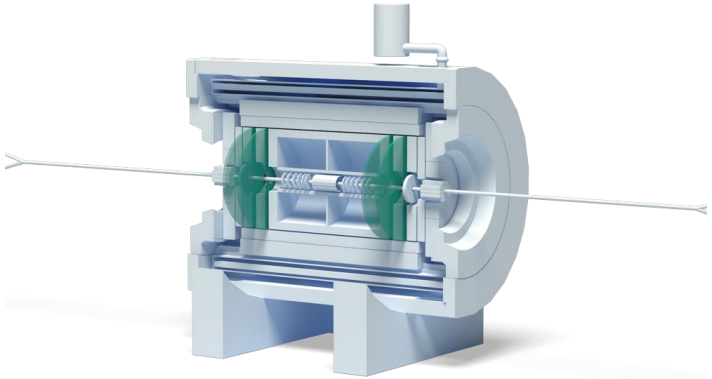
Adaptation advanced regulators to control gas system for Time of Flight detector in the NICA experimental complex



Master thesis

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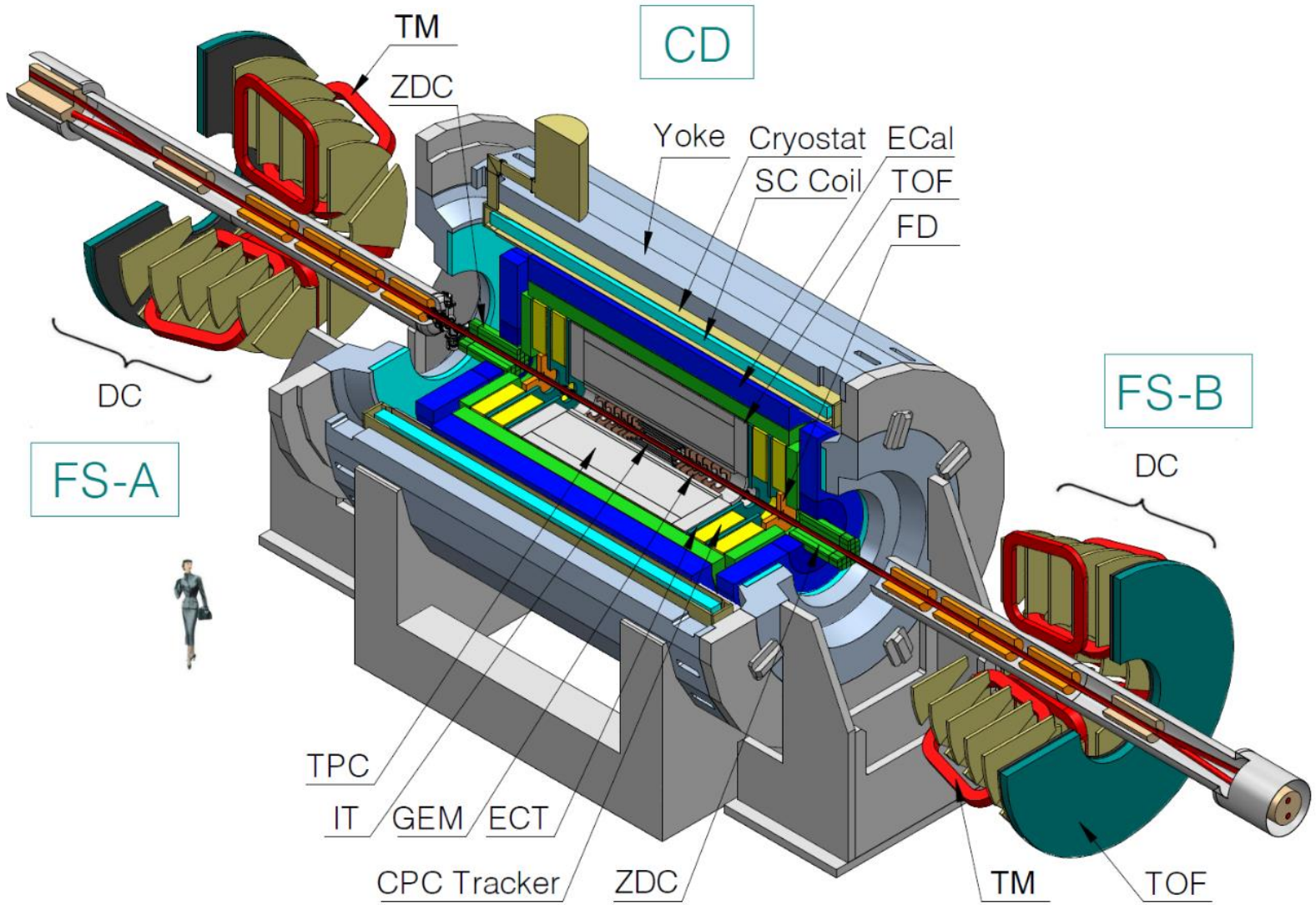
Purpose of the work

This thesis covers of implementation advanced regulator structure to control gas system for Time of Flight (TOF) detector at Nuclotron-based Ion Collider fAcility (NICA) experiment. TOF is a type of gas detector that measure the particle's time of flight at heavy ion collisions. For proper operation, it needs a gas with an appropriate composition and pressure.

Regulation algorithm have to:

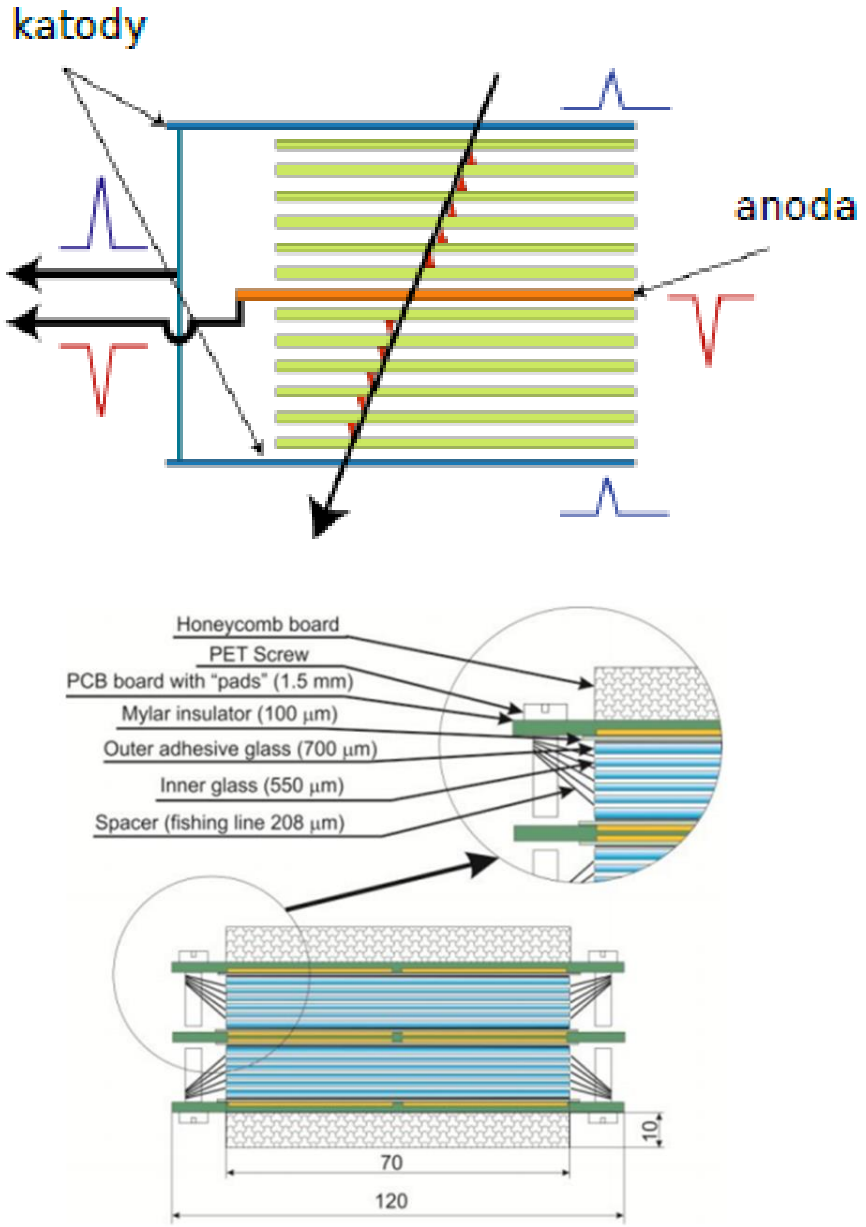
1. Deliver gases mixture to detector chambers at overpressure 3-5 mbar relative to the current atmospheric pressure
2. Preserve appropriate composition of gases mixture 90% C2H2F4 + 5% i-C4H10 + 5% SF6
3. Provide flows that lead to three gases recirculation in the detector during the day

Multi Purpose Detector (MPD)



Rys. 1 http://nica.jinr.ru/files/mpd_layout.htm

Time of Flight (TOF) construction



Rys. 2 **M**ulitgap **R**esistive **P**late **C**hamber

Operation mixture of gases:

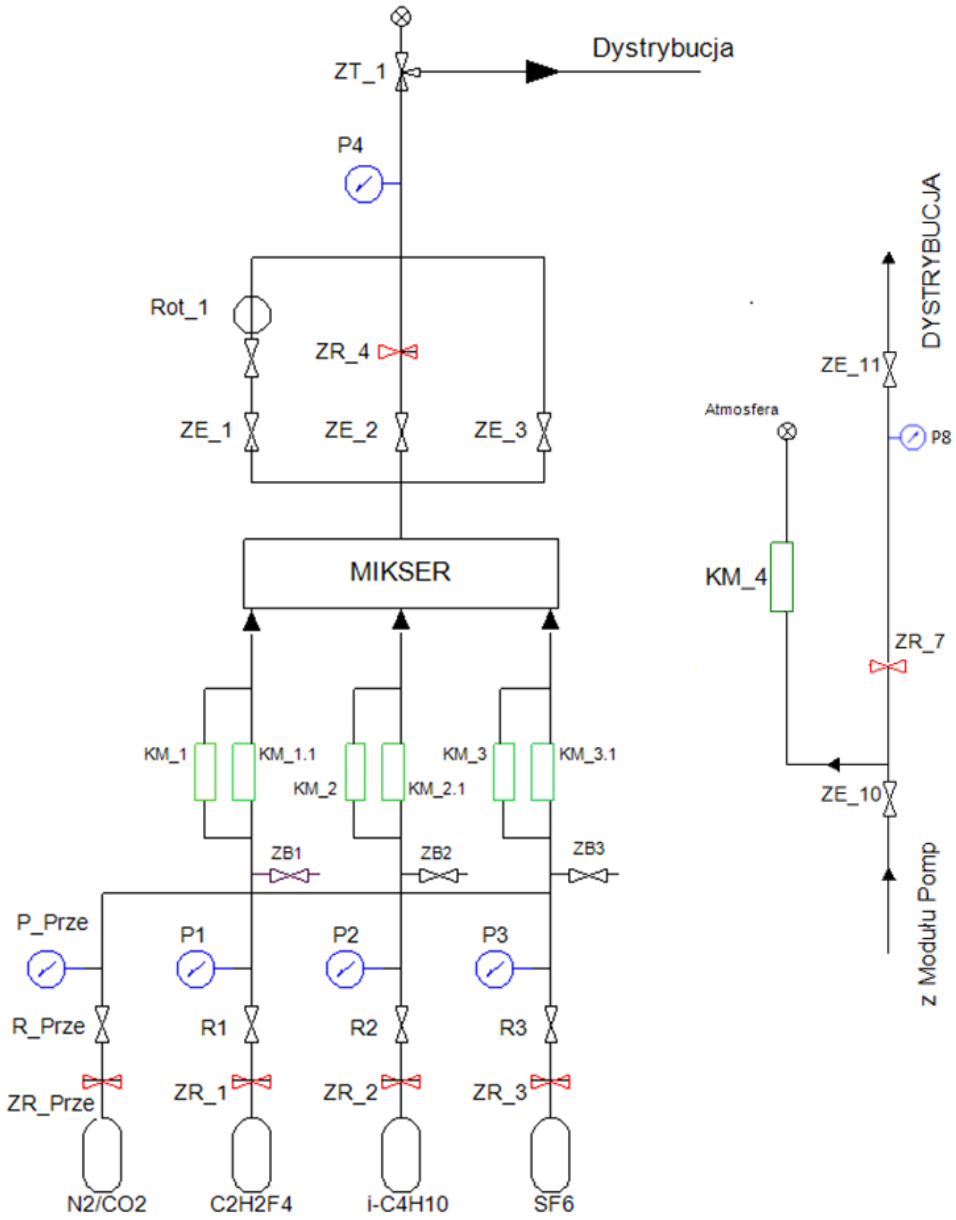
90% $C_2H_2F_4$ – tetrafluoroethane

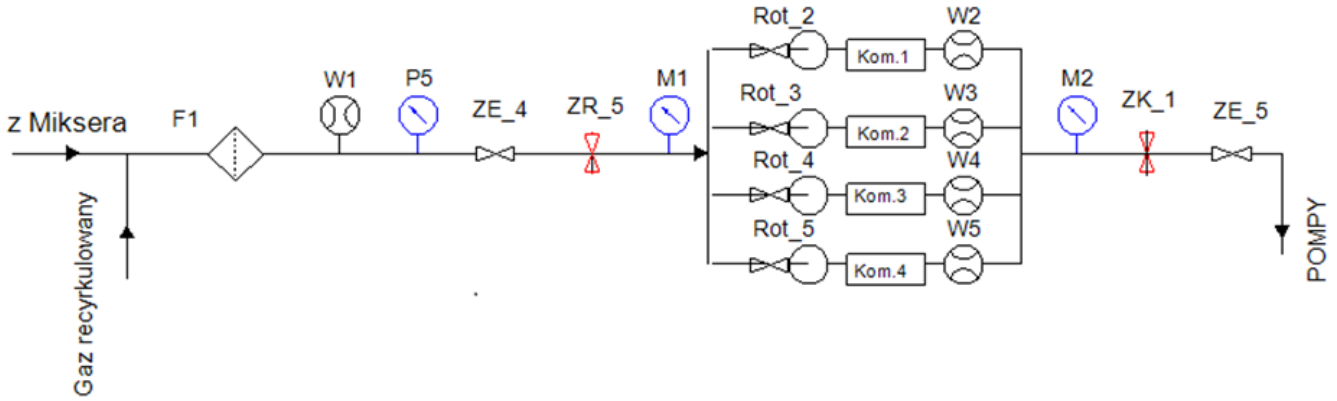
5% SF6 – sulfur hexafluoride

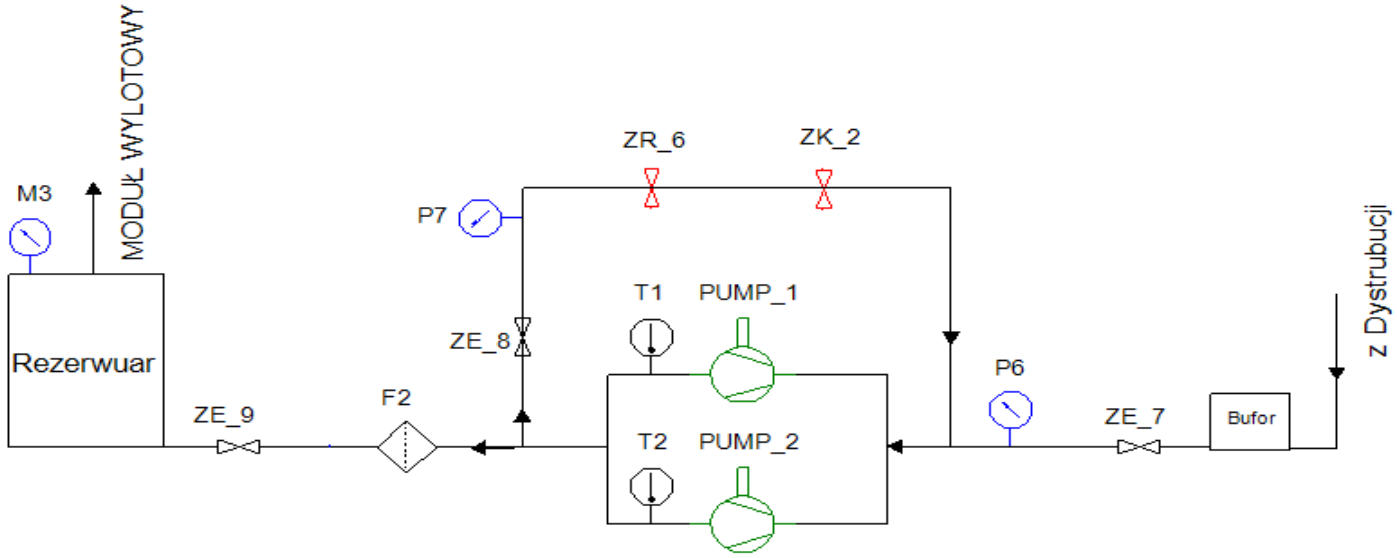
5% i-C_4H_{10} – isobutane

N_2 – nitrogen (for purifying)

Scheme of gas system







Mathematical model

$$(ZR\_1 - ZR\_1_u) * \frac{0{,}046}{5s+1} + (KM\_1 - KM\_1_u) * \frac{-0{,}023}{10s+1} + P1_n = P1 \quad (1.1)$$

$$(ZR\_2 - ZR\_2_u) * \frac{0{,}046}{5s+1} + (KM\_2 - KM\_2_u) * \frac{-0{,}017}{10s+1} + P2_n = P2 \quad (1.2)$$

$$(ZR\_3 - ZR\_3_u) * \frac{0{,}046}{5s+1} + (KM\_3 - KM\_3_u) * \frac{-0{,}028}{10s+1} + P3_n = P3 \quad (1.3)$$

$$(KM_1 - KM_{1_u}) * \frac{0{,}094}{5s+1} + SK1_n = SK1 \quad (1.4)$$

$$(KM_2 - KM_{2_u}) * \frac{0{,}04}{5s+1} + SK2_n = SK2 \quad (1.5)$$

$$(KM_3 - KM_{3_u}) * \frac{0{,}065}{5s+1} + SK3_n = SK3 \quad (1.6)$$

$$(ZR\_4 - ZR\_4_u) * \frac{0{,}033}{5s+1} + (ZR\_1 - ZR\_1_u) * \frac{0{,}03}{10s+1} + (ZR_2 - ZR_{2_u}) * \frac{0{,}03}{10s+1} + (ZR_3 - ZR_{3_u}) * \frac{0{,}03}{10s+1} + [(KM\_1 - KM\_1_u) * \frac{0{,}2}{10s+1} + (KM\_2 - KM\_2_u) * \frac{0{,}11}{10s+1} + (KM\_3 - KM\_3_u) * \frac{0{,}15}{10s+1} + P4_n = P4 \quad (1.7)$$

$$(ZR\_7 - ZR\_7_u) * \frac{0{,}021}{10s+1} + (ZR\_5 - ZR\_5_u) * \frac{-0{,}033}{10s+1} + P4 * \frac{0{,}7}{5s+1} + P5_n = P5 \quad (1.8)$$

$$(ZR\_5 - ZR\_5_u) * \frac{0{,}025}{5s+1} + (ZK\_1 - ZK\_1_u) * \frac{-0{,}025}{5s+1} + M1_n = M1 \quad (1.9)$$

$$(ZR\_4 - ZR\_4_u) * \frac{0{,}023}{10s+1} + (ZR\_7 - ZR\_7_u) * \frac{1{,}5}{10s+1} + (ZR\_5 - ZR\_5_u) * \frac{-0{,}026}{10s+1} + W1_n = W1 \quad (1.10)$$

