Study on Heat Dissipation Performance of the Central Beam Pipe of AGORA

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2026.10.24

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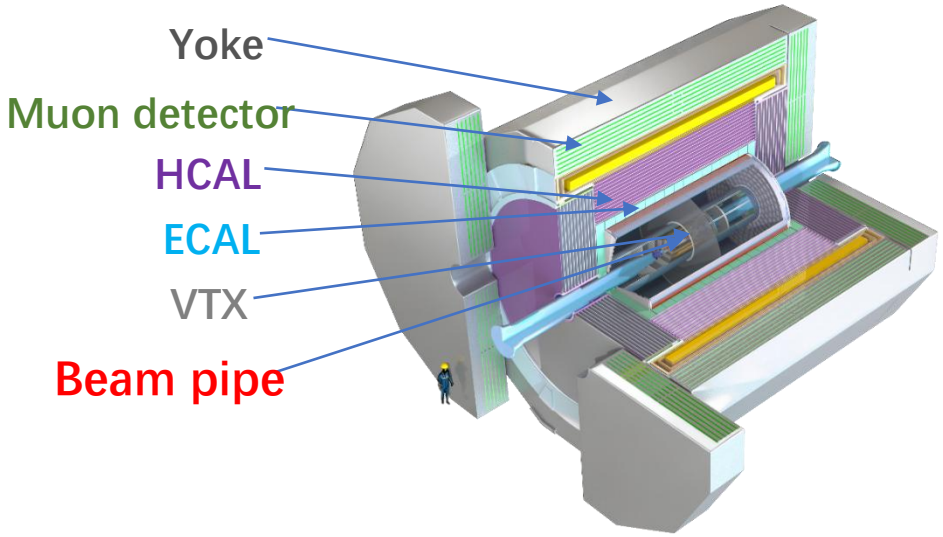
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Research Background

Beam-pipe heat dissipation is critical to stable detector operation



AGORA

Introduction:

As the core component for particle detection in the collision region, the central beam pipe directly determines vertex-detector resolution and data reliability.

Heat sources:

Beam-induced heating and irradiation effects of the materials themselves.

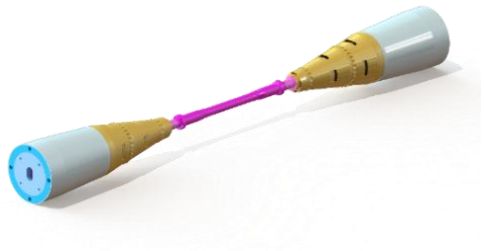
Risks of uneven cooling:

Local thermal deformation, vacuum degradation and Be-material decay; in severe cases these shift the detection path, cause signal loss, and limit overall stability.

Related Work

Beam-pipe parameters of major collider detectors worldwide

Detector	Beam pipe length (mm)	Central inner diameter (mm)	Central inner wall (mm)	Central outer wall (mm)	Inner-outer gap (mm)	Central section material
ALTAS	7300	58	0.8 (single wall)	/	/	BE
Belle-B	170	58	0.35	0.6	0.5	BE
FCC	180	20	0.35	0.35	1	AL-BE alloy
BSEⅢ	300	63	0.8	0.6	0.8	BE
AGORA	380	20	0.2	0.15	0.2	BE



AGORA beam pipe

Advantage:

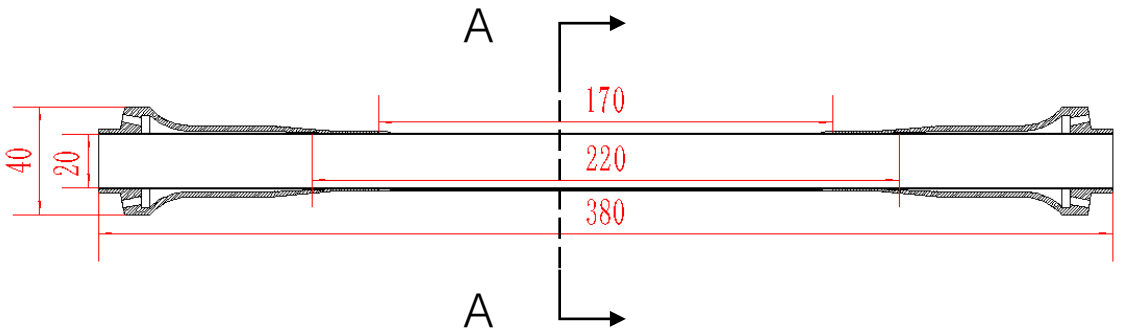
The AGORA beam pipe currently has the thinnest wall, smallest gap and lowest material budget.

Current issues:

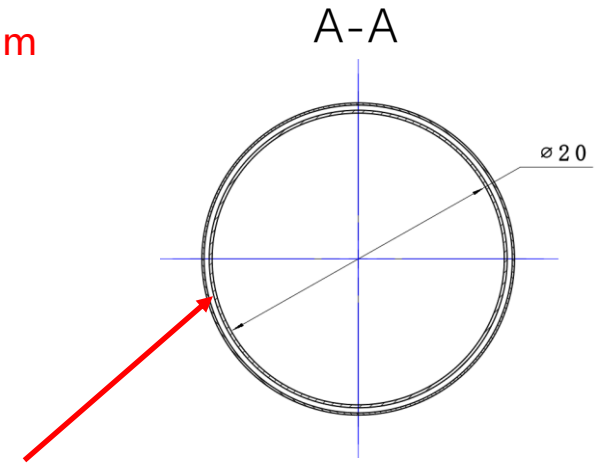
Coolant self-weight and imperfect double-wall coaxiality may cause uneven flow in the annular gap, degrading cooling performance.

