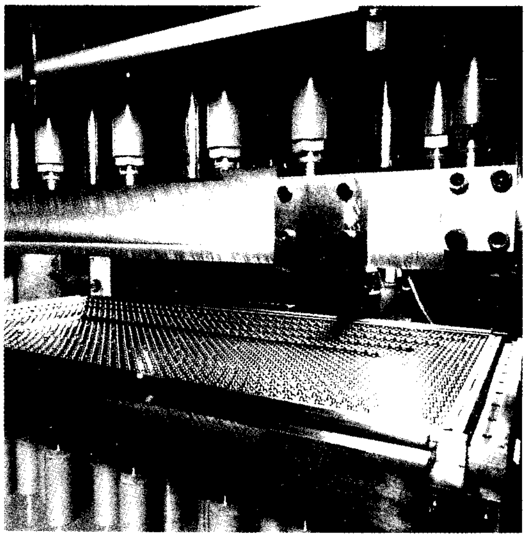


Fig. 7. Pressing tool.

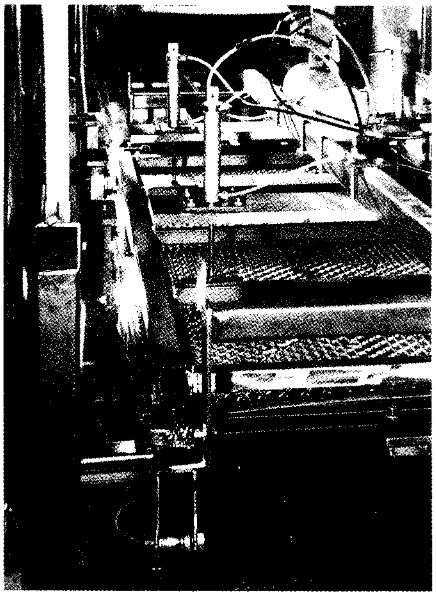


Fig. 8. Welding of a twin plate.

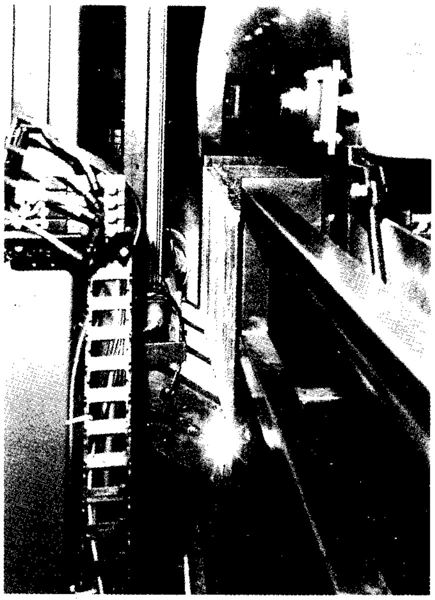


Fig. 9. Special block welding machine.

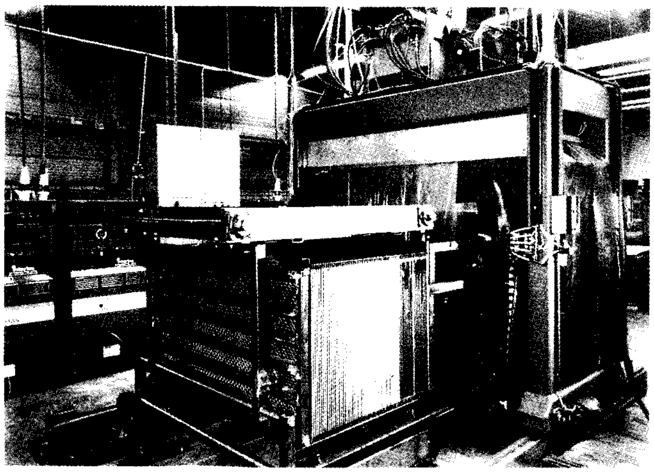


Fig. 10. Block welding.