$$(ZK\_1 - ZK\_1_u) * \frac{-0{,}025}{5s+1} + (ZR_5 - ZR_{5_u}) * \frac{0{,}025}{5s+1} + (ZK_2 - ZK_{2_u}) * \frac{-0{,}018}{10s+1} + M2_n = M2 \quad (1.11)$$

$$(ZR\_5 - ZR\_5_u) * \frac{2{,}6}{5s+1} + (ZK\_2 - ZK\_2_u) * \frac{-1{,}8}{5s+1} + (ZK\_1 - ZK\_1_u) * \frac{-2{,}6}{5s+1} + W2_n = W2 \quad (1.12)$$

$$(ZK\_1 - ZK\_1_u) * \frac{0{,}025}{5s+1} + (ZK\_2 - ZK\_2_u) * \frac{-0{,}018}{5s+1} + P6_n = P6 \quad (1.13)$$

$$(ZK\_2 - ZK\_2_u) * \frac{-0{,}28}{5s+1} + P7_n = P7 \quad (1.14)$$

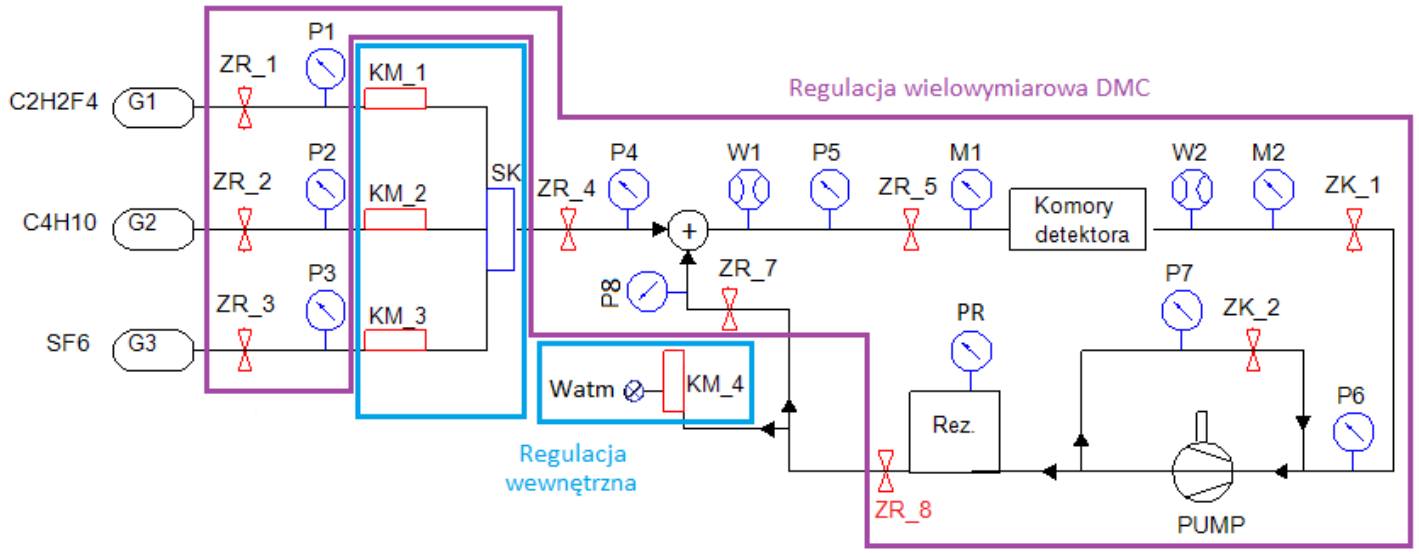
$$(ZK\_2 - ZK\_2_u) * \frac{0{,}028}{5s+1} + (KM\_4 - KM\_4_u) * \frac{-0{,}15}{5s+1} + PR_n = PR \quad (1.15)$$

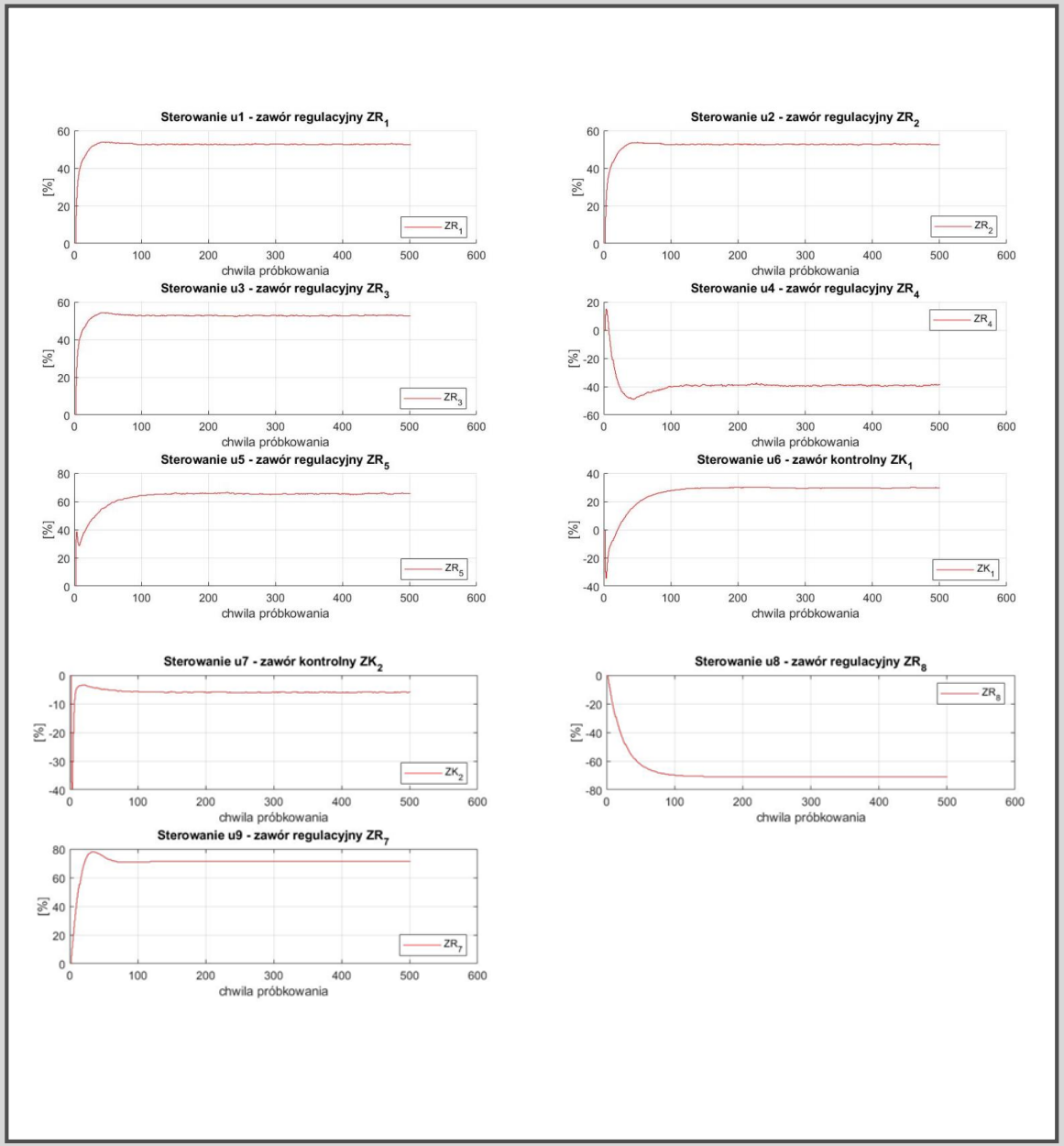
$$(KM\_4 - KM\_4_u) * \frac{-0{,}095}{5s+1} + Watm_n = Watm \quad (1.16)$$