Simulation

Initial Be-pipe scheme & thermal-power setup



Unit: mm





Inner Be wall 0.2 mm; outer Be wall 0.15 mm
Annular cooling channel in central section: 0.2 mm
Inlet velocity : 0.5, 0.6, 0.8, 1.0, 1.2, 1.6 (m/s)
Total thermal power (rounded): 225 W

Range	Power/side	Power both	Area	Heat flux	Material
mm	W	W	m^2	W/m^2	
0~110	72.85	145.70	0.0100519	14490	BE
110~190	38.58	77.15	0.0119348	6460	AL

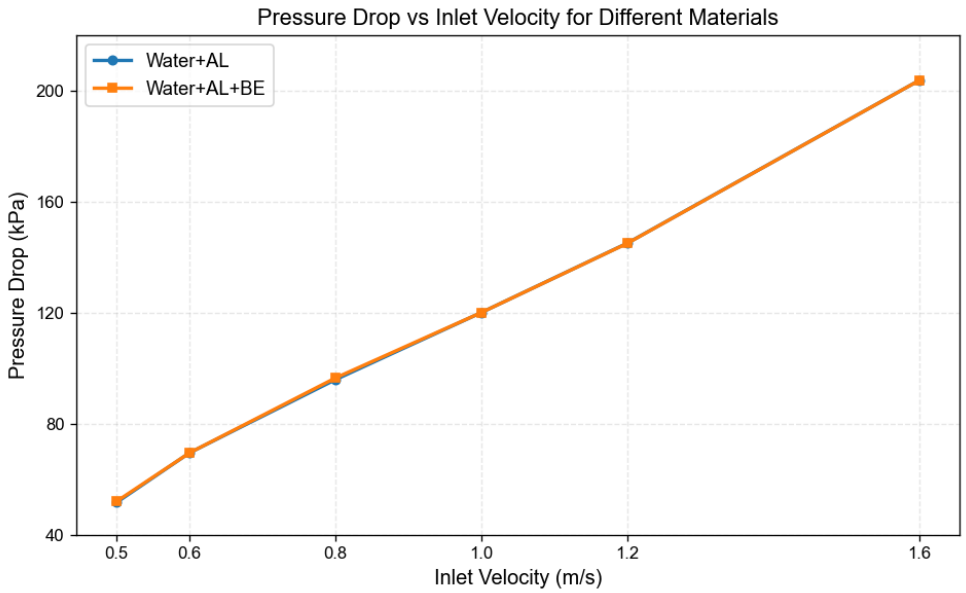
Simulation

Al-alloy as Be substitute: negligible impact on pressure drop & temperature

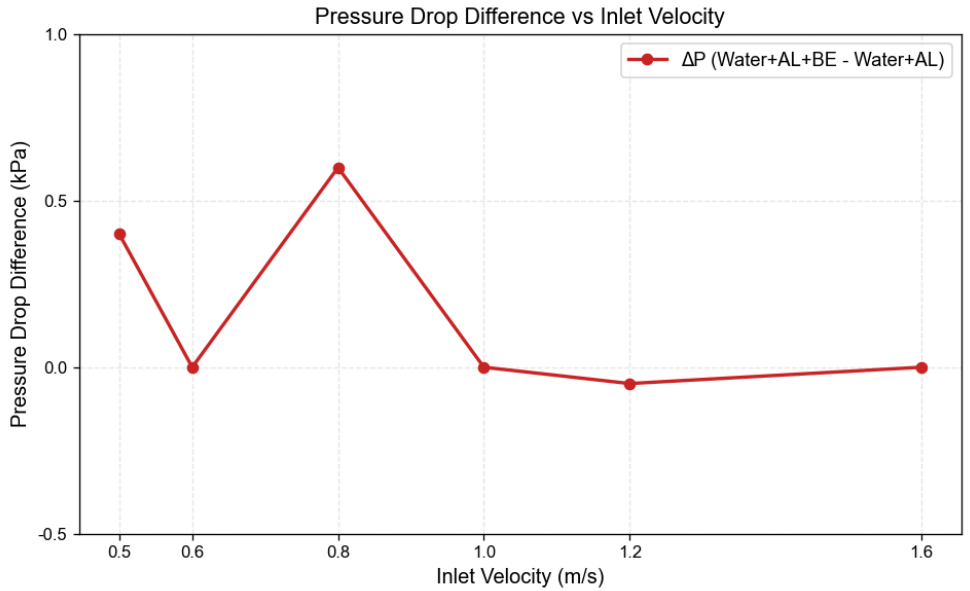
Background: Beryllium was originally chosen, but Be dust is highly toxic, experiments are difficult and fabrication costly; an alternative is sought.

Result: Replacing Be with Al-alloy changes pressure drop by < 1 kPa and outer-wall peak temp. by < 0.15 ℃.

