TRANSLATION


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**Heizkessel- und Behälterbau GesmbH**

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**A-4710 Grieskirchen**

| Your reference: | Your message from | Our reference: | Date: |
|---|---|---|---|
| Order No. 22114/1 | 26.05.2003 | 03-UWC/Wels-EX-126 SD/SD | 06.05.2004 |

**Subject:** Test of the boiler type Turbomat 150 in accordance with ÖNORM EN 303-5

# T E S T  R E P O R T

of the accredited testing laboratory and supervisory board

concerning the tests performed in the period of 17.07. – 25.07.2003


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| | |
|---|---|
| **Testing laboratory:** | TÜV Austria<br>Division Environmental Technology and Chemistry<br>Am Thalbach 15<br>A-4600 Thalheim/Wels |
| **Test report no.:** | 03-UWC/Wels-EX-126 |
| **Test report date:** | 06.05.2004 |

Test report concerning the test of the heating boiler type Turbomat 150
in accordance with ÖNORM EN 303-5

| | |
|---|---|
| **Client:** | Fröling Heizkessel- und Behälterbau GesmbH,<br>Industriestraße 12, A-4710 Grieskirchen |
| **Manufacturer:** | Fröling Heizkessel- und Behälterbau GesmbH,<br>Industriestraße 12, A-4710 Grieskirchen |
| **Test place:** | Test rig of the company Fröling Heizkessel- und Behälterbau GesmbH,<br>Industriestraße 12, A-4710 Grieskirchen |
| **Kind of testing:** | Test of a biomass heating system |
| **Order number:** | Order no. 22114/1 from 26.05.2003 |
| **Day of testing:** | 17.07. – 25.07.2003 |
| **Contents:** | 57 Pages<br>4 Enclosures |

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|---|---|
| **Task:** | Test of the heating boiler type Turbomat 150 in accordance with ÖNORM EN 303-5 |

# TABLE OF CONTENTS

1. Task definition ..... 7
1.1 Client ..... 7
1.2 Manufacturer ..... 7
1.3 Location / Measurement ..... 7
1.4 Unit ..... 7
1.5 Date of tests ..... 7
1.6 Cause of measurement ..... 8
1.7 Task ..... 8
1.7.1 Emission limit values and requirements of the boiler efficiencies ..... 9
1.8 Coordination ..... 12
1.9 List of all persons who locally took part at sampling ..... 12
1.10 Participation of further institutes ..... 12
1.11 Technically responsible persons ..... 12
2. Description of the unit ..... 13
2.1 Kind of unit ..... 13
2.2 technical description of the unit ..... 13
2.2.1 Technical data (in accordance to the manufacturer´s specification) ..... 14
2.2.1.1 Boiler ..... 14
2.2.1.2 Firing ..... 14
2.2.1.3 Primary air fan ..... 14
2.2.1.4 Heat exchanger, integrated in the boiler ..... 14
2.2.1.5 Appliances for emission collection ..... 15
2.2.1.6 Appliances for emission reduction ..... 15
2.2.1.7 Data of emission source ..... 15
3. Bases ..... 16
4. Test of the general requirements ..... 18
4.1 Construction requirements ..... 18
4.1.1 General requirements ..... 18
4.1.2 Production documentation ..... 19
4.1.2.1 Drawings ..... 19
4.1.2.2 Manufacturing controls ..... 19
4.1.3 Heating boilers made of steel and non-ferrous materials ..... 19
4.1.3.1 Execution of welding work ..... 19
4.1.3.2 Welding seams and welding fillers ..... 20
4.1.3.3 Parts of steel subject to pressure ..... 20
4.1.3.4 Minimum wall thicknesses ..... 20

4.1.4 Safety and design requirements ..... 20
4.1.4.1 Venting of the water sections and gas flue passages ..... 20
4.1.4.2 Cleaning of heating surfaces ..... 21
4.1.4.3 Inspection of the flame ..... 21
4.1.4.4 Water tightness ..... 21
4.1.4.5 Replacement parts ..... 21
4.1.4.6 Water side connections ..... 21
4.1.4.7 Connections for control and indicating equipment, and safety thermostat ..... 22
4.1.4.8 Thermal insulation ..... 22
4.1.4.9 Water side resistance of the boiler ..... 22
4.1.4.10 Temperature control and limiting devices ..... 23
4.1.4.11 Combustion chamber ..... 23
4.1.4.12 Ash chamber ..... 23
4.1.4.13 Stoking devices ..... 23
4.1.4.14 Heating boiler accessories ..... 24
4.1.4.15 Electrical safety ..... 24
4.2 Pressure tests ..... 24
4.2.1 Tests to be carried out before production ..... 24
4.2.2 Test during production ..... 25
4.3 Designation ..... 25
4.3.1 Information on the boiler plate ..... 25
4.3.2 Data plate requirements ..... 25
4.4 Technical documentation, supplied with the boiler ..... 26
4.4.1 Technical information and installation instructions ..... 26
4.4.2 Operating instructions ..... 27
5. Test of the boiler performance requirements ..... 28
5.1 Conducting the boiler performance test ..... 28
5.1.1 Choice and condition of the tested boiler ..... 28
5.1.2 Setting up the test rig ..... 28
5.1.3 Measured quantities ..... 28
5.1.4 General test conditions ..... 29
5.1.5 Determination of the boiler efficiency ..... 30
5.1.6 Determination of the exhaust gas loss (loss through sensible heat of the products of combustion) ..... 32
5.1.7 Determination of the emission values ..... 32
5.1.8 Surface temperatures ..... 33
5.2 Determination of the water side resistance ..... 33
5.3 Test fuels ..... 33
5.3.1 Fuel analysis ..... 34

5.4 Measurement instruments and methods ..... 34
5.4.1 Flue gas boundary conditions ..... 34
5.4.1.1 Flue gas volume and flue gas velocity ..... 34
5.4.1.2 Static pressure in the flue gas pipe (draught) ..... 35
5.4.1.3 Air pressure at the height of the sampling point ..... 35
5.4.1.4 Flue gas temperature ..... 35
5.4.1.5 Ambient air temperature ..... 35
5.4.1.6 Proportion of water vapour in the flue gas (flue gas humidity) ..... 36
5.4.1.7 Flue gas density ..... 36
5.4.2 Gaseous and vapour emissions ..... 36
5.4.2.1 Continuously recorded measurement instruments ..... 36
5.4.2.2 Measurement location design ..... 37
5.4.2.3 Recording of the measured values ..... 38
5.4.2.4 Adjustment of the measurement instruments ..... 38
5.4.2.5 Check of the instrument characteristic ..... 39
5.4.2.6 Response time of the overall measuring apparatus ..... 39
5.4.3 Particulate emissions ..... 39
5.4.3.1 Dust ..... 39
5.4.4 Surface temperatures ..... 40
5.4.5 Water side resistance ..... 40
5.5 Sampling points for the determination of the emission values ..... 40
5.6 Operating conditions of the unit during the measurements ..... 41
6. Test results ..... 43
6.1 Emission behavior of the biomass boiler ..... 43
6.1.1 Fuel gas boundary conditions ..... 43
6.1.2 Dust ..... 44
6.1.3 Carbon monoxide (CO), nitrogen oxides (NOx) and organic gaseous substances (OGC) ..... 47
6.2 Boiler efficiency and combustion period ..... 49
6.2.1 Exhaust gas loss (loss through sensible heat of the products of combustion) ..... 50
6.3 Water side resistance ..... 50
6.4 Surface temperatures ..... 51
6.5 Function check of the temperature controller, the safety limiter and on the device for dissipating excess heat ..... 52
6.5.1 Function check of the temperature controller and the safety limiter being installed at the heating boiler ..... 52
6.5.2 Function check on the device for dissipating excess heat ..... 52
6.5.3 Test results ..... 53

6.5.3.1 Function check of the temperature controller being installed at the heating boiler of the type Turbomat 150 ..... 53
6.5.3.2 Function check of the safety temperature limiter being installed at the heating boiler ..... 53
6.5.3.3 Function check on the device for dissipating excess heat ..... 54
7. Summary ..... 54
7.1 Emission values – Turbomat 150 ..... 56
7.2 Boiler efficiency and exhaust gas loss – Turbomat 150 ..... 57

Enclosures:

Appendix 1: Drawings of the heating boiler type Turbomat 150 (2 pages) (Zeichnungen des Heizkessels der Type Turbomat 150

Appendix 2: Photo of the heating boiler (Lichtbild des Heizkessels)

Appendix 3: Diagram of the concentration processes of the emission measurements accomplished in the context of the type test (6 pages) (Darstellung der Konzentrationsverläufe der im Rahmen der Typenprüfung durchgeführten Emissionsmessungen)

Appendix 4: Description of the operating conditions of the unit during the measurements (12 pages) (Darstellung der Betriebsweise der Anlage im Messzeitraum)

# 1 TASK DEFINITION

## 1.1 CLIENT

Fröling Heizkessel- und Behälterbau GesmbH, Industriestraße 12, A-4710 Grieskirchen.

Contact: Mr. Dipl.-Ing. Meindlhumer
Telephone number: 0043-(0)7248-606-0

## 1.2 MANUFACTURER

Fröling Heizkessel- und Behälterbau GesmbH, Industriestraße 12, A-4710 Grieskirchen.

## 1.3 LOCATION / MEASUREMENT

Test rig of Fröling Heizkessel- und Behälterbau GesmbH, Industriestraße 12, A-4710 Grieskirchen.

## 1.4 UNIT

The subject unit is a biomass heating system of the make Fröling, type Turbomat 150, with the objective of producing useful heat for the purpose of room heating and water heating.

The unit is subject in Austria to the regulations of ÖNORM EN 303-5 and the Austrian law (Art. 15a B-VG "Vereinbarung über Schutzmaßnahmen betreffend Kleinfeuerungen", Art. 15a B-VG "Vereinbarung über die Einsparung von Energie", and the regulation concerning heating systems (BGBl. 331/1997)).

The fuels chipped wood and wood pellets, which are used in accordance to the manufacturer´s specification in the biomass boiler type, are generally fired.

## 1.5 DATE OF TESTS

The tests of the boiler type were performed in the period of 17.07. up to 25.07.2003.
The exact measuring times are given at the measuring results.

## 1.6 CAUSE OF MEASUREMENT

(a) Type test performance in accordance to ÖNORM EN 303-5

(b) Verification of the compliance with the regulations of the agreement of the Austrian Federal States according to article 15a of the Federal Constitution about "Schutzmaßnahmen betreffend Kleinfeuerungen" and about "Einsparung von Energie".

(c) Verification of the compliance with the regulations of the Austrian Federal Law Gazette Part II No. 331/1997 (FAV, BGBl. 331/1997, regulation concerning heating systems).

(d) Verification of the compliance with the emission values and boiler efficiencies with the funding guidelines of the Austrian Kommunalkredit AG, determined in the context of the type test.

(e) Verification of the compliance with the emission values and boiler efficiencies with the requirements of the Bavarian Department of State for agriculture and forests, determined in the context of the type test, for the promotion of biomass heating systems between 100 kW and 500 kW in Bavaria (BioKomm and BioHeiz500).

## 1.7 TASK

(a) Type test performance in accordance to ÖNORM EN 303-5

(b) Verification of the compliance with the regulations of the agreement of the Austrian Federal States according to article 15a of the Federal Constitution about "Schutzmaßnahmen betreffend Kleinfeuerungen" and about "Einsparung von Energie".

(c) Verification of the compliance with the regulations of the Austrian Federal Law Gazette Part II No. 331/1997 (FAV, BGBl. 331/1997, regulation concerning heating systems).

(d) Verification of the compliance with the emission values and boiler efficiencies with the funding guidelines of the Austrian Kommunalkredit AG, determined in the context of the type test.

(e) Verification of the compliance with the emission values and boiler efficiencies with the requirements of the Bavarian Department of State for agriculture and forests, determined in the context of the type test, for the promotion of biomass heating systems between 100 kW and 500 kW in Bavaria (BioKomm and BioHeiz500).

The tests should take place at the test rig which is set up at the Fröling Heizkessel- und Behälterbau GesmbH, which is equivalent with the requirements of the ÖNORM EN 303-5.

As test fuels the fuels chipped wood and wood pellets, which are used in accordance to the manufacturer´s specification in the biomass boiler type, should be fired.

### 1.7.1 Emission limit values and requirements of the boiler efficiencies

The emission limit values underlying the evaluation of the emission behavior and the boiler efficiency are mentioned below.

Limit values in accordance with ÖNORM EN 303-5, deviations from Austria

| Parameter | limit values in accordance with ÖNORM EN 303-5, boiler class 3 (related to 10 % $O_2$) | limit values in accordance with ÖNORM EN 303-5, deviations from Austria |
|---|---|---|
| Dust | 150 mg/m³ | 60 mg/MJ |
| Carbon monoxide (CO) | 2500 mg/m³ | 500 mg/MJ |
| Nitrogen oxides ($NO_x$, shown as $NO_2$) | - | 150 mg/MJ |
| Organic gaseous substances (OGC, shown as carbon) | 80 mg/m³ | 40 mg/MJ |
| Boiler efficiency | ≥ 80.1 % ($67+ 6\log Q_N$) | ≥ 85.1 % ($68.3+ 7.7\log Q_N$) |

The emission limits for CO, $NO_x$ and OGC are calculated as arithmetic average values of the emission over the entire test period (test duration at nominal heat output and test duration at minimum heat output shall be at least 6 hours, all determined emissions are related to a dry flue gas at standard condition at 0°C and 1013 mbar).

To determine the dust content the test period has to be divided into at minimum 4 equal time sections as per ÖNORM EN 303-5.
The measurements begin in each case at the start of the sections, with the first measurement taken when the test begins. The suction time per filter is limited to 30 min. The average dust content is determined from the 4 half-hour values at minimum.
At minimum heat output the proof of keeping the emission limit values for CO and OGC is to be only furnished.

The limit value for the boiler efficiency is calculated as arithmetic average value over the entire duration of test.

Limit values in accordance with the regulations of the agreement of the Austrian Federal States according to article 15a (art. 15a B-VG) of the Federal Constitution about "Schutzmaßnahmen betreffend Kleinfeuerungen" and about "Einsparung von Energie

| Parameter | Limit values in accordance with art. 15a B-VG |
|---|---|
| Dust | 60 mg/MJ |
| Carbon monoxide (CO) | 500 mg/MJ |
| Nitrogen oxides ($NO_x$, shown as $NO_2$) | 150 mg/MJ |
| Organic gaseous substances (OGC, shown as carbon) | 40 mg/MJ |
| Boiler efficiency | ≥ 85.1 % (68.3 + 7.7log$Q_N$) |

The emission limits for CO, $NO_x$ and OGC are calculated as arithmetic average values of the emission over the entire test period (test duration at nominal heat output and test duration at minimum heat output shall be at least 3 hours, all determined emissions are related to a dry flue gas at standard condition at 0°C and 1013 mbar).
The emission value for dust is the arithmetic average determined from 3 half-hour values at minimum in the test period.
At minimum heat output the proof of keeping the emission limit values for CO and OGC is to be only furnished.
The limit value for the boiler efficiency is calculated as arithmetic average value over the entire duration of test.

Limit values in accordance with the Austrian Federal Law Gazette Part II No. 331/1997 (FAV, BGBl. 331/1997, regulation concerning heating systems)

The emission limit values underlying the evaluation of the emission behavior and the exhaust gas loss (loss through sensible heat of the products of combustion) at nominal heat output are mentioned below (limit values in accordance with FAV, (BGBl. 331/1997)).

| Parameter | Limit values in accordance with FAV |
|---|---|
| Dust | 150 mg/m³ |
| Carbon monoxide (CO) | 800 mg/m³ |
| Nitrogen oxides ($NO_x$, shown as $NO_2$) | 250 mg/m³ |
| Organic gaseous substances (OGC, shown as carbon) | 50 mg/m³ |
| Exhaust gas loss | ≤ 19 % |

With the emission measurements the content of dust, CO, NOx and OGC at nominal heat output and at minimum heat output are determined at minimum three measured values as half-hour average values in test duration at least 3 hours.

The emission limits are related to a dry flue gas basis at 13 % oxygen and standard condition at 0°C and 1013 mbar.

They are considered as kept, if none of the determined half-hour average values exceed the emission limit value.

The limit value for exhaust gas loss at nominal heat is calculated as arithmetic average value over the entire duration of test.

Limit values in accordance with the funding guidelines of the Austrian Kommunalkredit AG

| Parameter | Limit values in accordance with the funding guidelines of the Austrian Kommunalkredit AG * |
|---|---|
| Dust | 100 mg/m³ |
| Carbon monoxide (CO) | 380 / 570 mg/m³ (NL/TL) |
| Nitrogen oxides ($NO_x$, shown as $NO_2$) | 250 mg/m³ |
| Organic gaseous substances (OGC, shown as carbon) | 45 mg/m³ |
| Boiler efficiency | ≥ 87 % |

NL … nominal heat output
TL … minimum heat output

* … Limit values in the heat output range 10 – 200 kW, related a dry flue gas basis at 13 % oxygen and standard condition at 0°C and 1013 mbar.

Limit values in accordance with the requirements of the Bavarian Department of State for agriculture and forests for the promotion of biomass heating systems between 100 kW and 500 kW in Bavaria (BioKomm and BioHeiz500)

| Parameter | Limit values in accordance with BioKomm * | Limit values in accordance with BioHeiz500 |
|---|---|---|
| Dust | 50 mg/m³ | 50 mg/m³ |
| Carbon monoxide (CO) | 250 mg/m³ | 150 mg/m³ |
| Nitrogen oxides ($NO_x$, shown as $NO_2$) | - | 250 mg/m³ |
| Boiler efficiency | ≥ 85 % | - |

* … Limit values in the heat output range 100 – 300 kW, related to a dry flue gas basis at 13 % oxygen and standard condition at 0°C and 1013 mbar.

## 1.8 COORDINATION

Coordination regarding date, measuring scope and procedure took place in the run-up of the measurements with Mr. Dipl.-Ing. Meindlhumer from the client.

## 1.9 LIST OF ALL PERSONS WHO LOCALLY TOOK PART AT SAMPLING

| | |
|---|---|
| On the part of TÜV Austria: | Mr. Schrögendorfer (specialist) |
| | Mr. Gusich (specialist in initial training) |
| On the part of the manufacturer: | Mr. Dipl.-Ing. Meindlhumer |
| | Mr. Ing. Doppler |
| | Mr. Kottal |

## 1.10 PARTICIPATION OF FURTHER INSTITUTES

The elementary analysis and the determination of the calorific value of the fuel samples taken by TÜV Austria in the context of the measurements were performed by the company Holzforschung Austria in Vienna.

All other tasks were performed by TÜV Austria.

## 1.11 TECHNICALLY RESPONSIBLE PERSONS

Ing. Mair, Tel. 0043-(0)7242/61383, direct dial 8208,
Ing. Pointner, Tel. 0043-(0)7242/61383, direct dial 8200.

# 2 DESCRIPTION OF THE UNIT

## 2.1 KIND OF UNIT

The subject unit is a biomass heating system of the make Fröling, type Turbomat 150, with the objective of producing useful heat for the purpose of room heating and water heating.
The unit is subject in Austria to the regulations of ÖNORM EN 303-5 and the Austrian law (Art. 15a B-VG "Vereinbarung über Schutzmaßnahmen betreffend Kleinfeuerungen", Art. 15a B-VG "Vereinbarung über die Einsparung von Energie", and the regulation concerning heating systems (BGBl. 331/1997).
The fuels chipped wood and wood pellets, which are used in accordance to the manufacturer´s specification in the biomass boiler type, are generally fired.

## 2.2 TECHNICAL DESCRIPTION OF THE UNIT

The subject unit is a biomass heating system of the make Fröling, type Turbomat 150, with a nominal heat output of 150 kW.

The fuels chipped wood and wood pellets, which are used in accordance to the manufacturer´s specification in the biomass boiler type, are generally fired.

The furnace is designed as a stoker with reciprocating grate bars with 2 mobile and 3 stationary rust elements.

The supply with the primary air takes place under the rust and the supply with secondary air takes place by steel tubes.

The control of the air supply for combustion takes place by means of a lambda probe.

In the biomass heating system there are integrated an exhaust gas heat exchanger and an efficiency optimization system for cleaning heating surfaces and to discharge flue dust.

Additionally the boiler is provided with an exhaust gas recirculation (AGR), with which a part of the exhaust gas is sucked off by means of an exhaust recirculation fan directly after the exhaust fan and afterwards it is fed into the primary zone of the combustion.
The purified waste gases are ducted to the stack of the unit.
The determination of the boiler heat output was made by a heat meter being installed at the test rig of the company Fröling.

Drawings of the biomass heating boiler type Turbomat 150 are given to the report in appendix 1.