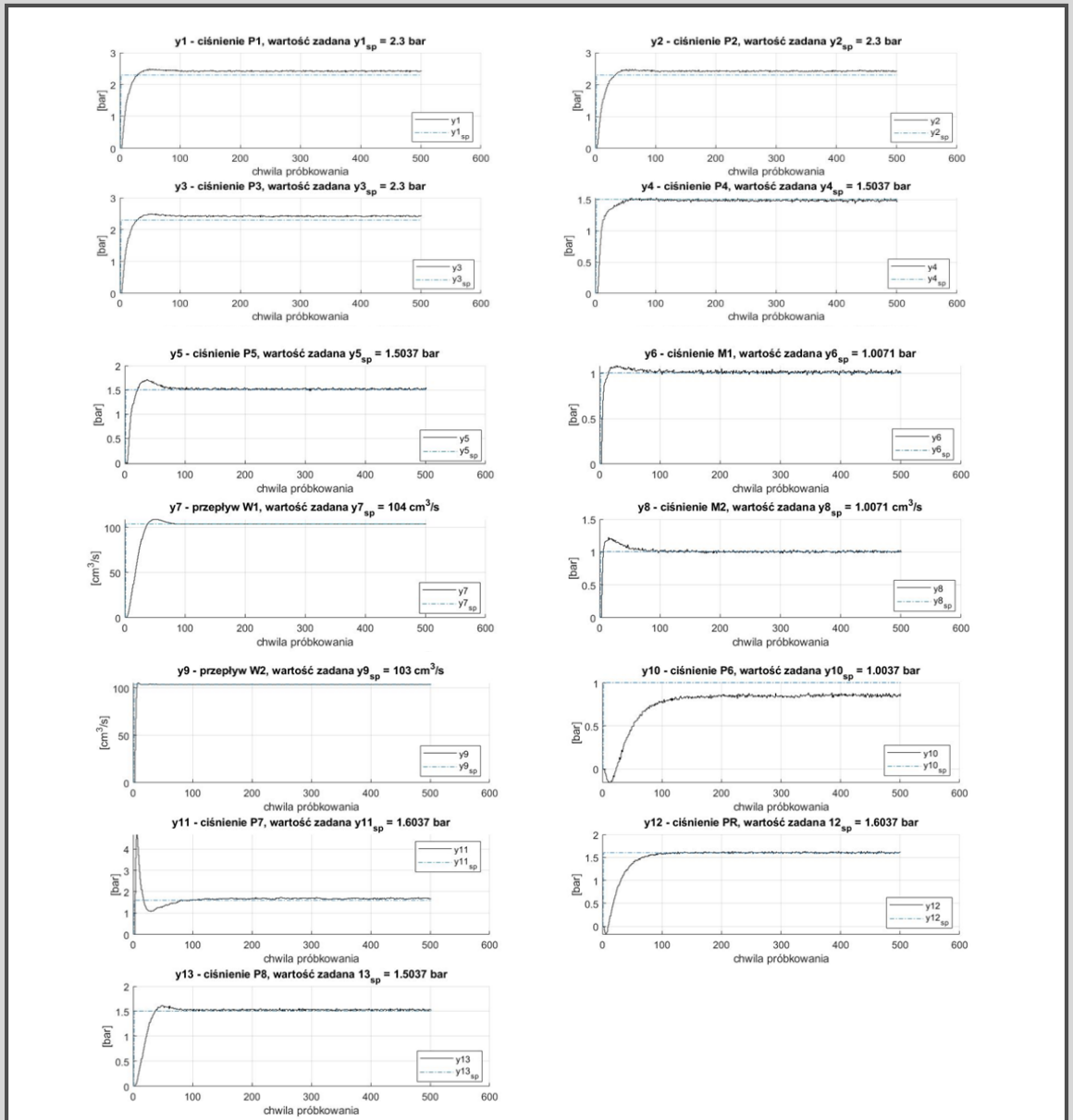
$$(ZR\_7 - ZR\_7_u) * \frac{0.0215}{5s+1} + P8_n = P8 \quad (1.17)$$

Regulation object

Wejścia n_u		Wyjścia n_y	
u1	ZR_1	**y1**	P1
u2	ZR_2	**y2**	P2
u3	ZR_3	**y3**	P3
u4	ZR_4	**y4**	P4
u5	ZR_5	**y5**	P5
u6	ZK_1	**y6**	M1
u7	ZK_2	**y7**	W1
u8	ZR_8	**y8**	M2
u9	ZR_7	**y9**	W2
		y10	P6
		y11	P7
		y12	PR
		y13	P8



