ASlab-T14

Process Description

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Modification history

Date	Description	Author
4.8.2009	Updated P&ID to match Demo2 designations	JUP
13.8.2009	Added interlock matrix with explanations. Split in two => this document contains the "process design" information.	JUP
24.8.2009	Changed TKK logo and cover page picture	JUP

Abstract

Document describes a laboratory scale process system for education and research demonstrations. The reference process is influenced by a fictional industrial heat production plant, which is loosely adapted to TKK's water process equipment. Included system description contains the functional process design.

Contents

1 Introduction

TKK's water process system can be used for demonstrating various process scenarios and related automation solutions for research and educational purposes. This document defines a fictional heat production system and its requirements for automation. The specification aims to be independent from implementation details and suitable for alternative target platforms (DCS, PLC).

Chapter 2 Main task of the system explains shortly the main task of the process system. Focus is on the purpose, what the system is expected to do. Following chapters concentrate on the technical details how the system and its automation realize the main task.

Chapter 3 Process System Description describes process designer's view to the system. This answers how the system implements its task and purpose. The functional structure is shown as P&ID and main process streams are highlighted in diagram and described in text. Process components, devices that enclose and directly affect the material process, are listed and their mechanical properties described. Functionality of the main process components is described.

2 Main Task of the System

Main task of the system is the following: Supply heat as heated and pressurized water to a process plant. Reuse the return water using closed-circuit stream. Compensate loss of water.

3 Process System Description

This chapter describes the process hardware and their functions, which implement the main tasks of the system.

3.1 General Design Requirements

Guidelines and directions from the process' main task perspective.

3.1.1 Engineering Units

- o Flow: ltr/min (1 ltr/min = 16,7 cm^3/s,)
- o Pressure: bar (g)
- o Temperature: Celsius
- o Level: mm (surface levels, widths, heights, depths)
- o Area: cm^2 (surface area)
- o Volume: ltr (dm^3)

3.1.2 Reference Designations

Reference designations from standards EN/DIN 6028 and ISO 10628 (References ISO 3511 parts 1,2,4 for some functional designations) are used.

3.2 Process System and Process Streams

P&I diagram in Figure 1 shows the structure and reference designations of the system and the main streams of the process.
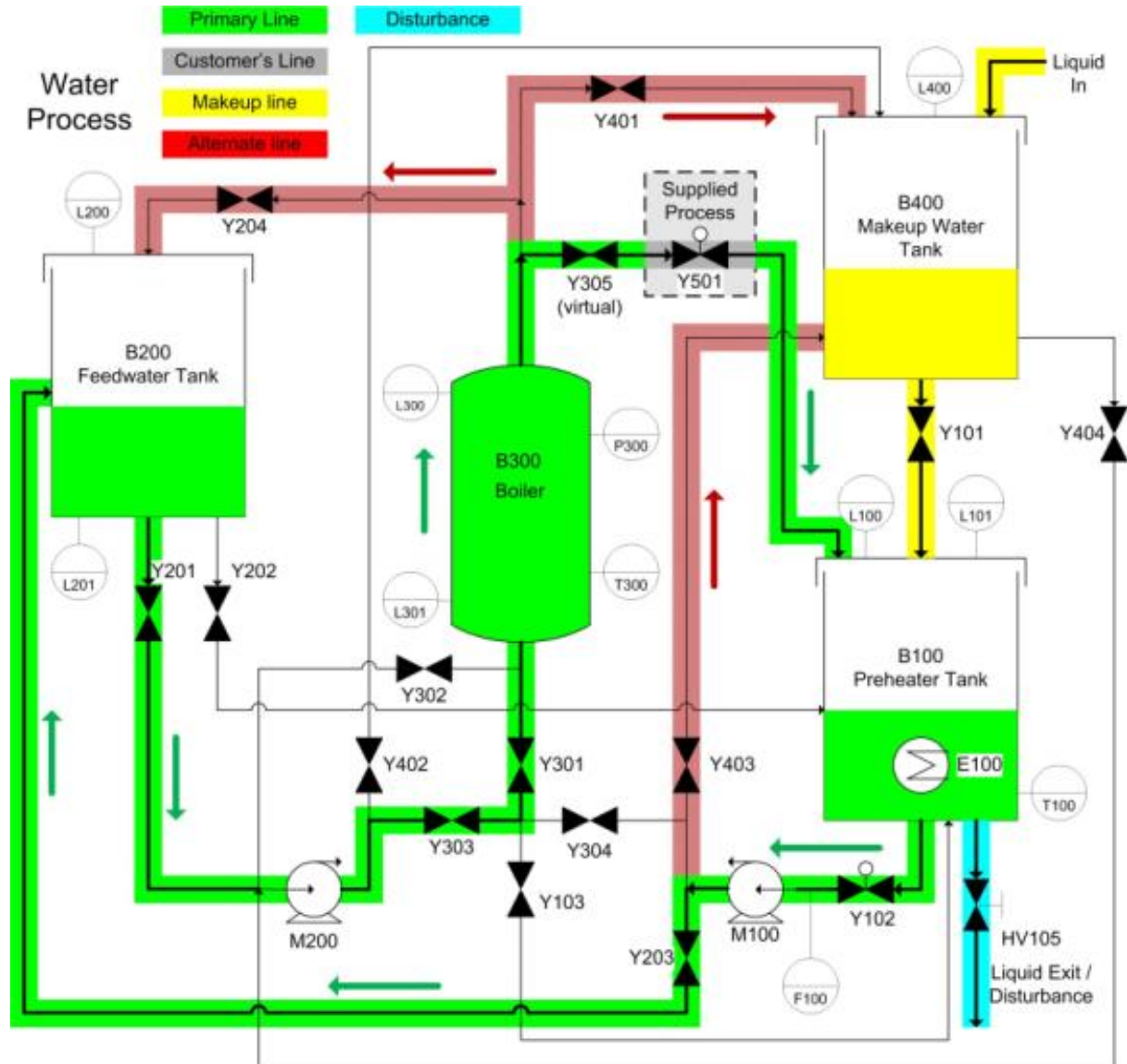
Figure 1 Process streams and instrumentation as P&ID (More detailed P&ID exist in appendix)