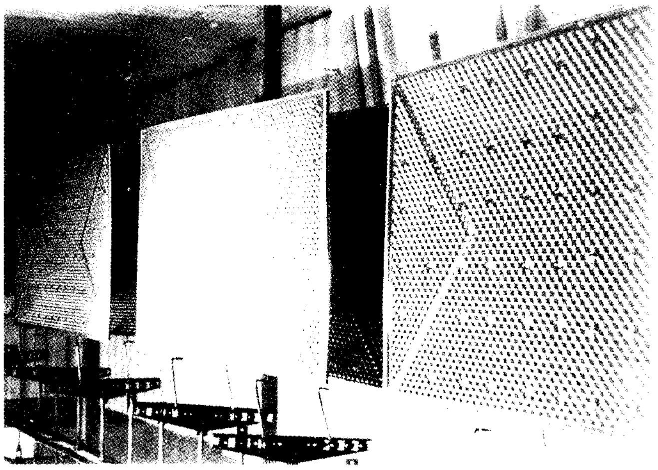


Fig. 11. Plate enamelling.

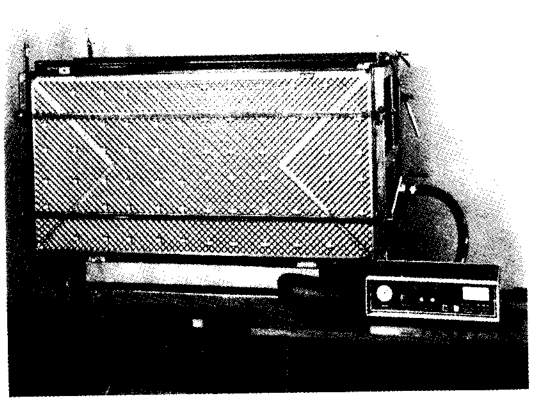


Fig. 12. Pressure test.

treated gas flows. Stainless steel expansion joints are used to absorb the thermal expansion between the casing and the heat exchanger.

All casing parts were manufactured from steel sheet 15 Mo 3. Detachable erection openings are provided to allow the installation and dismantling of the heat exchanger modules.

Supporting Steelwork/ DENOX Plant

Lattice girders, which simultaneously support the recuperator with the inlet flow and outlet flow hoods and also the reheating system and the DENOX plant, form the transition from the recuperator to the DENOX casing. This flow design was subjected to additional laboratory testing.

The illustration (Figure 14) shows the flow pattern during the test in the shallow water channel at the transition between the catalyst casing and the recuperator. The results of the calculations and of the flow tests were very consistent. The calculations show that smaller separation flows are to be expected with the larger Reynolds numbers of the original construction than occurred in the water model. This indicates a better flow through the heat exchangers.

DAGAVO

The steam-heated gas heater to reheat the flue gases consists of a desuperheater and a condenser section. The heating surface for the desuperheating and condensing processes is formed by a continuous fin tube coil (Figure 15) with a 0.5° pitch. The superheated steam flows via the inlet header into the tube coils and cools down to 339 °C in the upper two tube rows. The steam is condensated in the following rows. The condensate is conveyed into the mixed air heater via a drain tank and is cooled there by 65 K. This measure ensures on the one hand that the required level of condensate cooling is achieved to avoid re-evaporation and on the other hand that the condensate waste heat is used to heat the mixed air for the NH_3/air system.

Fig. 14. Flow tests in shallow water channel.

2 × 2 DAGAVOs were arranged in parallel for the Westerholt DENOX plant. Each DAGAVO (Figure 16) has a heating surface of 2070 m^2. The fin tubes used have a pitch of 5.1 mm. The fins are welded to the core tube using the high-frequency method. Tubes made of 10 CrMo 9 10 are used in the desuperheating section and tubes made of 15 Mo 3 in the condenser section.