### 2.2.1 Technical data (in accordance to the manufacturer´s specification)

#### 2.2.1.1 Boiler

| | |
|---|---|
| Manufacturer: | Fröling Heizkessel- und Behälterbau GesmbH |
| Type: | Turbomat 150 |
| Production number: | 150 0001 . N. 17 |
| Year of construction: | 2003 |
| Nominal heat output: | 150 kW |
| Heat output range: | 45 – 150 kW |
| Allowable fuels: | chipped wood G 50 / wood pellets (in accordance with ÖNORM M 7133/7135) |
| Nominal heat generated by fuel: | 164 kW |
| Maximum allowable operating temperature: | 95°C |
| Maximum allowable operating pressure: | 3 bar |
| Water content: | 385 l |
| Boiler class: | 3 |
| Electrical connection: | 400V; 50 Hz; 22 A; 1100 W |

#### 2.2.1.2 Firing

| | |
|---|---|
| Manufacturer: | Fröling Heizkessel- und Behälterbau GesmbH |
| Construction: | stoker with reciprocating grate bars with 2 mobile and 3 stationary rust elements |
| Type: | Turbomat 150 |
| Year of construction: | 2003 |
| Air supply for combustion: | primary and secondary – controlled by means of a lambda probe. |

#### 2.2.1.3 Primary air fan

| | |
|---|---|
| Manufacturer of the motor: | company EBM |
| Motor type: | G2E140-AE77-01 |
| Engine power: | 105 W |
| Year of construction: | 1997 |

#### 2.2.1.4 Heat exchanger, integrated in the boiler

| | |
|---|---|
| Manufacturer: | Fröling Heizkessel- und Behälterbau GesmbH |

#### 2.2.1.5 Appliances for emission collection

Exhaust fan

| | |
|---|---|
| Manufacturer: | Klima Celje |
| Type: | 104CVX200/4 |
| Production number: | 115759 |
| Year of construction: | 2003 |
| Volume flow: | 0.39 $m^3/s$ |
| Speed: | 2770 $min^{-1}$ |
| Required output: | 1.1 kW |

#### 2.2.1.6 Appliances for emission reduction

Exhaust gas recirculation (AGR)

| | |
|---|---|
| Construction: | exhaust gas recirculation by means of an exhaust gas fan |

Exhaust gas recirculation fan:

| | |
|---|---|
| Manufacturer of the motor: | Dietz |
| Motor type: | WN14Q |
| Speed: | 2890 $min^{-1}$ |
| Engine power: | 0.45 kW |

Efficiency optimization system (WOS):

| | |
|---|---|
| Manufacturer: | Fröling Heizkessel- und Behälterbau GesmbH |
| Intended use: | for cleaning heating surfaces and to discharge flue ash |
| Reduced pollutants: | dust |

#### 2.2.1.7 Data of emission source

| | |
|---|---|
| Construction: | stainless steel |
| Number of stack drafts: | 1 |
| Stack height over ground: | 10.1 m |
| Diameter: | D = 0.35 m |
| Sectional area: | A = 0,096 $m^2$ |

# 3 BASES

- Accreditation decree of the Minister of Economics and Labour, No. 92714/206-I/12/03, issued at May 07, 2003, valid from 06.07.2001.

- Quality assurance system of the TÜV Austria.

- ÖNORM EN 303-5 - "Heating boilers – Part 5: Heating boilers for solid fuels, hand and automatically stocked, nominal heat output of up to 300 kW – Terminology, requirements, testing and marking"; 01.07.1999.

- ÖNORM EN 304 - "Heating boilers – Test code for heating boilers for atomizing oil burners"; 1992/A1:1998.

- OÖ LGBl. 56/1995 – "Agreement according to article 15 a B-VG about "Schutzmaßnahmen betreffend Kleinfeuerungen"", July 18, 1995.

- 388. BGBl. "Agreement between the Austrian Federation and the Austrian Federal States according to article 15a B-VG about "Einsparung von Energie"", June 9, 1995.

- 331. Federal Law Gazette of the Minister of Economic Matters on the construction, the mode of operation, the equipment and the permissible extent of the emission from units to the firing of solid, liquid and gaseous fuels in commercial plants (regulation concerning heating systems – FAV), November, 18, 1997.

- Funding guidelines of the Austrian Kommunalkredit AG.

- Guideline of the Bavarian Department of State for agriculture and forests for the aid of automatically stocked biomass heating systems (solid biomass) up to 500 kW in Bavaria (BioKomm), rev. 1 from 19.06.2001, No. M 5-7235.4-5741.

- Guideline of the Bavarian Department of State for agriculture and forests for the aid of small biomass heating stations between 100 kW and 500 kW in Bavaria (BioHeiz 500, from 27.08.2001 No. M 5-7235.4-5744.

- ÖNORM M 7510-4 – "Checking of heating systems for solid fuels with nominal heat output up to 300 kW", May, 01, 1997.

- ÖNORM M 9415 – Part 1 - "Measuring technique; Measurement of the emission of substances into the atmosphere; General requirements", May, 01, 1991.

- ÖNORM M 9466 - "Emission limits for air contaminants of wood incineration plants of a nominal fuel heat output from 50 kW onwards; Requirements and testing on the site"; June, 01, 1998.

- ÖNORM M 5861-1 - "Manual determination of particle concentrations in fluid gases; Gravimetric Method, General requirements"; April, 01, 1993.

- VDI 2066, Part 1 - "Particulate matter measurement; measuring of particulate matter in flowing gases; gravimetric determination of dust load; Oversight", October 1974.

- VDI 2456, Part 5 - "Gaseous emission measurement; measurement of nitrogen monoxide; chemiluminescence unit; thermo electron model 10;" May 1978.

- VDI 2456, Part 6 - "Gaseous emission measurement; determination of the sum of nitrogen monoxide and nitrogen dioxide as nitrogen monoxide by use of a converter;" May 1978.

- VDI 2459, Part 6 - "Gaseous emission measurement; measurement of carbon monoxide concentration; non-dispersive infrared absorption method"; November 1980.

- VDI 3481, Part 1 - "Gaseous emission measurement; determination of hydrocarbon concentration; flame-ionization-detector (FID);" August 1975.

- DIN 4702-2 - "Central heating boilers; test code"; March 1990.

- VDI/VDE 2640, Part 3, "Measurement of gas flow in circular, annular or rectangular sections of conduits velocity area method"; Nov. 1983.

- DIN 52183 – "Testing of wood; determination of moisture content"; Nov., 01, 1997.

- DIN 43710 - "Measurement and control; electrical temperature sensors, reference tables and materials of thermocouples"; September 77.

- Test report of Holzforschung Austria about the analysis of chipped wood and wood pellets, order no. 1012/2003-RB, from 26.08.2003.

- Operating instructions and installation instructions, drawings and test documents of the Fröling Heizkessel- und Behälterbau GesmbH for the heating boiler type Turbomat 150.

# 4 TEST OF THE GENERAL REQUIREMENTS

## 4.1 CONSTRUCTION REQUIREMENTS

For the subject biomass heating system of the make Fröling, type Turbomat 150, a statement of the manufacturer was handed over to TÜV Austria, that the requirements of ÖNORM EN 303-5 are observed.
A copy of the production documentation, in which the corresponding drawings, the manufacturing controls, the execution of welding work, the welding seams and welding fillers, the wall thicknesses and the safety designs are comprehended, were handed over the TÜV Austria and can be looked into in the test centre Thalheim/Wels.

In looking over the production documentation, which was handed over the TÜV Austria, no difference to the construction requirements of ÖNORM EN 303-5 could be ascertained.

The essential construction requirements of ÖNORM EN 303-5 for the subject boiler type are described below.

### 4.1.1 General requirements

Boilers shall be fire-resistant and safe to operate. They shall be made of non-combustible materials and shall be resistant to deformation and shall be such that

- they shall withstand the stresses arising during normal operation;
- the heat carrier (water) shall not become heated to a dangerous extent;
- gases shall not leak from the boiler in dangerous quantities into the place of installation;
- when the boiler is operated correctly flames do not flare out and embers do not fall out;
- dangerous accumulations of combustible gases in the combustion chamber and in the flues are prevented;

Component parts of covers, operating controls, safety devices and electrical accessories shall be arranged in such a way that their surface temperature, under steady state conditions, do not exceed those specified either by the manufacturer or in the component part standard.

The materials for the parts subject to pressure shall be in accordance with generally accepted technical requirements. They shall be suitable for the purpose and treatment intended.
The mechanical and physical properties as well as the chemical composition of the materials shall be guaranteed by the relevant material producer.

### 4.1.2 Production documentation

#### 4.1.2.1 Drawings

The following shall be specified in the boiler drawings or in the relevant documents:

- the materials used;
- the welding process, the seam type and the welding fillers;
- the maximal allowable operating temperature in °C;
- the maximal allowable operating pressure in bar;
- the test pressure in bar;
- the nominal heat output in kW in accordance with the fuel

#### 4.1.2.2 Manufacturing controls

A Quality Manual shall be compiled on the inspections and tests necessary during the manufacturing process.
Before starting the production and in the serial production the manufacturer has to see for himself, that according to his Quality Assurance System, the execution of construction work corresponds to the construction regulations, the specified materials has been used in the manufacturing, the welding has been done correctly and all needed tests were performed successfully.

A Quality Manual and a quality management system certified after EN ISO 9001 do exist for the entire product choice of the subject boiler manufacturer.

### 4.1.3 Heating boilers made of steel and non-ferrous materials

#### 4.1.3.1 Execution of welding work

Boiler manufacturers who carry out welding work shall meet the requirements of EN 287-1 and EN 287-2.

There are to be used here:

- only welders who are qualified in the welding of the materials to be processed may be used
- equipment shall be available to allow defect free welding to be carried out
- supervision of the welding shall be carried out by staff qualified in welding (at least one supervisor shall be so qualified, here: 1 welding technologist and 1 welding foreman)

#### 4.1.3.2 Welding seams and welding fillers

The used materials shall be suitable for welding.
In executing the welding seams the adherence of the requirements of the ÖNORM EN 303-5 has to be observed and be ensured by appropriate controls.
Welding fillers shall be suitable for the material being used.

#### 4.1.3.3 Parts of steel subject to pressure

The steels listed in table 1 of the ÖNORM EN 303-5 shall be used.
The specifications of the materials are documented by works certificates (in accordance with EN 10204, with the exception of small parts) by the boiler manufacturer.

#### 4.1.3.4 Minimum wall thicknesses

The minimum wall thicknesses shall comply with the thicknesses listed in ÖNORM EN 303-5, table 3, point 4.1.3.4 by taking account of

- the maximum allowable operating pressure,
- the nominal heat output and
- the material properties

### 4.1.4 Safety and design requirements

#### 4.1.4.1 Venting of the water sections and gas flue passages

The boiler and its components shall be designed in such a way that their respective water sections can be fully vented.
The boiler shall be so designed that under normal operation in accordance with the manufacturer's instructions no undue boiling noises occur. The combustion chamber and the flue gas passages shall be designed in such a way that no dangerous accumulation of combustible gases is possible.

For the subject heating boiler type the installation is carried out increasing lightly towards the flow connection. In accordance to the manufacturer´s specification the venting of the water section needs to be provided by customer with a connection in the flow.
The correct installation of the heating boiler (increasing lightly towards the flow connection), the preparation of a corresponding connection in the flow needed by customer and the venting procedure has to be included in the installation instructions and in the operation instructions.

#### 4.1.4.2 Cleaning of heating surfaces

The heating surfaces shall be accessible from the flue gas side for inspection and cleaning with chemical agents and brushes. A sufficient number and appropriate arrangement of cleaning openings shall be provided. If special tools (for example special brushes) are required for cleaning and maintenance of the boiler these should be supplied.

At the heating boiler type Turbomat 150 the cleaning of the heating surfaces is made automatically by the integrated WOS-system. Cleaning of the heating surface further can be done over the door of the combustion chamber, the inspection door installed in the zone of the first turning chamber and over 1 cleaning cap above the WOS.

In accordance to the manufacturer´s specification 1 brush, 1 flat scraper and 1 triangular scraper are provided as cleaning implements.

#### 4.1.4.3 Inspection of the flame

A facility shall be provided which allows inspection of the flame or fire bed. If this facility is a door, then hazard-free inspection shall be possible (here: inspection glass on the front top side of the retort, situated behind the door of the combustion chamber).

#### 4.1.4.4 Water tightness

Holes for screws and similar components which are used for the attachment of removable parts shall not enter into spaces through which water flows. This does not apply to pockets for measuring or control and safety equipment.

#### 4.1.4.5 Replacement parts

Replacement and spare parts (e.g. inserts, shaped firebricks, turbulators etc.) shall be designed, made or marked in such a way that their installation in accordance with the manufacturer's instructions shall be correct.

#### 4.1.4.6 Water side connections

Adaptor nipples shall comply with the Standards ISO 7-1 ISO 7-1, ISO 7-2, ISO 228-1 and ISO 228-2 and flange connections shall comply with ISO 7005-1, ISO 7005-2 and ISO 7005-3. The arrangement of the connections shall be such that they are easily accessible and the function of each respective connection can be adequately fulfilled. There shall be sufficient space around the connection to allow the installation of the connecting pipes (flanges, bolts) with necessary tools.

Threaded pipe connections above DN 50 should not be recommended. Threaded pipe connections with nominal diameters above DN 80 are not permissible. If connections are fitted with flanges, the mating flanges and seals shall also be supplied except standardized flanges are available (here: flow and return connection DN 65 PN6, further connections ½ inch to 1 inch).

Every boiler shall have at least one connection for filling and emptying. This connection may be common.
It is possible to provide these connections outside the boiler if satisfactory filling and emptying of the boiler can be assured.
At the heating boiler type Turbomat 150 a connection with a dimension of ¾ inch is installed (requirement as per EN 303-5: G 3/4 for nominal heat outputs above 70 kW).

#### 4.1.4.7 Connections for control and indicating equipment, and safety thermostat

Every boiler shall be equipped with at least one connection for an immersion pocket for temperature control, safety-temperature limiter and thermometer. Its minimum nominal diameter shall be G 1/2 (here: 2 immersion shells, each with ½ inch).

Deviations are allowed, provided that the control devices are supplied with the boiler, and that they can not be substituted by other components.

The position of the connections shall be chosen in such a way that the temperature of the boiler water is recorded with sufficient accuracy. Where additional connections for safety devices such as a pressure detector, monometer, low water cut-out device or a safety valve are provided for, their size, especially the safety valve is to be determined according to the output of the boiler.

#### 4.1.4.8 Thermal insulation

All boilers shall be fitted with thermal insulation. The thermal insulation shall withstand normal thermal and mechanical stresses. It shall be made of non-combustible material and shall not give off fumes during normal running.

#### 4.1.4.9 Water side resistance of the boiler

The water side resistances was determined for those flows which correspond to the nominal heat output with two temperature differences of 10 K and 20 K between the flow and return connections of the boiler. The results are mentioned in the test report in point 6.3.

#### 4.1.4.10 Temperature control and limiting devices

The control and safety devices described in the sections below and the appropriate installation options shall be provided for each boiler, depending on the type of firing system and the type of protection provided for the installations in which the boiler is to be fitted. The equipment required in each case shall be supplied by the boiler manufacturers along with the boiler; if not precise specifications shall be given in the installation instructions, in particular the limit values and time constants for safety temperature limiter.

When used in thermostatically protected heating installations the firing system shall be either rapidly or partly disconnectable, and/or the heat or residual heat output not absorbed by the heating system shall be dissipated reliably using a safety heat exchanger or equivalent devices.

For the subject unit following equipment variant is realized:

The firing system is partly disconnectable; the necessary equipment consists of:

- a temperature controller;
- a safety temperature limiter (manual reset);
- a reliable device for dissipating the residual heat output

#### 4.1.4.11 Combustion chamber

The combustion chamber shall be designed in such a way that the fuel moves freely and the duration of the combustion period is assured.

#### 4.1.4.12 Ash chamber

The capacity of the ash chamber shall be adequate for a combustion period of at least 12 hours using the stipulated fuel and at nominal heat output – taking into account the unobstructed flow of air under the grate.
If – like in this case – the system is designed with devices for automatic ash and clinker removal, the above requirement shall be considered as met.

#### 4.1.4.13 Stoking devices

Automatic stoking systems shall be designed with a safety device to prevent back-burning into the feeder or metering device or creating a blow-back.

According to the manufacturer informations the subject heating boiler type Turbomat 150 is used in normal case with a charging chute with fire shutter or otherwise with a suitable star feeder.

#### 4.1.4.14 Heating boiler accessories

If the boiler is factory equipped with additional fittings and if they need to be serviced to ensure the correct operation and safety of the boiler, the design should not require extensive dismantling work.

#### 4.1.4.15 Electrical safety

Before the start of production, boilers shall be subjected to the electrical tests.
The requirements of electrical safety are to be conducted on the basis of EN 60335-1.

(1) General specifications
- type of the boiler protection (in accordance with EN 60529);
- specifications concerning electrical components (e.g. switches, relays).

(2) Certificates of conformity:
Detailed certification is to be supplied by the equipment manufacturer for:
- heating;
- operation of equipment with electrical heating elements under overload condition;
- interference suppression;
- thermal endurance, resistance to creeping.

Appropriate CE Conformity Declarations made by the boiler manufacturer and an EMC compatibility test of the boiler control are hand on at TÜV Austria for inspection.

### 4.2 PRESSURE TESTS

Before the start of production, boilers shall be subjected to the rating test. During production the construction and water pressure tests shall be carried out.
At this all boilers and their parts shall be subjected to a hydraulic or pneumatic pressure test in the works of the manufacturer. No leakage shall occur.

#### 4.2.1 Tests to be carried out before production

The type test pressure is $2 \times p_1$ using hydraulic pressure ($p_1$ is the maximum permissible operating pressure, here: $p_1 = 3$ bar).

The test period shall be at least 10 minutes and if it is to apply to a range of boilers, the test shall be carried out on at least 3 boiler sizes (smallest, medium and largest size). No leakage or noticeable permanent deformation shall occur during the test.

A record shall be made of the test giving the following details:

- exact description of the boiler tested stating the drawing number;
- test pressure in bar and duration of the test;
- test result;
- place and date of the test including the names of persons carrying out the test. The test shall be signed by, as a minimum the works tester responsible and one witness.

A type test record of the boiler type Turbomat 150 is on hand at TÜV Austria (test pressure 2 x $p_1$ = 6 bar, test duration 15 minutes).

### 4.2.2 Test during production

The test pressure shall be according to ÖNORM EN 303-5 1.3 x $p_1$ (here: $p_1$ = 3 bar), with a minimum of 4 bar.

## 4.3 DESIGNATION

Each heating boiler shall have a data plate. The boiler data plate shall be written in the language of the boiler´s country of destination and be affixed in an accessible spot.

### 4.3.1 Information on the boiler plate

a) name and company domicile of the manufacturer and, where available, the manufacturer's symbol;
b) trade designation, type under which the boiler is marketed;
c) production number and year of construction (coding is permissible at the manufacturer's discretion);
d) nominal heat output and heat output range in kW for each type of fuel;
e) boiler class;
f) maximal allowable operating pressure in bar;
g) maximal allowable operating temperature in °C;
h) water content in l;
i) electrical connection (V, Hz, A) and wattage in W.

### 4.3.2 Data plate requirements

The material and labelling used for the plate shall be durable. The labelling shall be abrasion-proof. Under normal operating conditions the plate shall not discolour so as to make its information difficult to read.

## 4.4 TECHNICAL DOCUMENTATION, SUPPLIED WITH THE BOILER

For each boiler the documents listed below shall be available, preferably in the language of the boiler's country of destination; the documents specified under point 4.4 shall be enclosed with every boiler.

Because the heating boiler type Turbomat 150 showed exhaust gas temperatures below 160 K above room temperature in the context of the type tests performed by TÜV Austria at nominal heat output (see point 6.1.1) the boiler manufacturer shall make recommendations in the installation instructions regarding the flue installation in order to ensure sufficient draught and to prevent sooting up of the chimney and condensation.

Drafts of the technical information, the installation instructions and the operating instructions of the boiler control system were handed over the TÜV Austria in the context of the tests and can be looked into in the test centre Thalheim/Wels.

The technical documents being enclosed with the boiler shall contain the indications mentioned in point 4.4 and has to be updated.

### 4.4.1 Technical information and installation instructions

These documents shall contain at least the following indications:

- necessary draught in mbar;
- water content in l;
- exhaust gas temperature at nominal heat output and minimum heat output in °C;
- exhaust mass flow nominal heat output and minimum heat output in kg/s;
- flue pipe diameter in mm;
- water-side resistance in mbar;
- nominal heat output and heat output range for each type of fuel in kW;
- boiler class;
- combustion period in hours for each type of fuel at $Q_N$;
- setting range fort he temperature controller in °C;
- minimal return temperature at boiler return tapping in °C;
- fuel type and water content as well as fuel size;
- filling chamber capacity in litres and filling opening dimensions in mm;
- necessary accumulator storage in litres if $Q_{min} > 0.3\ Q_N$;
- auxiliary power requirement in W;
- cold water temperature and pressure for safety heat exchanger in bar;
- electrical connections including appliance- and main-switch-off.

The installation instructions shall contain information concerning:

- the on-site assembly of the boiler (if necessary) and the required pressure test;
- the installation;
- the commissioning, with information on the boiler output to be set in the output range;
- instructions on the location and fitting of the sensors for the control, display and safety equipment.

In addition the document shall in general contain references to the Standards and Regulations to be observed on the safety equipment of the installation.

### 4.4.2 Operating instructions

The operating instructions shall contain references to:

- the operation of the boiler, stoking and opening doors without risk;
- cleaning and cleaning intervals, including the equipment required fort he cleaning operations;
- measures to be taken in the event of malfunction;
- the reasons for recommending a regular, competent maintenance service and the necessary maintenance intervals;
- the type of fuel and water content and the fuel size (with the direction of the layers in the case of wood chips);
- the maximum filling height for fuel in the filling chamber;
- the combustion period for fuel types at nominal heat output.

Other documents (brochures, etc.) shall not contain any information that is in contradiction with those of the operating instructions.

# 5 TEST OF THE BOILER PERFORMANCE REQUIREMENTS

## 5.1 BOILER PERFORMANCE TEST

### 5.1.1 Choice and condition of the tested boiler

Fittings and accessories supplied by the manufacturer have been installed and used correctly at the tested boiler. The operating and installation instructions were considered.
The condition and the equipment of the boiler to be tested were conforming to the normal supply specification in accordance with the manufacturer´s instruction and the documents provided to TÜV Austria.
Additional thermal insulation to parts in contact with water, products of combustion and fire were not used.

The boiler manufacturer shall ensure that all boilers of the tested boiler type conform to the requirements of the ÖNORM EN 303-5.

### 5.1.2 Setting up the test rig

The boiler performance test has been carried out at the test rig of the Fröling Heizkessel- und Behälterbau GesmbH in Grieskirchen.
The test rig and the flue gas measuring section corresponded with the requirements of the ÖNORM EN 303-5.
The measuring instruments and the measuring methods corresponded with the requirements of the ÖNORM EN 303-5.

