PROGRESS WITH THE INDUSTRIAL ACTUATOR REAL DATA BENCHMARK STUDY

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- What was done?
- What faults?
- Human factor fault
- Data file structure
- Added value
- End remarks

DAMADICS Workshop

ROBUST METHODS IN FAULT DIAGNOSIS
HULL
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What was done?
Concise progress report between September and December 2001

- 19 successful artificial fault simulation sessions in sugar factory Lublin
- Upgrading factory equipment with the instruments necessary to perform demanded experiments
- Installing the SCADA system suited for Damadics purposes
- Acquiring the 32 process data between October 29 and November 22,2001 (sampling time 1s)
- Post processing the data to achieve transferable data files.
- Identifying records from faulty states
- Fault specification
- Publishing the data in the internet http://diag.mchtr.pw.edu.pl/damadics

What faults were introduced?

Control valve faults

f_1 - valve clogging
f_2 - valve or valve seat sedimentation
f_3 - valve or valve seat erosion
f_4 - increase of valve or bushing friction
f_5 - external leakage (leaky bushing, covers)
f_6 - internal leakage (valve tightness)
f_7 - medium evaporation or critical flow

Pneumatic servo-motor faults

f_8 - twisted servomotor's rod
f_9 - servomotor's housing or terminals tightness
f_{10} - servomotor's diaphragm perforation
f_{11} - servomotor's spring fault

Positioner faults

f_{12} - electropneumatic transducer fault
f_{13} - rod displacement sensor fault
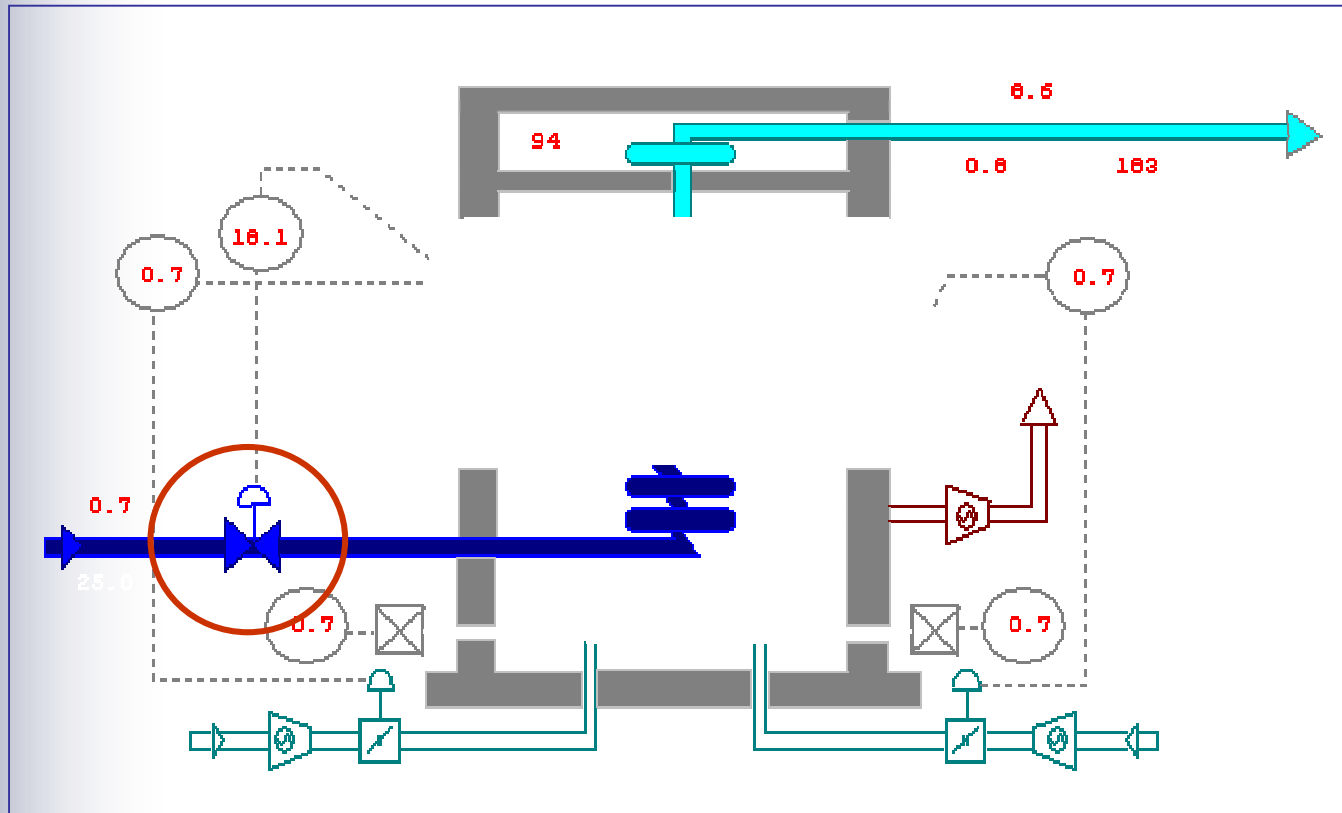f_{14} - pressure sensor fault
f_{15} - positioner spring fault

2001

General faults/external faults

f_{16} - positioner supply pressure drop
f_{17} - unexpected pressure change across the valve
f_{18} - fully or partly opened bypass valves
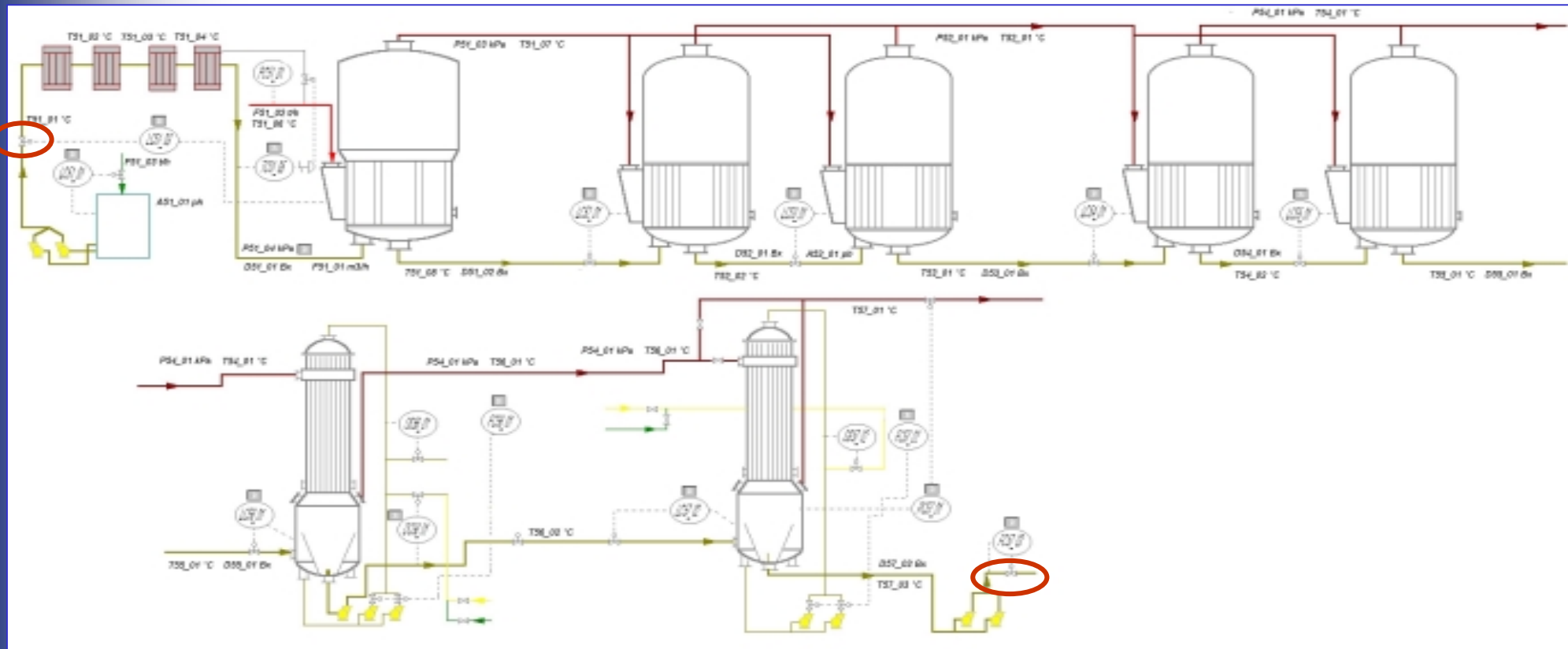f_{19} - flow rate sensor fault

Steam boiler
(synoptic overview)

Water level control loop

Control loop tag: LC74_20

Evaporation station

Thin juice level control loop in the first section of evaporation station : LC51_03
Thick juice flow control loop at the outlet of the fifth section of evaporation station : FC57_03

Data files structure

Principles

- Each data file contains data acquired from one day.
- Data are structured in a form of a matrix (86400 rows x 33 columns) of real numbers.
- First column contains time stamp (number of seconds passing from hour 0:00:00).
- Columns are related to the process variables while rows are corresponding to the time stamps.
- *NaN* string represents dummy data in the case of data lack (if any)

Data files structure

Development and Application of Methods for Actuator Diagnosis in Industrial Control Systems, FP5 DAMADICS Project

Control loop quality statistic evaluation
(off-line diagnostics)

Histogram of juice level in evaporator from October 29, 2001

Evaporator
(I-st section)

T51_02 °C T51_03 °C T51_04 °C

P51_03 kPa   T51_07 °C

PC51_01

T51_01 °C

F51_02 t/h
T51_06 °C

LC51_03

F51_03 t/h

LC51_01

TC51_06

A51_01 ph

P51_04 kPa

D51_01 Bx   F51_01 m3/h

T51_08 °C D51_02 Bx

Thin juice level control loop

Control loop quality statistic evaluation
(off-line diagnostics)

Histogram of juice level in evaporator from October 27, 2001
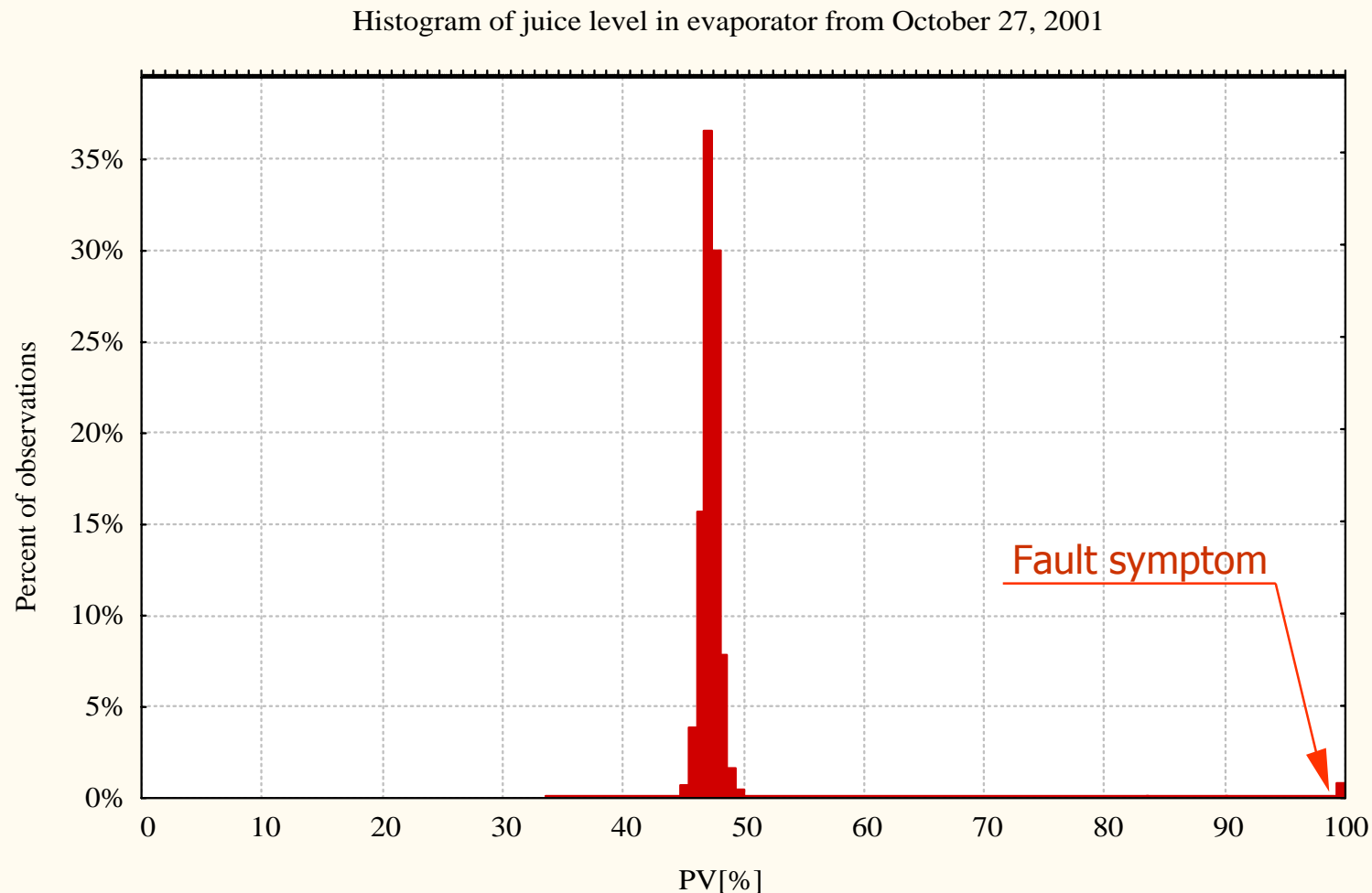
Faulty situation vivisection
(human factor fault)