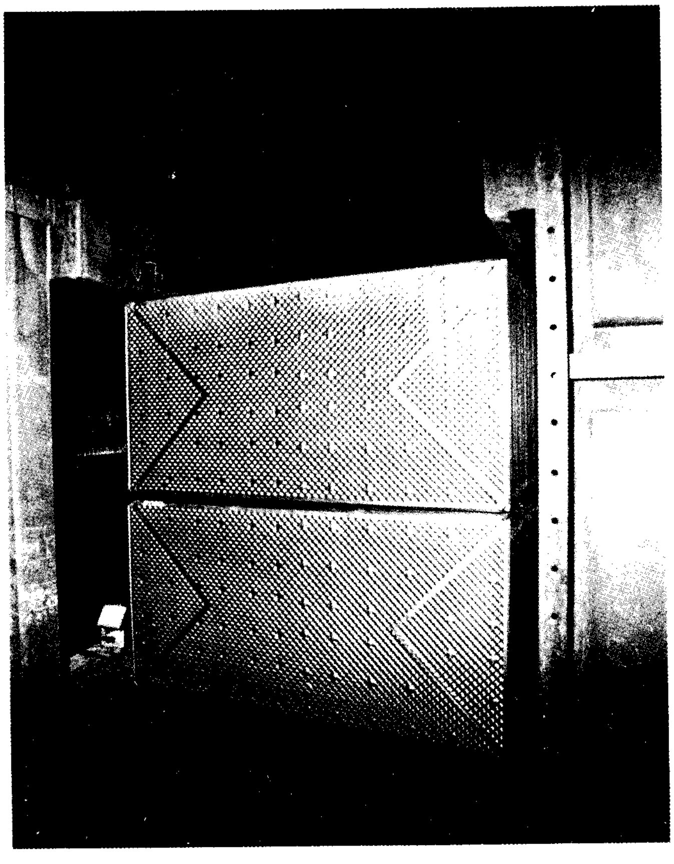


Fig. 13 a) Heat exchanger — Twin layer.

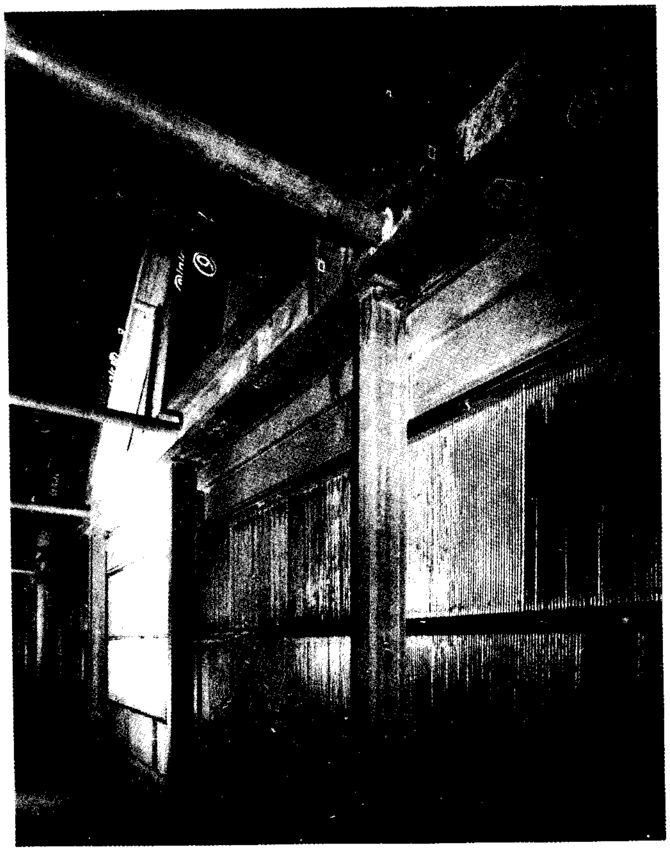


Fig. 13 b) Heat exchanger — Twin layer.

Fig. 15. DAGAVO tube coil.