Pressure-drop difference after material substitution < 1 kPa



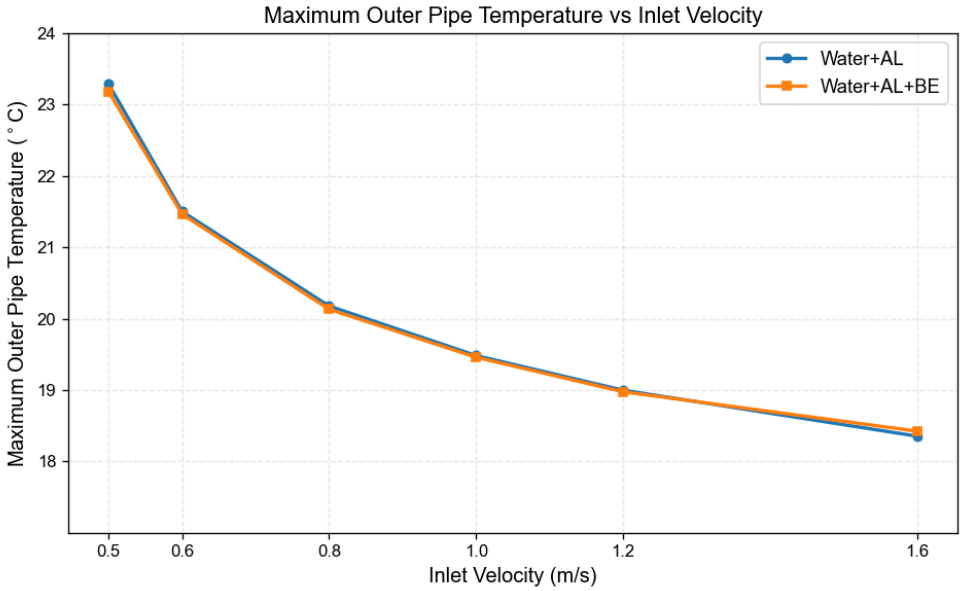
Pressure drop comparison



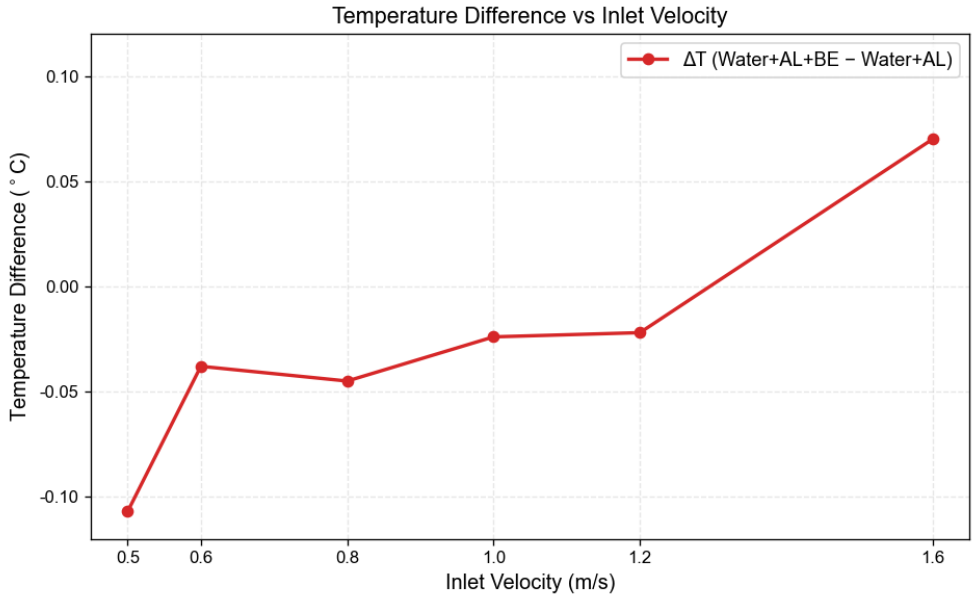
Pressure-drop difference

Simulation

Outer-wall peak-temp. difference stays below 0.15 ℃ after substitution



Outer-wall peak-temp. comparison



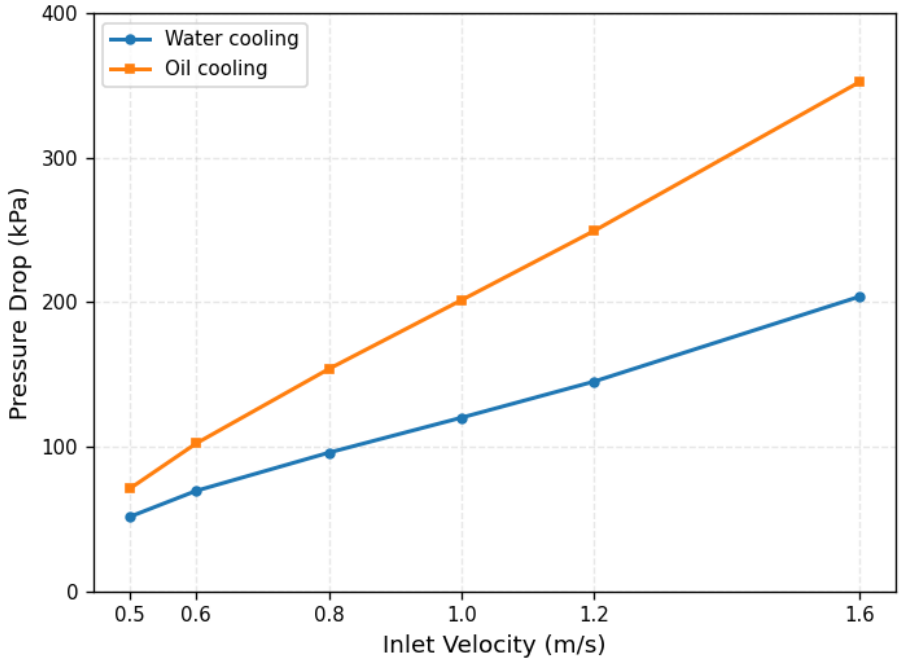
Outer-wall peak-temp. difference

Simulation

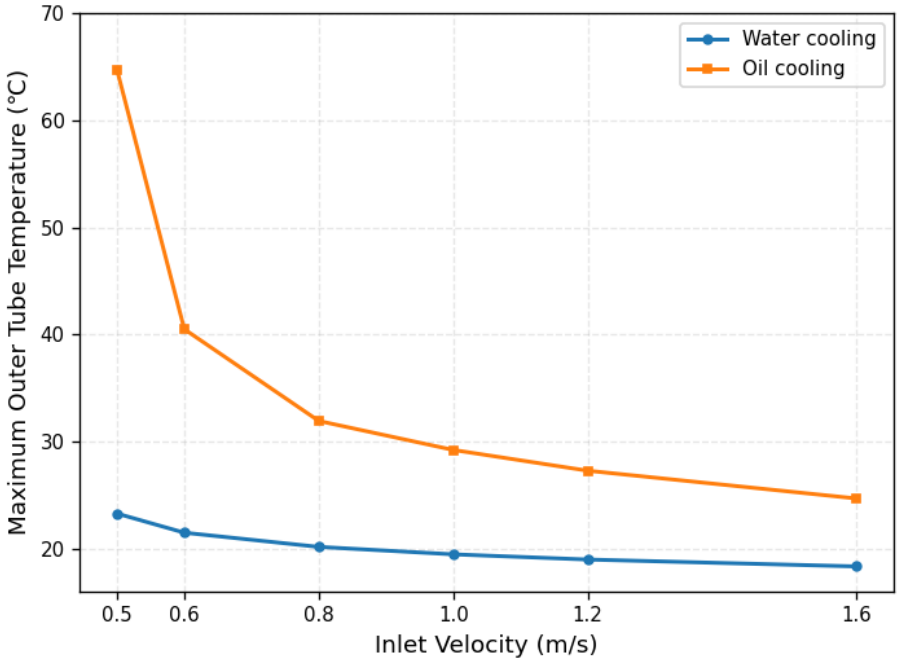
Water cooling outperforms oil cooling: lower pressure drop, better cooling

Design requirements: outer-wall peak temp. < 20 ℃; pressure drop < 100 kPa