Juice level in evaporator (snap-shot from faulty state)
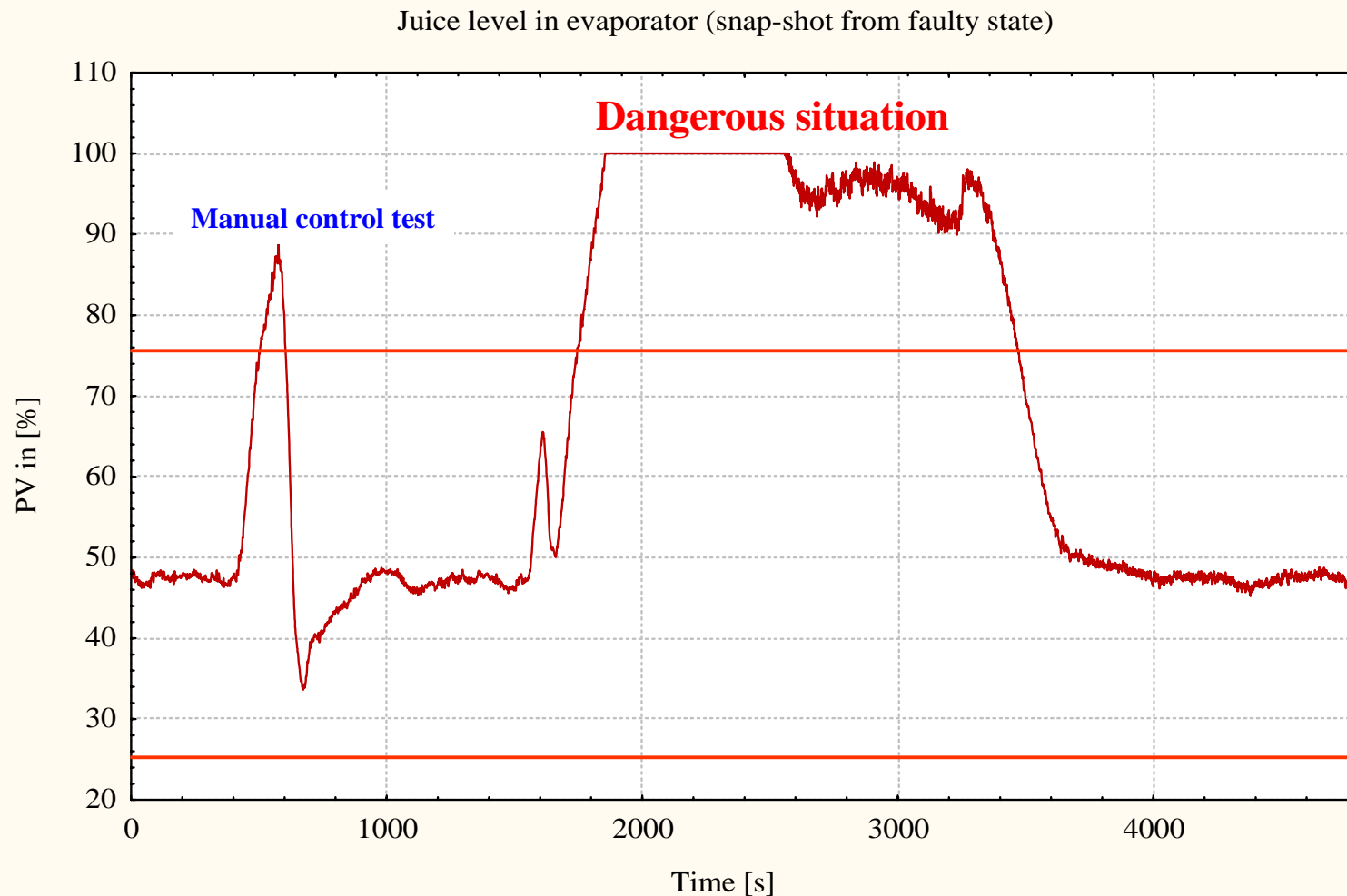
Artificial fault generation
(bypass valve leakage)
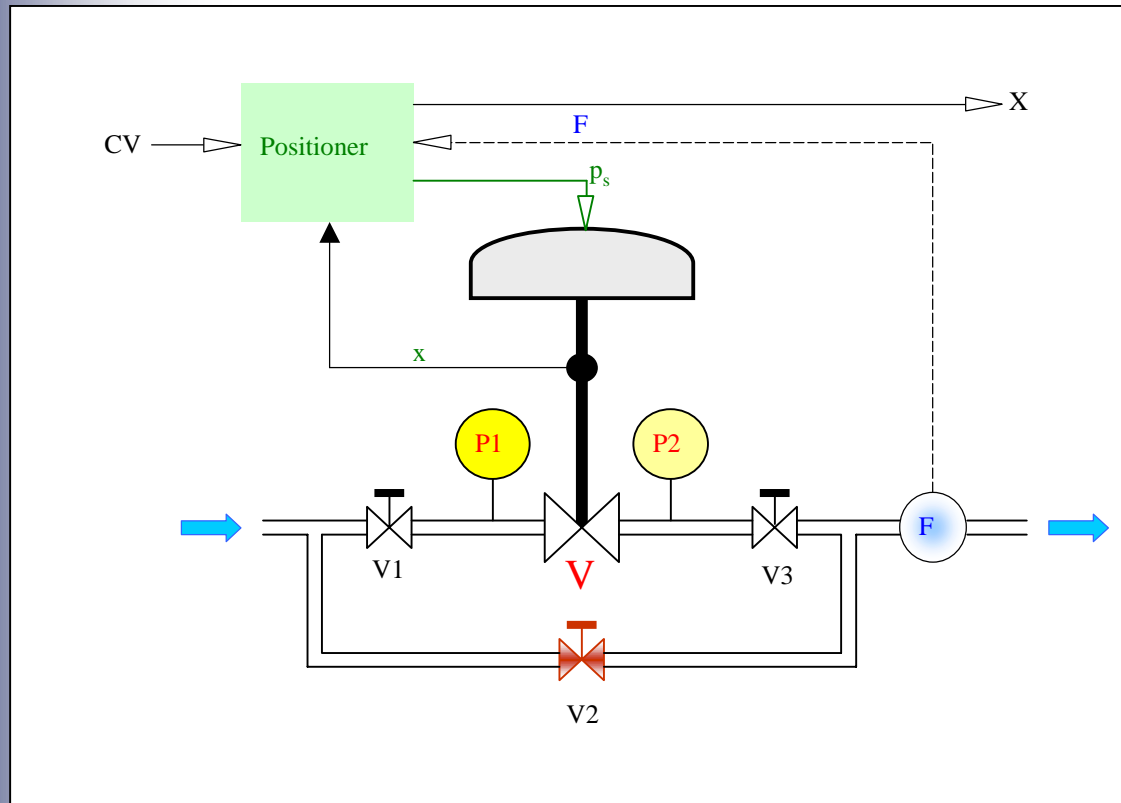
Scenario:

1. Partly opening the V2 bypass valve.
   (Valve internal and external leakage simulation)

Artificial fault generation

Fault f18 - partly opened bypass valve on Actuator 1

Fault:	partly opened bypass valve on actuator 1 (f18)
Plant:	evaporator I stage
Date:	October 30, 2001
Duration:	58800 (valve opening) – 59800 (valve closing) s
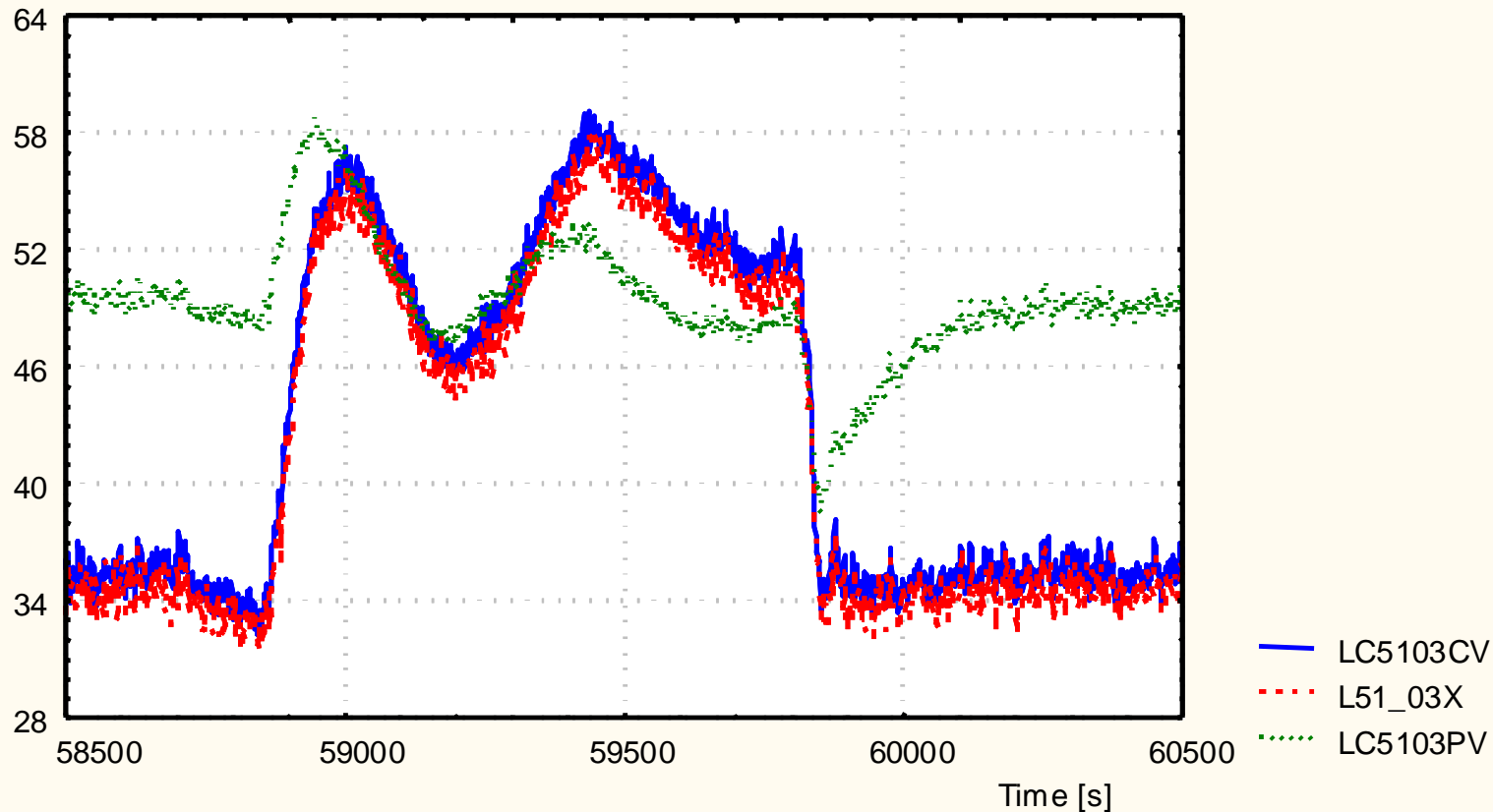
Artificial fault generation

Fault f16 – positioner supply pressure drop on Actuator 1

Fault:	positioner supply pressure drop on Actuator 1 (f16)
Plant:	evaporator I stage
Date:	November 9, 2001
Duration:	57275 (pressure drop) – 57550 (pressure ok) s
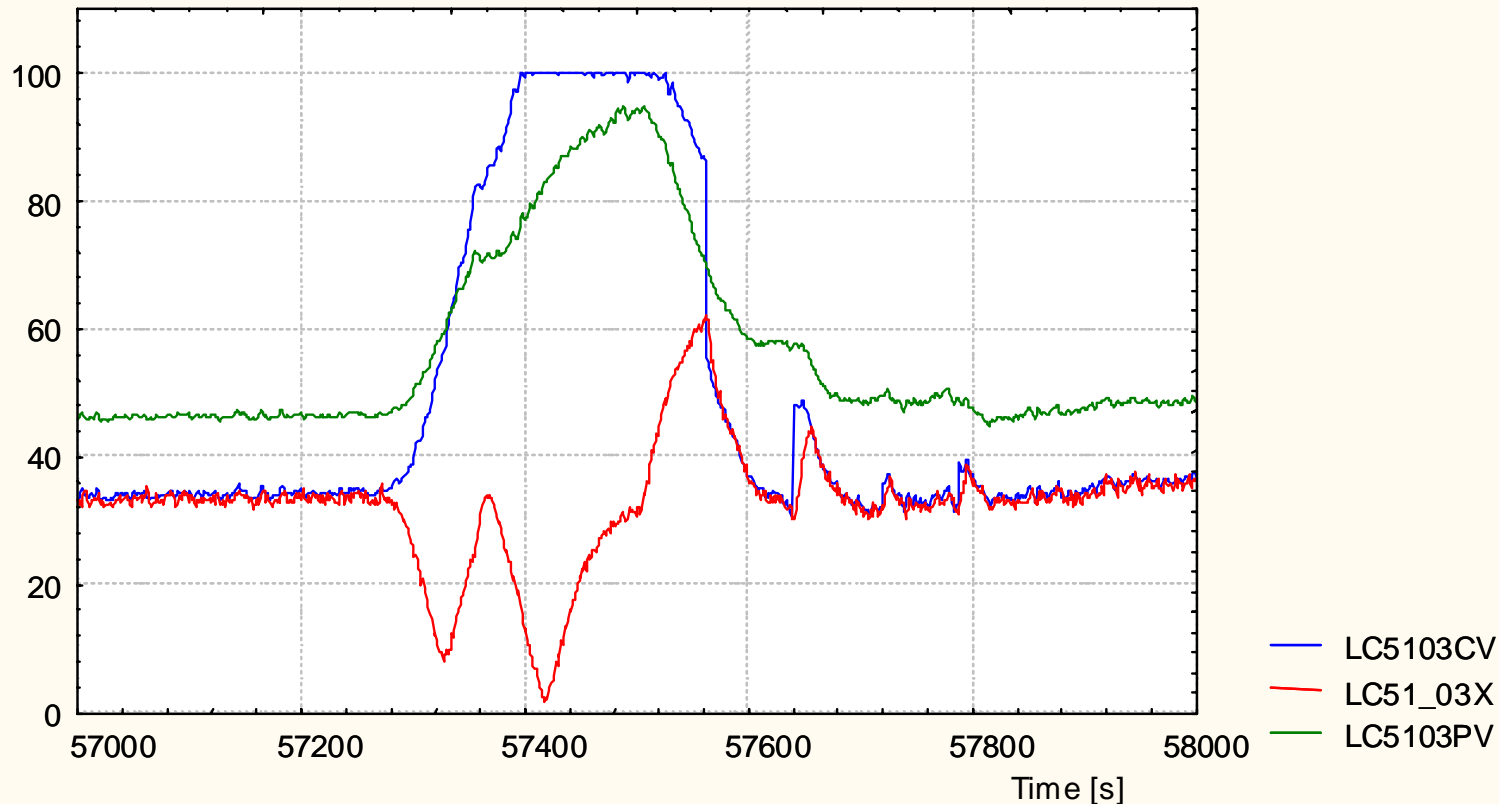
Artificial fault generation
Fault f18 – partly opened bypass valve on Actuator 1