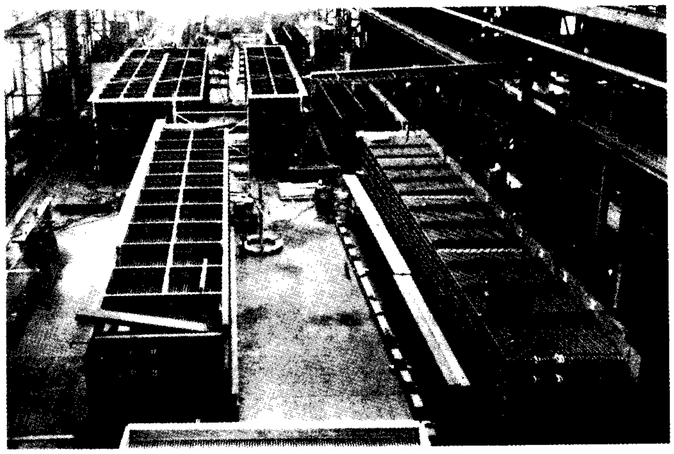


Fig. 16. DAGAVO manufacturing.

An aligned tube arrangement was selected. The steam inlet header, the fin tube coils and the drain header are accommodated in the casing of the DENOX plant.

Flue Gas Denitrification

NH_3/Air Injection and Static Mixing Systems

The flue gas denitrification unit with NH_3/air injection and a static mixing system is constructed as follows. The NH_3/air mixture is injected into the untreated gas via 24 individually adjustable jets per system section. The jet outlets are located in the immediate vicinity of the lower mixing discs (Figure 17).

The circular discs set diagonally to the direction of flow generate extended steady-state vortices with greater turbulence perpendicular to the main direction of flow. This results in intensive mixing. Two levels of mixers arranged aligned above one another bring about the required thorough mixing of the NH_3/air mixture with the heated untreated gas (Figure 18).

The geometry of the system was designed in collaboration with Rheinisch-Westfälische Technische Hochschule, Aachen.

Catalyst

The flue gases are denitrated in 2 × 4 catalysts (Figure 19) each with a width of 2 m and arranged in parallel. The NH_3/mixed air injection system connected upstream is arranged symmetrically in 2 × 2 lanes. The rectifier level and the catalyst level are for the time being not occupied. The catalyst volume used amounts to 195 m^3 for an anticipated service life of 16 000 hours. Under full-load operation the ammonia leakage should not exceed the value of 5 vpm at the end of the cycle. The catalyst is designed for the following data:

Flue gas mass flow	2 × 710 500 m^3/h (s.t.p., moist)
NO_x (5 % O_2) upstream of catalyst	1 900 mg/m^3 (s.t.p., dry)
Degree of denitrification	87 %
Type of catalyst	honeycomb, 4 pitch
Number of layers	1
Active catalyst length	2 × 500 mm
Supplier	BASF

Washing System

A washing system (Figure 20) which can be used whilst the plant is at a standstill, is provided to remove any deposits which form on the treated gas side of the heat exchanger plates. This mobile, transferable equipment can be moved to each platform level in front of the heat exchanger lane to be cleaned and then operated within the heat exchanger casing on the rails provided for this purpose. The water is supplied through hoses. The washing water is distributed over the plates by a distribution pipe, collected in the treated gas outlet hood and injected into the boiler plant firing equipment.

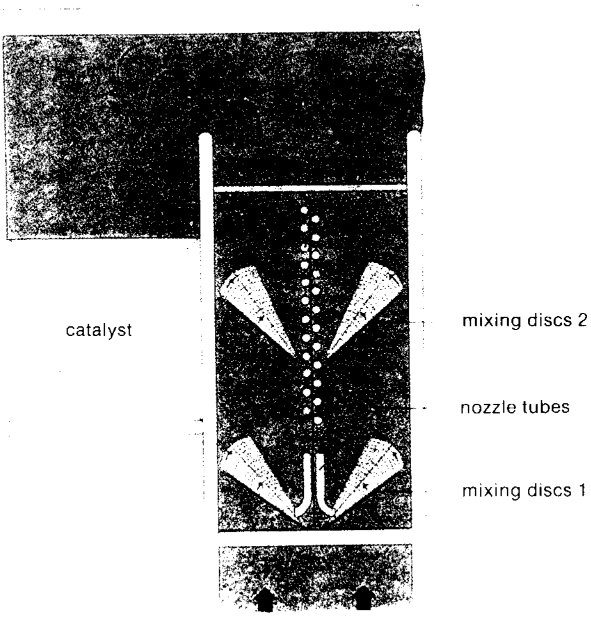


Fig. 17. Static mixing system/section drawing.