The useful heat output transmitted to the water was determined by a calibrated heat meter by measuring the flow of the water circulating in the boiler circuit and its temperature rise.

The determination of the boiler efficiency of the biomass heating system has been performed in accordance with the formalism of the direct method expressed in ÖNORM EN 303-5.

### 5.1.3 Measured quantities

One-off measurement:

- water content of the fuel;
- fuel mass added;
- combustion period;
- surface temperatures (at nominal heat output in a typical operating condition in accordance with ÖNORM EN 303-5)

Continuous measurement:

- heat output;
- flow temperature;
- return temperature;
- flow;
- ambient temperature;
- exhaust temperature;
- oxygen concentration ($O_2$);
- carbon monoxide concentration (CO);
- concentration of organic gaseous substances (OGC, shown as organically bound carbon);
- nitrogen oxides concentration (sum of NO and $NO_2$, shown as $NO_2$)

Discontinuous measurement:

- draught (static pressure in the flue gas pipe);
- dust content

### 5.1.4 General test conditions

To determine the heat output, boiler efficiency, combustion period, composition of the combustion gas, exit flue temperature, draught and emission properties, the boiler has been operated throughout the tests within the specified heat output range.

The boiler heat output is the average of the output recorded during the test period.

At nominal heat output the boiler was operated in such a way that continuous running was possible without thermostat cut-off.
The minimum heat output was regulated by a control device.

The boiler was brought to operating temperature before the start of measurements, the draught was adjusted in accordance with the manufacturer instruction and the boiler was operated during the test in accordance with the manufacturer instruction.

The test duration and thus also the combustion period duration was both at nominal heat output and at minimum heat output at least 6 hours.

The continuously registering measuring instruments for the determination of pollutant concentrations of the flue gas were taken at the test rig the day before the test.

The ambient temperature values were between 15°C and 30°C.

During tests at nominal heat output it was made certain that the mean value of flow temperature lay between 70°C and 90°C, whereby the mean temperature difference lay between flow and return between 10 K and 25 K.

Further during tests at nominal heat output the temperature mentioned below was maintained:

$$\frac{t_V + t_A}{2} - t_L \geq 40.0K$$

Where:

$t_V$ flow temperature in °C
$t_A$ return temperature in °C
$t_L$ ambient temperature in °C

During tests at minimum heat output this was regulated before starting the test and also made certain that the mean value of flow temperature lay between 70°C and 90°C.

### 5.1.5 Determination of the boiler efficiency

The efficiency of the biomass heating system was determined according to the formalism of the direct method shown in ÖNORM EN 303-5 and related on the basis of the net calorific value $H_u$ of the fuels being used.

During the test duration the boiler heat output was determined as average of the recorded values of the output.

The determination of the fuel mass fed to the biomass heating system took place via weighing with a balance of the make Karl Öllinger GmbH, model IT 3000 (last calibration: 2002).

For this purpose before starting the test the fuel feed by worm, which is normally installed at the unit, was deactivated and exchanged with an ad hoc provided collecting main box (nominal contents 1 $m^3$) for fuel feed, equipped with a worm conveyer system.

The filling of the collecting main box took place in a batch process (manual filling of weighed amounts of fuel from metal boxes with a nominal content of 0.5 $m^3$ by means of a forklift).

The useful heat output transmitted to the water was determined by a calibrated heat meter by measuring the flow of the water circulating in the boiler circuit and its temperature rise.

Technical data of the heat meter

| | |
|---|---|
| Manufacturer: | Kamstrup |
| Type: | Ultraflow 65-SCMBH-372 |
| Production number: | 01/4187548 |
| Nominal diameter: | DN 80 |
| Flow range/meter factor: | 0.4 - 40 m³/h / 5 imp./l |
| Temperature measurements: | Pt 100 |
| Date of last calibration: | 2002 |
| Transmitter: | |
| Manufacturer: | Kamstrup |
| Type: | Multical 66C43A1372 |
| Production number: | 4187548/2001 |
| Flow range: | 0.4 - 40 m³/h |
| Meter factor: | 5 imp./l |

Calculation of the boiler efficiency

$$Q_B = \frac{m_B.Hu}{3600} \qquad \eta_K = \frac{Q}{Q_B}.100$$

$Q$..... heat output, the useful heat to water delivered by a boiler per unit time in kW

$Q_B$..... heat input, the amount of heat in unit time which is supplied to the furnace of the heating boiler by the fuel based on its net calorific value $H_U$. in kW

$H_U$..... net calorific value of the test fuel, as fired basis in kJ/kg

$\eta_K$..... boiler efficiency, ratio of the delivered useful heat output to the heat input in %

The estimated measurement uncertainty of the total procedure for the determination of the boiler efficiency is ± 2 per cent.

### 5.1.6 Determination of the exhaust gas loss (loss through sensible heat of the products of combustion)

The exhaust loss of the biomass heating system was calculated by the formalism mentioned below in accordance to the 331. Federal Law Gazette of the Minister of Economic Matters on the construction, the mode of operation, the equipment and the permissible extent of the emission from units to the firing of solid, liquid and gaseous fuels in commercial plants (regulation concerning heating systems – FAV) from 18.11.1997:

Exhaust gas loss (%) $q_A = (t_A - t_L) . [A_2/(21 - O_2) + B]$

$t_A$..... exhaust gas temperature °C (measured on the measuring point after flue exit of the boiler)
$t_L$..... ambient temperature in °C
$O_2$..... dry oxygen content of the flue gas in % of vol.
$A_2$..... 0.6655 for biomass with the test fuel pellets (water content of the fuel: 7.5 %)
0.6807 for biomass with the test fuel chipped wood (water content of the fuel: 18.8 %)
B..... 0.0104 for biomass with the test fuel pellets (water content of the fuel: 7.5 %)
0.0123 for biomass with the test fuel chipped wood (water content of the fuel: 18.8 %)

The input data used for the calculation of the exhaust gas loss at the measuring point after flue exit of the boiler are mentioned in point 6.1.

The estimated measurement uncertainty of the total procedure for the determination of the exhaust gas loss is ± 0.5 per cent.

### 5.1.7 Determination of the emission values

The average $O_2$, CO, OGC and NOx contents are determined over the entire test period.

To determine the dust content the test period was divided into at minimum 4 equal time sections and the suction time per filter was limited to 30 minutes.
The average dust content was determined from the 4 half-hours values at minimum.

The volume of combustion gas was calculated by means of combustion gas calculation using the DIN 4702 on the basis the chemical elementary analysis of the test fuel and the amount of fuel fired in the test period.

The velocity of the flue gas at the measurement point used to determine dust emissions was calculated from the volume of combustion gas, taking into account of pressure, temperature and moisture content.

For the calculation of the mean value of the emissions of $O_2$, CO, OGC and NOx the measured concentrations have to be weighted of the flue gas volume.
In accordance to ÖNORM EN 303-5 the acceptable approximation for the calculation of the mean value – the calculation of the mean value of the period independent of the volume stream of the flue gas – was used.

The part of organic gas parts was determined as organically bound carbon (OGC) in dry flue gas.

The determination of the part of organic gas parts (OGC) was performed without splitting the individual components with a flame ionistion detector (FID) for which calibration propane was used.

The sum of nitrogen oxides ($NO_x$), measured as sum of nitrogen monoxide (NO) and nitrogen dioxide ($NO_2$), is calculated and shown as nitrogen dioxide ($NO_2$).

### 5.1.8 Surface temperatures

For the determination of the mean surface temperature at nominal heat output the boiler surface was divided in 12 incremental areas, whereby for each area between 3 and 6 measuring points were regarded.

Under the same conditions the critical surface temperatures (e.g. boiler doors, operating levers etc.) and the surface temperature on the outside of the boiler bottom were measured at nominal heat output.

## 5.2 DETERMINATION OF THE WATER SIDE RESISTANCE

The water side resistance was determined for the flow which is equivalent to the rated output of the healing boiler at a temperature difference of $\Delta t = 10$ K and $\Delta t = 20$ K between the flow and the return.

## 5.3 TEST FUELS

The tests were performed with test fuels of commercial quality mentioned below.
The supply of the test fuels took place via the boiler manufacturer.

| | |
|---|---|
| Test fuel 1: | pellets, compressed wood HP 1, PVA No. 36202, company Glechner |
| Test fuel 2: | chipped wood B1, pine, size G50 |

### 5.3.1 Fuel analysis

In the test period samples of the test fuels were taken by the specialist of the TÜV Austria (Mr. Schrögendorfer).

The determination of the water content of the fuel samples took place via drying process in a drying oven in accordance to DIN 51718 (DIN 52183) in the test centre Thalheim/Wels of the TÜV Austria.

The elementary analysis and the determination of the net calorific value of the fuel samples were performed by the company Holzforschung Austria in Vienna. The results of the fuel analysis are shown in the test report of Holzforschung Austria about the analysis of chipped wood and wood pellets, order no. 1012/2003-RB, from 26.08.2003.

The results of the fuel analysis of the test fuels fired in the test period performed by TÜV Austria and Holzforschung Austria are mentioned below (related to raw condition).

| | test fuel pellets | test fuel chipped wood |
|---|---|---|
| Net calorific value of the fuel ($H_u$): | 17110 kJ/kg | 14480 kJ/kg |
| Water content of the test fuel (W): | 7.5 % of mass | 18.8 % of mass |
| Carbon content of the test fuel (C): | 46.1 % of mass | 41.0 % of mass |
| Hydrogen content of the test fuel (H): | 3.8 % of mass | 3.2 % of mass |
| Oxygen content of the test fuel (O): | 41.9 % of mass | 36.4 % of mass |
| Nitrogen content of the test fuel (N): | 0.2 % of mass | 0.2 % of mass |

## 5.4 MEASUREMENT INSTRUMENTS AND METHODS

### 5.4.1 Flue gas boundary conditions

#### 5.4.1.1 Flue gas volume and flue gas velocity

The volume of combustion gas was calculated by means of combustion gas calculation using the DIN 4702 on the basis the chemical elementary analysis of the test fuel and the amount of fuel fired in the test period.

The velocity of the flue gas at the measurement point used to determine dust emissions was calculated from the volume of combustion gas, taking into account of pressure, temperature and moisture content.

#### 5.4.1.2 Static pressure in the flue gas pipe (draught)

| | |
|---|---|
| Measuring Method: | determination of differential pressure between static pressure in the flue gas pipe and ambient pressure |
| Guideline: | VDI 2066, Part 1 |
| Instrument: | Prandtl´s pitot tube in combination with a calibrated micromanometer |
| Manufacturer: | Special Instruments |
| Type: | Digima FP auto zero |
| Range: | 0 – 5 hPa |
| Uncertainty: | ± 5 % of the measured value |

#### 5.4.1.3 Air pressure at the height of the sampling point

| | |
|---|---|
| Instrument: | calibrated precision barometer for the measurement of the absolute air pressure |
| Manufacturer: | Lufft |
| Type: | Model 2039, transportable |
| Uncertainty: | ± 1 hPa |

#### 5.4.1.4 Flue gas temperature

| | |
|---|---|
| Measuring method: | thermoelectric |
| Guideline: | DIN 43710 |
| Instrument: | Fe-Cu-Ni thermocouple with a digital display instrument |
| Manufacturer: | Mesa Electronic |
| Type: | A009.411.40.40 |
| Uncertainty: | range ≤ 150°C: ± 3°C<br>range > 150°C: ± 2 % of the measured value |

#### 5.4.1.5 Ambient air temperature

| | |
|---|---|
| Instrument: | electronic hand measuring instrument with Pt 100 |
| Manufacturer: | Testo |
| Type: | Testo 925 |
| Uncertainty: | ± 1°C |

#### 5.4.1.6 Proportion of water vapour in the flue gas (flue gas humidity)

| | |
|---|---|
| Measuring method: | two-thermometer-method |
| Instrument: | psychrometer |
| Uncertainty: | ± 10 % of the measured value |

#### 5.4.1.7 Flue gas density

Calculated taking into account the flue gas proportions of $O_2$, $CO_2$, $N_2$, CO, flue gas humidity, flue gas temperature and the pressure in the duct.

### 5.4.2 Gaseous and vapour emissions

#### 5.4.2.1 Continuously recorded measurement instruments

$O_2$:

| | |
|---|---|
| Manufacturer: | Servomex |
| Type: | OA570 |
| Measurement method: | paramagnetism |
| Range: | 0-25 % of vol. |
| Uncertainty: | ± 0.2 % of vol. |

$CO_2$:

| | |
|---|---|
| Manufacturer: | Siemens |
| Type: | Ultramat 22P |
| Measurement method: | non-dispersive infrared absorption |
| Range: | 0-20 % of vol. |
| Uncertainty: | ± 0.2 % of vol. |

CO

Range up to 1000 ppm:

| | |
|---|---|
| Manufacturer: | Siemens |
| Type: | Ultramat 22P |
| Measurement method: | non-dispersive infrared absorption |
| Range: | 0-1000 ppm |
| Uncertainty: | range up to 100 ppm: ± 2 ppm<br>range 100-1000 ppm: ± 2 % of the measured value |

Range up to 1 vol.-%:

| | |
|---|---|
| Manufacturer: | Maihak |
| Type: | Unor 6 N |
| Measurement method: | non-dispersive infrared absorption |
| Range: | 0-1 vol-% (0 – 10000 ppm) |
| Uncertainty: | range > 1000 ppm: ± 2 % of the measured value |

| | | |
|---|---|---|
| $NO_x$ | Manufacturer: | Monitor Labs |
| | Type: | Model 8840 |
| | Measurement method: | chemiluminescence |
| | Converter: | stainless steel converter (thermostated on 750°C) |
| | Used range: | 0-500 mg NO/m³ |
| | Uncertainty: | ± 1.5 % of range performance |
| C | Manufacturer: | Testa |
| | Type: | FID 123 |
| | Measurement method: | flame ionisation |
| | Used ranges: | 0-100 and 0-1000 ppm $C_3H_8$ |
| | Uncertainty: | ± 1.5 % of range performance |

#### 5.4.2.2 Measurement location design

The measurement location design for the determination of the gaseous components of flue gas at the measuring point is mentioned below.

Sampling probe

| | |
|---|---|
| Material/heating: | stainless steel, heated by flue gas |
| Length: | 0.5 m |
| Inside diameter: | 6 mm |
| Outside diameter: | 8 mm |

Filter

| | |
|---|---|
| Manufacturer: | Testa |
| Type: | fine-mesh filter 1004 B, 5 µm |
| Material/heating: | stainless steel, heated on 180°C |

The sampling line was divided after the fine-mesh filter in the sampling lines mentioned below:

- sampling line 1: for determination of the concentration of organic gaseous substances (C)
- sampling line 2: for determination of the concentrations of $O_2$, CO, $CO_2$ and $NO_x$

Sampling lines 1 and 2

| | |
|---|---|
| Manufacturer: | Winkler |
| Material/heating: | Teflon, heated on 180°C |
| Length: | 5 m |

| | |
|---|---|
| Outside diameter: | 8 mm |
| Inside diameter: | 6 mm |

Measurement gas cooler (gas treatment, situated after sampling line 2)

| | |
|---|---|
| Manufacturer: | Bühler |
| Type: | EGK-4 |
| Temperature, regulated to: | 4°C |
| Numbers of cooling channels: | 2 |

Sampling line 3 (situated after gas treatment)

| | |
|---|---|
| Material/heating: | Teflon, unheated |
| Length: | approx. 20 m |
| Outside diameter: | 6 mm |
| Inside diameter: | 4 mm |

#### 5.4.2.3 Recording of the measured values

| | |
|---|---|
| Logging software: | software Dasylab, company Dewetron |
| Module: | ISM 100 intelligent sensor module V.2.O., company Gantner |
| Scanning rate: | 1 second |
| Resolution A/D-transducer: | 16 bit |
| Uncertainty: | ± 0.3 % of the measured value |

#### 5.4.2.4 Adjustment of the measurement instruments

Before starting and after finishing the test periods the reference points of the gas analysis instruments were adjusted by feeding test gases of the companies Messer Griesheim and Siad mentioned below.

| Parameter | Test gas concentration as per certificate of analysis | Manufacturer | Tolerance of test gas analysis in accordance to the manufacturer´s specification |
|---|---|---|---|
| CO | 790 ppm CO | Siad VTG | ± 2 % of test gas concentration |
| $CO_2$ | 16.14 % of vol. $CO_2$ | Siad VTG | ± 2 % of test gas concentration |
| $NO_x$ | 393 mg NO/m³ | Siad VTG | ± 2 % of test gas concentration |
| C | 93.1 ppm $C_3H_8$ | Messer Griesheim | ± 2 % of test gas concentration |

The adjustment of the reference points of the $O_2$-measuring instruments was taken by ambient air. The adjustment of the zero points of the gas analysis instruments was taken by nitrogen of the quality 5.0.

#### 5.4.2.5 Check of the instrument characteristic

In accordance to the quality assurance manual of the TÜV Austria the check of the instrument characteristics is done once a year. Recordings can be looked into in the test centre Thalheim/Wels.

#### 5.4.2.6 Response time of the overall measuring apparatus

The response time ($t_{90}$ – time) for the slowest operating component ($NO_x$) amounted to maximally 126 seconds and was determined by the time which was needed by bringing the probe into the duct up to reaching 90 % of the final value.

### 5.4.3 Particulate emissions

#### 5.4.3.1 Dust

| | |
|---|---|
| Sampling probe: | titanium, heated by flue gas |
| Position of the filter holder: | internal in duct |
| Particle filter: | plane filter made of quartz fibre |
| Quartz flat filter: Manufacturer: | Munktell Filter AB, Sweden |
| Type: | MK 360 |
| Extraction capacity: | 99,998 % related to 0.3 µ in accordance to DOP-test |
| Temperature stability: | max. 950°C work temperature |
| Material: | maximum pure silicia-fibre |
| Characteristics: | not hydrophobic, no organic bonding agents |
| Differential pressure: | 180 Pa at 3 cm/s exhaust velocity |
| Transfer of the samples: | the time period between sampling and weighing of the used dust filters amounted to 3 – 7 days |
| Uncertainty: | ± 5 % of the measured value, ± 0.74 mg/m³ at minimum |
| Sampling and analysis: | in accordance to ÖNORM M 5861-1 |
| Drying temperature of the collection medium | |
| before exposure: | 110 °C |
| after exposure: | 110 °C |
| Drying time of the collection medium (equilibration) | |
| before and after exposure: | approx. 24 hours (in the dessiccator) |

Gas volume meter for the determination of the flue gas sucked off during dust sampling:

| | |
|---|---|
| Manufacturer: | Elster |
| Type: | dry design, G 4 |
| Commerce error limit: | ± 4 % of the measured value |

Analysis balance:

| | |
|---|---|
| Manufacturer: | Mettler |
| Type: | AE 163 |
| Graduation: | 0.01 mg (weighing range 0 – 31 g) |

The leakage test of the apparatus for dust measurement took place via applying a vacuum before the performance of the single measurements.

The oxygen concentration at the measuring point of dust took place at the outlet of the gas meter with an oxygen meter of the type OA 570, company Servomex (see point 5.3.2.1).

### 5.4.4 Surface temperatures

| | |
|---|---|
| Instrument: | surface thermometer with thermocouples type J-K |
| Manufacturer: | Omega |
| Model: | HH22 |
| Uncertainty: | ± 1°C |

### 5.4.5 Water side resistance

| | |
|---|---|
| Instrument: | measuring instrument for differential pressure |
| Manufacturer: | CBI |
| Production number: | 0806 60404 |
| Range: | - 5 up to + 205 hPa |
| Last calibration: | 2002 |
| Uncertainty: | ± 5 % of the measured value |

## 5.5 SAMPLING POINTS FOR THE DETERMINATION OF THE EMISSION VALUES

The measurements took place at the measuring points mentioned below.

Measuring point after the flue exit of the boiler for determination of the flue gas temperature

The measuring point was situated directly after the flue exit of the boiler in the vertical flue gas pipe between the flue exit of the boiler and the exhaust fan.

Measuring point for the determination of the gaseous pollutants

The sampling took place from the flue gas pipe between the exhaust fan and the inlet of the flue gas into the chimney.

| | |
|---|---|
| Length of the straight inlet: | approx. 1.1 m |
| Length of the straight outlet: | approx. 1.3 m |
| Circular cross section: | D = 0.18 m |

Measuring point chimney

The sampling for the determination of the dust concentration of the flue gases and the flue gas volume took place from the chimney of the unit.

| | |
|---|---|
| Length of straight inlet: | approx. 1.4 m |
| Length of straight outlet: | > 5 m |
| Circular cross section: | D = 0.34 m |

## 5.6 OPERATING CONDITIONS OF THE UNIT DURING THE MEASUREMENTS

The heating boiler of the type Turbomat 150 set up at the test rig of the Fröling Heizkessel- und Behälterbau GesmbH became fired at nominal heat output (full load) and at maximum 30 % of the heat output of the biomass heating system (minimum heat output in accordance to the manufacturer´s instructions, partial load) with the test fuels mentioned below in the test period (17.07. – 25.07.2003).

| | |
|---|---|
| Test fuel 1: | pellets, compressed wood HP 1, PVA No. 36202, company Glechner, w = 7.5 % |
| Test fuel 2: | chipped wood B1, pine, size G50, w = 18.8 % |

The determination of the amount of heat input which was supplied to the furnace of the heating boiler by fuel took place analytically after weighing the supplied fuel mass and with the analysis data determined from the fuel analysis of the samples by the TÜV Austria and the Holzforschung Austria.

The useful heat output transmitted to the water was determined by a calibrated heat meter by measuring the flow of the water circulating in the boiler circuit and its temperature rise.

The operating conditions of the boiler unit during the measurements are shown below.

Descriptions of the operating conditions of the unit during the test period are given to the test report in appendix 4.