Fault:	partly opened bypass valve on actuator 1 (f18)
Plant:	evaporator I stage
Date:	November 9, 2001
Duration:	58830 (valve opening) – 5930 (valve closing) s

Artificial fault generation

Fault f18 – partly opened bypass valve on Actuator 1

Fault:	partly opened bypass valve on actuator 1 (f18)
Plant:	evaporator I stage
Date:	November 9, 2001
Duration:	58520 (valve opening) – 58625 (valve closing) s

Artificial fault generation

Fault f18 – partly opened bypass valve on Actuator 1

Fault:	partly opened bypass valve on actuator 1 (f18)
Plant:	evaporator I stage
Date:	November 17, 2001
Duration:	54600 (valve opening) – 54700 (valve closing) s
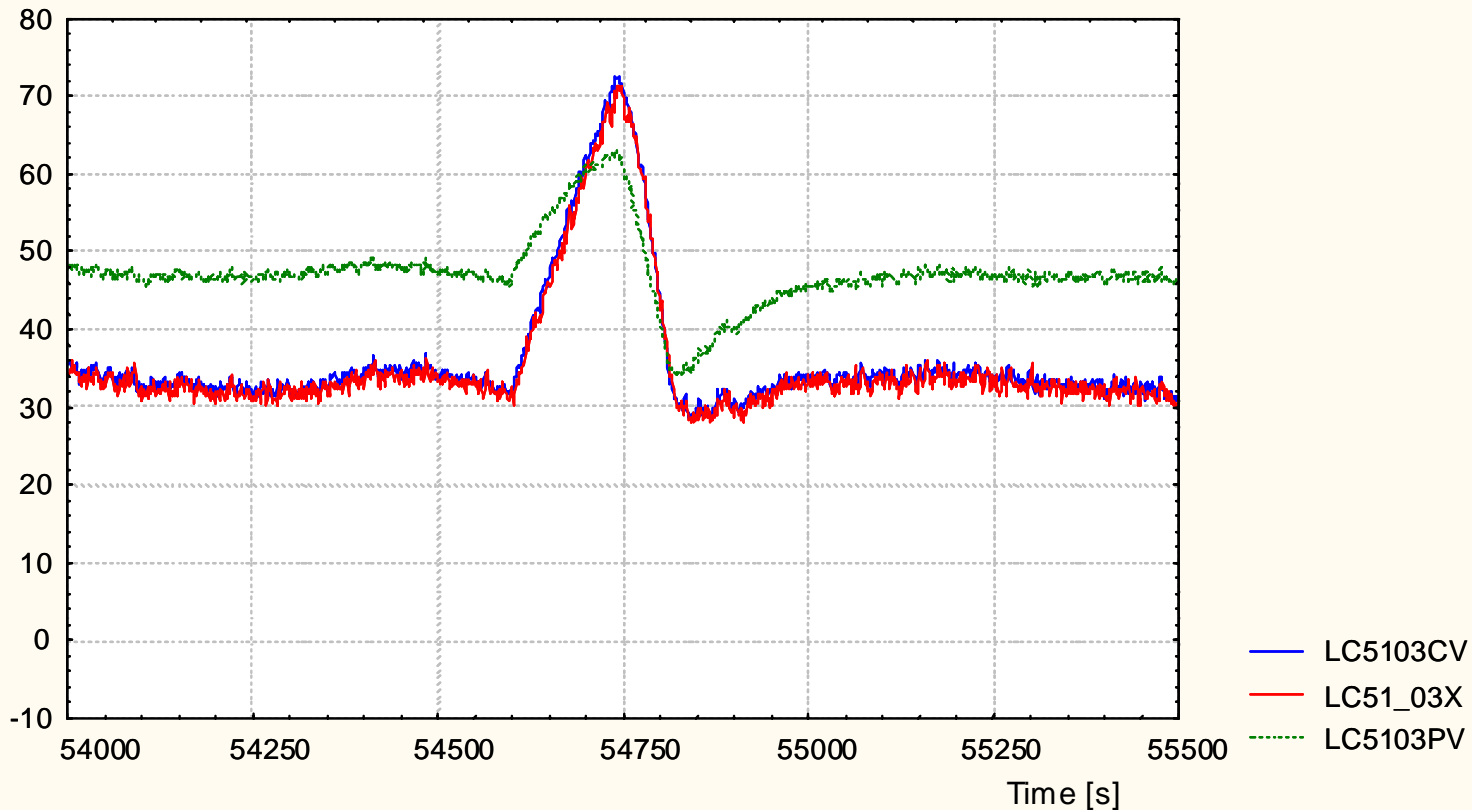
Artificial fault generation
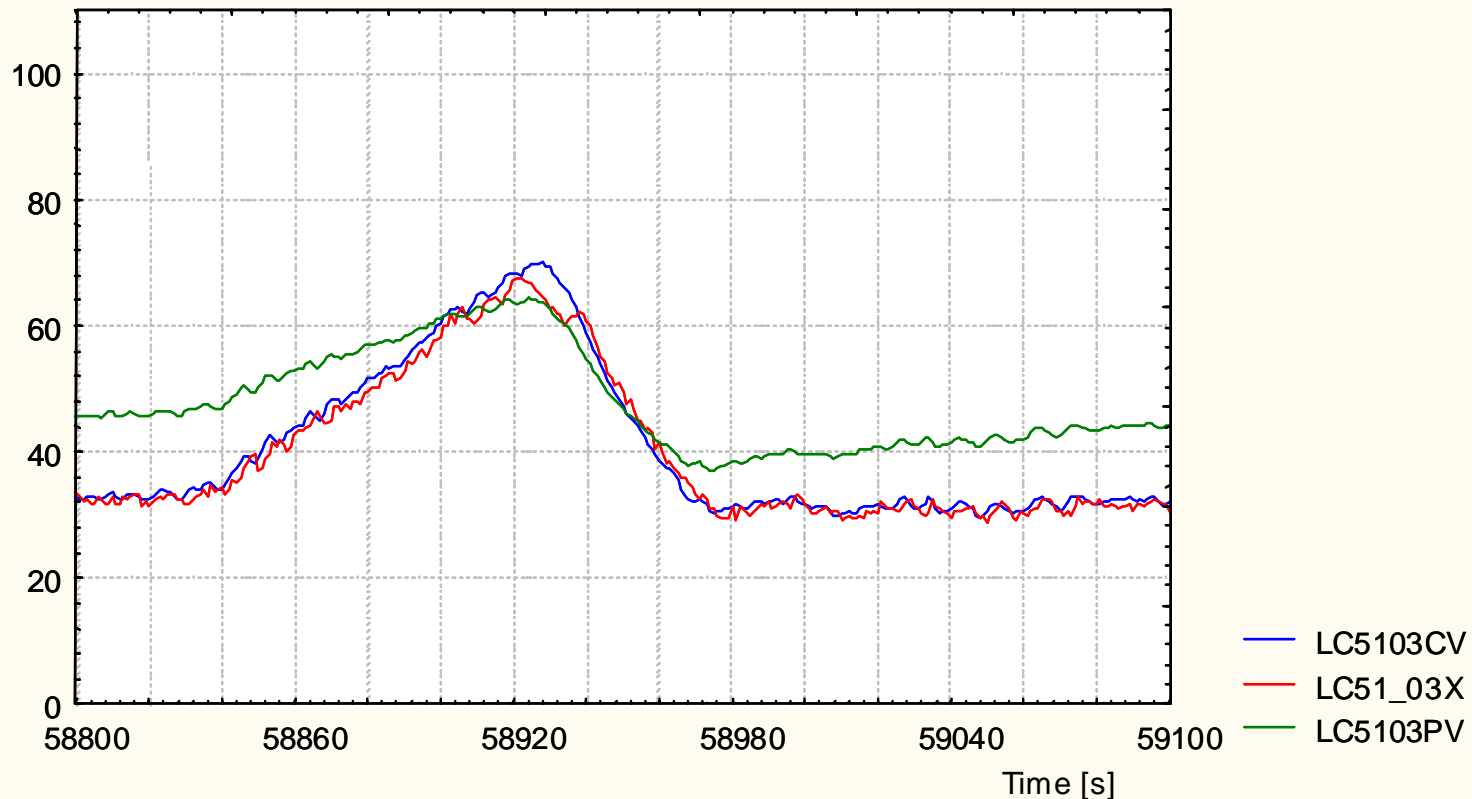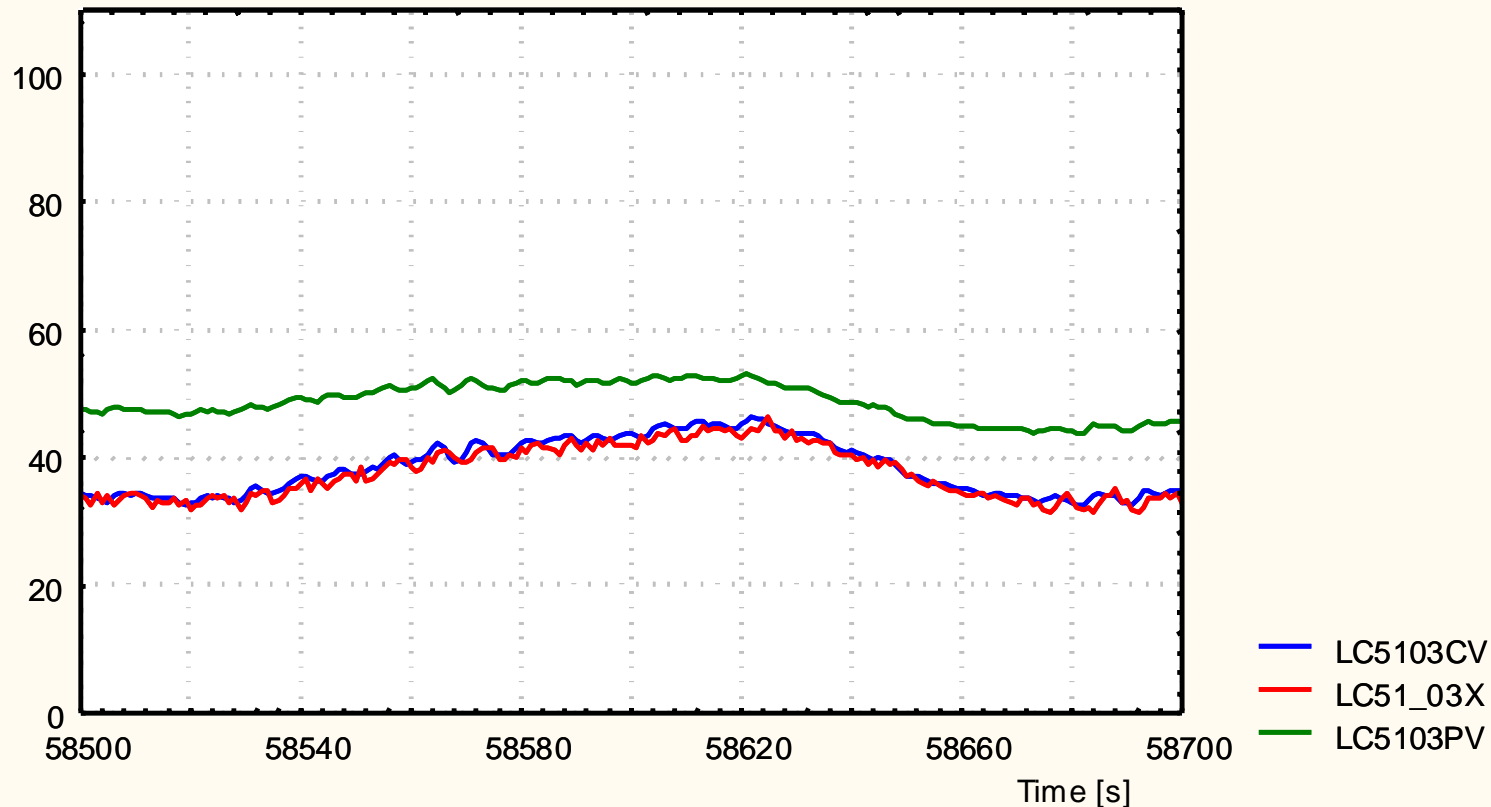
Fault f16 – positioner supply pressure drop on Actuator 1