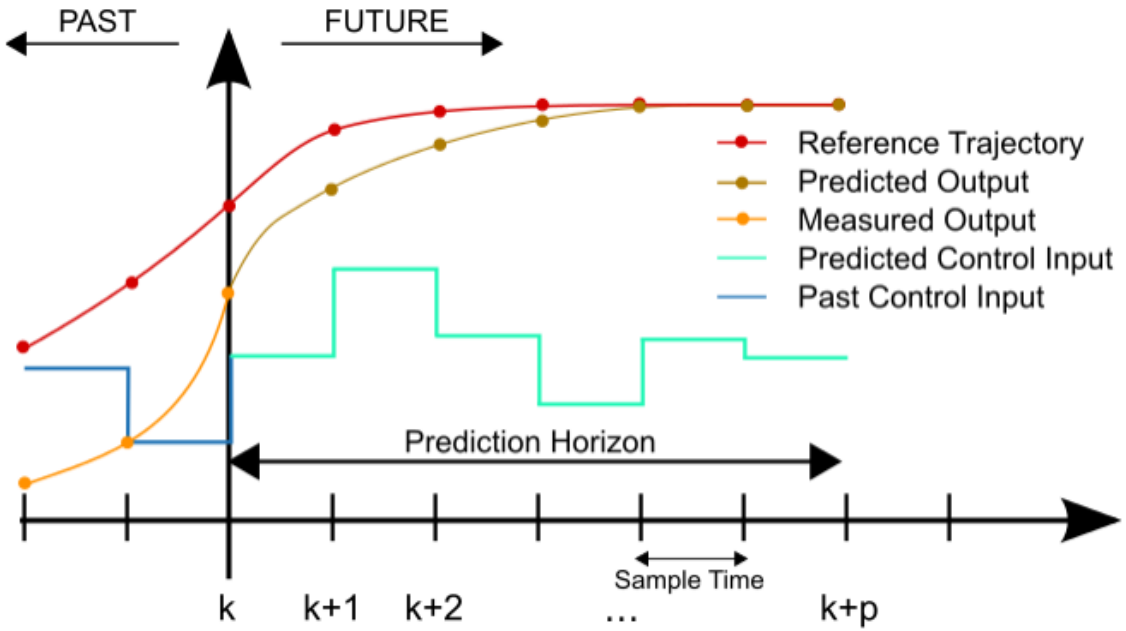

Sterowanie u1 - zawór regulacyjny ZR1
Sterowanie u2 - zawór regulacyjny ZR2
Sterowanie u3 - zawór regulacyjny ZR3
Sterowanie u4 - zawór regulacyjny ZR4
Sterowanie u5 - zawór regulacyjny ZR5
Sterowanie u6 - zawór kontrolny ZK1
Sterowanie u7 - zawór kontrolny ZK2
Sterowanie u8 - zawór regulacyjny ZR8
Sterowanie u9 - zawór regulacyjny ZR7
[%]
chwila próbkowania


y1 - ciśnienie P1, wartość zadana y1sp = 2.3 bar
y2 - ciśnienie P2, wartość zadana y2sp = 2.3 bar
y3 - ciśnienie P3, wartość zadana y3sp = 2.3 bar
y4 - ciśnienie P4, wartość zadana y4sp = 1.5037 bar
y5 - ciśnienie P5, wartość zadana y5sp = 1.5037 bar
y6 - ciśnienie M1, wartość zadana y6sp = 1.0071 bar
y7 - przepływ W1, wartość zadana y7sp = 104 cm3/s
y8 - ciśnienie M2, wartość zadana y8sp = 1.0071 cm3/s
y9 - przepływ W2, wartość zadana y9sp = 103 cm3/s
y10 - ciśnienie P6, wartość zadana y10sp = 1.0037 bar
y11 - ciśnienie P7, wartość zadana y11sp = 1.6037 bar
y12 - ciśnienie PR, wartość zadana 12sp = 1.6037 bar
y13 - ciśnienie P8, wartość zadana 13sp = 1.5037 bar
[bar]
[cm3/s]
chwila próbkowania

Predictive regulator DMC

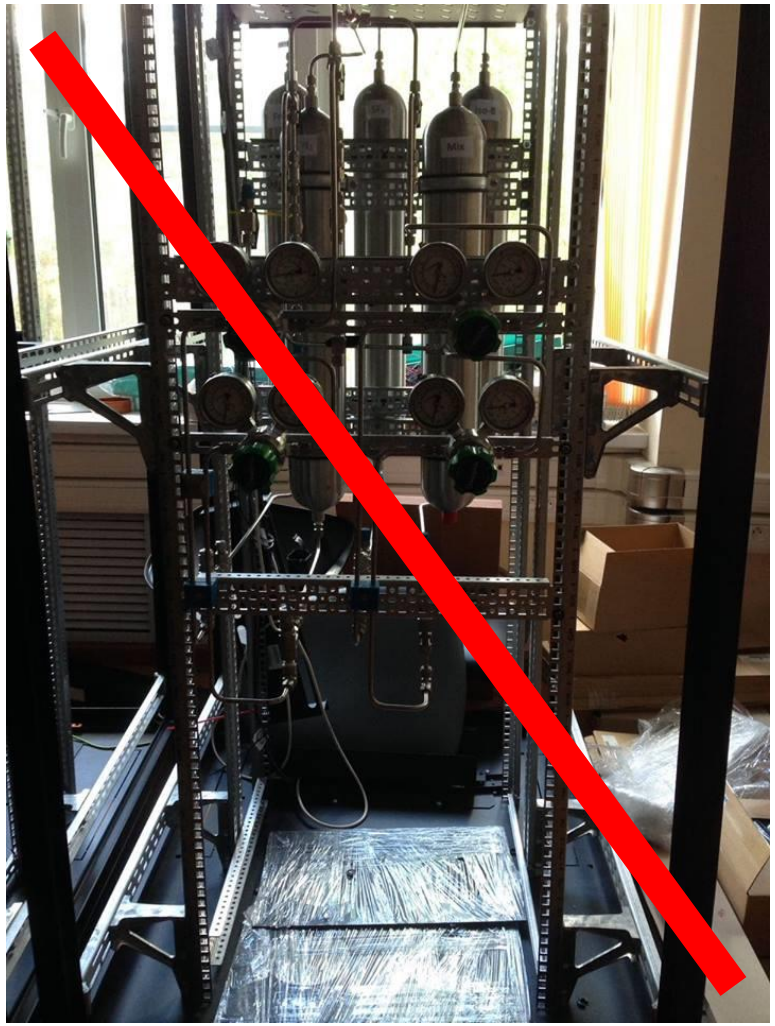
PID controller continuously calculates an error value e(t) as the difference between a desired setpoint (SP) and a measured process variable.

DMC regulators predict behave of the system in advance on prediction horizon.
To proper work it needs:
- model of the process
- past control values
- cost function J