Operating conditions of the unit during the measurements – test fuel wooden pellets

| Parameter | Nominal heat output | | Minimum heat output |
|---|---|---|---|
| | Operation without AGR | Operation with AGR | Operation without AGR |
| Date of measurements | 21.07.2003 | 21.07.2003 | 18.07.2003 |
| Measuring time (from – to) | 08:01-14:01 | 15:26-21:26 | 08:11-14:11 |
| Test duration (hours) | 6.0 | 6.0 | 6.0 |
| Boiler temperature (°C) | 80 | 81 | 78 |
| Combustion chamber temperature (°C) | 922 | 849 | 688 |
| Negative pressure in the combustion chamber (Pa) | 45 | 46 | 26 |
| Feed (%) | 6.8 | 5.1 | 1.7 |
| Primary air (%) | 38 | 21 | 21 |
| Secondary air (%) | 17 | 20 | 76 |
| Exhaust gas recirculation position AGR (%) | 0 | 62 | 0 |
| Water amount added (flow, l/h) | 6404 | 6405 | 2106 |
| Flow temperature (°C) | 78.1 | 78.8 | 74.8 |
| Return temperature (°C) | 57.9 | 58.9 | 57.1 |
| Temperature difference flow-return (°C) | 20.2 | 19.9 | 17.7 |
| Heat output useful generated (kW) | 149.9 | 147.8 | 43.2 |
| Heat output in % of nominal heat output | 99.9 | 98.5 | 28.8 |
| Fuel mass added (kg) | 206.8 | 206.4 | 57.3 |
| Fuel mass fired per hour (kg/h) | 34.5 | 34.4 | 9.55 |

Operating conditions of the unit during the measurements – test fuel chipped wood

| Parameter | Nominal heat output | | Minimum heat output |
|---|---|---|---|
| | Operation without AGR | Operation with AGR | Operation without AGR |
| Date of measurements | 22.07.2003 | 25.07.2003 | 24.07.2003 |
| Measuring time (from – to) | 10:24-16:24 | 08:34-14:34 | 12:12-18:42 |
| Test duration (hours) | 6.0 hours | 6.0 hours | 6.5 hours |
| Boiler temperature (°C) | 81 | 84 | 83 |
| Combustion chamber temperature (°C) | 912 | 887 | 606 |
| Negative pressure in the combustion chamber (Pa) | 45 | 45 | 20 |
| Feed (%) | 36 | 35 | 9.6 |
| Primary air (%) | 40 | 21 | 18 |
| Secondary air (%) | 30 | 12 | 9 |
| Exhaust gas recirculation position AGR (%) | 0 | 59 | 0 |
| Water amount added (flow, l/h) | 6402 | 6406 | 2122 |
| Flow temperature (°C) | 78.7 | 81.4 | 79.6 |
| Return temperature (°C) | 58.9 | 61.1 | 61.7 |
| Temperature difference flow-return (°C) | 19.9 | 20.4 | 17.9 |
| Heat output useful generated (kW) | 147.9 | 151.6 | 43.8 |
| Heat output in % of nominal heat output | 98.6 | 101.1 | 29.2 |
| Fuel mass added (kg) | 242.4 | 250.8 | 76.1 |
| Fuel mass fired per hour (kg/h) | 40.4 | 41.8 | 11.7 |

# 6 TEST RESULTS

## 6.1 EMISSION BEHAVIOR OF THE BIOMASS BOILER

All given pollutant emissions are calculated as mass of the components in the dimension mg/MJ as average values over the mentioned measuring periods.
They are related to the energy content of the fuel used in the furnace as well as related to a dry flue gas basis at 0°C, 1013 hPa.

Additional the concentrations of the components related to a dry flue gas basis at 0°C, 1013 hPa at actual oxygen content and calculated on hypothetical oxygen contents of 10 % $O_2$ and 13 % $O_2$ are given as average values in the dimension mg/m³ over the mentioned measuring periods.

The measurement uncertainty of the used measurement instruments and the measurement methods are given in point 6 of the test report.

### 6.1.1 Fuel gas boundary conditions

Test fuel wooden pellets

| Parameter | Nominal heat output | | Minimum heat output |
|---|---|---|---|
| | Operation without AGR | Operation with AGR | Operation without AGR |
| Date of measurements | 21.07.2003 | 21.07.2003 | 18.07.2003 |
| Measuring time (from – to) | 08:01-14:01 | 15:26-21:26 | 08:11-14:11 |
| Test duration (hours) | 6.0 | 6.0 | 6.0 |
| Air pressure at the height of the sampling point (hPa) | 979 | 977 | 985 |
| Ambient air temperature (°C) | 28 | 30 | 26 |
| Flue gas temperature at the measuring point after the flue exit of the boiler (°C) | 147 | 170 | 80 |
| Flue gas temperature at the measuring point chimney (°C) | 114 | 133 | 56 |
| Static pressure in the flue gas pipe (hPa) | - 0.14 | - 0.15 | - 0.09 |
| Oxygen concentration (% of vol.) | 8.2 | 7.7 | 10.2 |
| Carbon dioxide concentration (% of vol.) | 12.3 | 12.7 | 10.5 |
| Flue gas humidity (kg/m³) | 0.10 | 0.10 | 0.08 |
| Specific volume of dry flue gas (m³/kg fuel) | 6.9 | 6.7 | 8.1 |
| Fuel mass fired per hour (kg/h) | 34.5 | 34.4 | 9.55 |
| Dry flue gas volume (m³/h) | 238 | 230 | 77 |
| Flue gas velocity at the measuring point dust (m/s) | 1.2 | 1.2 | 0.3 |

Test fuel chipped wood

| Parameter | Nominal heat output | | Minimum heat output |
|---|---|---|---|
| | Operation without AGR | Operation with AGR | Operation without AGR |
| Date of measurements | 22.07.2003 | 25.07.2003 | 24.07.2003 |
| Measuring time (from – to) | 10:24-16:24 | 08:34-14:34 | 12:12-18:42 |
| Test duration (hours) | 6.0 hours | 6.0 hours | 6.5 hours |
| Air pressure at the height of the sampling point (hPa) | 980 | 978 | 972 |
| Ambient air temperature (°C) | 30 | 24 | 28 |
| Flue gas temperature at the measuring point after the flue exit of the boiler (°C) | 147 | 166 | 88 |
| Flue gas temperature at the measuring point chimney (°C) | 117 | | 70 |
| Static pressure in the flue gas pipe (hPa) | - 0.15 | - 0.17 | - 0.10 |
| Oxygen concentration (% of vol.) | 8.7 | 7.3 | 13,4 |
| Carbon dioxide concentration (% of vol.) | 12.0 | 13.4 | 7.3 |
| Flue gas humidity (kg/m³) | 0.11 | 0.13 | 0.07 |
| Specific volume of dry flue gas (m³/kg fuel) | 6.3 | 5.7 | 10.4 |
| Fuel mass fired per hour (kg/h) | 40.4 | 41.8 | 11.7 |
| Dry flue gas volume (m³/h) | 255 | 238 | 122 |
| Flue gas velocity at the measuring point dust (m/s) | 1.3 | 1.3 | 0.5 |

### 6.1.2 Dust

Test fuel wooden pellets, nominal heat output without AGR

Biomass boiler type: Turbomat 150
Date of measurements: 21.07.2003
Test period: 08:01 – 14:01

| Measuring time | actual $O_2$-concentration | Dust concentration related to | | | Dust emission |
|---|---|---|---|---|---|
| | | actual $O_2$ | 10 % $O_2$ of vol. | 13 % $O_2$ of vol. | |
| from – to | % of vol. | mg/m³ | mg/m³ | mg/m³ | mg/MJ |
| 08:07-08:37 | 8.5 | 28 | 25 | 18 | 12 |
| 09:01-09:31 | 8.2 | 17 | 15 | 11 | 7 |
| 10:01-10:31 | 8.3 | 29 | 25 | 18 | 12 |
| 11:01-11:31 | 8.1 | 12 | 10 | 7 | 5 |
| 12:01-12:31 | 8.0 | 13 | 11 | 8 | 5 |
| 13:01-13:31 | 7.8 | 13 | 11 | 8 | 5 |
| Average | 8.2 | 19 | 16 | 12 | 8 |

Test fuel wooden pellets, nominal heat output with AGR

Biomass boiler type: Turbomat 150
Date of measurements: 21.07.2003
Test period: 15:26 – 21:26

| Measuring time from – to | actual $O_2$-concentration % of vol. | Dust concentration related to actual $O_2$ mg/m³ | 10 % $O_2$ of vol. mg/m³ | 13 % $O_2$ of vol. mg/m³ | Dust emission mg/MJ |
|---|---|---|---|---|---|
| 15:26-15:56 | 9.0 | 11 | 10 | 7 | 5 |
| 16:26-16:56 | 9.1 | 22 | 20 | 15 | 10 |
| 17:26-17:56 | 7.2 | 9 | 7 | 5 | 4 |
| 18:26-18:56 | 7.7 | 8 | 7 | 5 | 3 |
| 19:26-19:56 | 6.9 | 11 | 9 | 6 | 4 |
| 20:26-20:56 | 7.1 | 20 | 16 | 12 | 8 |
| Average | 7.8 | 14 | 12 | 8 | 6 |

Test fuel wooden pellets, minimum heat output

Biomass boiler type: Turbomat 150
Date of measurements: 18.07.2003
Test period: 08:11 – 14:11

| Measuring time from – to | actual $O_2$-concentration % of vol. | Dust concentration related to actual $O_2$ mg/m³ | 10 % $O_2$ of vol. mg/m³ | 13 % $O_2$ of vol. mg/m³ | Dust emission mg/MJ |
|---|---|---|---|---|---|
| 08:41-09:11 | 9.6 | 12 | 12 | 8 | 6 |
| 09:15-09:45 | 9.4 | 11 | 10 | 8 | 5 |
| 11:41-12:11 | 9.8 | 22 | 22 | 16 | 11 |
| 12:41-13:11 | 10.0 | 36 | 36 | 26 | 18 |
| Average | 9.7 | 20 | 20 | 15 | 10 |

Test fuel chipped wood, nominal heat output without AGR

Biomass boiler type: Turbomat 150
Date of measurements: 22.07.2003
Test period: 10:24 – 16:24

| Measuring time from – to | actual $O_2$-concentration % of vol. | Dust concentration related to actual $O_2$ mg/m³ | 10 % $O_2$ of vol. mg/m³ | 13 % $O_2$ of vol. mg/m³ | Dust emission mg/MJ |
|---|---|---|---|---|---|
| 10:24-10:54 | 8.6 | 41 | 36 | 26 | 18 |
| 11:24-11:54 | 8.4 | 48 | 42 | 30 | 21 |
| 12:24-12:54 | 8.5 | 32 | 28 | 20 | 14 |
| 13:24-13:54 | 8.7 | 34 | 30 | 22 | 15 |
| 14:24-14:54 | 8.4 | 54 | 47 | 34 | 23 |
| 15:24-15:54 | 8.5 | 38 | 33 | 24 | 17 |
| Average | 8.5 | 41 | 36 | 26 | 18 |

Test fuel chipped wood, nominal heat output with AGR

Biomass boiler type: Turbomat 150
Date of measurements: 25.07.2003
Test period: 08:34 – 14:34

| Measuring time from – to | actual $O_2$-concentration % of vol. | Dust concentration related to actual $O_2$ mg/m³ | 10 % $O_2$ of vol. mg/m³ | 13 % $O_2$ of vol. mg/m³ | Dust emission mg/MJ |
|---|---|---|---|---|---|
| 08:34-09:04 | 7.1 | 51 | 40 | 29 | 20 |
| 09:34-10:34 | 7.1 | 48 | 38 | 28 | 19 |
| 10:34-11:04 | 7.2 | 43 | 34 | 25 | 17 |
| 11:34-12:04 | 7.0 | 79 | 62 | 45 | 31 |
| 12:34-13:34 | 7.2 | 51 | 41 | 30 | 20 |
| 13:34-14:04 | 7.5 | 50 | 41 | 30 | 20 |
| Average | 7.2 | 54 | 43 | 31 | 21 |

Test fuel chipped wood, minimum heat output

Biomass boiler type: Turbomat 150
Date of measurements: 24.07.2003
Test period: 12:12 – 18:42

| Measuring time from – to | actual O2-concentration % of vol. | Dust concentration related to actual O2 mg/m³ | 10 % O2 of vol. mg/m³ | 13 % O2 of vol. mg/m³ | Dust emission mg/MJ |
|---|---|---|---|---|---|
| 13:42-14:12 | 13.4 | 26 | 38 | 27 | 19 |
| 14:42-15:12 | 13.0 | 29 | 40 | 29 | 20 |
| 15:42-16:12 | 13.5 | 25 | 37 | 27 | 18 |
| 17:12-17:42 | 13.2 | 22 | 31 | 23 | 15 |
| Average | 13.3 | 26 | 37 | 27 | 18 |

### 6.1.3 Carbon monoxide (CO), nitrogen oxides (NOx) and organic gaseous substances (OGC)

Test fuel wooden pellets

| Parameter | Nominal heat output | | Minimum heat output |
|---|---|---|---|
| | Operation without AGR | Operation with AGR | Operation without AGR |
| Date of measurements | 22.07.2003 | 25.07.2003 | 24.07.2003 |
| Measuring time (from – to) | 10:24-16:24 | 08:34-14:34 | 12:12-18:42 |
| Heat output useful generated (kW) | 149.9 | 147.8 | 43.2 |
| Oxygen concentration (% of vol.) | 8.2 | 7.7 | 10.2 |
| Emission of carbon monoxide (CO) | | | |
| at actual $O_2$ (mg/m³) | 112 | 44 | 139 |
| related to 10 % $O_2$ (mg/m³) | 96 | 36 | 142 |
| related to 13 % $O_2$ (mg/m³) | 70 | 26 | 103 |
| related to the energy content (mg/MJ) | 48 | 18 | 70 |
| Emission of nitrogen oxides (NOx) | | | |
| at actual $O_2$ (mg/m³) | 190 | 202 | 140 |
| related to 10 % $O_2$ (mg/m³) | 163 | 167 | 143 |
| related to 13 % $O_2$ (mg/m³) | 119 | 122 | 104 |
| related to the energy content (mg/MJ) | 81 | 83 | 71 |
| Emission of gaseous org. substances (OGC) | | | |
| at actual $O_2$ (mg/m³) | 2 | 2 | 3 |
| related to 10 % $O_2$ (mg/m³) | 2 | 2 | 3 |
| related to 13 % $O_2$ (mg/m³) | 1 | 1 | 2 |
| related to the energy content (mg/MJ) | 1 | 1 | 2 |

Test fuel chipped wood

| Parameter | Nominal heat output | | Minimum heat output |
|---|---|---|---|
| | Operation without AGR | Operation with AGR | Operation without AGR |
| Date of measurements | 22.07.2003 | 25.07.2003 | 24.07.2003 |
| Measuring time (from – to) | 10:24-16:24 | 08:34-14:34 | 12:12-18:42 |
| Heat output useful generated (kW) | 147.9 | 151.6 | 43.8 |
| Oxygen concentration (% of vol.) | 8.7 | 7.3 | 13.4 |
| Emission of carbon monoxide (CO) | | | |
| at actual $O_2$ (mg/m³) | 88 | 139 | 141 |
| related to 10 % $O_2$ (mg/m³) | 79 | 112 | 204 |
| related to 13 % $O_2$ (mg/m³) | 57 | 81 | 149 |
| related to the energy content (mg/MJ) | 39 | 55 | 101 |
| Emission of nitrogen oxides (NOx) | | | |
| at actual $O_2$ (mg/m³) | 206 | 211 | 127 |
| related to 10 % $O_2$ (mg/m³) | 184 | 169 | 184 |
| related to 13 % $O_2$ (mg/m³) | 134 | 123 | 134 |
| related to the energy content (mg/MJ) | 91 | 84 | 91 |
| Emission of gaseous org. substances (OGC) | | | |
| at actual $O_2$ (mg/m³) | 5 | 3 | 1 |
| related to 10 % $O_2$ (mg/m³) | 4 | 2 | 2 |
| related to 13 % $O_2$ (mg/m³) | 3 | 2 | 2 |
| related to the energy content (mg/MJ) | 2 | 1 | 1 |

## 6.2 BOILER EFFICIENCY AND COMBUSTION PERIOD

The efficiency of the biomass heating system was determined according to the formalism of the direct method shown in ÖNORM EN 303-5 (see point 4.6).
Below the calculated results as average of the recorded average values are given for the respective test duration.

Boiler efficiency and combustion period – test fuel wooden pellets

| Parameter | Nominal heat output | | Minimum heat output |
|---|---|---|---|
| | Operation without AGR | Operation with AGR | Operation without AGR |
| Date of measurements | 21.07.2003 | 21.07.2003 | 18.07.2003 |
| Measuring time (from – to) | 08:01-14:01 | 15:26-21:26 | 08:11-14:11 |
| Test duration (hours) | 6.0 | 6.0 | 6.0 |
| Combustion period (hours) | 6.0 | 6.0 | 6.0 |
| Fuel mass added (kg) | 206.8 | 206.4 | 57.3 |
| Fuel mass fired per hour (kg/h) | 34.5 | 34.4 | 9.55 |
| Net calorific value of the test fuel, related to raw condition ($H_u$, kJ/kg) | 17110 | 17110 | 17110 |
| Heat output useful generated (Q, kW) | 149.9 | 147.8 | 43.2 |
| Heat output ($Q_B$, kW) | 163.8 | 163.5 | 45.4 |
| Boiler efficiency, direct (%) | 91.5 | 90.4 | 95.2 |

Boiler efficiency and combustion period – test fuel chipped wood

| Parameter | Nominal heat output | | Minimum heat output |
|---|---|---|---|
| | Operation without AGR | Operation with AGR | Operation without AGR |
| Date of measurements | 22.07.2003 | 25.07.2003 | 24.07.2003 |
| Measuring time (from – to) | 10:24-16:24 | 08:34-14:34 | 12:12-18:42 |
| Test duration (hours) | 6.0 hours | 6.0 hours | 6.5 hours |
| Combustion period (hours) | 6.0 | 6.0 | 6.5 |
| Fuel mass added (kg) | 242.4 | 250.8 | 76.1 |
| Fuel mass fired per hour (kg/h) | 40.4 | 41.8 | 11.7 |
| Net calorific value of the test fuel, related to raw condition ($H_u$, kJ/kg) | 14480 | 14480 | 14480 |
| Heat output useful generated (Q, kW) | 147.9 | 151.6 | 43.8 |
| Heat output ($Q_B$, kW) | 162.5 | 168.1 | 47.1 |
| Boiler efficiency, direct (%) | 91.0 | 90.2 | 93.0 |

### 6.2.1 Exhaust gas loss (loss through sensible heat of the products of combustion)

The exhaust gas loss of the biomass heating system (loss through sensible heat of the products of combustion) calculated by the formalism in accordance to the BGBl. 331/1997 (see point 4.7) is mentioned below.

Input data used for the calculation:

$t_A$..... exhaust gas temperature °C (measured on the measuring point after flue exit of the boiler)
$t_L$..... ambient temperature in °C
$O_2$..... dry oxygen content of the flue gas in % of vol.
$A_2$..... 0.6655 for biomass with the test fuel pellets (water content of the fuel: 7.5 %)
0.6807 for biomass with the test fuel chipped wood (water content of the fuel: 18.8 %)
B..... 0.0104 for biomass with the test fuel pellets (water content of the fuel: 7.5 %)
0.0123 for biomass with the test fuel chipped wood (water content of the fuel: 18.8 %)

The input data used for the calculation of the exhaust gas loss at the measuring point after flue exit of the boiler are mentioned in point 6.1 of the test report.

Calculated exhaust gas loss at nominal heat output

Test fuel wooden pellets:

Nominal heat output without AGR $q_A$ = 7.4 %
Nominal heat output with AGR: $q_A$ = 8.5 %
Minimum heat output: $q_A$ = 3.9 %

Test fuel chipped wood:

Nominal heat output without AGR $q_A$ = 7.9 %
Nominal heat output with AGR: $q_A$ = 8.8 %
Minimum heat output: $q_A$ = 6.1 %

## 6.3 WATER SIDE RESISTANCE

The water side resistance of the heating boiler Turbomat 150 was determined for the flow which is equivalent to the rated output of the boiler at a temperature difference of $\Delta t$ = 10 K and $\Delta t$ = 20 K between the flow and the return on 25.07.2003.

| Flow (l/h) | Temperature difference (K) | Differential pressure (mbar) |
|---|---|---|
| 6400 | 20 | 6.1 |
| 12850 | 10 | 22.3 |

## 6.4 SURFACE TEMPERATURES

For the determination of the mean surface temperature at nominal heat output the boiler surface was divided in 12 incremental areas, whereby for each area between 3 and 6 measuring points were regarded.

The critical surface temperatures (e.g. boiler doors, operating levers etc.) were measured at nominal heat output (under the same conditions).

The surface temperatures determined in the context of the tests are summary shown in the table below.

| Operating condition | Covering panel | Doors, cleaning port covers | Outside of the boiler bottom | Operating levers | Room-temperature |
|---|---|---|---|---|---|
| | maximum value | maximum value | maximum value | maximum value | |
| Fuel wood pellets– nominal heat output without AGR | 67°C | 95°C | 58°C | 59°C | 28°C |
| Fuel wood pellets– nominal heat output with AGR | 59°C | 83°C | 56°C | 49°C | 30°C |
| Fuel chipped wood – nominal heat output without AGR | 65°C | 93°C | 61°C | 60°C | 30°C |
| Fuel chipped wood – nominal heat output with AGR | 58°C | 80°C | 51°C | 49°C | 24°C |

In all tests the mean surface temperature of boiler doors and cleaning port covers on the operator side did not exceed the permissible temperature difference of 100 K against room temperature in accordance to ÖNORM EN 303-5.

The surface temperature on the outside of the boiler bottom did not exceed the room temperature by more than 65 K.

The surface temperatures of the operating levers and all parts which shall be touched by hand during operation of the boiler did not exceed the room temperature by more than 35 K.