Fault: positioner supply pressure drop on actuator 1 (f16)
Plant: evaporator I stage
Date: November 17, 2001
Duration: 56670 (pressure drop) – 56770 (pressure ok) s
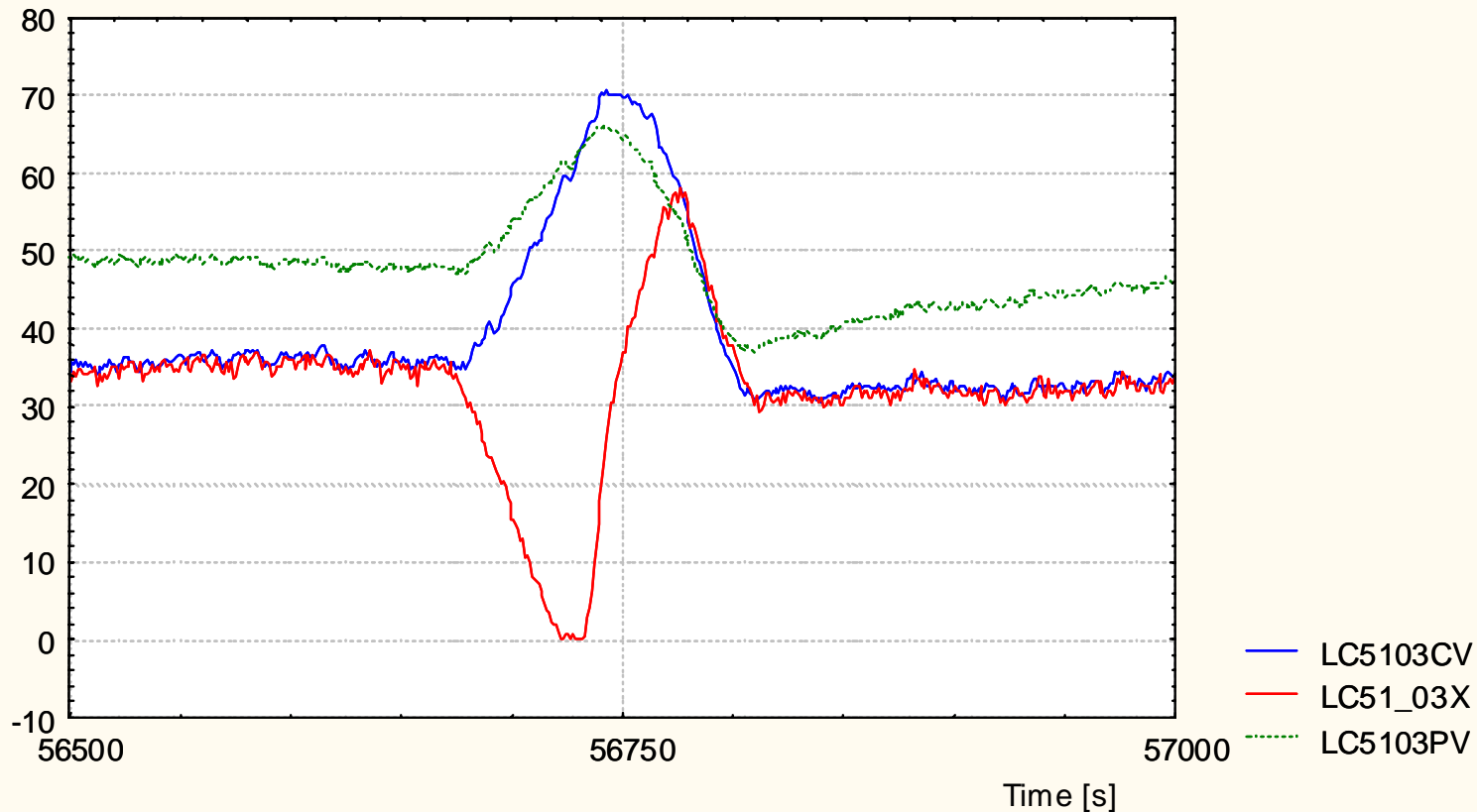
Legend:
- LC5103CV (blue)
- LC51_03X (red)
- LC5103PV (green dotted)

Artificial fault generation

Fault f17 – Unexpected pressure drop across the valve in Actuator 1

Fault:	Unexpected pressure drop across the valve in Actuator 1 (f17)
Plant:	evaporator I stage
Date:	November 20, 2001
Duration:	37780 (pressure measurement off) – 38400 (pressure measurement on) s
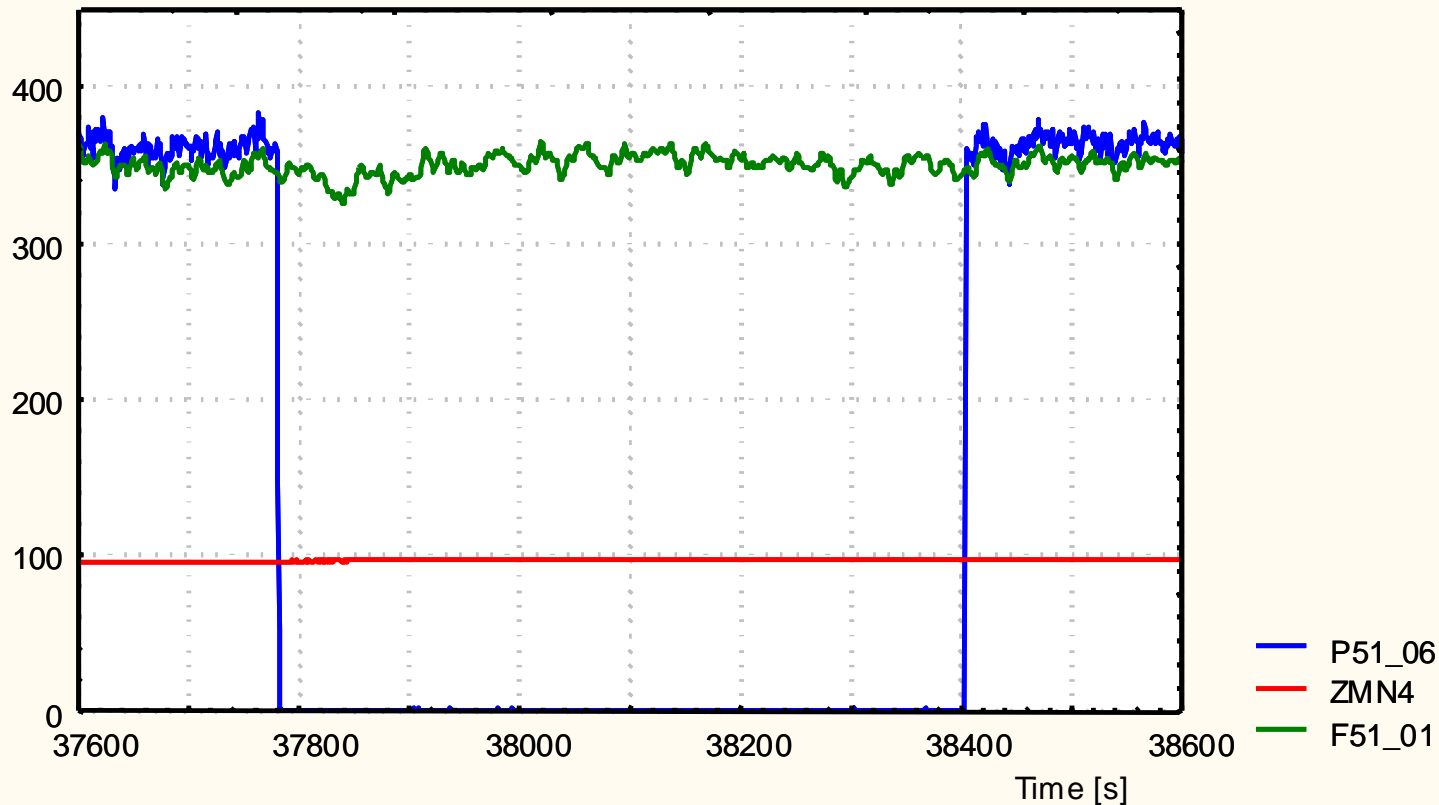
Artificial fault generation

Fault f17 – Unexpected pressure drop across the valve in Actuator 2

Fault:	Unexpected pressure drop across the valve in Actuator 2 (f17)
Plant:	evaporation stage V
Date:	November 17, 2001
Duration:	53780 (thick juice outflow pump switch off) – 53794 (thick juice outflow pump switch on) s

Artificial fault generation

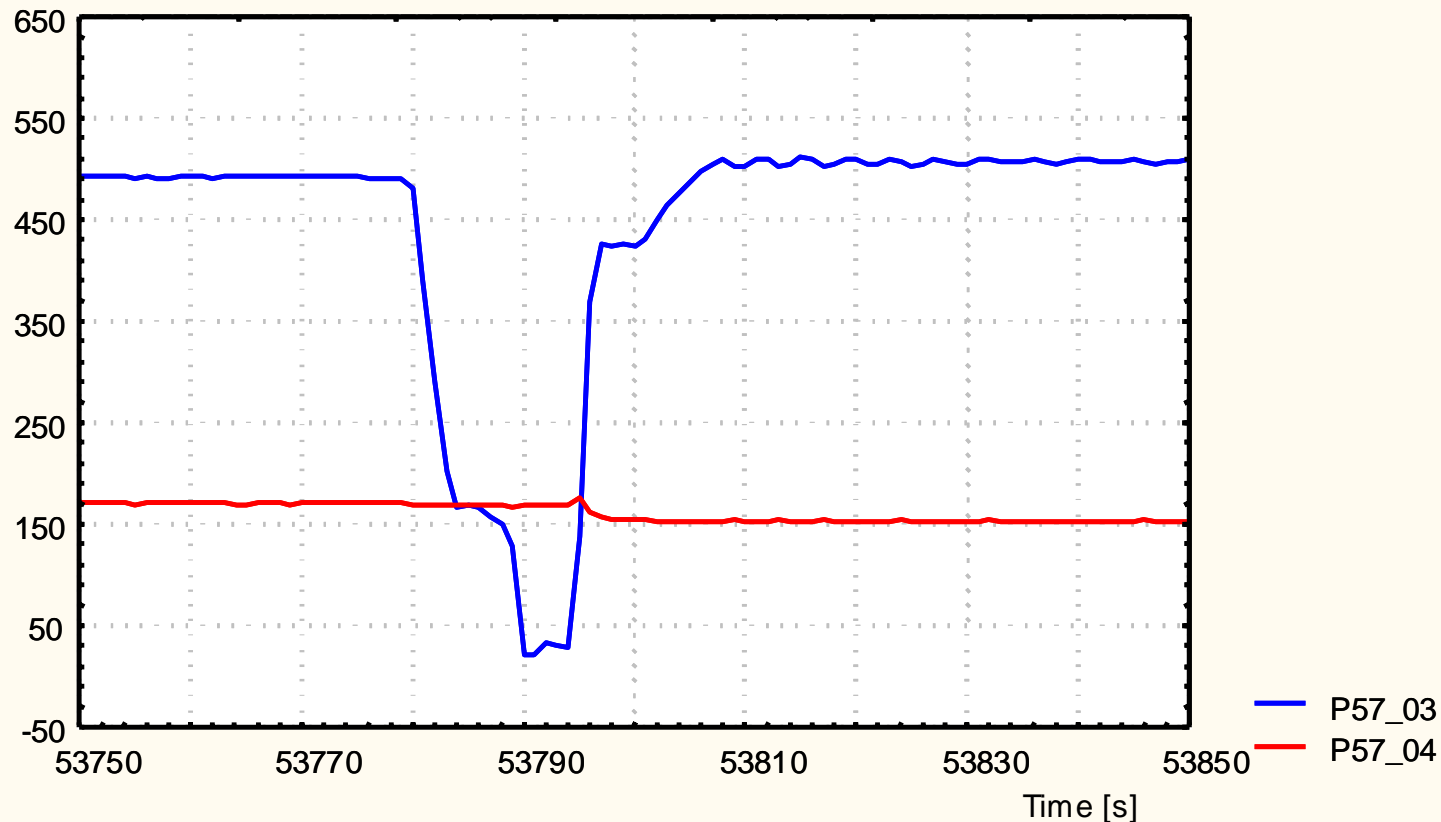*Fault f17 – Unexpected pressure drop across the valve in Actuator 2*

Fault: unexpected pressure drop across the valve in Actuator 2 (f17)
Plant: evaporation stage V
Date: November 17, 2001
Duration: 54193 (thick juice outflow pump switch off) – 54215 (thick juice outflow pump switch on) s

Artificial fault generation
Fault f19 – Flow rate sensor fault in Actuator 2*

Fault: flow rate sensor fault in Actuator 2 (f19)
Plant: evaporator stage V
Date: November 17, 2001
Duration: 55482 (sensor fault on) – 55517 (sensor fault off) s

Artificial fault generation
Fault f19* – Flow rate sensor fault in Actuator 2

Fault: flow rate sensor fault in Actuator 2 (f19)
Plant: evaporator stage V
Date: November 17, 2001
Duration: 55977 (sensor fault on) – 56015 (sensor fault off) s

