QM

Biomass DH Plants

Standard hydraulic schemes

Part I

Hans Rudolf Gabathuler
Hans Mayer

Working group QM Biomass DH Plants

Switzerland: Holzenergie Schweiz

Austria: AEE - Institute for Sustainable Technologies

Baden-Württemberg: University of Applied Forest Sciences Rottenburg

Bayern: C.A.R.M.E.N. e.V.

Italy: APE FVG - Agenzia per l'Energia del Friuli Venezia Giulia

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QM Holzheizwerke® (Quality Management (QM) for Biomass District Heating (DH) Plants) refers to the quality standards for biomass heating plants jointly developed by partners from Switzerland, Baden-Württemberg, Bavaria, Rhineland-Palatinate and Austria. The main aspects of the quality standards include professional design, planning and implementation of the heating plant and the heating grid. Important quality criteria encompass high operational reliability, precise control, low emissions and economical fuel logistics. The aim is to achieve an energy-efficient, environmentally friendly and economical operation of the entire plant.

QM for Biomass DH Plants is designed for hot water systems which are used to generate heat. Systems for generating electricity are not taken into account.

These **Standard hydraulic schemes - Part I** are tried and tested solutions for monovalent or bivalent heat production systems for one or two biomass boilers, without or with storage tank. Numerous solutions for space heating and domestic hot water supply are also described for the heat consumer side. If a standard hydraulic scheme is chosen, the design and functional description of the system is particularly simple: calculations are made in prepared tables and questions about the system concept can be answered by simply ticking a box. This enables efficient quality assurance and reduces planning errors to a minimum. Further tried and tested solutions have been published as "Standard hydraulic schemes - Part II".

The collected knowledge is published in **German as series of publications "QM Holzheizwerke". English versions of selected volumes are available.**

Band 1: Q-Leitfaden (mit Q-Plan)
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Band 2: Standard-Schaltungen – Teil I
ISBN 978-3-937441-92-4

Band 3: Muster-Ausschreibung Holzkessel
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Band 4: Planungshandbuch
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Band 5: Standard-Schaltungen – Teil II
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English versions:

Volume 1: Q-Guidelines

Volume 2 and Volume 5: Standard hydraulic schemes

Volume 4: Planning Handbook

The publications of Quality Management for Biomass District Heating Plants can be downloaded or requested www.qm-biomass-dh-plants.com

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Heating Plants

Standard hydraulic schemes

Part I

Hans Rudolf Gabathuler
Hans Mayer

Based on the second, expanded edition

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Working group Quality Management for Biomass District Heating Plants in different countries

Switzerland:
Holzenergie Schweiz with the financial support of the Swiss Federal Office of Energy
www.qmholzheizwerke.ch
www.holzenergie.ch

Austria:
AEE INTEC – AEE - Institute for Sustainable Technologies
www.klimaaktiv.at/qmheizwerke

Germany:
Baden-Württemberg: University of Applied Forest Sciences Rottenburg
Bayern: C.A.R.M.E.N. e.V.
www.qmholzheizwerke.de

Italy:
APE FVG - Agenzia per l'Energia del Friuli Venezia Giulia
www.ape.fvg.it

These websites contain information and publications on the subject of biomass energy. From there you can also download further documents and software tools.

Team of the working group Quality Management for Biomass District Heating Plants

Jürgen Good (Management), Verenum, CH
Stefan Thalmann, Verenum, CH

Daniel Binggeli, Federal Office of Energy, CH

Andreas Keel, Holzenergie Schweiz, CH

Andres Jenni, ardens GmbH, CH

Patrick Küttel, DM Energieberatung AG, CH

Harald Schrammel, AEE INTEC, AT
Sabrina Metz, AEE INTEC, AT

Gilbert Krapf, C.A.R.M.E.N. e.V., DE
Niels Alter, C.A.R.M.E.N. e.V., DE
Christian Leuchtweis, C.A.R.M.E.N. e.V., DE

Harald Thorwart, University of Applied Forest Sciences Rottenburg, DE
Johanna Eichermüller, University of Applied Forest Sciences Rottenburg, DE

Former team members:

Ruedi Bühler, Umwelt und Energie, CH

Hans Rudolf Gabathuler, Gabathuler Beratung GmbH, CH

Franz Promitzer, LandesEnergieVerein Steiermark, AT

Helmut Böhnisch, Climate Protection and Energy Agency Baden-Württemberg GmbH, DE

Helmut Bunk, Holzenergie-Beratung Bunk Ltd., DE

Bernhard Pex, C.A.R.M.E.N. e.V., DE

Bernd Textor, Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg, DE

Joachim Walter, Transferstelle für Rationelle und Regenerative Energienutzung Bingen, DE

Authors

Hans Rudolf Gabathuler, Gabathuler Beratung GmbH

Hans Mayer, Mayer Ingenieur GmbH

Collaboration

Ruedi Bühler, Environment and Energy

Andres Jenni, ardens GmbH

Translation team

Carles Ribas Tugores, AEE INTEC

Christian Ramerstorfer, AEE INTEC

Foreword to the second, expanded edition

In the last four years, many wood heating plants have been built according to the present standard hydraulic schemes. Thanks to the quality management system **QM for Biomass DH Plants**, it has fortunately been possible to confirm that the proposed solutions are indeed operationally reliable, energy-efficient, environmentally friendly and economical.

In addition, a lot of experience has been gained, which has been incorporated into the present second edition as various minor additions and improvements. Errors have also been corrected, of course. Here are the most important changes:

■ Shortly after the first edition was published, it became apparent that the recording of the storage charge status was causing difficulties. Therefore, a leaflet with various solutions was published on the Internet. In the new edition, the recording of the storage tank state of charge is now described in detail, making the leaflet superfluous for users of the present edition.

■ Bivalent three-boiler systems with 2 biomass boilers and 1 oil/gas boiler have been built relatively often recently. The advantage compared to a monovalent system with two biomass boilers is that the biomass boilers can be designed smaller, and compared to a bivalent system with only one biomass boiler, there is the advantage that a satisfactory summer operation can be realised with the small biomass boiler. Therefore, two new standard hydraulic schemes have been included: Bivalent three-boiler system (2 biomass boilers, 1 oil-gas boiler) without storage tank (short designation WE7) and with storage tank (short designation WE8).

■ Specifications for the time programme control were omitted for all circuits because the entry of the time programmes is very time-consuming, the time programmes often change later and are also of secondary importance for the correct functioning of the system.

■ The operating mode "manual" is still provided, but no longer mandatory.

■ The measuring point list for the automatic data recording system previously provided a return of the actual value of the firing rate by the subordinate I&C system of the biomass boiler (no standard available signal). This actual value was deleted from the measuring point list. Instead, a "boiler-internal setpoint value of the firing rate (feedback)" (also standard available signal) was newly included in the measuring point list for all boilers.

■ Since volume 5 "Standard hydraulic schemes - Part II" has been published in the meantime, which deals with the control of the boiler circuit three-way valves for all common circuits in detail, the previous appendix 2 could be omitted.

The authors would like to thank the team of the QM Holzheizwerke working group, which made the revision and printing of this second edition possible. They hope that the second edition will also fulfil its task of being a reliable aid in the construction of operationally safe, energy-efficient, environmentally friendly and economical wood heating plants.

November 2010

Content

Introduction

Principles

The selection and description of the present **Standard hydraulic schemes - Part I** follows previously established principles:

1. One proven hydraulic circuit per application in heat production.

2. Heat production can be expanded hydraulically and in terms of control technology as desired. An exception was only made for the monovalent biomass heating plant without storage tank, where a minimum solution is permitted in addition to the regular solution, but which cannot be expanded.

3. Primary boiler and secondary boiler are not hydraulically defined. This means that only parallel hydraulic circuits are used for heat production (no series hydraulic circuits).

4. Control variable of the main controller is
   - for systems without a storage tank, the main supply temperature,
   - for systems with storage tanks, the storage tank charging status.

5. The correcting variable of the main controller is basically the setpoint of the firing rate of the biomass boiler internal controller, e.g. in the sequence
   Boiler 1 two-point - Boiler 1 continuous - Boiler 2 two-point - Boiler 2 continuous.

6. Strict coupling of hydraulic circuits with low pressure difference. This means that there is always a generously dimensioned bypass (“hydraulic separator") between two hydraulic circuits (each with its own pump).

7. All heat consumers connections for the lowest possible return temperature
   - in the central heating plant with low-pressure difference connection,
   - on the district heating network with differential pressure-affected connection.

8. compliance with minimum valve authorities (for definition see Planning Handbook [4]):
   - three-way valves ≥ 0,5
   - straight-way valves ≥ 0,3

Principle 5 has the consequence that only biomass boilers that can process an external setpoint signal for the firing rate (from the master control system) are suitable for use in the present "Standard hydraulic schemes - Part I". An exception here is the "minimum solution" for the monovalent single boiler system without storage tank WE1, here the boiler water temperature is controlled solely via the PLC (programmable logic controller) of the biomass boiler. Field-proven solutions that work without an external setpoint signal for the firing rate have been published as Standard hydraulic schemes - Part II [5].

The functional descriptions define the basic principles of the respective control concept. **The detailed realisation of the control concept** is left to the I&C supplier and the planner. Examples:
- Setting initial conditions
- Attenuation/delay of external signals
- Pre- and post-run times of circulating pumps
- Defined valve positions
- Detailed description of the unblocking and blocking criteria
- Detailed description of the operating modes
- Information on the time programme control
- Alarming information
- Specifications for control cabinets, plug connections, etc.
- Requirements for expansion system, filling devices, heating water quality, etc.
- Site-specific requirements for the safety functions

Overview

Standard hydraulic schemes are described which can be combined within certain limits:

■ **Heat production** (Table 1 and Table 2) with a low-pressure difference connection in the central heating plant:
- Monovalent biomass heating system without storage tank (standard hydraulic scheme WE1)
- Monovalent biomass heating system with storage tank (standard hydraulic scheme WE2)
- Bivalent biomass heating system without storage tank (standard hydraulic scheme WE3)
- Bivalent biomass heating system with storage tank (standard hydraulic scheme WE4)
- Monovalent two-boiler biomass heating system without storage tank (standard hydraulic scheme WE5)
- Monovalent two-boiler biomass heating system with storage tank (standard hydraulic scheme WE6)
- Bivalent three-boiler system without storage tank, 2 biomass boilers, 1 oil/gas boiler (standard hydraulic scheme WE7)
- Bivalent three-boiler system with storage tank, 2 biomass boilers, 1 oil/gas boiler (standard hydraulic scheme WE8)

■ **If a district heating network is present:** District heating network with pre-control, network pump and differential pressure control.

■ **Heat consumers in the central heating plant with low-pressure difference connection** (Table 3):
- Heating group without heat exchanger (standard hydraulic scheme WA1)
- Heating group with heat exchanger (standard hydraulic scheme WA2)
- Three variants of water heaters (for domestic hot water supply – see standard hydraulic schemes WA3a, WA3b, WA3c)

■ **Heat consumers on the district heating with differential pressure-affected connection** (Table 4):
- Heating group without heat exchanger (standard hydraulic scheme WA4)
- Heating group with heat exchanger (standard hydraulic scheme WA5)
- Combination of heating group without heat exchanger and water heater in three variants (standard hydraulic schemes WA6a, WA6b, WA6c).
- Combination of heating group with heat exchanger and water heater in three variants (standard hydraulic schemes WA7a, WA7b, WA7c).
- Connection with heat exchanger and several heating groups and water heater on the secondary side - (standard hydraulic scheme WA8)
- Heat transfer station with storage tank for several heating groups and water heaters (standard hydraulic scheme WA9)

Figure 5 shows an example of a complete standard hydraulic scheme consisting of a heat production system with low-pressure difference connections in the central heating plant and a district heating network with differential pressure-affected connections.

The choice of the standard hydraulic scheme for heat production (WE1 to WE8) is decisive for the design of the system. The design of monovalent systems must be very precise; with bivalent systems, uncertainties can be "covered" by the oil/gas boiler(s):

■ For **monovalent systems <u>without</u> storage** (WE1, WE5), the biomass boiler(s) must be designed for 100% of the heat output demand <u>including</u> load peaks (situation recording [7]: see load characteristic curve - solid line).

■ In **monovalent systems <u>with</u> storage** (WE2, WE6), the biomass boiler(s) can be designed for 100% of the heat output demand <u>without</u> load peaks (situation recording [7]: see load characteristic curve – dashed line) (only applies to systems with predominantly space heating).

■ In order to be able to cover 80...90% of the annual heat demand with biomass energy, the biomass boiler(s) of **bivalent systems <u>without</u> storage** (WE3, WE7) can be designed for 60...70% of the heat output demand (guiding value for systems with predominantly space heating).

■ In order to be able to cover 80...90% of the annual heat demand **with** biomass energy, the biomass boiler(s) of **bivalent systems with storage** (WE4, WE8) can be designed even lower to 50... 60% of the heat output demand (guiding value for systems with predominantly space heating).

■ The **oil/gas boiler in the case of bivalent systems** can then be designed for the total output or as a supplement to the total output in accordance with the safety considerations. Examples:

- In the case of a biomass boiler: Oil/gas boiler on total output (failure of biomass boiler is secured)
- In the case of two biomass boilers: addition of the smaller biomass boiler to the total output (failure of one of the two biomass boilers is secured).

Label	Description	Requirements
WE1	**Monovalent biomass heating system without storage tank** ■ 100% of the annual heat demand (heating, hot water and process heat demand) with biomass energy ■ Design of the biomass boiler for 100% heat output requirement including load peaks ■ Low-load operation (summer) only possible if the summer load is sufficiently high. ■ Heat capacity reserve for expansion only possible in exceptional cases due to low load problems	■ Boiler return temperature protection and pre-control: Valve authority ≥ 0,5 ■ Design temperature difference over the biomass boiler ≤ 15 K ** ■ Number of full load operating hours biomass boiler > 1500 h/a
WE2	**Monovalent biomass heating system with storage tank** ■ 100% of the annual heat demand (heating, hot water and process heat demand) with biomass energy ■ Peak loads covered by storage tank, i.e. design of the biomass boiler for 100% heat output demand without peak loads. ■ Low-load operation (summer) only possible if the summer load is sufficiently high. ■ Heat capacity reserve for expansion only possible in exceptional cases due to low load problems	■ Storage volume ≥ 1 h storage capacity (related to nominal biomass boiler output) * ■ Load control/boiler return temperature protection and pre-control: Valve authority ≥ 0,5 ■ Design temperature difference over the biomass boiler ≤ 15 K ** ■ Number of full load operating hours biomass boiler > 2000 h/a
WE3	**Bivalent biomass heating system without storage tank** ■ 80...90% of the annual heat demand (heating, hot water and process heat demand) with biomass energy ■ Design of the biomass boiler for 60... 70% * of the heat output requirement ■ Low-load operation (transition period/summer) with sufficient load by biomass boiler, otherwise by oil/gas boiler ■ High security of supply due to oil/gas boiler ■ Expansion reserve possible through oil/gas boiler (with corresponding reduction of the biomass coverage ratio)	■ Boiler return temperature protection for both boilers and pre-control: Valve authority ≥ 0,5 ■ Lay-out temperature difference above the biomass boiler ≤ 15 K ** ■ Number of full load operating hours biomass boiler > 2500 h/a; target 4000 h/a
WE4	**Bivalent biomass heating system with storage tank** ■ 80...90% of the annual heat demand (heating, hot water and process heat demand) with biomass energy ■ Peak loads covered by storage tank, i.e. design of the biomass boiler for 50...60% * of the heat output requirement ■ Low-load operation (transition period/summer) with sufficient load by biomass boiler, otherwise by oil/gas boiler ■ High security of supply due to oil/gas boiler ■ Heat capacity reserve for expansion possible through oil/gas boiler (with corresponding reduction of the biomass coverage ratio)	■ Storage volume ≥ 1 h storage capacity (related to nominal biomass boiler output) * ■ Load control/boiler return temperature protection for both boilers and pre-control: Valve authority ≥ 0,5 ■ Design temperature difference over the biomass boiler ≤ 15 K ** ■ Number of full load operating hours biomass boiler > 3500 h/a; target 4000 h/a
* Guiding value for systems with predominantly space heating ** Can be increased to reduce pump power consumption if it is ensured that this does not cause any control problems (e.g. oscillation of the boiler output due to temperature stratification).		

Table 1: Standard hydraulic schemes heat production WE1 to WE4

Label	Description	Requirements
WE5	**Monovalent two-boiler biomass heating system without storage tank** ■ 100% of the annual heat demand (heating, hot water and process heat demand) with biomass energy ■ Design of the biomass boilers for 100% heat output requirement including load peaks ■ Low-load operation (transition period/summer) generally possible due to the small biomass boiler ■ Heat capacity reserve for expansion possible with correspondingly high investment costs (expensive biomass boilers)	■ Boiler return temperature protection for both boilers and pre-control: Valve authority ≥ 0,5 ■ Design temperature difference above the boilers ≤ 15 K** ■ Number of full load operating hours biomass boiler 1+2 > 1500 h/a
WE6	**Monovalent two-boiler biomass heating system with storage tank** ■ 100% of the annual heat demand (heating, hot water and process heat demand) with biomass energy ■ Load peaks covered by storage, i.e. design of the biomass boiler for 100% heat output demand without load peaks ■ Low-load operation (transition period/summer) generally possible due to the small biomass boiler ■ Heat capacity reserve for expansion possible with correspondingly high investment costs (expensive biomass boilers)	■ Storage volume ≥ 1 h storage capacity (related to nominal output of larger biomass boiler) * ■ Load control/boiler return temperature protection for both boilers and pre-control: Valve authority ≥ 0,5 ■ Design temperature difference above the boilers ≤ 15 K ** ■ Number of full load operating hours biomass boiler 1+2 > 2000 h/a
WE7	**Bivalent three-boiler system without storage tank (2 biomass boilers, 1 oil/gas boiler)** ■ 80...90% of the annual heat demand (heating, hot water and process heat demand) with biomass energy ■ Design of the biomass boilers for 60... 70% * of the heat output requirement ■ Low-load operation (transition period/summer) usually possible through the small biomass boiler, otherwise through oil/gas boiler ■ High security of supply due to oil/gas boiler ■ Heat capacity reserve for expansion possible through oil/gas boiler (with corresponding reduction of the biomass coverage ratio)	■ boiler return temperature protection for all boilers and pre-control: Valve authority ≥ 0,5 ■ Design temperature difference above the biomass boilers ≤ 15 K ** ■ Number of full load operating hours biomass boiler 1+2 > 2500 h/a; target 4000 h/a
WE8	**Bivalent three-boiler system with storage tank (2 biomass boilers, 1 oil/gas boiler)** ■ 80...90% of the annual heat demand (heating, hot water and process heat demand) with biomass energy ■ Load peaks covered by storage, i.e. design of the biomass boiler for 50...60% * of the heat output requirement ■ Low-load operation (transition period/summer) usually possible through the small biomass boiler, otherwise through oil/gas boiler ■ High security of supply due to oil/gas boiler ■ Heat capacity reserve for expansion possible through oil/gas boiler (with corresponding reduction of the biomass coverage ratio)	■ Storage volume ≥ 1 h storage capacity (related to nominal output of the larger biomass boiler) * ■ Load control/boiler return temperature protection for both biomass boilers and pre-control: Valve authority ≥ 0,5 ■ Design temperature difference above the biomass boilers ≤ 15 K ** ■ Number of full load operating hours biomass boiler 1+2 > 3000 h/a; target 4000 h/a
* Guiding value for systems with predominantly space heating ** Can be increased to reduce pump power consumption if it is ensured that this does not cause any control problems (e.g. oscillation of the boiler output due to temperature stratification).		

Table 2: Standard hydraulic schemes heat production WE5 to WE8

Label	Description	Requirements
WA1	**Heating group without heat exchanger** ■ Direct connection with three-way valve (admixing hydraulic configuration)	■ In case of multiple groups: Maximum pressure drop across the variable flow sections ≤ 20% of the head of the smallest group pump ■ Valve authority ≥ 0,5
WA2	**Heating group with heat exchanger** ■ Indirect connection in case of large geodetic height difference of the system and/or high pump pressure in case of widespread systems (smaller operating pressure of the heating group possible)	■ Valve authority ≥ 0,5
WA3	**Water heater** ■ WA3a: External heat exchanger and charge control for stratified charging of the water heater (relatively constant high heating output with the lowest possible return temperature). ■ WA3b: External heat exchanger without charge control ■ WA3c: Internal heat exchanger	■ Valve authority ≥ 0,5

Table 3: Low-pressure-difference heating group connections in the central heating plant

Label	Description	Demands
WA4	**Heating group without heat exchanger** ■ Direct connection (injection system with straight-way valve)	■ Valve authority for straight-way ≥ 0,3
WA5	**Heating group with heat exchanger** ■ Indirect connection in case of large geodetic height difference of the system and/or high pump pressure in case of extensive systems (smaller operating pressure of the heating group possible)	■ Valve authority for straight-way valves ≥ 0,3
WA6	**Combination heating group without heat exchanger and water heater** ■ Direct connection of the heating group ■ WA6a: External heat exchanger for hot water preparation with charge control for stratified charging (relatively constant high heating output with the lowest possible return temperature). ■ WA6b: External heat exchanger for hot water preparation without charge control ■ WA6c: Water heater with internal heat exchanger	■ Valve authority for three-way valves ≥ 0,5 ■ Valve authority for straight-way valves ≥ 0,3
WA7	**Combination heating group with heat exchanger and water heater** ■ Indirect connection in case of large geodetic height difference of the system and/or high pump pressure in case of extensive systems (smaller operating pressure of the heating group possible) ■ WA7a: External heat exchanger for hot water preparation with charge control for stratified charging (relatively constant high heating output with the lowest possible return temperature). ■ WA7b: External heat exchanger for hot water preparation without charge control ■ WA7c: Water heater with internal heat exchanger	■ Valve authority for three-way valves ≥ 0,5 ■ Valve authority for straight-way valves ≥ 0,3
WA8	**Connection with heat exchanger and several heating groups and water heater on the secondary side** ■ Indirect connection of several heating groups in case of large geodetic height difference of the system and/or high pump pressure in case of extensive systems (smaller operating pressure of the heating groups possible) ■ Low-pressure difference connections on the secondary side analogous to the standard hydraulic schemes WA1 (heating groups) and WA3a...WA3c (water heaters)	■ In case of several groups on the secondary side: Maximum pressure drop across the variable flow sections ≤ 20% the head of the smallest group pump ■ Valve authority for three-way valves ≥ 0,5 ■ Valve authority for straight-way valves ≥ 0,3
WA9	**Heat transfer station with storage tank for several heating groups and water heaters** ■ For heat consumers with large peak loads ■ Low-pressure difference connections on the secondary side analogous to the standard hydraulic schemes WA1 (heating groups) and WA3a...WA3c (water heaters)	■ In case of several groups on the secondary side: Maximum pressure drop across the variable flow sections ≤ 20% the head of the smallest group pump ■ Valve authority for three-way valves ≥ 0,5 ■ Valve authority for straight-way valves ≥ 0,3

Table 4: differential pressure-affected heating group connections on the district heating network

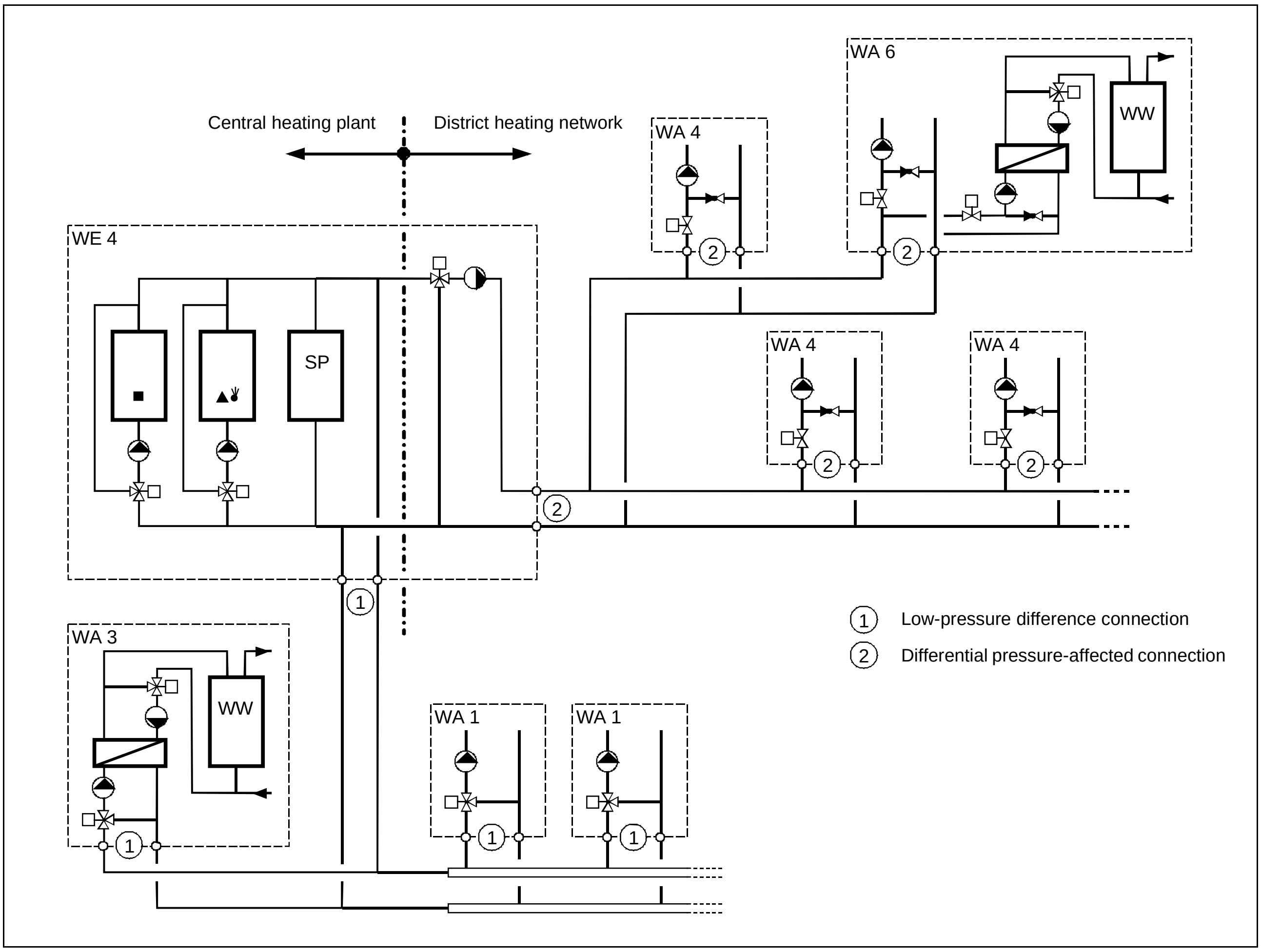

Figure 5: Example of a complete standard hydraulic scheme consisting of WE4 (bivalent biomass heating system with storage tank) with low-pressure difference connections in the central heating plant WA1 (heating groups) and WA3 (water heater) as well as differential pressure-affected connections on the district heating network WA 4 (heating groups) and WA6 (heating group with water heater). Note that, WW: Hot water (domestic hot water supply), SP: Storage tank.

I&C system levels

Within the standard hydraulic schemes for heat production, the following Instrumentation and Control (I&C) system levels are distinguished (example in Figure 6):

■ **User level** with interfaces to the master and subordinate I&C systems. A further distinction must be made here:
- Service and emergency operation (operating elements in the control cabinet)
- Operation selection (operation selection switch in the control cabinet as the simplest solution, input via PLC or input via master computer also possible)
- Change setpoints, time programmes, etc.

■ **Master I&C system** with interfaces to the user level and to the subordinate I&C systems. A further distinction must be made here:
- Control and regulation functions
- Data recording for operation optimisation (is mandatory as standard hydraulic scheme!)

■ **Subordinate I&C systems** with interfaces to the user level and to the master I&C system. A further distinction must be made here:
- I&C systems in the central heating plant (biomass boiler, oil/gas boiler, groups in the central heating plant).
- I&C systems at the trunk line (usually autonomous groups at the trunk line without interfaces to the central heating plant).

Table 7 shows how the I&C system levels can actually be realised using three typical examples.

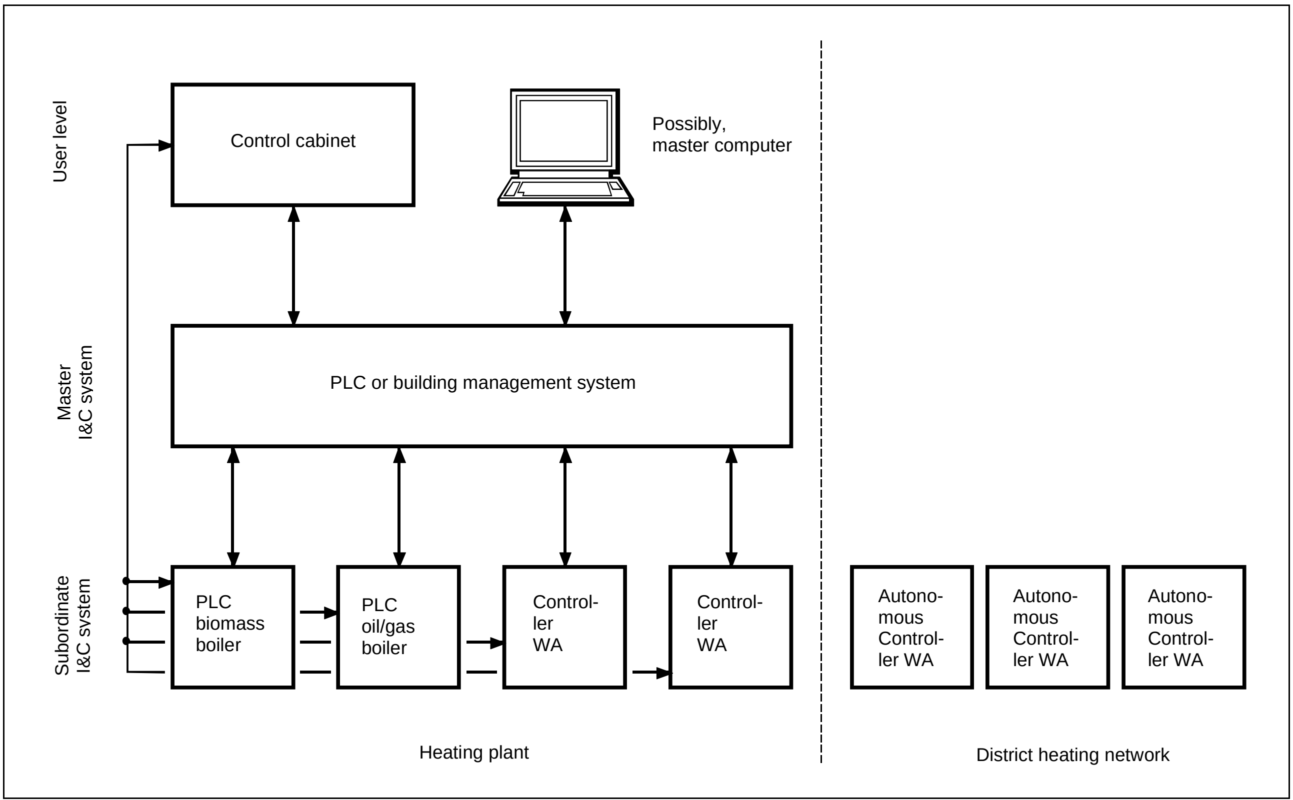

Figure 6: User level, master I&C system and subordinate I&C systems (example).

<table>
<tr><th colspan="2" rowspan="2">I&C system levels</th><th colspan="4">How are the I&C system levels realised?</th></tr>
<tr><td>Example 1: Realisation of the part with grey background with - individual control and regulation units; operating data recording with separate data logger</td><td>Example 2: Realisation of the part with grey background with a PLC or a small guidance system (e.g. slimmed-down version of a building management system with only one controller and minimum necessary control level)</td><td>Example 3: Realisation of the part with grey background with the extended PLC of the biomass boiler</td><td>Example 4: Realisation of the part with grey background with a building management system (the PLC of the biomass boiler cannot be replaced by the building management system here!)</td></tr>
<tr><td rowspan="3">User level</td><td>Service and emergency operation</td><td>Switch "Off-On-Auto" in the control cabinet</td><td>Switch "Off-On-Auto" in the control cabinet</td><td>Switch "Off-On-Auto" in the control cabinet</td><td>Switch "Off-On-Auto" in the control cabinet</td></tr>
<tr><td>Operational choice, summer/winter</td><td>Operation selection and summer/winter switch in the control cabinet</td><td>Operation selection and summer/winter switch in the control cabinet</td><td rowspan="7">Extended PLC of the biomass boiler</td><td rowspan="4">Building management system</td></tr>
<tr><td>Change setpoints, time programmes, etc.</td><td rowspan="2">Individual control and regulation units</td><td rowspan="3">PLC or small guidance system</td></tr>
<tr><td rowspan="2">Master I&C system</td><td>Control & regulate</td></tr>
<tr><td>Data recording</td><td>Data logger</td></tr>
<tr><td colspan="2" rowspan="3">Subordinate I&C systems in the central heating plant</td><td>PLC of the biomass boiler</td><td>PLC of the biomass boiler</td><td>PLC of the biomass boiler</td></tr>
<tr><td>Oil/gas boiler regulator</td><td>Oil/gas boiler regulator</td><td rowspan="3"></td></tr>
<tr><td>Group controller</td><td>Group controller</td></tr>
<tr><td colspan="2">Subordinate I&C systems in the district heating network</td><td>Autonomous group controllers</td><td>Autonomous group controllers</td><td>Autonomous group controllers</td></tr>
</table>

Table 7: Three typical implementation examples (Attention: automatic data recording must always be possible!)

Operating data recording for operational optimisation

For each standard hydraulic scheme, it is mandatory to record operating data (at least temporarily for the duration of the operating optimisation). This is assigned to the master I&C system. The following options are available:

■ Use of a **data logger** (at least temporarily during the period of operation optimisation) with interface in the form of outgoing standard signals for analogue signals (e.g. 0...10 V, 4...20 mA) and potential-free contacts for digital signals.

■ Realisation of data recording within a **PLC**. Whether this is possible depends on the hardware and software of the chosen system. A PC for data storage (at least temporarily for the duration of the operation optimisation) is usually required.

■ In the case of **small guidance systems** (e.g. slimmed-down version of a building management system with only one controller and a minimally necessary control level), data recording is usually provided for by the manufacturer today, but this usually requires a master computer (at least temporarily for the duration of the operational optimisation).

■ If a **larger building management system** is planned, the realisation of data recording should be possible without any problems.

How is a standard hydraulic scheme described?

The **standard hydraulic scheme** for the specific project at hand consists of the following parts:
- Title page (taken from Annex 2)
- Description of the heat production (chapters 1, 2, 3, 4, 5, 6, 7 or 8; filled in, ticked* and adapted to the actual planned hydraulic solution)
- If a district heating network exists: Description of the heat network (Chapter 9; completed, ticked and adapted to the actual planned hydraulic solution).
- System-specific amendments (Chapter 10)

For the system to be considered a standard hydraulic scheme, the following **requirements** must be met:
- Principle scheme, control scheme and the running text in chapters 1 to 9 may not be changed (exception: additions for a better understanding of the system). The current text contains "must" or "shall" formulations which are to be understood as indispensable requirements for the system to be considered a standard hydraulic scheme. "Can" formulations in the current text are to be understood as recommendations.
- All questions about the plant to be realised are to be answered by checking in the corresponding tables.
- All system-specific information is to be entered into the prepared tables.

The **prescribed outline** is to be adopted in order to avoid confusion and to facilitate the audit. Within chapter 10 "System-specific amendments ", the division into chapters is left to the user.

Standard hydraulic scheme with minor deviations: If the intended solution largely corresponds to a standard hydraulic scheme, but the listed requirements cannot be completely fulfilled, the corresponding standard hydraulic scheme can be corrected and supplemented. The deviations must be specifically highlighted and justified.

How is a non-standard hydraulic scheme described?

If there is no standard hydraulic scheme for the intended solution, the non-standard hydraulic scheme shall be described analogously to a standard hydraulic scheme.

The hydraulics and the control concept of one standard hydraulic scheme result logically from the other. Larger hydraulic schemes that are not defined as standard hydraulic schemes can therefore - thanks to the systematic structure of the already existing standard hydraulic schemes - be derived from them without any problems.

* The easiest way to change the "☐" symbol to "☒" is to double-click on it. Then you can select the tick symbol from the symbol list the first time, and when you click on it again, the tick symbol appears first in the list (of previous used symbols).

1. Monovalent biomass heating system without storage tank

1.1 Short description and responsibilities

1.1.1 User level

The simplest possible operation and a clear display of the main functions are required so that non-professional personnel can also operate the system:

■ The following requirements must be met for **service and emergency operation:**
- It must be possible to disable the automatic control system partially or completely for service work and in case of emergency operation (e.g. via switch "off/on/automatic").
- Manual operation of the control valves must be guaranteed (e.g. manual adjustment at the control valve, but this must not be disturbed by an incorrect control signal).
- All safety functions must be maintained

■ The **operating mode** shall be **selected** in one of the following ways:
- Via switches in a **conventional control panel** (usually in the control cabinet).
- Via a **PLC**; however, this is only an option if the hardware and software requirements for convenient operation are right.
- Via the master computer of a **control system**

■ Further operation, such as **adjusting setpoints, changing time programmes, etc.,** can be carried out directly on the master and subordinate I&C systems (if necessary, also via the Internet).

1.1.2 Master I&C system

The master I&C system takes care of all master control and regulation functions and links the subordinate I&C systems with each other. In addition, automatic data recording is also assigned to the master I&C system, which is mandatory as a standard hydraulic scheme (at least temporarily for the duration of the operation optimisation).

1.1.3 Subordinate I&C system 1: biomass boiler

The subordinate I&C system of the biomass boiler has to fulfil the following **functions:**
- Fire bed support operation or automatic ignition
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

If a **particle separator** is necessary, it must be controlled by the subordinate I&C system of the biomass boiler.

The **safety** of the biomass boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be ensured by the subordinate I&C system of the biomass boiler.

If the PLC of the biomass boiler can also fulfil the demands on the master I&C system (in particular also the automatic data recording), the **simultaneous use as a master and subordinate I&C system can be** tested.

1.1.4 Permissible minimum solution

If the functions of the master I&C system can be solved via individual controllers and/or the PLC in the biomass boiler, the boiler water temperature alone (same temperature but different measuring locations) can be controlled via the PLC of the biomass boiler instead of the boiler outlet temperature. Automatic data recording must then be realised via the PLC of the biomass boiler or via a data logger.

1.1.5 Selected structure of the I&C system levels

A person with main responsibility must be designated for the I&C planning (in particular also for the interface definition).

The structure of the I&C system levels with responsibilities chosen for the project to be described can be answered with Table 8.

I&C system level	Questions and answers
Permitted Minimum solution Section 1.1.4	Is the permissible minimum solution selected? ☐ Yes ☐ No
User level Section 1.1.1	Are the requirements for service and emergency operation met? ☐ Yes (mandatory for standard hydraulic scheme) ☐ No
	How does the operation mode selection take place? ☐ Switch in a conventional control panel ☐ Input via a PLC, sufficiently convenient operation is guaranteed ☐ Input via the master computer of the control system
	From where can the system be controlled and operated? ☐ Only in the central heating plant ☐ In the central heating plant and via modem ☐ In the central heating plant and via the internet
Master I&C system Section 1.1.2	How is the master I&C system implemented? ☐ Minimum solution: Control of the firing rate via the PLC of the biomass boiler; boiler return temperature protection with individual controller or via the PLC of the biomass boiler. ☐ Use of the PLC of the biomass boiler as a master I&C system ☐ Own master I&C system
	Connection of master/subordinate I&C system via standard interface [9]? ☐ Yes ☐ No
	How is the automatic data recording done? (Must also be answered for the minimum solution!) ☐ Data logger during operation optimisation, an interface is provided ☐ Internal data recording in the master I&C system
Subordinate I&C system 1: Biomass boiler Section 1.1.3	What is the position/tasks of the PLC of the biomass boiler? ☐ Minimum solution: Control of the boiler water temperature solely via the PLC of the biomass boiler ☐ It is used simultaneously as a master and subordinate I&C system ☐ It is subordinated to the master I&C system
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of all I&C system levels by the main planner ☐ Specification of all I&C system levels by the main planner with the involvement of I&C specialists
	How are the responsibilities (especially interface definitions) regulated at the execution and approval stage? ☐ Overall planning of all I&C system levels by the main planner ☐ Overall planning of all I&C system levels by biomass boiler supplier ☐ Overall planning of all I&C system levels by the supplier of the master I&C system ☐ Planning of each I&C system level by the respective supplier (not permitted for standard hydraulic schemes, as a main person responsible for I&C planning is explicitly required).

Table 8: Questions and answers on the chosen structure of the I&C system levels and responsibilities

1.2 Principle scheme and design

1.2.1 Hydraulic circuit

The hydraulic circuit must comply with Figure 9 The following requirements must be met:
- The hydraulic circuit must actually be made low in pressure difference by the bypass, i.e. the shortest possible bypass and pipe diameter bypass = pipe diameter main flow
- The interconnection of biomass boiler, bypass, low pressure distributor and pre-control must actually be low pressure differential (short pipes, large pipe diameters).

The installation is also considered a standard hydraulic scheme if
- one pump is realised by two or more pumps connected in parallel or in series,
- the pre-control of the district heating network is realised by two control valves connected in parallel or with a separate summer group,
- exhaust gas heat exchangers are integrated.

1.2.2 Hydraulic and control design

The hydraulic and control design must be carried out according to the generally accepted engineering standards. The requirements according to the Q-Guidelines [1] and the Planning Handbook [4] must be fulfilled, in particular:
- Boiler return temperature protection and pre-control: valve authority ≥ 0,5
- Design temperature difference of the biomass boiler ≤ 15 K; smaller temperature difference necessary if minimum permissible return temperature is high (e.g. with bark, landscape conservation wood); can be increased to reduce pump power consumption if it is ensured that this does not cause any control-related problems (e.g. oscillation of boiler output due to temperature stratification).
- The boiler inlet temperature should be at least 5 K higher than the minimum permissible return temperature (boiler return temperature protection).

The hydraulic and control design shall be presented and documented in accordance with Table 10.

A maximum permissible main return temperature T143 must be specified.

If the temperature difference between the boiler outlet temperature and the boiler inlet temperature is more than 10 K less than the temperature difference between the boiler outlet temperature and the maximum permissible main return temperature T143, it is recommended to provide a **bypass in the boiler circuit D111.**

Important: To ensure that the boiler can always deliver the output, it must be ensured that the main return temperature T143 cannot rise above the design value in any operating case (prescribe return temperature limiter for all consumers!).

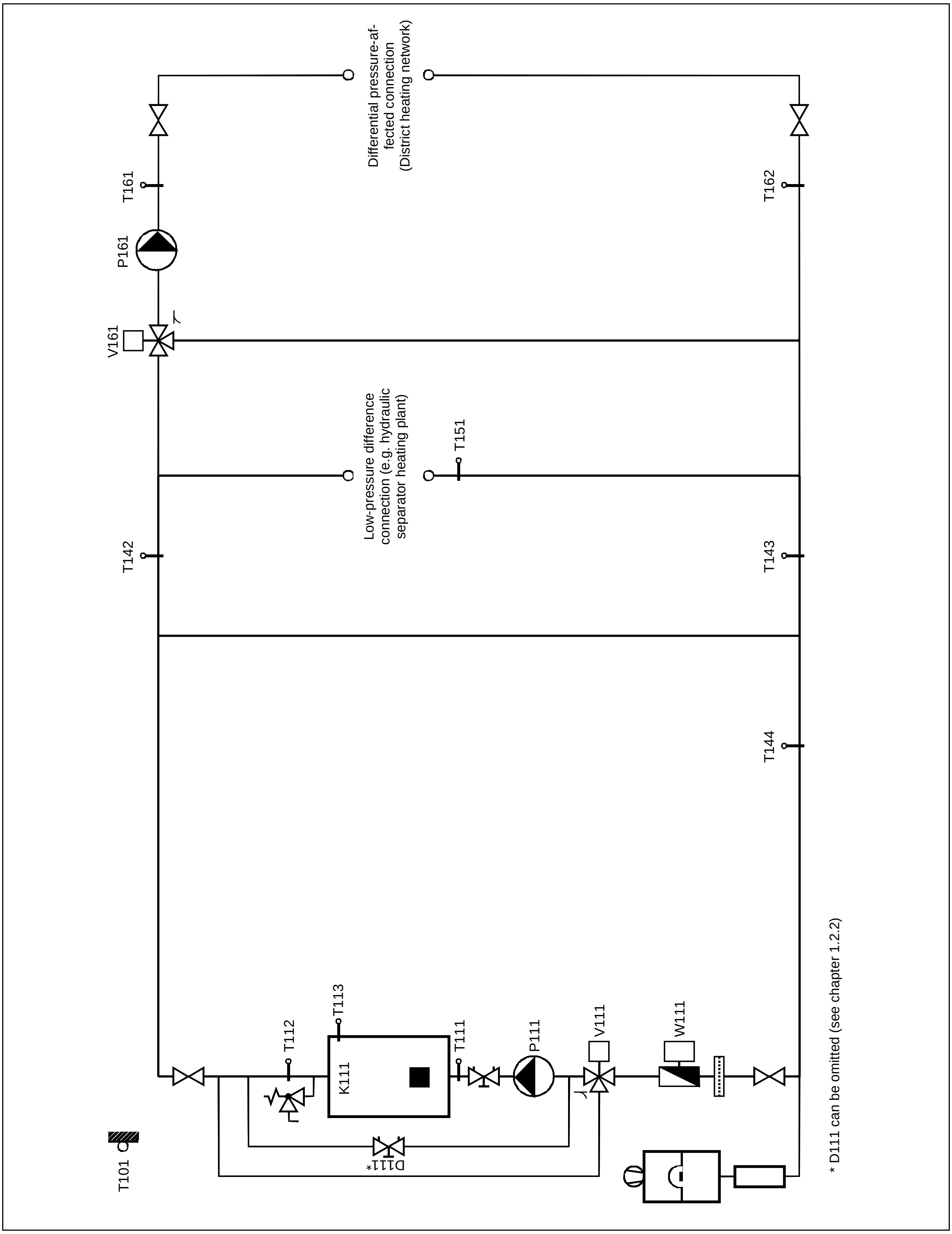

Figure 9: Principle scheme of standard hydraulic scheme for monovalent biomass heating system without storage tank. Safety devices and expansion system must be designed in accordance with the country-specific regulations.

Hydraulic and control system design	**Unit**	*Example*			**Label**
Heat capacity demand of the overall system					
Low-pressure difference connection	kW	*50*			
Differential pressure-affected connection (district heating network incl. losses)	kW	*250*			
Overall system	kW	*300*			
Guaranteed temperature limits					
Main supply temperature	°C	*85*			T142
Maximum permissible main return temperature	°C	*55*			T143
Minimum permissible boiler inlet temperature (boiler return temperature protection)	°C	*60*			T111
Maximum boiler water temperature (limit controller)	°C	*90*			T113
Maximum permissible boiler water temperature (safety monitor)	°C	*110*			T113
Boiler circuit					
Max. boiler output	kW	*300*			K111
Min. boiler output	kW	*90*			K111
Boiler outlet temperature	°C	*85*			T112/T113
Boiler pump flow rate	m3/h	*17,2*			P111
Boiler pump delivery head	m	*3*			P111
Resulting boiler inlet temperature	°C	*70*			T111
Resulting flow rate control valve boiler circuit	m3/h	*8,6*			V111
Resulting flow rate bypass	m3/h	*8,6*			D111
Pressure drop control valve	kPa	*10*			V111
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	–	*0,56*			V111
Design of pre-control and network pump in chapter 9!					

Table 10: Hydraulic and control system design. The design data of the system to be executed are to be entered according to the example (the exemplary values are to be deleted).

1.3 Functional description

1.3.1 Control scheme

The system can be controlled and regulated in two ways:

- **Standard hydraulic scheme with control of the boiler outlet temperature via the master I&C system (Figure 11):** The advantage of this solution is its compatibility with the other standard hydraulic schemes; a later extension is possible with the same control concept.
- **Permissible minimum solution according to section 1.1.4 (Figure 12):** Instead of the boiler outlet temperature, only the boiler water temperature (same temperature, but different measuring locations) is controlled via the PLC of the biomass boiler. This solution is cheaper, but in the case of a later extension, the control concept must be changed and the data recording for operation optimisation must be solved separately.

1.3.2 Operating modes

The following operating modes shall be provided:

- **Off:** The entire heat production system is out of operation, with the exception of the continuous operations (automatic expansion unit, etc.)
- **Manual:** Setpoint firing rate "manual" can be set as a fixed value 30...100% on the <u>master</u> I&C system; this operating mode is not mandatory.
- **Local:** The internal output control of the <u>subordinate</u> I&C system of the biomass boiler is activated (the master I&C system may be out of operation or defective).
- **Automatic:** The setpoint for the firing rate is specified by the master I&C system as a function of the boiler outlet temperature (= main control variable).
- **Other operating modes:** Especially for low-load operation (transition period, summer), other operating modes may be necessary (e.g. conventional "summer/winter" changeover).

Permissible minimum solution according to section 1.1.4 (Figure 12): The operating modes "manual" and "local" are omitted, and the main control variable in the operating mode "automatic" is not the boiler outlet temperature but the boiler water temperature.

1.3.3 Control

The control of the specification, limitation, weather compensation and time programme control of the setpoints as well as for the unblocking and blocking of boilers, pumps, etc. must be implemented by the master I&C system.