Fig. 18. Mixer internals.

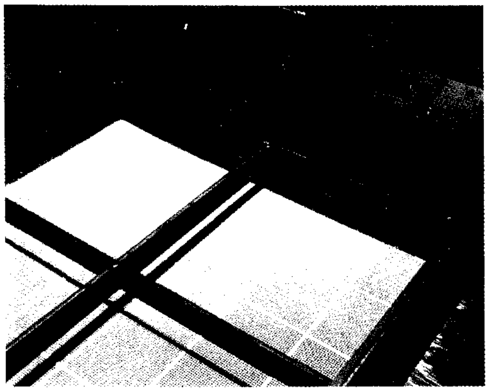


Fig. 19. Catalyst module.

Flue Gas Ducts, Dampers, Guide Vanes

The flue gas ducts between the desulphurization and denitrification plant were constructed with a Flake Line coating. Guide vanes made of glass (Figure 21) with a mounting construction made of stainless steel are used in this duct section to deflect the flue gases. The system developed and patented by VKR together with Flachglas AG has already proved successful in other plants. Compared to coated guide vanes, the service life is extended and the flow resistance reduced.

Articulated dampers with sealing air are used as flue gas shut-off fittings. Each compact DENOX plant can be shut down and inspected. The expansion joints required to compensate for expansion were made of 6 mm Viton on the untreated gas side and of teflon-coated glass fibre material on the treated gas side corresponding to the respective stresses.

Noise and Thermal Insulation

Combined noise and thermal insulation made of two layers of mineral fibre mats 2 × 120 mm with a relative density of 100 kg/m^3 was selected as noise and thermal insulation for the recuperator and DENOX casing as well as for the flue gas ducts and the inlet flow and outlet flow hoods. The mats are butted tightly together and fastened to the insulation pins with clips, the joints of the mats of the second layer being staggered in relation to the first layer. A sheet metal shell of 1.2 mm thick trapezoidal aluminium sections is mounted as the outer layer of the insulation. Stainless steel facade bolts, washers and neoprene gaskets are used to attach the metal sheets.

All casing structure sections with a web height of more than 200 mm are provided with a clearance lining (Figure 22).

Fig. 21. Glass guide vanes.

Civil Work and Erection

The civil work for the 2 × 50 % compact DENOX plant started in May 1989. The erection of the supporting structure (Figure 23) was carried out in August.

The DAGAVOs (Figure24) can be raised into position as a complete unit. The subsequent erection of the DENOX casing was carried out without any problems.

By the end of December 1989 the shell of both plants had been completed. The insulation work was then started.

The delivery and installation of the heat exchanger modules started at the end of January 1990. As the distances to be covered during the erection were short and direct, the 1248 modules weighing a total of 1500 tonnes were installed in a period of approx. 4 weeks. The catalyst was installed at the beginning of February 1990 in just one week. The compact DENOX plant was ready for operation at the end of March 1990. Figure 25 shows the installation of the heat exchanger modules.