Conclusion: Under identical conditions, water cooling gives lower pressure drop and better cooling than oil cooling.



Pressure drop comparison

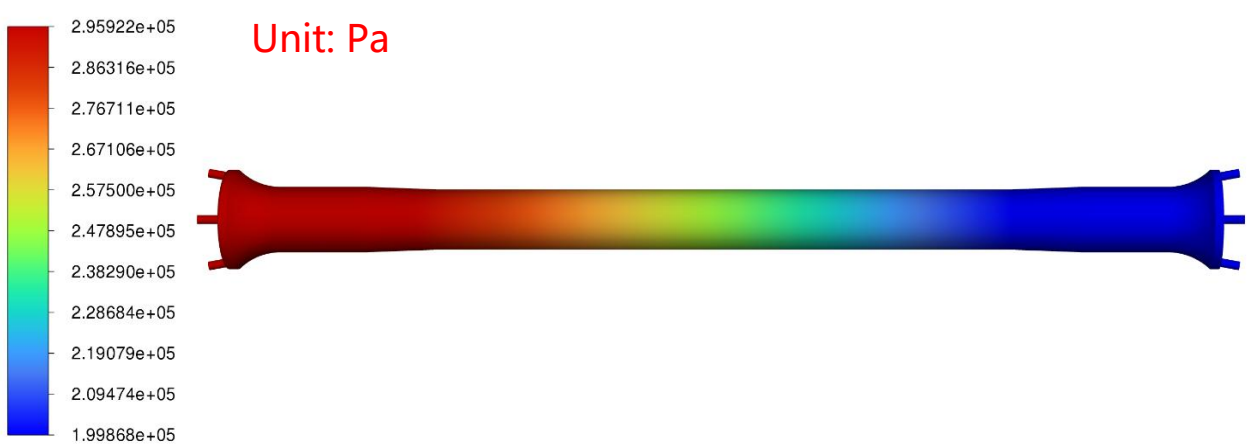


Outer-wall peak-temp. comparison

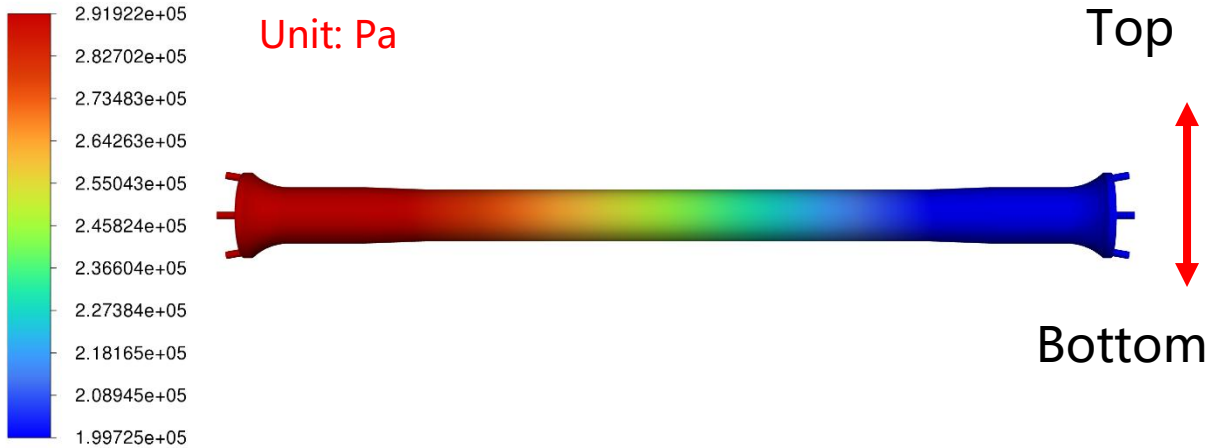
Simulation

Effect of 0.05 mm eccentricity on pressure distribution

- **Design requirements:** outer-wall peak temp. < 20 ℃; pressure drop < 100 kPa
- **Final parameters:** Al-alloy pipe, water cooling, inlet velocity 0.8 m/s, total power 225 W
- **Case:** simulating assembly misalignment - inner axis shifted 0.05 mm downward relative to outer pipe