With **weather compensation,** the outdoor air temperature can be recorded via a weather sensor on the north side of the building, and the outdoor air temperature can then be used on the one hand as an instantaneous value and on the other hand as a 24-h average value to guide the setpoints and unblocking criteria. Calculation of the 24-h mean value, for example, continuously over a window of the last 24 hours and recalculation every 15 minutes.

With a **time programme control,** time programme levels can be programmed for different functions.

Permissible minimum solution according to section 1.1.4 (Figure 12): The control is omitted.

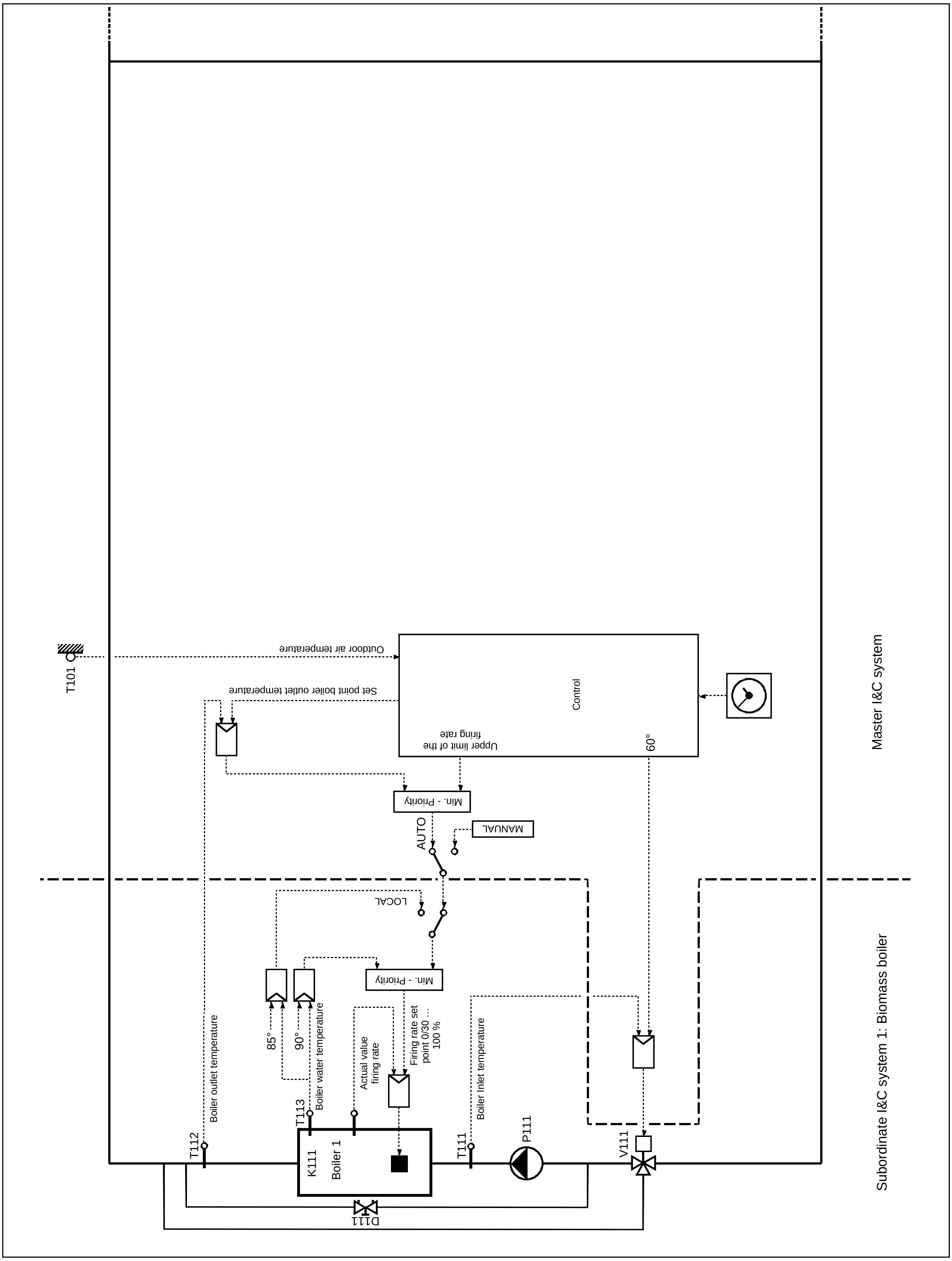

Figure 11: Control scheme standard hydraulic scheme monovalent biomass heating system without storage tank. The minimum priority switches route the lowest input signal to the output. Numerical values are to be understood as examples. Safety functions are not shown; these are to be implemented via the subordinate I&C system of the biomass boiler.

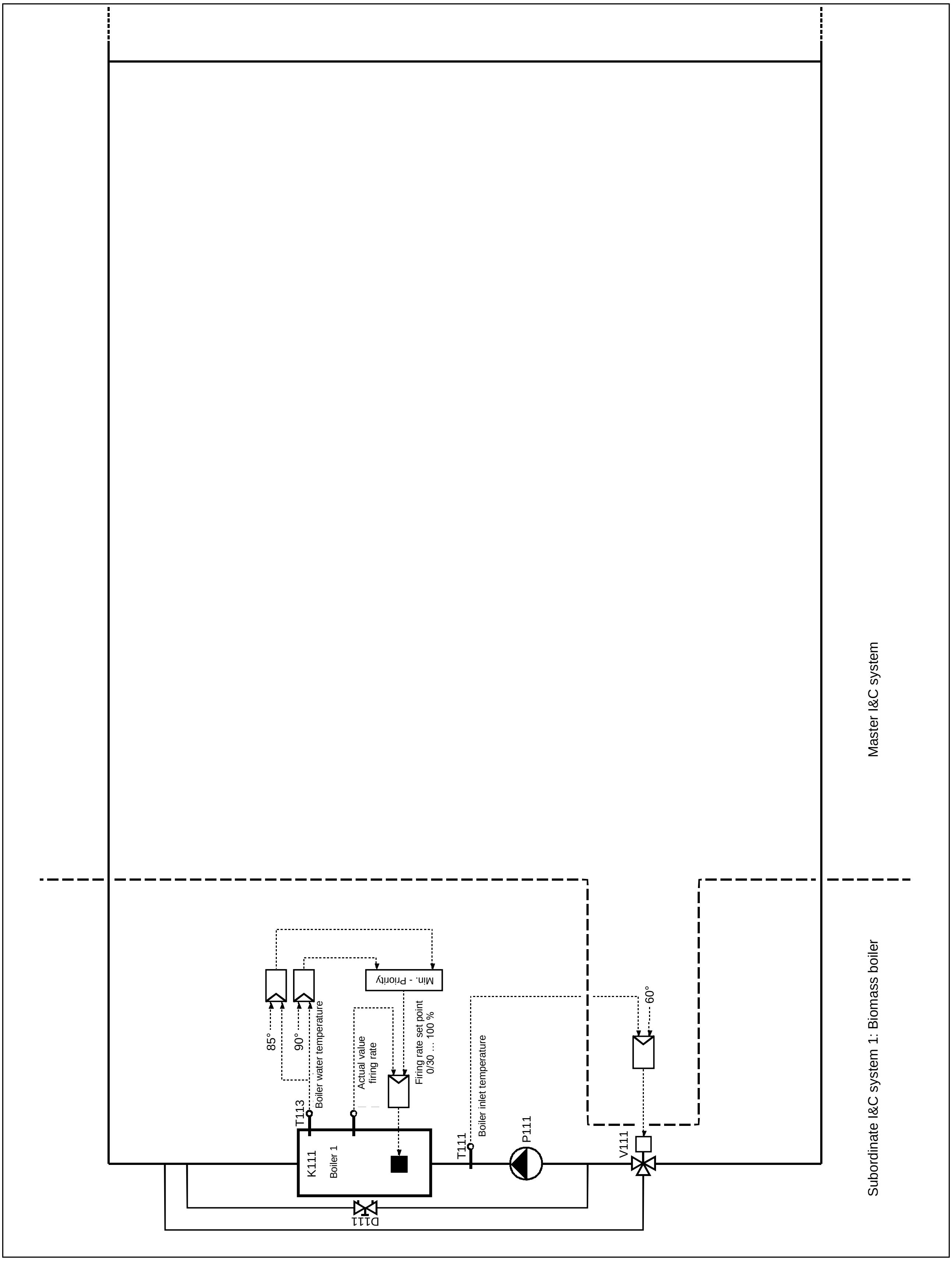

Figure 12: Control scheme of the permissible minimum solution for a monovalent biomass heating system without storage tank. The minimum priority switches route the lowest input signal to the output. Numerical values are to be understood as examples. Safety functions are not drawn in; these are to be realised via the subordinate I&C system of the biomass boiler.

1.3.4 Boiler circuit control

The boiler circuit is to be controlled by the master I&C system.

In the "automatic" operating mode, if the boiler inlet temperature falls below the limit value, control must take place at this limit value (= **boiler return temperature protection**).

In the "manual" operating mode, a boiler return temperature protection should also take place.

In the "local" operating mode, the boiler return temperature protection should continue to be in operation if the master I&C system is still functioning (which may no longer be the case in emergency operation).

Permissible minimum solution according to section 1.1.4 (Figure 12): The boiler return temperature protection is raised via individual controllers or via the PLC of the biomass boiler.

1.3.5 Boiler outlet temperature control

The control of the boiler outlet temperature is to be realised by the master I&C system.

The boiler exit temperature is to be controlled by adjusting the setpoint of the firing rate (= correcting variable) to a fixed value.

Permissible minimum solution according to section 1.1.4 (Figure 12): Instead of the boiler outlet temperature, only the boiler water temperature (same temperature, but different measuring locations) is controlled via the PLC of the biomass boiler.

1.3.6 Firing rate control

The firing rate is controlled via the subordinate I&C system of the biomass boiler.

The biomass-fired furnace shall be equipped with automatic ignition. If this is not possible or not reasonable according to the state of the art, it can be operated with fired bed support mode. In principle, the biomass-fired furnace should always be operated at the lowest possible output so that it has to be switched on and off as little as possible.

Permissible minimum solution according to section 1.1.4 (Figure 12): The following 4 paragraphs are not relevant!

The controller for the boiler outlet temperature T113 of the master I&C system specifies the setpoint value for the firing rate to the biomass firing system. With the help of the controller, the setpoint for the firing rate can then be additionally guided and limited.

The internal controller for the boiler water temperature T113 of the subordinate I&C system has the following functions:

- “Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the boiler outlet temperature T112, but limitation of the boiler water temperature T113 (e.g. to 90°C).
- “Local" operating mode: Control of the boiler water temperature T113 to a fixed value set on the subordinate I&C system (e.g. 85°C), limitation of the boiler water temperature T113 to a higher fixed value (e.g. to 90°C).
- Operating mode "automatic": Limiting the boiler water temperature T113 (e.g. to 90°C)

In the output control range of the biomass-fired furnace of 30...100%, the control should be continuous. Below this, the control must be in two-point mode. Switching between OFF (or fire bed support) and continuous control is done via the respective active I&C system. If the biomass boiler manufacturer so wishes, the switch-over can also always be made via the biomass boiler.

A recommendation for standard interfaces between the master I&C system and the biomass boiler, as well as a list of control unit and biomass boiler manufacturers offering these interfaces, can be downloaded from the Internet [9].

Important: The safety of the biomass boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be additionally ensured by the subordinate I&C system of the biomass boiler.

1.3.7 Chosen control concept

The concept applicable to the project to be described, how to control the boiler circuit, the boiler outlet temperature and the firing rate, shall be defined in Table 13

Operating mode	Boiler circuit control	Boiler outlet temperature control (= main control variable)	Firing rate regulation
Off	Inoperative		
Manual ☐ Not provided ☐ Minimum solution: "-manual" is omitted	☐ T111 boiler return temperature protection through master I&C system ☐ Limitation of boiler water temperature T113 by subordinate I&C system	☐ Boiler outlet temperature control T112 out of operation	☐ Setpoint adjustable as a fixed value on the master I&C system
Local ☐ Minimum solution: "local" is omitted	☐ Control of boiler water temperature T113 by subordinate I&C system	☐ Boiler outlet temperature control T112 out of operation	☐ Internal power controller of the subordinate I&C system activated
Automatic Summer operation? ☐ Yes ☐ No	☐ Minimum solution: T111 boiler return temperature protection by individual controller ☐ Minimum solution: boiler return temperature protection T111 by PLC of the biomass boiler ☐ T111 boiler return temperature protection through master I&C system ☐ Limitation of boiler water temperature T113 by subordinate I&C system	☐ Minimum solution: Control boiler water temperature T113 by internal controller of the biomass boiler ☐ Control of the boiler outlet temperature T 112 by a master I&C system; the correcting variable is the setpoint value of the firing rate.	☐ Minimum solution: Control of firing rate by internal controller of the biomass boiler ☐ Control of firing rate by subordinate I&C system; setpoint from master I&C system
Summary	Which operating modes are provided? ☐ Off ☐ Manual ☐ Local ☐ Automatic winter operation ☐ Automatic summer operation ☐ Other:		

Table 13: Questions and answers on the chosen control concept

1.4 Data recording for operational optimisation

All precautions are to be taken so that a proper operational optimisation can be carried out and the subsequent regular operation can be efficiently monitored. The measured variables to be recorded are to be marked with a cross in Table 14measured variables marked "Standard" must be able to be recorded in any case; the connection of the remaining measured variables is recommended. The measuring accuracy must meet the increased requirements of a measuring system.

The questions and answers on automatic data recording for operation optimisation in Table 15must be answered.

☑	**Standard**	**Measuring points**	**Label**
☐	Standard	Outdoor air temperature	T101
☐	Standard	Biomass boiler inlet temperature	T111
☐	Standard	Biomass boiler outlet temperature	T112
☐		Boiler water temperature (other measuring point)	T113
☐	Standard *	Main supply temperature after bypass	T142
☐	Standard	Main return temperature before bypass	T143
☐	Standard *	Main return temperature after bypass	T144
☐	Standard *	Return temperature of the low-pressure difference connection	T151
☐	Standard	Supply temperature of the pressure-difference connection	T161
☐	Standard *	Return temperature of the differential pressure-affected connection	T162
☐	Standard	Heat quantity/output heat meter biomass boiler **	W111
☐		Water quantity/flow rate heat meter biomass boiler **	W111
☐	Standard	Setpoint of the firing rate biomass boiler ***	
☐		Boiler-internal setpoint of the firing rate (feedback biomass boiler)	
☐	Standard	Exhaust gas temperature biomass boiler	
☐		Combustion chamber temperature biomass boiler	
☐	Standard *	Residual oxygen biomass boiler	
		Measuring points particle separator; type:	
☐			
☐			

* In order to reduce the effort for data recording, a reduction by these measuring points is accepted as permissible deviation for operation optimisation.
** The heat meter must be equipped with an interface for recording the heat quantity [kWh] or water quantity [m³]. The graphical representation, on the other hand, must be in terms of power [kW] or volume flow [m³/h].
*** Not applicable for the minimum solution.

Table 14: Measuring point list for automatic data recording. If the installation is to be considered a standard hydraulic scheme, it must be possible to record all measured variables marked "Standard".

Area	Questions and answers
Hardware	How is the automatic data recording for operation optimisation carried out? ☐ With a separate data logger ☐ With the PLC of the biomass boiler ☐ With the master I&C system
	How is the periodic reading of the data done? ☐ Reading out the data on site ☐ Readout via landline phone (POTS) connection ☐ Readout via ISDN telephone connection ☐ Readout via the Internet
Data recording	What is the measurement interval? ☐ 10 seconds (recommendation) ..... seconds
	What is the recording interval? ☐ 5 minutes (recommendation) ..... minutes
	How are the analogue values recorded? ☐ As an average value over the last recording interval (recommendation) ☐ As instantaneous value
	How is the recording done for meters? ☐ As a sum value over the last recording interval (recommendation) ☐ As current counter reading (Attention: is often set to zero by mistake)
	How is the recording of running times done? ☐ As runtime during the last recording interval (recommendation) ☐ As the current number of operating hours (Attention: is often accidentally set to zero)
	How large is the measured value memory? ☐ ≥ 30 days recording capacity (recommendation) ..... days recording capacity
Data evaluation	What is the output format for evaluation in EXCEL? ☐ CSV file with columns = time and measuring points, rows = values (recommendation) ☐ Other:
	How is the graphical representation done? ☐ Related data as a weekly overview (recommendation) ☐ Related data as a daily overview (recommendation) ☐ Representation of heat, oil, gas, operating hours meters as output or volume flow (demand) ☐ Other:
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of the autom. data recording by the main planner ☐ Specification of the automatic data recording by the main planner with the involvement of the I&C specialist
	How are the responsibilities regulated at the execution and approval stage? ☐ Planning of the autom. data recording by the main planner ☐ Planning of autom. data recording by biomass boiler suppliers ☐ Planning of the autom. data recording by the supplier of the master I&C system
	How are responsibilities regulated during operational optimisation? ☐ Readout and data evaluation by main planner ☐ Readout by biomass boiler supplier, data evaluation by main planner ☐ Readout by supplier of master I&C system, data evaluation by main planner ☐ Readout by operator, data evaluation by main planner ☐ Readout and data evaluation by operator

Table 15: Questions and answers on automatic data recording for operation optimisation

1.5 Annex to the approval protocol

The execution phase is concluded by the approval test. At this time, an addendum to the approval protocol shall be drawn up in accordance with Table 17.

The questions in Table 16 must be answered at the beginning of the tendering phase. The annex to the approval protocol according to Table 17 does not have to be filled in until the end of the execution phase. However, it is recommended to use these tables already during the tendering and execution phase for the preliminary determination of the planning values; so that the functionality of the system is clearly recognisable.

Who prepares the annex to the approval protocol? ☐ Main planner ☐ Biomass boiler supplier ☐ Supplier of the I&C system

Table 16: Questions and answers on the annex to the approval protocol

Description		**Unit**	*Example*			
Master I&C system Connection of master/subordinate I&C system via standard interface [9]? ☐ Yes ☐ No						
■ Boiler return temperature protection						
Boiler inlet temperature limit		°C	*60*			
■ **Boiler outlet temperature control** ☐ <u>Minimum solution</u>: not applicable Who specifies OFF (or fired bed support) and steady regulation? ☐ The active control system ☐ Always the biomass boiler						
Boiler outlet temperature setpoint		°C	*85*			
Continuous regulation	P-Band	%	*200*			
	Integration time	Min.	*20*			
Two-point controller	Continuous control at setpoint firing control	%	*≥35*			
	OFF (or fire bed support) at setpoint firing rate.	%	*≤25*			
Biomass boiler						
■ **Heat output settings**						
Set minimum heat output with the reference fuel		kW	*90*			
Set maximum heat output with the reference fuel		kW	*300*			
■ **Subordinate I&C system 1** ☐ <u>Minimum solution</u>: Boiler water temperature is the main control variable						
Boiler water temperature setpoint (for minimum solution)		°C	–			
Boiler water temperature limitation		°C	*90*			
Safety shutdown at boiler water temperature		°C	*110*			

Table 17: Annex to the approval protocol - setting values; exemplary values are to be deleted

2. Monovalent biomass heating system with storage tank

2.1 Short description and responsibilities

2.1.1 User level

The simplest possible operation and a clear display of the main functions are required so that non-professional personnel can also operate the system:

■ The following requirements must be met for **service and emergency operation:**
- It must be possible to disable the automatic control system partially or completely for service work and in case of emergency operation (e.g. via switch "off/on/automatic").
- Subordinate I&C systems must be able to be operated independently of the master I&C system (e.g. in the event of failure of the master I&C system).
- Manual operation of the control valves must be guaranteed (e.g. manual adjustment at the control valve, but this must not be disturbed by an incorrect control signal).
- All safety functions must be maintained

■ The **operation mode selection** shall be made in one of the following ways:
- Via switches in a **conventional control panel** (usually in the control cabinet).
- Via a **PLC**; however, this is only an option if the hardware and software requirements for convenient operation are right.
- Via the master computer of a **control system**

■ Further operation, such as **adjusting setpoints, changing time programmes, etc.,** can be carried out directly on the master and subordinate I&C systems (if necessary, also via the Internet).

2.1.2 Master I&C system

The master I&C system takes care of all master control and regulation functions and links the subordinate I&C systems with each other. In addition, automatic data recording is also assigned to the master I&C system, which is mandatory as a standard hydraulic scheme (at least temporarily for the duration of the operation optimisation).

2.1.3 Subordinate I&C system 1: biomass boiler

The subordinate I&C system of the biomass boiler has to fulfil the following **functions:**
- Fire bed support operation or automatic ignition
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

If a **particle separator** is necessary, it must be controlled by the subordinate I&C system of the biomass boiler.

The **safety** of the biomass boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be ensured by the subordinate I&C system of the biomass boiler.

If the PLC of the biomass boiler can also fulfil the demands on the master I&C system (in particular also the automatic data recording), the **simultaneous use as a master and subordinate I&C system** can be tested.

2.1.4 Selected structure of the I&C system levels

A person with main responsibility must be designated for the I&C planning (in particular also for the interface definition).

The structure of the I&C system levels with responsibilities chosen for the project to be described can be answered with Table 18.

I&C system level	Questions and answers
User level Section 2.1.1	Are the requirements for service and emergency operation met? ☐ Yes (mandatory for standard hydraulic scheme) ☐ No
	How does the operation mode selection take place? ☐ Switch in a conventional control panel ☐ Input via a PLC, sufficiently convenient operation is guaranteed ☐ Input via the master computer of the control system
	From where can the system be controlled and operated? ☐ Only in the central heating ☐ In the central heating plant and via modem ☐ In the central heating plant and via the internet
Master I&C system Section 2.1.2	How is the master I&C system implemented? ☐ Individual controller as master I&C system ☐ Use of the PLC of the biomass boiler as a master I&C system ☐ Own master I&C system
	Connection of master/subordinate I&C system via standard interface [9]? ☐ Yes ☐ No
	How is the automatic data recording done? ☐ Data logger during operation optimisation, an interface is provided ☐ Internal data recording in the master I&C system
Subordinate I&C system 1: Biomass boiler Section 2.1.3	What is the position/tasks of the PLC of the biomass boiler? ☐ It is used simultaneously as a master and subordinate I&C system ☐ It is subordinated to the master I&C system
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of all I&C levels by the main planner ☐ Specification of all I&C levels by the main planner with the involvement of I&C specialists
	How are the responsibilities (especially interface definitions) regulated at the execution and approval stage? ☐ Overall planning of all I&C system levels by the main planner ☐ Overall planning of all I&C system levels by biomass boiler supplier ☐ Overall planning of all I&C system levels by the supplier of the master I&C system ☐ Planning of each I&C system level by the respective supplier (not permitted for standard hydraulic scheme, as a main person responsible for I&C planning is explicitly required).

Table 18: Questions and answers on the chosen structure of the I&C system levels and responsibilities

2.2 Principle scheme and design

2.2.1 Hydraulic circuit

The hydraulic circuit must comply with Figure 19 The following requirements must be met:

- The interconnection of biomass boiler, storage tank, low-pressure difference connection and pre-control must actually be low pressure differential (short pipes, large pipe diameters).
- The storage facility must be consistently designed as a stratified storage facility.
- Storage connections with cross-section enlargement (speed reduction), baffle plate (refraction of the water jet) and, if necessary, siphoned (prevention of one-pipe circulation).
- Storage connections only top and bottom (no connections in between)
- No pipes may be routed inside the storage tank (danger of "thermal agitation").
- Whenever possible, the storage tank should not be divided among several containers. If this requirement cannot be met, the following must be observed:
  - No connections between the storages
  - When controlling the storage tank charging state, each storage tank is to be considered as a control unit (problem: due to the individual stratification in each storage tank, the warmer storage tank can be colder at the bottom than the colder storage tank at the top).

The installation is also considered a standard hydraulic scheme if

- one pump is realised by two or more pumps connected in parallel or in series,
- the pre-control of the district heating network is realised by two control valves connected in parallel or with a separate summer group,
- exhaust gas heat exchanger can be integrated.

2.2.2 Hydraulic and control design

The hydraulic and control design must be carried out according to the generally accepted engineering standards. The requirements according to the Q-Guideline [1] and the Planning Handbook [4] must be fulfilled, in particular:

- Storage volume ≥ 1 h storage capacity related to nominal biomass boiler output
- Load control/boiler return temperature protection and pre-control: Valve authority ≥ 0,5
- Design temperature difference above the biomass boiler ≤ 15 K; smaller temperature difference necessary if minimum permissible return temperature is high (e.g. with bark, landscape conservation wood); it can be increased to reduce pump power consumption if it is ensured that this does not cause any control-related problems (e.g. oscillation of boiler output due to temperature stratification).
- The boiler inlet temperature should be at least 5 K higher than the minimum permissible return temperature (boiler return temperature protection).

The hydraulic and control design shall be presented and documented in accordance with Table 20

A maximum permissible main return temperature T243 shall be specified.

If the temperature difference between the boiler outlet temperature and the boiler inlet temperature is more than 10 K less than the temperature difference between the boiler outlet temperature and the maximum permissible main return temperature T243, it is recommended to provide a **bypass in the boiler circuit D211.**

Important: To ensure that the boiler can always deliver the output, it must be ensured that the main return temperature T243 cannot rise above the design value in any operating case (prescribe return temperature limiter for all consumers!).

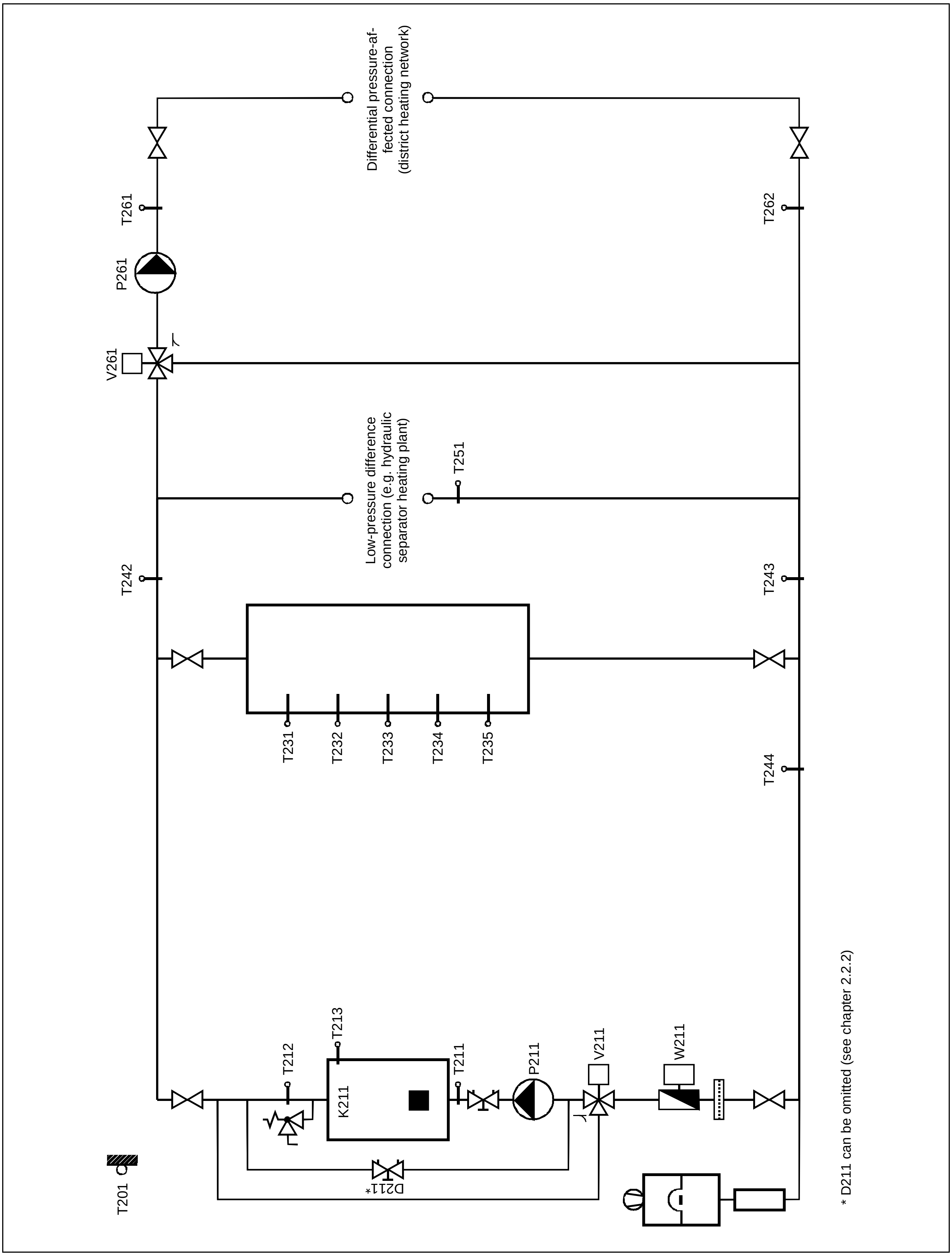

Figure 19: Principle scheme of a monovalent biomass heating system with storage tank. Safety devices and expansion system must be designed in accordance with the country-specific regulations.

Hydraulic and control system design	**Unit**	*Example*			**Label**
Storage					
Content	m3	*9*			
Heat capacity demand of the overall system					
Low-pressure difference connection	kW	*50*			
Differential pressure-affected connection (district heating network incl. losses)	kW	*250*			
Overall system	kW	*300*			
Guaranteed temperature limits					
Main supply temperature	°C	*85*			T242
Maximum permissible main return temperature	°C	*55*			T243
Minimum permissible boiler inlet temperature (boiler return temperature protection)	°C	*60*			T211
Maximum boiler water temperature (limit controller)	°C	*90*			T213
Maximum permissible boiler water temperature (safety monitor)	°C	*110*			T213
Boiler circuit					
Max. boiler output	kW	*300*			K211
Min. boiler output	kW	*90*			K211
Boiler outlet temperature	°C	*85*			T212/T213
Boiler pump flow rate	m3/h	*17,2*			P211
Boiler pump delivery head	m	*3*			P211
Resulting boiler inlet temperature	°C	*70*			T211
Resulting flow rate control valve boiler circuit	m3/h	*8,6*			V211
Resulting flow rate bypass	m3/h	*8,6*			D211
Pressure drop control valve	kPa	*10*			V211
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	–	*0,56*			V211
Design of pre-control and network pump in chapter 9!					

Table 20: Hydraulic and control system design. The design data of the system to be executed are to be entered according to the example (the exemplary values are to be deleted).

2.3 Functional description

2.3.1 Control scheme

The control and regulation of the system is to be carried out according to Figure 21.

2.3.2 Operating modes

The following operating modes shall be provided:

■ **Off:** The entire heat production system is out of operation, with the exception of the continuous operations (automatic expansion unit, etc.)

■ **Manual:** Setpoint firing rate "manual" can be set as a fixed value 30...100% on the master I&C system; this operating mode is not mandatory.

■ **Local:** The internal output control of the subordinate I&C system of the biomass boiler is activated (the master I&C system may be out of operation or defective).

■ **Automatic:** The setpoint value of the firing rate is specified by the master I&C system depending on the storage tank state of charge (= main control variable).

■ **Other operating modes:** Especially for low-load operation (transition period, summer), other operating modes may be necessary (e.g. conventional "summer/winter" changeover, low-load operation with "charge/discharge storage tank", etc.).

2.3.3 Control

The control for the specification, limitation, weather compensation and time programme control of the setpoints as well as for the unblocking and blocking of boilers, pumps, etc. must be implemented by the master I&C system.

With **weather compensation,** the outdoor air temperature can be recorded via a weather sensor on the north side of the building, and the outdoor air temperature can then be used on the one hand as an instantaneous value and on the other hand as a 24-h average value to guide the setpoints and unblocking criteria. Calculation of the 24-h mean value, for example, continuously over a window of the last 24 hours and recalculation every 15 minutes.

With a **time programme control,** time programme levels can be programmed for different functions.

2.3.4 Boiler circuit control

The boiler circuit is to be controlled by the master I&C system.

In the "automatic" operating mode, the **boiler outlet temperature** should be controlled continuously via the control valve in the boiler circuit to a fixed value. If the boiler inlet temperature falls below the limit value, the control should be set to this limit value (= **boiler return temperature protection**).

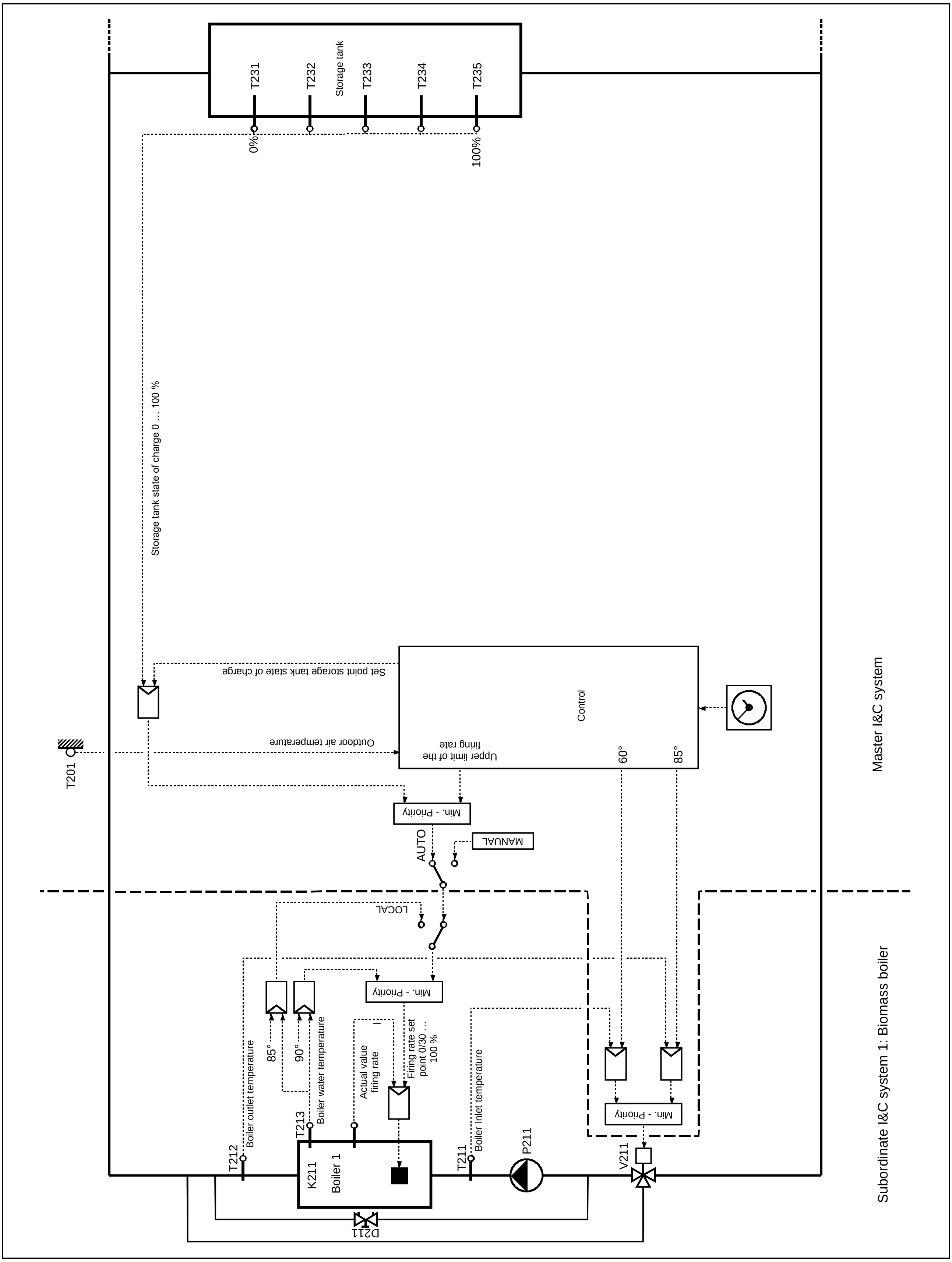

Figure 21: Control scheme standard hydraulic scheme monovalent biomass heating system with storage tank. The minimum priority switches route the lowest input signal to the output. Numerical values are to be understood as examples. Safety functions are not shown; these are to be implemented via the subordinate I&C system of the biomass boiler.

2.3.5 Storage tank charging state control

The control of the storage tank charging state is to be realised by the master I&C system.

The state of charge of the storage tank should be recorded via at least 5 temperature sensors that are evenly distributed over the height of the storage tank. This gives the state of charge of the storage tank from 0% to 100%.

Different variants are possible for recording the storage tank charging status. The following applies to variants 1 and 2:
w = Sensor signals "warm" when e.g. $T \geq 75°C$
k = Sensor signals "cold" when e.g. $T \leq 65°C$

Variant 1 (Table 22**):** With sensor values 20 - 40 - 60 - 80 - 100. For "all sensors cold" the value is 0. This variant results in a stepped actual value signal. Therefore, the (fast) P-component of the controller must not be too large, and disturbances must mainly be compensated via the (slow) I-component.

Variant 2: The stepped signal according to variant 1 can be smoothed by a first-order control delay element (PT1 element). However, the time constant of the PT1 element must not be too large, otherwise there is a risk that the inevitable time delay of the actual value signal will lead to disturbances. The "more continuous" actual value signal, however, allows a somewhat larger P component in the controller compared to variant 1.

Sensor (from top to bottom)					Value
1	2	3	4	5	
k	k	k	k	k	0
w	k	k	k	k	20
w	w	k	k	k	40
w	w	w	k	k	60
w	w	w	w	k	80
w	w	w	w	w	100

Table 22: Variant 1 (in stages)

Variant 3 (Table 23**):** A smoothing of the characteristic curve can also be achieved if the temperature of the active sensor is interpolated.

Sensor (from top to bottom)					Value
1	2	3	4	5	
< 60°C	< 60°C	< 60°C	< 60°C	< 60°C	0
60... 80°C	< 60°C	< 60°C	< 60°C	< 60°C	0...20
> 80°C	60... 80°C	< 60°C	< 60°C	< 60°C	20...40
> 80°C	> 80°C	60... 80°C	< 60°C	< 60°C	40...60
> 80°C	> 80°C	> 80°C	60... 80°C	< 60°C	60...80
> 80°C	> 80°C	> 80°C	> 80°C	60... 80°C	80...100

Table 23: Variant 3 (stepless)

With a good system, it can be assumed that for the sensor temperatures $T_1 ... T_5$ applies:

$T_1 \geq T_2 \geq T_3 \geq T_4 \geq T_5$ ($T_1 ... T_5$ from top to bottom)

The active sensor is highlighted in grey in Table 23 following rule applies:
- Sensor 1 active when all other sensor temperatures < 80°C
- Sensor 2 active when sensor temperature $T_1 > 80°C$
- Sensor 3 active when sensor temperature $T_2 > 80°C$
- Sensor 4 active when sensor temperature $T_3 > 80°C$
- Sensor 5 active when sensor temperature $T_4 > 80°C$

The quality of the interpolation (smoothing of the signal) depends on the thickness of the mixing zone in the storage tank, and this thickness is not a fixed quantity. For the same storage tank, it can be very different - depending on the flow rate, cooling, etc. Basically:
- Thickness of the mixing zone zero (ideal stratified storage) results in no smoothing at all, the signal is just as stepped as in variant 1
- Thickness of the mixing zone between zero and one probe distance results in an increasingly better smoothing of the signal
- Thickness of the mixing zone very slightly greater than one sensor spacing gives the best smoothing
- Thickness of the mixing zone significantly greater than a probe spacing results in poorer smoothing again

Variant 4: Average storage tank temperature as a measure of the storage tank state of charge. The disadvantage here is that the actual storage tank state of charge is reproduced differently depending on the thickness of the mixing zone, return temperature, cooling, etc: Thickness of the mixing zone zero (ideal stratified storage tank) results in no smoothing at all, the signal is just as stepped as in variant 1; when designed for 85/55°C, the control range is 30 K, when the return comes back in the morning with 25°C, it is suddenly 60 K.

More than 5 storage sensors: Only with this (in combination with variants 1 to 4) can the signal really be improved.

The storage tank is to be charged by a continuous control. This controller should have PI characteristics. As a result of the I-component, the storage tank can thus be charged to a setpoint of 60...80% without a permanent control deviation (as would be the case with the P controller) (in the case of a stepped signal, select a stepped value, e.g. 60%). If the heat consumers suddenly demand more power, the storage charging state drops and the firing rate is increased, and if less power is suddenly needed, the storage charging state rises and the firing rate is regulated back. In the first case, the upper half of the storage tank is available as a power reserve until the biomass boiler has reacted, and in the second case, the biomass boiler can deliver the temporary power surplus to the lower half of the storage tank.

In systems with automatic ignition, the storage tank should be completely charged and discharged with reduced output during low-load operation (required biomass boiler output below the minimum output). A suitable switching criterion must be defined for switching from "charge/discharge" to continuous control and back (e.g. manual switching or switching according to time programme and outdoor air temperature).

2.3.6 Firing rate control

The firing rate is controlled via the subordinate I&C system of the biomass boiler.

The biomass-fired furnace shall be equipped with automatic ignition. If this is not possible or not reasonable according to the state of the art, it can be operated with fire bed support mode. In principle, the biomass-fired furnace should always be operated at the lowest possible output so that it has to be switched on and off as little as possible.

The controller for the storage charging state of the master I&C system specifies the setpoint value for the firing rate to the biomass firing system. With the help of the control system, it should then be possible to additionally guide and limit the setpoint for the firing rate.

The internal controller for the boiler water temperature T213 of the subordinate I&C system has the following functions:

- “Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the storage tank charging state, but limitation of the boiler water temperature T213 (e.g. to 90°C).
- “Local" operating mode: Control of the boiler water temperature T213 to a fixed value set on the subordinate I&C system (e.g. 85°C), limitation of the boiler water temperature T213 to a higher fixed value (e.g. to 90°C).
- Operating mode "automatic": Limiting the boiler water temperature T213 (e.g. to 90°C)

In the output control range of the biomass-fired furnace of 30...100%, the control should be continuous. Below this, the control must be in two-point mode. Switching between OFF (or fire bed support) and continuous control is done via the respective active I&C system. If the biomass boiler manufacturer so wishes, the switchover can also always be made via the biomass boiler.

A recommendation for standard interfaces between the master I&C system and the biomass boiler, as well as a list of control unit and biomass boiler manufacturers offering these interfaces, can be downloaded from the Internet [9].

Important: The safety of the biomass boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be additionally ensured by the subordinate I&C system of the biomass boiler.

2.3.7 Chosen control concept

The concept applicable to the project to be described, how to control the boiler circuit, the storage tank charging state and the firing rate, shall be defined in Table 24

Operating mode	Boiler circuit control	Storage tank state of charge control (= main control variable)	Firing rate regulation
Off	Inoperative		
Manual ☐ Not provided	☐ T211 boiler return temperature protection through master I&C system ☐ Control of boiler outlet temperature T212 by master I&C system ☐ Limitation of boiler water temperature T213 by subordinate I&C system	☐ Storage tank charging status control out of operation	☐ Setpoint adjustable as a fixed value on the master I&C system
Local	☐ Control of boiler water temperature T213 by subordinate I&C system	☐ Storage tank charging status control out of operation	☐ Internal power controller of the subordinate I&C system activated
Automatic Summer operation? ☐ Yes ☐ No	☐ T211 boiler return temperature protection through master I&C system ☐ Control of boiler outlet temperature T212 by master I&C system ☐ Limitation of boiler water temperature T213 by subordinate I&C system	☐ Control of the storage tank charging status by the master I&C system; the correcting variable is the setpoint value of the firing rate. ☐ Charge/discharge storage tank (low load operation)	☐ Control of firing rate by subordinate I&C system; setpoint from master I&C system
Acquisition of storage tank state of charge	Number of storage tank sensors: ...... (at least 5) ☐ Stepped signal (variant 1) ☐ Smoothing with PT1 element (variant 2) ☐ Smoothing by interpolation via the temperature of the respective active sensor (variant 3) ☐ Average storage tank temperature as a measure of the storage tank charging status (variant 4)		
Summary	Which operating modes are provided? ☐ Off ☐ Manual ☐ Local ☐ Automatic winter operation by means of continuous storage control ☐ Automatic low-load operation (transition period, summer) by charging/discharging the storage tank ☐ Other:		

Table 24: Questions and answers on the chosen control concept

2.4 Data recording for operational optimisation

All precautions are to be taken so that a proper operational optimisation can be carried out and the subsequent regular operation can be efficiently monitored. The measured variables to be recorded are to be marked with a cross in Table 25measured variables marked "Standard" must be able to be recorded in any case; the connection of the remaining measured variables is recommended. The measuring accuracy must meet the increased requirements of a measuring system.

The questions and answers on automatic data recording for operation optimisation in Table 26must be answered.

☑	**Standard**	**Measuring points**	**Label**
☐	Standard	Outdoor air temperature	T201
☐	Standard	Biomass boiler inlet temperature	T211
☐	Standard	Biomass boiler outlet temperature	T212
☐		Boiler water temperature (other measuring point)	T213
☐	Standard *	Main supply temperature after storage tank	T242
☐	Standard	Main return temperature before storage tank	T243
☐	Standard *	Main return temperature after storage tank	T244
☐	Standard	Storage tank temperature (top)	T231
☐	Standard	Storage tank temperature	T232
☐	Standard	Storage tank temperature (middle)	T233
☐	Standard	Storage tank temperature	T234
☐	Standard	Storage tank temperature (bottom)	T235
☐	Standard *	Return temperature of the low-pressure difference connection	T251
☐	Standard	Supply temperature of the differential pressure-affected connection	T261
☐	Standard *	Return temperature of the differential pressure-affected connection	T262
☐	Standard	Heat quantity/output heat meter biomass boiler **	W211
☐		Water quantity/flow rate heat meter biomass boiler **	W211
☐	Standard	Setpoint value of the firing rate biomass boiler	
☐		Boiler-internal setpoint of the firing rate (feedback biomass boiler)	
☐	Standard	Actual value of the storage tank charging state	
☐	Standard	Exhaust gas temperature biomass boiler	
☐		Combustion chamber temperature biomass boiler	
☐	Standard *	Residual oxygen biomass boiler	
		Measuring points particle separator; type:	
☐			
☐			

* In order to reduce the effort for data recording, a reduction by these measuring points is accepted as permissible deviation for operation optimisation.

** The heat meter must be equipped with an interface for recording the heat quantity [kWh] or water quantity [m³]. The graphical representation, on the other hand, must be in terms of power [kW] or volume flow [m³/h].

Table 25: Measuring point list for automatic data recording. If the installation is to be considered a standard hydraulic scheme, it must be possible to record all measured variables marked "Standard".

Area	Questions and answers
Hardware	How is the automatic data recording for operation optimisation carried out? ☐ With a separate data logger ☐ With the PLC of the biomass boiler ☐ With the master I&C system
	How is the periodic reading of the data done? ☐ Reading out the data on site ☐ Readout via landline phone (POTS) connection ☐ Readout via ISDN telephone connection ☐ Readout via the Internet
Data recording	What is the measurement interval? ☐ 10 seconds (recommendation) ..... seconds
	What is the recording interval? ☐ 5 minutes (recommendation) ..... minutes
	How are the analogue values recorded? ☐ As an average value over the last recording interval (recommendation) ☐ As instantaneous value
	How is the recording done for meters? ☐ As a sum value over the last recording interval (recommendation) ☐ As current counter reading (Attention: is often set to zero by mistake)
	How is the recording of running times done? ☐ As runtime during the last recording interval (recommendation) ☐ As the current number of operating hours (Attention: is often accidentally set to zero)
	How large is the measured value memory? ☐ ≥ 30 days recording capacity (recommendation) ..... days recording capacity
Data evaluation	What is the output format for evaluation in Excel? ☐ CSV file with columns = time and measuring points, rows = values (recommendation) ☐ Other:
	How is the graphical representation done? ☐ Related data as a weekly overview (recommendation) ☐ Related data as a daily overview (recommendation) ☐ Representation of heat, oil, gas, operating hours meters as output or volume flow (demand) ☐ Other:
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of the autom. data recording by the main planner ☐ Specification of the automatic data recording by the main planner with the involvement of the I&C specialist
	How are the responsibilities regulated at the execution and approval stage? ☐ Planning of the autom. data recording by the main planner ☐ Planning of autom. data recording by biomass boiler suppliers ☐ Planning of the autom. data recording by the supplier of the master I&C system
	How are responsibilities regulated during operational optimisation? ☐ Readout and data evaluation by main planner ☐ Readout by biomass boiler supplier, data evaluation by main planner ☐ Readout by supplier of master I&C system, data evaluation by main planner ☐ Readout by operator, data evaluation by main planner ☐ Readout and data evaluation by operator

Table 26: Questions and answers on automatic data recording for operation optimisation

2.5 Annex to the approval protocol

The execution phase is concluded by the approval test. At this time, an addendum to the approval protocol shall be drawn up in accordance with Table 28.

The questions in Table 27 must be answered at the beginning of the tendering phase. The annex to the approval protocol according to Table 28 does not have to be filled in until the end of the execution phase. However, it is recommended to use these tables already during the tendering and execution phase for the preliminary determination of the planning values; so that the functionality of the system is clearly recognisable.