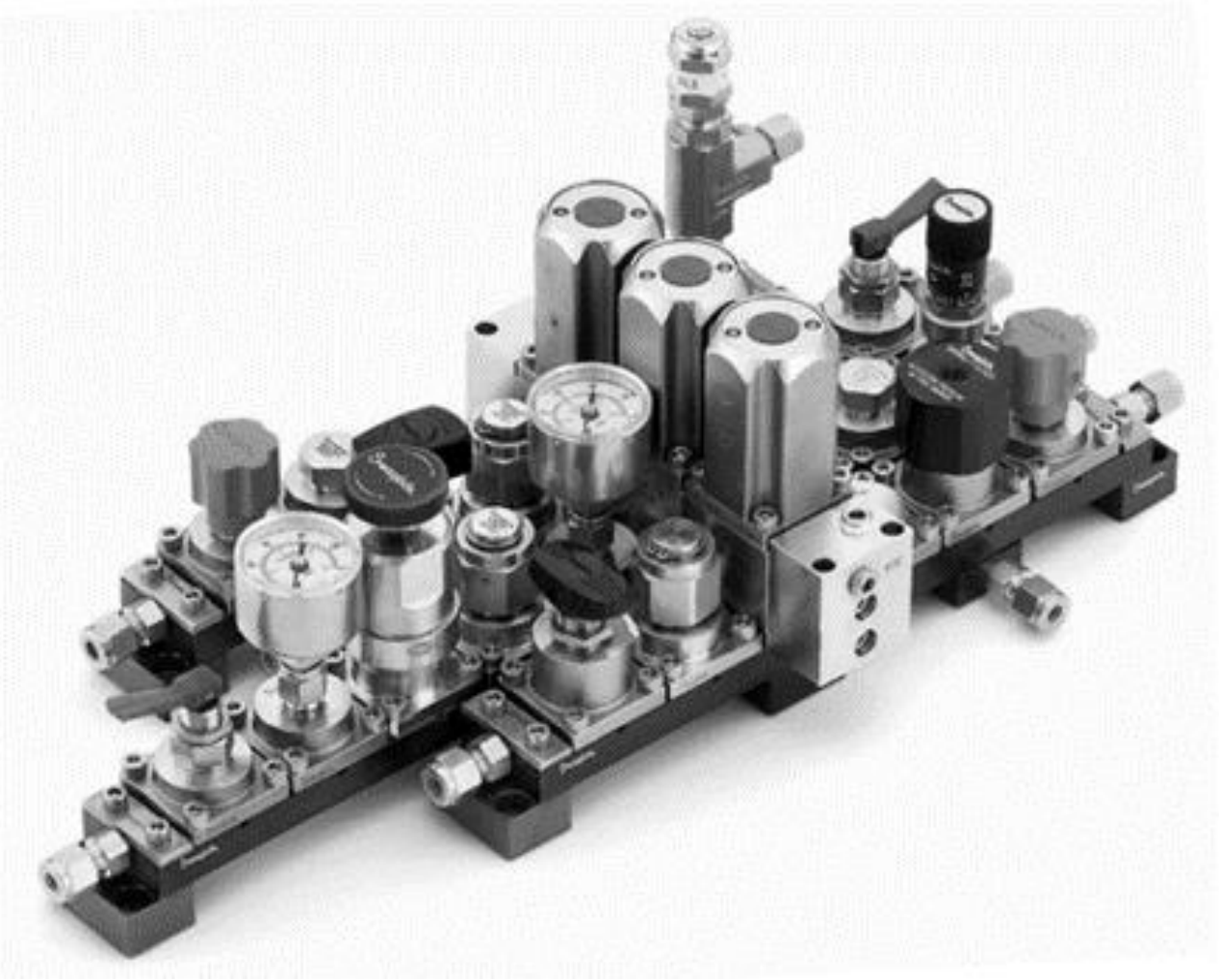


$$J(k) = \sum_{p=1}^{N} \left\| y^{zad}(k+p|k) - y^{0}(k+p|k) - \triangle y(k+p|k) \right\|_{\Psi}^{2} + \sum_{p=0}^{N_u-1} \left\| \triangle u(k+p|k) \right\|_{\Lambda}^{2}$$