## 6.5 FUNCTION CHECK OF THE TEMPERATURE CONTROLLER, THE SAFETY LIMITER AND ON THE DEVICE FOR DISSIPATING EXCESS HEAT

The function check of the temperature controller, the safety limiter and on the device for dissipating excess heat of the biomass heating system of the type Turbomat 150 was performed in accordance to ÖNORM EN 303-5 in the context of the emission behavior tests and the boiler efficiency tests of the unit.
For the determination of the flow temperatures and the boiler temperatures the temperature sensors of the boiler manufacturer installed at the unit were used.
Before test execution these sensors were compared with a calibrated Pt100-temperature sensor of the TÜV Austria and found in order.

### 6.5.1 Function check of the temperature controller and the safety limiter being installed at the heating boiler

Before starting the test the water-side flow rate was fixed to the specified flow rate for the rated output test. Afterwards the firing of the unit was adjusted that it corresponds to the nominal heat output of the boiler.
At the start of the test the flow temperature did not exceed a value of 75°C and the boiler temperature controller was adjusted to the maximum set value of 90°C + 3°C specified by the boiler manufacturer.
Afterwards the dissipated output was limited to approx. 40 % of the nominal heat output.
The test was continued up to responding the temperature controller, and afterwards the temperature was observed at which the boiler maximum temperature was reached.

The same test was repeated with the temperature controller out of function. This time it was checked if the safety temperature limiter switches off the heating at the highest value of the maximum value of 110°C specified by the boiler manufacturer.

### 6.5.2 Function check on the device for dissipating excess heat

With this test the heating boiler was operated at the highest heat output and the temperature controller was put out of function.
The function of the safety temperature limiter was maintained.
Further it was guaranteed by shut-off position of the consumers that no heat output were given off to the heating system.

The test was continued up to responding the safety temperature limiter, and afterwards the boiler temperature was observed at which the device for dissipating excess heat (emergency cooling) triggered.

### 6.5.3 Test results

#### 6.5.3.1 Function check of the temperature controller being installed at the heating boiler of the type Turbomat 150

Conditions at test start:

| | |
|---|---|
| Water-side flow rate: | flow rate equal the flow rate for the rated output test |
| Heat input: | according to nominal heat output of the heating boiler |
| Flow temperature: | 75°C |
| Boiler temperature controller: | set value 90°C + 3°C (as specified by manufacturer) |
| Dissipated output: | approx. 40 % of the nominal heat output |
| Safety temperature limiter: | response point for switch off at 100°C |

Test results

The temperature controller installed at the heating switched off the firing at a temperature of 93°C. Afterwards the boiler temperature still rose up to 99°C.
The safety temperature limiter or the device for dissipating excess heat did not trigger.

The requirements of the ÖNORM EN 303-5 regarding function of the temperature controller were thus fulfilled by the tested biomass boiler type Turbomat 150.

#### 6.5.3.2 Function check of the safety temperature limiter being installed at the heating boiler

Conditions at test start:

| | |
|---|---|
| Water-side flow rate: | flow rate equal the flow rate fort he rated output test |
| Heat input: | according to nominal heat output of the heating boiler |
| Flow temperature: | 72°C |
| Boiler temperature controller: | temperature controller deactivated |
| Dissipated output: | approx. 40 % of the nominal heat output |
| Safety temperature limiter: | response point for switch off at 100°C |

Test results

The safety temperature limiter switched off the firing of the heating boiler at 99°C.
The maximum boiler temperature was also 99°C.

The requirements of the ÖNORM EN 303-5 regarding function of the safety temperature limiter were thus fulfilled by the tested biomass boiler type Turbomat 150.

#### 6.5.3.3 Function check on the device for dissipating excess heat

Conditions at test start:

| | |
|---|---|
| Heat input: | according to nominal heat output of the heating boiler |
| Heat supplied: | no heat supplied to the heat distribution system |
| Flow temperature: | 71°C |
| Boiler temperature controller: | temperature controller deactivated |
| Dissipated output: | no heat output to the heating system |
| Safety temperature limiter: | response point for switch off at 100°C |
| Device for dissipating excess heat: | response point 105°C |
| | cold water temperature: 10°C |
| | cold water pressure: 1.9 bar |

Test results

The safety temperature limiter switched off the firing of the heating boiler at 99°C.
The device for dissipating excess heat triggered at a boiler temperature of 100°C.
The maximum boiler temperature was also 100°C.

The requirements of the ÖNORM EN 303-5 regarding function on the device for dissipating excess heat (emergency cooling) were thus fulfilled by the tested biomass boiler type Turbomat 150.

## 7 SUMMARY

The Fröling Biomassekessel- und Behälterbau GmbH assigned the TÜV Austria with the test of the biomass boiler type in the extent mentioned below.

a) Type test performance in accordance to ÖNORM EN 303-5

b) Verification of the compliance with the regulations of the agreement of the Austrian Federal States according to article 15a of the Federal Constitution about "Schutzmaßnahmen betreffend Kleinfeuerungen" and about "Einsparung von Energie".

c) Verification of the compliance with the regulations of the Austrian Federal Law Gazette Part II No. 331/1997 (FAV, BGBl. 331/1997, regulation concerning heating systems).

d) Verification of the compliance with the emission values and boiler efficiencies with the funding guidelines of the Austrian Kommunalkredit AG, determined in the context of the type test.

e) Verification of the compliance with the emission values and boiler efficiencies with the requirements of the Bavarian Department of State for agriculture and forests, determined in the context of the type test, for the promotion of biomass heating systems between 100 kW and 500 kW in Bavaria (BioKomm and BioHeiz500).

The tests took place at the test rig which is set up at the Fröling Heizkessel- und Behälterbau GesmbH, which is equivalent with the requirements of the ÖNORM EN 303-5.

The heating boiler of the type Turbomat 150 set up at the test rig of the Fröling Heizkessel- und Behälterbau GesmbH became fired at nominal heat output (full load) and at maximum 30 % of the heat output of the biomass heating system (minimum heat output in accordance to the manufacturer´s instructions, partial load) with the test fuels mentioned below in the test period (17.07. – 25.07.2003).

Test fuel 1: pellets, compressed wood HP 1, PVA No. 36202, company Glechner, w = 7.5 %
Test fuel 2: chipped wood B1, pine, size G50, w = 18.8 %

For the subject biomass heating system of the make Fröling, type Turbomat 150, a statement of the manufacturer was handed over to TÜV Austria, that the requirements of ÖNORM EN 303-5 are observed.
A copy of the production documentation, in which the corresponding drawings, the manufacturing controls, the execution of welding work, the welding seams and welding fillers, the wall thicknesses and the safety designs are comprehended, were handed over the TÜV Austria and can be looked into in the test centre Thalheim/Wels.

In looking over the production documentation, which was handed over the TÜV Austria, no difference to the construction requirements of ÖNORM EN 303-5 could be observed.

Further the surface temperatures, determined at nominal heat output, and the checked safety equipment (temperature controller, safety temperature limiter, device for dissipating excess heat) corresponded to the requirements of the ÖNORM EN 303-5.

The emission values, boiler efficiencies and exhaust gas losses (losses through sensible heat of the products of combustion) determined in the context of the tests are shown below in accordance to the ÖNORM EN 303-5 as arithmetic average values over the entire duration of the test periods.

## 7.1 EMISSION VALUES – TURBOMAT 150

Emission values related to 0°C, 1013 hPa and 10 % $O_2$ of vol.

| Fuel | Operating condition | Dust mg/m³ | CO mg/m³ | NOx mg/m³ | Org. C mg/m³ |
|---|---|---|---|---|---|
| Wooden pellets | Minimum heat output | 20 | 142 | 143 | 3 |
| | Nominal heat output without AGR | 16 | 96 | 163 | 2 |
| | Nominal heat output with AGR | 12 | 36 | 167 | 2 |
| Chipped wood B1 pine | Minimum heat output | 37 | 204 | 184 | 2 |
| | Nominal heat output without AGR | 36 | 79 | 184 | 4 |
| | Nominal heat output with AGR | 43 | 112 | 169 | 2 |

Emission values related to 0°C, 1013 hPa and 13 % $O_2$ of vol.

| Fuel | Operating condition | Dust mg/m³ | CO mg/m³ | NOx mg/m³ | Org. C mg/m³ |
|---|---|---|---|---|---|
| Wooden pellets | Minimum heat output | 15 | 103 | 104 | 2 |
| | Nominal heat output without AGR | 12 | 70 | 119 | 1 |
| | Nominal heat output with AGR | 8 | 26 | 122 | 1 |
| Chipped wood B1 pine | Minimum heat output | 27 | 149 | 134 | 2 |
| | Nominal heat output without AGR | 26 | 57 | 134 | 3 |
| | Nominal heat output with AGR | 31 | 81 | 123 | 2 |

Emission values related to the energy content of the fuel used

| Fuel | Operating condition | Dust mg/MJ | CO mg/MJ | NOx mg/MJ | Org. C mg/MJ |
|---|---|---|---|---|---|
| Wooden pellets | Minimum heat output | 10 | 70 | 71 | 2 |
| | Nominal heat output without AGR | 8 | 48 | 81 | 1 |
| | Nominal heat output with AGR | 6 | 18 | 83 | 1 |
| Chipped wood B1 pine | Minimum heat output | 18 | 101 | 91 | 1 |
| | Nominal heat output without AGR | 18 | 39 | 91 | 2 |
| | Nominal heat output with AGR | 21 | 55 | 84 | 1 |

AGR … exhaust gas recirculation

## 7.2 BOILER EFFICIENCY AND EXHAUST GAS LOSS – TURBOMAT 150

| Fuel | Operating condition (mode) | Exhaust gas loss | Boiler efficiency (direct method) |
|---|---|---|---|
| Wooden pellets | Minimum heat output | 3.9 % | 95.2 % |
| | Nominal heat output without AGR | 7.4 % | 91.5 % |
| | Nominal heat output with AGR | 8.5 % | 90.4 % |
| Chipped wood B1 pine | Minimum heat output | 6.1 % | 93.0 % |
| | Nominal heat output without AGR | 7.9 % | 91.0 % |
| | Nominal heat output with AGR | 8.8 % | 90.2 % |

AGR … exhaust gas recirculation

The test results of the heating boiler type Turbomat 150 of the company Fröling Heizkessel- und Behälterbau GesmbH which are represented in the subject test report adhered to the limits of emission values, the boiler efficiencies and the exhaust gas losses of the following guidelines, which are valid at the time of the test periods and that are mentioned in point 1.7, by firing the fuel types wood pellets and chipped wood (B1, pine).

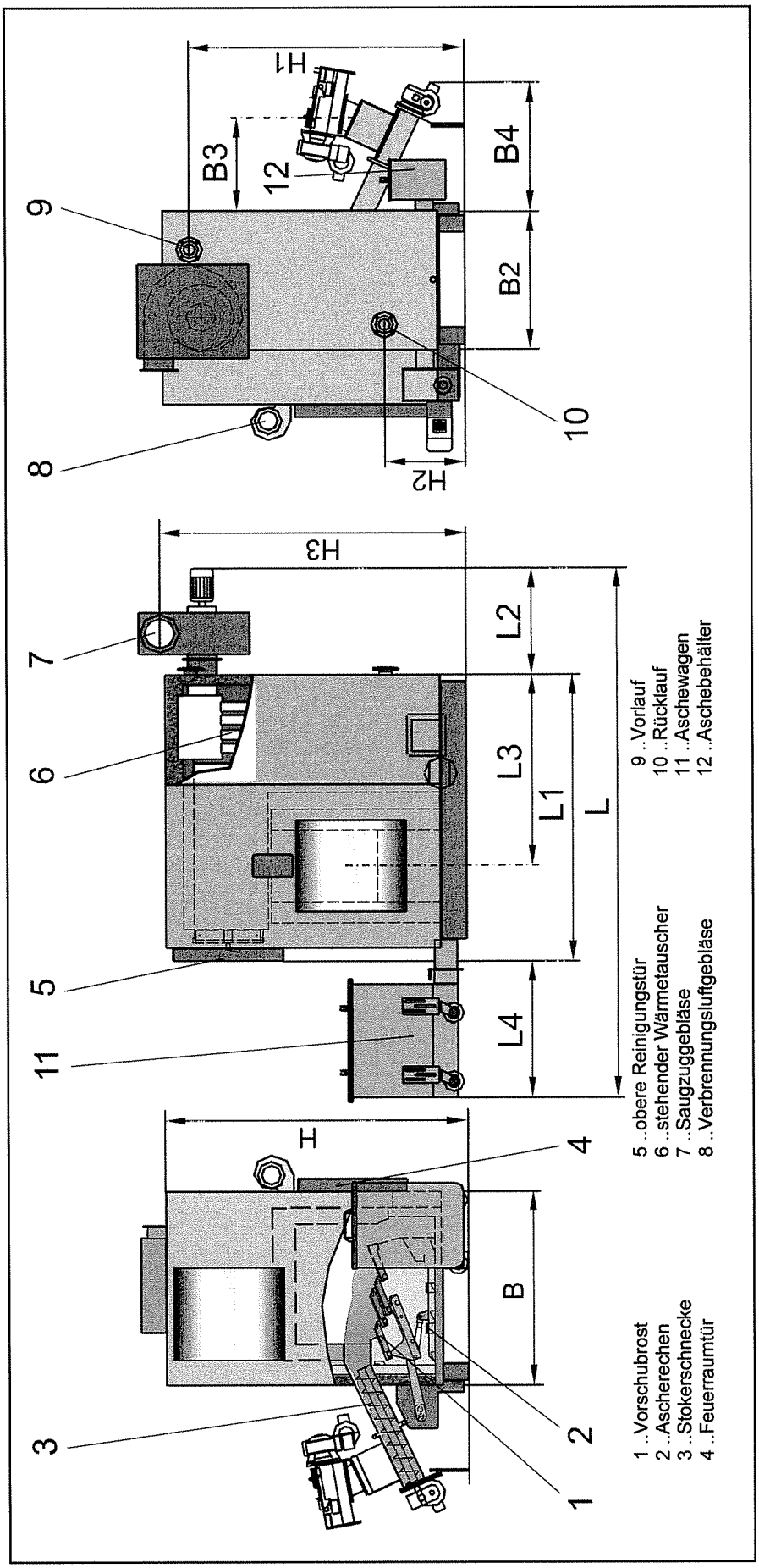
- ÖNORM EN 303-5, boiler class 3 (including the deviations for Austria)
- Art. 15a B-VG – Austrian agreement for the "Inverkehrbringung von Kleinfeuerungen"
- BioKomm of the Bavarian Department of State
- BioHeiz 500 of the Bavarian Department of States
- Funding guidelines of the Austrian Kommunalkredit AG

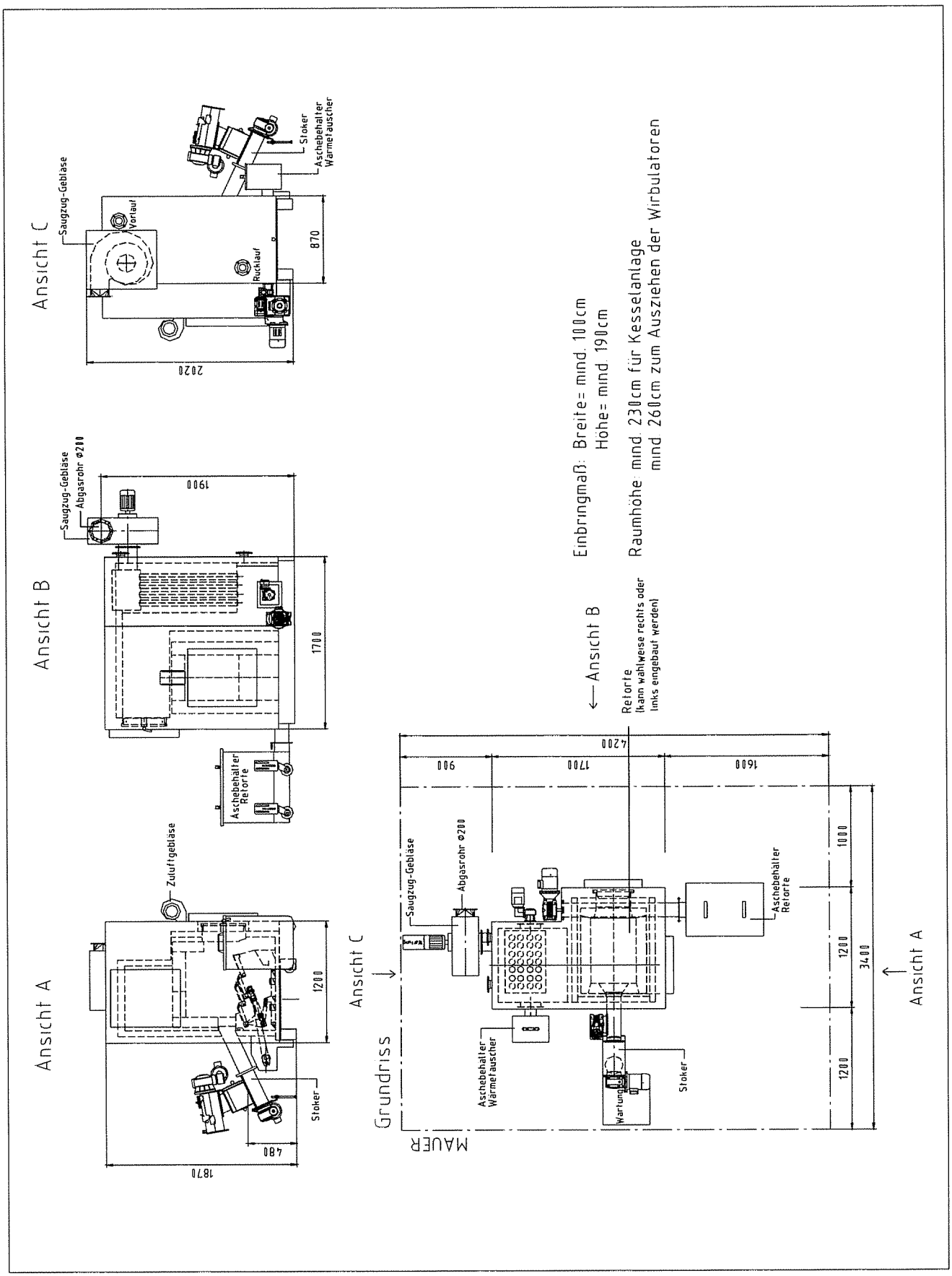
TÜV Austria
Test centre Wels
Division Environmental Technology and Chemistry