Who prepares the annex to the approval protocol? ☐ Main planner ☐ Biomass boiler supplier ☐ Supplier of the master I&C system

Table 27: Questions and answers on the annex to the approval protocol

Description		**Unit**	*Example*			
Master I&C system Connection of master/subordinate I&C system via standard interface [9]? ☐ Yes ☐ No						
■ **Load control**						
Boiler outlet temperature setpoint		°C	*85*			
■ **Boiler return temperature protection**						
Boiler inlet temperature limit		°C	*60*			
■ **Storage charge control** Who specifies OFF (or fire bed support) and steady regulation? ☐ The active control system ☐ Always the biomass boiler How is the "continuous control" switched to "charge/discharge storage tank"? ☐ Switchover by hand ☐ Other:						
Setpoint storage tank state of charge		%	*60*			
Setpoint storage tank sensor "warm"		°C	*≥75*			
Setpoint storage tank sensor "cold"		°C	*≤65*			
Continuous regulation	P-Band	%	*200*			
	Integration time	Min.	*20*			
Two-point controller	Continuous control at setpoint firing control	%	*≥35*			
	OFF (or fire bed support) at setpoint firing rate.	%	*≤25*			
Filling and emptying the storage	Biomass boiler ON at actual value of storage tank charging status	%	*0*			
	Biomass boiler OFF at actual value of storage tank charging status	%	*100*			
	Setpoint firing rate (fixed value)	%	*40*			
Biomass boiler						
■ **Heat output settings**						
Set minimum heat output with the reference fuel		kW	*90*			
Set maximum heat output with the reference fuel		kW	*300*			
■ **Subordinate I&C system 1**						
Boiler water temperature setpoint for "local" operating mode		°C	*85*			
Boiler water temperature limitation		°C	*90*			
Safety shutdown at boiler water temperature		°C	*110*			

Table 28: Annex to the approval protocol - setting values; exemplary values are to be deleted

3. Bivalent biomass heating system without storage tank

3.1 Short description and responsibilities

3.1.1 User level

The simplest possible operation and a clear display of the main functions are required so that non-professional personnel can also operate the system:

■ The following requirements must be met for **service and emergency operation:**
- It must be possible to disable the automatic control system partially or completely for service work and in case of emergency operation (e.g. via switch "off/on/automatic").
- Subordinate I&C systems must be able to be operated independently of the master I&C system (e.g. in the event of failure of the master I&C system).
- Manual operation of the control valves must be guaranteed (e.g. manual adjustment at the control valve, but this must not be disturbed by an incorrect control signal).
- All safety functions must be maintained

■ The **operation mode selection** shall be made in one of the following ways:
- Via switches in a **conventional control panel** (usually in the control cabinet).
- Via a **PLC**; however, this is only an option if the hardware and software requirements for convenient operation are right.
- Via the master computer of a **control system**

■ Further operation, such as **adjusting setpoints, changing time programmes, etc.,** can be carried out directly on the master and subordinate I&C systems (if necessary, also via the Internet).

3.1.2 Master I&C system

The master I&C system takes care of all master control and regulation functions and links the subordinate I&C systems with each other. In addition, automatic data recording is also assigned to the master I&C system, which is mandatory as a standard hydraulic scheme (at least temporarily for the duration of the operation optimisation).

3.1.3 Subordinate I&C system 1: biomass boiler

The subordinate I&C system of the biomass boiler has to fulfil the following **functions:**
- Fire bed support operation or automatic ignition
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

If a **particle separator** is necessary, it must be controlled by the subordinate I&C system of the biomass boiler.

The **safety** of the biomass boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be ensured by the subordinate I&C system of the biomass boiler.

If the PLC of the biomass boiler can also fulfil the demands on the master I&C system (in particular also the automatic data recording), the **simultaneous use as a master and subordinate I&C system** can be tested.

3.1.4 Subordinate I&C system 2: oil/gas boiler

The subordinate I&C system of the oil/gas boiler has to fulfil the following **functions:**

- pre-purge, ignition and flame monitoring
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system (continuous in modulating operation, in stages in multi-stage operation)
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

The **safety** of the oil/gas boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be ensured by the subordinate I&C system of the oil/gas boiler.

3.1.5 Selected structure of the I&C system levels

A person with main responsibility must be designated for the I&C planning (in particular also for the interface definition).

The structure of the I&C system levels with responsibilities chosen for the project to be described can be answered with Table 29.

I&C system level	Questions and answers
User level Section 3.1.1	Are the requirements for service and emergency operation met? ☐ Yes (mandatory for standard hydraulic scheme) ☐ No
	How does the operation mode selection take place? ☐ Switch in a conventional control panel ☐ Input via a PLC, sufficiently convenient operation is guaranteed ☐ Input via the master computer of the control system
	From where can the system be controlled and operated? ☐ Only in the central heating plant ☐ In the central heating plant and via modem ☐ In the central heating plant and via the internet
Master I&C system Section 3.1.2	How is the master I&C system implemented? ☐ Individual controller as master I&C system ☐ Use of the PLC of the biomass boiler as a master I&C system ☐ Own master I&C system
	Connection of master/subordinate I&C systems via standard interface [9]? ☐ Yes ☐ No
	How is the automatic data recording done? ☐ Data logger during operation optimisation, an interface is provided ☐ Internal data recording in the master I&C system
Subordinate I&C system 1: Biomass boiler Section 3.1.3	What is the position/tasks of the PLC of the biomass boiler? ☐ It is used simultaneously as a master and subordinate I&C system ☐ It is subordinated to the master I&C system
Subordinate I&C system 2: Oil/gas boiler Section 3.1.4	What is the position/tasks of the I&C system of the oil/gas boiler? ☐ It is subordinated to the master I&C system
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of all I&C levels by the main planner ☐ Specification of all I&C levels by the main planner with the involvement of I&C specialists
	How are the responsibilities (especially interface definitions) regulated at the execution and approval stage? ☐ Overall planning of all I&C levels by the main planner ☐ Overall planning of all I&C levels by biomass boiler supplier ☐ Overall planning of all I&C levels by the supplier of the master I&C system ☐ Planning of each I&C level by the respective supplier (not permitted for standard hydraulic scheme, as a main person responsible for I&C planning is explicitly required).

Table 29: Questions and answers on the chosen structure of the I&C levels and responsibilities

3.2 Principle scheme and design

3.2.1 Hydraulic circuit

The hydraulic circuit must comply with Figure 30 The following requirements must be met:

- The circuit must actually be made low in pressure difference by the bypass, i.e. the shortest possible bypass and pipe diameter bypass = pipe diameter main flow
- The interconnection of biomass boiler, oil/gas boiler, bypass, low-pressure difference connection and pre-control must actually be low pressure differential (short pipes, large pipe diameters).
- Make sure that the sensor for the main supply temperature is properly mixed (install a static mixer if necessary).

The installation is also considered a standard hydraulic scheme if

- one pump is realised by two or more pumps connected in parallel or in series,
- the pre-control of the district heating network is realised by two control valves connected in parallel or with a separate summer group,
- exhaust gas heat exchanger can be integrated.

3.2.2 Hydraulic and control design

The hydraulic and control design must be carried out according to the generally accepted engineering standards. The requirements according to the Q-Guideline [1] and the Planning Handbook [4] must be fulfilled, in particular:

- Boiler return temperature protection for both boilers and pre-control: Valve authority ≥ 0,5
- Design temperature difference above the biomass boiler ≤ 15 K; smaller temperature difference necessary if minimum permissible return temperature is high (e.g. with bark, landscape conservation wood); can be increased to reduce pump power consumption if it is ensured that this does not cause any control-related problems (e.g. oscillation of boiler output due to temperature stratification).
- The boiler inlet temperature should be at least 5 K higher than the minimum permissible return temperature (boiler return temperature protection).

If the oil/gas boiler does not require a boiler return temperature protection, the three-way valve can be replaced by a tightly closing motorised damper.

The hydraulic and control design shall be presented and documented in accordance with Table 31

A maximum permissible main return temperature T343 shall be specified.

If the temperature difference between the boiler outlet temperature and the boiler inlet temperature is more than 10 K less than the temperature difference between the boiler outlet temperature and the maximum permissible main return temperature T343, a **bypass** can be provided in **the boiler circuit D311/D321** (may not be desirable for keeping the boiler water temperatures low).

Important: To ensure that the boilers can always deliver the output, it must be ensured that the main return temperature T343 cannot rise above the design value in any operating case (prescribe return temperature limiter for all consumers!).

Hydraulically and in terms of control technology, this circuit is demanding. Ultimately, the main planner must decide whether the present WE3 circuit without storage tank is feasible or whether the next WE4 circuit with storage tank is necessary. The following requirements should be met for the WE3 circuit:

- No too large load peaks and no oversized boilers
- Relatively stable main control variable (main supply temperature), i.e. no disturbance variables occurring abruptly with high power and a stably set pre-control.
- A sufficiently large distance must be possible between the setpoint of the main supply temperature and the limitation of the boiler water temperature of the biomass boiler, so that a "floating" of the boilers without limitation of the biomass boiler output is possible (see section 3.3.9)
- Useful unblocking and blocking criteria for the sequence control of biomass boiler - oil/gas boiler, in order to be able to successfully prevent frequent switching on and off.

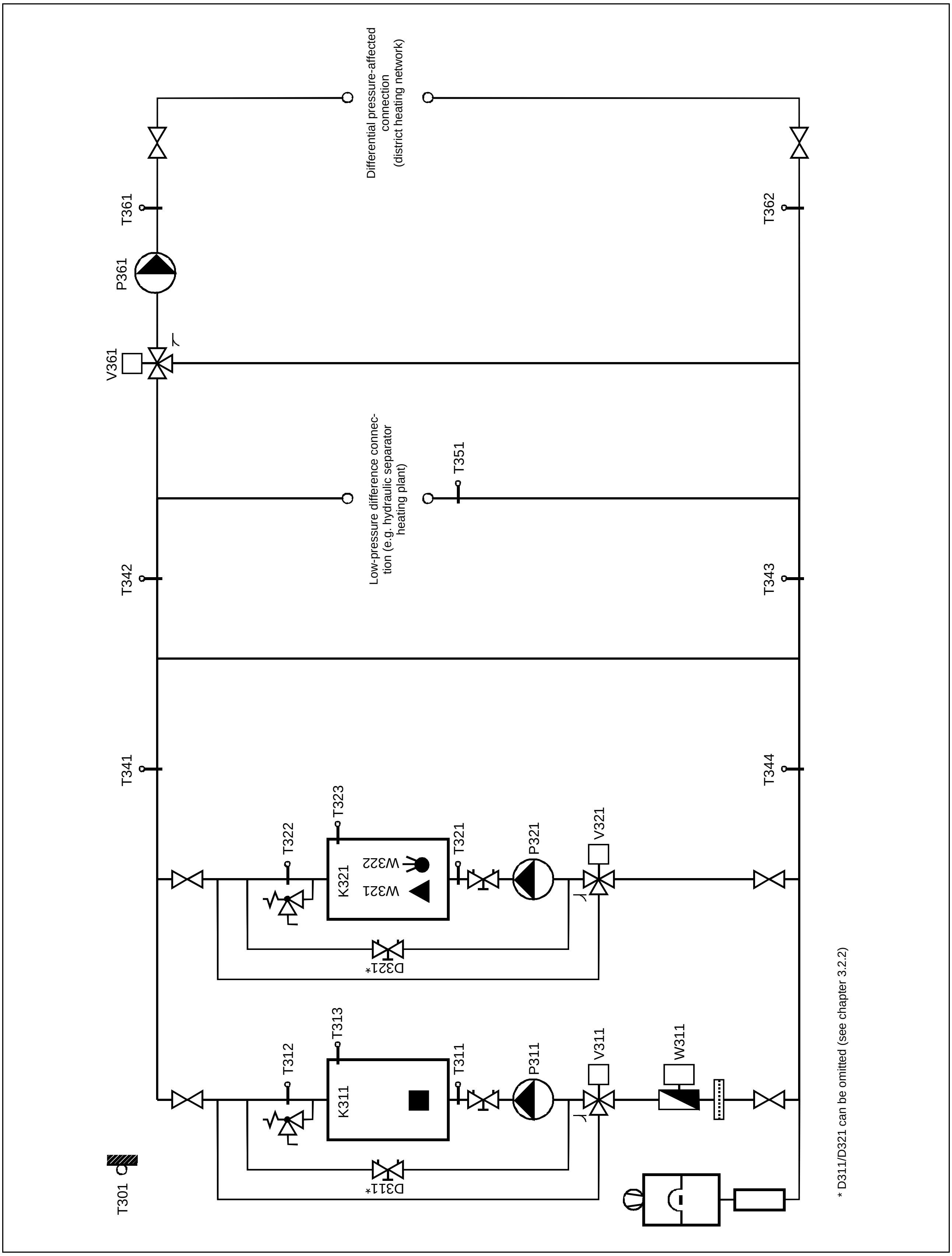

Figure 30: Principle scheme of a dual-fuel biomass heating system without storage tank. Safety devices and expansion system must be designed in accordance with the country-specific regulations.

Hydraulic and control system design	**Unit**	*Example*			**Label**
Heat capacity demand of the overall system					
Low-pressure difference connection	kW	*80*			
Differential pressure-affected connection (district heating network incl. losses)	kW	*620*			
Overall system	kW	*700*			
Guaranteed temperature limits					
Main supply temperature	°C	*85*			T342
Maximum permissible main return temperature	°C	*55*			T343
Minimum permissible biomass boiler inlet temperature (boiler return temperature protection)	°C	*60*			T311
Maximum boiler water temperature biomass boiler (limiting controller)	°C	*90*			T313
Max. permissible boiler water temperature biomass boiler (safety monitor)	°C	*110*			T313
Minimum permissible oil/gas boiler inlet temp. (boiler return temperature protection)	°C	*60*			T321
Maximum boiler water temperature oil/gas boiler (limiting controller)	°C	*90*			T323
Max. permissible boiler water temperature oil/gas boiler (safety monitor)	°C	*110*			T323
Boiler circuit biomass boiler					
Max. boiler output*)*	kW	*500*			K311
Min. boiler output	kW	*150*			K311
Boiler outlet temperature	°C	*85*			T312/T313
Boiler pump flow rate	m3/h	*28,7*			P311
Boiler pump delivery head	m	*3*			P311
Resulting boiler inlet temperature	°C	*70*			T311
Resulting flow rate control valve boiler circuit	m3/h	*28,7*			V311
Resulting flow rate bypass	m3/h	*0*			D311
Pressure drop control valve	kPa	*10*			V311
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	- –	*0,56*			V311
Boiler circuit oil/gas boiler					
Max. boiler output	kW	*700*			K321
Min. boiler output	kW	*280*			K321
Boiler outlet temperature	°C	*85*			T322/T323
Boiler pump flow rate	m3/h	*40,1*			P321
Boiler pump delivery head	m	*3*			P321
Resulting boiler inlet temperature	°C	*70*			T321
Resulting flow rate control valve boiler circuit	m3/h	*40,1*			V321
Resulting flow rate bypass	m3/h	*0*			D321
Pressure drop control valve	kPa	*10*			V321
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	- –	*0,56*			V321
Design of pre-control and network pump in chapter 9!					

Table 31: Hydraulic and control design. To keep the boiler water temperatures low, it makes sense to keep the temperature difference over the boilers low; therefore, the bypasses D311/D321 were omitted in the example. The design data of the system to be executed are to be entered according to the example (the exemplary values are to be deleted).

3.3 Functional description

3.3.1 Control scheme

The control and regulation of the system is to be carried out according to Figure 32.

3.3.2 Operating modes

The following operating modes shall be provided:

- **Off:** The entire heat production system is out of operation, with the exception of the continuous operations (automatic expansion unit, etc.)
- **Manual:** Setpoint firing rate for both the biomass boiler and the oil/gas boiler can be set "manually" as fixed values on the master I&C system; this operating mode is not mandatory.
- **Local:** The internal output controllers of the subordinate I&C systems of the biomass boiler or the oil/gas boiler are activated (the master I&C system may be out of operation or defective).
- **Automatic:** The setpoint for the firing rate is specified as a sequence for both the biomass boiler and the oil/gas boiler by the master I&C system as a function of the main supply temperature (= main control variable).
- **Other operating modes:** Especially for low-load operation (transition period, summer), other operating modes may be necessary (e.g. conventional "summer/winter" changeover, low-load operation with "oil/gas boiler alone", etc.).

3.3.3 Control

The control for the specification, limitation, weather compensation and time programme control of the setpoints as well as for the unblocking and blocking of boilers, pumps, etc. must be implemented by the master I&C system.

With **weather compensation,** the outdoor air temperature can be recorded via a weather sensor on the north side of the building, and the outdoor air temperature can then be used on the one hand as an instantaneous value and on the other hand as a 24-h average value to guide the setpoints and unblocking criteria. Calculation of the 24-h mean value, for example, continuously over a window of the last 24 hours and recalculation every 15 minutes.

With a **time programme control,** time programme levels can be programmed for different functions.

3.3.4 Boiler circuit control biomass boiler

The control of the boiler circuit for the biomass boiler is to be realised by the master I&C system.

In the "automatic" operating mode, if the boiler inlet temperature falls below the limit value, control must take place at this limit value (= **boiler return temperature protection**).

In the "manual" operating mode, a boiler return temperature protection should also take place.

In the "local" operating mode, the boiler return temperature protection should continue to be in operation if the master I&C system is still functioning (which may no longer be the case in emergency operation).

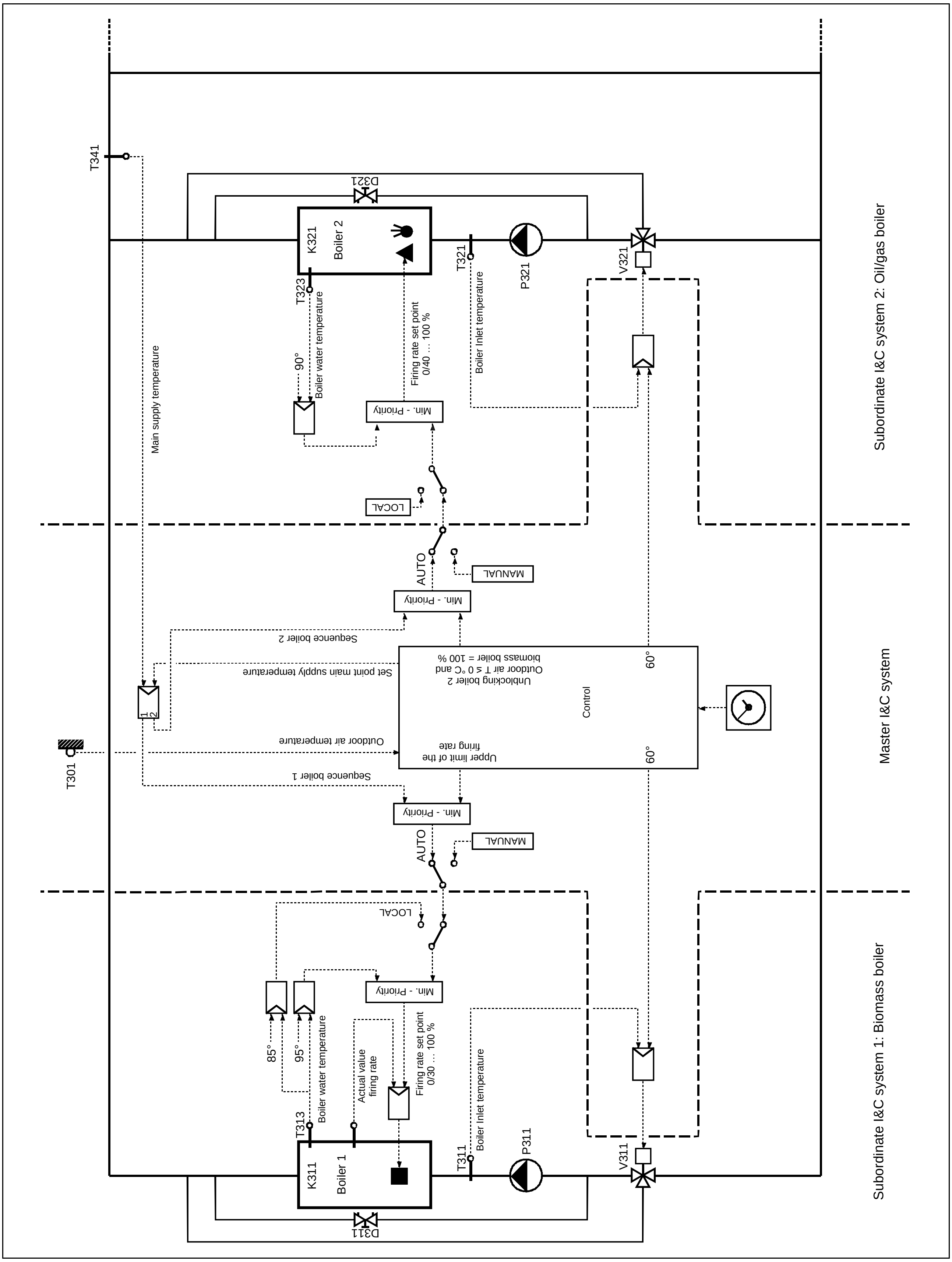

Figure 32: Control scheme standard hydraulic scheme bivalent biomass heating system without storage tank. The minimum priority switches route the lowest input signal to the output. Numerical values are to be understood as examples. Safety functions are not shown; these are to be realised via the subordinate I&C systems of the boilers.

3.3.5 Boiler circuit control oil/gas boiler

The control of the boiler circuit for the oil/gas boiler is to be realised by the master I&C system.

In the "automatic" operating mode, if the boiler inlet temperature falls below the limit value, control must take place at this limit value (= **boiler return temperature protection**).

In the "manual" operating mode, a boiler return temperature protection should also take place.

In the "local" operating mode, the boiler return temperature protection should continue to be in operation if the master I&C system is still functioning (which may no longer be the case in emergency operation).

If the oil/gas boiler does not require a return temperature protection, this function is omitted.

3.3.6 Main supply temperature control

The control of the main supply temperature is to be realised by the master I&C system.

The main supply temperature is to be controlled to a fixed value by adjusting the setpoint values of the firing rate (= correcting variables) for the biomass boiler and the oil/gas boiler in sequence.

Important: The firing rates of the boilers are controlled via the main supply temperature, i.e. the mixed temperature of the two boiler outlet temperatures. Careful hydraulic balancing is necessary and the controllers for limiting the boiler water temperatures must be set 5...15 K above the setpoint of the main supply temperature.

3.3.7 Firing rate control biomass boiler

The firing rate is controlled via the subordinate I&C system of the biomass boiler.

The biomass-fired furnace shall be equipped with automatic ignition. If this is not possible or not reasonable according to the state of the art, it can be operated with fired bed support mode. In principle, the biomass-fired furnace should always be operated at the lowest possible output so that it has to be switched on and off as little as possible.

The controller for the main supply temperature of the master I&C system specifies the setpoint for the firing rate to the biomass-fired furnace. With the help of the control system, the setpoint for the firing rate can then be additionally guided and limited.

The internal controller for the boiler water temperature T313 of the subordinate I&C system has the following functions:

- “Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the main supply temperature T341, but limitation of the boiler water temperature T313 (e.g. to 95°C).
- “Local" operating mode: Control of the boiler water temperature T313 to a fixed value set on the subordinate I&C system (e.g. 85°C), limitation of the boiler water temperature T313 to a higher fixed value (e.g. to 95°C).
- Operating mode "automatic": Limiting the boiler water temperature T313 (e.g. to 95°C)

In the output control range of the biomass-fired furnace of 30...100%, the control should be continuous. Below this, the control must be in two-point mode. Switching between OFF (or fire bed support) and continuous control is done via the respective active I&C system. If the biomass boiler manufacturer so wishes, the switchover can also always be made via the biomass boiler.

A recommendation for standard interfaces between the master I&C system and the biomass boiler, as well as a list of control unit and biomass boiler manufacturers offering these interfaces, can be downloaded from the Internet [9].

Important: The safety of the biomass boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be additionally ensured by the subordinate I&C system of the biomass boiler.

3.3.8 Firing rate control oil/gas boiler

The firing rate is controlled via the subordinate I&C system of the oil/gas boiler.

The control of the firing rate should be continuous (for modulating operation) or in stages (for multi-stage operation). In principle, the oil/gas boiler should always be operated at the lowest possible output, and it should only be unblocked when the biomass boiler has not been able to provide the output at full load for a long time.

The controller for the main supply temperature of the master I&C system gives the setpoint value of the firing rate to the oil/gas boiler in sequence to the biomass boiler.

The internal controller for the boiler water temperature T323 of the subordinate I&C system has the following functions:

- “Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the main supply temperature T341, but limitation of the boiler water temperature T323 (e.g. to 90°C).
- “Local" operating mode: Control of the boiler water temperature T323 to a fixed value set on the subordinate I&C system (e.g. 90°C).
- Operating mode "automatic": Limiting the boiler water temperature T323 (e.g. to 90°C)

Important: The safety of the oil/gas boiler, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be additionally ensured by the subordinate I&C system of the oil/gas boiler.

3.3.9 Sequence control biomass boiler - oil/gas boiler

The downstream connection of the biomass boiler - oil/gas boiler must be implemented by the master I&C system.

The sequence controller for the firing rate of the two boilers must be designed and supplemented with suitable unblocking and blocking criteria in such a way that it reliably prevents the oil/gas boiler from being switched on too frequently.

Examples of unblocking and blocking criteria for the oil/gas boiler are:

- Unblocking when certain minimum outdoor air temperature AND setpoint of the firing rate of the biomass boiler is set to 100% for a certain time.
- Blocking (switching back) when the setpoint value of the firing rate of the biomass boiler has returned to 90% for a certain time.

If the biomass boiler goes on fault, the oil/gas boiler must be unblocked automatically.

The boiler that is not in operation must be completely isolated hydraulically from the rest of the system (no faulty circulation due to overrun times, incorrectly set three-way valves, short circuits via safety lines, etc.).

Note: When switched on, boiler 2 has the full volume flow at minimum output and thus a smaller temperature difference between inlet and outlet than at full load. This deviation causes a "floating" of the boiler water temperatures: The temperature of boiler 1 (full load) is higher and that of boiler 2 (partial load) lower than the main supply temperature. This must be taken into account in the design so that the limitation of the boiler water temperature of boiler 1 can be set sufficiently high.

It is permissible to control the oil/gas boiler using the three-way valve if this improves the control quality:

- Oil/gas boiler correcting variable = setpoint of the firing rate (as before), but additional outlet temperature control for the oil/gas boiler.
- Correcting variable oil/gas boiler = Stroke of the three-way valve in the boiler circuit (instead of the setpoint of the firing rate); boiler water temperature controlled by the subordinate I&C system of the oil/gas boiler.
- It shall be indicated where the measurement location of the main control variable is (T341 or T342? Maximum precedence at T344?).

3.3.10 Chosen control concept

The concept applicable to the project to be described, how to control the boiler circuits, the main supply temperature and the firing rates, shall be defined in Table 33

Operating mode	**Boiler circuit control:** **- Biomass boiler** **- Oil/gas boiler**	**Main supply temperature control** **(= main control variable)**	**Regulation of firing rates** **- Biomass boiler** **- Oil/gas boiler**
Off	Inoperative		
Manual ☐ Not provided	☐ T311/T321 boiler return temperature protection systems by master I&C system ☐ Limitation of boiler water temperatures T313/T323 by subordinate I&C systems	☐ Control main supply temperature T341 out of operation	☐ Setpoints of the two firing rates can be set as fixed values on the master I&C system
Local	☐ Control of boiler water temperatures T313/T323 by subordinate I&C systems	☐ Control main supply temperature T341 out of operation	☐ Internal power controllers of the subordinate I&C systems activated
Automatic Summer operation? ☐ Yes, with biomass boiler ☐ Yes, with oil/gas boiler ☐ No	☐ T311/T321 boiler return temperature protection systems by master I&C system ☐ Limiting boiler water temperatures T313/T323 by subordinate I&C systems	☐ Control of the main supply temperature T341 by the master I&C system in the sequence biomass boiler - oil/gas boiler; the correcting variables are the setpoints of the two firing rates. Other permissible solutions: ☐ Additional outlet temperature control for oil/gas boiler ☐ Correcting variable oil/gas boiler = Stroke three-way valve in boiler circuit Measuring point main supply temperature ☐ for T341 ☐ at T342 ☐ Maximum priority at T344	☐ Control of the two firing rates by the subordinate I&C systems; setpoints from the master I&C system in sequence biomass boiler - oil/gas boiler
Summary	Which operating modes are provided? ☐ Off ☐ Manual (for each boiler) ☐ Local (for each boiler) ☐ Automatic winter operation with biomass boiler and oil/gas boiler ☐ Automatic low-load operation (transition period, summer) with biomass boiler) ☐ Automatic low-load operation (transition period, summer) with oil-gas boiler ☐ Oil/gas boiler alone (e.g. revision biomass boiler, emergency operation) ☐ Other:		

Table 33: Questions and answers on the chosen control concept

3.4 Data recording for operational optimisation

All precautions must be taken so that a proper operational optimisation can be carried out and the subsequent regular operation can be efficiently monitored. The measured variables to be recorded are to be marked with a cross in Table 34 measured variables marked "Standard" must be able to be recorded in any case; the connection of the remaining measured variables is recommended. The measuring accuracy must meet the increased requirements of a measuring system.

The questions and answers on automatic data recording for operational optimisation in Table 35 must be answered.

☑	Standard	Measuring points	Label
☐	Standard	Outdoor air temperature	T301
☐	Standard	Biomass boiler inlet temperature	T311
☐	Standard	Biomass boiler outlet temperature	T312
☐		Boiler water temperature biomass boiler (other measuring point)	T313
☐	Standard	Oil/gas boiler inlet temperature	T321
☐	Standard	Oil/gas boiler outlet temperature	T322
☐		Boiler water temperature oil-gas boiler (other measuring point)	T323
☐	Standard	Main supply temperature before bypass	T341
☐	Standard *	Main supply temperature after bypass	T342
☐	Standard	Main return temperature before bypass	T343
☐	Standard *	Main return temperature after bypass	T344
☐	Standard *	Return temperature of the low-pressure difference connection	T351
☐	Standard	Supply temperature of the differential pressure-affected connection	T361
☐	Standard *	Return temperature of the differential pressure-affected connection	T362
☐	Standard	Heat quantity/output heat meter biomass boiler **	W311
☐		Water quantity/flow rate heat meter biomass boiler **	W311
☐	Standard	Oil/gas meter, if modulating oil/gas boiler ***	W321/W322
☐	Standard	Operating hours stage 1/2, if two-stage oil/gas boiler	W321/W322
☐	Standard	Setpoint value of the firing rate biomass boiler	
☐		Boiler-internal setpoint of the firing rate (feedback biomass boiler)	
☐	Standard	Setpoint of the firing rate oil/gas boiler	
☐		Boiler-internal setpoint of the firing rate (feedback signal oil/gas boiler)	
☐	Standard	Exhaust gas temperature biomass boiler	
☐		Combustion chamber temperature biomass boiler	
☐	Standard *	Residual oxygen biomass boiler	
		Measuring points particle separator; type:	
☐			
☐			

* In order to reduce the effort for data recording, a reduction by these measuring points is accepted as permissible deviation for operation optimisation.

** The heat meter must be equipped with an interface for recording the heat quantity [kWh] or water quantity [m³]. The graphical representation, however, must be in terms of power [kW] or volume flow [m³/h].

*** The oil/gas meter must be equipped with an interface for recording the oil or gas quantity [dm³ or m³]. The graphical representation, however, must be made as a volume flow [dm³/h or m³/h].

Table 34: Measuring point list for automatic data recording. If the installation is to be considered a standard hydraulic scheme, it must be possible to record all measured variables marked "Standard".

Area	Questions and answers
Hardware	How is the automatic data recording for operation optimisation carried out? ☐ With a separate data logger ☐ With the PLC of the biomass boiler ☐ With the master I&C system
	How is the periodic reading of the data done? ☐ Reading out the data on site ☐ Readout via landline phone (POTS) connection ☐ Readout via ISDN telephone connection ☐ Readout via the Internet
Data recording	What is the measurement interval? ☐ 10 seconds (recommendation)..... seconds
	What is the recording interval? ☐ 5 minutes (recommendation)..... minutes
	How are the analogue values recorded? ☐ As an average value over the last recording interval (recommendation) ☐ As instantaneous value
	How is the recording done for meters? ☐ As a sum value over the last recording interval (recommendation) ☐ As current counter reading (Attention: is often set to zero by mistake)
	How is the recording of running times done? ☐ As runtime during the last recording interval (recommendation) ☐ As the current number of operating hours (Attention: is often accidentally set to zero)
	How large is the measured value memory? ☐ ≥ 30 days recording capacity (recommendation)..... days recording capacity
Data evaluation	What is the output format for evaluation in EXCEL? ☐ CSV file with columns = time and measuring points, rows = values (recommendation) ☐ Other:
	How is the graphical representation done? ☐ Related data as a weekly overview (recommendation) ☐ Related data as a daily overview (recommendation) ☐ Representation of heat, oil, gas, operating hours meters as output or volume flow (demand) ☐ Other:
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of the autom. data recording by the main planner ☐ Specification of the automatic data recording by the main planner with the involvement of the I&C specialist
	How are the responsibilities regulated at the execution and approval stage? ☐ Planning of the autom. data recording by the main planner ☐ Planning of autom. data recording by biomass boiler suppliers ☐ Planning of the autom. data recording by the supplier of the master I&C system
	How are responsibilities regulated during operational optimisation? ☐ Readout and data evaluation by main planner ☐ Readout by biomass boiler supplier, data evaluation by main planner ☐ Readout by supplier of master I&C system, data evaluation by main planner ☐ Readout by operator, data evaluation by main planner ☐ Readout and data evaluation by operator

Table 35: Questions and answers on automatic data recording for operation optimisation

3.5 Annex to the approval protocol

The execution phase is concluded by the approval test. At this time, an addendum to the approval protocol is to be drawn up in accordance with Table 37.

The questions in Table 36 be answered at the beginning of the tendering phase. The annex to the approval protocol according to Table 37 to be filled in at the end of the execution phase. However, it is recommended to use these tables already during the tendering and execution stage for the preliminary determination of the planning values; so that the functionality of the system is clearly recognisable.

Who prepares the addendum to the approval protocol? ☐ Main planner ☐ Biomass boiler supplier ☐ Supplier of the master I&C system

Table 36: Questions and answers on the annex to the approval protocol

Description		Unit	*Example*			
Master I&C system Connection of master/subordinate I&C systems via standard interface [9]? ☐ Yes ☐ No						
■ **Boiler return temperature protection**						
Boiler inlet temperature limit biomass boiler		°C	*60*			
Boiler inlet temperature limit oil/gas boiler		°C	*60*			
■ **Main supply temperature control** Who specifies OFF (or fire bed support) and steady regulation? ☐ The active control system ☐ Always the biomass boiler						
Main supply temperature setpoint		°C	*85*			
Continuous regulation in sequence	P-band for sequence 1 (biomass boiler)	%	*200*			
	Integration time for sequence 1 (biomass boiler)	Min.	*20*			
	P-band for sequence 2 (oil/gas boiler)	%	*200*			
	Integration time for sequence 2 (oil/gas boiler)	Min.	*20*			
Two-point controller in the sequence	Biomass boiler continuous control at setpoint firing rate.	%	*≥35*			
	Biomass boiler OFF/fire bed at setpoint firing rate	%	*≤25*			
	Oil/gas boiler stage 1 ON at setpoint firing rate	%	*≥45*			
	Oil/gas boiler stage 1 OFF at setpoint firing rate	%	*≤35*			
	Oil/gas boiler stage 2 ON at setpoint firing rate	%	*≥75*			
	Oil/gas boiler stage 2 OFF at setpoint firing rate	%	*≤65*			
■ **Sequence control biomass boiler - oil/gas boiler (modify if necessary)**						
Unblocking criterion: Outdoor air temperature AND (setpoint firing rate biomass boiler AND delay time)		°C % Min.	*≤0* *100* *30*			
Blocking criterion: Setpoint firing rate biomass boiler AND delay time		% Min.	*90* *10*			
Biomass boiler						
■ **Heat output settings**						
Set minimum heat output with the reference fuel		kW	*150*			
Set maximum heat output with the reference fuel		kW	*500*			
■ **Subordinate I&C system 1**						
Boiler water temperature setpoint for "local" operating mode		°C	*85*			
Boiler water temperature limitation		°C	*95*			
Safety shutdown at boiler water temperature		°C	*110*			
Oil/gas boiler						
■ **Heat output settings**						
Set minimum heat output		kW	*280*			
Set maximum heat output ☐ stage 1+2 ☐ modulating		kW	*700*			
■ **Subordinate I&C system 2**						
Boiler water temperature limitation		°C	*90*			
Safety shutdown at boiler water temperature		°C	*110*			

Table 37: Annex to the approval protocol - setting values; exemplary values are to be deleted

4. Bivalent biomass heating system with storage tank

4.1 Short description and responsibilities

4.1.1 User level

The simplest possible operation and a clear display of the main functions are required so that non-professional personnel can also operate the system:

■ The following requirements must be met for **service and emergency operation:**

- It must be possible to disable the automatic control system partially or completely for service work and in case of emergency operation (e.g. via switch "off/on/automatic")
- Subordinate I&C systems must be able to be operated independently of the master I&C system (e.g. in the event of failure of the master I&C system).
- Manual operation of the control valves must be guaranteed (e.g. manual adjustment at the control valve, but this must not be disturbed by an incorrect control signal).
- All safety functions must be maintained

■ The **operation mode selection** shall be made in one of the following ways:

- Via switches in a **conventional control panel** (usually in the control cabinet), this solution has proven itself in practice.
- Via a **PLC**; however, this is only an option if the hardware and software requirements for convenient operation are right.
- Via the master computer of a **control system**

■ Further operation, such as **adjusting setpoints, changing time programmes, etc.,** can be carried out directly on the master and subordinate I&C systems (if necessary, also via the Internet).

4.1.2 Master I&C system

The master I&C system takes care of all master control and regulation functions and links the subordinate I&C systems with each other. In addition, automatic data recording is also assigned to the master I&C system, which is mandatory as a standard hydraulic scheme (at least temporarily for the duration of the operation optimisation).

4.1.3 Subordinate I&C system 1: biomass boiler

The subordinate I&C system of the biomass boiler has to fulfil the following **functions:**

- Fire bed support operation or automatic ignition
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

If a **particle separator** is necessary, it must be controlled by the subordinate I&C system of the biomass boiler.

The **safety** of the biomass boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be ensured by the subordinate I&C system of the biomass boiler.

If the PLC of the biomass boiler can also fulfil the demands on the master I&C system (in particular also the automatic data recording), the **simultaneous use as a master and subordinate I&C system** can be tested.

4.1.4 Subordinate I&C system 2: oil/gas boiler

The subordinate I&C system of the oil/gas boiler has to fulfil the following **functions:**

- Pre-purge, ignition and flame monitoring
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system (continuous in modulating operation, in stages in multi-stage operation)
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

The **safety** of the oil/gas boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be ensured by the subordinate I&C system of the oil/gas boiler.

4.1.5 Selected structure of the I&C system levels

A person with main responsibility must be designated for the I&C planning (in particular also for the interface definition).

The structure of the I&C system levels with responsibilities chosen for the project to be described can be answered with Table 38.

I&C system level	Questions and answers
User level Section 4.1.1	Are the requirements for service and emergency operation met? ☐ Yes (mandatory for standard hydraulic scheme) ☐ No
	How does the operation mode selection take place? ☐ Switch in a conventional control panel ☐ Input via a PLC, sufficiently convenient operation is guaranteed ☐ Input via the master computer of the control system
	From where can the system be controlled and operated? ☐ Only in the central heating plant ☐ In the central heating plant and via modem ☐ In the central heating plant and via the internet
Master I&C system Section 4.1.2	How is the master I&C system implemented? ☐ Individual controller as master I&C system ☐ Use of the PLC of the biomass boiler as a master I&C system ☐ Own master I&C system
	Connection of master/subordinate I&C systems via standard interface [9]? ☐ Yes ☐ No
	How is the automatic data recording done? ☐ Data logger during operation optimisation, an interface is provided ☐ Internal data recording in the master I&C system
Subordinate I&C system 1: Biomass boiler Section 4.1.3	What is the position/tasks of the PLC of the biomass boiler? ☐ It is used simultaneously as a master and subordinate I&C system ☐ It is subordinated to the master I&C system
Subordinate I&C system 2: Oil/gas boiler Section 4.1.4	What is the position/tasks of the I&C system of the oil/gas boiler? ☐ It is subordinated to the master I&C system
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of all I&C levels by the main planner ☐ Specification of all I&C levels by the main planner with the involvement of I&C specialists
	How are the responsibilities (especially interface definitions) regulated at the execution and approval stage? ☐ Overall planning of all I&C levels by the main planner ☐ Overall planning of all I&C levels by biomass boiler supplier ☐ Overall planning of all I&C levels by the supplier of the master I&C system ☐ Planning of each I&C level by the respective supplier (not permitted for standard hydraulic scheme, as a main person responsible for I&C planning is explicitly required).

Table 38: Questions and answers on the chosen structure of the I&C levels and responsibilities

4.2 Principle scheme and design

4.2.1 Hydraulic circuit

The hydraulic circuit must comply with Figure 39 The following requirements must be met:

- The interconnection of biomass boiler, oil/gas boiler, storage tank, low-pressure difference connection and pre-control must actually be low pressure differential (short pipes, large pipe diameters).
- The storage system must be consistently designed as a stratified storage system.
- Storage connections with cross-section enlargement (speed reduction), baffle plate (refraction of the water jet) and, if necessary, siphoned (prevention of one-pipe circulation).
- Storage connections only top and bottom (no connections in between)
- No pipes may be routed inside the storage tank (danger of "thermal agitation").
- Whenever possible, the storage tank should not be divided among several containers. If this requirement cannot be met, the following must be observed:
  - No connections between the storages
  - When controlling the storage tank charging state, each storage tank is to be considered as a control unit (problem: due to the individual stratification in each storage tank, the warmer storage tank can be colder at the bottom than the colder storage tank at the top).

The installation is also considered a standard hydraulic scheme if

- one pump is realised by two or more pumps connected in parallel or in series,
- the pre-control of the district heating network is realised by two control valves connected in parallel or with a separate summer group,
- exhaust gas heat exchanger can be integrated.

4.2.2 Hydraulic and control design

The hydraulic and control design must be carried out according to the generally accepted engineering standards. The requirements according to the Q-Guideline [1] and the Planning Handbook [4] must be fulfilled, in particular:

- Storage volume ≥ 1 h storage capacity related to nominal biomass boiler output
- Load control/boiler return temperature protection for both boilers and pre-control: Valve authority ≥ 0,5
- Design temperature difference above the biomass boiler ≤ 15 K; smaller temperature difference necessary if minimum permissible return temperature is high (e.g. with bark, landscape conservation wood); can be increased to reduce pump power consumption if it is ensured that this does not cause any control-related problems (e.g. oscillation of boiler output due to temperature stratification).
- The boiler inlet temperature should be at least 5 K higher than the minimum permissible return temperature (boiler return temperature protection).

The hydraulic and control design shall be presented and documented in accordance with Table 40.

A maximum permissible main return temperature T443 shall be specified.

If the temperature difference between the boiler outlet temperature and the boiler inlet temperature is more than 10 K less than the temperature difference between the boiler outlet temperature and the maximum permissible main return temperature T443, it is recommended to provide a **bypass in the boiler circuit D411/D421.**

Important: To ensure that the boilers can always deliver the output, it must be ensured that the main return temperature T443 cannot rise above the design value in any operating case (prescribe return temperature limiter for all consumers!).

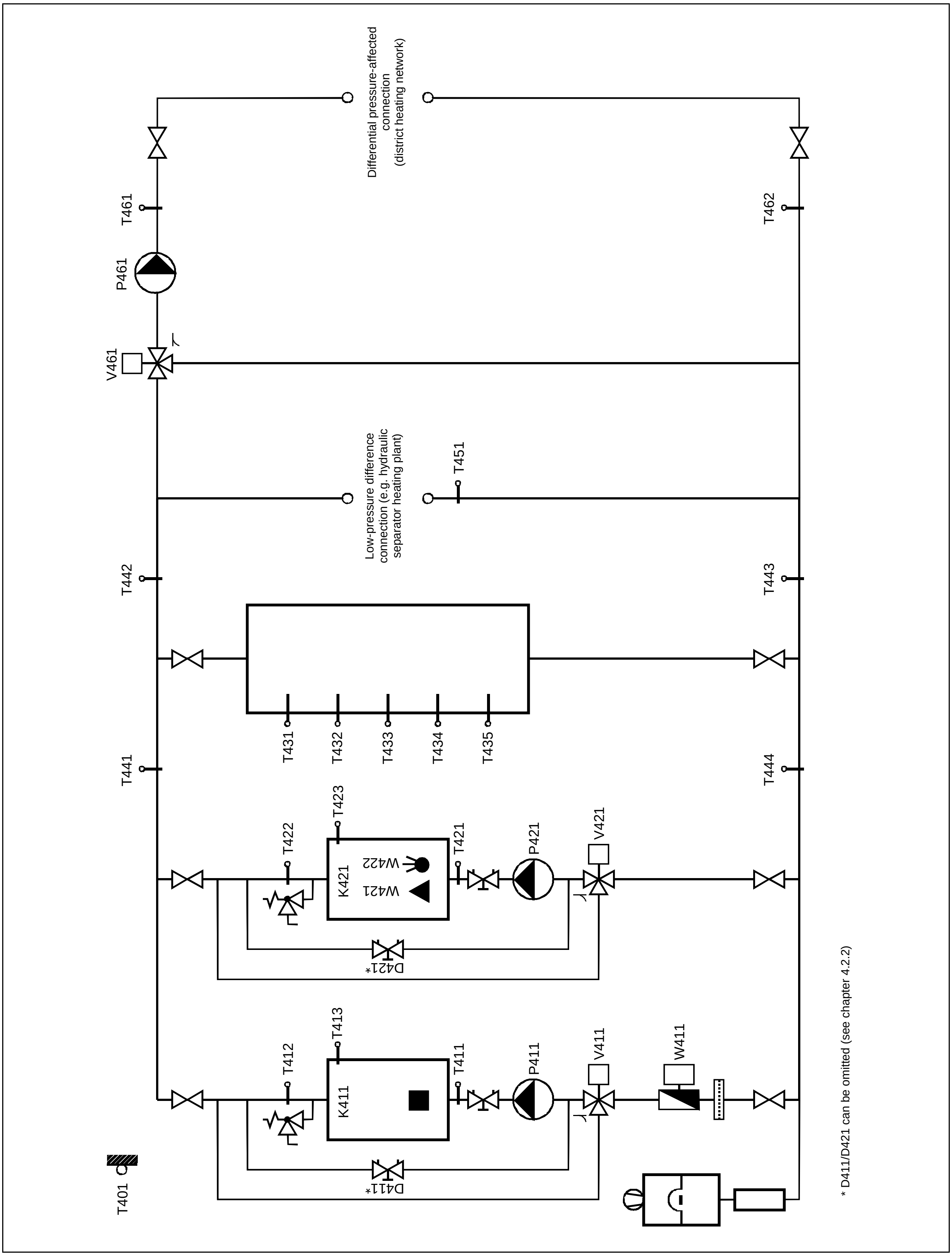

Figure 39: Principle scheme of a dual-fuel biomass heating system with storage tank. Safety devices and expansion system must be designed in accordance with the country-specific regulations.

Hydraulic and control system design	**Unit**	*Example*			**Label**
Storage					
Content	m3	*10*			
Heat capacity demand of the overall system					
Low-pressure difference connection	kW	*80*			
Differential pressure-affected connection (district heating network incl. losses)	kW	*620*			
Overall system	kW	*700*			
Guaranteed temperature limits					
Main supply temperature	°C	*85*			T442
Maximum permissible main return temperature	°C	*55*			T443
Minimum permissible biomass boiler inlet temperature (boiler return temperature protection)	°C	*60*			T411
Maximum boiler water temperature biomass boiler (limiting controller)	°C	*90*			T413
Max. permissible boiler water temperature biomass boiler (safety monitor)	°C	*110*			T413
Minimum permissible oil/gas boiler inlet temp. (boiler return temperature protection)	°C	*60*			T421
Maximum boiler water temperature oil/gas boiler (limiting controller)	°C	*90*			T423
Max. permissible boiler water temperature oil/gas boiler (safety monitor)	°C	*110*			T423
Boiler circuit biomass boiler					
Max. boiler output	kW	*350*			K411
Min. boiler output	kW	*105*			K411
Boiler outlet temperature	°C	*85*			T412/T413
Boiler pump flow rate	m3/h	*20,1*			P411
Boiler pump delivery head	m	*3*			P411
Resulting boiler inlet temperature	°C	*70*			T411
Resulting flow rate control valve boiler circuit	m3/h	*10,0*			V411
Resulting flow rate bypass	m3/h	*10,0*			D411
Pressure drop control valve	kPa	*10*			V411
Pressure drop section with variable volume flow	kPa	*8*			- –
Resulting valve authority	- –	*0,56*			V411
Boiler circuit oil/gas boiler					
Max. boiler output	kW	*700*			K421
Min. boiler output	kW	*280*			K421
Boiler outlet temperature	°C	*85*			T422/T423
Boiler pump flow rate	m3/h	*40,1*			P421
Boiler pump delivery head	m	*3*			P421
Resulting boiler inlet temperature	°C	*70*			T421
Resulting flow rate control valve boiler circuit	m3/h	*20,1*			V421
Resulting flow rate bypass	m3/h	*20,1*			D421
Pressure drop control valve	kPa	*10*			V421
Pressure drop section with variable volume flow	kPa	*8*			- –
Resulting valve authority	- –	*0,56*			V421
Design of pre-control and network pump in chapter 9!					

Table 40: Hydraulic and control system design. The design data of the system to be executed are to be entered according to the example (the exemplary values are to be deleted).

4.3 Functional description

4.3.1 Control scheme

The control and regulation of the system is to be carried out according to Figure 41.

4.3.2 Operating modes

The following operating modes shall be provided:

■ **Off:** The entire heat production system is out of operation, with the exception of the continuous operations (automatic expansion unit, etc.)

■ **Manual:** Setpoint firing rate for both the biomass boiler and the oil/gas boiler can be set "manually" as fixed values on the master I&C system; this operating mode is not mandatory.

■ **Local:** The internal output controllers of the subordinate I&C systems of the biomass boiler or the oil/gas boiler are activated (the master I&C system may be out of operation or defective).