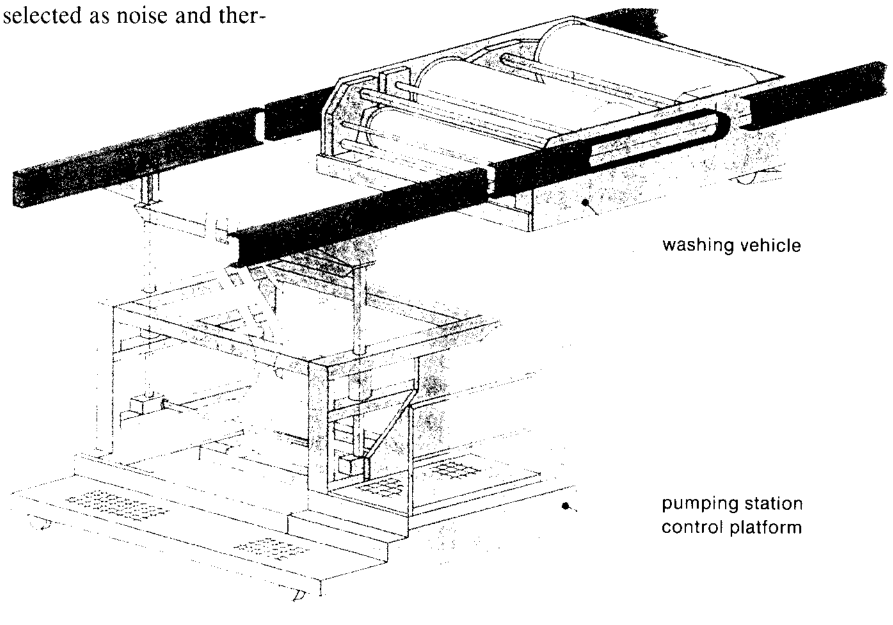


Fig. 20. Washing system.

Quality Assurance

Great emphasis was placed on quality assurance. The stringent quality requirements were strictly observed by checking the system design in co-operation with the Institut für Technische Thermodynamik, Rheinisch-Westfälische Technische Hochschule, Aachen, by checking the construction with the statics inspector, by carrying out quality control at the works and by having the erection supervised by Rheinisch-Westfälischer Technischer Überwachungs-Verein TÜV.

The activities involved in the supervision of the civil work and erection ensured that any necessary rectifications transmitted back to the construction and manufacturing departments, e.g.

- comparison of required/as-built values, order/manufacturing,
- check for completeness, especially in the case of components ordered from subsuppliers,
- examination of welding work and construction in accordance with DIN 8563,
- check for expansion and settling and examination of the construction,
- check for correct positioning on the bearing,

could be implemented.

The injection of NH$_3$ was monitored as per TRD 450—452. Coated parts were constructed as per the VDI Directive 2532. The quality of the enamelled heating surfaces was examined in accordance with the examination procedures given in the manual from the Deutsche Emaille Zentrale (German Enamel Organization).