The authorized signatory: Ing. R. Mair

Technischer Überwachungs-Verein TÜV ÖSTERREICH Österreich

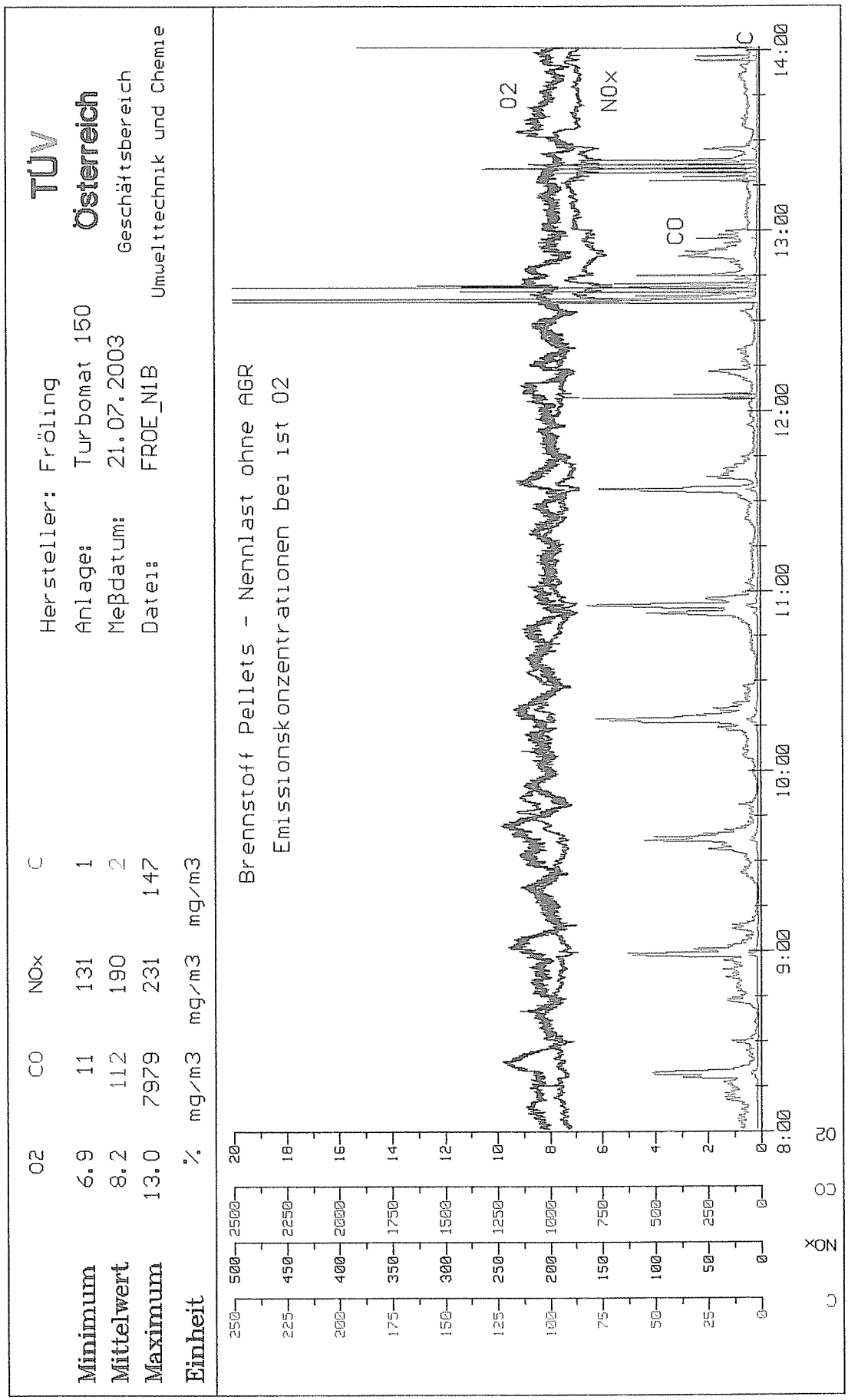
The examiner: Ing. G. Schrögendorfer

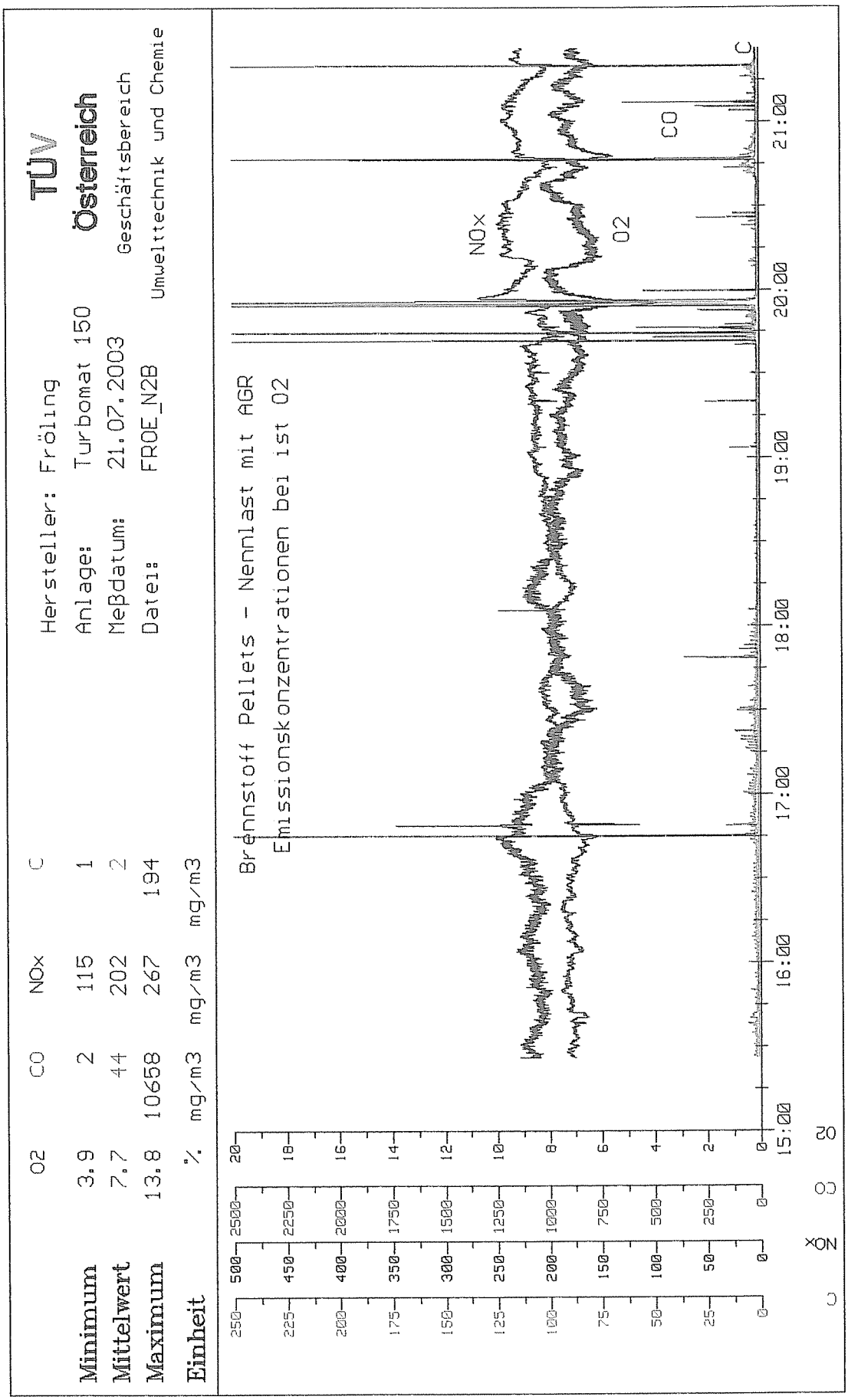

H1
B3
B4
B2
H2
H3
L2
L3
L1
L
L4
H
B
1 2 3 4 5 6 7 8 9 10 11 12
1 ..Vorschubrost
2 ..Ascherechen
3 ..Stokerschnecke
4 ..Feuerraumtür
5 ..obere Reinigungstür
6 ..stehender Wärmetauscher
7 ..Saugzuggebläse
8 ..Verbrennungsluftgebläse
9 ..Vorlauf
10 ..Rücklauf
11 ..Aschewagen
12 ..Aschebehälter


Ansicht C
Saugzug-Gebläse
Vorlauf
Rücklauf
Stoker
Aschebehälter
Wärmetauscher
870
2020
Ansicht B
Saugzug-Gebläse
Abgasrohr ø200
1900
1700
Aschebehälter
Retorte
Ansicht A
Zuluftgebläse
1200
Stoker
480
1870
Einbringmaß: Breite= mind. 100cm
Höhe= mind 190cm
Raumhöhe: mind. 230cm für Kesselanlage
mind 260cm zum Ausziehen der Wirbulatoren
← Ansicht B
Retorte
(kann wahlweise rechts oder
links eingebaut werden)
Ansicht C →
Grundriss
MAUER
4200
900
1700
1600
Saugzug-Gebläse
Abgasrohr ø200
Aschebehälter
Retorte
1000
1200
3400
1200
Aschebehälter
Wärmetauscher
Stoker
Wartungstür
Ansicht A

TÜV ÖSTERREICH

# Lichtbild des Heizkessels des Fabrikates Fröling, Type Turbomat 150

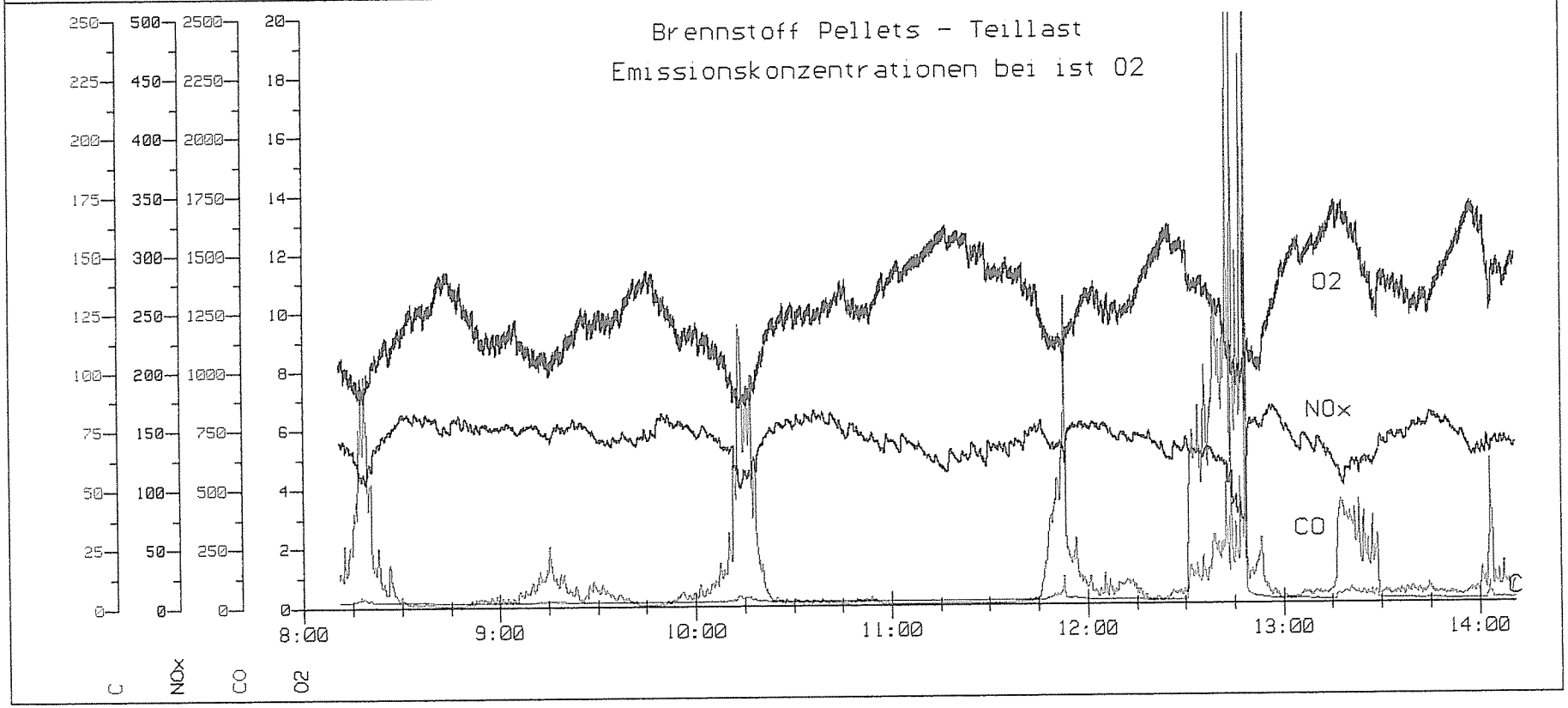

TÜV Österreich
Geschäftsbereich Umwelttechnik und Chemie
Hersteller: Frölin
Anlage: Turbomat 150
Meßdatum: 21.07.2003
Datei: FROE_N1B
O2 CO NOx C
Minimum 6.9 11 131 1
Mittelwert 8.2 112 190 2
Maximum 13.0 7979 231 147
Einheit % mg/m3 mg/m3 mg/m3
Brennstoff Pellets - Nennlast ohne AGR
Emissionskonzentrationen bei 1st O2
O2
NOx
CO
C
8:00
9:00
10:00
11:00
12:00
13:00
14:00

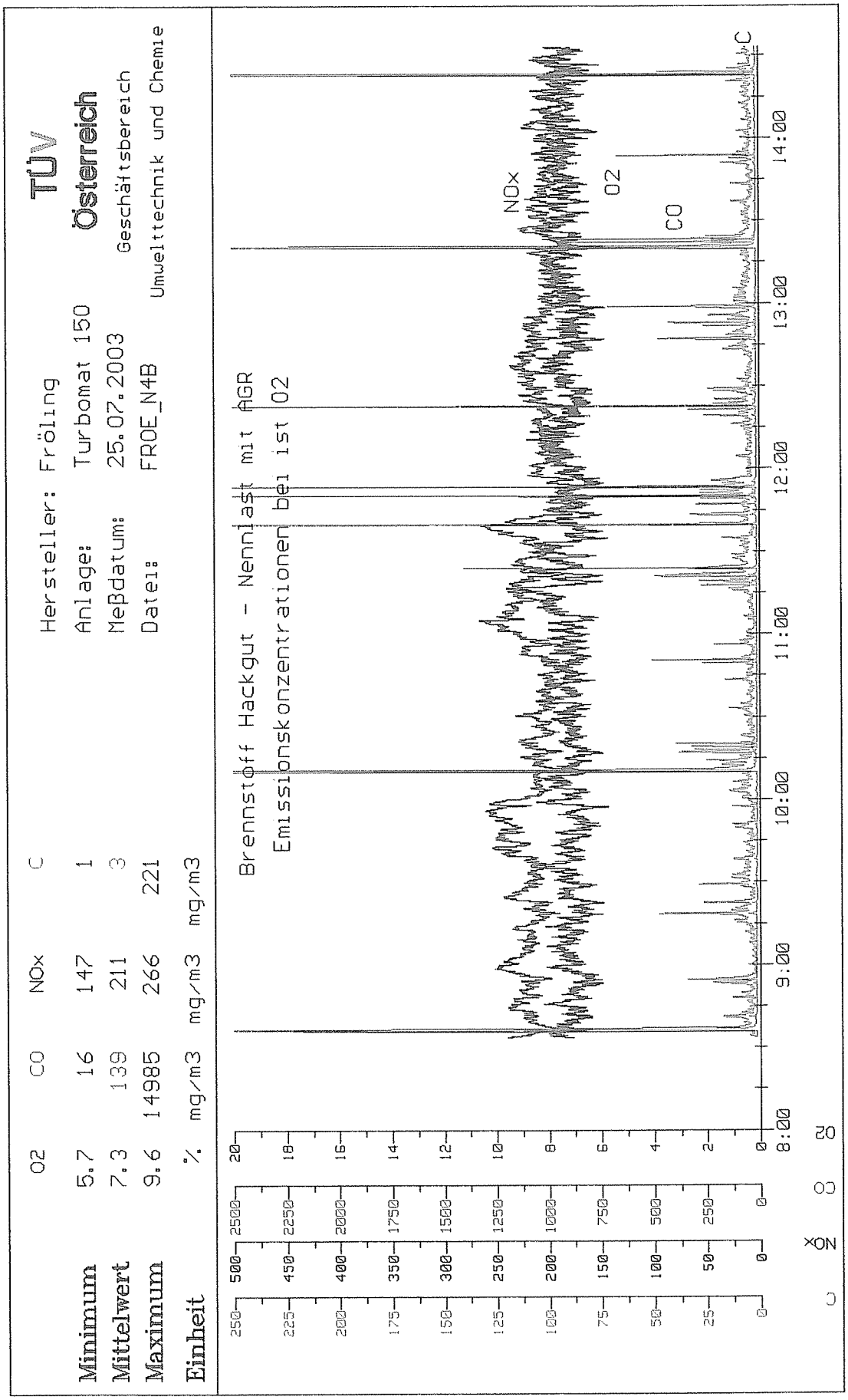

TÜV Österreich
Geschäftsbereich Umwelttechnik und Chemie
Hersteller: Fröling
Anlage: Turbomat 150
Meßdatum: 21.07.2003
Datei: FROE_N2B
O2 CO NOx C
Minimum 3.9 2 115 1
Mittelwert 7.7 44 202 2
Maximum 13.8 10658 267 194
Einheit % mg/m3 mg/m3 mg/m3
Brennstoff Pellets - Nennlast mit AGR
Emissionskonzentrationen bei 1st 02
NOx
02
CO
C
15:00
16:00
17:00
18:00
19:00
20:00
21:00

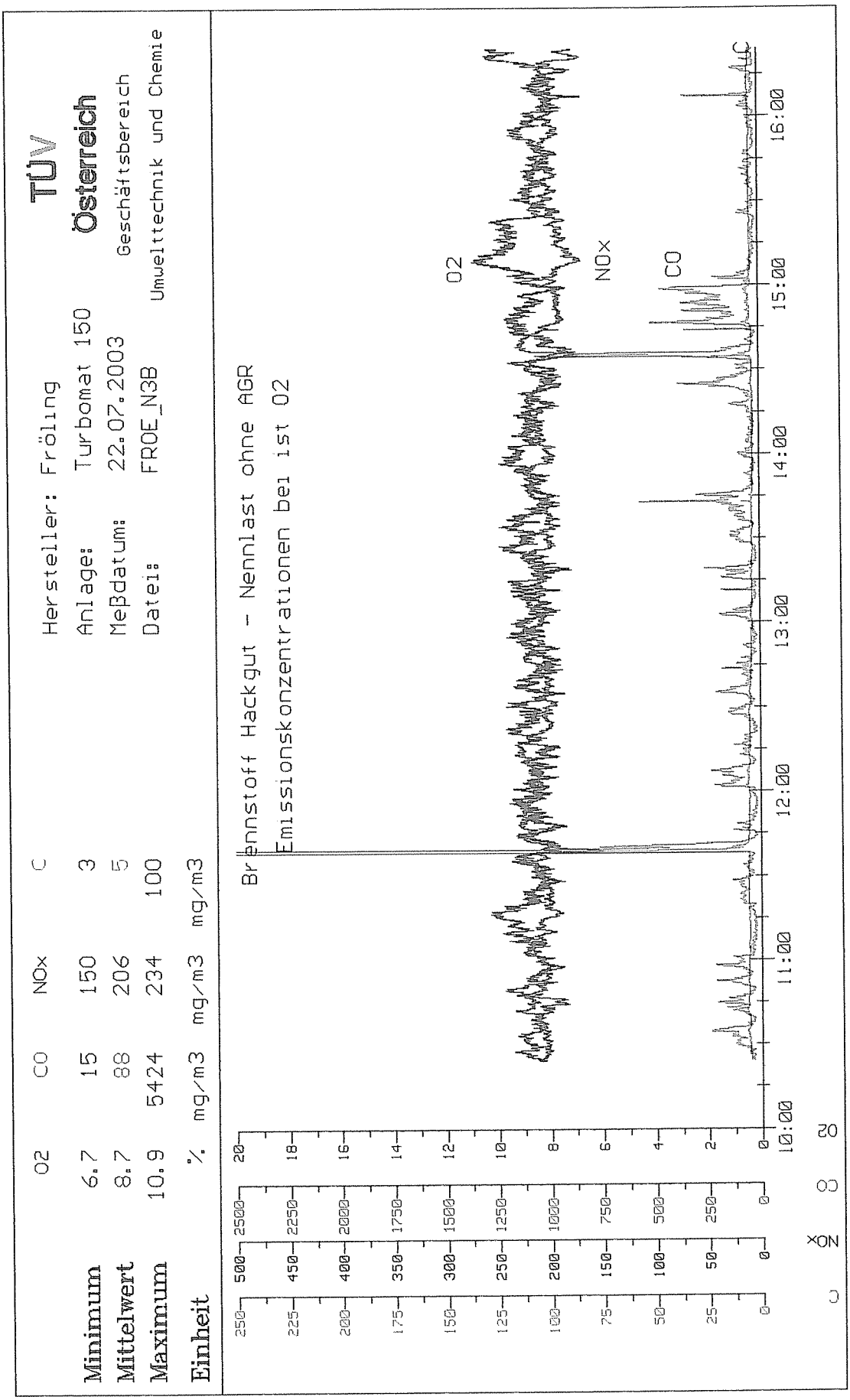
| | O2 | CO | NOx | C |
|---|---|---|---|---|
| Minimum | 6.7 | 0 | 68 | 1 |
| Mittelwert | 10.2 | 139 | 140 | 3 |
| Maximum | 13.7 | 7160 | 167 | 164 |
| Einheit | % | mg/m3 | mg/m3 | mg/m3 |

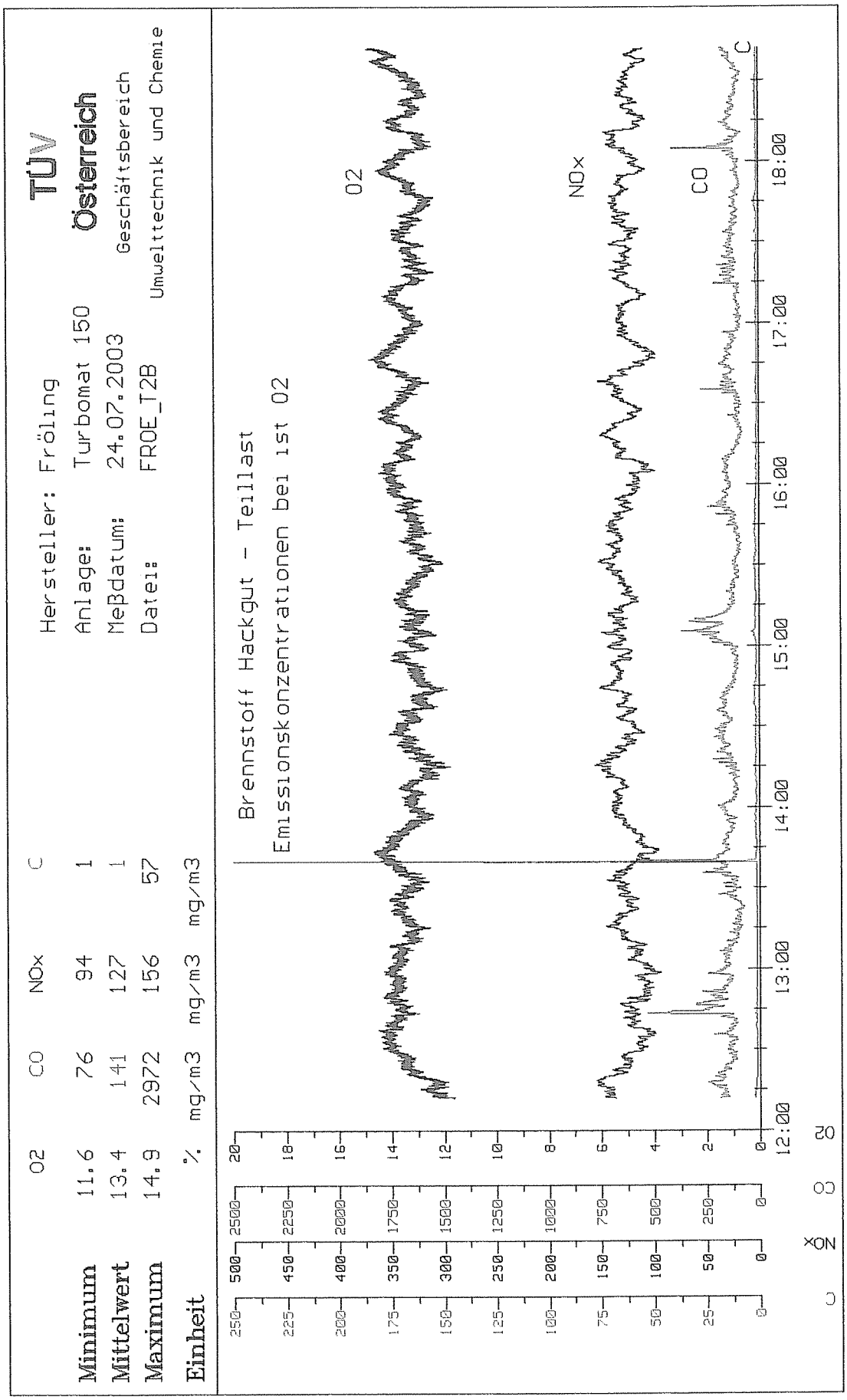
Hersteller: Fröling
Anlage: Turbomat 150
Meßdatum: 18.07.2003
Datei: FROE_T1B