■ **Automatic:** The setpoint value of the firing rate is specified as a sequence for both the biomass boiler and the oil/gas boiler by the master I&C system depending on the storage tank state of charge (= controlled variable).

■ **Other operating modes:** Especially for low-load operation (transition period, summer), other operating modes may be necessary (e.g. conventional "summer/winter" changeover, low-load operation with "charge/discharge storage tank", low-load operation with "oil/gas boiler alone", etc.).

4.3.3 Control

The control for the specification, limitation, weather compensation and time programme control of the setpoints as well as for the unblocking and blocking of boilers, pumps, etc. must be implemented by the master I&C system.

With **weather compensation,** the outdoor air temperature can be recorded via a weather sensor on the north side of the building, and the outdoor air temperature can then be used on the one hand as an instantaneous value and on the other hand as a 24-h average value to guide the setpoints and unblocking criteria. Calculation of the 24-h mean value, for example, continuously over a window of the last 24 hours and recalculation every 15 minutes.

With a **time programme control,** time programme levels can be programmed for different functions.

4.3.4 Boiler circuit control biomass boiler

The control of the boiler circuit for the biomass boiler is to be realised by the master I&C system.

In the "automatic" operating mode, the **boiler outlet temperature** should be controlled continuously via the control valve in the boiler circuit to a fixed value. If the boiler inlet temperature falls below the limit value, the control should be set to this limit value (= **boiler return temperature protection**).

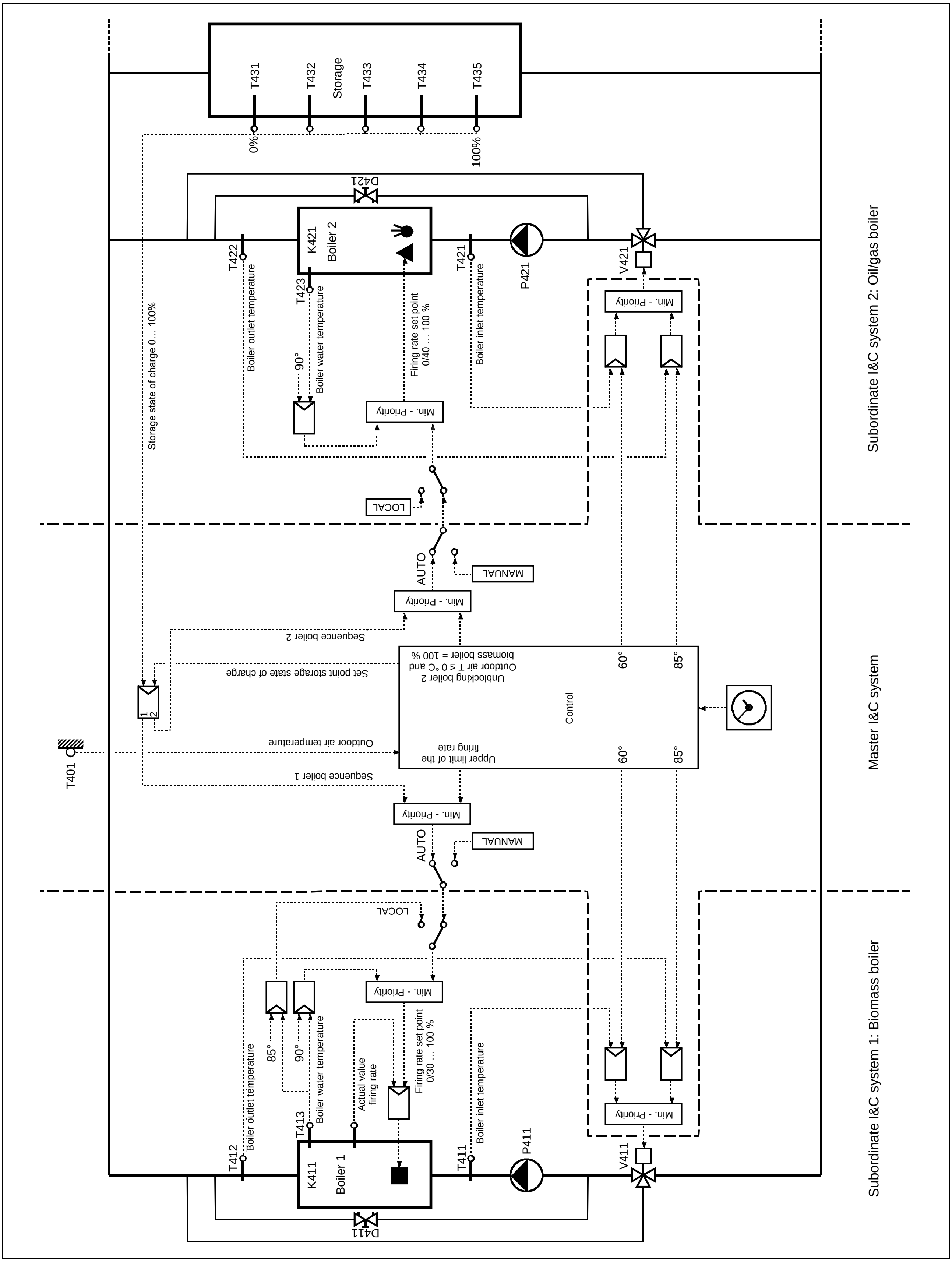

Figure 41: Control scheme standard hydraulic scheme bivalent biomass heating system with storage tank. The minimum priority switches route the lowest input signal to the output. Numerical values are to be understood as examples. Safety functions are not shown; these are to be realised via the subordinate I&C systems of the boilers.

4.3.5 Boiler circuit control oil/gas boiler

The control of the boiler circuit for the oil/gas boiler is to be realised by the master I&C system.

In the "automatic" operating mode, the **boiler outlet temperature** should be controlled continuously via the control valve in the boiler circuit to a fixed value. If the boiler inlet temperature falls below the limit value, the control should be set to this limit value (= **boiler return temperature protection**).

To prevent uncontrolled charging of the storage tank in "manual", "local" or "oil/gas boiler alone" mode, the oil/gas boiler should be switched off when the storage tank is charged to an adjustable value (e.g. off at 20% and on again at 0%).

4.3.6 Storage tank charging status control

The control of the storage tank charging state is to be realised by the master I&C system.

The state of charge of the storage tank should be recorded via at least 5 temperature sensors that are evenly distributed over the height of the storage tank. This gives the state of charge of the storage tank from 0% to 100%.

Different variants are possible for recording the storage tank charging status. The following applies to variants 1 and 2:
w = Sensor signals "warm" when e.g. $T \geq 75°C$
k = Sensor signals "cold" when e.g. $T \leq 65°C$

Variant 1 (Table 42**):** With sensor values 20 - 40 - 60 - 80 - 100. For "all sensors cold" the value is 0. This variant results in a stepped actual value signal. Therefore, the (fast) P component of the controller must not be too large, and disturbances must mainly be compensated via the (slow) I component.

Variant 2: The stepped signal according to variant 1 can be smoothed by a first-order control delay element (PT1 element). However, the time constant of the PT1 element must not be too large, otherwise there is a risk that the inevitable time delay of the actual value signal will lead to disturbances. The "more continuous" actual value signal, however, allows a somewhat larger P component in the controller compared to variant 1.

Sensor (from top to bottom)					Value
1	2	3	4	5	
k	k	k	k	k	0
w	k	k	k	k	20
w	w	k	k	k	40
w	w	w	k	k	60
w	w	w	w	k	80
w	w	w	w	w	100

Table 42: Variant 1 (in stages)

Variant 3 (Table 43**):** A smoothing of the characteristic curve can also be achieved if the temperature of the active sensor is interpolated.

Sensor (from top to bottom)					Value
1	2	3	4	5	
< 60°C	< 60°C	< 60°C	< 60°C	< 60°C	0
60...80°C	< 60°C	< 60°C	< 60°C	< 60°C	0...20
> 80°C	60...80°C	< 60°C	< 60°C	< 60°C	20...40
> 80°C	> 80°C	60...80°C	< 60°C	< 60°C	40...60
> 80°C	> 80°C	> 80°C	60...80°C	< 60°C	60...80
> 80°C	> 80°C	> 80°C	> 80°C	60...80°C	80...100

Table 43: Variant 3 (stepless)

With a good system, it can be assumed that for the sensor temperatures $T_1...T_5$ applies:

$T_1 \geq T_2 \geq T_3 \geq T_4 \geq T_5$ ($T_1...T_5$ from top to bottom)

The active sensor is highlighted in grey in Table 43 following rule applies:
- Sensor 1 active when all other sensor temperatures < 80°C
- Sensor 2 active when sensor temperature $T_1 > 80°C$
- Sensor 3 active when sensor temperature $T_2 > 80°C$

- Sensor 4 active when sensor temperature $T_3 > 80°C$
- Sensor 5 active when sensor temperature $T_4 > 80°C$

The quality of the interpolation (smoothing of the signal) depends on the thickness of the mixing zone in the storage tank, and this thickness is not a fixed quantity. With the same storage tank, it can be very different - depending on the flow rate, cooling, etc. Basically:
- thickness of the mixing zone zero (ideal stratified storage) results in no smoothing at all, the signal is just as stepped as in variant 1
- thickness of the mixing zone between zero and one probe distance results in an increasingly better smoothing of the signal
- Thickness of the mixing zone very slightly greater than one sensor spacing gives the best smoothing
- Thickness of the mixing zone significantly greater than a probe spacing results in poorer smoothing again

Variant 4: Average storage tank temperature as a measure of the storage tank state of charge. The disadvantage here is that the actual storage tank state of charge is reproduced differently depending on the thickness of the mixing zone, return temperature, cooling, etc: Thickness of the mixing zone zero (ideal stratified storage tank) results in no smoothing at all, the signal is just as stepped as in variant 1; when designed for 85/55°C, the control range is 30 K, when the return comes back in the morning with 25°C, it is suddenly 60 K.

More than 5 storage sensors: Only with this (in combination with variants 1 to 4) can the signal really be improved.

The storage tank is to be charged by a continuous control. This controller should have PI characteristics. As a result of the I component, the storage tank can thus be charged to a setpoint of 60...80% without a permanent control deviation (as would be the case with the P controller) (in the case of a stepped signal, select a stepped value, e.g. 60%). If the heat consumers suddenly demand more power, the storage charging state drops and the firing rate is increased, and if less power is suddenly needed, the storage charging state rises and the firing rate is regulated back. In the first case, the upper half of the storage tank is available as a power reserve until the biomass boiler has reacted, and in the second case, the biomass boiler can deliver the temporary power surplus to the lower half of the storage tank.

In systems with automatic ignition, the storage tank should be completely charged and discharged with reduced output during low-load operation (required biomass boiler output below the minimum output). A suitable switching criterion must be defined for switching from "charge/discharge" to continuous control and back (e.g. manual switching or switching according to time programme and outdoor air temperature).

4.3.7 Firing rate control biomass boiler

The firing rate is controlled via the subordinate I&C system of the biomass boiler.

The biomass-fired furnace shall be equipped with automatic ignition. If this is not possible or not reasonable according to the state of the art, it can be operated with fired bed support mode. In principle, the biomass-fired furnace should always be operated at the lowest possible output so that it has to be switched on and off as little as possible.

The controller for the storage charging state of the master I&C system specifies the setpoint value for the firing rate to the biomass firing system. With the help of the control system, the setpoint for the firing rate can then be additionally guided and limited.

The internal controller for the boiler water temperature T413 of the subordinate I&C system has the following functions:
- “Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the storage tank charging state, but limitation of the boiler water temperature T413 (e.g. to 90°C).
- “Local" operating mode: Control of the boiler water temperature T413 to a fixed value set on the subordinate I&C system (e.g. 85°C), limitation of the boiler water temperature T413 to a higher fixed value (e.g. to 90°C);
- Operating mode "automatic": Limiting the boiler water temperature T413 (e.g. to 90°C)

In the output control range of the biomass-fired furnace of 30...100%, the control should be continuous. Below this, the control must be in two-point mode. Switching between OFF (or fire bed support) and continuous control is done via the respective active I&C system. If the biomass boiler manufacturer so wishes, the switch-over can also always be made via the biomass boiler.

A recommendation for standard interfaces between the master I&C system and the biomass boiler, as well as a list of control unit and biomass boiler manufacturers offering these interfaces, can be downloaded from the Internet [9].

Important: The safety of the biomass boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be additionally ensured by the subordinate I&C system of the biomass boiler.

4.3.8 Firing rate control oil/gas boiler

The firing rate is controlled via the subordinate I&C system of the oil/gas boiler.

The control of the firing rate should be continuous (for modulating operation) or in stages (for multi-stage operation). In principle, the oil/gas boiler should always be operated at the lowest possible output, and it should only be unblocked when the biomass boiler has not been able to provide the output at full load for a long time.

The controller for the storage charging state of the master I&C system gives the setpoint value of the firing rate to the oil/gas boiler in sequence to the biomass boiler.

The internal controller for the boiler water temperature T423 of the subordinate I&C system has the following functions:

- “Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the main supply temperature T441, but limitation of the boiler water temperature T423 (e.g. to 90°C).
- “Local" operating mode: Control of the boiler water temperature T423 to a fixed value set on the subordinate I&C system (e.g. 90°C).
- Operating mode "automatic": Limiting the boiler water temperature T423 (e.g. to 90°C)

Important: The safety of the oil/gas boiler, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be additionally ensured by the subordinate I&C system of the oil/gas boiler.

4.3.9 Sequence control biomass boiler - oil/gas boiler

The downstream connection between the biomass boiler and the oil/gas boiler must be implemented by the master I&C system.

The sequence controller for the firing rate of the two boilers must be designed and supplemented with suitable unblocking and blocking criteria in such a way that it reliably prevents the oil/gas boiler from being switched on too frequently.

Examples of unblocking and blocking criteria for the oil/gas boiler are:

- Unblocking when certain minimum outdoor air temperature AND setpoint of the firing rate of the biomass boiler is set to 100% for a certain time
- Blocking (switching back) when the setpoint value of the firing rate of the biomass boiler has returned to 90% for a certain time.

If the biomass boiler goes on fault, the oil/gas boiler must be unblocked automatically.

The boiler that is not in operation must be completely isolated hydraulically from the rest of the system (no faulty circulation due to overrun times, incorrectly set three-way valves, short circuits via safety lines, etc.).

4.3.10 Chosen control concept

The concept applicable to the project to be described, how the control of the boiler circuits, the storage tank charging state and the firing rates is to be carried out, is to be defined in Table 44

Operating mode	**Boiler circuit control: - Biomass boiler - Oil/gas boiler**	**Storage tank state of charge control (= main control variable)**	**Regulation of firing rates - Biomass boiler - Oil/gas boiler**
Off	Inoperative		
Manual ☐ Not provided	☐ T411/T421 boiler return temperature protection systems by master I&C system ☐ Control of boiler outlet temperatures T412/T422 by master I&C system ☐ Limitation of boiler water temperatures T413/T423 by subordinate I&C systems	☐ Storage tank charging status control out of operation	☐ Setpoints of the two firing rates can be set as fixed values on the master I&C system
Local	☐ Control of boiler water temperatures T413/T423 by subordinate I&C systems	☐ Storage tank charging status control out of operation	☐ Internal power controllers of the subordinate I&C systems activated
Automatic Summer operation? ☐ Yes, with biomass boiler ☐ Yes, with oil/gas boiler ☐ No	☐ T411/T421 boiler return temperature protection systems by master I&C system ☐ Control of boiler outlet temperatures T412/T422 by master I&C system ☐ Limitation of boiler water temperatures T413/T423 by subordinate I&C systems	☐ Control of the storage tank charging state by the master I&C system in the sequence biomass boiler - oil/gas boiler; the correcting variable is the setpoint values of the two firing rates. ☐ Charge/discharge storage tank (low load operation)	☐ Control of the two firing rates by the subordinate I&C systems; setpoints from the master I&C system in sequence biomass boiler - oil/gas boiler
Acquisition of storage tank state of charge	Number of storage tank sensors: ...... (at least 5) ☐ Stepped signal (variant 1) ☐ Smoothing with PT1 element (variant 2) ☐ Smoothing by interpolation via the temperature of the respective active sensor (variant 3) ☐ Average storage tank temperature as a measure of the storage tank charging status (variant 4)		
Summary	Which operating modes are provided? ☐ Off ☐ Manual (for each boiler) ☐ Local (for each boiler) ☐ Automatic winter operation by means of continuous storage control ☐ Automatic low-load operation (transition period, summer) by charging/discharging the storage tank ☐ Automatic low-load operation (transition period, summer) with oil/gas boiler ☐ Oil/gas boiler alone (e.g. revision biomass boiler, emergency operation) ☐ Other:		

Table 44: Questions and answers on the chosen control concept

4.4 Data recording for operational optimisation

All precautions are to be taken so that a proper operational optimisation can be carried out and the subsequent regular operation can be efficiently monitored. The measured variables to be recorded are to be marked with a cross in Table 45measured variables marked "Standard" must be able to be recorded in any case; it is recommended to connect the remaining measured variables. The measuring accuracy must meet the increased requirements of a measuring system.

The questions and answers on automatic data recording for operational optimisation in Table 46must be answered.

☑	Standard	Measuring points	Label
☐	Standard	Outdoor air temperature	T401
☐	Standard	Biomass boiler inlet temperature	T411
☐	Standard	Biomass boiler outlet temperature	T412
☐		Boiler water temperature Biomass boiler (other measuring point)	T413
☐	Standard	Oil/gas boiler inlet temperature	T421
☐	Standard	Oil/gas boiler outlet temperature	T422
☐		Boiler water temperature oil-gas boiler (other measuring point)	T423
☐	Standard *	Main supply temperature before storage tank	T441
☐	Standard *	Main supply temperature after storage tank	T442
☐	Standard	Main return temperature before storage tank	T443
☐	Standard *	Main return temperature after storage tank	T444
☐	Standard	Storage tank temperature (top)	T431
☐	Standard	Storage tank temperature	T432
☐	Standard	Storage tank temperature (middle)	T433
☐	Standard	Storage tank temperature	T434
☐	Standard	Storage tank temperature (bottom)	T435
☐	Standard *	Return temperature of the low-pressure difference connection	T451
☐	Standard	Supply temperature of the differential pressure-affected connection	T461
☐	Standard *	Return temperature of the differential pressure-affected connection	T462
☐	Standard	Heat quantity/output heat meter biomass boiler **	W411
☐		Water quantity/flow rate heat meter biomass boiler **	W411
☐	Standard	Oil/gas meter, if modulating oil/gas boiler ***	W421/W422
☐	Standard	Operating hours stage 1/2, if two-stage oil/gas boiler	W421/W422
☐	Standard	Setpoint value of the firing rate biomass boiler	
☐		Boiler-internal setpoint of the firing rate (feedback biomass boiler)	
☐	Standard	Setpoint of the firing rate oil/gas boiler	
☐		Boiler-internal setpoint of the firing rate (feedback signal oil/gas boiler)	
☐	Standard	Actual value of the storage tank charging state	
☐	Standard	Exhaust gas temperature biomass boiler	
☐		Combustion chamber temperature biomass boiler	
☐	Standard *	Residual oxygen biomass boiler	
		Measuring points particle separator; type:	
☐			
☐			

* In order to reduce the effort for data recording, a reduction by these measuring points is accepted as permissible deviation for operation optimisation.

** The heat meter must be equipped with an interface for recording the heat quantity [kWh] or water quantity [m³]. The graphical representation, however, must be in terms of power [kW] or volume flow [m³/h].

*** The oil/gas meter must be equipped with an interface for recording the oil or gas quantity [dm³ or m³]. The graphical representation, however, must be made as a volume flow [dm³/h or m³/h].

Table 45: Measuring point list for automatic data recording. If the installation is to be considered a standard hydraulic scheme, it must be possible to record all measured variables marked "Standard".

Area	Questions and answers
Hardware	How is the automatic data recording for operation optimisation carried out? ☐ With a separate data logger ☐ With the PLC of the biomass boiler ☐ With the master I&C system
	How is the periodic reading of the data done? ☐ Reading out the data on site ☐ Readout via landline phone (POTS) connection ☐ Readout via ISDN telephone connection ☐ Readout via the Internet
Data recording	What is the measurement interval? ☐ 10 seconds (recommendation)..... seconds
	What is the recording interval? ☐ 5 minutes (recommendation)..... minutes
	How are the analogue values recorded? ☐ As an average value over the last recording interval (recommendation) ☐ As instantaneous value
	How is the recording done for meters? ☐ As a sum value over the last recording interval (recommendation) ☐ As current counter reading (Attention: is often set to zero by mistake)
	How is the recording of running times done? ☐ As runtime during the last recording interval (recommendation) ☐ As the current number of operating hours (Attention: is often accidentally set to zero)
	How large is the measured value memory? ☐ ≥ 30 days recording capacity (recommendation)..... days recording capacity
Data evaluation	What is the output format for evaluation in EXCEL? ☐ CSV file with columns = time and measuring points, rows = values (recommendation) ☐ Other:
	How is the graphical representation done? ☐ Related data as a weekly overview (recommendation) ☐ Related data as a daily overview (recommendation) ☐ Representation of heat, oil, gas, operating hours meters as output or volume flow (demand) ☐ Other:
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of the autom. data recording by the main planner ☐ Specification of the automatic data recording by the main planner with the involvement of the I&C specialist
	How are the responsibilities regulated at the execution and approval stage? ☐ Planning of the autom. data recording by the main planner ☐ Planning of autom. data recording by biomass boiler suppliers ☐ Planning of the autom. data recording by the supplier of the master I&C system
	How are responsibilities regulated during operational optimisation? ☐ Readout and data evaluation by main planner ☐ Readout by biomass boiler supplier, data evaluation by main planner ☐ Readout by supplier of master I&C system, data evaluation by main planner ☐ Readout by operator, data evaluation by main planner ☐ Readout and data evaluation by operator

Table 46: Questions and answers on data recording for operational optimisation

4.5 Annex to the approval protocol

The execution phase is concluded by the approval test. At this time, an addendum to the approval protocol shall be drawn up in accordance with Table 48.

The questions in Table 47 be answered at the beginning of the tendering phase. The annex to the approval protocol according to Table 48 only has to be filled in at the end of the execution phase. However, it is recommended to use these tables already during the tendering and execution phase for the preliminary determination of the planning values; so that the functionality of the system is clearly recognisable.

Who prepares the addendum to the approval protocol? ☐ Main planner ☐ Biomass boiler supplier ☐ Supplier of the master I&C system

Table 47: Questions and answers on the annex to the approval protocol

Description		**Unit**	*Example*			
Master I&C system Connection of master/subordinate I&C systems via standard interface [9]? ☐ Yes ☐ No						
■ **Boiler return temperature protection**						
Boiler inlet temperature limit biomass boiler		°C	*60*			
Boiler inlet temperature limit oil/gas boiler		°C	*60*			
■ **Storage charge control** Who specifies OFF (or fire bed support) and steady regulation? ☐ The active control system ☐ Always the biomass boiler How is the "continuous control" switched to "charge/discharge storage tank"? ☐ Switchover by hand ☐ Other:						
Setpoint storage tank state of charge		%	*60*			
Setpoint storage tank sensor "warm"		°C	*≥75*			
Setpoint storage tank sensor "cold"		°C	*≤65*			
Continuous regulation in sequence	P-band for sequence 1 (biomass boiler)	%	*200*			
	Integration time for sequence 1 (biomass boiler)	Min.	*20*			
	P-band for sequence 2 (oil/gas boiler)	%	*200*			
	Integration time for sequence 2 (oil/gas boiler)	Min.	*20*			
Two-point controller in the sequence	Biomass boiler continuous control at setpoint firing rate.	%	*≥35*			
	Biomass boiler OFF/fire bed at setpoint firing rate	%	*≤25*			
	Oil/gas boiler stage 1 ON at setpoint firing rate	%	*≥45*			
	Oil/gas boiler stage 1 OFF at setpoint firing rate	%	*≤35*			
	Oil/gas boiler stage 2 ON at setpoint firing rate	%	*≥75*			
	Oil/gas boiler stage 2 OFF at setpoint firing rate	%	*≤65*			
Filling and emptying the reservoir	Biomass boiler ON at actual value of storage tank charging status	%	*0%*			
	Biomass boiler OFF at actual value of storage tank charging status	%	*100%*			
	Setpoint firing rate (fixed value)	%	*40%*			
■ **Sequence control biomass boiler - oil/gas boiler (modify if necessary)**						
Unblocking criterion: Outdoor air temperature AND (setpoint firing rate biomass boiler AND delay time)		°C % Min.	*≤ 0* *100* *30*			
Blocking criterion: Setpoint firing rate biomass boiler AND delay time		% Min.	*90* *10*			
Biomass boiler						
■ **Heat output settings**						
Set minimum heat output with the reference fuel		kW	*105*			
Set maximum heat output with the reference fuel		kW	*350*			
■ **Subordinate I&C system 1**						
Boiler water temperature setpoint for "local" operating mode		°C	*85*			
Boiler water temperature limitation		°C	*95*			
Safety shutdown at boiler water temperature		°C	*110*			
Oil/gas boiler						
■ **Heat output settings**						
Set minimum heat output		kW	*280*			
Set maximum heat output ☐ stage 1+2 ☐ modulating		kW	*700*			
■ **Subordinate I&C system 2**						
Boiler water temperature limitation		°C	*90*			
Safety shutdown at boiler water temperature		°C	*110*			

Table 48: Annex to the approval protocol - setting values; exemplary values are to be deleted

5. Monovalent two-boiler biomass heating system without storage tank

5.1 Short description and responsibilities

5.1.1 User level

The simplest possible operation and a clear display of the main functions are required so that non-professional personnel can also operate the system:

■ The following requirements must be met for **service and emergency operation:**

- It must be possible to disable the automatic control system partially or completely for service work and in case of emergency operation (e.g. via switch "off/on/automatic").
- Subordinate I&C systems must be able to be operated independently of the master I&C system (e.g. in case of failure of the master I&C system).
- Manual operation of the control valves must be guaranteed (e.g. manual adjustment at the control valve, but this must not be disturbed by an incorrect control signal).
- All safety functions must be maintained

■ The **operation mode selection** shall be made in one of the following ways:

- Via switches in a **conventional control panel** (usually in the control cabinet).
- Via a **PLC**; however, this is only an option if the hardware and software requirements for convenient operation are right.
- Via the master computer of a **control system**

■ Further operation, such as **adjusting setpoints, changing time programmes, etc.,** can be carried out directly on the master and subordinate I&C systems (if necessary, also via the Internet).

5.1.2 Master I&C system

The master I&C system takes care of all master control and regulation functions and links the subordinate I&C systems with each other. In addition, automatic data recording is also assigned to the master I&C system, which is mandatory as a standard hydraulic scheme (at least temporarily for the duration of the operation optimisation).

5.1.3 Subordinate I&C systems biomass boilers

The subordinate I&C systems of the biomass boilers have to fulfil the following **functions:**

- Fire bed support operation or automatic ignition
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

If **particle separators** are necessary, these are to be controlled by the subordinate I&C systems of the biomass boilers.

The **safety** of the biomass boilers, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be ensured by the subordinate I&C systems of the biomass boilers.

If the PLCs of the biomass boilers can also fulfil the requirements for the master I&C system (in particular also the automatic data recording), the **simultaneous use as a master and subordinate I&C system** can be tested.

5.1.4 Selected structure of the I&C system levels

A person with main responsibility must be designated for the I&C planning (in particular also for the interface definition).

The structure of the I&C system levels with responsibilities chosen for the project to be described can be answered with Table 49.

I&C system level	Questions and answers
User level Section 5.1.1	Are the requirements for service and emergency operation met? ☐ Yes (mandatory for standard hydraulic scheme) ☐ No
	How does the operation mode selection take place? ☐ Switch in a conventional control panel ☐ Input via a PLC, sufficiently convenient operation is guaranteed ☐ Input via the master computer of the control system
	From where can the system be controlled and operated? ☐ Only in the central heating plant ☐ In the central heating plant and via modem ☐ In the central heating plant and via the internet
Master I&C system Section 5.1.2	How is the master I&C system implemented? ☐ Individual controller as master I&C system ☐ Use of the common PLC of the biomass boilers as a master I&C system ☐ Own master I&C system
	Connection of master/subordinate I&C systems via standard interface [9]? ☐ Yes ☐ No
	How is the automatic data recording done? ☐ Data logger during operation optimisation, an interface is provided ☐ Internal data recording in the master I&C system
Subordinate I&C sys-tems of the biomass boilers Section 5.1.3	What is the position/tasks of the PLCs of the biomass boilers? ☐ A single PLC for both biomass boilers, which is used simultaneously as the master and subordinate I&C systems ☐ A single PLC for both biomass boilers, subordinated to the master I&C system ☐ Separate PLC for both biomass boilers, subordinated to the master I&C system
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of all I&C levels by the main planner ☐ Specification of all I&C levels by the main planner with the involvement of I&C specialists
	How are the responsibilities (especially interface definitions) regulated at the execution and approval stage? ☐ Overall planning of all I&C levels by the main planner ☐ Overall planning of all I&C levels by biomass boiler supplier ☐ Overall planning of all I&C levels by the supplier of the master I&C system ☐ Planning of each I&C level by the respective supplier (not permitted for standard hydraulic scheme, as a main person responsible for I&C planning is explicitly required).

Table 49: Questions and answers on the chosen structure of the I&C levels and responsibilities

5.2 Principle scheme and design

5.2.1 Hydraulic circuit

The hydraulic circuit must comply with Figure 50 The following requirements must be met:
- The circuit must actually be made low in pressure difference by the bypass, i.e. the shortest possible bypass and pipe diameter bypass = pipe diameter main flow
- The interconnection of the biomass boilers, the bypass, the low-pressure difference connection and the pre-control must actually be low pressure differential (short pipes, large pipe diameters).
- Make sure that the sensor for the main supply temperature is properly mixed (install a static mixer if necessary).

The installation is also considered a standard hydraulic scheme if
- one pump is realised by two or more pumps connected in parallel or in series,
- the pre-control of the district heating network is realised by two control valves connected in parallel or with a separate summer group,
- only one common heat meter is installed for both boilers in the main return (to check the boiler output, the other boiler must be out of operation!),
- exhaust gas heat exchanger can be integrated.

5.2.2 Hydraulic and control design

The hydraulic and control design must be carried out according to the generally accepted engineering standards. The requirements according to the Q-Guideline [1] and the Planning Handbook [4] must be fulfilled, in particular:
- Boiler return temperature protection for both boilers and pre-control: Valve authority ≥ 0,5
- Design temperature difference above the biomass boilers ≤ 15 K; smaller temperature difference necessary if minimum permissible return temperature is high (e.g. with bark, landscape conservation wood); can be increased to reduce pump power consumption if it is ensured that this does not cause any control-related problems (e.g. oscillation of boiler output due to temperature stratification).
- The boiler inlet temperature should be at least 5 K higher than the minimum permissible return temperature (boiler return temperature protection).

The hydraulic and control design shall be presented and documented in accordance with Table 51.

A maximum permissible main return temperature T543 shall be specified.

If the temperature difference between the boiler outlet temperature and the boiler inlet temperature is more than 10 K less than the temperature difference between the boiler outlet temperature and the maximum permissible main return temperature T543, it is recommended to provide a **bypass in the boiler circuit D511/D521.**

Important: To ensure that the boilers can always deliver the output, it must be ensured that the main return temperature T543 cannot rise above the design value in any operating case (prescribe return temperature limiter for all consumers!).

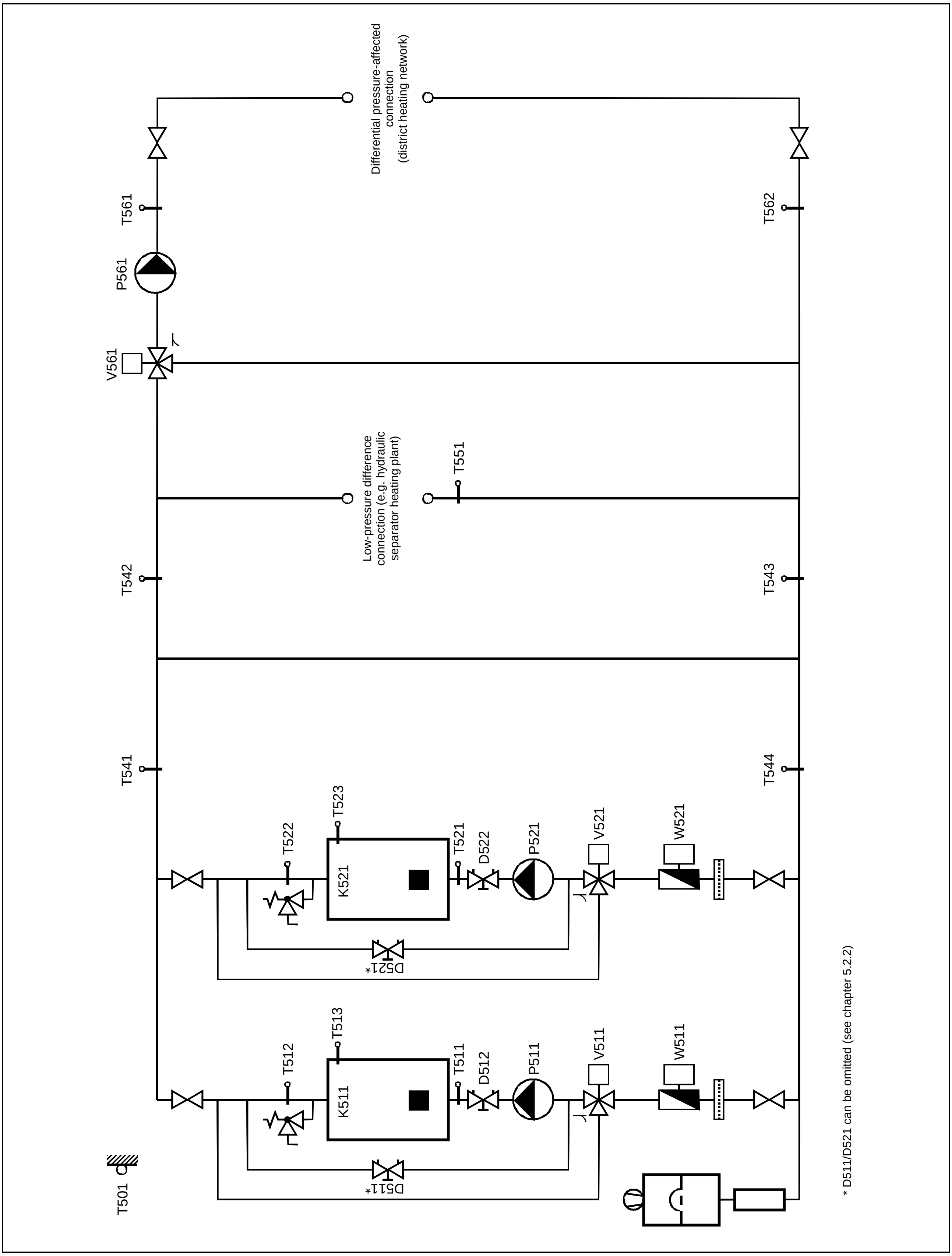

Figure 50: Principle scheme of a monovalent two-boiler biomass heating system without storage tank. Safety devices and expansion system must be designed in accordance with the country-specific regulations.

Hydraulic and control system design	**Unit**	*Example*			**Label**
Heat capacity demand of the overall system					
Low-pressure difference connection	kW	*80*			
Differential pressure-affected connection (district heating network incl. losses)	kW	*620*			
Overall system	kW	*700*			
Guaranteed temperature limits					
Main supply temperature	°C	*85*			T542
Maximum permissible main return temperature	°C	*55*			T543
Minimum permissible inlet temperature Biomass boiler 1 (boiler return temperature protection)	°C	*60*			T511
Maximum boiler water temperature Biomass boiler 1 (limiting controller)	°C	*90*			T513
Max. permissible boiler water temp. Biomass boiler 1 (safety monitor)	°C	*110*			T513
Minimum permissible inlet temperature Biomass boiler 2 (boiler return temperature protection)	°C	*60*			T521
Maximum boiler water temperature Biomass boiler 2 (limiting controller)	°C	*90*			T523
Max. permissible boiler water temp. Biomass boiler 2 (safety monitor)	°C	*110*			T523
Boiler circuit Biomass boiler 1					
Max. boiler output	kW	*230*			K511
Min. boiler output	kW	*70*			K511
Boiler outlet temperature	°C	*85*			T512/T513
Boiler pump flow rate	m3/h	*13,2*			P511
Boiler pump delivery head	m	*3*			P511
Resulting boiler inlet temperature	°C	*70*			T511
Resulting flow rate control valve boiler circuit	m3/h	*6,6*			V511
Resulting flow rate bypass	m3/h	*6,6*			D511
Pressure drop control valve	kPa	*10*			V511
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	- –	*0,56*			V511
Boiler circuit Biomass boiler 2					
Max. boiler output	kW	*470*			K521
Min. boiler output	kW	*140*			K521
Boiler outlet temperature	°C	*85*			T522/T523
Boiler pump flow rate	m3/h	*27,0*			P521
Boiler pump delivery head	m	*3*			P521
Resulting boiler inlet temperature	°C	*70*			T521
Resulting flow rate control valve boiler circuit	m3/h	*13,5*			V521
Resulting flow rate bypass	m3/h	*13,5*			D521
Pressure drop control valve	kPa	*10*			V521
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	- –	*0,56*			V521
Design of pre-control and network pump in chapter 9!					

Table 51: Hydraulic and control system design. The design data of the system to be executed are to be entered according to the example (the exemplary values are to be deleted).

5.3 Functional description

5.3.1 Control scheme

The control and regulation of the system should be carried out according to Figure 52.

5.3.2 Operating modes

The following operating modes shall be provided:

- **Off:** The entire heat production system is out of operation, with the exception of the continuous operations (automatic expansion unit, etc.)
- **Manual:** Setpoint firing rate for each of the two biomass boilers can be set "manually" as fixed values on the master I&C system; this operating mode is not mandatory
- **Local:** The internal power controllers of the subordinate I&C systems of the biomass boilers are activated (the master I&C system may be out of operation or defective)
- **Automatic:** The setpoint for the firing rate is specified for both biomass boilers by the master I&C system as a function of the main supply temperature (= main control variable) as a sequence control.
- **Boiler 1 alone - Boiler 2 alone - Sequence control:** Manual changeover of low-load operation to operation with automatic sequence control and back
- **Other operating modes:** Especially for low-load operation (transition period, summer), other operating modes may be necessary (e.g. conventional "summer/winter" changeover, etc.).

5.3.3 Control

The control for the specification, limitation, weather compensation and time programme control of the setpoints as well as for the unblocking and blocking of boilers, pumps, etc. must be implemented by the master I&C system.

With **weather compensation,** the outdoor air temperature can be recorded via a weather sensor on the north side of the building, and the outdoor air temperature can then be used on the one hand as an instantaneous value and on the other hand as a 24-h average value to guide the setpoints and unblocking criteria. Calculation of the 24-h mean value, for example, continuously over a window of the last 24 hours and recalculation every 15 minutes.

With a **time programme control,** time programme levels can be programmed for different functions.

5.3.4 Boiler circuit control biomass boilers

The control of the boiler circuits of the biomass boilers is to be realised by the master I&C system.

In the "automatic" operating mode, if the boiler inlet temperature falls below the limit value, control must take place at this limit value (= **boiler return temperature protection**).

In the "manual" operating mode, a boiler return temperature protection should also take place.

In the "local" operating mode, the boiler return temperature protection should continue to be in operation if the master I&C system is still functioning (which may no longer be the case in emergency operation).

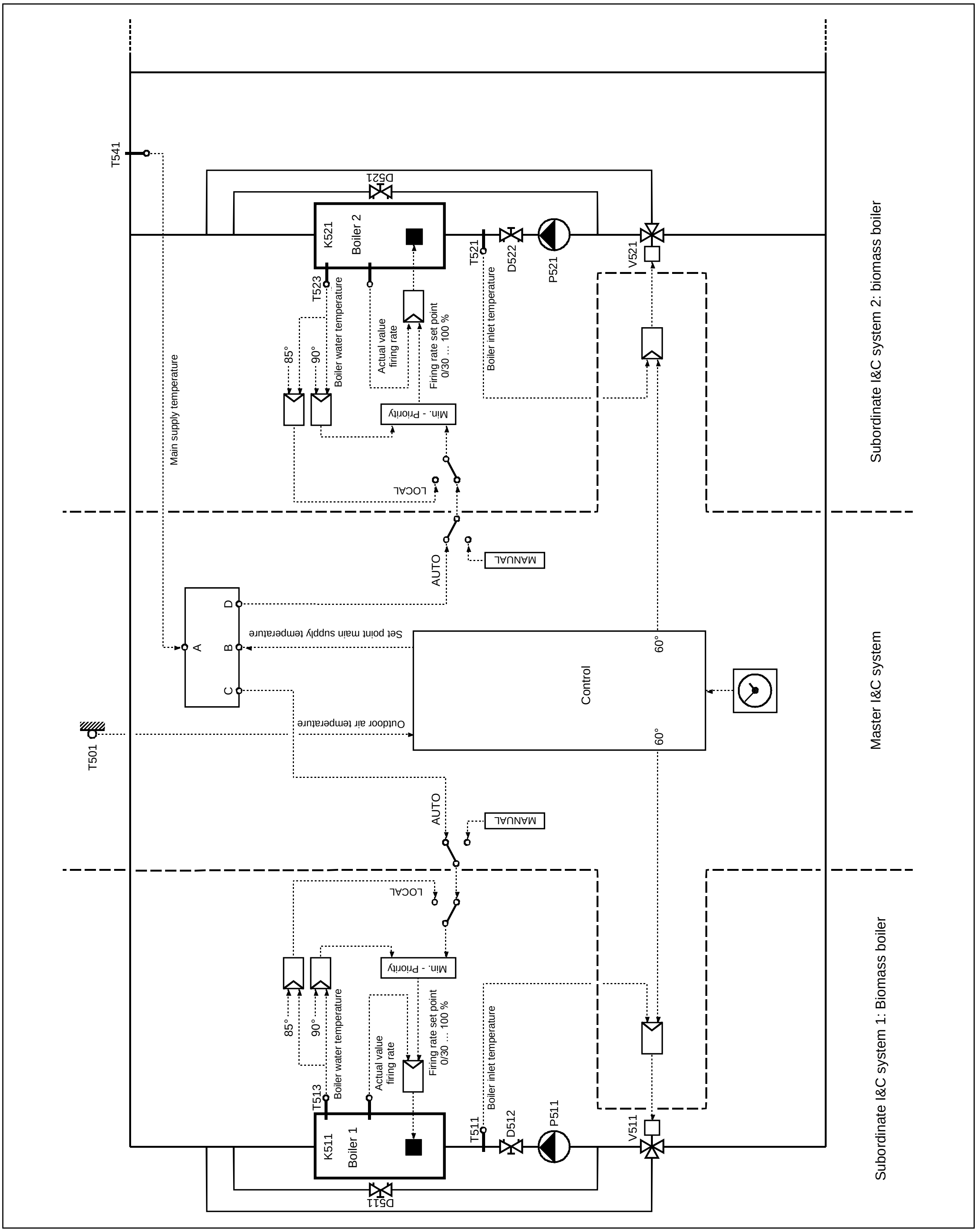

Figure 52: Control scheme standard hydraulic scheme monovalent two-boiler biomass heating system without storage tank. For the sequence control, see Figure 53. The minimum priority switches route the lowest input signal to the output. Numerical values are to be understood as examples. Safety functions are not shown; these are to be realised via the subordinate I&C systems of the boilers.

5.3.5 Main supply temperature control

The control of the main supply temperature is to be realised by the master I&C system.

The main supply temperature must be controlled to a fixed value by adjusting the setpoint values of the firing rate (= correcting variables) for the biomass boilers as a sequence control.

Important: The firing rates of the two biomass boilers are controlled in parallel via the main supply temperature, i.e. the mixed temperature of the two boiler outlet temperatures. To ensure that both biomass boilers operate as parallel as possible, careful hydraulic balancing is necessary, and the controllers for limiting the boiler water temperatures T513 and T523 must be set 5...10 K above the setpoint of the main supply temperature.

5.3.6 Firing rate control biomass boilers

The firing rate is controlled via the subordinate I&C systems of the biomass boilers.

At least Biomass boiler 1 shall be equipped with automatic ignition. If this is not possible or not reasonable according to the state of the art, fired bed support operation can be used. In principle, the biomass-fired furnace should always be operated at the lowest possible output so that they have to be switched on and off as little as possible.

The controller for the main supply temperature of the master I&C system provides the setpoints for the firing rate to the biomass firing units as a sequence control. With the help of the controller, the setpoints for the firing rate can then be additionally guided and limited.

The internal controllers for the boiler water temperatures T513/T523 of the two subordinate I&C systems have the following functions:

- “Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the main supply temperature T541, but limitation of the boiler water temperature T513/T523 (e.g. to 90°C).
- “Local" operating mode: Control of the boiler water temperature T513/T523 to a fixed value set on the subordinate I&C system (e.g. 85°C), limitation of the boiler water temperature T513/T523 to a fixed value higher by approx. 5...10 K (e.g. to 90°C).
- Operating mode "automatic": Limiting the boiler water temperature T513/T523 (e.g. to 90°C)

In the output control range of the biomass-fired furnace of 30...100%, the control should be continuous. Below this, the control must be in two-point mode. Switching between OFF (or fire bed support) and continuous control is done via the respective active I&C system. If the biomass boiler manufacturer so wishes, the switchover can also always be made via the biomass boiler.

A recommendation for standard interfaces between the master I&C system and the biomass boiler, as well as a list of control unit and biomass boiler manufacturers offering these interfaces, can be downloaded from the Internet [9].

Important: The safety of the biomass boilers, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be additionally ensured by the subordinate I&C system of the biomass boilers.

5.3.7 Sequence control biomass boilers

The sequence control of the biomass boilers is to be realised by the master I&C system.

The following example assumes a power split of the two biomass boilers of 33% for boiler 1 and 67% for boiler 2. Switching from low-load operation to operation with automatic sequence control and back is done manually (percentages refer to the total output):

- Manual switchover to boiler 2 alone (20...67%) if boiler 1 alone (10...33%) can no longer cover the daily demand
- Manual switchover to automatic sequence control if boiler 2 alone (20...67%) can no longer cover the daily demand.

- Manual switch back to boiler 2 alone (20...67%) when the daily demand can again be covered by boiler 2 alone for the foreseeable future.
- Manual switch back to boiler 1 alone (10...33%) when the daily demand can again be covered by boiler 1 alone for the foreseeable future.

The automatic sequence control must be carried out as follows (percentages refer to the total power):
- boiler 2 alone (20...67%)
- Automatic connection of boiler 1 (10...33%) by means of automatic ignition (or fired bed support operation for large systems) if boiler 2 (20...67%) can no longer cover the hourly heat demand.
- Parallel operation boiler 1 and boiler 2 (together 30...100%)
- Automatic switch back to boiler 2 alone (20...67%) if the hourly heat demand falls below the sum of the two minimum outputs of 30%.

Figure 53 shows an example of the implementation of the sequence control.

The boiler that is not in operation must be completely isolated hydraulically from the rest of the system (no faulty circulation due to overrun times, incorrectly set three-way valves, short circuits via safety lines, etc.).

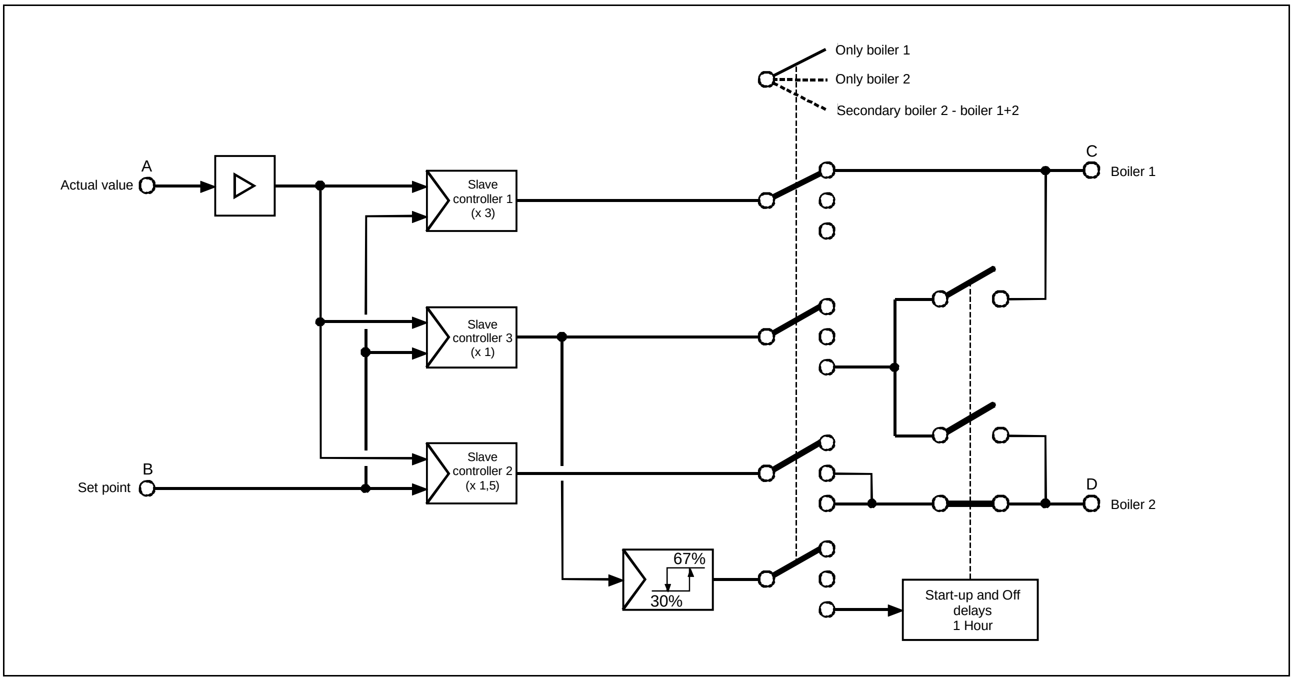

Figure 53: Example for the realisation of the sequence control. Interfaces A-D refer to Figure 52. To ensure that the circuit gain is the same for all three control circuits, the transmission coefficients of the three controllers are to be selected in a ratio of 3 : 1,5 : 1 (P-band reciprocal values 0,33 : 0,67 : 1).