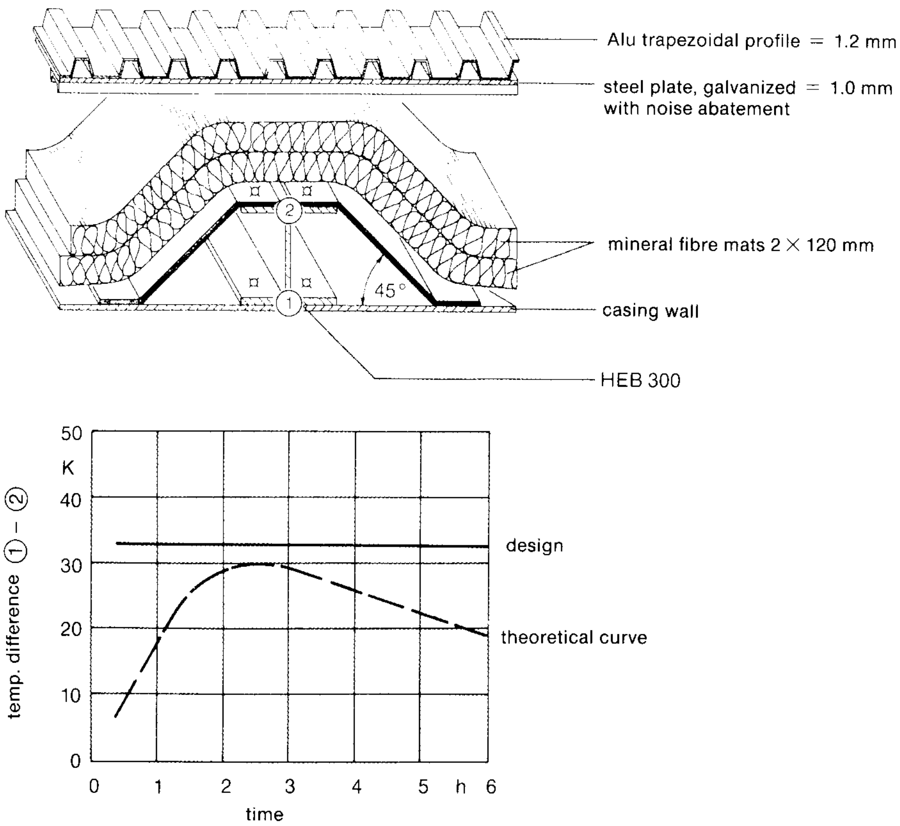


Fig. 22. Clearance insulation.

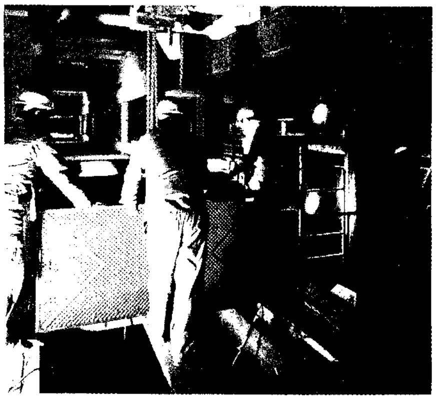


Fig. 25. Erection of modules.

Fig. 26. MARA measuring system.

The injection of NH_3 was optimized using the MARA measuring system from VKR (Figure 26) and with the help of a titanium measuring network which is installed beneath the catalyst level.

Summary

This new power station component shows that a concept for flue gas denitrification based on the low-dust process can be built up using proven elements and that it fulfills the set requirements, namely

- no flue gas leakages,
- compact unit,
- reduced investment and operating costs,
- simple erection.

Figure 27 shows the compact DENOX plant in February 1990.

We hope that with this concept we have taken a step towards the future. The first steps along the path of this solution can now be regarded as having been taken. It was possible to complete the compact DENOX plant on schedule despite the limited space available and above all to complete it within the specified cost framework.

We hope that we will be able to report about the next, hopefully just as successful steps, namely the commissioning and above all the safe operation of the DENOX plant, at one of the next VGB meetings.

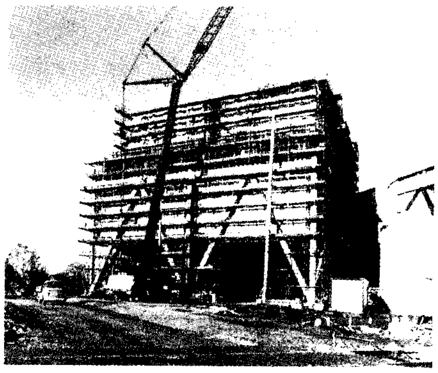


Fig. 27. Compact DENOX plant, February 1990.

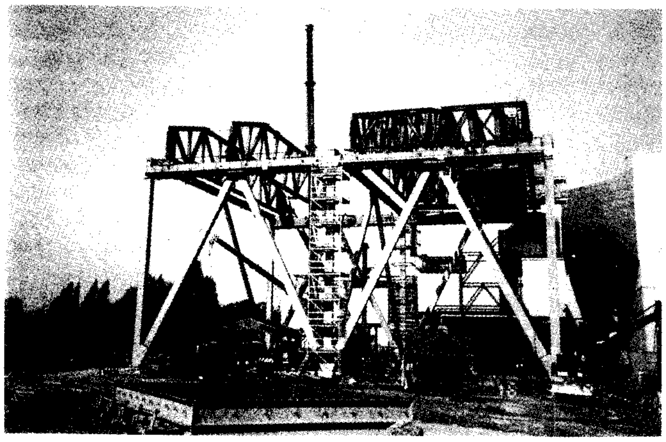


Fig. 23. Erection of scaffolding.