Pressure contour: aligned pipe

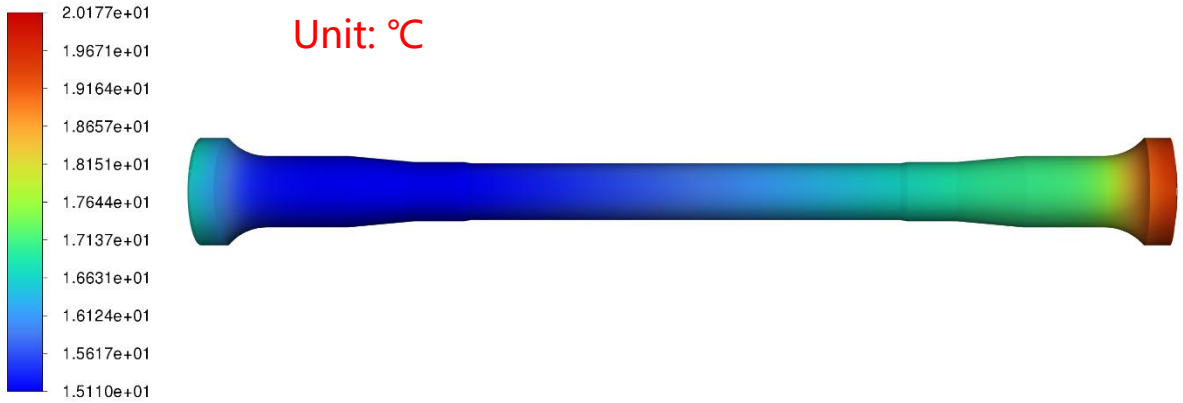


Pressure contour: eccentric pipe

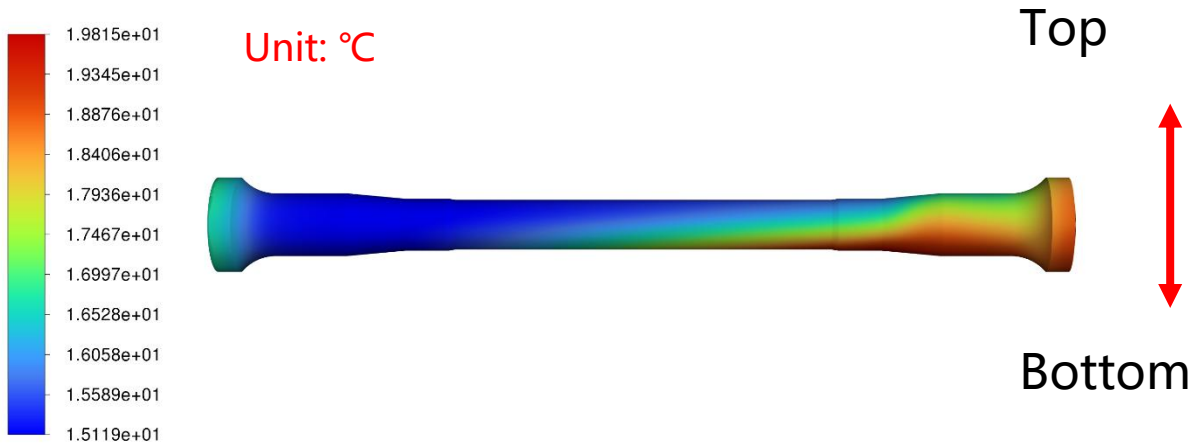
Simulation

Eccentricity raises offset-side wall temp. and enlarges the hot region

Conclusion: The 0.05 mm shift barely changes overall pressure drop and peak temp., but raises the offset-side wall temp. and enlarges the hot region.



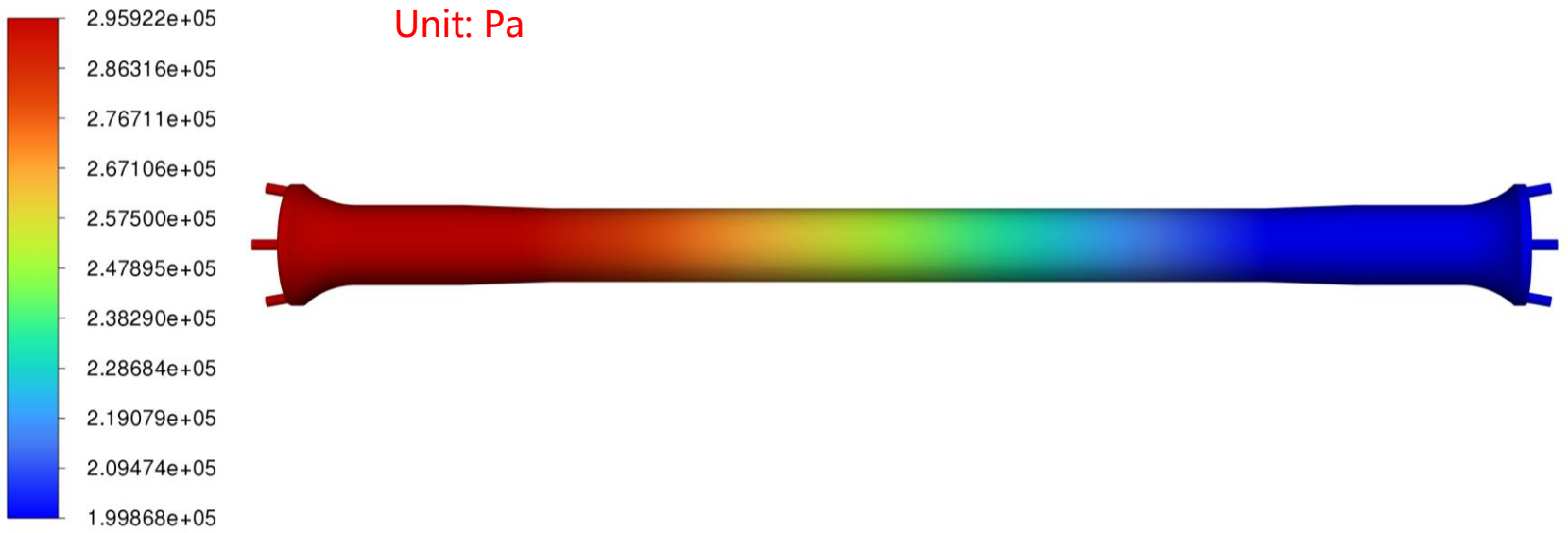
Outer-wall temp. contour: aligned
(excl. no-channel regions)