5.3.8 Chosen control concept

The concept applicable to the project to be described, how to control the boiler circuits, the main supply temperature and the firing rates, shall be defined in Table 54

Operating mode	**Boiler circuit control:** **- Biomass boiler 1** **- Biomass boiler 2**	**Main supply temperature control** **(= main control variable)**	**Regulation of firing rates** **- Biomass boiler 1** **- Biomass boiler 2**
Off	Inoperative		
Manual ☐ Not provided	☐ T511/T521 boiler return temperature protection systems by master I&C system ☐ Limitation of boiler water temperatures T513/T523 by subordinate I&C systems	☐ Control main supply temperature T541 out of operation	☐ Setpoints of the two firing rates can be set as fixed values on the master I&C system
Local	☐ Control of boiler water temperatures T513/T523 by subordinate I&C systems	☐ Control main supply temperature T541 out of operation	☐ Internal power controllers of the subordinate I&C systems activated
Automatic Summer operation? ☐ Yes ☐ No	☐ T511/T521 boiler return temperature protection systems by master I&C system ☐ Limitation of boiler water temperatures T513/T523 by subordinate I&C systems	☐ Control of main supply temperature T541 by master I&C system according to special sequence control; the correcting variable is the setpoint values of the two firing rates.	☐ Control of the two firing rates by the subordinate I&C systems; setpoints from the master I&C system according to special sequence control
Summary	Which operating modes are provided? ☐ Off ☐ Manual (for each boiler) ☐ Local (for each boiler) ☐ Automatic winter operation Biomass boiler 1 alone (small boiler) ☐ Automatic winter operation Biomass boiler 2 alone (large boiler) ☐ Automatic winter operation Biomass boiler 1 + 2 in parallel (without automatic sequence control) ☐ Automatic sequence control Biomass boiler 2 alone - Biomass boiler 1 + 2 in parallel ☐ Automatic low-load operation (transition period, summer) with Biomass boiler 1 ☐ Other:		

Table 54: Questions and answers on the chosen control concept.

5.4 Data recording for operational optimisation

All precautions must be taken so that a proper operational optimisation can be carried out and the subsequent regular operation can be efficiently monitored. The measured variables to be recorded are to be marked with a cross in Table 55 measured variables marked "Standard" must be able to be recorded in any case; the connection of the remaining measured variables is recommended. The measuring accuracy must meet the increased requirements of a measuring system.

The questions and answers on automatic data recording for operation optimisation in Table 56 must be answered.

☑	**Standard**	**Measuring points**	**Label**
☐	Standard	Outdoor air temperature	T501
☐	Standard	Inlet temperature Biomass boiler 1	T511
☐	Standard	Outlet temperature Biomass boiler 1	T512
☐		Boiler water temperature Biomass boiler 1 (other measuring point)	T513
☐	Standard	Inlet temperature Biomass boiler 2	T521
☐	Standard	Outlet temperature Biomass boiler 2	T522
☐		Boiler water temperature Biomass boiler 2 (other measuring point)	T523
☐	Standard	Main supply temperature before bypass	T541
☐	Standard *	Main supply temperature after bypass	T542
☐	Standard	Main return temperature before bypass	T543
☐	Standard *	Main return temperature after bypass	T544
☐	Standard *	Return temperature of the low-pressure difference connection	T551
☐	Standard	Supply temperature of the differential pressure-affected connection	T561
☐	Standard *	Return temperature of the differential pressure-affected connection	T562
☐	Standard	Heat quantity/output heat meter Biomass boiler 1 **	W511
☐		Water quantity/flow rate heat meter Biomass boiler 1 **	W511
☐	Standard	Heat quantity/output heat meter Biomass boiler 2 **	W521
☐		Water quantity/flow rate heat meter Biomass boiler 2 **	W521
☐	Standard	Setpoint of the firing rate Biomass boiler 1	
☐		Boiler-internal setpoint of the firing rate (feedback signal Biomass boiler 1)	
☐	Standard	Setpoint of the firing rate Biomass boiler 2	
☐		Boiler-internal setpoint of the firing rate (feedback signal Biomass boiler 2)	
☐	Standard	Flue gas temperature Biomass boiler 1	
☐		Combustion chamber temperature Biomass boiler 1	
☐	Standard *	Residual oxygen Biomass boiler 1	
☐	Standard	Flue gas temperature Biomass boiler 1	
☐		Combustion chamber temperature Biomass boiler 1	
☐	Standard *	Residual oxygen Biomass boiler 1	
		Measuring points Particle separator 1; type:	
☐			
☐			
		Measuring points Particle separator 2; type:	
☐			
☐			

* In order to reduce the effort for data recording, a reduction by these measuring points is accepted as permissible deviation for operation optimisation.

** The heat meter must be equipped with an interface for recording the heat quantity [kWh] or water quantity [m³]. The graphical representation, however, must be in terms of output [kW] or volume flow [m³/h]. A common heat meter for both boilers in the main return is permissible (to check the boiler output, the other boiler must be out of operation).

Table 55: Measuring point list for automatic data recording. If the installation is to be considered a standard hydraulic scheme, it must be possible to record all measured variables marked "Standard".

Area	Questions and answers
Hardware	How is the automatic data recording for operation optimisation carried out? ☐ With a separate data logger ☐ With the PLC of the biomass boiler ☐ With the master I&C system
	How is the periodic reading of the data done? ☐ Reading out the data on site ☐ Readout via landline phone (POTS) connection ☐ Readout via ISDN telephone connection ☐ Readout via the Internet
Data recording	What is the measurement interval? ☐ 10 seconds (recommendation)..... seconds
	What is the recording interval? ☐ 5 minutes (recommendation)..... minutes
	How are the analogue values recorded? ☐ As an average value over the last recording interval (recommendation) ☐ As instantaneous value
	How is the recording done for meters? ☐ As a sum value over the last recording interval (recommendation) ☐ As current counter reading (Attention: is often set to zero by mistake)
	How is the recording of running times done? ☐ As runtime during the last recording interval (recommendation) ☐ As the current number of operating hours (Attention: is often accidentally set to zero)
	How large is the measured value memory? ☐ ≥ 30 days recording capacity (recommendation)..... days recording capacity
Data evaluation	What is the output format for evaluation in EXCEL? ☐ CSV file with columns = time and measuring points, rows = values (recommendation) ☐ Other:
	How is the graphical representation done? ☐ Related data as a weekly overview (recommendation) ☐ Related data as a daily overview (recommendation) ☐ Representation of heat, oil, gas, operating hours meters as output or volume flow (demand) ☐ Other:
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of the autom. data recording by the main planner ☐ Specification of the automatic data recording by the main planner with the involvement of the I&C specialist
	How are the responsibilities regulated at the execution and approval stage? ☐ Planning of the autom. data recording by the main planner ☐ Planning of autom. data recording by biomass boiler suppliers ☐ Planning of the autom. data recording by the supplier of the master I&C system
	How are responsibilities regulated during operational optimisation? ☐ Readout and data evaluation by main planner ☐ Readout by biomass boiler supplier, data evaluation by main planner ☐ Readout by supplier of master I&C system, data evaluation by main planner ☐ Readout by operator, data evaluation by main planner ☐ Readout and data evaluation by operator

Table 56: Questions and answers on automatic data recording for operation optimisation

5.5 Annex to the approval protocol

The execution phase is concluded by the approval test. At this time, an addendum to the approval protocol is to be drawn up in accordance with Table 58.

The questions in Table 57 must be answered at the beginning of the tendering phase. The annex to the approval protocol according to Table 58 only has to be filled in at the end of the execution phase. However, it is recommended to use these tables already during the tendering and execution phase for the preliminary determination of the planning values; so that the functionality of the system is clearly recognisable.

Who prepares the addendum to the approval protocol? ☐ Main planner ☐ Biomass boiler supplier ☐ Supplier of the master I&C system

Table 57: Questions and answers on the annex to the approval protocol

Description		Unit	*Example*			
Master I&C system Connection of master/subordinate I&C systems via standard interface [9]? ☐ Yes ☐ No						
■ **Boiler return temperature protection**						
Boiler inlet temperature limit Biomass boiler 1		°C	*60*			
Boiler inlet temperature limit Biomass boiler 2		°C	*60*			
■ **Main supply temperature control** Who specifies OFF (or fire bed support) and steady regulation? ☐ The active control system ☐ Always the biomass boiler						
Main supply temperature setpoint		°C	*85*			
Continu-ous control Slave con-troller	P-band slave controller 1 (Biomass boiler 1 alone)	%	*75*			
	Integration time slave controller 1 (Biomass boiler 1 alone)	Min.	*20*			
	P-band slave controller 2 (Biomass boiler 2 alone)	%	*150*			
	Integration time slave controller 2 (Biomass boiler 2 alone)	Min.	*20*			
	P-band slave controller 3 (Biomass boiler 1+2)	%	*225*			
	Integration time slave controller 3 (Biomass boiler 1+2)	Min.	*20*			
Two-point controller	Biomass boiler 1 continuous control at setpoint firing rate.	%	*≥35*			
	Biomass boiler 1 OFF/fire bed at setpoint firing rate	%	*≤25*			
	Biomass boiler 2 continuous control at setpoint firing rate.	%	*≥35*			
	Biomass boiler 2 OFF/fire bed at setpoint firing rate	%	*≤25*			
■ **Sequence control Biomass boiler 2 - Biomass boiler 1+2 (modify if necessary)**						
Unblocking criterion Biomass boiler 1: Setpoint firing rate Biomass boiler 2 (in % of total output) AND delay time		% Min.	*100 (67)* *60*			
Blocking criterion Biomass boiler 1: Setpoint firing rate Biomass boiler 1+2 AND delay time		% Min.	*30* *60*			
Biomass boiler 1						
■ **Heat output settings**						
Set minimum heat output with the reference fuel		kW	*70*			
Set maximum heat output with the reference fuel		kW	*230*			
■ **Subordinate I&C system 1**						
Boiler water temperature setpoint for "local" operating mode		°C	*85*			
Boiler water temperature limitation		°C	*90*			
Safety shutdown at boiler water temperature		°C	*110*			
Biomass boiler 2						
■ **Heat output settings**						
Set minimum heat output with the reference fuel		kW	*140*			
Set maximum heat output with the reference fuel		kW	*470*			
■ **Subordinate I&C system 2**						
Boiler water temperature setpoint for "local" operating mode		°C	*85*			
Boiler water temperature limitation		°C	*90*			
Safety shutdown at boiler water temperature		°C	*110*			

Table 58: Annex to the approval protocol - setting values; exemplary values are to be deleted

6. Monovalent two-boiler biomass heating system with storage tank

6.1 Short description and responsibilities

6.1.1 User level

The simplest possible operation and a clear display of the main functions are required so that non-professional personnel can also operate the system:

■ The following requirements must be met for **service and emergency operation:**
- It must be possible to disable the automatic control system partially or completely for service work and in case of emergency operation (e.g. via switch "off/on/automatic").
- Subordinate I&C systems must be able to be operated independently of the master I&C system (e.g. in case of failure of the master I&C system).
- Manual operation of the control valves must be guaranteed (e.g. manual adjustment at the control valve, but this must not be disturbed by an incorrect control signal).
- All safety functions must be maintained

■ The **operation mode selection** shall be made in one of the following ways:
- Via switches in a **conventional control panel** (usually in the control cabinet).
- Via a **PLC**; however, this is only an option if the hardware and software requirements for convenient operation are right.
- Via the master computer of a **control system**

■ Further operation, such as **adjusting setpoints, changing time programmes, etc.,** can be carried out directly on the master and subordinate I&C systems (if necessary, also via the Internet).

6.1.2 Master I&C system

The master I&C system takes care of all master control and regulation functions and links the subordinate I&C systems with each other. In addition, automatic data recording is also assigned to the master I&C system, which is mandatory as a standard hydraulic scheme (at least temporarily for the duration of the operation optimisation).

6.1.3 Subordinate I&C systems biomass boilers

The subordinate I&C systems of the biomass boilers have to fulfil the following **functions:**
- Fire bed support operation or automatic ignition
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

If **particle separators** are necessary, these are to be controlled by the subordinate I&C systems of the biomass boilers.

The **safety** of the biomass boilers, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be ensured by the subordinate I&C systems of the biomass boilers.

If the PLCs of the biomass boilers can also fulfil the requirements for the master I&C system (in particular also the automatic data recording), the **simultaneous use as a master and subordinate I&C system** can be tested.

6.1.4 Selected structure of the I&C system levels

A person with main responsibility must be designated for the I&C planning (in particular also for the interface definition).

The structure of the I&C system levels with responsibilities chosen for the project to be described can be answered with Table 59.

I&C system level	**Questions and answers**
User level Section 6.1.1	Are the requirements for service and emergency operation met? ☐ Yes (mandatory for standard hydraulic scheme) ☐ No
	How does the operation mode selection take place? ☐ Switch in a conventional control panel ☐ Input via a PLC, sufficiently convenient operation is guaranteed ☐ Input via the master computer of the control system
	From where can the system be controlled and operated? ☐ Only in the central heating plant ☐ In the central heating plant and via modem ☐ In the central heating plant and via the internet
Master I&C system Section 6.1.2	How is the master I&C system implemented? ☐ Individual controller as master I&C system ☐ Use of the common PLC of the biomass boilers as a master I&C system ☐ Own master I&C system
	Connection of master/subordinate I&C systems via standard interface [9]? ☐ Yes ☐ No
	How is the automatic data recording done? ☐ Data logger during operation optimisation, an interface is provided ☐ Internal data recording in the master I&C system
Subordinate I&C systems of the biomass boilers Section 6.1.3	What is the position/tasks of the PLCs of the biomass boilers? ☐ A single PLC for both biomass boilers, which is used simultaneously as the master and subordinate I&C systems ☐ A single PLC for both biomass boilers, subordinated to the master I&C system ☐ Separate PLC for both biomass boilers, subordinated to the master I&C system
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of all I&C levels by the main planner ☐ Specification of all I&C levels by the main planner with the involvement of I&C specialists
	How are the responsibilities (especially interface definitions) regulated at the execution and approval stage? ☐ Overall planning of all I&C levels by the main planner ☐ Overall planning of all I&C levels by biomass boiler supplier ☐ Overall planning of all I&C levels by the supplier of the master I&C system ☐ Planning of each I&C level by the respective supplier (not permitted for standard hydraulic scheme, as a main person responsible for I&C planning is explicitly required).

Table 59: Questions on the chosen structure of the I&C levels and responsibilities

6.2 Principle scheme and design

6.2.1 Hydraulic circuit

The hydraulic circuit must comply with Figure 60 The following requirements must be met:

- The interconnection of the biomass boilers, the storage tank, the low-pressure difference connection and the pre-control must actually be low pressure differential (short pipes, large pipe diameters).
- The storage system must be consistently designed as a stratified storage system.
- Storage connections with cross-section enlargement (speed reduction), baffle plate (refraction of the water jet) and, if necessary, siphoned (prevention of one-pipe circulation).
- Storage connections only top and bottom (no connections in between)
- No pipes may be routed inside the storage tank (danger of "thermal agitation").
- Whenever possible, the storage tank should not be divided among several containers. If this requirement cannot be met, the following must be observed:
  - No connections between the storages
  - When controlling the storage tank charging state, each storage tank is to be considered as a control unit (problem: due to the individual stratification in each storage tank, the warmer storage tank can be colder at the bottom than the colder storage tank at the top).

The installation is also considered a standard hydraulic scheme if

- one pump is realised by two or more pumps connected in parallel or in series,
- the pre-control of the district heating network is realised by two control valves connected in parallel or with a separate summer group,
- only one common heat meter is installed for both boilers in the main return (to check the boiler output, the other boiler must be out of operation!),
- exhaust gas heat exchanger can be integrated.

6.2.2 Hydraulic and control design

The hydraulic and control design must be carried out according to the generally accepted engineering standards. The requirements according to the Q-Guideline [1] and the Planning Handbook [4] must be fulfilled, in particular:

- Storage volume ≥ 1 h storage capacity related to the nominal output of the larger biomass boiler
- Load control/boiler return temperature protection for both boilers and pre-control: Valve authority ≥ 0,5
- Design temperature difference above the biomass boilers ≤ 15 K; smaller temperature difference necessary if minimum permissible return temperature is high (e.g. with bark, landscape conservation wood); can be increased to reduce pump power consumption if it is ensured that this does not cause any control-related problems (e.g. oscillation of boiler output due to temperature stratification).
- The boiler inlet temperature should be at least 5 K higher than the minimum permissible return temperature (boiler return temperature protection).

The hydraulic and control design shall be presented and documented in accordance with Table 61.

A maximum permissible main return temperature T643 shall be specified.

If the temperature difference between the boiler outlet temperature and the boiler inlet temperature is more than 10 K less than the temperature difference between the boiler outlet temperature and the maximum permissible main return temperature T643, it is recommended to provide a **bypass in the boiler circuit D611/D621.**

Important: To ensure that the boilers can always deliver the output, it must be ensured that the main return temperature T643 cannot rise above the design value in any operating case (prescribe return temperature limiter for all consumers!).

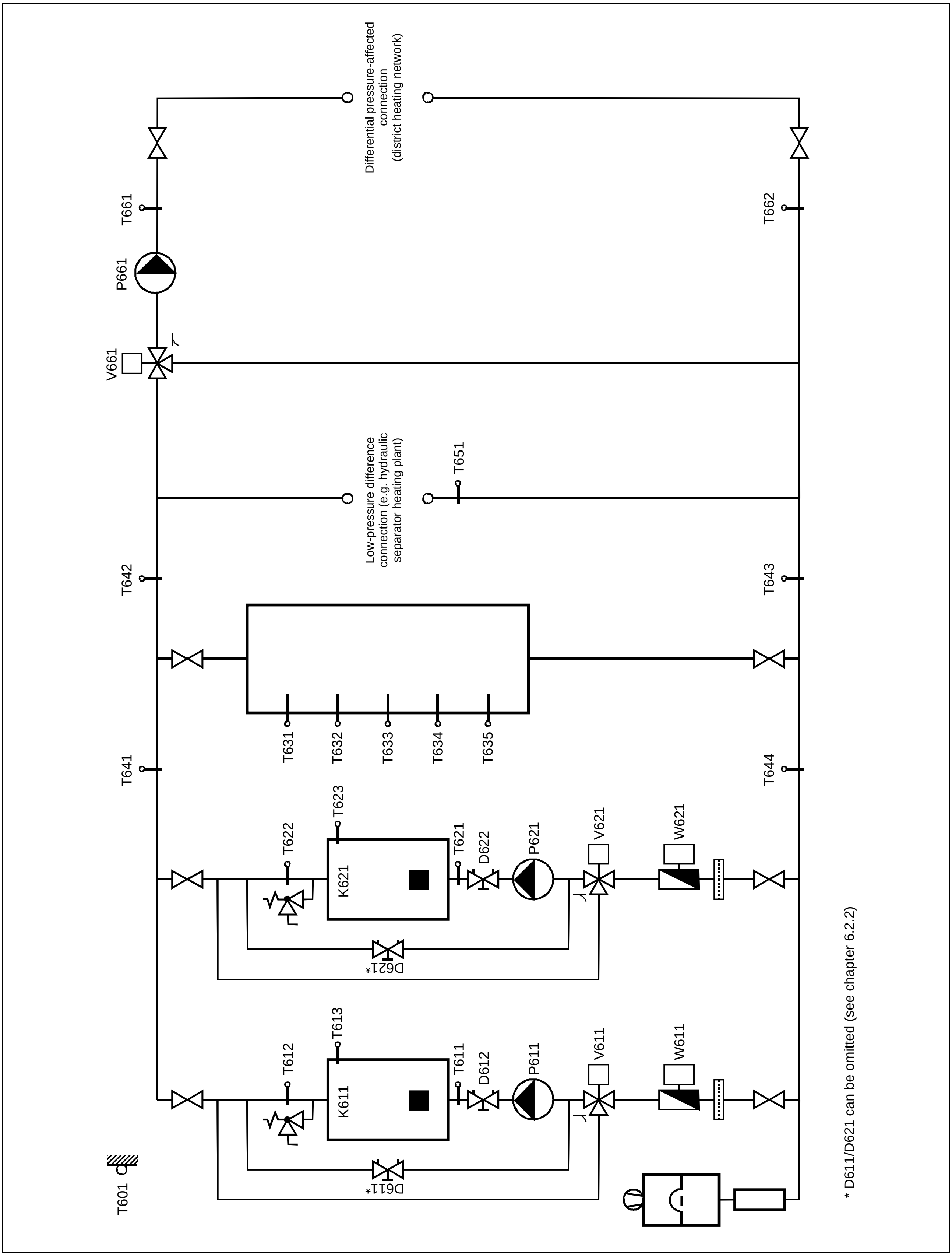

Figure 60: Principle scheme of a monovalent two-boiler biomass heating system with storage tank. Safety devices and expansion system must be designed in accordance with the country-specific regulations.

Hydraulic and control system design	**Unit**	*Example*			**Label**
Storage					
Content	m3	*14*			
Heat capacity demand of the overall system					
Low-pressure difference connection	kW	*80*			
Differential pressure-affected connection (district heating network incl. losses)	kW	*620*			
Overall system	kW	*700*			
Guaranteed temperature limits					
Main supply temperature	°C	*85*			T642
Maximum permissible main return temperature	°C	*55*			T643
Minimum permissible inlet temperature Biomass boiler 1 (boiler return temperature protection)	°C	*60*			T611
Maximum boiler water temperature Biomass boiler 1 (limiting controller)	°C	*90*			T613
Max. permissible boiler water temperature Biomass boiler 1 (safety monitor)	°C	*110*			T613
Minimum permissible inlet temp. Biomass boiler 2 (boiler return temperature protection)	°C	*60*			T621
Maximum boiler water temperature Biomass boiler 2 (limiting controller)	°C	*90*			T623
Max. permissible boiler water temperature Biomass boiler 2 (safety monitor)	°C	*110*			T623
Boiler circuit Biomass boiler 1					
Max. boiler output	kW	*230*			K611
Min. boiler output	kW	*70*			K611
Boiler outlet temperature	°C	*85*			T612/T613
Boiler pump flow rate	m3/h	*13,2*			P611
Boiler pump delivery head	m	*3*			P611
Resulting boiler inlet temperature	°C	*70*			T611
Resulting flow rate control valve boiler circuit	m3/h	*6,6*			V611
Resulting flow rate bypass	m3/h	*6,6*			D611
Pressure drop control valve	kPa	*10*			V611
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	–	*0,56*			V611
Boiler circuit Biomass boiler 2					
Max. boiler output	kW	*470*			K621
Min. boiler output	kW	*140*			K621
Boiler outlet temperature	°C	*85*			T622/T623
Boiler pump flow rate	m3/h	*27,0*			P621
Boiler pump delivery head	m	*3*			P621
Resulting boiler inlet temperature	°C	*70*			T621
Resulting flow rate control valve boiler circuit	m3/h	*13,5*			V621
Resulting flow rate bypass	m3/h	*13,5*			D621
Pressure drop control valve	kPa	*10*			V621
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	–	*0,56*			V621
Design of pre-control and network pump in chapter 9!					

Table 61: Hydraulic and control system design. The design data of the system to be executed are to be entered according to the example (the exemplary values are to be deleted).

6.3 Functional description

6.3.1 Control scheme

The control and regulation of the system is to be carried out according to Figure 62.

6.3.2 Operating modes

The following operating modes shall be provided:

- **Off:** The entire heat production system is out of operation, with the exception of the continuous operations (automatic expansion unit, etc.)
- **Manual:** Setpoint firing rate for each of the two biomass boilers can be set "manually" as fixed values on the master I&C system; this operating mode is not mandatory
- **Local:** The internal power controllers of the subordinate I&C systems of the biomass boilers are activated (the master I&C system may be out of operation or defective)
- **Automatic:** The setpoint for the firing rate is specified for both biomass boilers by the master I&C system as a function of the storage tank charging status (= main control variable) as a sequence control.
- **Boiler 1 alone - Boiler 2 alone - Sequence control:** Manual changeover of low-load operation to operation with automatic sequence control and back
- **Other operating modes:** Especially for low-load operation (transition period, summer), other operating modes may be necessary (e.g. conventional "summer/winter" changeover, low-load operation with "charge/discharge storage tank", etc.).

6.3.3 Control

The control for the specification, limitation, weather compensation and time programme control of the setpoints as well as for the unblocking and blocking of boilers, pumps, etc. must be implemented by the master I&C system.

With **weather compensation,** the outdoor air temperature can be recorded via a weather sensor on the north side of the building, and the outdoor air temperature can then be used on the one hand as an instantaneous value and on the other hand as a 24-h average value to guide the setpoints and unblocking criteria. Calculation of the 24-h mean value, for example, continuously over a window of the last 24 hours and recalculation every 15 minutes.

With a **time programme control,** time programme levels can be programmed for different functions.

6.3.4 Boiler circuit control biomass boilers

The control of the boiler circuits of the biomass boilers is to be realised by the master I&C system.

In the "automatic" operating mode, the **boiler outlet temperature** should be controlled continuously via the control valve in the boiler circuit to a fixed value. If the boiler inlet temperature falls below the limit value, the control should be set to this limit value (= **boiler return temperature protection**).

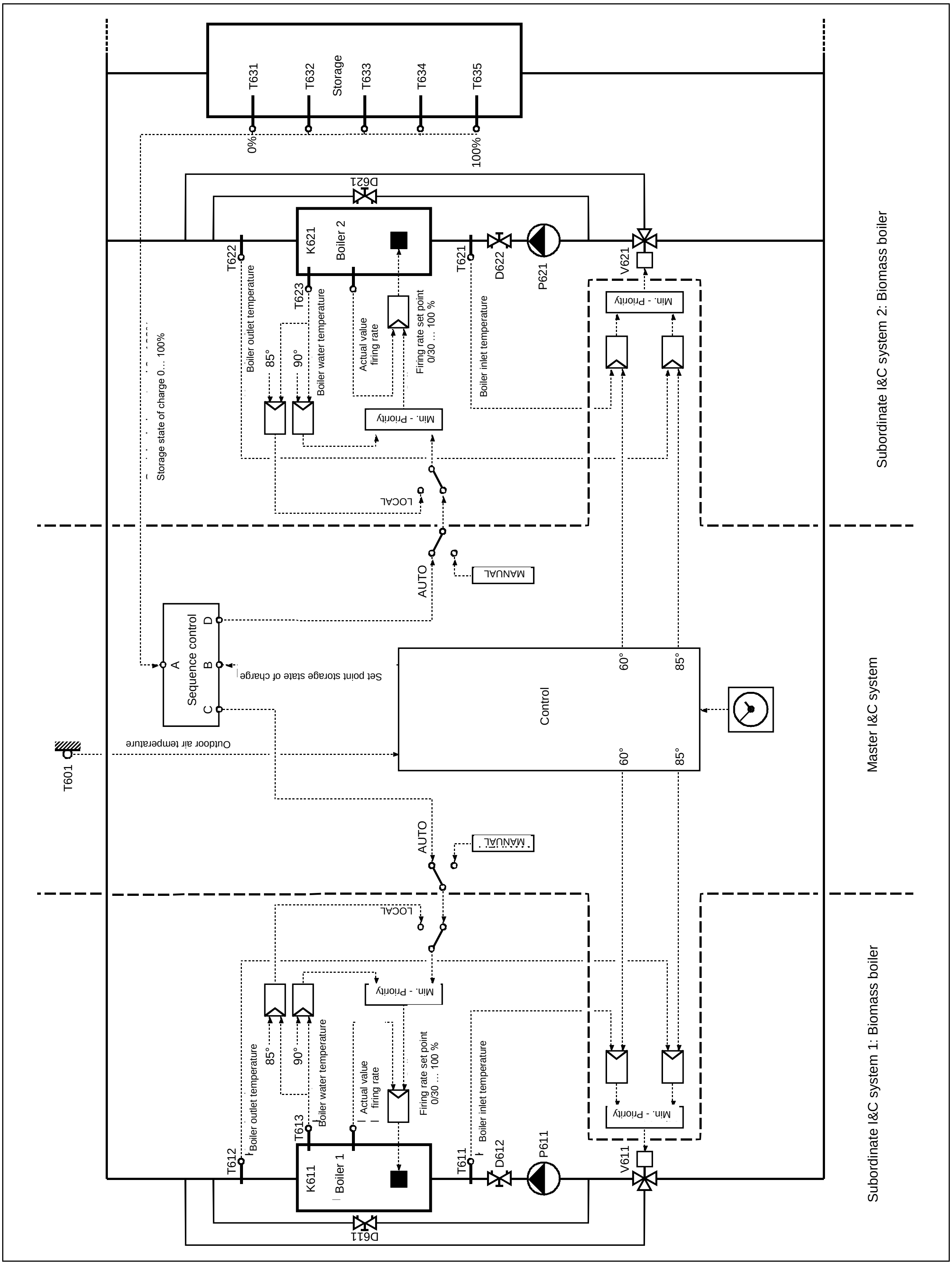

Figure 62: Control scheme standard hydraulic scheme monovalent two-boiler system with storage tank. Sequence control, see Figure 62. The minimum priority switches route the lowest input signal to the output. Numerical values are to be understood as examples. Safety functions are not shown; these are to be implemented via the subordinate I&C systems of the boilers.

6.3.5 Storage tank charging status control

The control of the storage tank charging state is to be realised by the master I&C system.

The state of charge of the storage tank should be recorded via at least 5 temperature sensors that are evenly distributed over the height of the storage tank. This gives the state of charge of the storage tank from 0% to 100%.

Different variants are possible for recording the storage tank charging status. The following applies to variants 1 and 2:
w = Sensor signals "warm" when e.g. $T \geq 75°C$
k = Sensor signals "cold" when e.g. $T \leq 65°C$

Variant 1 (Table 63**):** With sensor values 20 - 40 - 60 - 80 - 100. For "all sensors cold" the value is 0. This variant results in a stepped actual value signal. Therefore, the (fast) P component of the controller must not be too large, and disturbances must mainly be compensated via the (slow) I component.

Variant 2: The stepped signal according to variant 1 can be smoothed by a first-order control delay element (PT1 element). However, the time constant of the PT1 element must not be too large, otherwise there is a risk that the inevitable time delay of the actual value signal will lead to disturbances. The "more continuous" actual value signal, however, allows a somewhat larger P component in the controller compared to variant 1.

Sensor (from top to bottom)					Value
1	2	3	4	5	
k	k	k	k	k	0
w	k	k	k	k	20
w	w	k	k	k	40
w	w	w	k	k	60
w	w	w	w	k	80
w	w	w	w	w	100

Table 63: Variant 1 (in stages)

Variant 3 (Table 64**):** A smoothing of the characteristic curve can also be achieved if the temperature of the active sensor is interpolated.

Sensor (from top to bottom)					Value
1	2	3	4	5	
< 60°C	< 60°C	< 60°C	< 60°C	< 60°C	0
60...80°C	< 60°C	< 60°C	< 60°C	< 60°C	0...20
> 80°C	60...80°C	< 60°C	< 60°C	< 60°C	20...40
> 80°C	> 80°C	60...80°C	< 60°C	< 60°C	40...60
> 80°C	> 80°C	> 80°C	60...80°C	< 60°C	60...80
> 80°C	> 80°C	> 80°C	> 80°C	60...80°C	80...100

Table 64: Variant 3 (stepless)

With a good system, it can be assumed that for the sensor temperatures $T_1 ... T_5$ applies:

$T_1 \geq T_2 \geq T_3 \geq T_4 \geq T_5$ ($T_1 ... T_5$ from top to bottom)

The active sensor is highlighted in grey in Table 64 following rule applies:
- Sensor 1 active when all other sensor temperatures < 80°C
- Sensor 2 active when sensor temperature $T_1 > 80°C$
- Sensor 3 active when sensor temperature $T_2 > 80°C$
- Sensor 4 active when sensor temperature $T_3 > 80°C$
- Sensor 5 active when sensor temperature $T_4 > 80°C$

The quality of the interpolation (smoothing of the signal) depends on the thickness of the mixing zone in the storage tank, and this thickness is not a fixed quantity. With the same storage tank, it can be very different - depending on the flow rate, cooling, etc. Basically:
- thickness of the mixing zone zero (ideal stratified storage) results in no smoothing at all, the signal is just as stepped as in variant 1
- thickness of the mixing zone between zero and one probe distance results in an increasingly better smoothing of the signal
- Thickness of the mixing zone very slightly greater than one sensor spacing gives the best smoothing
- Thickness of the mixing zone significantly greater than a probe spacing results in poorer smoothing again

Variant 4: Average storage tank temperature as a measure of the storage tank state of charge. The disadvantage here is that the actual storage tank state of charge is reproduced differently depending on the thickness of the mixing zone, return temperature, cooling, etc: Thickness of the mixing zone zero (ideal stratified storage tank) results in no smoothing at all, the signal is just as stepped as in variant 1; when designed for 85/55°C, the control range is 30 K, when the return comes back in the morning at 25°C, this is suddenly 60 K.

More than 5 storage sensors: Only with this (in combination with variants 1 to 4) can the signal really be improved.

The storage tank is to be charged by a continuous control. This controller should have PI characteristics. As a result of the I component, the storage tank can thus be charged to a setpoint of 60...80% without a permanent control deviation (as would be the case with the P controller) (in the case of a stepped signal, select a stepped value, e.g. 60%). If the heat consumers suddenly demand more power, the storage charging state drops and the firing rate is increased, and if less power is suddenly needed, the storage charging state rises and the firing rate is regulated back. In the first case, the upper half of the storage tank is available as a power reserve until the biomass boiler has reacted, and in the second case, the biomass boiler can deliver the temporary power surplus to the lower half of the storage tank.

In systems with automatic ignition, the storage tank should be completely charged and discharged with reduced output during low-load operation (required biomass boiler output below the minimum output). A suitable switching criterion must be defined for switching from "charge/discharge" to continuous control and back (e.g. manual switching or switching according to time programme and outdoor air temperature).

6.3.6 Firing rate control biomass boilers

The firing rate is controlled via the subordinate I&C systems of the biomass boilers.

At least Biomass boiler 1 shall be equipped with automatic ignition. If this is not possible or not reasonable according to the state of the art, fired bed support operation can be used. In principle, the biomass-fired furnace should always be operated at the lowest possible output so that they have to be switched on and off as little as possible.

The controller for the storage charging state of the master I&C system specifies the setpoints for the firing rate to the biomass-fired furnace as a sequence control. With the help of the controller, the setpoints for the firing rate can then be additionally guided and limited.

The internal controllers for the boiler water temperatures T613/T623 of the two subordinate I&C systems have the following functions:

- "Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the main supply temperature T641, but limitation of the boiler water temperature T613/T623 (e.g. to 90°C).
- "Local" operating mode: Control of the boiler water temperature T613/T623 to a fixed value set on the subordinate I&C system (e.g. 85°C), limitation of the boiler water temperature T613/T623 to a higher fixed value (e.g. to 90°C).
- Operating mode "automatic": Limiting the boiler water temperature T613/T623 (e.g. to 90°C)

In the output control range of the biomass-fired furnace of 30...100%, the control should be continuous. Below this, the control must be in two-point mode. Switching between OFF (or fire bed support) and continuous control is done via the respective active I&C system. If the biomass boiler manufacturer so wishes, the switchover can also always be made via the biomass boiler.

A recommendation for standard interfaces between the master I&C system and the biomass boiler, as well as a list of control unit and biomass boiler manufacturers offering these interfaces, can be downloaded from the Internet [9].

Important: The safety of the biomass boilers, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be additionally ensured by the subordinate I&C system of the biomass boilers.

6.3.7 Sequence control biomass boilers

The sequence control of the biomass boilers is to be realised by the master I&C system.

The following example assumes a power split of the two biomass boilers of 33% for boiler 1 and 67% for boiler 2. Switching from low-load operation to operation with automatic sequence control and back is done manually (percentages refer to the total output):

- Manual switchover to boiler 2 alone (20...67%) if boiler 1 alone (10...33%) can no longer cover the daily demand
- Manual switchover to automatic sequence control if boiler 2 alone (20...67%) can no longer cover the daily demand.
- Manual switch back to boiler 2 alone (20...67%) when the daily demand can again be covered by boiler 2 alone for the foreseeable future.
- Manual switch back to boiler 1 alone (10...33%) when the daily demand can again be covered by boiler 1 alone for the foreseeable future.

The automatic sequence control must be carried out as follows (percentages refer to the total power):

- boiler 2 alone (20...67%)
- Automatic connection of boiler 1 (10...33%) by means of automatic ignition (or fired bed support operation for large systems) if boiler 2 (20...67%) can no longer cover the hourly heat demand.
- Parallel operation boiler 1 and boiler 2 (together 30...100%)
- Automatic switch back to boiler 2 alone (20...67%) if the hourly heat demand falls below the sum of the two minimum outputs of 30%.

Figure 65 shows an example of the implementation of the sequence control.

The boiler that is not in operation must be completely isolated hydraulically from the rest of the system (no faulty circulation due to overrun times, incorrectly set three-way valves, short circuits via safety lines, etc.).

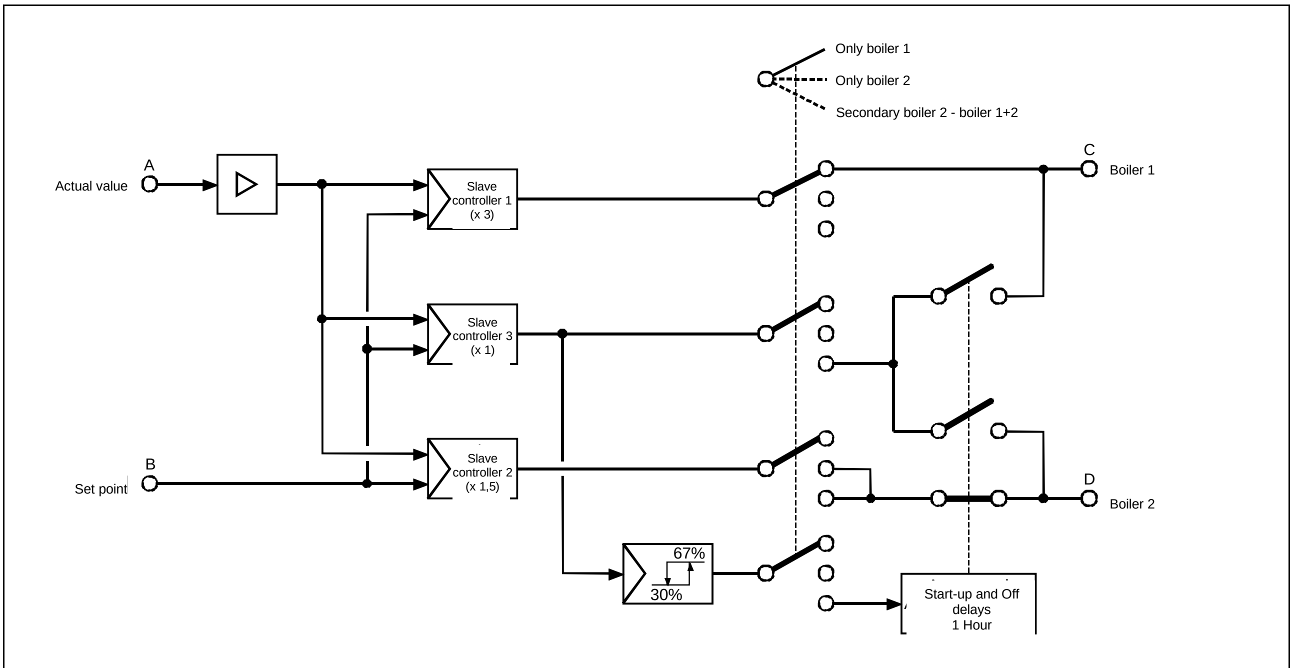

Figure 65: Example for the realisation of the sequence control. Interfaces A-D refer to Figure 62. To ensure that the circuit gain is the same for all three control circuits, the transmission coefficients of the three controllers are to be selected in a ratio of 3 : 1,5 : 1 (P-band reciprocal values 0,33 : 0,67 : 1).

6.3.8 Chosen control concept

The concept applicable to the project to be described, how the control of the boiler circuits, the storage tank charging state and the firing rates is to be carried out, is to be defined in Table 66 (an example is entered).

Operating mode	**Boiler circuit control: - Biomass boiler 1 - Biomass boiler 2**	**Storage tank state of charge control (= main control variable)**	**Regulation of firing rates - Biomass boiler 1 - Biomass boiler 2**
Off	Inoperative		
Manual ☐ Not provided	☐ T611/T621 boiler return temperature protection systems by master I&C system ☐ Control of boiler outlet temperatures T612/T622 by master I&C system ☐ Limitation of boiler water temperatures T613/T623 by subordinate I&C systems	☐ Storage tank charging status control out of operation	☐ Setpoints of the two firing rates can be set as fixed values on the master I&C system
Local	☐ Control of boiler water temperatures T613/T623 by subordinate I&C systems	☐ Storage tank charging status control out of operation	☐ Internal power controllers of the subordinate I&C systems activated
Automatic Summer operation? ☐ Yes ☐ No	☐ T611/T621 boiler return temperature protection systems by master I&C system ☐ Control of boiler outlet temperatures T612/T622 by master I&C system ☐ Limitation of boiler water temperatures T613/T623 by subordinate I&C systems	☐ Control of the storage tank charging status by the master I&C system according to a special sequence control; the correcting variable is the setpoint values of the two firing rates. ☐ Charge/discharge storage tank (low load operation)	☐ Control of the two firing rates by the subordinate I&C systems; setpoints from the master I&C system according to special sequence control
Acquisition of storage tank state of charge	Number of storage tank sensors: ...... (at least 5) ☐ Stepped signal (variant 1) ☐ Smoothing with PT1 element (variant 2) ☐ Smoothing by interpolation via the temperature of the respective active sensor (variant 3) ☐ Average storage tank temperature as a measure of the storage tank charging status (variant 4)		
Summary	Which operating modes are provided? ☐ Off ☐ Manual (for each boiler) ☐ Local (for each boiler) ☐ Automatic winter operation Biomass boiler 1 alone (small boiler) ☐ Automatic winter operation Biomass boiler 2 alone (large boiler) ☐ Automatic winter operation Biomass boiler 1 + 2 in parallel (without automatic sequence control) ☐ Automatic sequence control Biomass boiler 2 alone - Biomass boiler 1 + 2 in parallel ☐ Automatic low-load operation (transition period, summer) by charging/discharging storage with Biomass boiler 1 ☐ Other:		

Table 66: Questions and answers on the chosen control concept

6.4 Data recording for operational optimisation

All precautions must be taken so that a proper operational optimisation can be carried out and the subsequent regular operation can be efficiently monitored. The measured variables to be recorded are to be marked with a cross in Table 67 measured variables marked "Standard" must be able to be recorded in any case; the connection of the remaining measured variables is recommended. The measuring accuracy must meet the increased requirements of a measuring system.

The questions and answers on automatic data recording for operation optimisation in Table 68 must be answered.

☑	Standard	Measuring points	Label
☐	Standard	Outdoor air temperature	T601
☐	Standard	Inlet temperature Biomass boiler 1	T611
☐	Standard	Outlet temperature Biomass boiler 1	T612
☐		Boiler water temperature Biomass boiler 1 (other measuring point)	T613
☐	Standard	Inlet temperature Biomass boiler 2	T621
☐	Standard	Outlet temperature Biomass boiler 2	T622
☐		Boiler water temperature Biomass boiler 2 (other measuring point)	T623
☐	Standard *	Main supply temperature before storage tank	T641
☐	Standard *	Main supply temperature after storage tank	T642
☐	Standard	Main return temperature before storage tank	T643
☐	Standard *	Main return temperature after storage tank	T644
☐	Standard	Storage tank temperature (top)	T631
☐	Standard	Storage tank temperature	T632
☐	Standard	Storage tank temperature (middle)	T633
☐	Standard	Storage tank temperature	T634
☐	Standard	Storage tank temperature (bottom)	T635
☐	Standard *	Return temperature of the low-pressure difference connection	T651
☐	Standard	Supply temperature of the differential pressure-affected connection	T661
☐	Standard *	Return temperature of the differential pressure-affected connection	T662
☐	Standard	Heat quantity/output heat meter Biomass boiler 1 **	W611
☐		Water quantity/flow rate heat meter Biomass boiler 1 **	W611
☐	Standard	Heat quantity/output heat meter Biomass boiler 2 **	W621
☐		Water quantity/flow rate heat meter Biomass boiler 2 **	W621
☐	Standard	Setpoint of the firing rate Biomass boiler 1	
☐		Boiler-internal setpoint of the firing rate (feedback signal Biomass boiler 1)	
☐	Standard	Setpoint of the firing rate Biomass boiler 2	
☐		Boiler-internal setpoint of the firing rate (feedback signal Biomass boiler 2)	
☐	Standard	Actual value of the storage tank charging state	
☐	Standard	Flue gas temperature Biomass boiler 1	
☐		Combustion chamber temperature Biomass boiler 1	
☐	Standard *	Residual oxygen Biomass boiler 1	
☐	Standard	Flue gas temperature Biomass boiler 1	
☐		Combustion chamber temperature Biomass boiler 1	
☐	Standard *	Residual oxygen Biomass boiler 1	
		Measuring points Particle separator 1; type:	
☐			
☐			
		Measuring points Particle separator 2; type:	
☐			
☐			

* In order to reduce the effort for data recording, a reduction by these measuring points is accepted as permissible deviation for operation optimisation.

** The heat meter must be equipped with an interface for recording the heat quantity [kWh] or water quantity [m³]. The graphical representation, however, must be in terms of output [kW] or volume flow [m³/h]. A common heat meter for both boilers in the main return is permissible (to check the boiler output, the other boiler must be out of operation).

Table 67: Measuring point list for automatic data recording. If the installation is to be considered a standard hydraulic scheme, it must be possible to record all measured variables marked "Standard".

Area	Questions and answers
Hardware	How is the automatic data recording for operation optimisation carried out? ☐ With a separate data logger ☐ With the PLC of the biomass boiler ☐ With the master I&C system
	How is the periodic reading of the data done? ☐ Readout of data on site, i.e. no telephone connection/modem necessary ☐ landline phone connection with analogue modem ☐ ISDN telephone connection with terminal adapter
Data recording	What is the measurement interval? ☐ 10 seconds (recommendation)..... seconds
	What is the recording interval? ☐ 5 minutes (recommendation)..... minutes
	How are the analogue values recorded? ☐ As an average value over the last recording interval (recommendation) ☐ As instantaneous value
	How is the recording done for meters? ☐ As a sum value over the last recording interval (recommendation) ☐ As current counter reading (Attention: is often set to zero by mistake)
	How is the recording of running times done? ☐ As runtime during the last recording interval (recommendation) ☐ As the current number of operating hours (Attention: is often accidentally set to zero)
	How large is the measured value memory? ☐ ≥ 30 days recording capacity (recommendation)..... days recording capacity
Data evaluation	What is the output format for evaluation in EXCEL? ☐ CSV file with columns = time and measuring points, rows = values (recommendation) ☐ Other:
	How is the graphical representation done? ☐ Related data as a weekly overview (recommendation) ☐ Related data as a daily overview (recommendation) ☐ Representation of heat, oil, gas, operating hours meters as output or volume flow (demand) ☐ Other:
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of the autom. data recording by the main planner ☐ Specification of the automatic data recording by the main planner with the involvement of the I&C specialist
	How are the responsibilities regulated at the execution and approval stage? ☐ Planning of the autom. data recording by the main planner ☐ Planning of autom. data recording by biomass boiler suppliers ☐ Planning of the autom. data recording by the supplier of the master I&C system
	How are responsibilities regulated during operational optimisation? ☐ Readout and data evaluation by main planner ☐ Readout by biomass boiler supplier, data evaluation by main planner ☐ Readout by supplier of master I&C system, data evaluation by main planner ☐ Readout by operator, data evaluation by main planner ☐ Readout and data evaluation by operator

Table 68: Questions and answers on automatic data recording for operation optimisation

6.5 Annex to the approval protocol

The execution phase is concluded by the approval test. At this time, an addendum to the approval protocol is to be drawn up in accordance with Table 70.

The questions in Table 69 must be answered at the beginning of the tendering phase. The annex to the approval protocol according to Table 70 does not have to be filled in until the end of the execution phase. However, it is recommended to use these tables already during the tendering and execution phase for the provisional determination of the planning values; only in this way will the functioning of the system be clearly recognisable.