3.2.1 Primary Stream

The closed loop primary stream of the process is highlighted in P&ID with green color. *Preheater Tank* (B100) receives water returned from the *Supplied Process*. Water is heated here to a desired temperature (E100). Preheated water is pumped with *Preheater Pump* (M100) to *Feedwater Tank* (B200). From there, water is pumped and pressurized with *Feedwater Pump* (M200) through the *Boiler* (B300) to the *Supplied Process*.

The *Supplied Process'* load varies (simulated with control valve Y501) and the supply pressure from the *Boiler* to the customer's line needs to be controlled.

The loss of water in the primary stream, due to *Disturbance* (evaporation, leakage, etc.), is compensated using the *Makeup Stream*. Disturbances may be simulated using manual *Exit Valve* (HV105).

3.2.2 Makeup Stream

The *Makeup Stream* is highlighted in P&ID with yellow color. If the amount of water in the *Primary Stream* decreases too much, water is added from the *Makeup Water Tank* (B400) to the *Preheater Tank* (B100).

3.2.3 Alternate Streams

These are various bypass routes used during start-up and abnormal conditions.

PreheaterToMakeup Stream (Y403) is used during separated start-up of the *Preheater* and some abnormal conditions. For example, if total water amount is too high (expansion), it can be routed back to Makeup Tank.

BoilerToFeedwater Stream (Y204) is used during separated start-up of the *Boiler* and some abnormal conditions.

BoilerToMakeup Stream (Y401) is used during start-up of the *Primary Stream*, bypassing the *Supplied Process*, before opening the *Customer's Line* (Y305). It may also be used in some abnormal conditions.

3.3 Process Components

Process components are devices that enclose and influence the system's material flows. Their physical properties, e.g. volumes of tanks and flow rates of pumps, etc. are listed in A APPENDIX – Process Components. The process system is comprised of following components:

Preheater Tank (B100)

Heater (E100)

Preheater Pump (M100)

PreheaterExitControlValve (Y102)

PreheaterToFeedwater Valve (Y203)

Feedwater Tank (B200)

FeedwaterExitValve (Y201)

Feedwater Pump (M200)

Transfer Valve (Y303)

BoilerValve (Y301)

Boiler (B300)

SupplyValve (Y305) [Virtual on/off valve, simulated by control valve Y501]

Supplied Process Load (Y501) [Control valve, which is also used to simulate Y305]

Makeup Water Tank (B400)

MakeupWaterExitValve (Y101)

BoilerToFeedwater Valve (Y204)

BoilerToMakeup Valve (V401)

FeedwaterPumpToMakeup Valve (Y402)

PreheaterPumpToMakeup Valve (Y403)

3.4 Functional Descriptions of Major Process Components

Descriptions of main process components' functionalities, including streams, controlled process variables, produced warnings, alarms and interlocks.