FC57_03
FC5703CV
FC57_03X

Artificial fault generation

Fault f19 – Flow rate sensor fault in Actuator 2*

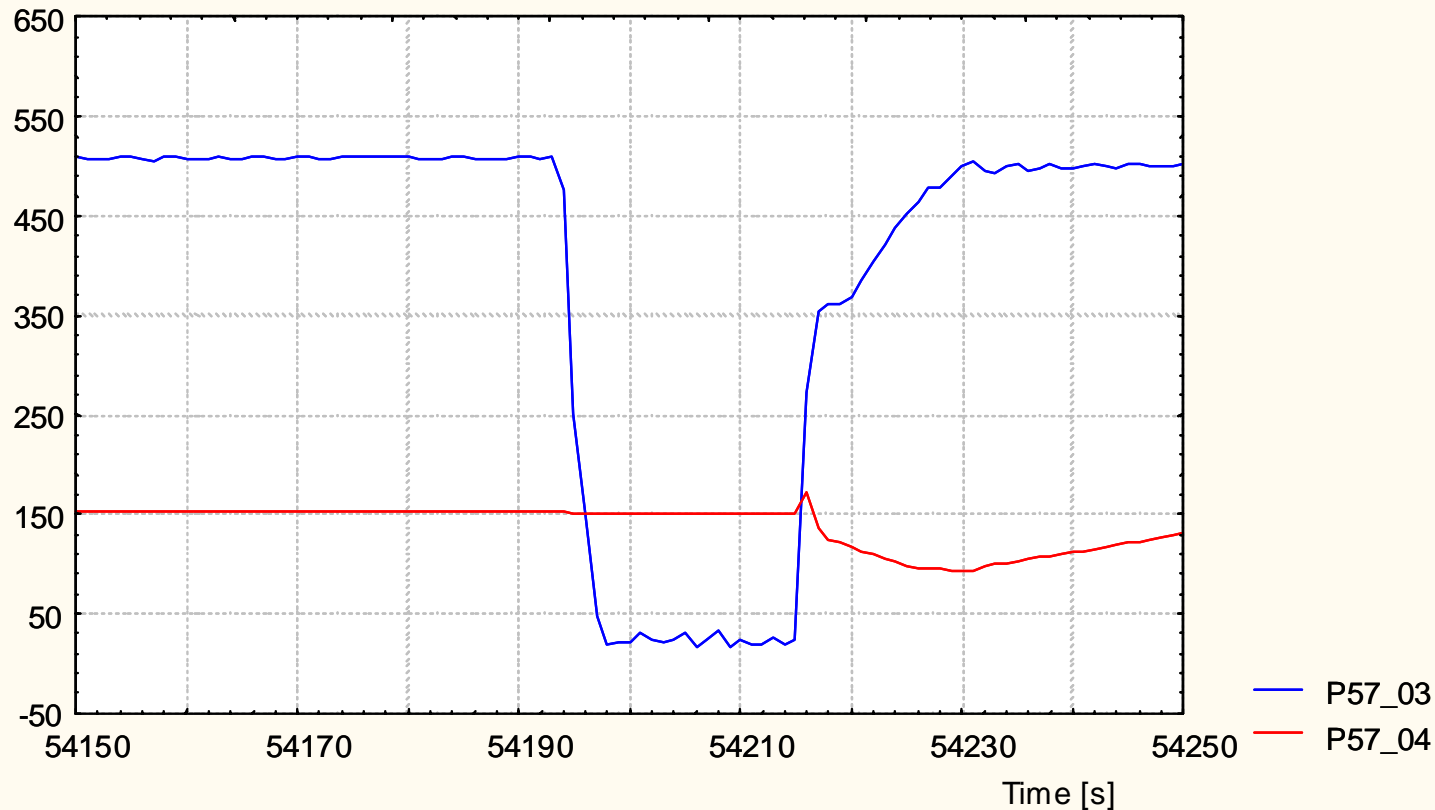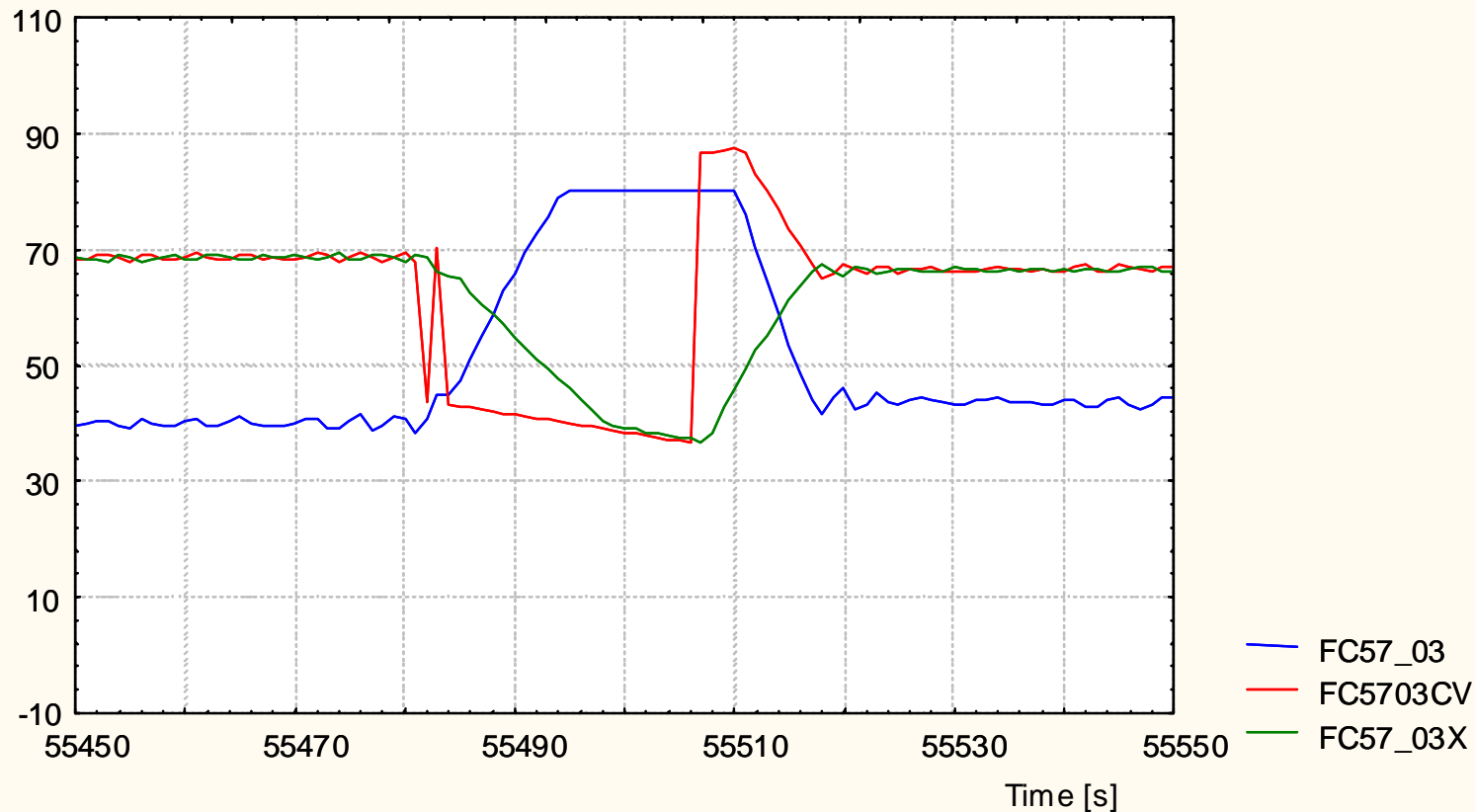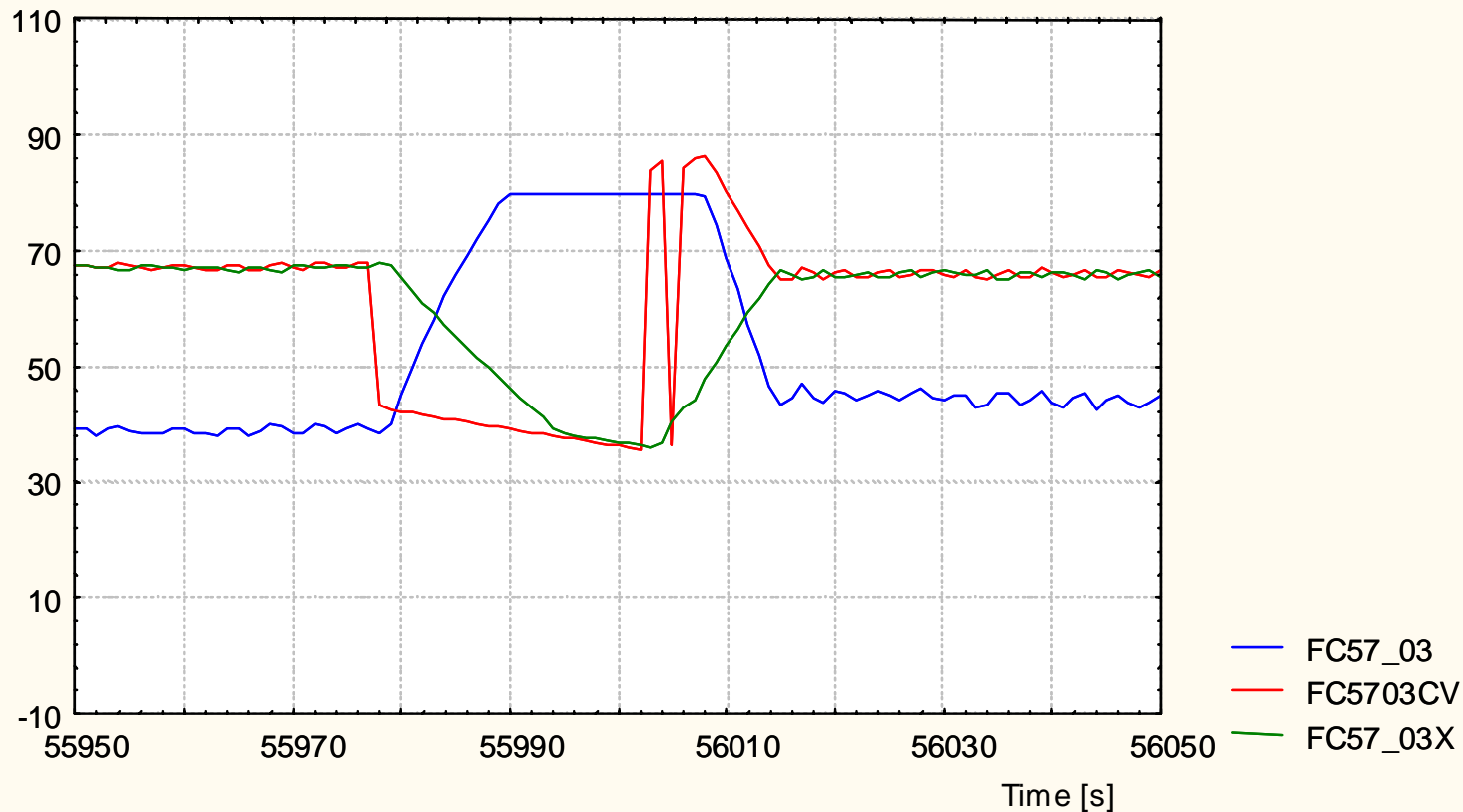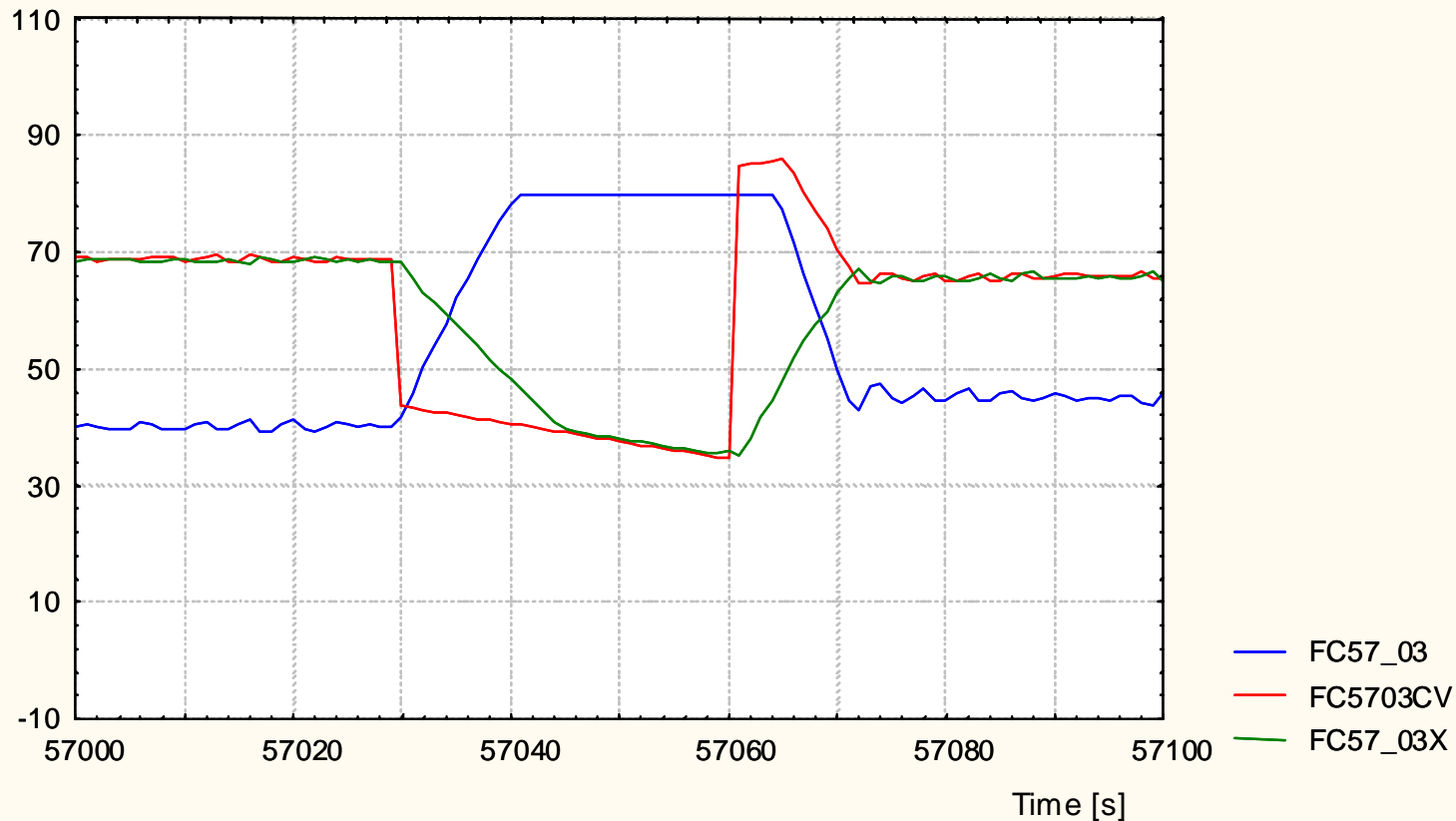|	
Fault:	flow rate sensor fault in Actuator 2 (f19)
Plant:	evaporator stage V
Date:	November 17, 2001
Duration:	57030 (sensor fault on) – 57072 (sensor fault off) s

Artificial fault generation
Fault f17 – Unexpected pressure drop across the valve in Actuator 2