Outer-wall temp. contour: eccentric
(excl. no-channel regions)

Simulation

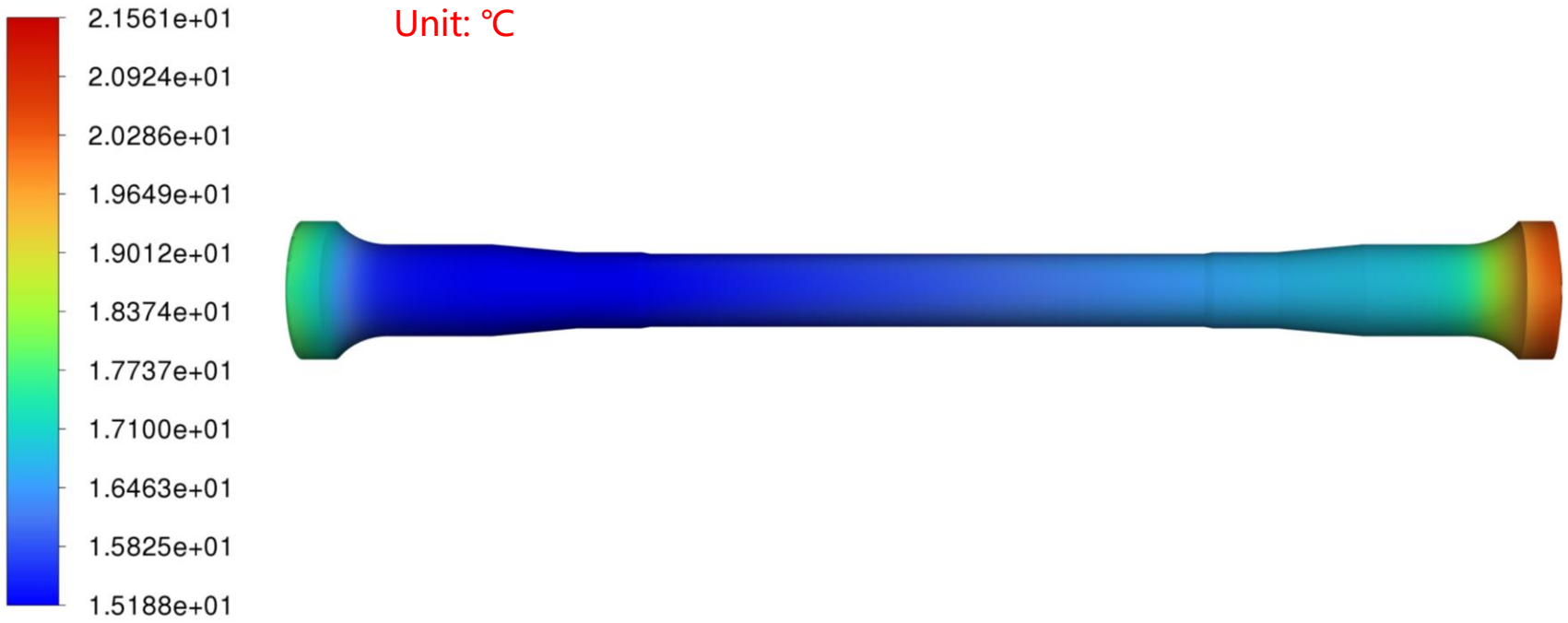
- At a uniform 260 W conservative load, 0.8 m/s water flow meets the design requirements
- **Design requirements:** outer-wall peak temp. < 20 ℃; pressure drop < 100 kPa
- **Final parameters:** Al-alloy pipe, water cooling, 0.8 m/s inlet, conservative load 260 W for a sufficient safety margin
- **Conservative result:** pressure drop 96 kPa; temp. 21.6 ℃ (conservative estimate)



Pressure contour of the beam pipe

Simulation

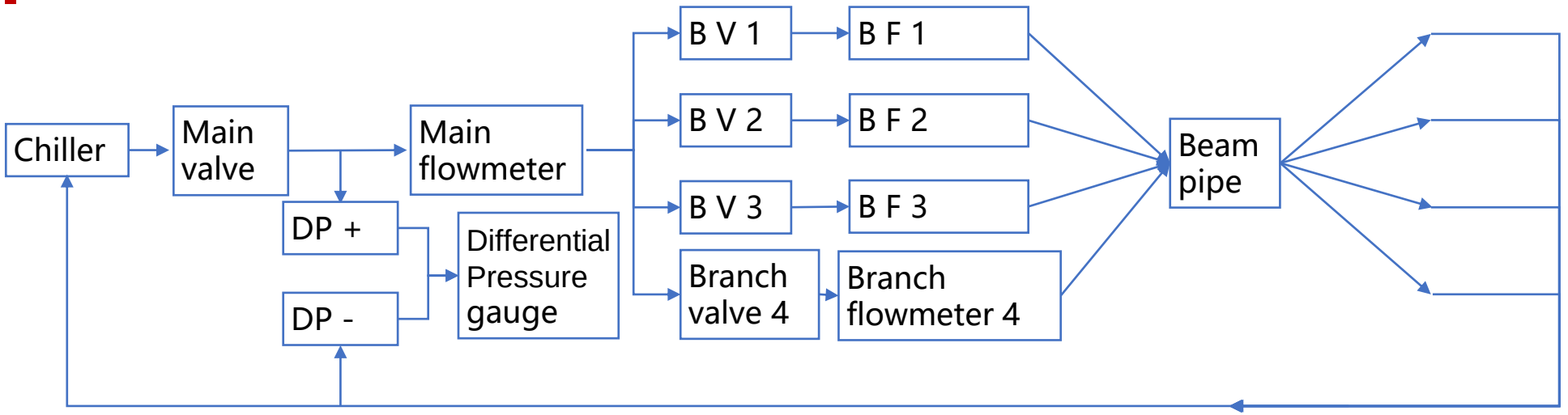
Outer-wall temperature contour under the final scheme