3.4.1 Preheater Tank B100

Tank receives water from the Supplied Process and compensation water from the Makeup Water Tank. The Preheater Tank supplies heated water to Feedwater Tank. In abnormal conditions supply may be directed back to Makeup Water Tank or to sewer via manual Exit Valve (used also to simulate disturbances).

Surface level of the Tank is controlled using *Makeup Water Valve* (Y101). Desired level should be maintained within +/-5mm or less around setpoint. Valve Y101 is of type on/off. Limits of desirable operating range should be far enough from overflowing and from draining the preheater pump and drying the heater.

Heat is produced using an on/off Heater element E100. Temperature should be controlled within +/- 0,5C from setpoint.

Warnings and alarms of surface level and water temperature (LL, L, H, HH) should be produced.

Preheater pump should be protected by shutting it off when level goes under LL-alarm limit.

Heater should be protected by shutting it off when level goes under LL-alarm limit.

Overflow of the tank should be prevented by using the level's HH alarm and a separate overflow indicator. These should close all inlet streams, including the customer line (Y305).

3.4.2 Preheater Pump M100

Preheater pump generates exit flow from Preheater tank B100 to Feedwater tank B200 (or any other specified direction).

Flow is controlled using the PreheaterExitControlValve (Y102).

Dry operation of the pump should be prevented. The pump should not be operated against a closed valve.

3.4.3 Feedwater Tank B200

Feedwater is received from Preheater B100 via PreheaterToFeedwater Valve (Y203). Water is then fed to Boiler B300 through FeedwaterExitValve (Y201).

Surface level is controlled using the flow generated with Preheater Pump (M100).

In some abnormal conditions, water may be returned from the boiler via BoilerToFeedwater Valve (Y204).

Warnings and alarms of surface level (LL, L, H, HH) should be produced.

Overflow is protected by closing inlet valves PreheaterToFeedwater Valve (Y203) and BoilerToFeedwater Valve (Y204).

Feedwater pump should be protected from draining by shutting it off when B200 level goes under LL limit.

3.4.4 Boiler B300

Boiler is fed from Feedwater Tank B200 using Feedwater Pump (M200) via Feedwater Exit Valve (Y201), Transfer Valve (Y303) and Boiler Valve (Y301). Water flows to customer's line via Supply Valve (Y305).

Boiler pressure is controlled using Feedwater Pump (M200).

Warnings and alarms of boiler pressure (LL, L, H, HH) should be produced.

In subsystem startup and some abnormal conditions stream can be directed back to Feedwater Tank (Y204) or to Makeup Water Tank (Y401).

Overpressure should be prevented by opening BoilerToFeedwater Valve (Y204).

3.5 Safeguarding Requirements

Following safeguarding measures should be implemented:

1. Prevent overflow of Preheater B100 (group 10)
2. Prevent damage of Heater E100 due dry operation (group 20)
3. Prevent overheating of Preheater B100 (group 20)
4. Prevent pumping against closed valve with pump M100 (group 30)
5. Prevent overflow of Feedwater tank B200 (group 40)
6. Prevent overpressure in Boiler B300 (group 50)
7. Prevent dry operation of Preheater pump M100 (group 60)
8. Prevent dry operation of Feedwater pump M200 (group 70)
9. Prevent pumping against closed valve with pump M200 (group 80)

Required interlocks are presented as a causality matrix. Group code specifies which interlock causes have a certain effect via an operator. Name22 column specifies which devices are used (effected).

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Cause definitions										Effect definitions		
group	transition	op. state	name11	name12	status	not	value	unit	operator	name21	name22	status
10	activate			=H1.T1.L100.LI	HH				OR		=H1.T1.Y101.YS	closed
10	activate			=H1.T1.L101.LS	on						=H1.T3.Y305.YS	closed
20	activate			=H1.T1.L100.LI	LL				OR		=H1.T1.E100.EC	off
20	activate			=H1.T1.T100.TI	HH							
30	activate			=H1.T2.Y203.YS	closed				OR		=H1.T1.M100.SC	off
30	activate			=H1.T1.Y102.YC	closed							
40	activate			=H1.T2.L200.LI	HH						=H1.T2.Y203.YS	closed
											=H1.T2.Y204.YS	closed
50	activate			=H1.T3.P300.PI	HH						=H1.T2.Y204.YS	open
60	activate			=H1.T1.L100.LI	LL						=H1.T1.Y102.YC	closed
70	activate			=H1.T2.L200.LI	LL						=H1.T2.Y201.YS	closed
80	activate			=H1.T2.Y201.YS	closed						=H1.T2.M200.SC	off

Interlock Causality Matrix

3.6 Sequential Operation

There are some needs for sequential functions in the process. Here is an overview of the required sequence functions. More detailed specification is in chapter 5.