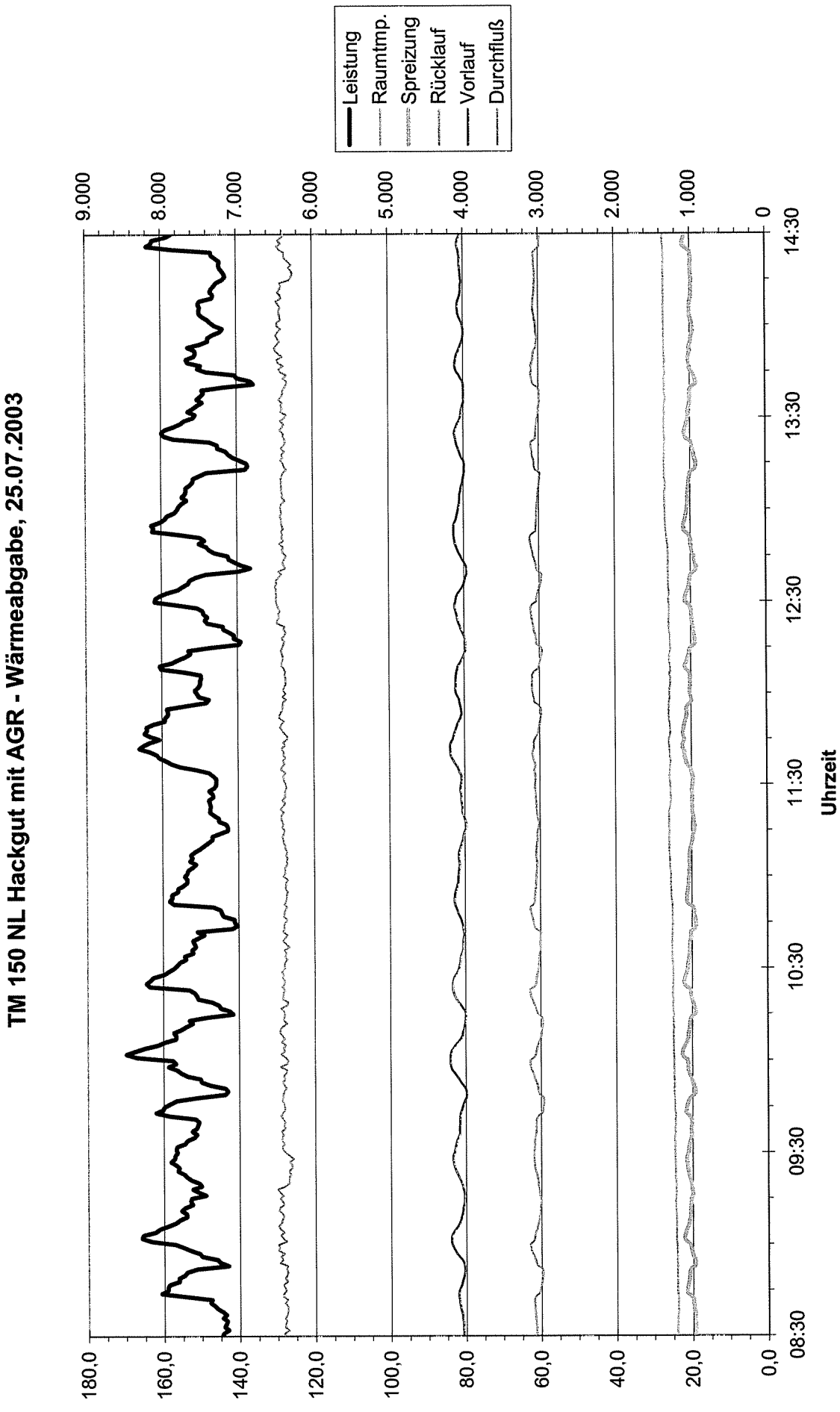
TÜV Österreich
Geschäftsbereich
Umwelttechnik und Chemie




TÜV Österreich
Geschäftsbereich Umwelttechnik und Chemie
Hersteller: Fröling
Anlage: Turbomat 150
Meßdatum: 25.07.2003
Datei: FROE_N4B
O2 CO NOx C
Minimum 5.7 16 147 1
Mittelwert 7.3 139 211 3
Maximum 9.6 14985 266 221
Einheit % mg/m3 mg/m3 mg/m3
Brennstoff Hackgut - Nennlast mit AGR
Emissionskonzentrationen bei ist O2
NOx
O2
CO
8:00
9:00
10:00
11:00
12:00
13:00
14:00


Hersteller: Frölng
Anlage: Turbomat 150
Meßdatum: 22.07.2003
Datei: FR0E_N3B
TÜV Österreich
Geschäftsbereich Umwelttechnik und Chemie
O2 CO NOx C
Minimum 6.7 15 150 3
Mittelwert 8.7 88 206 5
Maximum 10.9 5424 234 100
Einheit % mg/m3 mg/m3 mg/m3
Brennstoff Hackgut - Nennlast ohne AGR
Emissionskonzentrationen bei ist 02
O2
NOx
CO
10:00
11:00
12:00
13:00
14:00
15:00
16:00


TÜV Österreich
Geschäftsbereich Umwelttechnik und Chemie
Hersteller: Frölng
Anlage: Turbomat 150
MeBdatum: 24.07.2003
Datei: FROE_T2B
O2 CO NOx C
Minimum 11.6 76 94 1
Mittelwert 13.4 141 127 1
Maximum 14.9 2972 156 57
Einheit % mg/m3 mg/m3 mg/m3
Brennstoff Hackgut - Teillast
Emissionskonzentrationen bei 1st 02
O2
NOx
CO
12:00
13:00
14:00
15:00
16:00
17:00
18:00


TM 150 NL Hackgut mit AGR - Wärmeabgabe, 25.07.2003
Leistung
Raumtmp.
Spreizung
Rücklauf
Vorlauf
Durchfluß
9.000
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0
180,0
160,0
140,0
120,0
100,0
80,0
60,0
40,0
20,0
0,0
08:30
09:30
10:30
11:30
12:30
13:30
14:30
Uhrzeit

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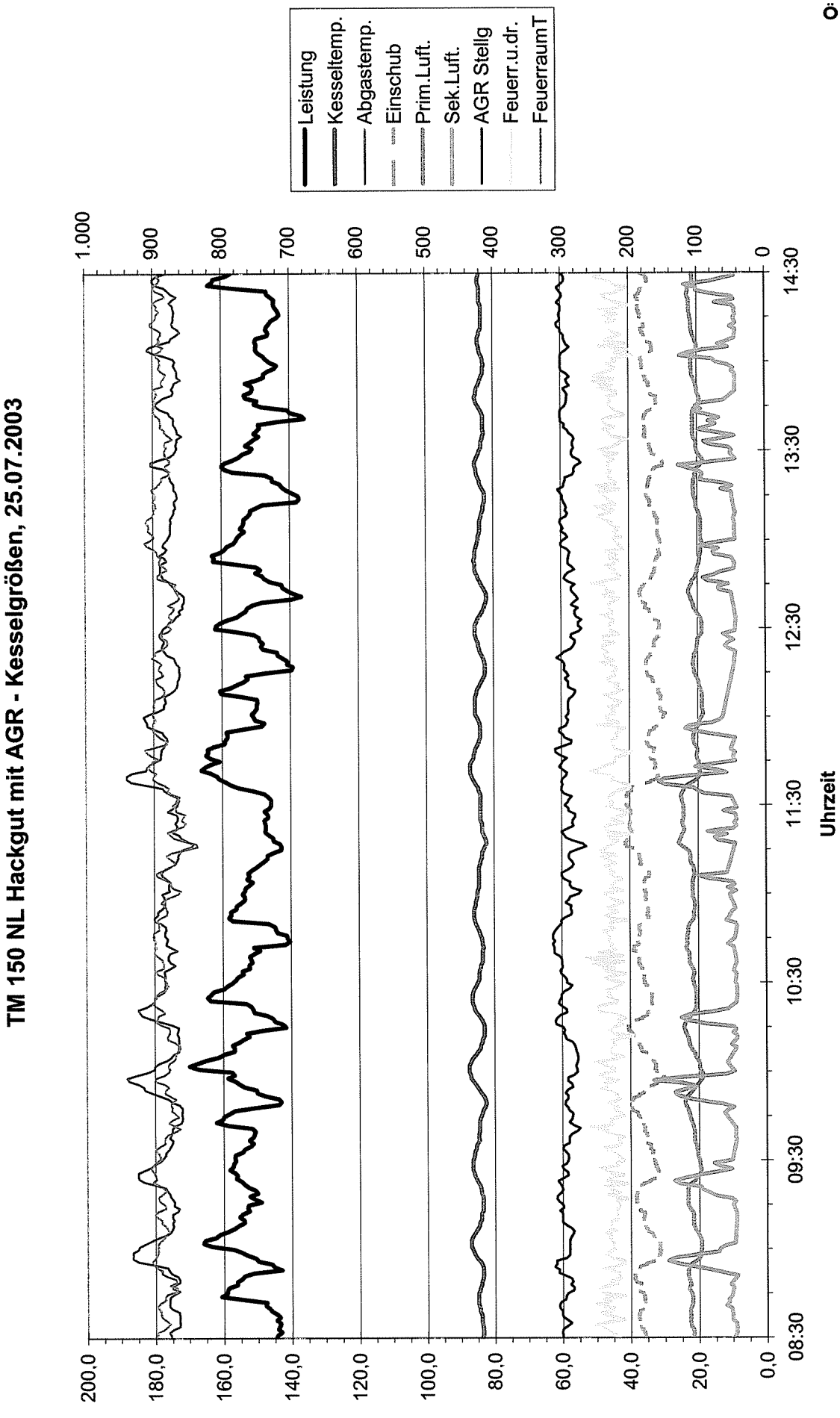

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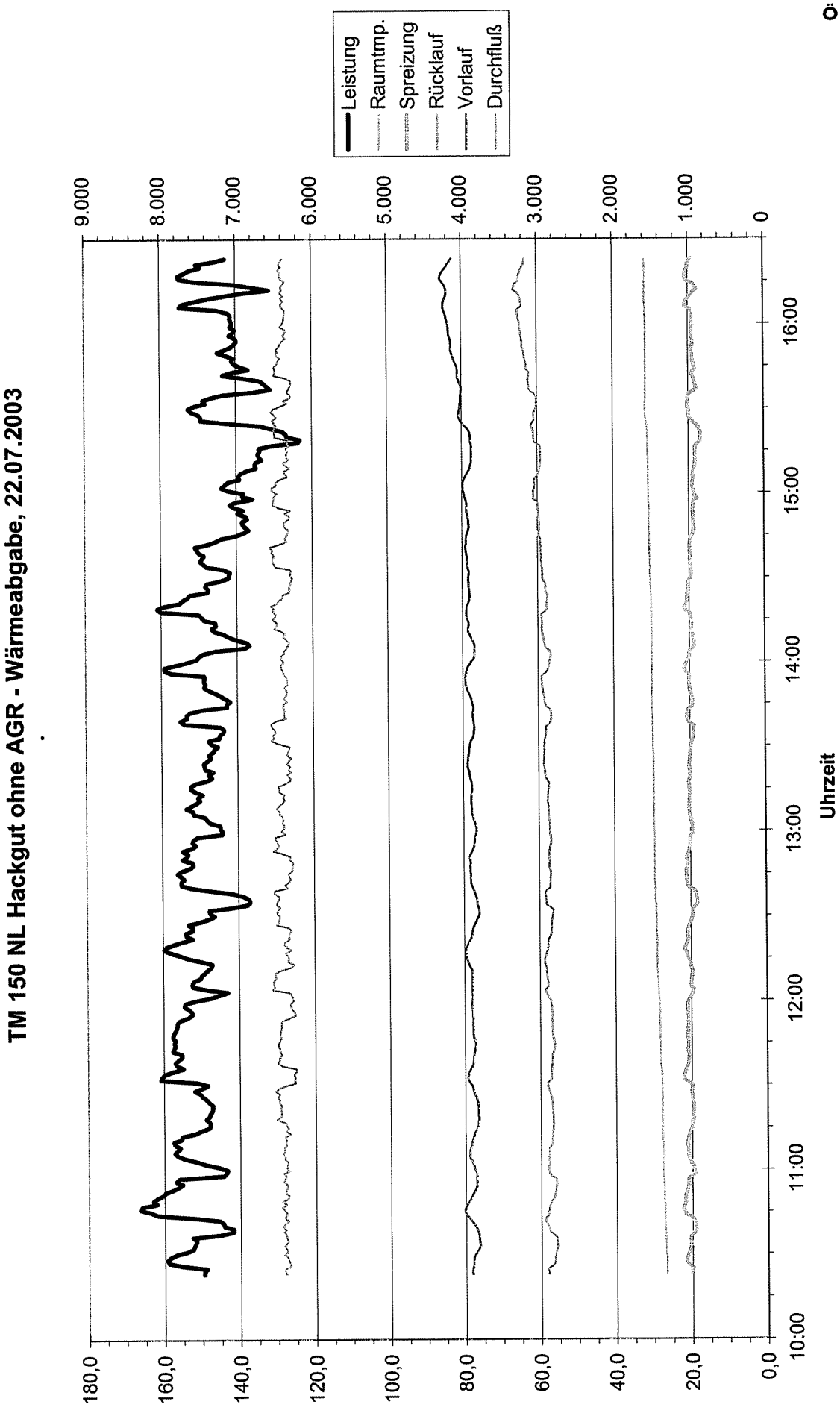

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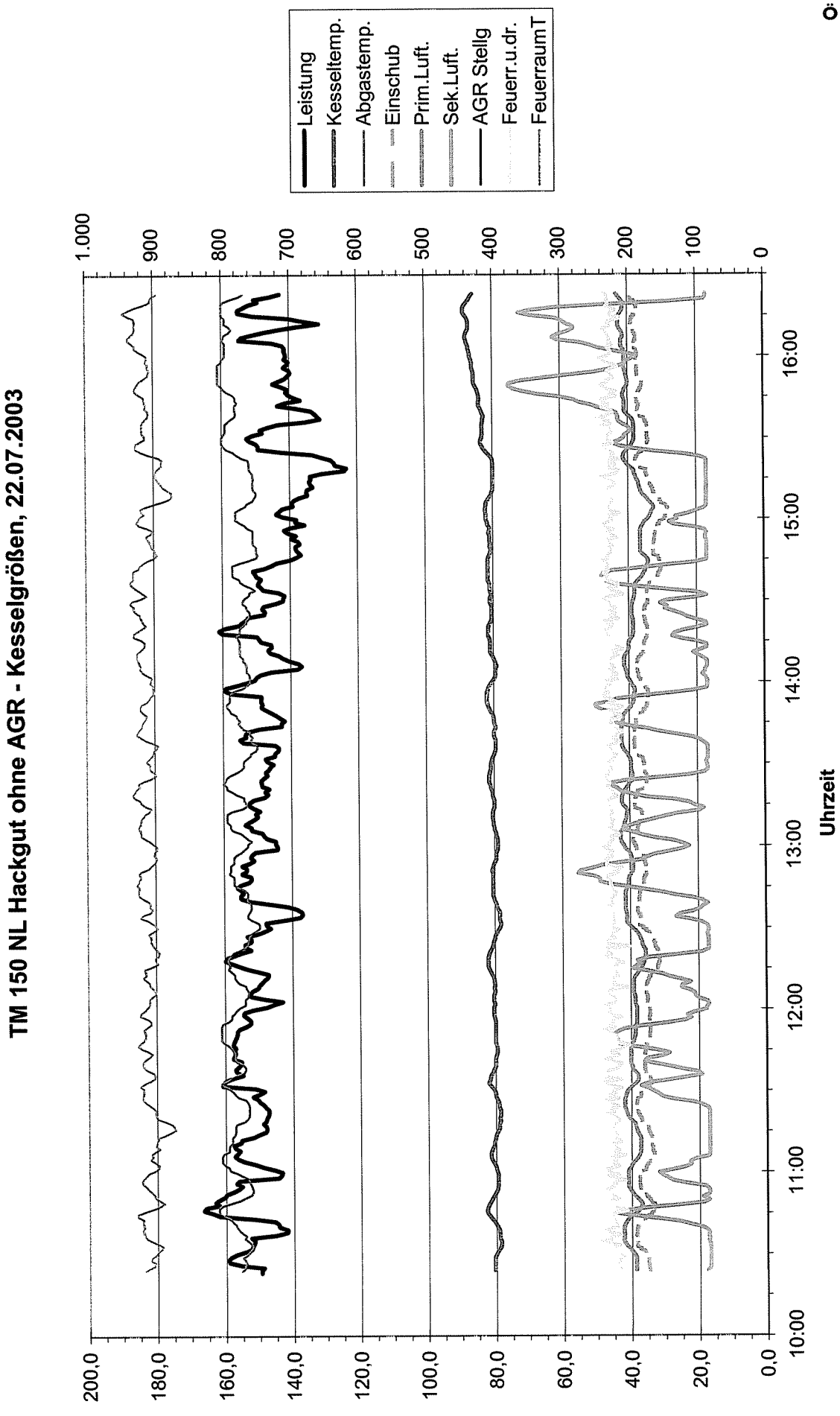

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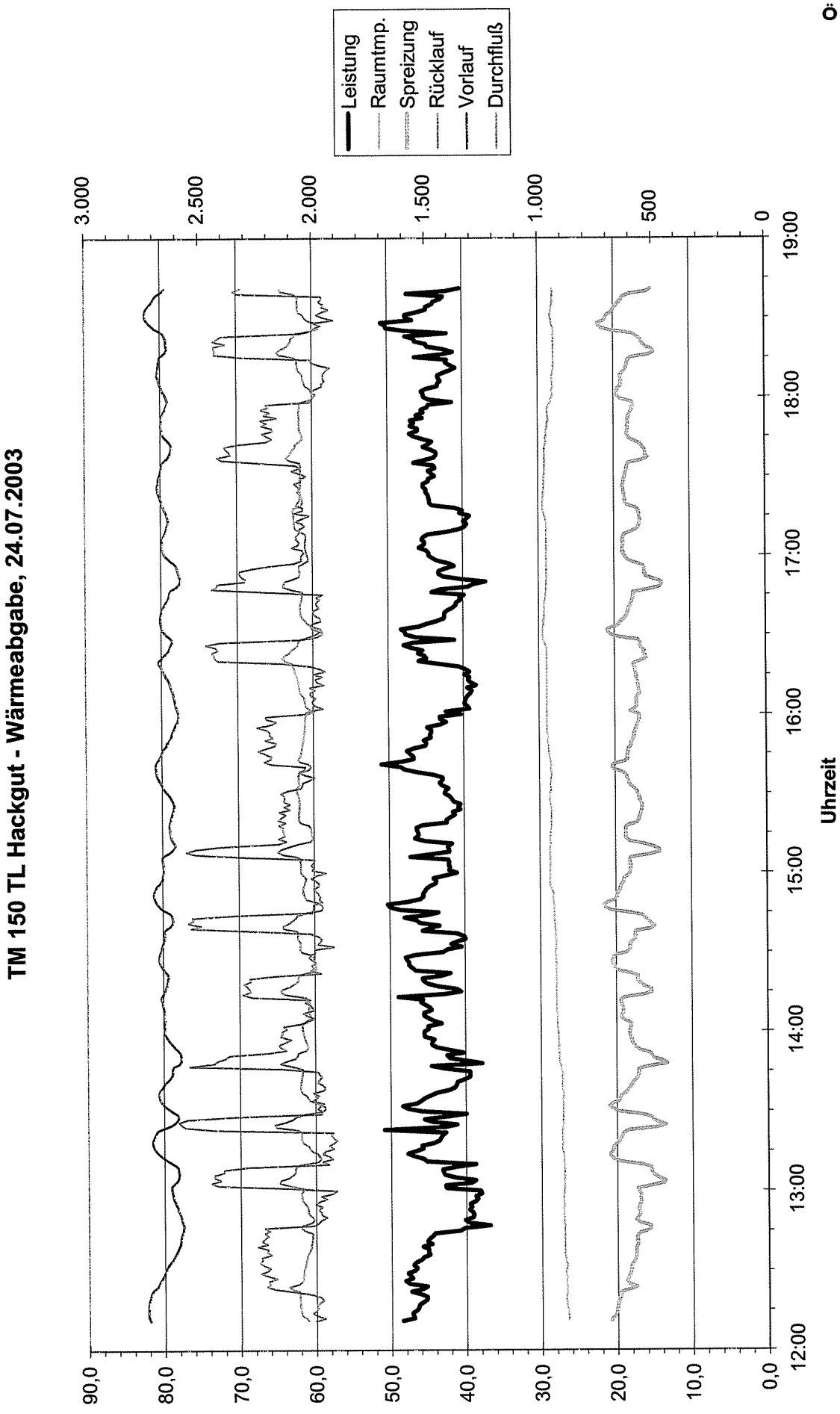