Who prepares the addendum to the approval protocol? ☐ Main planner ☐ Biomass boiler supplier ☐ Supplier of the master I&C system

Table 69: Questions and answers on the annex to the approval protocol

<table>
<tr><th colspan="2">Description</th><th>Unit</th><th>Example</th><th></th><th></th><th></th></tr>
<tr><td colspan="2">Master I&C system
Connection of master/subordinate I&C systems via standard interface [9]?
☐ Yes ☐ No</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">■ Load control</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Boiler outlet temperature setpoint Biomass boiler 1</td><td>°C</td><td>85</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Setpoint boiler outlet temperature Biomass boiler 2</td><td>°C</td><td>85</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">■ Boiler return temperature protection</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Boiler inlet temperature limit Biomass boiler 1</td><td>°C</td><td>60</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Boiler inlet temperature limit Biomass boiler 2</td><td>°C</td><td>60</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">■ Storage charge control
Who specifies OFF (or fire bed support) and steady regulation?
☐ The active control system ☐ Always the biomass boiler
How is the "continuous control" switched to "charge/discharge storage tank"? ☐ Switchover by hand ☐ Other:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Setpoint storage tank state of charge</td><td>%</td><td>60</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Setpoint storage tank sensor "warm”</td><td>°C</td><td>≥75</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Setpoint storage tank sensor "cold”</td><td>°C</td><td>≤65</td><td></td><td></td><td></td></tr>
<tr><td rowspan="6">Continuous regulation in sequence</td><td>P-band slave controller 1 (Biomass boiler 1 alone)</td><td>%</td><td>75</td><td></td><td></td><td></td></tr>
<tr><td>Integration time slave controller 1 (Biomass boiler 1 alone)</td><td>Min.</td><td>20</td><td></td><td></td><td></td></tr>
<tr><td>P-band slave controller 2 (Biomass boiler 2 alone)</td><td>%</td><td>150</td><td></td><td></td><td></td></tr>
<tr><td>Integration time slave controller 2 (Biomass boiler 2 alone)</td><td>Min.</td><td>20</td><td></td><td></td><td></td></tr>
<tr><td>P-band slave controller 3 (Biomass boiler 1+2)</td><td>%</td><td>225</td><td></td><td></td><td></td></tr>
<tr><td>Integration time slave controller 3 (Biomass boiler 1+2)</td><td>Min.</td><td>20</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Two-point controller in the sequence</td><td>Biomass boiler 1 continuous control at setpoint firing rate.</td><td>%</td><td>≥35</td><td></td><td></td><td></td></tr>
<tr><td>Biomass boiler 1 OFF/fire bed at setpoint firing rate</td><td>%</td><td>≤25</td><td></td><td></td><td></td></tr>
<tr><td>Biomass boiler 2 continuous control at setpoint firing rate.</td><td>%</td><td>≥35</td><td></td><td></td><td></td></tr>
<tr><td>Biomass boiler 2 OFF/fire bed at setpoint firing rate</td><td>%</td><td>≤25</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">■ Sequence control Biomass boiler 2 - Biomass boiler 1+2 (modify if necessary)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Unblocking criterion Biomass boiler 1:
Setpoint firing rate Biomass boiler 2 (in % of total output)
AND delay time</td><td>%
Min.</td><td>100 (67)
60</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Blocking criterion Biomass boiler 1:
Setpoint firing rate Biomass boiler 1+2
AND delay time</td><td>%
Min.</td><td>30
60</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Biomass boiler 1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">■ Heat output settings</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Set minimum heat output with the reference fuel</td><td>kW</td><td>70</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Set maximum heat output with the reference fuel</td><td>kW</td><td>230</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">■ Subordinate I&C system 1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Boiler water temperature setpoint for "local" operating mode</td><td>°C</td><td>85</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Boiler water temperature limitation</td><td>°C</td><td>90</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Safety shutdown at boiler water temperature</td><td>°C</td><td>110</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Biomass boiler 2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">■ Heat output settings</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Set minimum heat output with the reference fuel</td><td>kW</td><td>140</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Set maximum heat output with the reference fuel</td><td>kW</td><td>470</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">■ Subordinate I&C system 2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Boiler water temperature setpoint for "local" operating mode</td><td>°C</td><td>85</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Boiler water temperature limitation</td><td>°C</td><td>90</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Safety shutdown at boiler water temperature</td><td>°C</td><td>110</td><td></td><td></td><td></td></tr>
</table>

Table 70: Annex to the approval protocol - setting values; exemplary values are to be deleted

7. Bivalent three-boiler system without storage tank (2 biomass boilers, 1 oil/gas boiler)

7.1 Short description and responsibilities

7.1.1 User level

The simplest possible operation and a clear display of the main functions are required so that non-professional personnel can also operate the system:

■ The following requirements must be met for **service and emergency operation:**
- It must be possible to disable the automatic control system partially or completely for service work and in case of emergency operation (e.g. via switch "off/on/automatic").
- Subordinate I&C systems must be able to be operated independently of the master I&C system (e.g. in case of failure of the master I&C system).
- Manual operation of the control valves must be guaranteed (e.g. manual adjustment at the control valve, but this must not be disturbed by an incorrect control signal).
- All safety functions must be maintained

■ The **operation mode selection** shall be made in one of the following ways:
- Via switches in a conventional control panel (usually in the control cabinet).
- Via a PLC; however, this is only an option if the hardware and software requirements for convenient operation are right.
- Via the master computer of a **control system**

■ Further operation, such as **adjusting setpoints, changing time programmes, etc.,** can be carried out directly on the master and subordinate I&C systems (if necessary, also via the Internet).

7.1.2 Master I&C system

The master I&C system takes care of all master control and regulation functions and links the subordinate I&C systems with each other. In addition, automatic data recording is also assigned to the master I&C system, which is mandatory as a standard hydraulic scheme (at least temporarily for the duration of the operation optimisation).

7.1.3 Subordinate I&C systems biomass boilers

The subordinate I&C systems of the biomass boilers have to fulfil the following **functions:**
- Fire bed support operation or automatic ignition
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

If **particle separators** are necessary, these are to be controlled by the subordinate I&C systems of the biomass boilers.

The **safety** of the biomass boilers, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be ensured by the subordinate I&C systems of the biomass boilers.

If the PLCs of the biomass boilers can also fulfil the requirements for the master I&C system (in particular also the automatic data recording), the **simultaneous use as a master and subordinate I&C system can be** tested.

7.1.4 Subordinate I&C system oil/gas boiler

The subordinate I&C system of the oil/gas boiler has to fulfil the following **functions:**
- pre-purge, ignition and flame monitoring
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system (continuous in modulating operation, in stages in multi-stage operation)
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

The **safety** of the oil/gas boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be ensured by the subordinate I&C system of the oil/gas boiler.

7.1.5 Selected structure of the I&C system levels

A person with main responsibility must be designated for the I&C planning (in particular also for the interface definition).

The structure of the I&C system levels with responsibilities chosen for the project to be described can be answered with Table 71.

I&C system level	Questions and answers
User level Section 7.1.1	Are the requirements for service and emergency operation met? ☐ Yes (mandatory for standard hydraulic scheme) ☐ No
	How does the operation mode selection take place? ☐ Switch in a conventional control panel ☐ Input via a PLC, sufficiently convenient operation is guaranteed ☐ Input via the master computer of the control system
	From where can the system be controlled and operated? ☐ Only in the central heating plant ☐ In the central heating plant and via modem ☐ In the central heating plant and via the internet
Master I&C system Section 7.1.2	How is the master I&C system implemented? ☐ Individual controller as master I&C system ☐ Use of the common PLC of the biomass boilers as a master I&C system ☐ Own master I&C system
	Connection of master/subordinate I&C systems via standard interface [9]? ☐ Yes ☐ No
	How is the automatic data recording done? ☐ Data logger during operation optimisation, an interface is provided ☐ Internal data recording in the master I&C system
Subordinate I&C systems of the biomass boilers Section 7.1.3	What is the position/tasks of the PLCs of the biomass boilers? ☐ A single PLC for both biomass boilers, which is used simultaneously as the master and subordinate I&C systems ☐ A single PLC for both biomass boilers, subordinated to the master I&C system ☐ Separate PLC for both biomass boilers, subordinated to the master I&C system
Subordinate I&C system of the Oil/gas boiler Section 7.1.4	What is the position/tasks of the I&C system of the oil/gas boiler? ☐ It is subordinated to the master I&C system
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of all I&C levels by the main planner ☐ Specification of all I&C levels by the main planner with the involvement of I&C specialists
	How are the responsibilities (especially interface definitions) regulated at the execution and approval stage? ☐ Overall planning of all I&C levels by the main planner ☐ Overall planning of all I&C levels by biomass boiler supplier ☐ Overall planning of all I&C levels by the supplier of the master I&C system ☐ Planning of each I&C level by the respective supplier (not permitted for standard hydraulic scheme, as a main person responsible for I&C planning is explicitly required).

Table 71: Questions and answers on the chosen structure of the I&C levels and responsibilities

7.2 Principle scheme and design

7.2.1 Hydraulic circuit

The hydraulic circuit must comply with Figure 72 The following requirements must be met:

9. The circuit must actually be made low in pressure difference by the bypass, i.e. the shortest possible bypass and pipe diameter bypass = pipe diameter main flow
10. The interconnection of the biomass boiler, the oil/gas boiler, the bypass, the low-pressure difference connection and the pre-control must actually be low pressure differential (short pipes, large pipe diameters).
11. Make sure that the sensor for the main supply temperature is properly mixed (install a static mixer if necessary).

The installation is also considered a standard hydraulic scheme if
- one pump is realised by two or more pumps connected in parallel or in series,
- the pre-control of the district heating network is realised by two control valves connected in parallel or with a separate summer group,
- only one common heat meter is installed for both biomass boilers in the main return (to check the boiler output, the other boiler must be out of operation!),
- exhaust gas heat exchanger can be integrated.

7.2.2 Hydraulic and control design

The hydraulic and control design must be carried out according to the generally accepted engineering standards. The requirements according to the Q-Guideline [1] and the Planning Handbook [4] must be fulfilled, in particular:

- Boiler return temperature protection for the boilers and the pre-control: Valve authority ≥ 0,5
- Design temperature difference above the biomass boilers ≤ 15 K; smaller temperature difference necessary if minimum permissible return temperature is high (e.g. with bark, landscape conservation wood); can be increased to reduce pump power consumption if it is ensured that this does not cause any control-related problems (e.g. oscillation of boiler output due to temperature stratification).
- The boiler inlet temperature should be at least 5 K higher than the minimum permissible return temperature (boiler return temperature protection).

If the oil/gas boiler does not require a boiler return temperature protection, the three-way valve can be replaced by a tightly closing motorised damper.

The hydraulic and control design shall be presented and documented in accordance with Table 73 and Table 74.

A maximum permissible main return temperature T743 shall be specified.

If the temperature difference between the boiler outlet temperature and the boiler inlet temperature is more than 10 K less than the temperature difference between the boiler outlet temperature and the maximum permissible main return temperature T743, a **bypass** can be provided in **the boiler circuit D711/D721/D731** (may not be desirable for keeping the boiler water temperatures low).

Important: To ensure that the boilers can always deliver the output, it must be ensured that the main return temperature T743 cannot rise above the design value in any operating case (prescribe return temperature limiter for all consumers!).

Hydraulically and in terms of control technology, this circuit is demanding. Ultimately, the main planner must decide whether the present WE7 circuit without storage tank is feasible or whether the next WE8 circuit with storage tank is necessary. The following requirements should be met for the WE7 circuit:
- No too large load peaks and no oversized boilers
- Relatively stable main control variable (main supply temperature), i.e. no disturbance variables occurring abruptly with high power and a stably set pre-control.
- A sufficiently large distance must be possible between the setpoint of the main supply temperature and the limitation of the boiler water temperatures of the biomass boilers, so that a "floating" of the boilers without limitation of the biomass boiler outputs is possible.
- Useful unblocking and blocking criteria for the sequence control of biomass boiler 1+2 - oil/gas boiler, in order to successfully prevent frequent switching on and off.

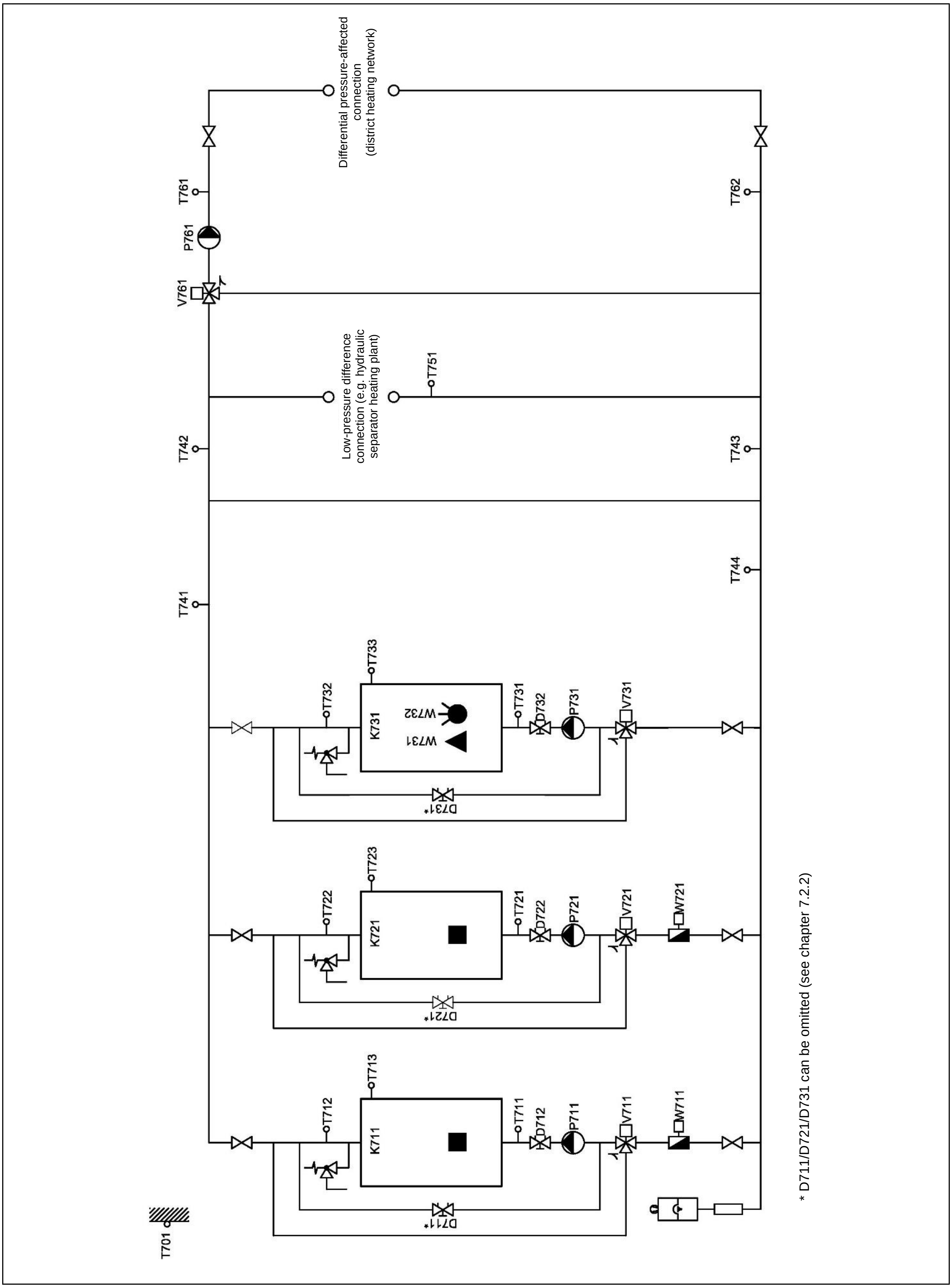

Figure 72: Principle scheme of a bivalent three-boiler system without storage tank. Safety devices and expansion system must be designed in accordance with the country-specific regulations.

Hydraulic and control system design	**Unit**	*Example*			**Label**
Heat capacity demand of the overall system					
Low-pressure difference connection	kW	*200*			
Differential pressure-affected connection (district heating network incl. losses)	kW	*1800*			
Overall system	kW	*2000*			
Guaranteed temperature limits					
Main supply temperature	°C	*85*			T742
Maximum permissible main return temperature	°C	*55*			T743
Minimum permissible inlet temperature Biomass boiler 1 (boiler return temperature protection)	°C	*60*			T711
Maximum boiler water temperature Biomass boiler 1 (limiting controller)	°C	*90*			T713
Max. permissible boiler water temperature Biomass boiler 1 (safety monitor)	°C	*110*			T713
Minimum permissible inlet temp. Biomass boiler 2 (boiler return temperature protection)	°C	*60*			T721
Maximum boiler water temperature Biomass boiler 2 (limiting controller)	°C	*90*			T723
Max. permissible boiler water temperature Biomass boiler 2 (safety monitor)	°C	*110*			T723
Minimum permissible inlet temperature oil-gas boiler (boiler return temperature protection)	°C	*60*			T731
Maximum boiler water temperature oil-gas boiler (limiting controller)	°C	*90*			T733
Max. perm. boiler water temperature oil-gas boiler (safety monitor)	°C	*110*			T733
Boiler circuit Biomass boiler 1					
Max. boiler output	kW	*450*			K711
Min. boiler output	kW	*135*			K711
Boiler outlet temperature	°C	*85*			T712/T713
Boiler pump flow rate	m3/h	*25,8*			P711
Boiler pump delivery head	m	*3*			P711
Resulting boiler inlet temperature	°C	*70*			T711
Resulting flow rate control valve boiler circuit	m3/h	*25,8*			V711
Resulting flow rate bypass	m3/h	*0*			D711
Pressure drop control valve	kPa	*10*			V711
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	- –	*0,56*			V711
Boiler circuit Biomass boiler 2					
Max. boiler output	kW	*900*			K721
Min. boiler output	kW	*270*			K721
Boiler outlet temperature	°C	*85*			T722/T723
Boiler pump flow rate	m3/h	*51,6*			P721
Boiler pump delivery head	m	*3*			P721
Resulting boiler inlet temperature	°C	*70*			T721
Resulting flow rate control valve boiler circuit	m3/h	*51,6*			V721
Resulting flow rate bypass	m3/h	*0*			D721
Pressure drop control valve	kPa	*10*			V721
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	- –	*0,56*			V721

Table 73: Hydraulic and control design (Part 1). To keep the boiler water temperatures low, it makes sense to keep the temperature difference over the boilers low; therefore, bypasses D711/7321/D731 were omitted in the example. The design data of the system to be executed are to be entered according to the example (the exemplary values are to be deleted).

Hydraulic and control system design	**Unit**	*Example*			**Label**
Boiler circuit oil/gas boiler					
Max. boiler output	kW	*1550*			K731
Min. boiler output	kW	*620*			K731
Boiler outlet temperature	°C	*85*			T732/T733
Boiler pump flow rate	m3/h	*88,9*			P731
Boiler pump delivery head	m	*3*			P731
Resulting boiler inlet temperature	°C	*70*			T731
Resulting flow rate control valve boiler circuit	m3/h	*88,9*			V731
Resulting flow rate bypass	m3/h	*0*			D731
Pressure drop control valve	kPa	*10*			V731
Pressure drop section with variable volume flow	kPa	*8*			- –
Resulting valve authority	- –	*0,56*			V731
Design of pre-control and network pump in chapter 9!					

Table 74: Hydraulic and control design (Part 2). To keep the boiler water temperatures low, it makes sense to keep the temperature difference over the boilers low; therefore, bypasses D711/7321/D731 were omitted in the example. The design data of the system to be executed are to be entered according to the example (the exemplary values are to be deleted).

7.3 Functional description

7.3.1 Control scheme

The control and regulation of the system should be carried out according to Figure 75and Figure 76.

7.3.2 Operating modes

The following operating modes shall be provided:

■ **Off:** The entire heat production system is out of operation, with the exception of the continuous operations (automatic expansion unit, etc.)

■ **Manual:** Setpoint firing rate for each of the two biomass boilers can be set "manually" as fixed values on the master I&C system; this operating mode is not mandatory

■ **Local:** The internal power controllers of the subordinate I&C systems of the boilers are activated (the master I&C system may be out of operation or defective)

■ **Automatic:** The setpoint for the firing rate is specified for all boilers by the master I&C system as a function of the main supply temperature (= main control variable) as a sequence control.

■ **Biomass boiler 1 alone - Biomass boiler 2 alone - Sequence control:** Manual changeover from low-load operation to operation with automatic sequence control and back

■ **Other operating modes:** Especially for low-load operation (transition period, summer), other operating modes may be necessary (e.g. conventional "summer/winter" changeover, low-load operation with "oil/gas boiler alone", etc.).

7.3.3 Control

The control for the specification, limitation, weather compensation and time programme control of the setpoints as well as for the unblocking and blocking of boilers, pumps, etc. must be implemented by the master I&C system.

With **weather compensation,** the outdoor air temperature can be recorded via a weather sensor on the north side of the building, and the outdoor air temperature can then be used on the one hand as an instantaneous value and on the other hand as a 24-h average value to guide the setpoints and unblocking criteria. Calculation of the 24-h mean value, for example, continuously over a window of the last 24 hours and recalculation every 15 minutes.

With a **time programme control,** time programme levels can be programmed for different functions.

7.3.4 Boiler circuit control biomass boilers

The control of the boiler circuits of the biomass boilers is to be realised by the master I&C system.

In the "automatic" operating mode, if the boiler inlet temperature falls below the limit value, control must take place at this limit value (= **boiler return temperature protection**).

In the "manual" operating mode, a boiler return temperature protection should also take place.

In the "local" operating mode, the boiler return temperature protection should continue to be in operation if the master I&C system is still functioning (which may no longer be the case in emergency operation).

7.3.5 Boiler circuit control oil/gas boiler

The control of the boiler circuit for the oil/gas boiler is to be realised by the master I&C system.

In the "automatic" operating mode, if the boiler inlet temperature falls below the limit value, control must take place at this limit value (= **boiler return temperature protection**).

In the "manual" operating mode, a boiler return temperature protection should also take place.

In the "local" operating mode, the boiler return temperature protection should continue to be in operation if the master I&C system is still functioning (which may no longer be the case in emergency operation).

If the oil/gas boiler does not require a return temperature protection, this function is omitted.

7.3.6 Main supply temperature control

The control of the main supply temperature is to be realised by the master I&C system.

The main supply temperature is to be controlled to a fixed value by adjusting the setpoint values of the firing rate (= correcting variables) for the three boilers.

Important: The firing rates of the three boilers are controlled via the main supply temperature, i.e. the mixed temperature of the three boiler outlet temperatures. Careful hydraulic balancing is necessary and the controllers for limiting the boiler water temperatures must be set 5...10 K above the setpoint of the main supply temperature.

7.3.7 Firing rate control biomass boilers

The firing rate is controlled via the subordinate I&C systems of the biomass boilers.

At least Biomass boiler 1 shall be equipped with automatic ignition. If this is not possible or not reasonable according to the state of the art, fired bed support operation can be used. In principle, the biomass-fired furnace should always be operated at the lowest possible output so that they have to be switched on and off as little as possible.

The controller for the main supply temperature of the master I&C system specifies the setpoints for the firing rate to the biomass firing units as a sequence control. With the help of the controller, the setpoints for the firing rate can then be additionally guided and limited.

The internal controllers for the boiler water temperatures T713/T723 of the two subordinate I&C systems have the following functions:

- “Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the main supply temperature T741, but limitation of the boiler water temperature T713/T723 (e.g. to 90°C).
- “Local" operating mode: Control of the boiler water temperature T713/T723 to a fixed value set on the subordinate I&C system (e.g. 85°C), limitation of the boiler water temperature T713/T723 to a fixed value higher by approx. 5...10 K (e.g. to 90°C).
- Operating mode "automatic": Limiting the boiler water temperature T713/T723 (e.g. to 90°C)

In the output control range of the biomass-fired furnace of 30...100%, the control should be continuous. Below this, the control must be in two-point mode. Switching between OFF (or fire bed support) and continuous control is done via the respective active I&C system. If the biomass boiler manufacturer so wishes, the switch-over can also always be made via the biomass boiler.

A recommendation for standard interfaces between the master I&C system and the biomass boiler, as well as a list of control unit and biomass boiler manufacturers offering these interfaces, can be downloaded from the Internet [9].

Important: The safety of the biomass boilers, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be additionally ensured by the subordinate I&C system of the biomass boilers.

7.3.8 Firing rate control oil/gas boiler

The firing rate is controlled via the subordinate I&C system of the oil/gas boiler.

The control of the firing rate should be continuous (for modulating operation) or in stages (for multi-stage operation). In principle, the oil/gas boiler should always be operated at the lowest possible output, and it should only be unblocked when the biomass boilers have not been able to provide the output at full load for a long time.

The controller for the main supply temperature of the master I&C system gives the setpoint value of the firing rate to the oil/gas boiler in sequence to the biomass boilers.

The internal controller for the boiler water temperature of the subordinate I&C system has the following functions:

- “Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the main supply temperature T741, but limitation of the boiler water temperature (e.g. to 90°C).
- “Local" operating mode: Control of the boiler water temperature to a fixed value set on the subordinate I&C system (e.g. 90°C).
- Operating mode "automatic": Limiting the boiler water temperature (e.g. to 90°C)

Important: The safety of the oil/gas boiler, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be additionally ensured by the subordinate I&C system of the oil/gas boiler.

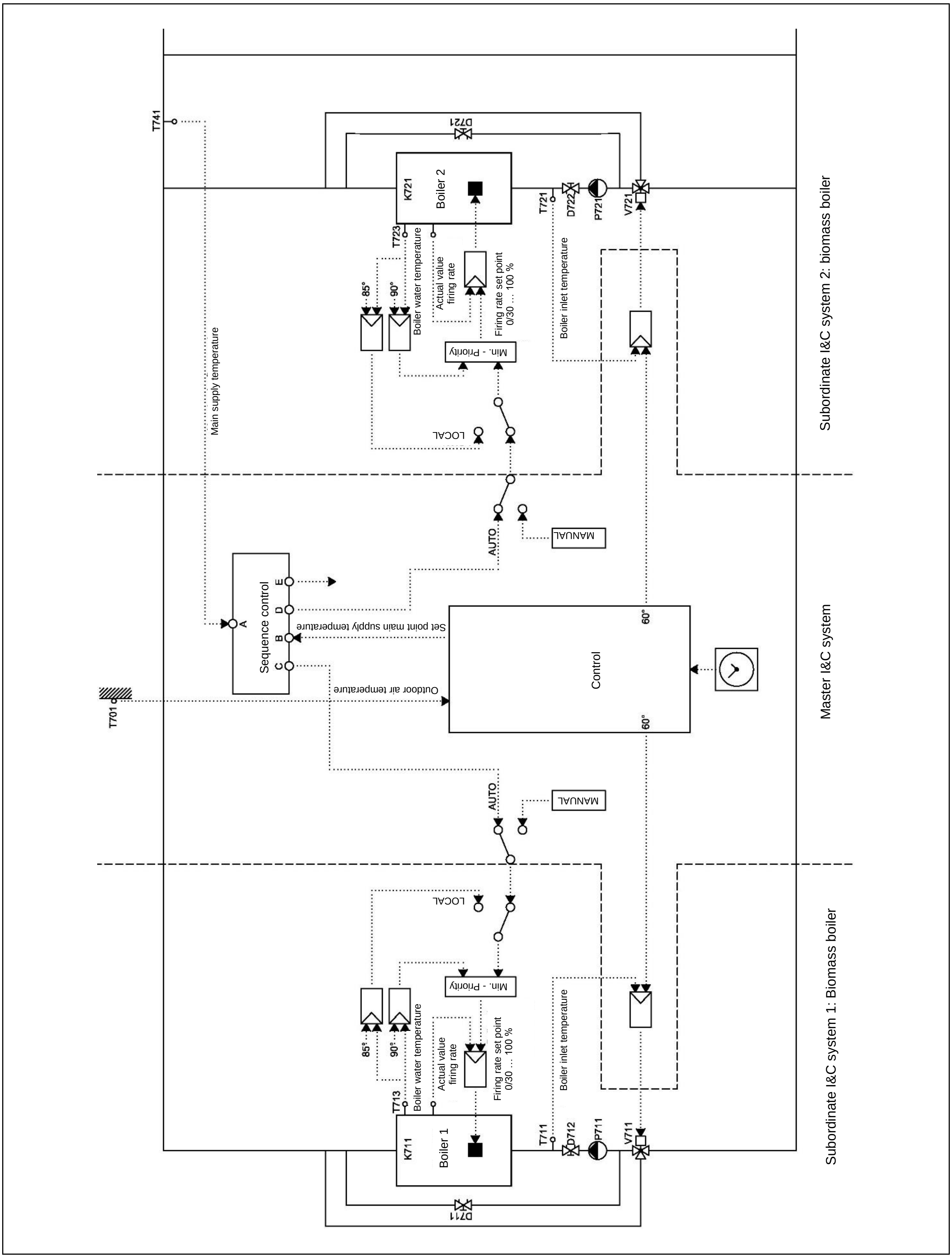

Figure 75: Control scheme for the two biomass boilers. Sequence control see Figure 77. The minimum priority switches route the lowest input signal to the output. Numerical values are to be understood as examples. Safety functions are not shown; these are to be realised via the subordinate I&C systems of the boilers.

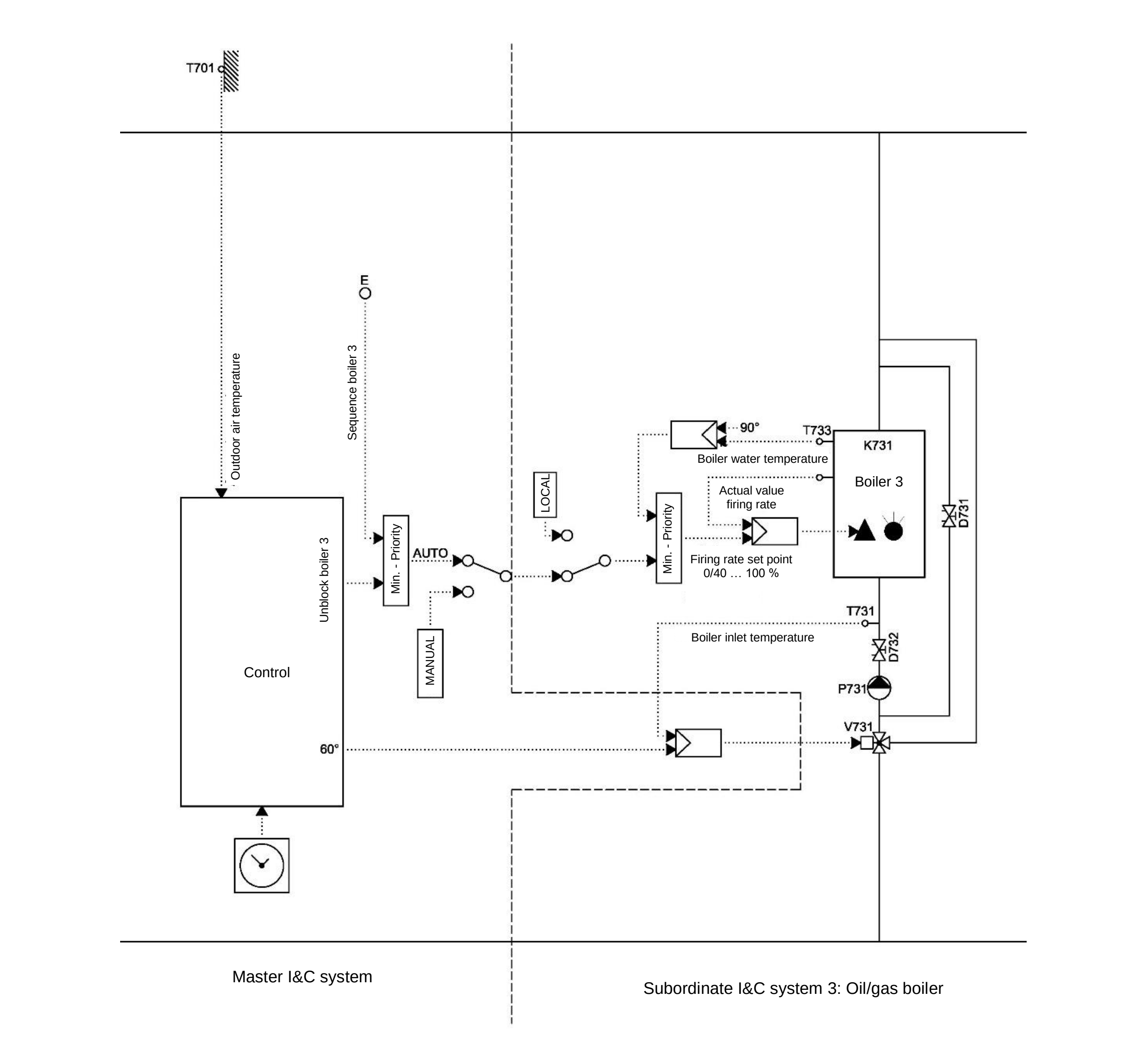

Figure 76: Control scheme for the oil/gas boiler. Sequence boiler 3 (input E) see Figure 75. The minimum priority switches route the lowest input signal to the output. Numerical values are to be understood as examples. Safety functions are not drawn in; these are to be realised via the subordinate I&C systems of the boilers.

7.3.9 Sequence control biomass boilers

The sequence control of the biomass boilers is to be realised by the master I&C system.

The following example assumes a power split of the two biomass boilers of 33% for boiler 1 and 67% for boiler 2. Switching from low-load operation to operation with automatic sequence control and back is done manually (percentages refer to the total output of the two biomass boilers):

- Manual switchover to boiler 2 alone (20...67%) if boiler 1 alone (10...33%) can no longer cover the daily demand
- Manual switchover to automatic sequence control if boiler 2 alone (20...67%) can no longer cover the daily demand.
- Manual switch back to boiler 2 alone (20...67%) when the daily demand can again be covered by boiler 2 alone for the foreseeable future.

- Manual switch back to boiler 1 alone (10...33%) when the daily demand can again be covered by boiler 1 alone for the foreseeable future.

The automatic sequence control must be carried out as follows (percentages refer to the total output of the two biomass boilers):
- boiler 2 alone (20...67%)
- Automatic connection of boiler 1 (10...33%) by means of automatic ignition (or fired bed support operation for large systems) if boiler 2 (20...67%) can no longer cover the hourly heat demand.
- Parallel operation boiler 1 and boiler 2 (together 30...100%)
- Automatic switch back to boiler 2 alone (20...67%) if the hourly heat demand falls below the sum of the two minimum outputs of 30%.

Figure 77 shows an example of the implementation of the sequence control.

The boiler that is not in operation must be completely isolated hydraulically from the rest of the system (no faulty circulation due to overrun times, incorrectly set three-way valves, short circuits via safety lines, etc.).

7.3.10 Sequence control biomass boiler 1+2 - oil/gas boiler

The sequence control biomass boiler 1+2 - oil/gas boiler is to be implemented by the master I&C system.

The sequence controller of the oil/gas boiler must be designed and supplemented with suitable unblocking and blocking criteria in such a way that the oil/gas boiler is reliably prevented from being switched on too frequently.

Examples of unblocking and blocking criteria for the oil/gas boiler are:
- Unblocking when certain minimum outdoor air temperature AND setpoint of the firing rate of the two biomass boilers is set to 100% for a certain time.
- Blocking (switching back) when the setpoint value of the firing rate of the two biomass boilers has returned to 90% for a certain time.

If a biomass boiler goes on fault, the oil/gas boiler must be unblocked automatically.

When the oil/gas boiler is not in operation, it must be completely isolated hydraulically from the rest of the system (no faulty circulation due to overrun times, incorrectly set three-way valves, short circuits via safety lines, etc.).

It is permissible to control the oil/gas boiler using the three-way valve if this improves the control quality:
- Oil/gas boiler correcting variable = setpoint of the firing rate (as before), but additional outlet temperature control for the oil/gas boiler.
- Correcting variable oil/gas boiler = Stroke of the three-way valve in the boiler circuit (instead of the setpoint of the firing rate); boiler water temperature controlled by the subordinate I&C system of the oil/gas boiler.
- Indicate where the measurement location of the main control variable is (T741 or T742? Maximum precedence at T744?).

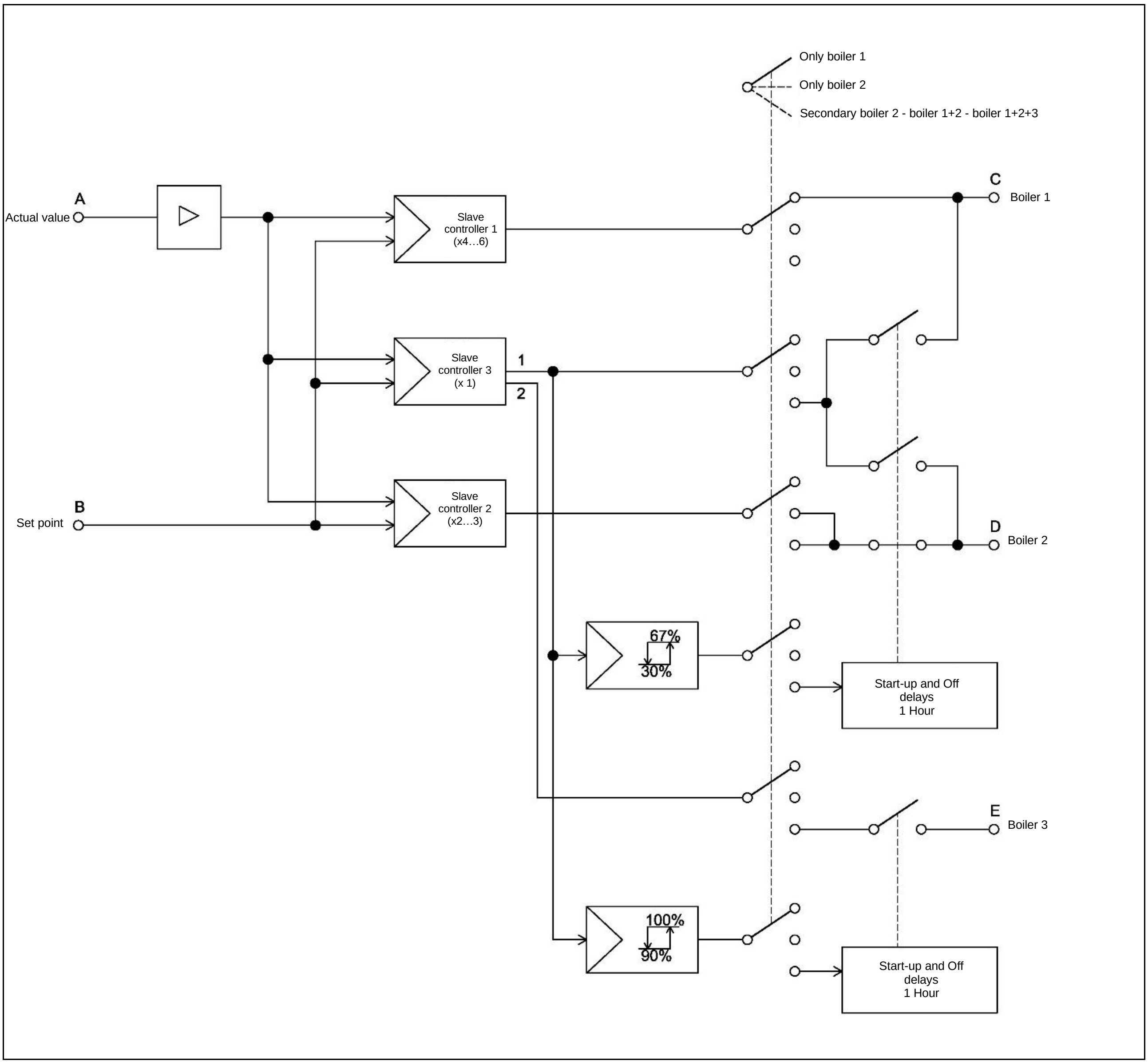

Figure 77: Example of the realisation of the sequence controller. Slave controller 3 is a sequence controller with two outputs. The interfaces A-E refer to Figure 75 and Figure 76. To ensure that the circuit gain is the same for all three control circuits, the transfer coefficients of the three controllers (depending on the design) are to be selected in a ratio of 4...6 : 2...3 : 1 (P-band reciprocal values 0,25...0,17 : 0,5...0,33 : 1).

7.3.11 Chosen control concept

The concept applicable to the project to be described, how to control the boiler circuits, the main supply temperature and the firing rates, shall be defined in Table 78.

Operating mode	**Boiler circuit control:** **- Biomass boiler 1** **- Biomass boiler 2** **- Oil/gas boiler**	**Main supply temperature control** **(= main control variable)**	**Regulation of firing rates** **- Biomass boiler 1** **- Biomass boiler 2** **- Oil/gas boiler**
Off	Inoperative		
Manual ☐ Not provided	☐ Boiler return temperature protection through master I&C system ☐ Limiting boiler water temperatures through subordinate I&C systems	☐ Control main supply temperature T741 out of operation	☐ Setpoints of the two firing rates can be set as fixed values on the master I&C system
Local	☐ Control of boiler water temperatures by subordinate I&C systems	☐ Control main supply temperature T741 out of operation	☐ Internal power controllers of the subordinate I&C systems activated
Automatic Summer operation? ☐ Yes, with biomass boiler ☐ Yes, with oil/gas boiler ☐ No	☐ Boiler return temperature protection through master I&C system ☐ Limiting boiler water temperatures through subordinate I&C systems	☐ Control of main supply temperature T741 by master I&C system according to special sequence control; the control variable is the setpoint values of the firing rates. <u>Other permissible solutions</u>: ☐ Additional outlet temperature control for oil/gas boiler ☐ Control variable oil/gas boiler = Stroke three-way valve in boiler circuit Measuring point Main supply temperature ☐ for T741 ☐ at T742 ☐ Maximum priority at T744	☐ Control of the firing rates by the subordinate I&C systems; setpoints from the master I&C system according to the special sequence control.
Summary	Which operating modes are provided? ☐ Off ☐ Manual (for each boiler) ☐ Local (for each boiler) ☐ Automatic winter operation Biomass boiler 1 alone (small boiler) ☐ Automatic winter operation Biomass boiler 2 alone (large boiler) ☐ Automatic winter operation Biomass boiler 1 + 2 in parallel (without automatic sequence control) ☐ Automatic sequence control Biomass boiler 2 alone - Biomass boiler 1 + 2 in parallel - oil/gas boiler ☐ Automatic low-load operation (transition period, summer) with Biomass boiler 1 ☐ Automatic low-load operation (transition period, summer) with oil-gas boiler ☐ Oil/gas boiler alone (e.g. revision biomass boiler, emergency operation) ☐ Other:		

Table 78: Questions and answers on the chosen control concept.

7.4 Data recording for operation optimisation

All precautions are to be taken so that a proper operational optimisation can be carried out and the subsequent regular operation can be efficiently monitored. The measured variables to be recorded are to be marked with a cross in Table 79 and Table 80 measured variables marked "Standard" must be able to be recorded in any case; the connection of the remaining measured variables is recommended. The measuring accuracy must meet the increased requirements of a measuring system.

The questions and answers on automatic data recording for operation optimisation in Table 81 must be answered.

☑	Standard	Measuring points	Label
☐	Standard	Outdoor air temperature	T701
☐	Standard	Inlet temperature Biomass boiler 1	T711
☐	Standard	Outlet temperature Biomass boiler 1	T712
☐		Boiler water temperature Biomass boiler 1 (other measuring point)	T713
☐	Standard	Inlet temperature Biomass boiler 2	T721
☐	Standard	Outlet temperature Biomass boiler 2	T722
☐		Boiler water temperature Biomass boiler 2 (other measuring point)	T723
☐	Standard	Inlet temperature oil/gas boiler	T731
☐	Standard	Outlet temperature oil/gas boiler	T732
☐		Boiler water temperature oil/gas boiler (other measuring point)	T733
☐	Standard	Main supply temperature before bypass	T741
☐	Standard *	Main supply temperature after bypass	T742
☐	Standard	Main return temperature before bypass	T743
☐	Standard *	Main return temperature after bypass	T744
☐	Standard *	Return temperature of the low-pressure difference connection	T751
☐	Standard	Supply temperature of the differential pressure-affected connection	T761
☐	Standard *	Return temperature of the differential pressure-affected connection	T762
* In order to reduce the effort for data recording, a reduction by these measuring points is accepted as permissible deviation for operation optimisation.			

Table 79: Measuring point list for automatic data recording (part 1). If the installation is to be considered a standard hydraulic scheme, it must be possible to record all measured variables marked "Standard".

☑	**Standard**	**Measuring points**	**Label**
☐	Standard	Heat quantity/output heat meter Biomass boiler 1 **	W711
☐		Water quantity/flow rate heat meter Biomass boiler 1 **	W711
☐	Standard	Heat quantity/output heat meter Biomass boiler 2 **	W721
☐		Water quantity/flow rate heat meter Biomass boiler 2 **	W721
☐	Standard	Oil/gas meter, if modulating oil/gas boiler ***	W731/W732
☐	Standard	Operating hours stage 1/2, if two-stage oil/gas boiler	W731/W732
☐	Standard	Setpoint of the firing rate Biomass boiler 1	
☐		Boiler-internal setpoint of the firing rate (feedback signal Biomass boiler 1)	
☐	Standard	Setpoint of the firing rate Biomass boiler 2	
☐		Boiler-internal setpoint of the firing rate (feedback signal Biomass boiler 2)	
☐	Standard	Setpoint of the firing rate oil/gas boiler	
☐		Boiler-internal setpoint of the firing rate (feedback signal oil/gas boiler)	
☐	Standard	Flue gas temperature Biomass boiler 1	
☐		Combustion chamber temperature Biomass boiler 1	
☐	Standard *	Residual oxygen Biomass boiler 1	
☐	Standard	Flue gas temperature Biomass boiler 1	
☐		Combustion chamber temperature Biomass boiler 1	
☐	Standard *	Residual oxygen Biomass boiler 1	
		Measuring points Particle separator 1; type:	
☐			
☐			
		Measuring points Particle separator 2; type:	
☐			
☐			

* In order to reduce the effort for data recording, a reduction by these measuring points is accepted as permissible deviation for operation optimisation.

** The heat meter must be equipped with an interface for recording the heat quantity [kWh] or water quantity [m³]. The graphical representation, however, must be in terms of output [kW] or volume flow [m³/h]. A common heat meter for both boilers in the main return is permissible (to check the boiler output, the other boiler must be out of operation).

*** The oil/gas meter must be equipped with an interface for recording the oil or gas quantity [dm³ or m³]. The graphical representation, however, must be made as a volume flow [dm³/h or m³/h].

Table 80: Measuring point list for automatic data recording (part 2). If the installation is to be considered a standard hydraulic scheme, it must be possible to record all measured variables marked "Standard".

Area	Questions and answers
Hardware	How is the automatic data recording for operation optimisation carried out? ☐ With a separate data logger ☐ With the PLC of the biomass boiler ☐ With the master I&C system
	How is the periodic reading of the data done? ☐ Reading out the data on site ☐ Readout via landline phone (POTS) connection ☐ Readout via ISDN telephone connection ☐ Readout via the Internet
Data recording	What is the measurement interval? ☐ 10 seconds (recommendation)..... seconds
	What is the recording interval? ☐ 5 minutes (recommendation)..... minutes
	How are the analogue values recorded? ☐ As an average value over the last recording interval (recommendation) ☐ As instantaneous value
	How is the recording done for meters? ☐ As a sum value over the last recording interval (recommendation) ☐ As current counter reading (Attention: is often set to zero by mistake)
	How is the recording of running times done? ☐ As runtime during the last recording interval (recommendation) ☐ As the current number of operating hours (Attention: is often accidentally set to zero)
	How large is the measured value memory? ☐ ≥ 30 days recording capacity (recommendation)..... days recording capacity
Data evaluation	What is the output format for evaluation in EXCEL? ☐ CSV file with columns = time and measuring points, rows = values (recommendation) ☐ Other:
	How is the graphical representation done? ☐ Related data as a weekly overview (recommendation) ☐ Related data as a daily overview (recommendation) ☐ Representation of heat, oil, gas, operating hours meters as output or volume flow (demand) ☐ Other:
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of the autom. data recording by the main planner ☐ Specification of the automatic data recording by the main planner with the involvement of the I&C specialist
	How are the responsibilities regulated at the execution and approval stage? ☐ Planning of the autom. data recording by the main planner ☐ Planning of autom. data recording by biomass boiler suppliers ☐ Planning of the autom. data recording by the supplier of the master I&C system
	How are responsibilities regulated during operational optimisation? ☐ Readout and data evaluation by main planner ☐ Readout by biomass boiler supplier, data evaluation by main planner ☐ Readout by supplier of master I&C system, data evaluation by main planner ☐ Readout by operator, data evaluation by main planner ☐ Readout and data evaluation by operator

Table 81: Questions and answers on automatic data recording for operation optimisation

7.5 Annex to the approval protocol

The execution phase is concluded by the approval test. At this time, an addendum to the approval protocol shall be drawn up in accordance with Table 82 to Table 84.

The questions in Table 82must be answered at the beginning of the tendering phase. The annex to the approval protocol according to Table 83 and Table 84 must only be completed at the end of the execution phase. However, it is recommended to use these tables already during the tendering and execution phase for the preliminary determination of the planning values; so that the functionality of the system is clearly recognisable.