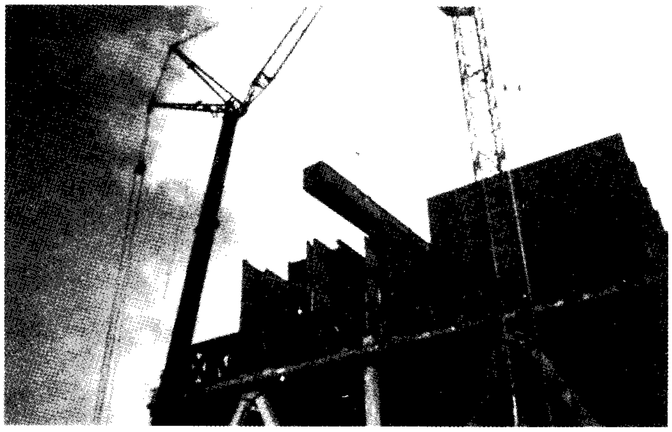
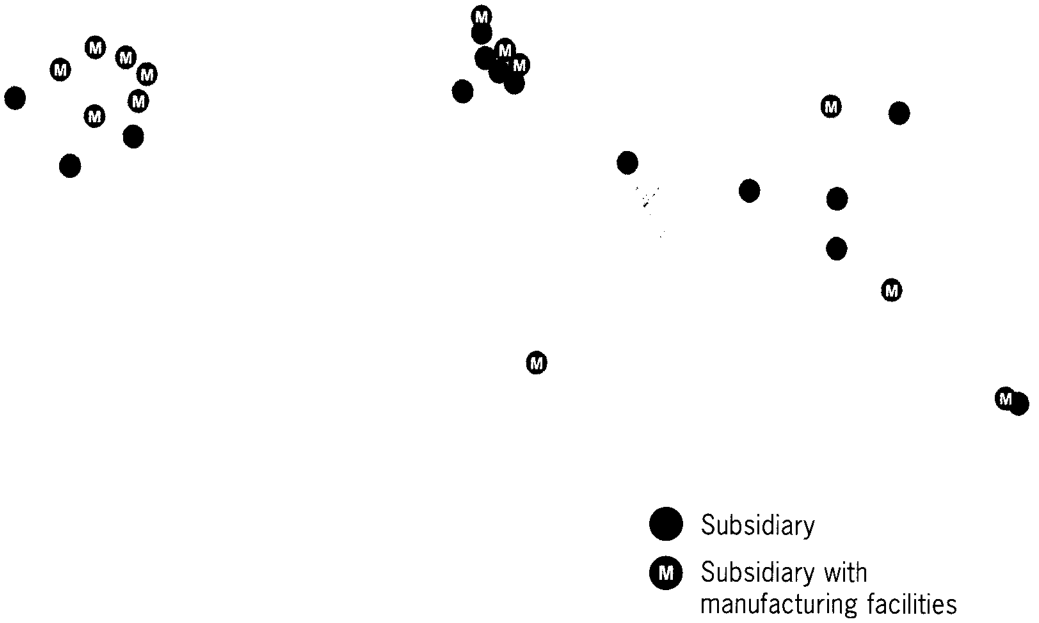


Fig. 24. Erection of DAGAVO.

PAGE
INTENTIONALLY
LEFT
BLANK

PAGE
INTENTIONALLY
LEFT
BLANK

SPECIAL PUBLICATION TH94e



Balcke-Dürr Energietechnik GmbH
Hans-Joachim-Balcke-Strasse
46049 Oberhausen/Germany
Phone: +49 (0) 208 / 83 37 - 0
Fax: +49 (0) 208 / 83 37 - 299