Fault: unexpected pressure drop across the valve in Actuator 2 (f17)
Plant: evaporator stage V
Date: November 20, 2001
Duration: start at 44400 (added pressure offset on P57_03)
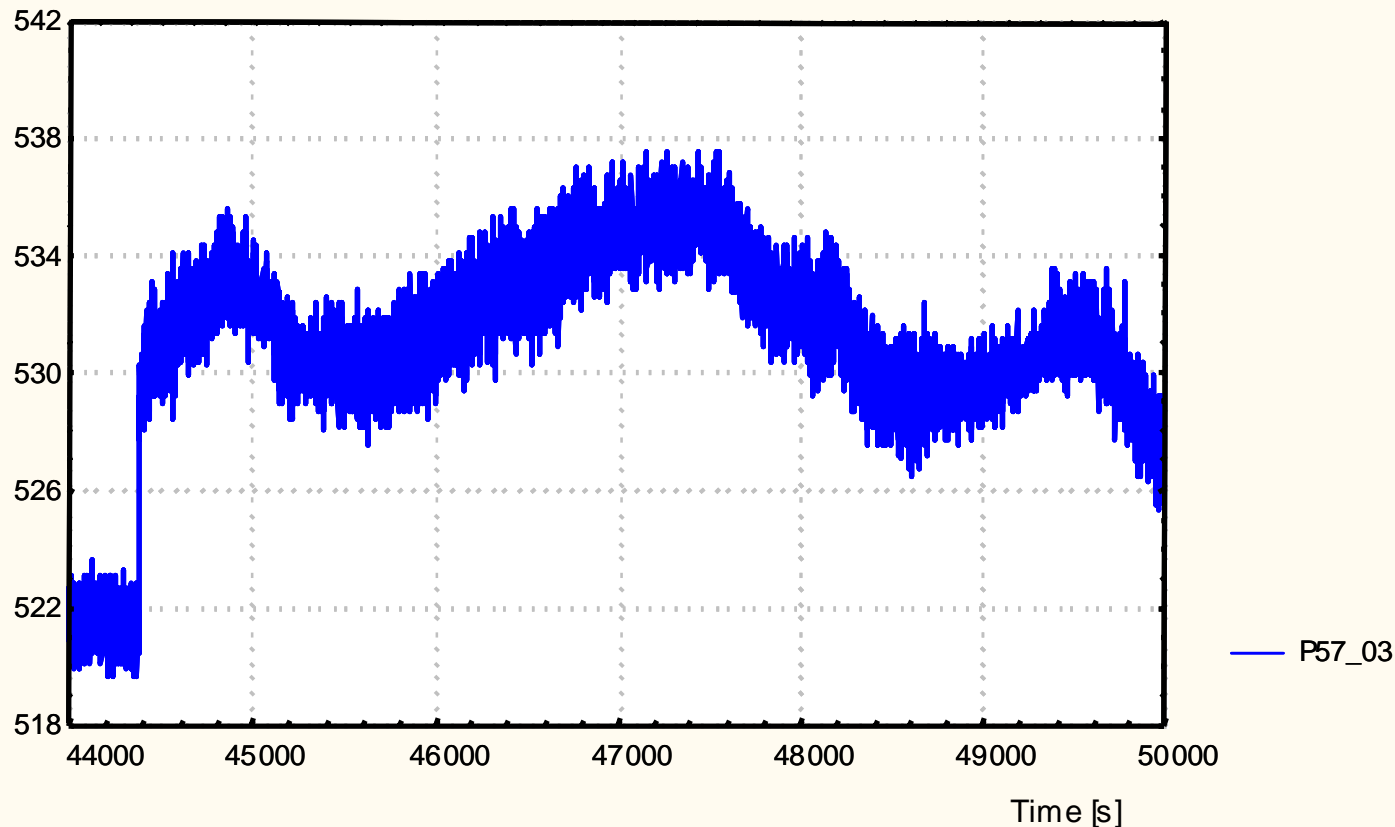
Artificial fault generation
Fault f18 - Partly opened bypass valve on actuator

Fault:	partly opened bypass valve on Actuator 3 (f18)
Plant:	steam boiler
Date:	October 30, 2001
Duration:	57340 (valve opening) – 57890 (valve closing) s
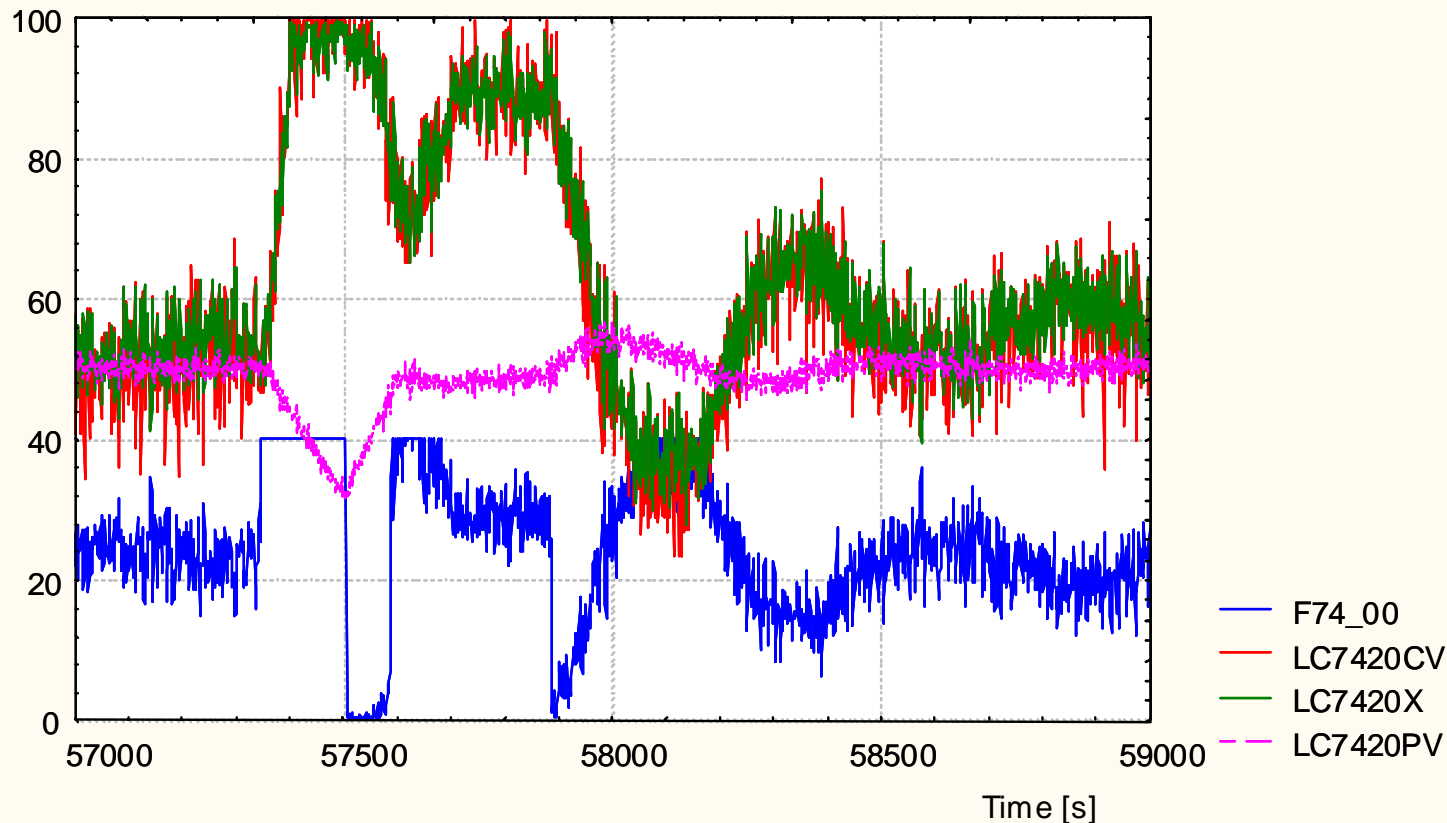
Legend:
- F74_00
- LC7420CV
- LC7420X
- LC7420PV

Time [s]

Artificial fault generation
Fault f16 – Positioner supply pressure drop on Actuator 3

Fault:	positioner supply pressure drop on Actuator 3 (f16)
Plant:	steam boiler
Date:	November 9, 2001
Duration:	60650 (pressure drop) – 60700 (pressure ok) s
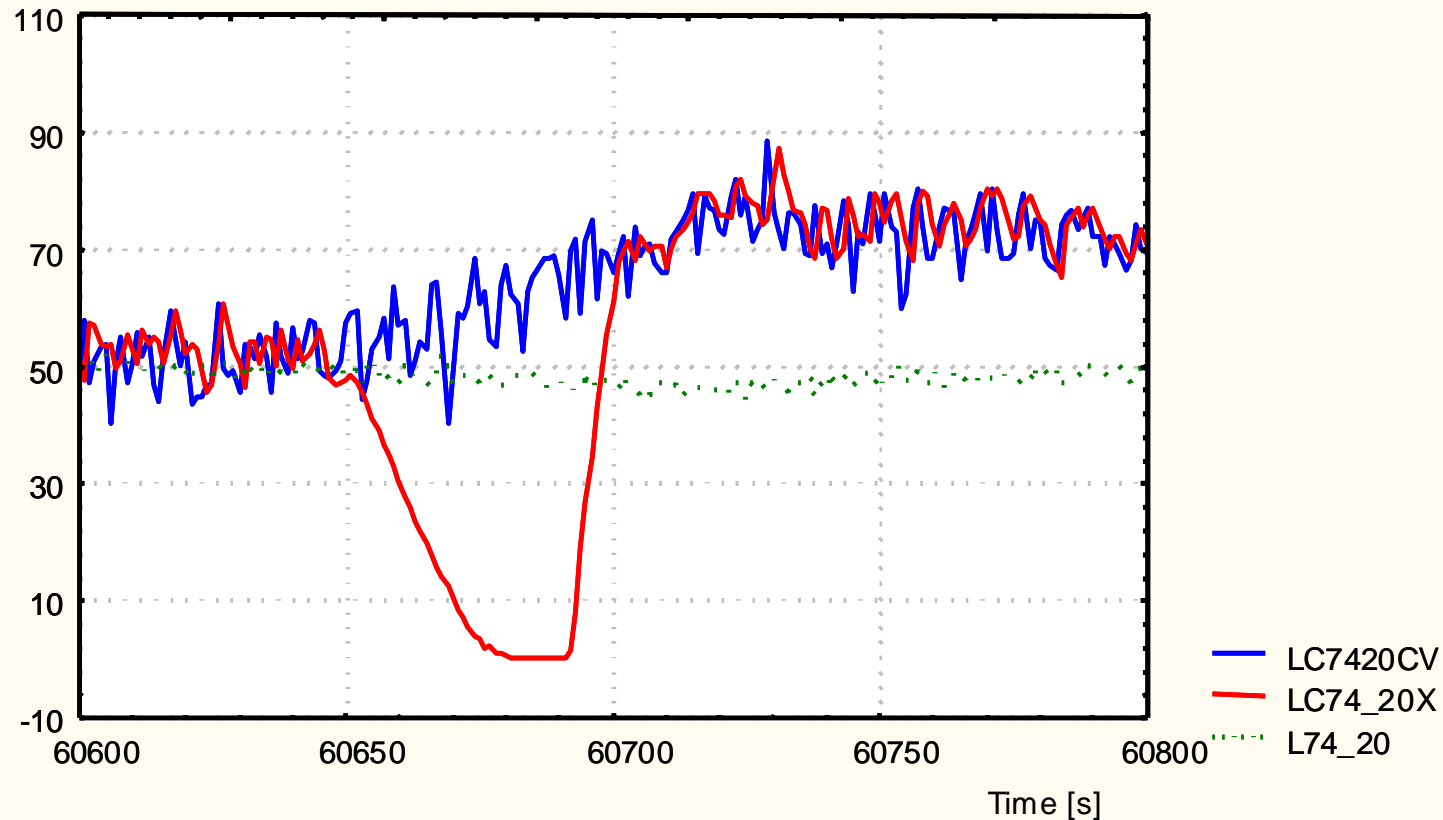
Legend: LC7420CV, LC74_20X, L74_20
Time [s]

Artificial fault generation
Fault f16 – Positioner supply pressure drop on Actuator 3

Fault:	positioner supply pressure drop on Actuator 3 (f16)
Plant:	steam boiler
Date:	November 9, 2001
Duration:	60870 (pressure drop) – 60960 (pressure ok) s

Legend:
- LC7420CV
- LC74_20X
- L74_20

Time [s]