Who prepares the addendum to the approval protocol? ☐ Main planner ☐ Biomass boiler supplier ☐ Supplier of the master I&C system

Table 82: Questions and answers on the annex to the approval protocol

Description		**Unit**	*Example*			
Master I&C system Connection of master/subordinate I&C systems via standard interface [9]? ☐ Yes ☐ No						
■ **Boiler return temperature protection**						
Boiler inlet temperature limit Biomass boiler 1		°C	*60*			
Boiler inlet temperature limit Biomass boiler 2		°C	*60*			
Boiler inlet temperature limit oil/gas boiler		°C	*60*			
■ **Main supply temperature control** Who specifies OFF (or fire bed support) and steady regulation? ☐ The active control system ☐ Always the biomass boiler						
Main supply temperature setpoint		°C	*85*			
Continuous control Slave controller	P-band slave controller 1 (Biomass boiler 1 alone)	%	*75*			
	Integration time slave controller 1 (Biomass boiler 1 alone)	Min.	*20*			
	P-band slave controller 2 (Biomass boiler 2 alone)	%	*150*			
	Integration time slave controller 2 (Biomass boiler 2 alone)	Min.	*20*			
	P-band slave controller 3 (Biomass boiler 1+2)	%	*225*			
	Integration time slave controller 3 (Biomass boiler 1+2)	Min.	*20*			
Two-point controller (oil/gas boiler in sequence)	Biomass boiler 1 continuous control at setpoint firing rate.	%	*≥35*			
	Biomass boiler 1 OFF/fire bed at setpoint firing rate	%	*≤25*			
	Biomass boiler 2 continuous control at setpoint firing rate.	%	*≥35*			
	Biomass boiler 2 OFF/fire bed at setpoint firing rate	%	*≤25*			
	Oil/gas boiler stage 1 ON at setpoint firing rate	%	*≥45*			
	Oil/gas boiler stage 1 OFF at setpoint firing rate	%	*≤35*			
	Oil/gas boiler stage 2 ON at setpoint firing rate	%	*≥75*			
	Oil/gas boiler stage 2 OFF at setpoint firing rate	%	*≤65*			

Table 83: Supplement to the approval protocol (part 1) - setting values; exemplary values are to be deleted

Description	Unit	*Example*			
■ Sequence control Biomass boiler 2 - Biomass boiler 1+2 (modify if necessary)					
Unblocking criterion Biomass boiler 1: Setpoint firing rate Biomass boiler 2 (in % of total output) AND delay time	 % Min.	 *100 (67)* *60*			
Blocking criterion Biomass boiler 1: Setpoint firing rate Biomass boiler 1+2 AND delay time	 % Min.	 *30* *60*			
■ Sequence control Biomass boiler 1+2 - oil/gas boiler (modify if necessary)					
Unblocking criterion: Outdoor air temperature AND (setpoint firing rate Biomass boiler 1+2 AND delay time)	°C % Min.	*≤ 0* *100* *30*			
Blocking criterion: Setpoint firing rate Biomass boiler 1+2 AND delay time	% Min.	*90* *10*			
Biomass boiler 1					
■ Heat output settings					
Set minimum heat output with the reference fuel	kW	*135*			
Set maximum heat output with the reference fuel	kW	*450*			
■ Subordinate I&C system 1					
Boiler water temperature setpoint for "local" operating mode	°C	*85*			
Boiler water temperature limitation	°C	*95*			
Safety shutdown at boiler water temperature	°C	*110*			
Biomass boiler 2					
■ Heat output settings					
Set minimum heat output with the reference fuel	kW	*270*			
Set maximum heat output with the reference fuel	kW	*900*			
■ Subordinate I&C system 2					
Boiler water temperature setpoint for "local" operating mode	°C	*85*			
Boiler water temperature limitation	°C	*95*			
Safety shutdown at boiler water temperature	°C	*110*			
Oil/gas boiler					
■ Heat output settings					
Set minimum heat output	kW	*620*			
Set maximum heat output	kW	*1550*			
■ Subordinate I&C system 3					
Boiler water temperature limitation	°C	*90*			
Safety shutdown at boiler water temperature	°C	*110*			

Table 84: Annex to the approval protocol (part 2) - setting values; exemplary values to be deleted

8. Bivalent three-boiler system with storage (2 biomass boilers, 1 oil/gas boiler)

8.1 Short description and responsibilities

8.1.1 User level

The simplest possible operation and a clear display of the main functions are required so that non-professional personnel can also operate the system:

■ The following requirements must be met for **service and emergency operation:**
- It must be possible to disable the automatic control system partially or completely for service work and in case of emergency operation (e.g. via switch "off/on/automatic").
- Subordinate I&C systems must be able to be operated independently of the master I&C system (e.g. in case of failure of the master I&C system).
- Manual operation of the control valves must be guaranteed (e.g. manual adjustment at the control valve, but this must not be disturbed by an incorrect control signal).
- All safety functions must be maintained

■ The **operation mode selection** shall be made in one of the following ways:
- Via switches in a conventional control panel (usually in the control cabinet).
- Via a PLC; however, this is only an option if the hardware and software requirements for convenient operation are right.
- Via the master computer of a **control system**

■ Further operation, such as **adjusting setpoints, changing time programmes, etc.,** can be carried out directly on the master and subordinate I&C systems (if necessary, also via the Internet).

8.1.2 Master I&C system

The master I&C system takes care of all master control and regulation functions and links the subordinate I&C systems with each other. In addition, automatic data recording is also assigned to the master I&C system, which is mandatory as a standard hydraulic scheme (at least temporarily for the duration of the operation optimisation).

8.1.3 Subordinate I&C systems of the biomass boilers

The subordinate I&C systems of the biomass boilers have to fulfil the following **functions:**
- Fire bed support operation or automatic ignition
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

If **particle separators** are necessary, these are to be controlled by the subordinate I&C systems of the biomass boilers.

The **safety** of the biomass boilers, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be ensured by the subordinate I&C systems of the biomass boilers.

If the PLCs of the biomass boilers can also fulfil the requirements for the master I&C system (in particular also the automatic data recording), the **simultaneous use as a master and subordinate I&C system can be** tested.

8.1.4 Subordinate I&C system of the oil/gas boiler

The subordinate I&C system of the oil/gas boiler has to fulfil the following **functions:**
- pre-purge, ignition and flame monitoring
- Control of the firing rate in manual and automatic operation based on the setpoint specification of the master I&C system (continuous in modulating operation, in stages in multi-stage operation)
- Control of the boiler water temperature during local operation
- Limitation of the firing rate due to the boiler water temperature in all operating modes

The **safety** of the oil/gas boiler, i.e. preventing the maximum permissible boiler water temperature from being exceeded, must be ensured by the subordinate I&C system of the oil/gas boiler.

8.1.5 Selected structure of the I&C system levels

A person with main responsibility must be designated for the I&C planning (in particular also for the interface definition).

The structure of the I&C system levels with responsibilities chosen for the project to be described can be answered with Table 85.

I&C system level	Questions and answers
User level Section 8.1.1	Are the requirements for service and emergency operation met? ☐ Yes (mandatory for standard hydraulic scheme) ☐ No
	How does the operation mode selection take place? ☐ Switch in a conventional control panel ☐ Input via a PLC, sufficiently convenient operation is guaranteed ☐ Input via the master computer of the control system
	From where can the system be controlled and operated? ☐ Only in the central heating plant ☐ In the central heating plant and via modem ☐ In the central heating plant and via the internet
Master I&C system Section 8.1.2	How is the master I&C system implemented? ☐ Individual controller as master I&C system ☐ Use of the common PLC of the biomass boilers as a master I&C system ☐ Own master I&C system
	Connection of master/subordinate I&C systems via standard interface [9]? ☐ Yes ☐ No
	How is the automatic data recording done? ☐ Data logger during operation optimisation, an interface is provided ☐ Internal data recording in the master I&C system
Subordinate I&C sys-tems of the biomass boilers Section 8.1.3	What is the position/tasks of the PLCs of the biomass boilers? ☐ A single PLC for both biomass boilers, which is used simultaneously as the master and subordinate I&C systems ☐ A single PLC for both biomass boilers, subordinated to the master I&C system ☐ Separate PLC for both biomass boilers, subordinated to the master I&C system
Subordinate I&C sys-tem of the Oil/gas boiler Section 8.1.4	What is the position/tasks of the I&C system of the oil/gas boiler? ☐ It is subordinated to the master I&C system
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of all I&C levels by the main planner ☐ Specification of all I&C levels by the main planner with the involvement of I&C specialists
	How are the responsibilities (especially interface definitions) regulated at the execution and approval stage? ☐ Overall planning of all I&C levels by the main planner ☐ Overall planning of all I&C levels by biomass boiler supplier ☐ Overall planning of all I&C levels by the supplier of the master I&C system ☐ Planning of each I&C level by the respective supplier (not permitted for standard hydraulic scheme, as a main person responsible for I&C planning is explicitly required).

Table 85: Questions on the chosen structure of the I&C levels and responsibilities

8.2 Principle scheme and design

8.2.1 Hydraulic circuit

The hydraulic circuit must comply with Figure 86 The following requirements must be met:
The interconnection of the biomass boiler, the oil/gas boiler, the storage tank, the low-pressure difference connection and the pre-control must actually be low pressure differential (short pipes, large pipe diameters).

- The storage system must be consistently designed as a stratified storage system.
- Storage connections with cross-section enlargement (speed reduction), baffle plate (refraction of the water jet) and, if necessary, siphoned (prevention of one-pipe circulation).
- Storage connections only top and bottom (no connections in between)
- No pipes may be routed inside the storage tank (danger of "thermal agitation").
- Whenever possible, the storage tank should not be divided among several containers. If this requirement cannot be met, the following must be observed:
    - No connections between the storages
    - When controlling the storage tank charging state, each storage tank is to be considered as a control unit (problem: due to the individual stratification in each storage tank, the warmer storage tank can be colder at the bottom than the colder storage tank at the top).

The installation is also considered a standard hydraulic scheme if

- one pump is realised by two or more pumps connected in parallel or in series,
- the pre-control of the district heating network is realised by two control valves connected in parallel or with a separate summer group,
- only one common heat meter is installed for both biomass boilers in the main return (to check the boiler output, the other boiler must be out of operation!),

exhaust gas heat exchanger can be integrated.

8.2.2 Hydraulic and control design

The hydraulic and control design must be carried out according to the generally accepted engineering standards. The requirements according to the Q-Guideline [1] and the Planning Handbook [4] must be fulfilled, in particular:

- Storage volume ≥ 1 h storage capacity related to the nominal output of the larger biomass boiler
- Load control/boiler return temperature protection for the boilers and the pre-control: Valve authority ≥ 0,5
- Design temperature difference above the biomass boilers ≤ 15 K; smaller temperature difference necessary if minimum permissible return temperature is high (e.g. with bark, landscape conservation wood); can be increased to reduce pump power consumption if it is ensured that this does not cause any control-related problems (e.g. oscillation of boiler output due to temperature stratification).
- The boiler inlet temperature should be at least 5 K higher than the minimum permissible return temperature (boiler return temperature protection).

The hydraulic and control design shall be presented and documented in accordance with Table 87 and Table 88.

A maximum permissible main return temperature T843 shall be specified.

If the temperature difference between the boiler outlet temperature and the boiler inlet temperature is more than 10 K less than the temperature difference between the boiler outlet temperature and the maximum permissible main return temperature T843, it is recommended to provide a **bypass in the boiler circuit D811/D821/D831.**

Important: To ensure that the boilers can always deliver the output, it must be ensured that the main return temperature T843 cannot rise above the design value in any operating case (prescribe return temperature limiter for all consumers!).

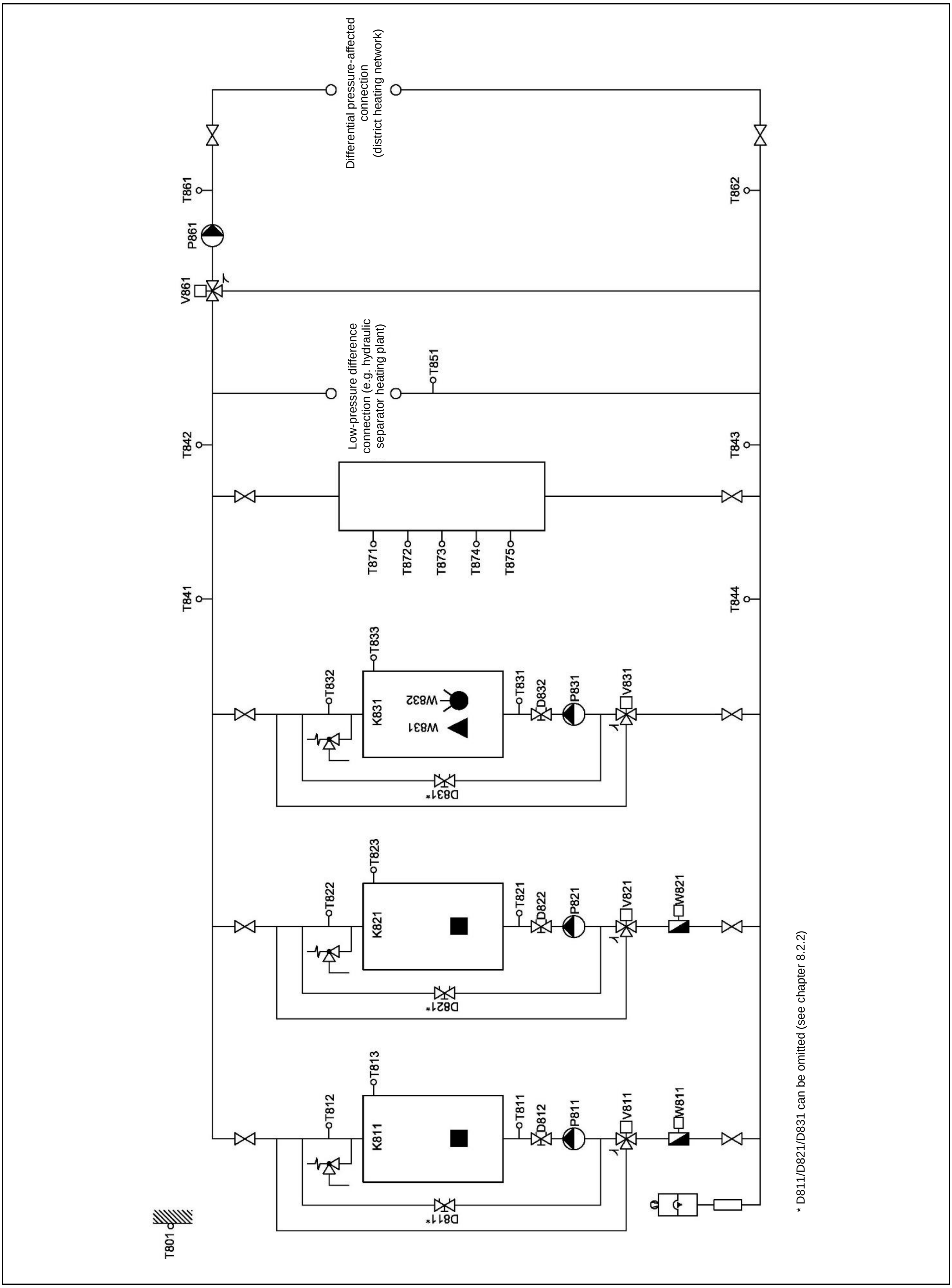

Figure 86: Principle scheme of a bivalent three-boiler system with storage tank. Safety devices and expansion system must be designed in accordance with the country-specific regulations.

Hydraulic and control system design	Unit	*Example*			Label
Storage					
Content	m3	*14*			
Heat capacity demand of the overall system					
Low-pressure difference connection	kW	*200*			
Differential pressure-affected connection (district heating network incl. losses)	kW	*1800*			
Overall system	kW	*2000*			
Guaranteed temperature limits					
Main supply temperature	°C	*85*			T542
Maximum permissible main return temperature	°C	*55*			T543
Minimum permissible inlet temperature Biomass boiler 1 (boiler return temperature protection)	°C	*60*			T511
Maximum boiler water temperature Biomass boiler 1 (limiting controller)	°C	*90*			T513
Max. permissible boiler water temperature Biomass boiler 1 (safety monitor)	°C	*110*			T513
Minimum permissible inlet temperature Biomass boiler 2 (boiler return temperature protection)	°C	*60*			T521
Maximum boiler water temperature Biomass boiler 2 (limiting controller)	°C	*90*			T523
Max. permissible boiler water temperature Biomass boiler 2 (safety monitor)	°C	*110*			T523
Minimum permissible inlet temperature oil-gas boiler (boiler return temperature protection)	°C	*60*			T521
Maximum boiler water temperature oil-gas boiler (limiting controller)	°C	*90*			T523
Max. perm. boiler water temperature oil-gas boiler (safety monitor)	°C	*110*			T523
Boiler circuit Biomass boiler 1					
Max. boiler output	kW	*330*			K811
Min. boiler output	kW	*100*			K811
Boiler outlet temperature	°C	*85*			T812/T813
Boiler pump flow rate	m3/h	*18,9*			P811
Boiler pump delivery head	m	*3*			P811
Resulting boiler inlet temperature	°C	*70*			T811
Resulting flow rate control valve boiler circuit	m3/h	*9,5*			V811
Resulting flow rate bypass	m3/h	*9,5*			D811
Pressure drop control valve	kPa	*10*			V811
Pressure drop section with variable volume flow	kPa	*8*			- –
Resulting valve authority	–	*0,56*			V811
Boiler circuit Biomass boiler 2					
Max. boiler output	kW	*670*			K821
Min. boiler output	kW	*200*			K821
Boiler outlet temperature	°C	*85*			T822/T823
Boiler pump flow rate	m3/h	*38,4*			P821
Boiler pump delivery head	m	*3*			P821
Resulting boiler inlet temperature	°C	*70*			T821
Resulting flow rate control valve boiler circuit	m3/h	*19,2*			V821
Resulting flow rate bypass	m3/h	*19,2*			D821
Pressure drop control valve	kPa	*10*			V821
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	0,56	*0,56*			V821

Table 87: Hydraulic and control system design (Part 1). The design data of the system to be executed are to be entered according to the example (the exemplary values are to be deleted).

Hydraulic and control system design	**Unit**	*Example*			**Label**
Boiler circuit oil/gas boiler					
Max. boiler output	kW	*1670*			K831
Min. boiler output	kW	*670*			K831
Boiler outlet temperature	°C	*85*			T832/T833
Boiler pump flow rate	m3/h	*95,8*			P831
Boiler pump delivery head	m	*3*			P831
Resulting boiler inlet temperature	°C	*70*			T831
Resulting flow rate control valve boiler circuit	m3/h	*47,9*			V831
Resulting flow rate bypass	m3/h	*47,9*			D831
Pressure drop control valve	kPa	*10*			V831
Pressure drop section with variable volume flow	kPa	*8*			- –
Resulting valve authority	- –	*0,56*			V831
Design of pre-control and network pump in chapter 9!					

Table 88: Hydraulic and control system design (Part 2). The design data of the system to be executed are to be entered according to the example (the exemplary values are to be deleted).

8.3 Functional description

8.3.1 Control scheme

The control and regulation of the system should be carried out according to Figure 91 and Figure 92.

8.3.2 Operating modes

The following operating modes shall be provided:

■ **Off:** The entire heat production system is out of operation, with the exception of the continuous operations (automatic expansion unit, etc.)

■ **Manual:** Setpoint firing rate for each of the two biomass boilers can be set "manually" as fixed values on the master I&C system; this operating mode is not mandatory

■ **Local:** The internal power controllers of the subordinate I&C systems of the boilers are activated (the master I&C system may be out of operation or defective)

■ **Automatic:** The setpoint for the firing rate is specified for all boilers by the master I&C system as a function of the storage tank charging status (= main control variable) as a sequence control.

■ **Biomass boiler 1 alone - Biomass boiler 2 alone - Sequence control:** Manual changeover from low-load operation to operation with automatic sequence control and back

■ **Other operating modes:** Especially for low-load operation (transition period, summer), other operating modes may be necessary (e.g. conventional "summer/winter" changeover, low-load operation with "charge/discharge storage tank", low-load operation with "oil/gas boiler alone", etc.).

8.3.3 Control

The control for the specification, limitation, weather compensation and time programme control of the setpoints as well as for the unblocking and blocking of boilers, pumps, etc. must be implemented by the master I&C system.

With **weather compensation,** the outdoor air temperature can be recorded via a weather sensor on the north side of the building, and the outdoor air temperature can then be used on the one hand as an instantaneous value and on the other hand as a 24-h average value to guide the setpoints and unblocking criteria. Calculation of the 24-h mean value, for example, continuously over a window of the last 24 hours and recalculation every 15 minutes.

With a **time programme control,** time programme levels can be programmed for different functions.

8.3.4 Boiler circuit control biomass boilers

The control of the boiler circuits of the biomass boilers is to be realised by the master I&C system.

In the "automatic" operating mode, the **boiler outlet temperature** should be controlled continuously via the control valve in the boiler circuit to a fixed value. If the boiler inlet temperature falls below the limit value, the control should be set to this limit value (= **boiler return temperature protection**).

8.3.5 Boiler circuit control oil/gas boiler

The control of the boiler circuit for the oil/gas boiler is to be realised by the master I&C system.

In the "automatic" operating mode, the **boiler outlet temperature** should be controlled continuously via the control valve in the boiler circuit to a fixed value. If the boiler inlet temperature falls below the limit value, the control should be set to this limit value (= **boiler return temperature protection**).

To prevent uncontrolled charging of the storage tank in "manual", "local" or "oil/gas boiler alone" mode, the oil/gas boiler should be switched off when the storage tank is charged to an adjustable value (e.g. off at 20% and on again at 0%).

8.3.6 Storage tank charging status control

The control of the storage tank charging state is to be realised by the master I&C system.

The state of charge of the storage tank should be recorded via at least 5 temperature sensors that are evenly distributed over the height of the storage tank. This gives the state of charge of the storage tank from 0% to 100%.

Different variants are possible for recording the storage tank charging status. The following applies to variants 1 and 2:
w = Sensor signals "warm" when e.g. T ≥ 75°C
k = Sensor signals "cold" when e.g. T ≤ 65°C

Variant 1 (Table 89**):** With sensor values 20 - 40 - 60 - 80 - 100. For "all sensors cold" the value is 0. This variant results in a stepped actual value signal. Therefore, the (fast) P component of the controller must not be too large, and disturbances must mainly be compensated via the (slow) I component.

Variant 2: The stepped signal according to variant 1 can be smoothed by a first-order control delay element (PT1 element). However, the time constant of the PT1 element must not be too large, otherwise there is a risk that the inevitable time delay of the actual value signal will lead to disturbances. However, the "more continuous" actual value signal allows a somewhat larger P component in the controller compared to variant 1.

Sensor (from top to bottom)					Value
1	2	3	4	5	
k	k	k	k	k	0
w	k	k	k	k	20
w	w	k	k	k	40
w	w	w	k	k	60
w	w	w	w	k	80
w	w	w	w	w	100

Table 89: Variant 1 (in stages)

Variant 3 (Table 90**):** A smoothing of the characteristic curve can also be achieved if the temperature of the active sensor is interpolated.

Sensor (from top to bottom)					Value
1	2	3	4	5	
< 60°C	< 60°C	< 60°C	< 60°C	< 60°C	0
60...80°C	< 60°C	< 60°C	< 60°C	< 60°C	0...20
> 80°C	60...80°C	< 60°C	< 60°C	< 60°C	20...40
> 80°C	> 80°C	60...80°C	< 60°C	< 60°C	40...60
> 80°C	> 80°C	> 80°C	60...80°C	< 60°C	60...80
> 80°C	> 80°C	> 80°C	> 80°C	60...80°C	80...100

Table 90: Variant 3 (stepless)

With a good system, it can be assumed that for the sensor temperatures $T_1...T_5$ applies:

$T_1 \geq T_2 \geq T_3 \geq T_4 \geq T_5$ ($T_1...T_5$ from top to bottom)

The active sensor is highlighted in grey in Table 90 following rule applies:
- Sensor 1 active when all other sensor temperatures < 80°C
- Sensor 2 active when sensor temperature T_1 > 80°C
- Sensor 3 active when sensor temperature T_2 > 80°C
- Sensor 4 active when sensor temperature T_3 > 80°C
- Sensor 5 active when sensor temperature T_4 > 80°C

The quality of the interpolation (smoothing of the signal) depends on the thickness of the mixing zone in the storage tank, and this thickness is not a fixed quantity. For the same storage tank, it can be very different - depending on the flow rate, cooling, etc. Basically:
- thickness of the mixing zone zero (ideal stratified storage) results in no smoothing at all, the signal is just as stepped as in variant 1
- thickness of the mixing zone between zero and one probe distance results in an increasingly better smoothing of the signal
- Thickness of the mixing zone very slightly greater than one sensor spacing gives the best smoothing
- Thickness of the mixing zone significantly greater than a probe spacing results in poorer smoothing again

Variant 4: Average storage tank temperature as a measure of the storage tank state of charge. The disadvantage here is that the actual storage tank state of charge is reproduced differently depending on the thickness of the mixing zone, return temperature, cooling, etc: Thickness of the mixing zone zero (ideal stratified storage tank) results in no smoothing at all, the signal is just as stepped as in variant 1; when designed for 85/55°C, the control range is 30 K, when the return comes back in the morning at 25°C, this is suddenly 60 K.

More than 5 storage sensors: Only with this (in combination with variants 1 to 4) can the signal really be improved.

The storage tank is to be charged by a continuous control. This controller should have PI characteristics. As a result of the I component, the storage tank can thus be charged to a setpoint of 60...80% without a permanent control deviation (as would be the case with the P controller) (in the case of a stepped signal, select a stepped value, e.g. 60%). If the heat consumers suddenly demand more power, the storage charging state drops and the firing rate is increased, and if less power is suddenly needed, the storage charging state rises and the firing rate is regulated back. In the first case, the upper half of the storage tank is available as a power reserve until the biomass boiler has reacted, and in the second case, the biomass boiler can deliver the temporary power surplus to the lower half of the storage tank.

In systems with automatic ignition, the storage tank should be completely charged and discharged with reduced output during low-load operation (required biomass boiler output below the minimum output). A suitable switching criterion must be defined for switching from "charge/discharge" to continuous control and back (e.g. manual switching or switching according to time programme and outdoor air temperature).

8.3.7 Firing rate control biomass boilers

The firing rate is controlled via the subordinate I&C systems of the biomass boilers.

At least Biomass boiler 1 shall be equipped with automatic ignition. If this is not possible or not reasonable according to the state of the art, fired bed support operation can be used. In principle, the biomass-fired furnace should always be operated at the lowest possible output so that they have to be switched on and off as little as possible.

The controller for the storage charging state of the master I&C system specifies the setpoints for the firing rate to the biomass-fired furnace as a sequence control. With the help of the controller, the setpoints for the firing rate can then be additionally guided and limited.

The internal controllers for the boiler water temperatures T813/T823 of the two subordinate I&C systems have the following functions:

- “Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the main supply temperature T841, but limitation of the boiler water temperature T813/T823 (e.g. to 90°C).
- “Local" operating mode: Control of the boiler water temperature T813/T823 to a fixed value set on the subordinate I&C system (e.g. 85°C), limitation of the boiler water temperature T813/T823 to a fixed value about 5 K higher (e.g. to 90°C).
- Operating mode "automatic": Limiting the boiler water temperature T813/T823 (e.g. to 90°C)

In the output control range of the biomass-fired furnace of 30...100%, the control should be continuous. Below this, the control must be in two-point mode. Switching between OFF (or fire bed support) and continuous control is done via the respective active I&C system. If the biomass boiler manufacturer so wishes, the switch-over can also always be made via the biomass boiler.

A recommendation for standard interfaces between the master I&C system and the biomass boiler, as well as a list of control unit and biomass boiler manufacturers offering these interfaces, can be downloaded from the Internet [9].

Important: The safety of the biomass boilers, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be additionally ensured by the subordinate I&C system of the biomass boilers.

8.3.8 Firing rate control oil/gas boiler

The firing rate is controlled via the subordinate I&C system of the oil/gas boiler.

The control of the firing rate should be continuous (for modulating operation) or in stages (for multi-stage operation). In principle, the oil/gas boiler should always be operated at the lowest possible output, and it should only be unblocked when the biomass boilers have not been able to provide the output at full load for a long time.

The controller for the storage charging state of the master I&C system gives the setpoint value of the firing rate to the oil/gas boiler in sequence to the biomass boilers.

The internal controller for the boiler water temperature of the subordinate I&C system has the following functions:

- “Manual" operating mode (not mandatory): Control of the firing rate to a fixed value set on the master I&C system, i.e. no control of the main supply temperature T841, but limitation of the boiler water temperature (e.g. to 90°C).
- “Local" operating mode: Control of the boiler water temperature to a fixed value set on the subordinate I&C system (e.g. 90°C).
- Operating mode "automatic": Limiting the boiler water temperature (e.g. to 90°C)

Important: The safety of the oil/gas boiler, i.e. the prevention of exceeding the maximum permissible boiler water temperature, must be additionally ensured by the subordinate I&C system of the oil/gas boiler.

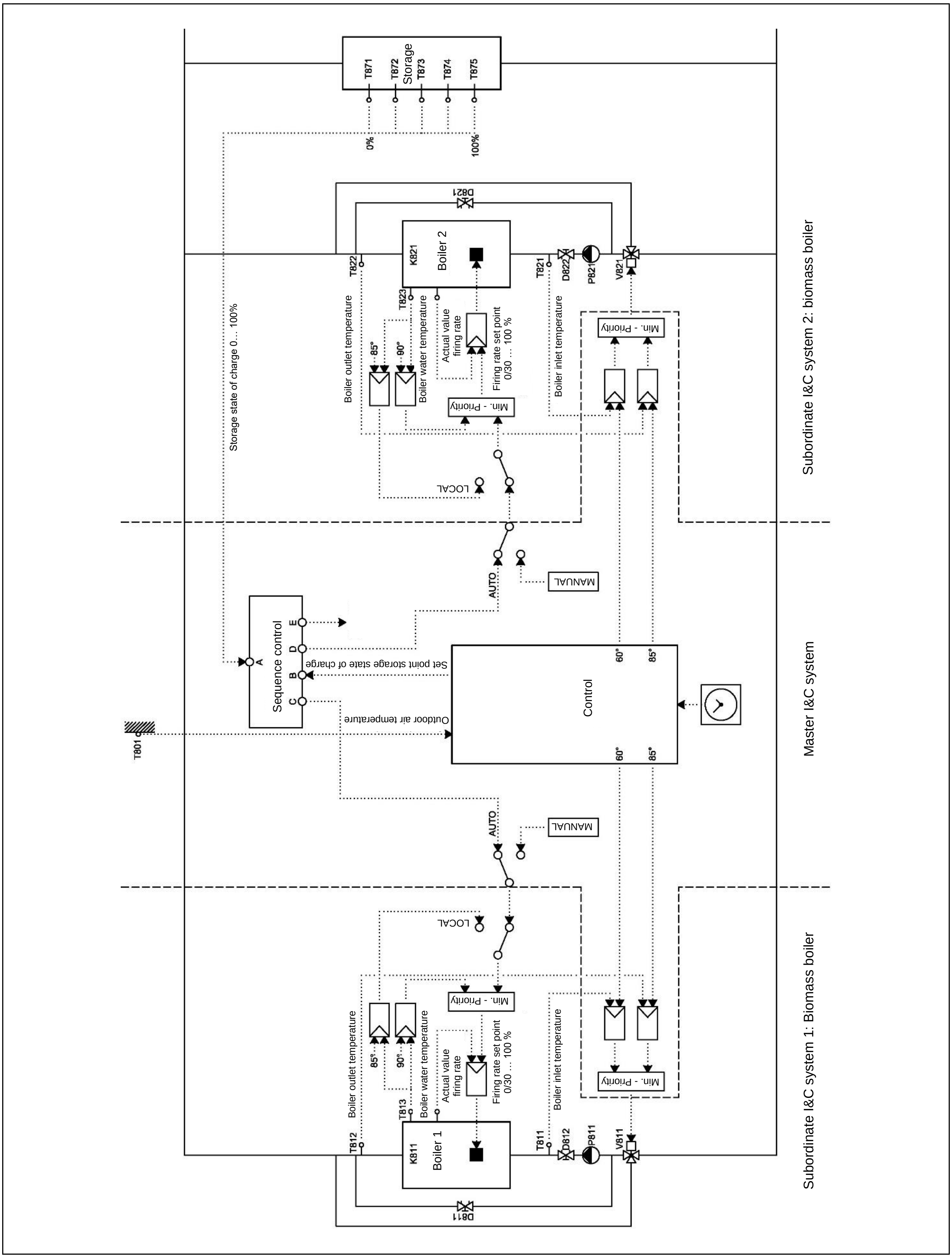

Figure 91: Control scheme for the two biomass boilers. Sequence control see Figure 93. The minimum priority switches route the lowest input signal to the output. Numerical values are to be understood as examples. Safety functions are not shown; these are to be realised via the subordinate I&C systems of the boilers.

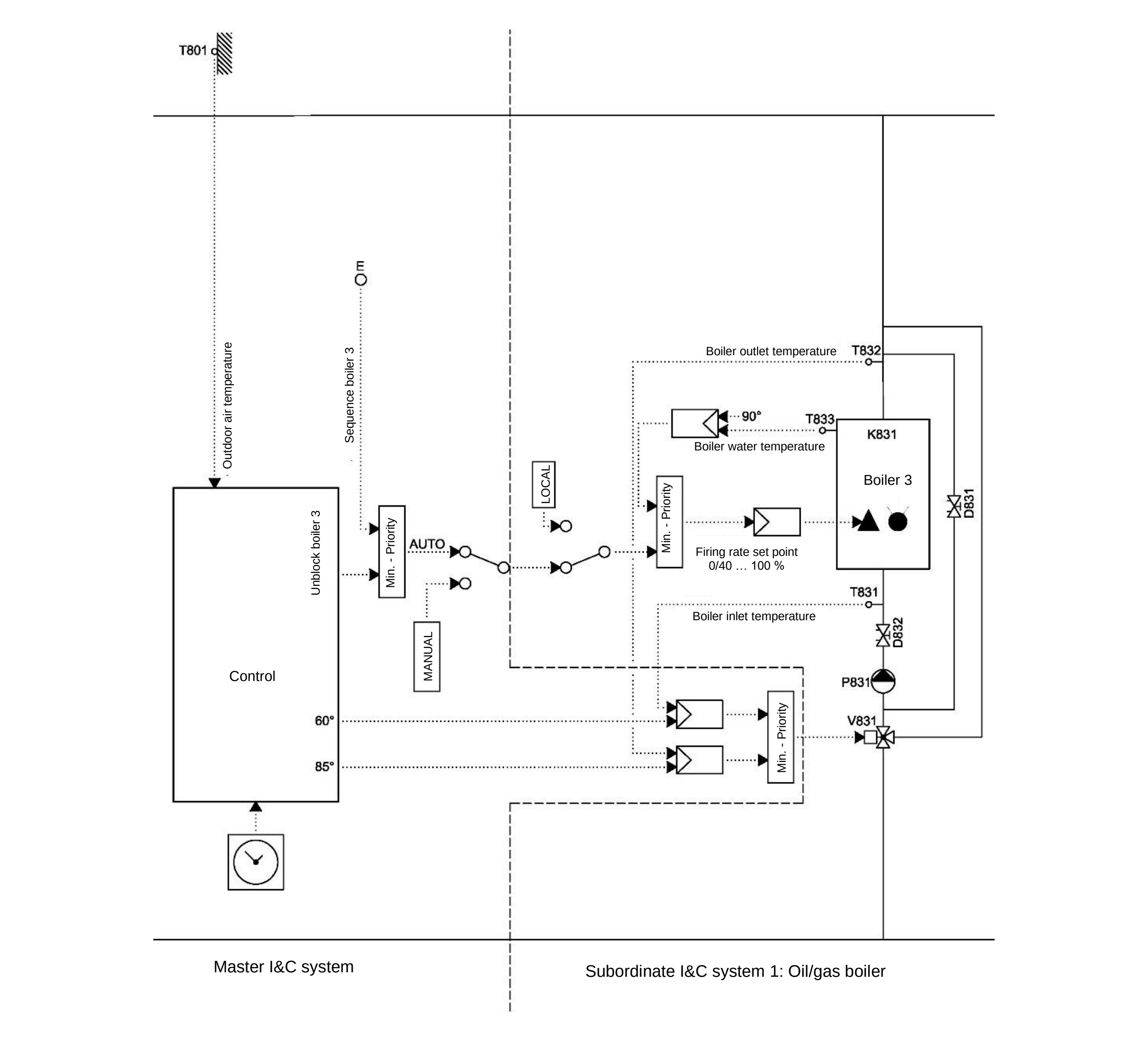

Figure 92: Control scheme for the oil/gas boiler. Sequence boiler 3 (input E) see Figure 93. The minimum priority switches route the lowest input signal to the output. Numerical values are to be understood as examples. Safety functions are not shown; these are to be realised via the subordinate I&C systems of the boilers.

8.3.9 Sequence control biomass boilers

The sequence control of the biomass boilers is to be realised by the master I&C system.

The following example assumes a power split of the two biomass boilers of 33% for boiler 1 and 67% for boiler 2. Switching from low-load operation to operation with automatic sequence control and back is done manually (percentages refer to the total output of the two biomass boilers):
- Manual switchover to boiler 2 alone (20...67%) if boiler 1 alone (10...33%) can no longer cover the daily demand
- Manual switchover to automatic sequence control if boiler 2 alone (20...67%) can no longer cover the daily demand.
- Manual switch back to boiler 2 alone (20...67%) when the daily demand can again be covered by boiler 2 alone for the foreseeable future.
- Manual switch back to boiler 1 alone (10...33%) when the daily demand can again be covered by boiler 1 alone for the foreseeable future.

The automatic sequence control must be carried out as follows (percentages refer to the total output of the two biomass boilers):
- boiler 2 alone (20...67%)
- Automatic connection of boiler 1 (10...33%) by means of automatic ignition (or fired bed support operation for large systems) if boiler 2 (20...67%) can no longer cover the hourly heat demand.
- Parallel operation boiler 1 and boiler 2 (together 30...100%)
- Automatic switch back to boiler 2 alone (20...67%) if the hourly heat demand falls below the sum of the two minimum outputs of 30%.

An example of the implementation of the sequence control is shown in Figure 93.

The boiler that is not in operation must be completely isolated hydraulically from the rest of the system (no faulty circulation due to overrun times, incorrectly set three-way valves, short circuits via safety lines, etc.).

8.3.10 Sequence control biomass boiler 1+2 - oil/gas boiler

The sequence control biomass boiler 1+2 - oil/gas boiler is to be implemented by the master I&C system.

The sequence controller of the oil/gas boiler must be designed and supplemented with suitable unblocking and blocking criteria in such a way that the oil/gas boiler is reliably prevented from being switched on too frequently.

Examples of unblocking and blocking criteria for the oil/gas boiler are:
- Unblocking when certain minimum outdoor air temperature AND setpoint of the firing rate of the two biomass boilers is set to 100% for a certain time.
- Blocking (switching back) when the setpoint value of the firing rate of the two biomass boilers has returned to 90% for a certain time.

If a biomass boiler goes on fault, the oil/gas boiler must be unblocked automatically.

When the oil/gas boiler is not in operation, it must be completely isolated hydraulically from the rest of the system (no faulty circulation due to overrun times, incorrectly set three-way valves, short circuits via safety lines, etc.).

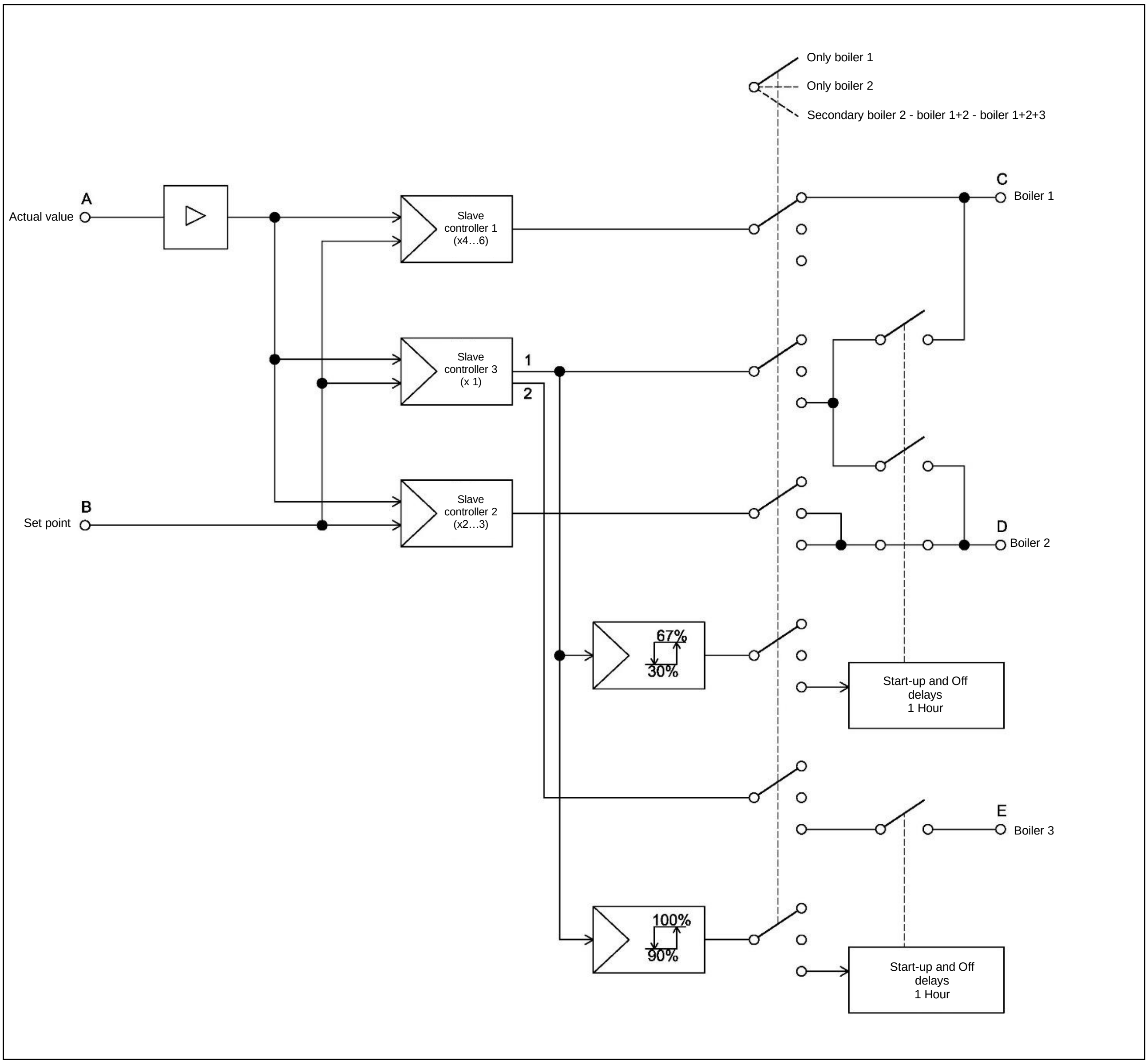

Figure 93: Example of the realisation of the sequence controller. Slave controller 3 is a sequence controller with two outputs. The interfaces A-E refer to Figure 91 and Figure 92. To ensure that the circuit gain is the same for all three control circuits, the transfer coefficients of the three controllers (depending on the design) are to be selected in a ratio of 4...6 : 2...3 : 1 (P-band reciprocal values 0,25...0,17 : 0,5...0,33 : 1).

8.3.11 Chosen control concept

The concept applicable to the project to be described as to how the control of the boiler circuits, the storage tank charging state and the firing rates is to be carried out is to be defined in Table 94 (an example is entered).

Operating mode	**Boiler circuit control: - Biomass boiler 1 - Biomass boiler 2 - Oil/gas boiler**	**Storage tank state of charge control (= main control variable)**	**Regulation of firing rates - Biomass boiler 1 - Biomass boiler 2 - Oil/gas boiler**
Off	Inoperative		
Manual ☐ Not provided	☐ Boiler return temperature protection through master I&C system ☐ Control of boiler outlet temperatures by master I&C system ☐ Limiting boiler water temperatures through subordinate I&C systems	☐ Storage tank charging status control out of operation	☐ Setpoint values of the firing rates can be set as fixed values on the master I&C system
Local	☐ Control of boiler water temperatures by subordinate I&C systems	☐ Storage tank charging status control out of operation	☐ Internal power controllers of the subordinate I&C systems activated
Automatic Summer operation? ☐ Yes, with biomass boiler ☐ Yes, with oil/gas boiler ☐ No	☐ Boiler return temperature protection through master I&C system ☐ Control of boiler outlet temperatures by master I&C system ☐ Limiting boiler water temperatures through subordinate I&C systems	☐ Control of the storage tank charging status by the master I&C system according to a special sequence control; the correcting variable is the setpoint values of the firing rates. ☐ Charge/discharge storage tank (low load operation)	☐ Control of the firing rates by the subordinate I&C systems; setpoints from the master I&C system according to the special sequence control.
Acquisition of storage tank state of charge	Number of storage tank sensors: ...... (at least 5) ☐ Stepped signal (variant 1) ☐ Smoothing with PT1 element (variant 2) ☐ Smoothing by interpolation via the temperature of the respective active sensor (variant 3) ☐ Average storage tank temperature as a measure of the storage tank charging status (variant 4)		
Summary	Which operating modes are provided? ☐ Off ☐ Manual (for each boiler) ☐ Local (for each boiler) ☐ Automatic winter operation Biomass boiler 1 alone (small boiler) ☐ Automatic winter operation Biomass boiler 2 alone (large boiler) ☐ Automatic winter operation Biomass boiler 1 + 2 in parallel (without automatic sequence control) ☐ Automatic sequence control Biomass boiler 2 alone - Biomass boiler 1 + 2 in parallel - oil/gas boiler ☐ Automatic low-load operation (transition period, summer) by charging/discharging storage with Biomass boiler 1 ☐ Automatic low-load operation (transition period, summer) with oil-gas boiler ☐ Oil/gas boiler alone (e.g. revision biomass boiler, emergency operation) ☐ Other:		

Table 94: Questions and answers on the chosen control concept

8.4 Data recording for operation optimisation

All precautions are to be taken so that a proper operational optimisation can be carried out and the subsequent regular operation can be efficiently monitored. The measured variables to be recorded are to be marked with a cross in Table 95 and Table 96 The measured variables marked "Standard" must be able to be recorded in any case; the connection of the remaining measured variables is recommended. The measuring accuracy must meet the increased requirements of a measuring system.

The questions and answers on automatic data recording for operational optimisation in Table 97must be answered.

☑	Standard	Measuring points	Label
☐	Standard	Outdoor air temperature	T801
☐	Standard	Inlet temperature Biomass boiler 1	T811
☐	Standard	Outlet temperature Biomass boiler 1	T812
☐		Boiler water temperature Biomass boiler 1 (other measuring point)	T813
☐	Standard	Inlet temperature Biomass boiler 2	T821
☐	Standard	Outlet temperature Biomass boiler 2	T822
☐		Boiler water temperature Biomass boiler 2 (other measuring point)	T823
☐	Standard	Inlet temperature oil/gas boiler	T831
☐	Standard	Outlet temperature oil/gas boiler	T832
☐		Boiler water temperature oil/gas boiler (other measuring point)	T833
☐	Standard *	Main supply temperature before storage tank	T841
☐	Standard *	Main supply temperature after storage tank	T842
☐	Standard	Main return temperature before storage tank	T843
☐	Standard *	Main return temperature after storage tank	T844
☐	Standard	Storage tank temperature (top)	T831
☐	Standard	Storage tank temperature	T832
☐	Standard	Storage tank temperature (middle)	T833
☐	Standard	Storage tank temperature	T834
☐	Standard	Storage tank temperature (bottom)	T835
☐	Standard *	Return temperature of the low-pressure difference connection	T851
☐	Standard	Supply temperature of the differential pressure-affected connection	T861
☐	Standard *	Return temperature of the differential pressure-affected connection	T862
*	In order to reduce the effort for data recording, a reduction by these measuring points is accepted as permissible deviation for operation optimisation.		

Table 95: Measuring point list for automatic data recording (part 1). If the installation is to be considered a standard hydraulic scheme, it must be possible to record all measured variables marked "Standard".

☑	Standard	Measuring points	Label
☐	Standard	Heat quantity/output heat meter Biomass boiler 1 **	W811
☐		Water quantity/flow rate heat meter Biomass boiler 1 **	W811
☐	Standard	Heat quantity/output heat meter Biomass boiler 2 **	W821
☐		Water quantity/flow rate heat meter Biomass boiler 2 **	W821
☐	Standard	Oil/gas meter, if modulating oil/gas boiler ***	W831/W832
☐	Standard	Operating hours stage 1/2, if two-stage oil/gas boiler	W831/W832
☐	Standard	Setpoint of the firing rate Biomass boiler 1	
☐		Boiler-internal setpoint of the firing rate (feedback signal Biomass boiler 1)	
☐	Standard	Setpoint of the firing rate Biomass boiler 2	
☐		Boiler-internal setpoint of the firing rate (feedback signal Biomass boiler 2)	
☐	Standard	Setpoint of the firing rate oil/gas boiler	
☐		Boiler-internal setpoint of the firing rate (feedback signal oil/gas boiler)	
☐	Standard	Actual value of the storage tank charging state	
☐	Standard	Flue gas temperature Biomass boiler 1	
☐		Combustion chamber temperature Biomass boiler 1	
☐	Standard *	Residual oxygen Biomass boiler 1	
☐	Standard	Flue gas temperature Biomass boiler 1	
☐		Combustion chamber temperature Biomass boiler 1	
☐	Standard *	Residual oxygen Biomass boiler 1	
		Measuring points Particle separator 1; type:	
☐			
☐			
		Measuring points Particle separator 2; type:	
☐			
☐			

* In order to reduce the effort for data recording, a reduction by these measuring points is accepted as permissible deviation for operation optimisation.

** The heat meter must be equipped with an interface for recording the heat quantity [kWh] or water quantity [m³]. The graphical representation, however, must be in terms of output [kW] or volume flow [m³/h]. A common heat meter for both boilers in the main return is permissible (to check the boiler output, the other boiler must be out of operation).

*** The oil/gas meter must be equipped with an interface for recording the oil or gas quantity [dm³ or m³]. The graphical representation, however, must be made as a volume flow [dm³/h or m³/h].

Table 96: Measuring point list for automatic data recording (part 2). If the installation is to be considered a standard hydraulic scheme, it must be possible to record all measured variables marked "Standard".