Modular technology

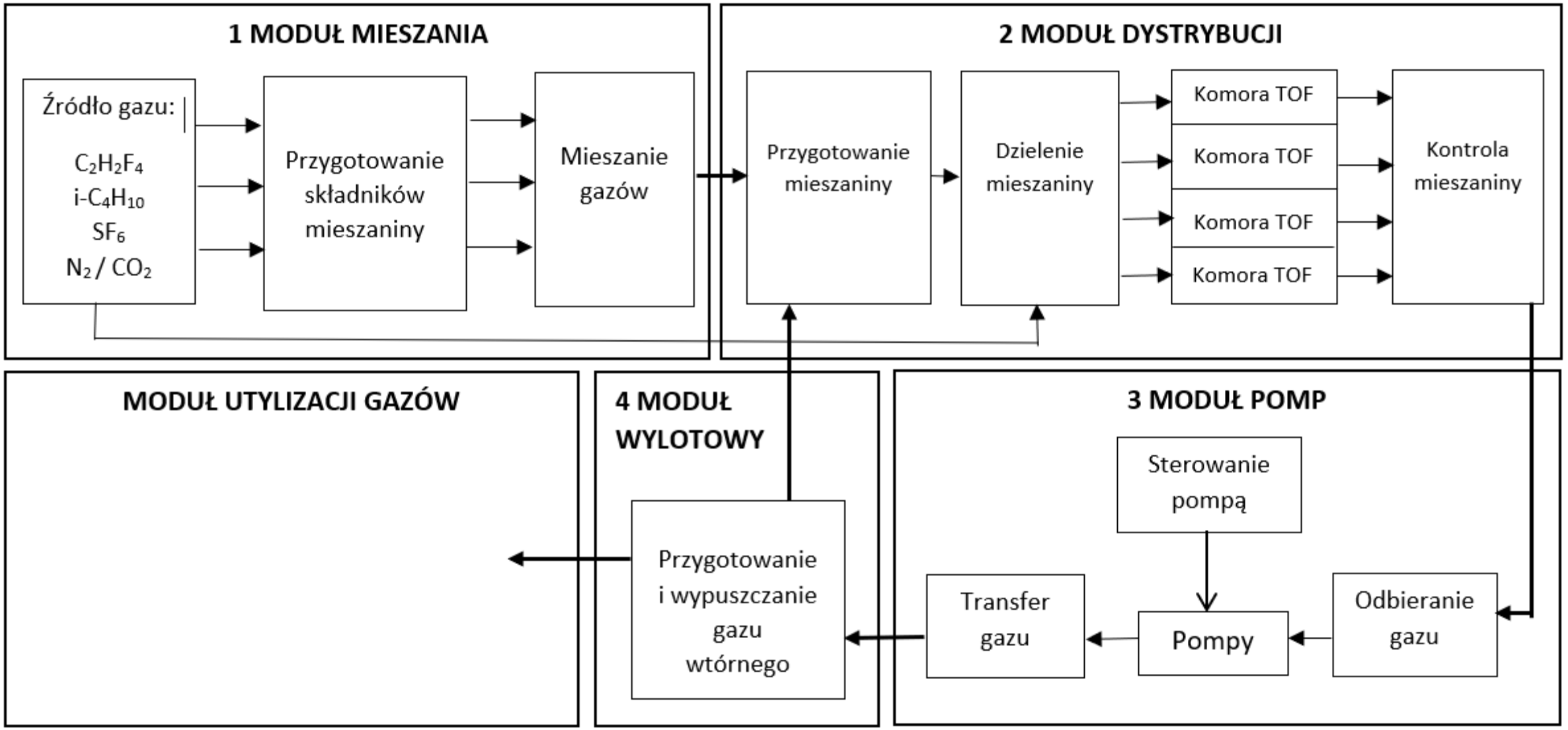


Rys. 3 Already existing control-measure infrastructure at JINR

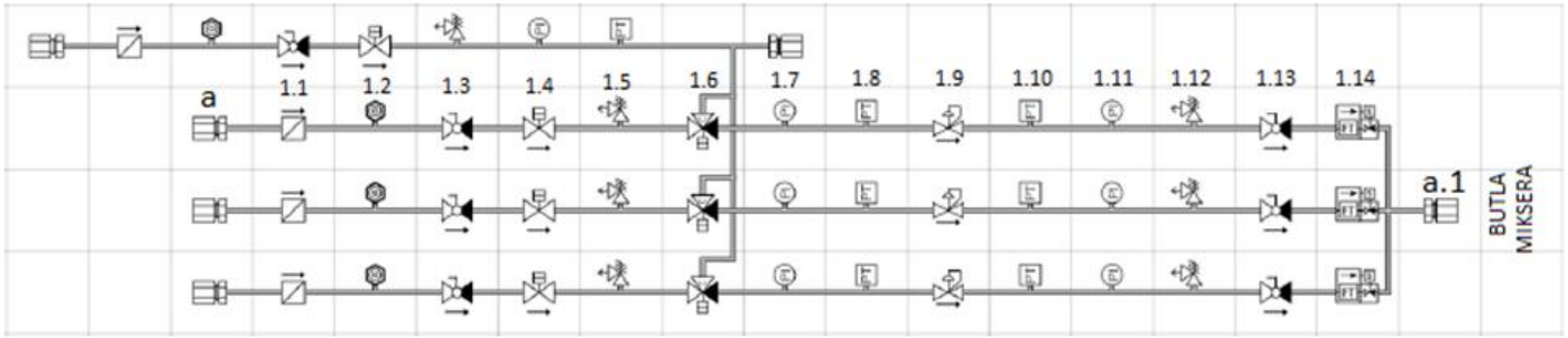


Rys. 4 Modular Platform Components (MPC)

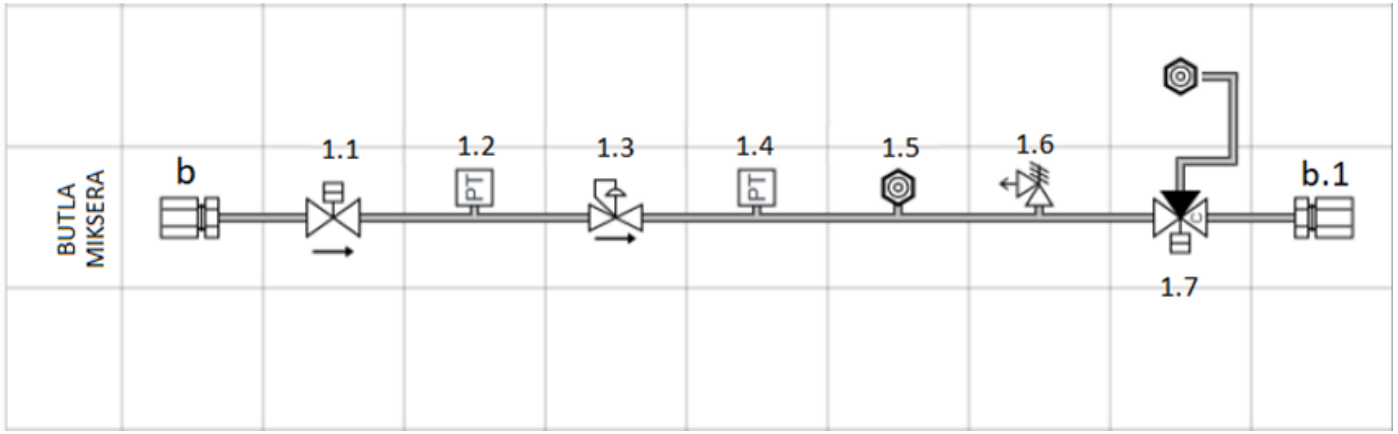
Block scheme for modular technology



Modular scheme



Rys. 5 Scheme created at MPC



Rys. 6 Scheme created at MPC

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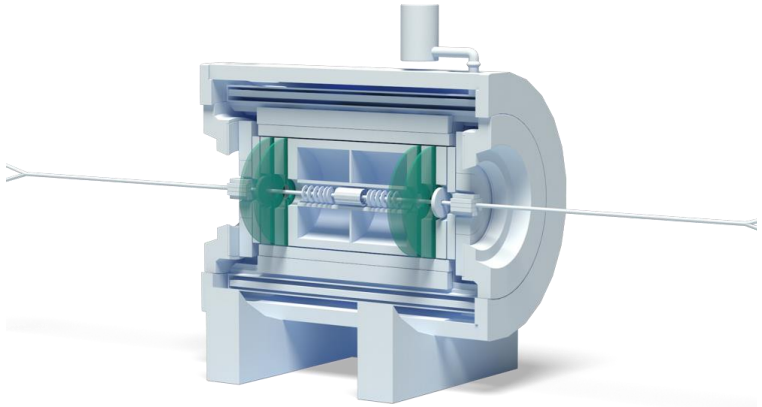
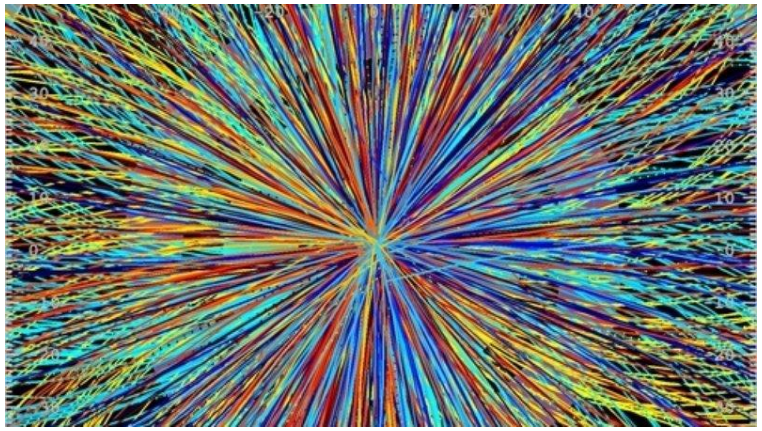
8. Swagelok. Modular Platform Components (MPC), Surface-Mount Components, Substrates, Manifolds, Mounting Components, and Assembly Hardware .





Thank you for your attention!

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