3.6.1 Filling Sequence

Filling Sequence should determine if there is enough water in the process and that the water is distributed in correct process locations. If this is not the case, the *Filling Sequence* should instruct the operator to add water manually to *Makeup Water Tank* (B400) and distribute it automatically as required by the *Heat Production Process*. *Filling Sequence* should be possible to be started at any situation and it should, with help from human operator, bring the process system to a state where Start-up Sequence can be started.

3.6.2 Start-up Sequence

Start-up Sequence should drive the process to a suitable state before opening the *Supply Line*. The process stream and relevant process variables should be as close to normal heat supply as possible, before opening the supply valve and starting the normal heat supply operation to customer's line. The main start-up sequence may consist of separate subsequences for different subprocesses. *Start-up Sequence* should bring the process system to a state where it can be commanded to initiate supply operation (*Supply Sequence*).

3.6.3 Supply Sequence

Supply Sequence runs and manages the normal heat supply process. Relevant process variables should be kept within their desired operating tolerances. *Shutdown Sequence* can be initiated at any time.

3.6.4 Shutdown Sequence

Shutdown Sequence reverses the *Startup Sequence*. It first closes the customer supply and brings the process safely and gradually down. *Shutdown Sequence* can be initiated at any stage of the process system operation.

3.6.5 Emptying Sequence

Emptying Sequence reverses the Filling Sequence. System is emptied of water with help of human operator.

3.7 Operator Interface

- o There should be one main display based on the P&ID of the process.
- o Additional displays for the various process units with related control loops.
- o Displays for interlocks and alarms are also needed.
- o Sequential operations should have operator interfaces for supervising and inputs.
- o Total amount of water in the system should be measured and shown. Warnings should be made, when total amount is close to total capacity. Also, when total amount exceeds sum of tanks' setpoints.

3.8 Additional Safety Requirements

o Total amount of water in the system should be measured and monitored. Warnings should be made, when total amount is close to system's total capacity (sum of tank capacities).

o All kinds of leakage and overflow should be prevented.

3.9 General Operating Principles

o When started up, equipment and control loops should be initially in manual mode.

o In manual mode, devices and loops should be in safe state, e.g. valves usually closed, pumps off, etc.

A. APPENDIX – Process Components

List the process components and their physical properties, e.g. volumes of tanks and flow rates of pumps, etc.

Preheater Tank (B100)

- Width: 191 mm
- Depth: 175 mm
- Surface area: 334,25 cm^2
- Height: 370 mm
- VolumeTOT: 12367,25 cm^3 = 12,37 ltr
- Volume_1cm: 0,33 ltr
- Height_1ltr: 3,0 cm
- Alarm_HH:
- Alarm_H:
- Alarm_L:
- Alarm_LL:

Heater (E100)

Preheater Pump (M100)

- Flowrate max (100%):   2.2 ltr/min

PreheaterControlValve (Y102)

PreheaterToFeedwater Valve (Y203)

Feedwater Tank (B200)

- Width: 191 mm
- Depth: 175 mm
- Surface area: 334,25 cm^2
- Height: 370 mm
- Volume_TOT: 12367,25 cm^3 = 12,37 ltr

- o Volume_1cm: 0,33 ltr
- o Height_1ltr: 3,0 cm
- o Alarm_HH:
- o Alarm_H:
- o Alarm_L:
- o Alarm_LL:

Feedwater Valve (Y201)

Feedwater Pump (M200)
- o Flowrate max (100%):   2.0 ltr/min

Transfer Valve (Y303)

Boiler Valve (Y301)

Boiler (B300)

Supply Valve (Y305)
"Virtual" on/off –valve. Simulated using Y501.