Area	Questions and answers
Hardware	How is the automatic data recording for operational optimisation carried out? ☐ With a separate data logger ☐ With the PLC of the biomass boiler ☐ With the master I&C system
	How is the periodic reading of the data done? ☐ Reading out the data on site ☐ Readout via landline phone (POTS) connection ☐ Readout via ISDN telephone connection ☐ Readout via the Internet
Data recording	What is the measurement interval? ☐ 10 seconds (recommendation)..... seconds
	What is the recording interval? ☐ 5 minutes (recommendation)..... minutes
	How are the analogue values recorded? ☐ As an average value over the last recording interval (recommendation) ☐ As instantaneous value
	How is the recording done for meters? ☐ As a sum value over the last recording interval (recommendation) ☐ As current counter reading (Attention: is often set to zero by mistake)
	How is the recording of running times done? ☐ As runtime during the last recording interval (recommendation) ☐ As the current number of operating hours (Attention: is often accidentally set to zero)
	How large is the measured value memory? ☐ ≥ 30 days recording capacity (recommendation)..... days recording capacity
Data evaluation	What is the output format for evaluation in EXCEL? ☐ CSV file with columns = time and measuring points, rows = values (recommendation) ☐ Other:
	How is the graphical representation done? ☐ Related data as a weekly overview (recommendation) ☐ Related data as a daily overview (recommendation) ☐ Representation of heat, oil, gas, operating hours meters as output or volume flow (demand) ☐ Other:
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of the autom. data recording by the main planner ☐ Specification of the automatic data recording by the main planner with the involvement of the I&C specialist
	How are the responsibilities regulated at the execution and approval stage? ☐ Planning of the autom. data recording by the main planner ☐ Planning of autom. data recording by biomass boiler suppliers ☐ Planning of the autom. data recording by the supplier of the master I&C system
	How are responsibilities regulated during operational optimisation? ☐ Readout and data evaluation by main planner ☐ Readout by biomass boiler supplier, data evaluation by main planner ☐ Readout by supplier of master I&C system, data evaluation by main planner ☐ Readout by operator, data evaluation by main planner ☐ Readout and data evaluation by operator

Table 97: Questions and answers on automatic data recording for operational optimisation

8.5 Annex to the approval protocol

The execution phase is concluded by the approval test. At this point, an addendum to the approval protocol is to be drawn up in accordance with Table 98 to Table 100.

The questions in Table 98 must be answered at the beginning of the tendering phase. The annex to the approval protocol according to Table 99 and Table 100 must only be completed at the end of the execution phase. However, it is recommended to use these tables already during the tendering and execution phase for the preliminary determination of the planning values; so that the functionality of the system is clearly recognisable.

Who prepares the addendum to the approval protocol? ☐ Main planner ☐ Biomass boiler supplier ☐ Supplier of the master I&C system

Table 98: Questions and answers on the annex to the approval protocol

Description		Unit	*Example*			
Master I&C system Connection of master/subordinate I&C systems via standard interface [9]? ☐ Yes ☐ No						
■ **Load control**						
Boiler outlet temperature setpoint Biomass boiler 1		°C	*85*			
Setpoint boiler outlet temperature Biomass boiler 2		°C	*85*			
Boiler outlet temperature setpoint oil/gas boiler		°C	*85*			
■ **Boiler return temperature protection**						
Boiler inlet temperature limit Biomass boiler 1		°C	*60*			
Boiler inlet temperature limit Biomass boiler 2		°C	*60*			
Boiler inlet temperature limit oil/gas boiler		°C	*60*			
■ **Storage charge control** Who specifies OFF (or fire bed support) and steady regulation? ☐ The active control system ☐ Always the biomass boiler How is the "continuous control" switched to "charge/discharge storage tank"? ☐ Switchover by hand ☐ Other:						
Setpoint storage tank state of charge		%	*60*			
Setpoint storage tank sensor "warm"		°C	*≥75*			
Setpoint storage tank sensor "cold"		°C	*≤65*			
Continuous control Slave controller	P-band slave controller 1 (Biomass boiler 1 alone)	%	*75*			
	Integration time slave controller 1 (Biomass boiler 1 alone)	Min.	*20*			
	P-band slave controller 2 (Biomass boiler 2 alone)	%	*150*			
	Integration time slave controller 2 (Biomass boiler 2 alone)	Min.	*20*			
	P-band slave controller 3 (Biomass boiler 1+2)	%	*225*			
	Integration time slave controller 3 (Biomass boiler 1+2)	Min.	*20*			
Two-point controller (oil/gas boiler in sequence)	Biomass boiler 1 continuous control at setpoint firing rate.	%	*≥35*			
	Biomass boiler 1 OFF/fire bed at setpoint firing rate	%	*≤25*			
	Biomass boiler 2 continuous control at setpoint firing rate.	%	*≥35*			
	Biomass boiler 2 OFF/fire bed at setpoint firing rate	%	*≤25*			
	Oil/gas boiler stage 1 ON at setpoint firing rate	%	*≥45*			
	Oil/gas boiler stage 1 OFF at setpoint firing rate	%	*≤35*			
	Oil/gas boiler stage 2 ON at setpoint firing rate	%	*≥75*			
	Oil/gas boiler stage 2 OFF at setpoint firing rate	%	*≤65*			

Table 99: Supplement to the approval protocol (part 1) - setting values; exemplary values are to be deleted

Description	**Unit**	*Example*			
■ **Sequence control Biomass boiler 2 - Biomass boiler 1+2 (modify if necessary)**					
Unblocking criterion Biomass boiler 1: Setpoint firing rate Biomass boiler 2 (in % of total output) AND delay time	 % Min.	 *100 (67)* *60*			
Blocking criterion Biomass boiler 1: Setpoint firing rate Biomass boiler 1+2 AND delay time	 % Min.	 *30* *60*			
■ **Sequence control Biomass boiler 1+2 - oil/gas boiler (modify if necessary)**					
Unblocking criterion: Outdoor air temperature AND (setpoint firing rate Biomass boiler 1+2 AND delay time)	°C % Min.	*≤ 0* *100* *30*			
Blocking criterion: Setpoint firing rate Biomass boiler 1+2 AND delay time	% Min.	*90* *10*			
Biomass boiler 1					
■ **Heat output settings**					
Set minimum heat output with the reference fuel	kW	*100*			
Set maximum heat output with the reference fuel	kW	*330*			
■ **Subordinate I&C system 1**					
Boiler water temperature setpoint for "local" operating mode	°C	*85*			
Boiler water temperature limitation	°C	*95*			
Safety shutdown at boiler water temperature	°C	*110*			
Biomass boiler 2					
■ **Heat output settings**					
Set minimum heat output with the reference fuel	kW	*200*			
Set maximum heat output with the reference fuel	kW	*670*			
■ **Subordinate I&C system 2**					
Boiler water temperature setpoint for "local" operating mode	°C	*85*			
Boiler water temperature limitation	°C	*95*			
Safety shutdown at boiler water temperature	°C	*110*			
Oil/gas boiler					
■ **Heat output settings**					
Set minimum heat output	kW	*670*			
Set maximum heat output	kW	*1670*			
■ **Subordinate I&C system 3**					
Boiler water temperature limitation	°C	*90*			
Safety shutdown at boiler water temperature	°C	*110*			

Table 100: Supplement to the approval protocol (part 2) - setting values; exemplary values are to be deleted

9. District heating network (if available)

9.1 Heat consumers

For the heat consumers, the questions in Table 101 answered.

Description	**Questions and answers**
Differential pressure-affected connections on the district heating network Chapter 12	How are the pressure-differential connections on the district heating network controlled? ☐ Individual controller ☐ PLC of the master I&C system for heat production ☐ PLC of the biomass boiler(s), which is used as the master I&C system of the heat production. ☐ Small guidance system ☐ Building management system Are differential pressure regulators installed? ☐ No ☐ Yes, pressure differential regulator between flow and return ☐ Yes, combination valves
Responsibilities according to phases and customers	How are responsibilities regulated at the tender planning stage? ☐ Specification of all customers by the main planner How are the responsibilities regulated at the execution and approval stage? ☐ Overall planning of all customers by the main planner ☐ Overall planning of all customers by the main supplier of the I&C systems ☐ Planning of each buyer by the respective supplier

Table 101: Questions and answers on heat consumers

9.2 District heating network

For the district heating network, the questions in Table 102 answered.

Description	Questions and answers
District heating network system	Which pipe system? ☐ Rigid plastic casing pipes, steel inner pipe ☐ Flexible plastic casing pipes, steel inner pipe ☐ Flexible plastic casing pipes, plastic inner pipe ☐ Flexible plastic casing pipes, double inner pipe steel ☐ Flexible plastic casing pipes, double inner pipe plastic ☐ Flexible steel casing pipes, steel inner pipe ☐ Other: Which monitoring and fault location system? ☐ Resistance method ☐ Pulse transit time method ☐ Other: How are the line connections made? ☐ Fittings ☐ Drilling How are the pipes laid? ☐ Thermally not pre-tensioned ☐ Thermally pre-tensioned
Extent	Total path length .... Trm Length of the most unfavourable trunk line relevant for the district heating network calculation .... Trm Length of the most unfavourable branch line relevant for the district heating network calculation .... Trm Length of the most unfavourable house connection relevant for the district heating network calculation .... Trm Decisive pipe length = 2 x (trunk line + branch line + house connection) ....m
District heating network calculation	How was the district heating network calculated? Method (e.g. software) .... - Heating water temperature used as a basis .... °C - Pipe roughness used as a basis ....mm Maximum flow velocity at DN ....m/s Pressure drop relevant trunk line + branch line + house connection .... kPa Specific pressure drop network pipe = pressure drop / relevant pipe length .... Pa/m Pressure drop of most unfavourable heat consumer (critical node) .... kPa Pressure drop rest (pre-control etc.) .... kPa Necessary delivery head of the network pump ....m Nominal pressure of the district heating network .... bar
Responsibilities	How are responsibilities regulated at the tender planning stage? ☐ Specification of the trunk line by the main planner ☐ Other: How are the responsibilities regulated at the execution and approval stage? ☐ Overall planning of the trunk line by the main planner ☐ Other:

Table 102: Questions and answers on district heating network

9.3 Pre-control, network pump, differential pressure control

The **pre-control** of the district heating network is to be weather-compensated and time programme-controlled by the master I&C system. The pre-control can be realised with one or two control valves (see Planning Handbook [4]).

Pre-control is not necessary if the heat network must always be operated at the temperature level of the heat production.

In the case of extensive district heating networks, **several network pumps** can also be used if the following conditions are met:

- Parallel connection of two pumps, if only one pump is in operation at a time (i.e. second pump is used as a standby pump)
- Parallel connection of several pumps, if several pumps are more favourable for achieving the required flow rate (efficiency, costs).
- Series connection of several pumps, if several pumps are more favourable for achieving the required head (efficiency, costs).

Sizing of the network pump according to Table 103

The network pump is to be equipped with a **differential pressure control.** The measuring point(s) of the differential pressure control must be selected in such a way that the pressure difference fluctuation in the network is only large enough to ensure faultless operation at every operating point (see Planning Handbook [4]).

For the chosen concept of pre-control and differential pressure control of the district heating network, the questions in Table 104 to be answered.

Hydraulic and control system design	**Unit**	*Example*			**Label**
Guaranteed temperature limits					
Maximum supply temperature district heating network	°C	*85*			T*61
Maximum permissible return temperature district heating network	°C	*55*			T*62
Pre-control and network pump					
Heat output district heating network	kW	*1000*			
Delivery flow network pump	m3/h	*28,7*			P*61
Delivery head network pump	m	*25*			P*61
Flow rate control valve Pre-control District heating network	m3/h	*28,7*			V*61
Pressure drop control valve	kPa	*10*			V*61
Pressure drop section with variable volume flow	kPa	*8*			
Resulting valve authority	–	*0,56*			V*61
Number corresponding to the standard hydraulic scheme used					

Table 103: Dimensioning of pre-control and network pump; exemplary values to be deleted

Assembly	Questions and answers
Weather-compen-sated pre-control district heating net-work	How is the pre-control realised? ☐ Through master I&C system ☐ By PLC of the biomass boiler ☐ Separate individual controller
	Number of control valves? ☐ 1 control valve ☐ 2 control valves in parallel
Network pump(s)	Number and mode of operation? ☐ One pump ☐ Two pumps in series; reason: ..... ☐ Two pumps in alternative operation ☐ Two pumps in parallel operation (not recommended!)
	Design? ☐ Canned pump(s) ☐ In-line pump(s) ☐ base-mounted pump(s)
Differential pressure control	How is the differential pressure control realised? ☐ Constant pressure control built into pump(s) ☐ Proportional pressure control built into pump(s) (so-called "negative" pump characteristic) ☐ Through master I&C system ☐ Through PLC of the biomass boiler ☐ Separate individual controller(s)
	What is the method for differential pressure control? ☐ Constant pressure above the pump(s) ☐ Proportional pressure over the pump(s) ☐ Constant pressure between flow and return at the pump(s) ☐ Constant pressure at a measuring point in the network; measuring point: ..... ☐ Bad point control at ..... Measuring locations in the network ☐ Control to the control valve position of the most unfavourable heat consumer in each case
	Type of speed adjustment? ☐ Built in pump(s) ☐ Separate frequency converter(s)

Table 104: Answers to the questions on pre-control of the network pump and differential pressure control

10. System-specific amendments

System-specific amendments should be integrated into this description if possible; these can be, for example:

- Special operating modes
- Information on the time programme control
- Alarming information
- Specifications for control cabinets, plug connections, etc.
- requirements for expansion subordinate, filling equipment, heating water quality, etc.
- Location-specific requirements for the safety functions

Chapter 10 is available for this purpose. The hierarchy of the chapter division is left to the user.

11. Heat consumers in the central heating plant (low pressure differential connections)

11.1 Possibilities of realisation

■ The control/regulation of the heating groups in the central heating plant by **individual controllers** is the simplest solution for smaller systems.

■ A solution via the **PLC of the master I&C system of the heat production** or **the PLC of the biomass boiler(s)** (if this is already used as the master I&C system of the heat production) is also possible.

■ For medium-sized and larger installations, it can also be a solution via a **small guidance system** or a **larger building management system**.

11.2 Hydraulic circuit

The standard hydraulic circuits are those shown in Figure 105:

■ WA1: Direct connection of a **heating group without heat exchanger** with three-way valve (mixing circuit)

■ WA2: Indirect connection of a **heating group with heat exchanger in** case of large geodetic height difference of the system and/or high pump pressure in case of extensive systems (smaller operating pressure of the heating group possible).

■ WA3a: Connection of a **hot water heater with external heat exchanger and charge control:** Results in a constant high heating output at a constant high hot water temperature and defined low return temperature

■ WA3b: Connection of a **water heater with external heat exchanger without charge control:** The charge control of the water heater according to WA3a can be dispensed with if the maximum permissible return temperature can nevertheless be guaranteed by suitable hydraulic and control measures (this requirement does not have to be met for a system without a storage tank).

■ WA3c: Connection of a **water heater with internal heat exchanger:** The maximum permissible return temperature must be guaranteed by suitable hydraulic and control measures (for a system without a storage tank, this requirement does not have to be met).

11.3 Hydraulic and control design

The hydraulic and control design must be carried out according to the generally accepted engineering standards. The requirements according to the Q-Guideline [1] and the Planning Handbook [4] must be fulfilled, in particular:

- Valve authority ≥ 0,5, i.e. Pressure drop across control valve ≥ Pressure drop across variable flow section
- In case of several heating groups with three-way valves: Prevention of mutual influence due to miscirculation, i.e. maximum pressure drop over the sections with variable flow ≤ 20% delivery head of the smallest group pump (first AND second requirement must be fulfilled!)
- If the maximum Supply temperature of the heating group is lower than the maximum supply temperature on the primary side, a bypass must be installed upstream of the group pump
- The circuits must be designed in such a way that the maximum permissible return temperature can be maintained in every operating case.

The **consumers on the secondary side of heat exchangers** (here in particular WA2) must always be connected as pressure-differential connections in accordance with section 12.2. Low-pressure-differential connections are only possible in exceptional cases if the secondary-side pressure drop of the heat exchanger at design flow meets the above-mentioned requirements.

11.4 Functional description

■ **WA1:** Weather-compensated supply temperature control. For systems with storage tank, return temperature limitation if there is a risk of exceeding the maximum permissible return temperature.

■ **WA2:** Weather-compensated control of the secondary-side supply temperature via the primary-side three-way valve. For systems with storage tank, primary-side return temperature limitation if there is a risk of exceeding the maximum permissible return temperature.

■ **WA3a:** Charge control of the hot water tank to a fixed value via the three-way valve on the secondary side. Switch-on sensor at the top (e.g. at 2/3 height) and switch-off sensor at the bottom of the storage tank. Primary-side control of the heat exchanger inlet temperature via the primary-side three-way valve (protection against calcification). In the case of a system with a storage tank, return temperature limitation on the primary side if there is a risk of the maximum permissible return temperature being exceeded.

■ **WA3b:** Switch-on sensor at the top (e.g. at 2/3 height) and switch-off sensor at the bottom of the storage tank. Primary-side control of the heat exchanger inlet temperature via the primary-side three-way valve (protection against calcification). In the case of a system with a storage tank, return temperature limitation on the primary side if there is a risk of the maximum permissible return temperature being exceeded.

■ **WA3c:** Switch-on sensor at the top (e.g. at 2/3 height) and switch-off sensor at the bottom of the storage tank. Primary-side control of the heat exchanger inlet temperature via the primary-side three-way valve (protection against calcification). In the case of a system with a storage tank, return temperature limitation on the primary side if there is a risk of the maximum permissible return temperature being exceeded.

The throttling elements with the footnote "not applicable if no temperature change" in Figure 105 required in the following cases, for example:

- The heat consumer is an underfloor heating system with a much lower supply temperature than the district heating network.
- Heat consumer is a hard water heating system (prevention of heat exchanger calcification).

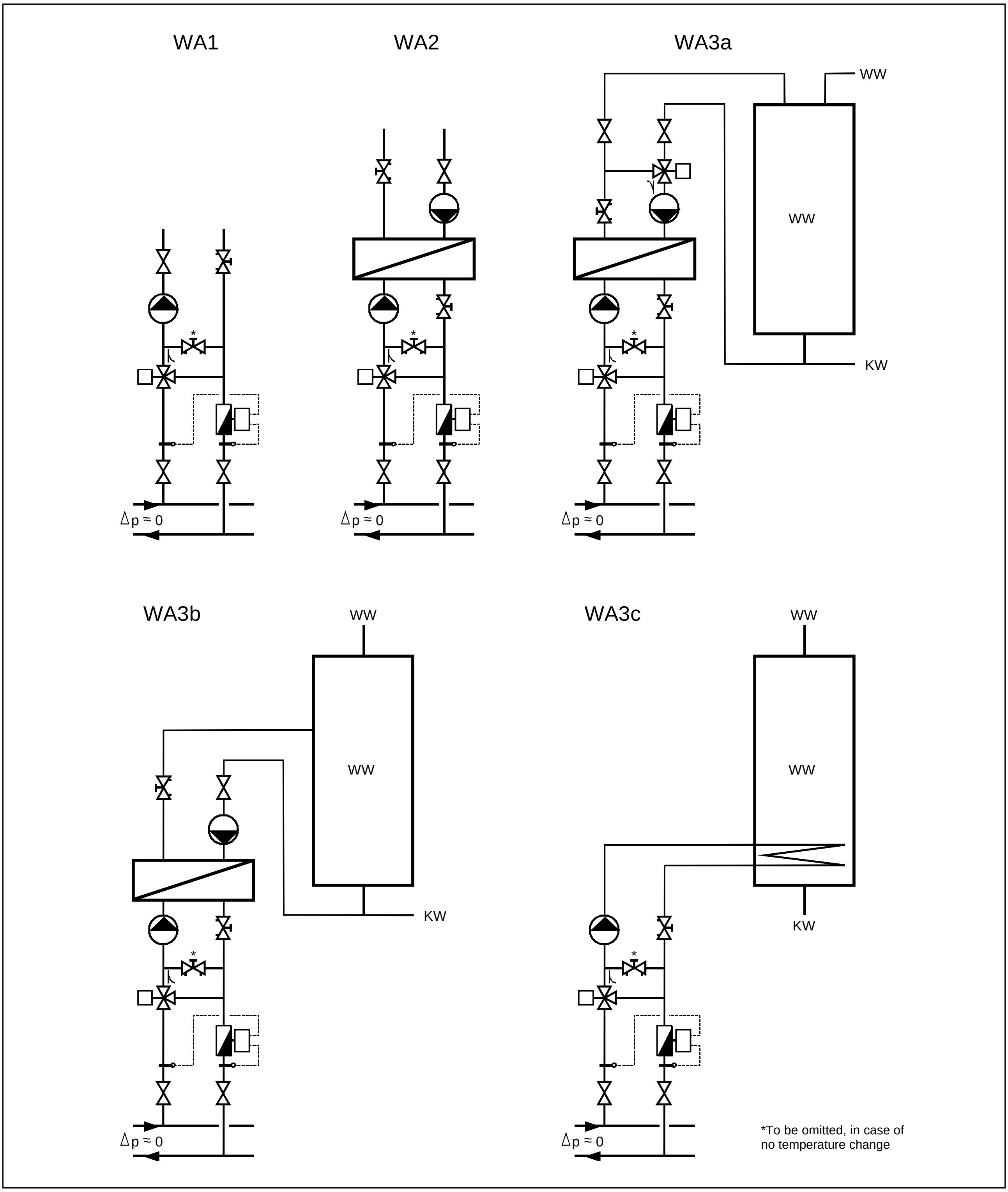

Figure 105: Principle scheme of low-pressure differential connections in the central heating plant. Safety devices and expansion system are not shown; these must be designed according to the country-specific regulations.

12. Heat consumers on the district heating network (connections with pressure difference)

12.1 Possibilities of realisation

■ Control/regulation of the district heating network connections by means of **individual controllers** is the simplest solution for smaller systems

■ For medium-sized and larger installations, it can also be a solution via a **small guidance system** or a **larger building management system**

12.2 Hydraulic circuit

The standard hydraulic circuits are those shown in Figure 106 and Figure 107:

■ WA4a: Direct connection of a **heating group without heat exchanger** by means of a throttle circuit (variable flow in the heating group, e.g. connection of an air heater).

■ WA4b: Direct connection of a **heating group without heat exchanger** by means of injection circuit with straight-way valve (constant flow in the heating group, e.g. connection of a radiator or underfloor heating).

■ WA5: Indirect connection of a **heating group with heat exchanger in** case of large geodetic height difference of the system and/or high pump pressure in case of extensive systems (smaller operating pressure of the heating group possible).

■ WA6: Combination **heating group without heat exchanger and water heater:**
- Direct connection of the heating group
- WA6a: Connection of a hot water heater with external heat exchanger and charge control: Results in a constant high heating output at a constant high hot water temperature and defined low return temperature.
- WA6b: Connection of a water heater with external heat exchanger without charge control: The charge control of the water heater according to WA3a can be dispensed with if the maximum permissible return temperature can nevertheless be guaranteed by suitable hydraulic and control measures.
- WA6c: Connection of a hot water heater with internal heat exchanger: The maximum permissible return temperature must be guaranteed by suitable hydraulic and control measures.

■ WA7: Combination **heating group with heat exchanger and water heater:**
- Indirect connection of the heating group in the case of large geodetic height difference of the system and/or high pump pressure in the case of extensive systems (smaller operating pressure of the heating group possible)
- WA7a: Connection of a hot water heater with external heat exchanger and charge control: Results in a constant high heating output at a constant high hot water temperature and defined low return temperature.
- WA7b: Connection of a water heater with external heat exchanger without charge control: The charge control of the water heater according to WA3a can be dispensed with if the maximum permissible return temperature can nevertheless be guaranteed by suitable hydraulic and control measures.
- WA7c: Connection of a hot water heater with internal heat exchanger: The maximum permissible return temperature must be guaranteed by suitable hydraulic and control measures.

■ WA8: **Connection with heat exchanger and several heating groups and water heater on the secondary side:**
- Indirect connection in case of large geodetic height difference of the system and/or high pump pressure in case of extensive systems (smaller operating pressure of the heating group possible).
- Low pressure differential connection on the secondary side analogous to the standard hydraulic schemes WA1 (heating groups) and WA3a...WA3c (water heaters)

Attention: This circuit is only possible if the secondary side connection of the heat exchanger can be made with such a low pressure difference that the following requirements are met:
- Valve authority ≥ 0,5, i.e. Pressure drop across control valve ≥ Pressure drop across section with variable flow (= heat exchanger + connection pipes)
- Maximum pressure drop across the variable flow sections≤).

■ WA9: **Heat transfer station with storage tank for several heating groups and water heaters:**
- For heat consumers with large peak loads
- Low pressure differential connection on the secondary side analogous to the standard hydraulic schemes WA1 (heating groups) and WA3a...WA3c (water heaters)

Attention: Observe the nominal pressure of the heating water tank.

The heat exchangers for hot water preparation in the standard hydraulic schemes WA6 and WA7 are always connected in the same way as circuit WA4a, so that hot water preparation with hard water is also possible (prevention of heat exchanger calcification). If this is not necessary (soft water or district heating network temperature always below 70°C), it is also possible to connect analogue circuit WA4b or WA5 (i.e. pump and non-return valve are omitted).

The check valves in the bypasses to prevent the return temperature rise due to miscirculation (flow primary > flow secondary) can be omitted if the disadvantages outweigh the advantage mentioned. Disadvantages are:
- Single-sided hydraulic decoupling
- Pump pressures are added in case of miscirculation
- Group gets warm despite the pump being switched off if the valve is opened unintentionally

Bypasses or overflow valves to ensure a minimum flow at the end of the strings (e.g. prevention of "cold taps") are only permissible if no other solution is possible and it can be guaranteed that the flow is so low that no malfunctions occur (hardly possible for systems with storage tanks!).

The circuits are also considered standard hydraulic schemes if
- the straight-way valves are mounted in the return,
- the differential pressure regulators are mounted in the flow,
- the differential pressure control takes place directly above each straight-way valve (combination valves).

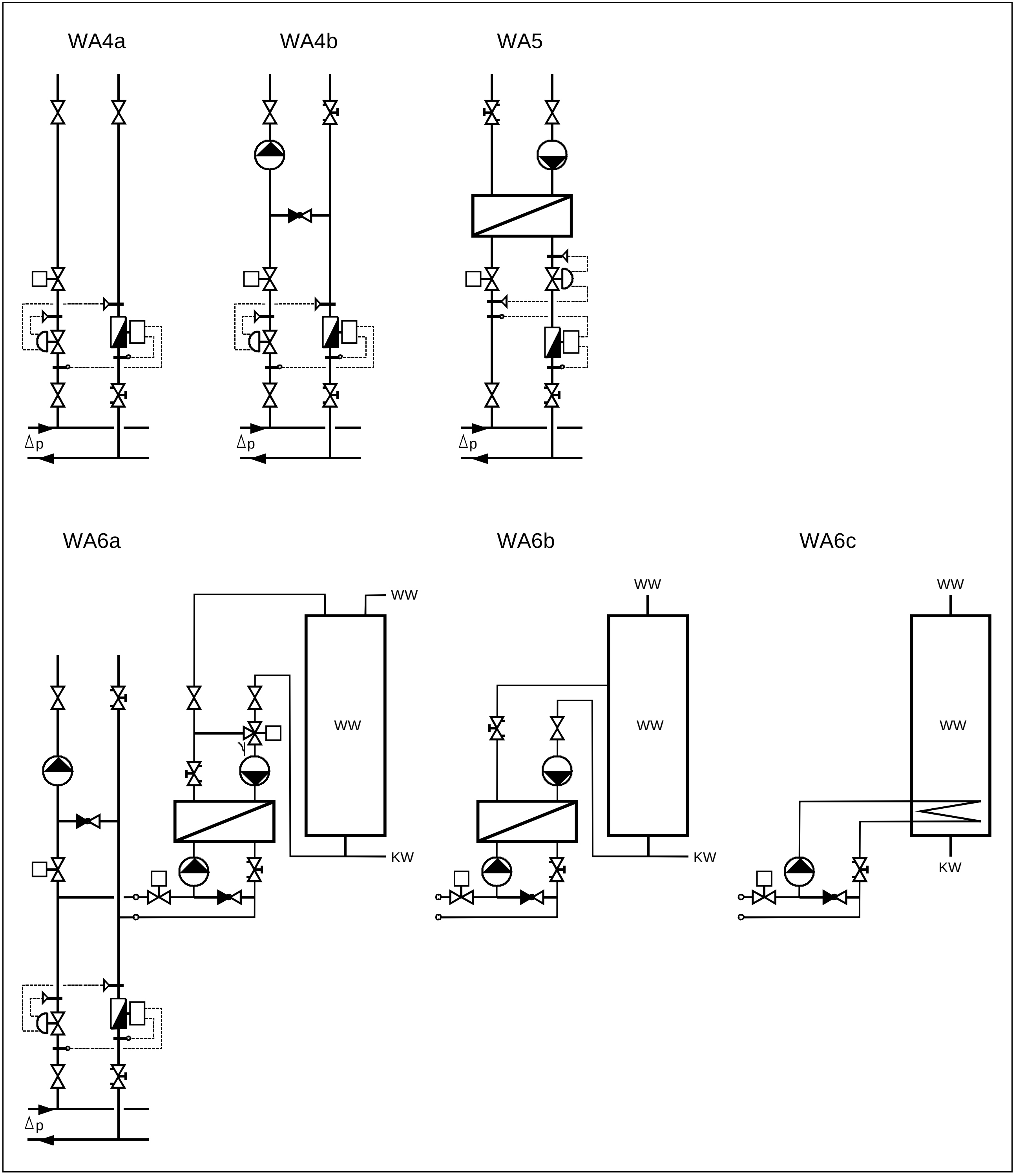

Figure 106: Principle scheme of pressure-differential connections on the district heating network WA4 to WA6. Safety devices and expansion equipment are not shown; these must be designed in accordance with the country-specific regulations.

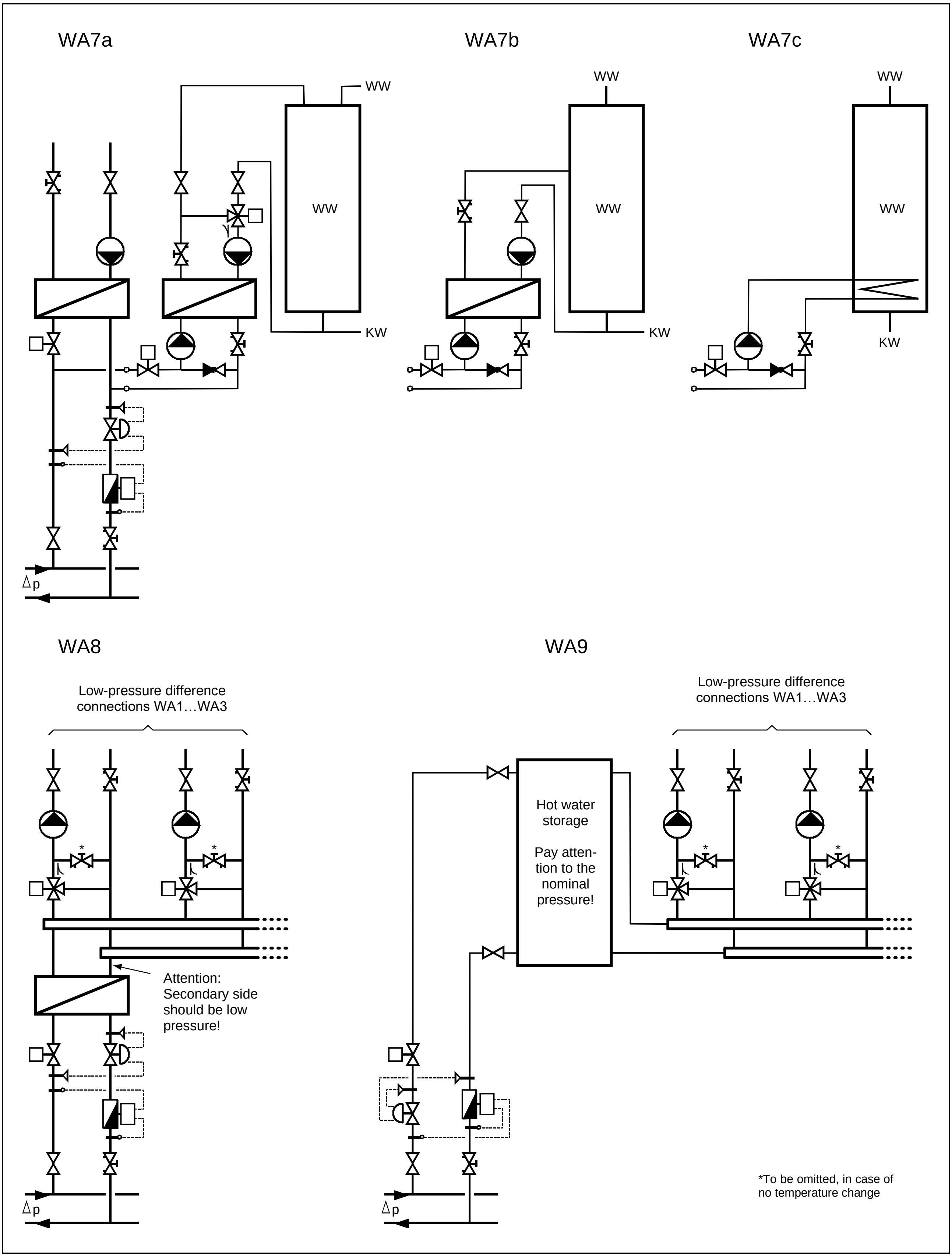

Figure 107: Principle scheme of pressure-differential connections on the district heating network WA7 to WA9. Safety devices and expansion equipment are not shown; these must be designed in accordance with the country-specific regulations.

12.3 Further variants

For all circuits with hot water preparation, there are still the following options (Figure 108):

■ **Residual heat utilisation:** Equipment with an additional heat exchanger in the cold-water line in order to cool down the return flow as much as possible. This circuit can be combined with all standard hydraulic schemes WA6 to WA9. Caution with high return temperatures and hard drinking water!

■ **Hot water preparation by means of instantaneous water heater:** This circuit can be combined with the standard hydraulic schemes WA6 to WA9 (connection analogous to variants a, b and c). The disadvantage of this circuit is:
- Oft insufficient hot water peak output
- The frequently occurring power peaks cannot be eliminated by a "boiler priority switch”
- Suitable for soft drinking water only

■ **Connections with jet pump:** This circuit can be used analogously to the standard hydraulic schemes WA4 to WA9. The jet pump results in temperature control with variable flow. For comparison: WA4a gives a flow control with variable flow, WA4b a temperature control with constant flow. Caution is advised because of the variable flow in poorly balanced heat consumer networks (danger of "dying" of poorly flowing system parts at low load).

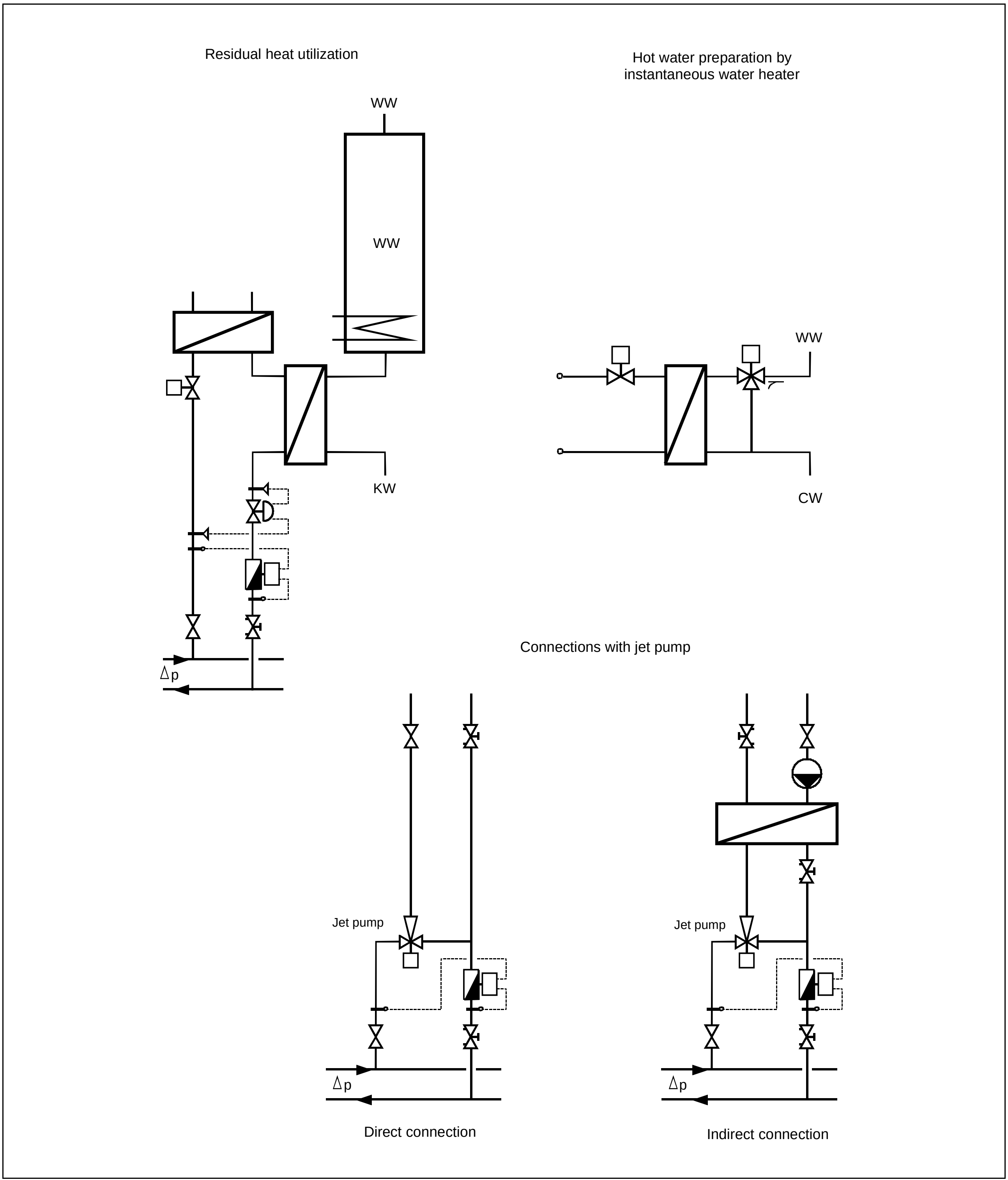

Figure 108: Residual heat utilisation for cooling the return flow as much as possible and hot water preparation by means of instantaneous water heater (for integration and possible problems see text!)

12.4 Hydraulic and control design

The hydraulic and control design must be carried out according to the generally accepted engineering standards. The requirements according to the Q-Guideline [1] and the Planning Handbook [4] must be fulfilled, in particular:

- Valve authority three-way valves ≥ 0,5
- Valve authority straight-way valves ≥ 0,3
- The circuits must be designed in such a way that the maximum permissible return temperature can be maintained in every operating case.

Taps on the secondary side of heat exchangers (here in particular WA5 and WA7 to WA9) should if possible - be connected as pressure-differential connections in accordance with the above-mentioned requirements. Low pressure differential connections are only possible if the secondary side pressure drop of the heat exchanger at design flow complies with the requirements of section 12.2.

12.5 Functional description

■ **WA4a and WA4b:** Weather-compensated supply temperature control. Return temperature limitation if there is a risk of exceeding the maximum permissible return temperature.

■ **WA5:** Weather-compensated control of the secondary-side supply temperature via the primary-side straight way valve. Primary-side return temperature limitation if there is a risk of exceeding the maximum permissible return temperature.

■ **WA6 Heating circuit:** Weather-compensated supply temperature control. Return temperature limitation if there is a risk of exceeding the maximum permissible return temperature. **Water heating:**

- WA6a: Charge control of the hot water tank to a fixed value via the three-way valve on the secondary side. Switch-on sensor at the top (e.g. at 2/3 height) and switch-off sensor at the bottom of the storage tank. Primary-side control of the heat exchanger inlet temperature via the primary-side three-way valve (protection against calcification). Return temperature limitation if there is a risk of exceeding the maximum permissible return temperature.
- WA6b: Switch-on sensor at the top (e.g. at 2/3 height) and switch-off sensor at the bottom of the storage tank. Primary-side control of the heat exchanger inlet temperature via the primary-side three-way valve (protection against calcification). Return temperature limitation if there is a risk of exceeding the maximum permissible return temperature.
- WA6c: Switch-on sensor at the top (e.g. at 2/3 height) and switch-off sensor at the bottom of the storage tank. Primary-side control of the heat exchanger inlet temperature via the primary-side three-way valve (protection against calcification). Return temperature limitation if there is a risk of exceeding the maximum permissible return temperature.

■ **WA7 Heating circuit:** Weather-compensated control of the secondary-side supply temperature via the primary-side straight way valve. Primary-side return temperature limitation if there is a risk of exceeding the maximum permissible return temperature. **Water heating:**

- WA7a: Charge control of the hot water tank to a fixed value via the three-way valve on the secondary side. Switch-on sensor at the top (e.g. at 2/3 height) and switch-off sensor at the bottom of the storage tank. Primary-side control of the heat exchanger inlet temperature via the primary-side three-way valve (protection against calcification). Return temperature limitation if there is a risk of exceeding the maximum permissible return temperature.
- WA7b: Switch-on sensor at the top (e.g. at 2/3 height) and switch-off sensor at the bottom of the storage tank. Primary-side control of the heat exchanger inlet temperature via the primary-side three-way valve (protection against calcification). Return temperature limitation if there is a risk of exceeding the maximum permissible return temperature.
- WA7c: Switch-on sensor at the top (e.g. at 2/3 height) and switch-off sensor at the bottom of the storage tank. Primary-side control of the heat exchanger inlet temperature via the primary-side three-way valve (protection against calcification). Return temperature limitation if there is a risk of exceeding the maximum permissible return temperature.

■ **WA8:** Primary-side control of the heat exchanger inlet temperature via the straight-way valve. Return temperature limitation if there is a risk of exceeding the maximum permissible return temperature. Secondary-side control according to the functional descriptions WA1 (heating groups) and WA3a...WA3c (water heaters).

■ **WA9:** Charging of the heating storage tank via the primary side through valve. Switch-on sensor at the top and switch-off sensor at the bottom of the heating tank. Secondary side control according to function descriptions WA1 (heating groups) and WA3a...WA3c (water heater).

Literature

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[2] Hans Rudolf Gabathuler, Hans Mayer: Standard hydraulic schemes - Part I. Straubing: C.A.R.M.E.N. e.V., 2nd, expanded edition 2010. ISBN 978-3-937441-92-1. (Series of publications QM Holzheizwerke, Volume 2).

[3] Arbeitsgemeinschaft QM Holzheizwerke: Muster-Ausschreibung Holzkessel. Straubing: C.A.R.M.E.N. e.V., 2004. ISBN 978-3-937441-93-X. (Series of publications QM Holzheizwerke, Volume 3).

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[5] Alfred Hammerschmid, Anton Stallinger: Standard-Schaltungen - Teil II. Straubing: C.A.R.M.E.N. e.V., 2006. ISBN 978-3-937441-95-6. (Schriftenreihe QM Holzheizwerke, Band 5)

[6] Bernhard Enzesberger, Johann Reinalter: Ratgeber zur Biomassekesselausschreibung (Version Österreich). Straubing: C.A.R.M.E.N. e.V., 2009. ISBN 978-3-937441-89-4. (Schriftenreihe QM Holzheizwerke, Band 6).

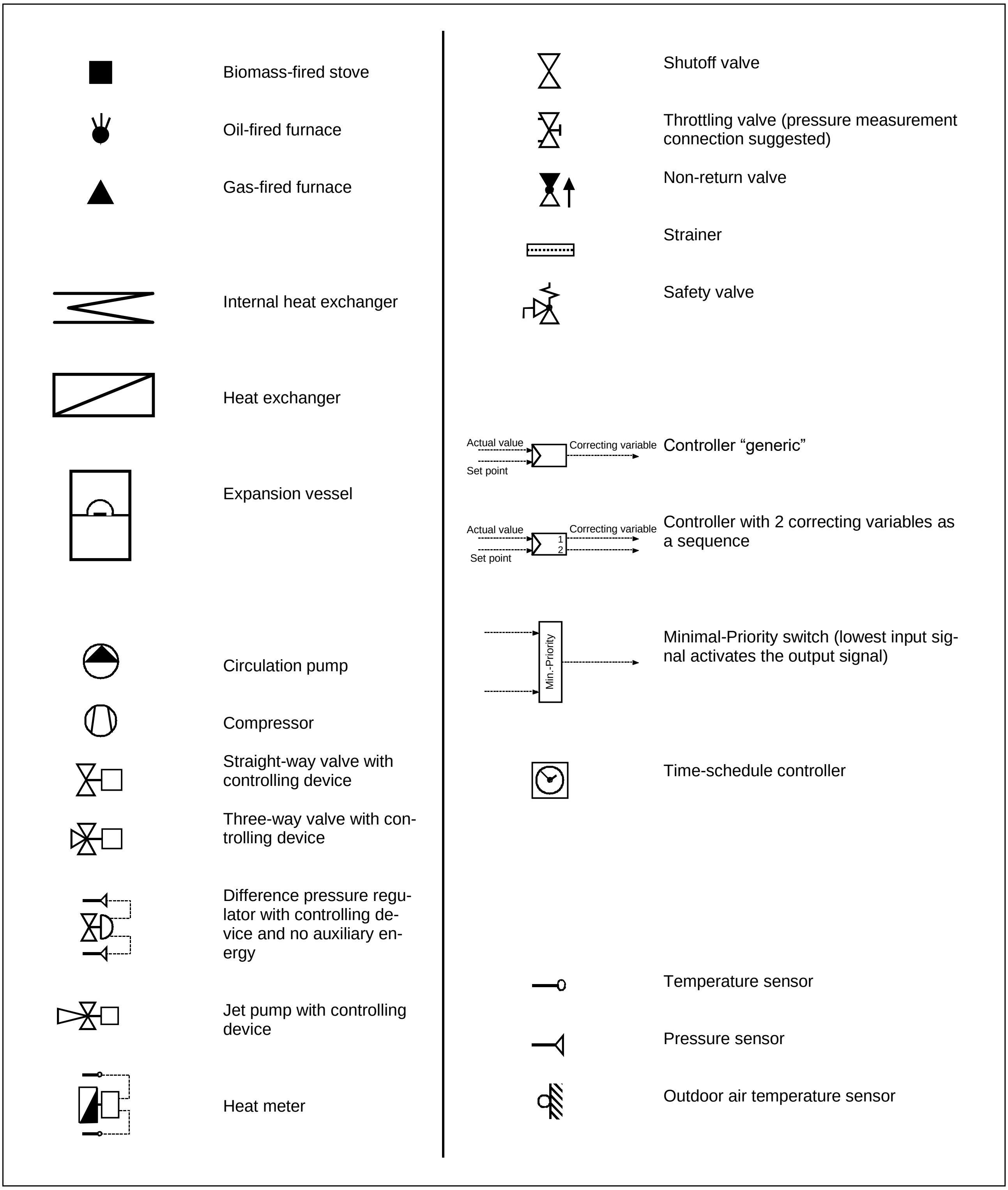
[7] Situation recording with EXCEL table. Both the EXCEL table and the manual are available as free downloads (see note).

[8] Frequently Asked Questions (FAQ). Problems that occur frequently are recorded as FAQs as quickly as possible and posted on the Internet. These can then be downloaded free of charge as individual FAQs or as a complete FAQ collection (see note).

[9] Recommendation Standard Interfaces. Both the recommendation and a list of biomass boiler and control unit manufacturers offering these standard interfaces are available as free downloads (see note).

Note: Titles [1] to [6] can be ordered from bookshops or directly from the QM Holzheizwerke website (see internet addresses on page 2). [7] to [9] and numerous other documents and software aids on the subject of biomass energy can also be found on this website.

Appendix 1: Symbols



Appendix 2: Title page

➔

QM
Biomass DH Plants

Hydraulic and control system solution

Short designation ....

Project number ....

Project	Plant designation: Plant address:
	Plant operator: Address: Contact person: Phone: .... Fax: .... E-mail: ....
Responsible for QM for Biomass District Heating Plants	Delegate of the plant operator: Phone: .... Fax: .... E-mail: ....
	Q-manager: Phone: .... Fax: .... E-mail: ....
Main planner	Company: Address: Clerk: Phone: .... Fax: .... E-mail: ....
Presentation of the main planner	This is a standard hydraulic scheme according to the documentation "Standard hydraulic schemes, 2nd edition". ☐ WE1 Monovalent without storage tank → chapter 1 ☐ WE2 Monovalent with storage tank → chapter 2 ☐ WE3 Bivalent without storage tank → chapter 3 ☐ WE4 Bivalent with storage tank → chapter 4 ☐ WE5 Monovalent two-boiler biomass heating system without storage tank → chapter 5 ☐ WE6 Monovalent two-boiler biomass heating system with storage tank → chapter 6 ☐ WE7 Bivalent three-boiler system without storage (2 biomass boilers, 1 oil/gas boiler) → chapter 7 ☐ WE8 Bivalent three-boiler system with storage (2 biomass boilers, 1 oil/gas boiler) → chapter 8 ☐ Non-standard hydraulic scheme → own description
	The chosen standard hydraulic scheme ☐ corresponds exactly to the specification ☐ contains the following deviations:
	Is a district heating network available? ☐ no ☐ yes → chapter 9
	Heat consumers

n°	**Low-pressure difference connections**	**n°**	**Differential pressure-affected connections**
	Non-standard hydraulic schemes		Non-standard hydraulic schemes
	Total		Total

System-specific amendments → chapter 10

10.1	
10.2	
10.3	
10.4	
10.5	
10.6	

Confirmation of the main planner	For the accuracy of the above statement and the attached documents: Date .... Signature ....

swissenergy

Holzenergie SCHWEIZ

AEE INTEC

C.A.R.M.E.N.
Centrales Agrar-Rohstoff-Marketing und Entwicklungs-Netzwerk

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