Artificial fault generation
Fault f16 – Positioner supply pressure drop on Actuator 3
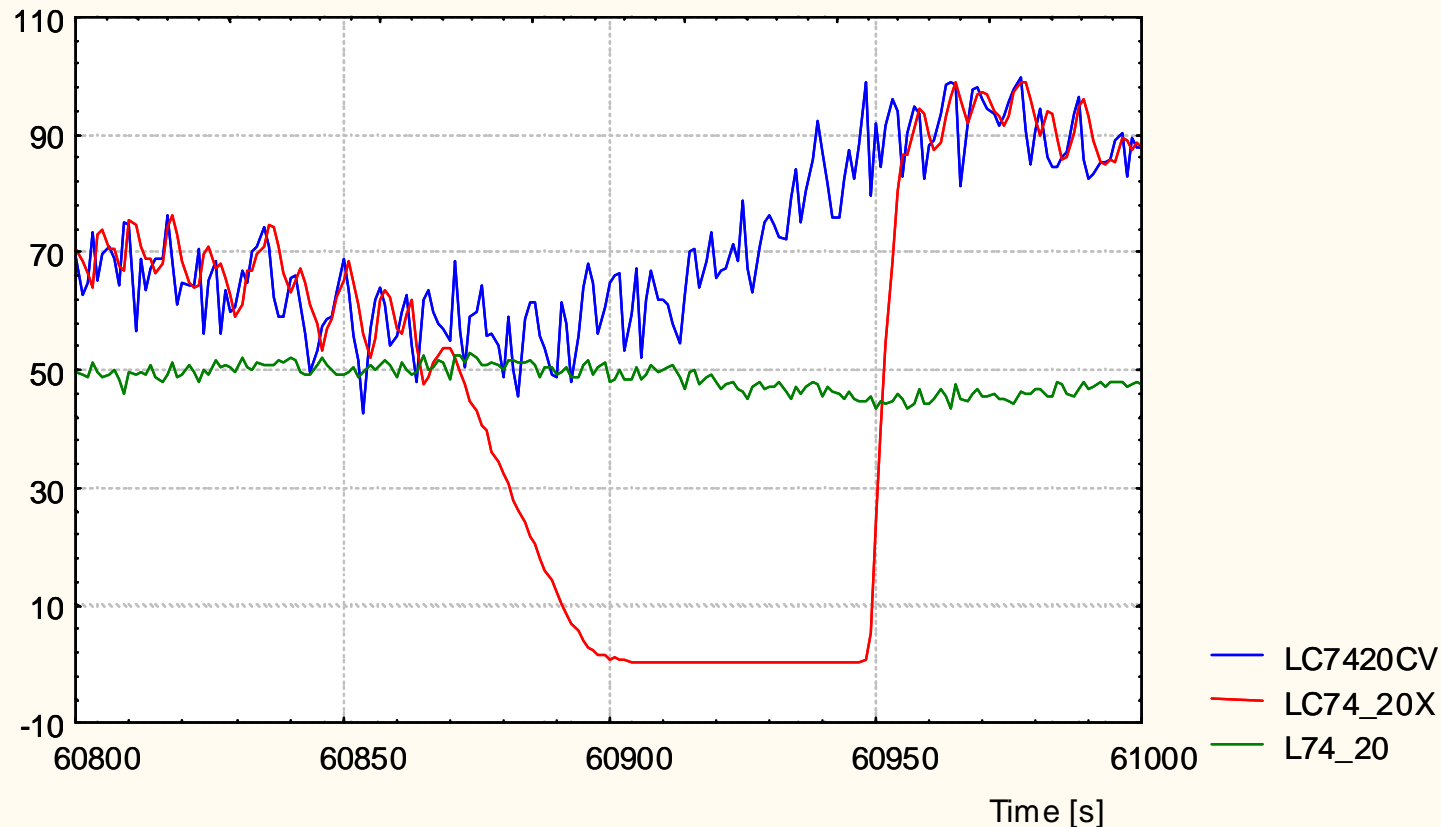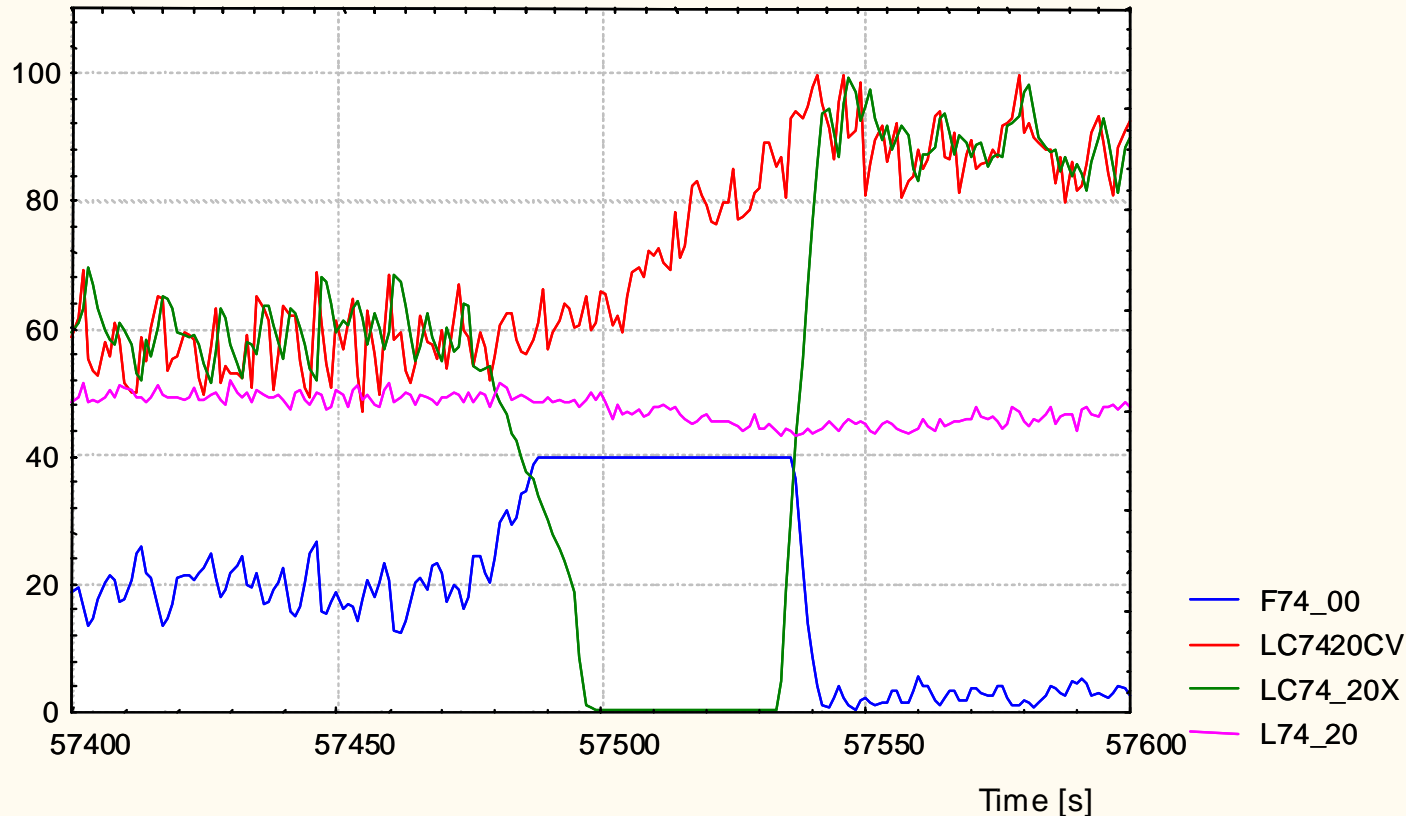
Fault:	positioner supply pressure drop on Actuator 3 (f16)
Plant:	steam boiler
Date:	November 17, 2001
Duration:	57475 (pressure drop) – 57530 (pressure ok) s

Legend: F74_00, LC7420CV, LC74_20X, L74_20

Time [s]

Artificial fault generation

Fault f16 – Positioner supply pressure drop on Actuator 3
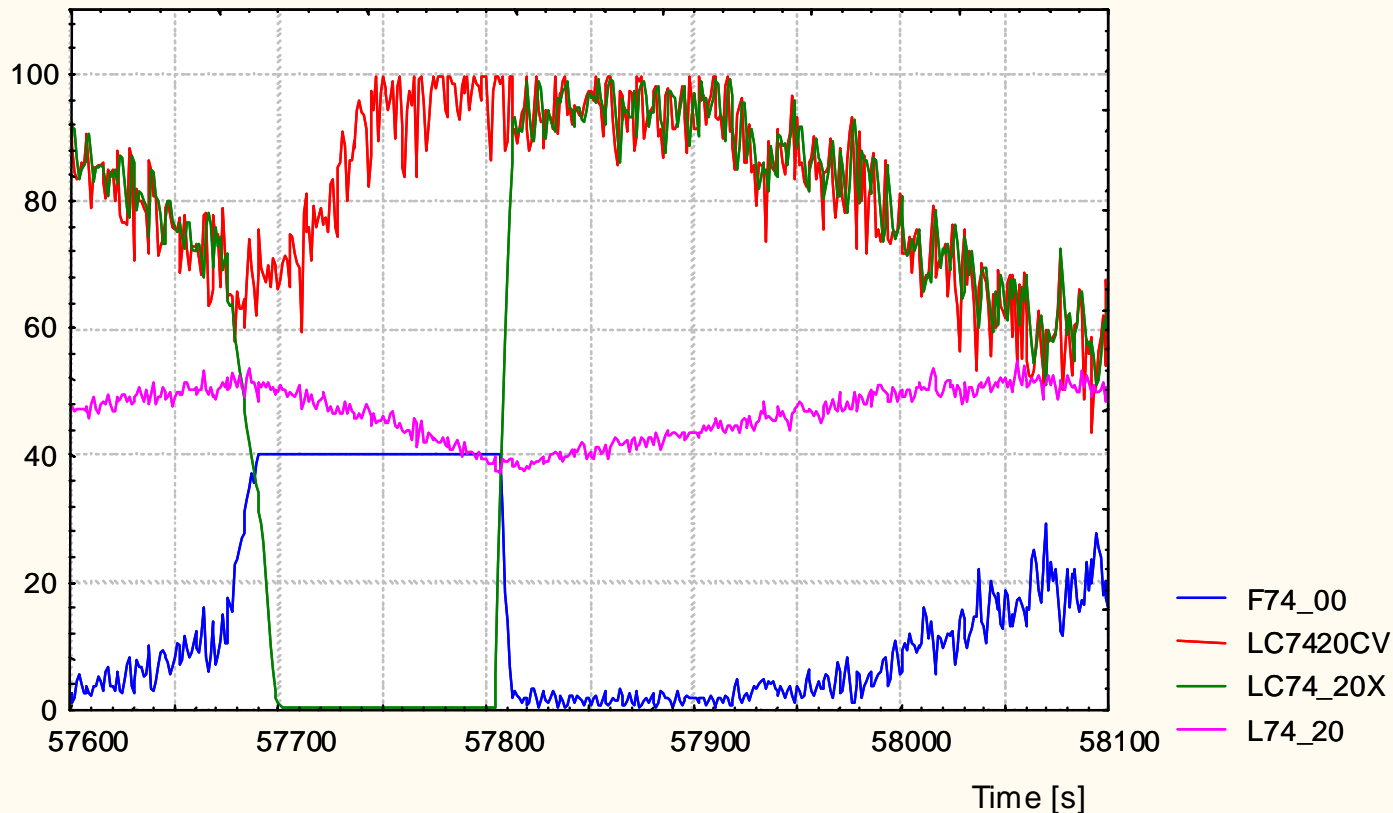
Fault:	positioner supply pressure drop on Actuator 3 (f16)
Plant:	steam boiler
Date:	November 17, 2001
Duration:	57675 (pressure drop) – 57800 (pressure ok) s

Artificial fault generation
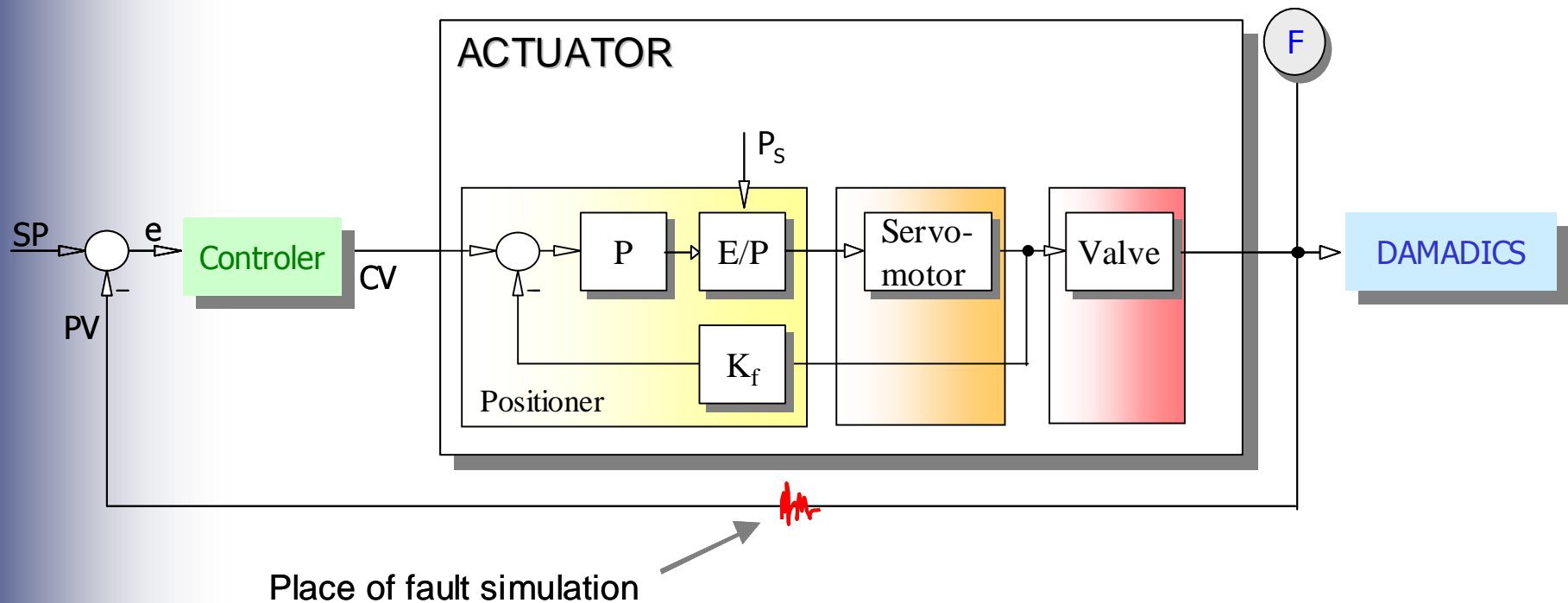*Fault f19 – Flow rate sensor fault in Actuator 3*