Supplied Process Load (Y501)

Makeup Water Tank (B400)
- o Width: 19,1 cm
- o Depth: 17,5 cm
- o Surface area: 334,25 cm^2
- o Height: 37,0 cm
- o VolumeTOT: 12367,25 cm^2 (12,37 ltr)
- o Volume_1cm: 0,33 ltr
- o Height_1ltr: 3,0 cm
- o Alarm_HH:
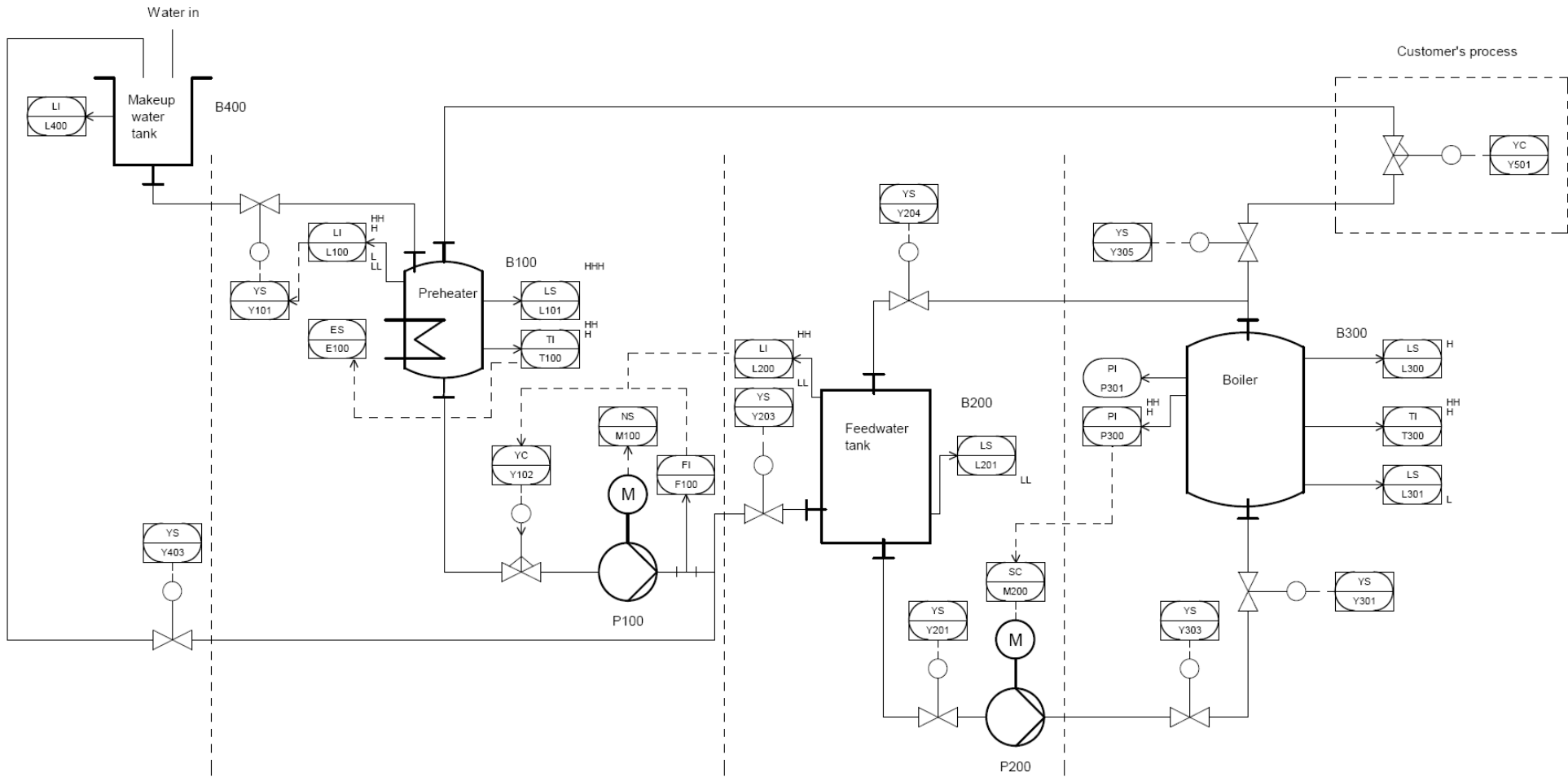- o Alarm_H:

- o   Alarm_L:
- o   Alarm_LL:

Makeup Water Valve (Y101)

BoilerToFeedwater Valve (Y204)

BoilerToMakeup Valve (Y401)

FeedwaterPumpToMakeup Valve (Y402)

PreheaterPumpToMakeup Valve (Y403)

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Process P&I-diagram (from a process engineering tool)