Outer-wall temp. contour
(excl. no-channel regions)

Experimental Setup & Selection

Experimental loop scheme & component selection



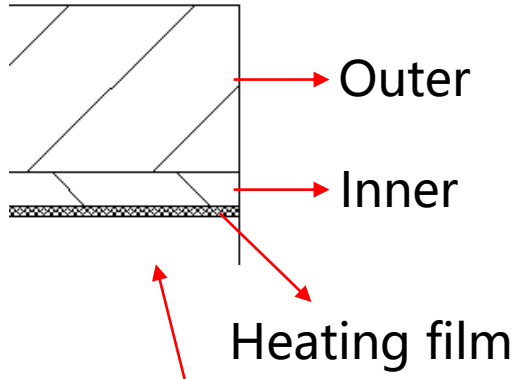
Device	Specification	Device	Specification
Chiller	10-40 ℃, stability +/-0.3 ℃, max head 25 m, max flow 10 L/min	Main flowmeter	Variable-area flowmeter, 0.6-6 L/min, OD12 barb fitting
Main valve	OD12 quick-connect stainless ball valve	Branch flowmeter	Variable-area flowmeter, 0.5-4 L/min, OD6 barb fitting
Branch valve	OD6 precision needle throttle valve with scale	DP gauge	Range 0-250 kPa, optional 4-20 mA
Water tubing	Main 8x12 mm, branch 4x6 mm, clear PVC hose (silicone optional)	1-to-4 manifold	Main OD12 4 branches OD6

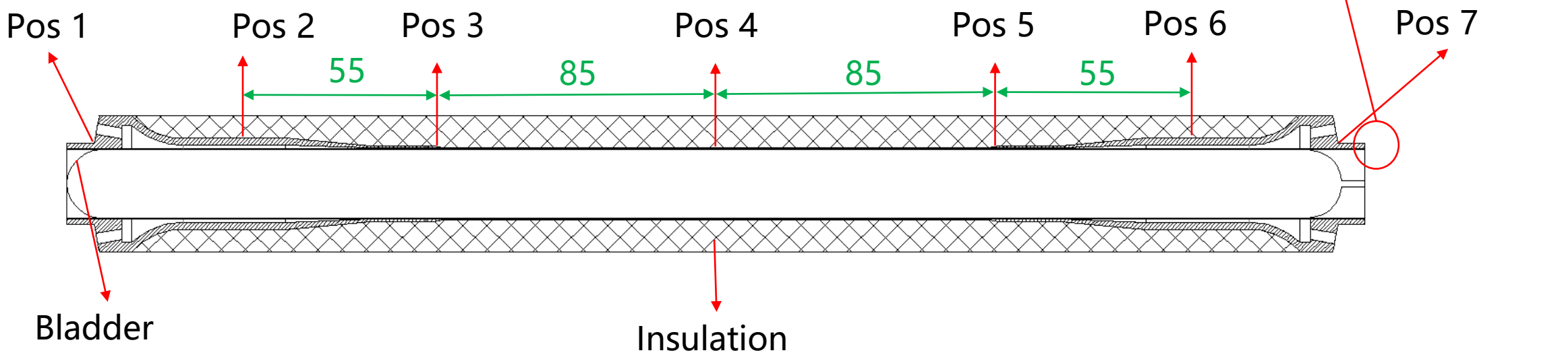
Heat-Source Simulation & Measurement

Layout of outer-wall temperature points & heating film

Setup:

The heating film is bonded to the inner wall with thermal silicone and pressed by an inflated rubber bladder; the outer wall is wrapped in insulation to suppress convection, simulating real conditions. 7 Class-A PT100 RTDs at Pos 1-7 measure the outer-wall temperature distribution.