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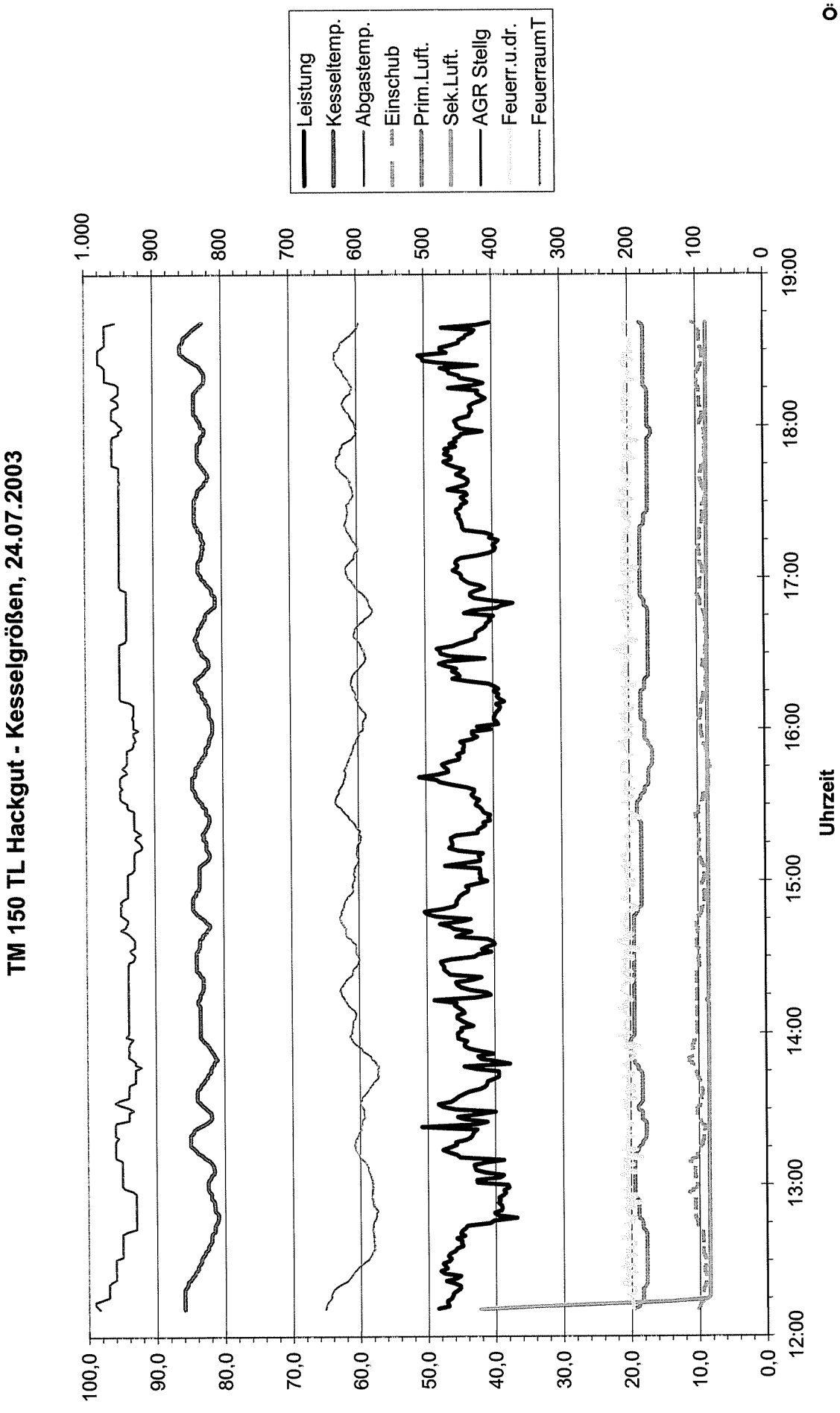

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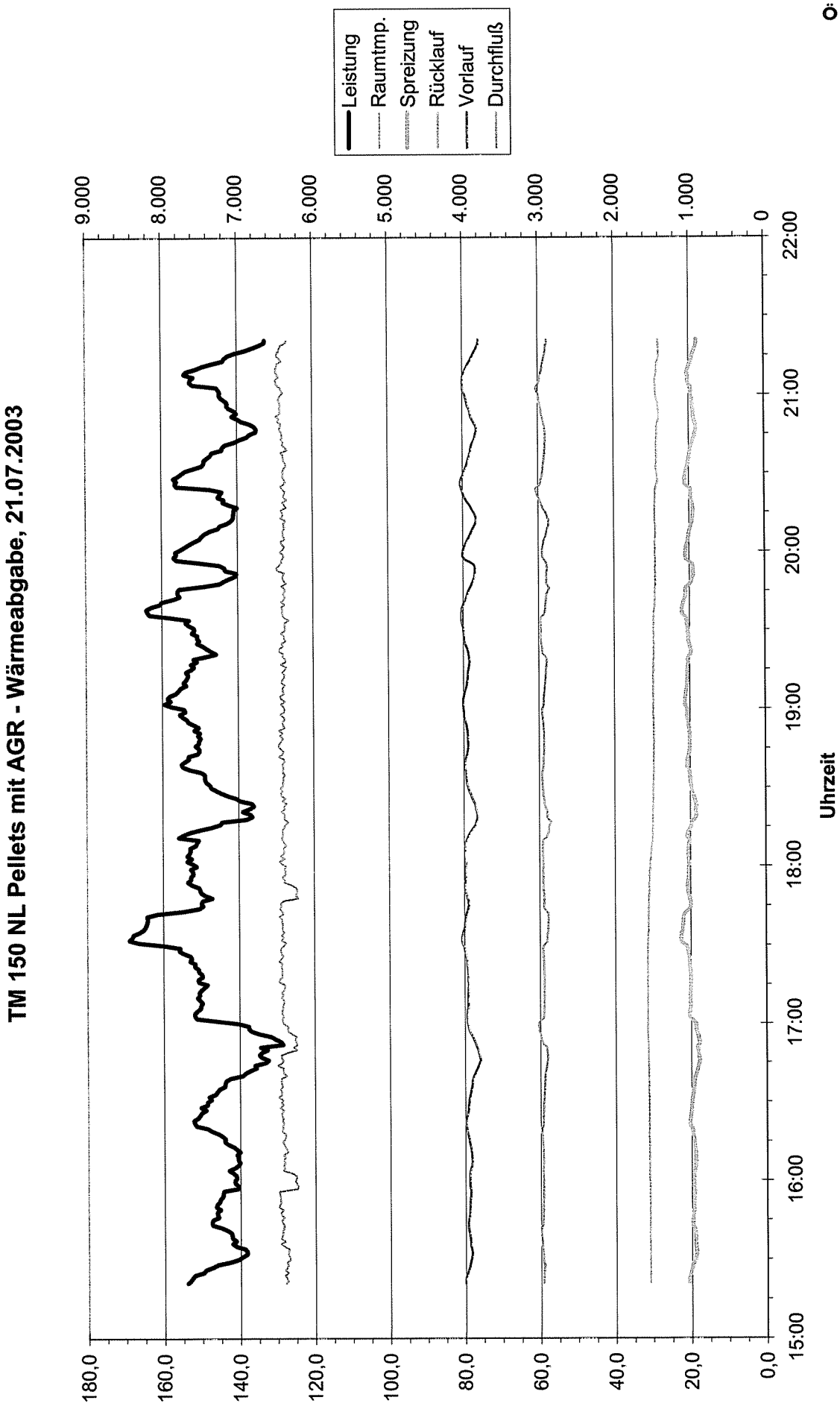

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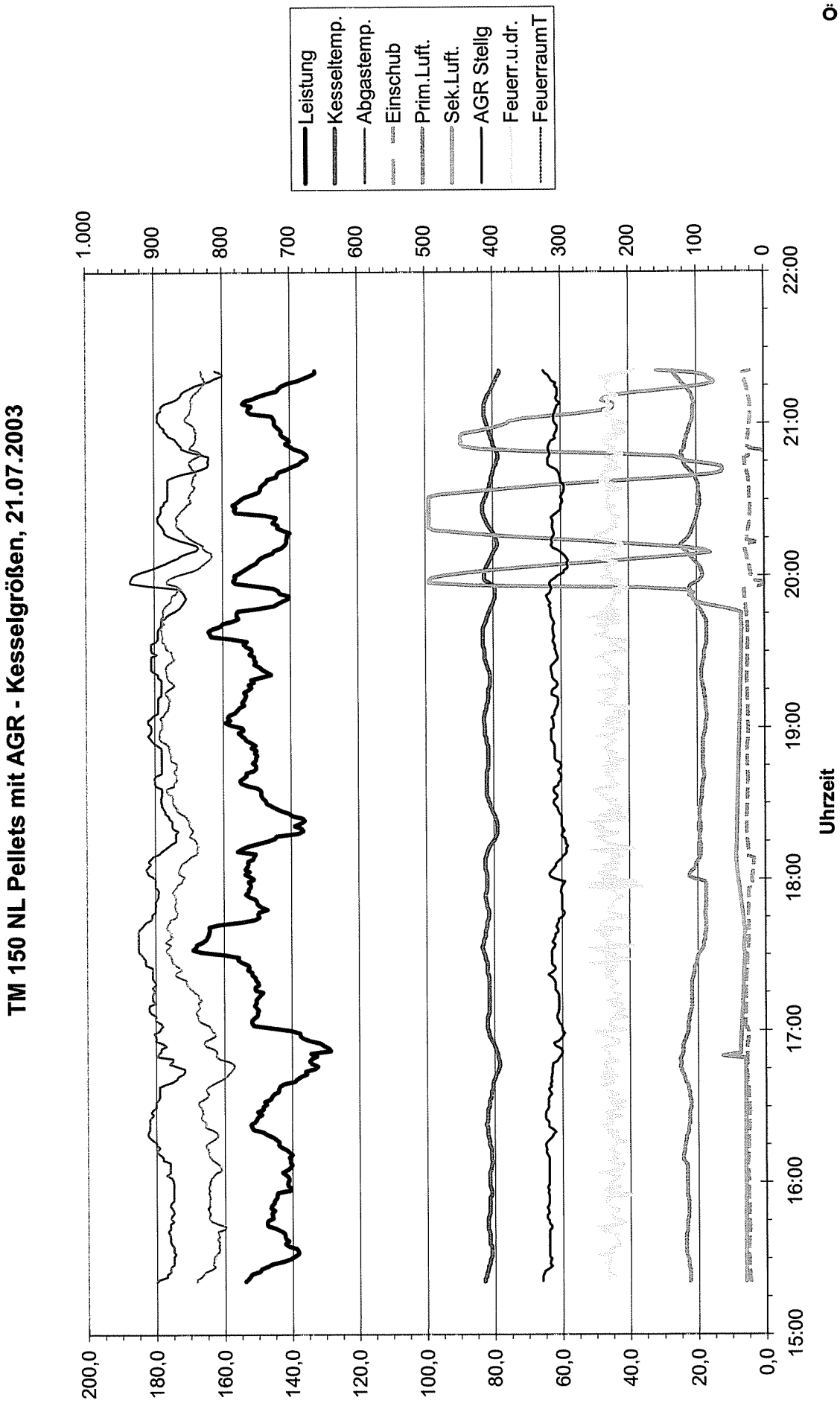

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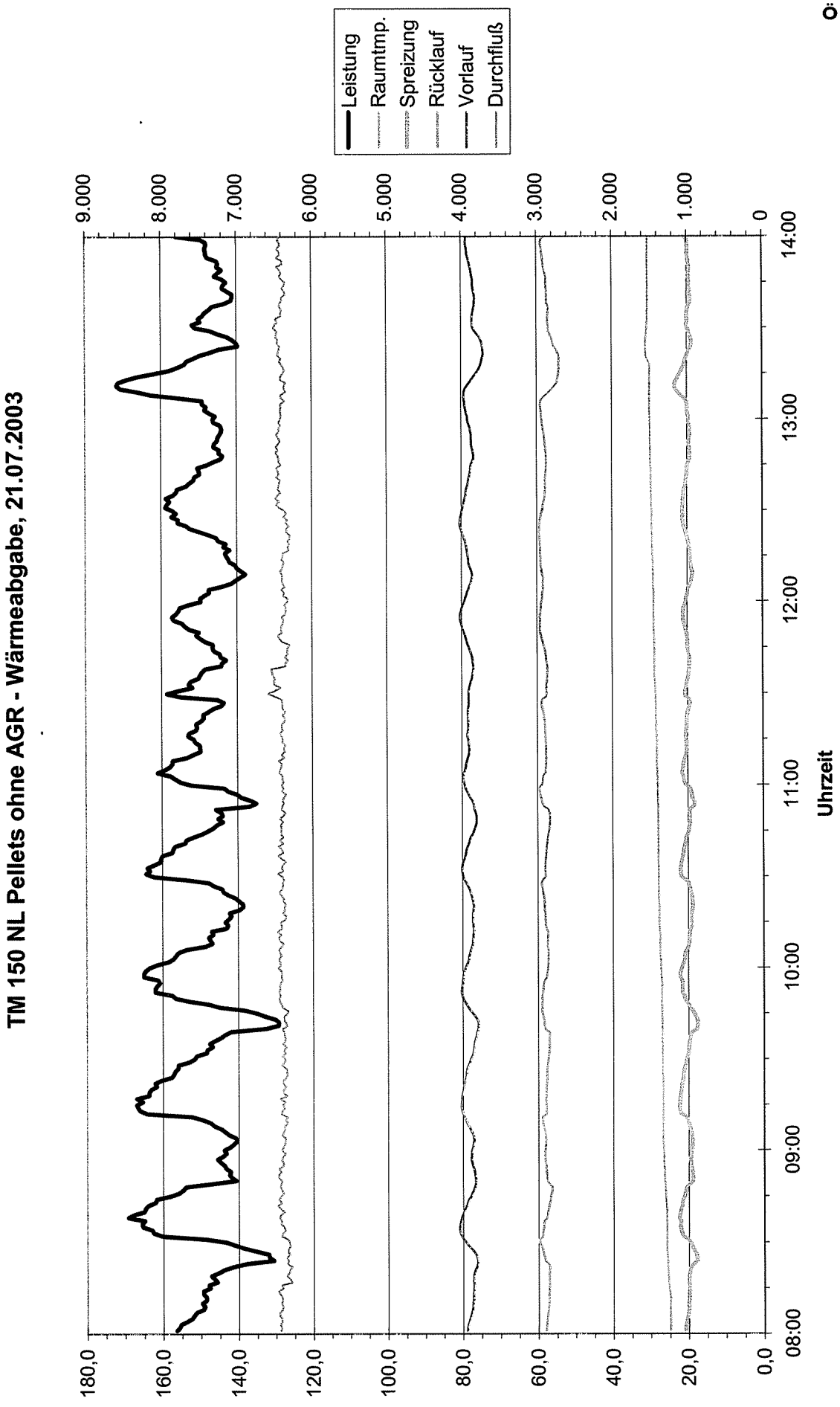

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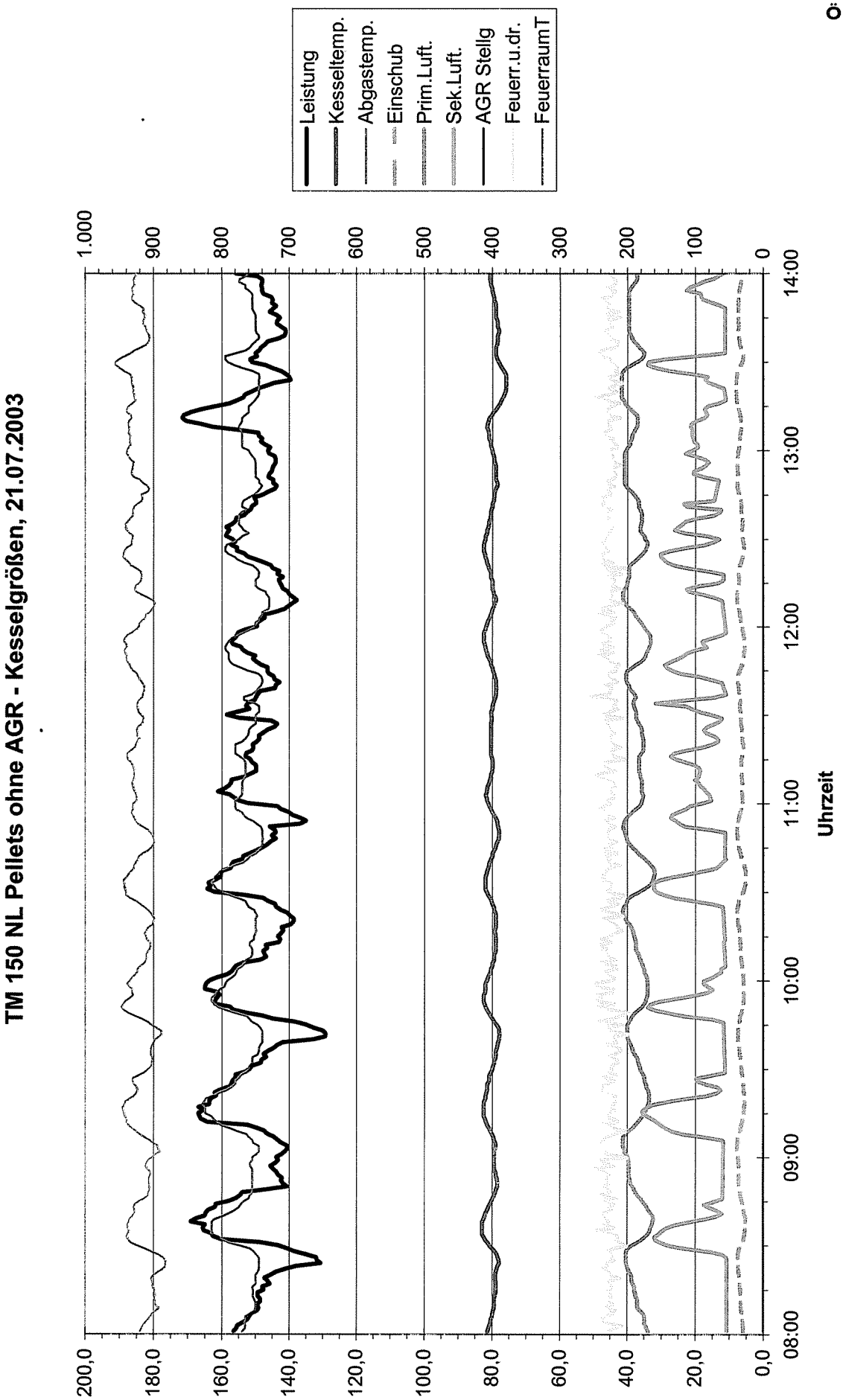

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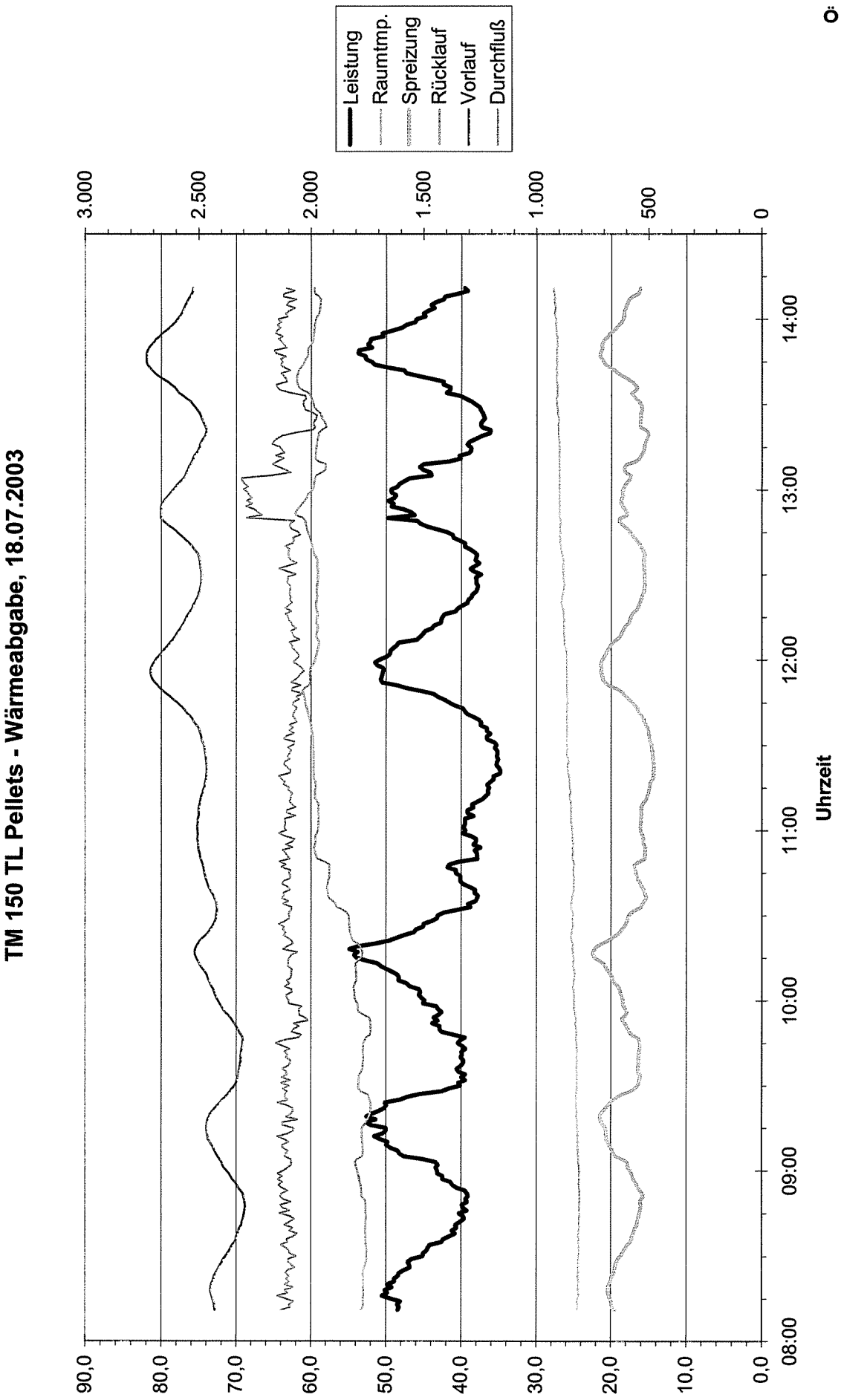

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