|	
Fault:	flow rate sensor fault in Actuator 3 (f19)
Plant:	steam boiler
Date:	November 17, 2001
Duration:	58150 (sensor fault on) – 58325 (sensor fault off) s
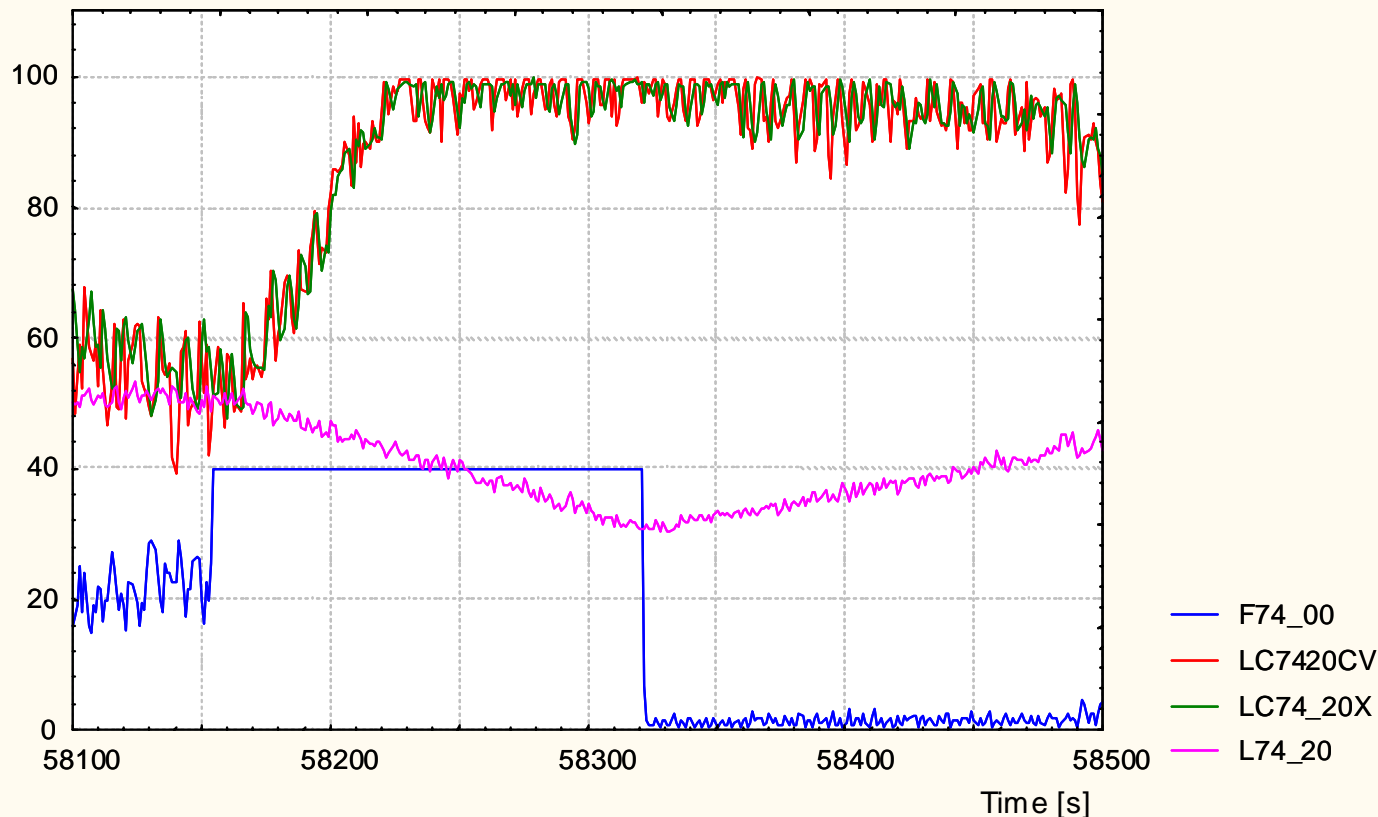
Artificial fault generation
Remark to f19 – Flow rate sensor fault in Actuator 2 (rather flow feedback fault)*

Actuator 2 works in flow control loop. Please pay attention that the flow signal available in DAMADICS data file is fault free. The fault was introduced only in the feedback of control loop.
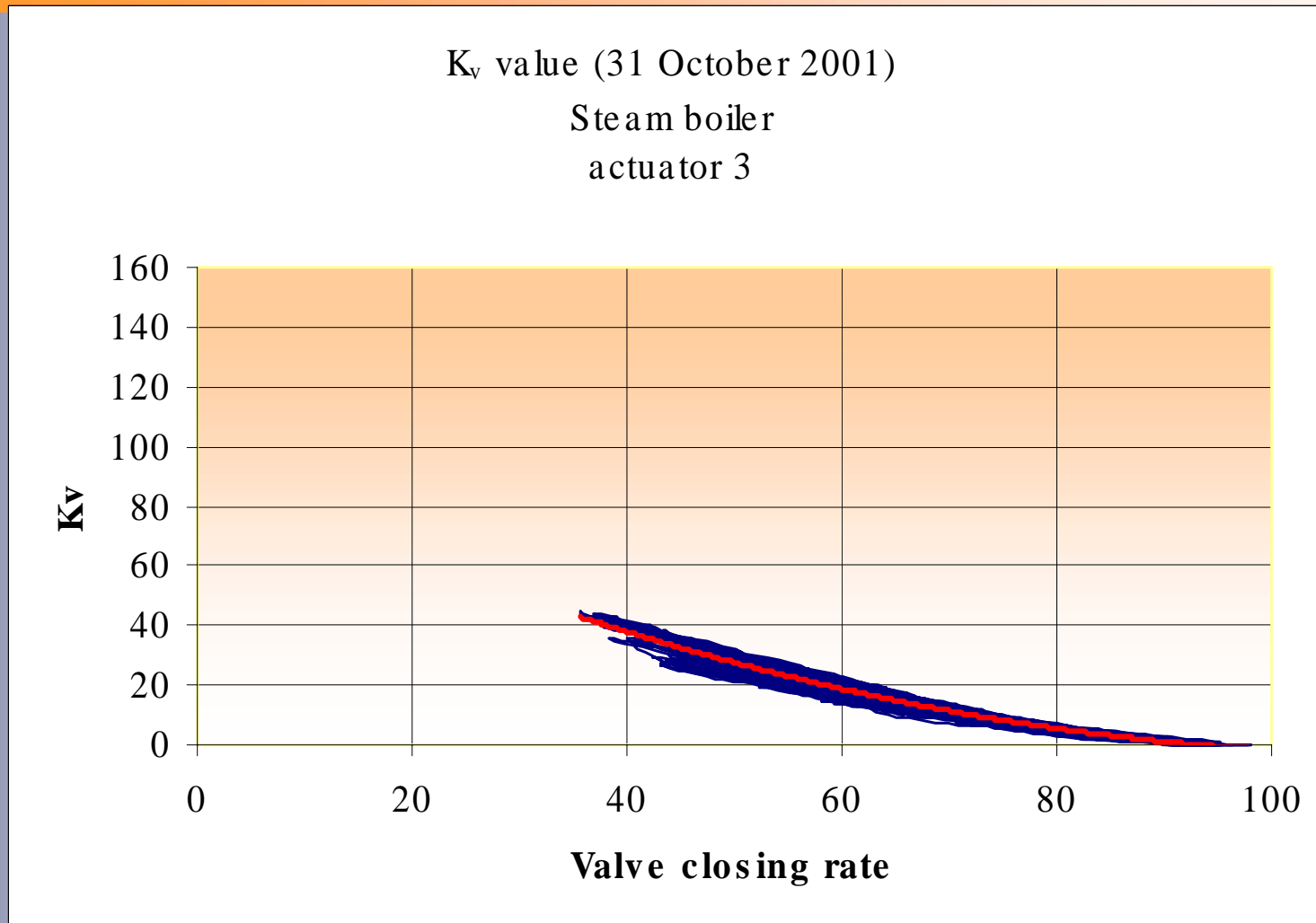

Place of fault simulation

Artificial fault generation

Remark to f19 – Flow rate sensor fault in Actuator 3
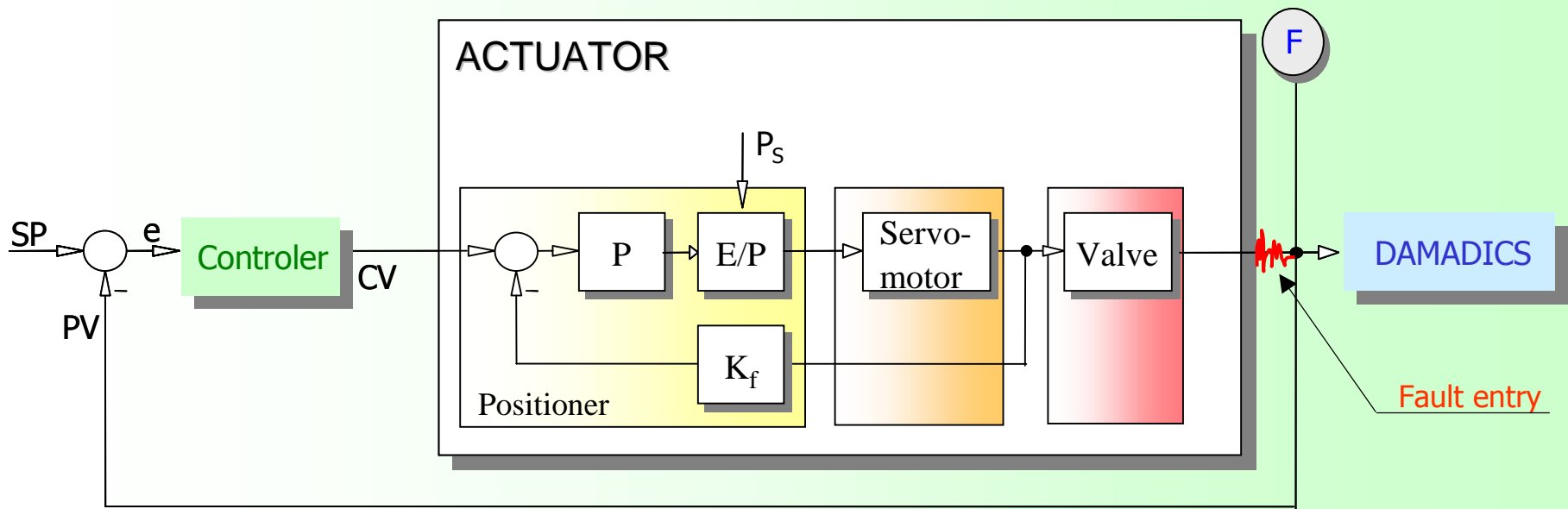
Fault free state
(additional profits – Kv value identification)

K_v value (31 October 2001)
Steam boiler
actuator 3

Faulty state
(Kv virtual change due to simulation of leckage)

Kv value (30 October 2001); Steam boiler; Actuator 3
Samples 57000-59000
Fault f18 (bypass opening and closing)

Valve closing rate in [%]
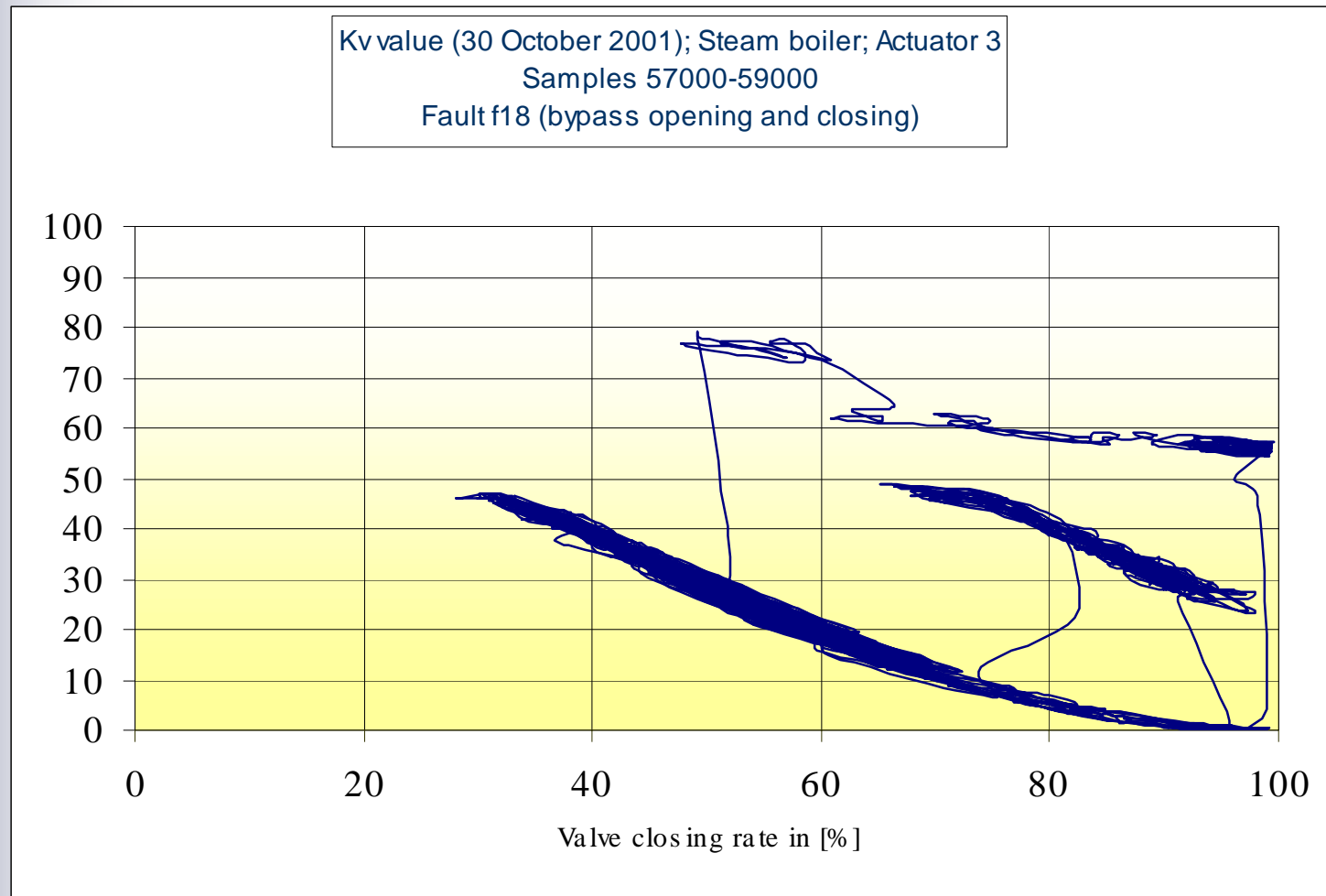
End remarks

The generation of hardware artificial faults can be dangerous for the process. Therefore not all known and identified faults can be simulated.

Data acquired from three actuators from sugar factory in autumn 2001 as well as detailed artificial fault specification are available from the web http://diag.mchtr.pw.edu.pl/damadics.

Experiments done are time and money expensive.