Experimental Progress

Al-alloy tubes integrally formed; accuracy meets requirements



Outer pipe



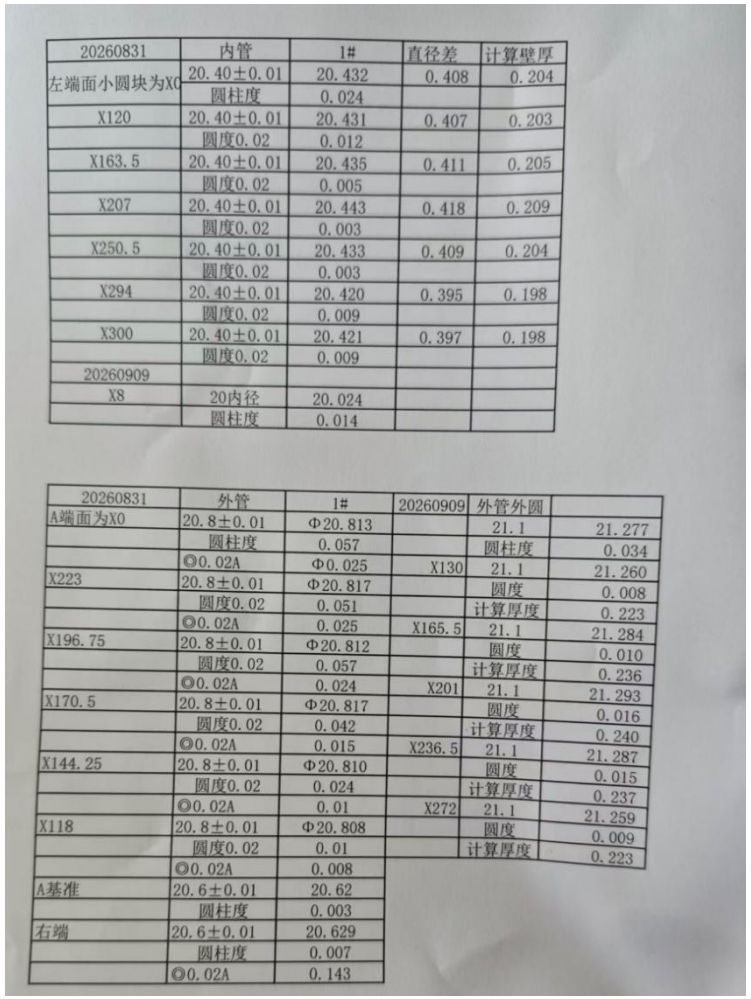
Mandrel

Inner pipe

Fabrication: Al-alloy; inner and outer pipes integrally formed, no welds at the reducer

Measurements: roundness, cylindricity, diameter and wall thickness are slightly large, but given thin-wall long-tube difficulty, accuracy basically meets requirements.

Note: both inner and outer sample tubes are 0.2 mm thick in the central section



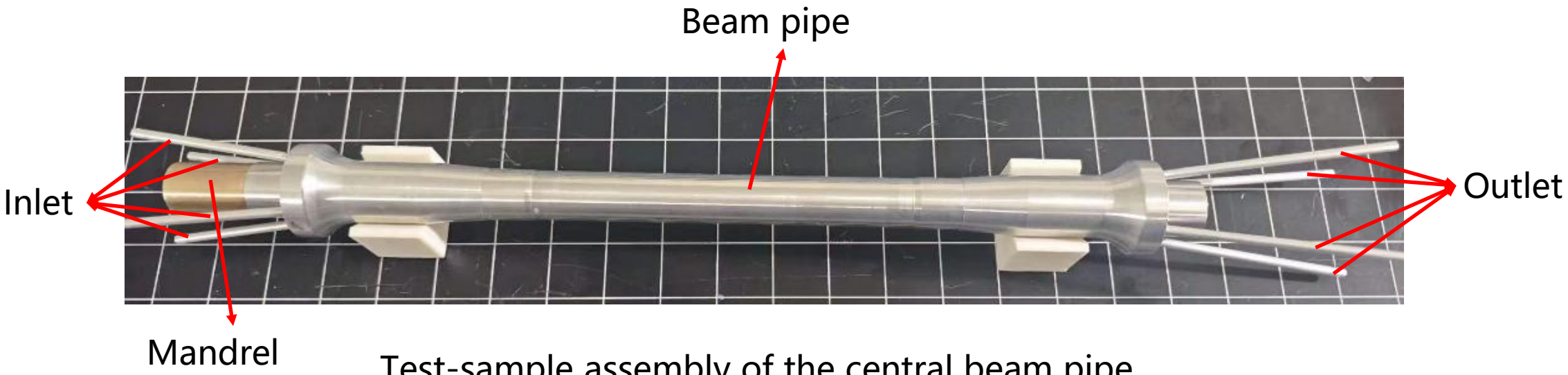
20260831	内管	1#	直径差	计算壁厚
左端面小圆块为X0	20.40±0.01	20.432	0.408	0.204
	圆柱度	0.024		
X120	20.40±0.01	20.431	0.407	0.203
	圆度0.02	0.012		
X163.5	20.40±0.01	20.435	0.411	0.205
	圆度0.02	0.005		
X207	20.40±0.01	20.443	0.418	0.209
	圆度0.02	0.003		
X250.5	20.40±0.01	20.433	0.409	0.204
	圆度0.02	0.003		
X294	20.40±0.01	20.420	0.395	0.198
	圆度0.02	0.009		
X300	20.40±0.01	20.421	0.397	0.198
	圆度0.02	0.009		
20260909				
X8	20内径	20.024		
	圆柱度	0.014		

20260831	外管	1#	20260909	外管外圆	
A端面为X0	20.8±0.01	Φ20.813		21.1	21.277
	圆柱度	0.057		圆柱度	0.034
	◎0.02A	Φ0.025	X130	21.1	21.260
X223	20.8±0.01	Φ20.817		圆度	0.008
	圆度0.02	0.051		计算厚度	0.223
	◎0.02A	0.025	X165.5	21.1	21.284
X196.75	20.8±0.01	Φ20.812		圆度	0.010
	圆度0.02	0.057		计算厚度	0.236
	◎0.02A	0.024	X201	21.1	21.293
X170.5	20.8±0.01	Φ20.817		圆度	0.016
	圆度0.02	0.042		计算厚度	0.240
	◎0.02A	0.015	X236.5	21.1	21.287
X144.25	20.8±0.01	Φ20.810		圆度	0.015
	圆度0.02	0.024		计算厚度	0.237
	◎0.02A	0.01	X272	21.1	21.259
X118	20.8±0.01	Φ20.808		圆度	0.009
	圆度0.02	0.01		计算厚度	0.223
	◎0.02A	0.008			
A基准	20.6±0.01	20.62			
	圆柱度	0.003			
右端	20.6±0.01	20.629			
	圆柱度	0.007			
	◎0.02A	0.143			

Measured results

Experimental Progress

Inner/outer pipes assembled; welding & rig setup underway



Test-sample assembly of the central beam pipe

- **Current status:** inner/outer pipes fabricated & assembled; welding underway
- **Next steps:** procure instrumentation; after welding, build the test rig and run cooling experiments

Thanks!