EIC Ansys Fluent Simulation Report

Friday, May 16, 2025

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Glossary

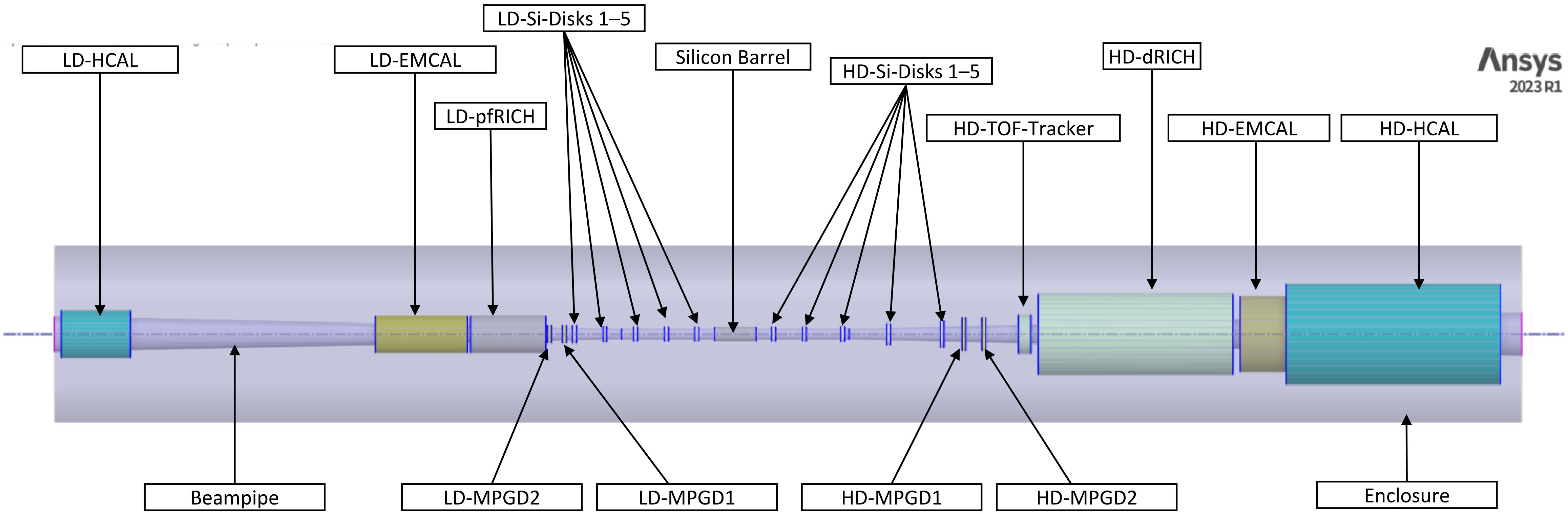
Acronyms used in the report are as follows:

CFD: Computational Fluid Dynamics
EIC : Electron Ion Collider
HD: Hadron Direction
LD: Lepton Direction
HCAL: Hadron Calorimeter
EMCAL: Electromagnetic Calorimeter
pfRICH: Proximity Focusing Ring Imagining Cherenkov
MPGD: Micro Pattern Gaseous Detector
TOF: Time Of Flight
dRICH: Dual-radiator Ring Imaging Cherenkov

Simulation Model

3D model consists of the beampipe, 22 detectors, and an enclosure

For simplicity, detectors in the model were represented by cylinders, allowing a CFD thermal simulation manageable by current DSG computing resources



System Information

Provides details of operating system specifications, computer hardware specifications, Fluent solver method, and turbulence option used in the simulation

Application	Fluent
Settings	3D, double precision, pressure-based, SST (Shear Stress Transport) k-omega
Version	25.1.0-10210
Source Revision	3b709034ad
Build Time	Nov 26, 2024, 13:29:29 EST
CPU	Intel(R) Xeon(R) W-2255
OS	Windows

Geometry and Mesh

Provide mesh metrics e.g. orthogonal quality for each model component—parameters that impact the simulation's accuracy and stability.

Mesh Size

The total number of cells, faces between cells, and nodes are generated based on the geometry complexity, desired mesh quality, and computer resources available.

The minimum mesh cell size was set to 2.5 mm, three layers between fluid and solid domains were set, and polyhedral mesh type was selected for the volume mesh.

Cells	Faces	Nodes
3585654	19456336	14074310

Mesh Quality

Minimum orthogonal quality ranges from 0 (unacceptable) to 1 (excellent). The volume mesh was improved by setting a limit for the minimum orthogonal quality to 0.280 (Good).

The aspect ratio is defined as a measure of the stretching of a cell based on the distance from the mesh cell centroid. Good quality mesh typically has an aspect ratio of ≤ 5 in the main flow region. While ideal aspect ratio is close to 1, higher values, even up to 100 or more, are acceptable.

Name	Type	Min orthogonal quality	Max aspect ratio
beampipe-air-vol-solid	Poly Cell	0.29404524	21.991253
enclosure-enclosure	Poly Cell	0.28000452	52.157037
ld-hcal	Poly Cell	0.39569447	21.983108
ld-emcal	Poly Cell	0.39628022	22.675015
ld-pfrich	Poly Cell	0.39160157	22.416554
ld-mpgd-2	Poly Cell	0.39728688	16.532249
ld-mpgd-1	Poly Cell	0.39788986	15.997825
ld-disk-5	Poly Cell	0.39874376	17.809741
ld-disk-4	Poly Cell	0.3986958	17.414631
ld-disk-3	Poly Cell	0.39936739	17.267653
ld-disk-2	Poly Cell	0.39941434	17.362587

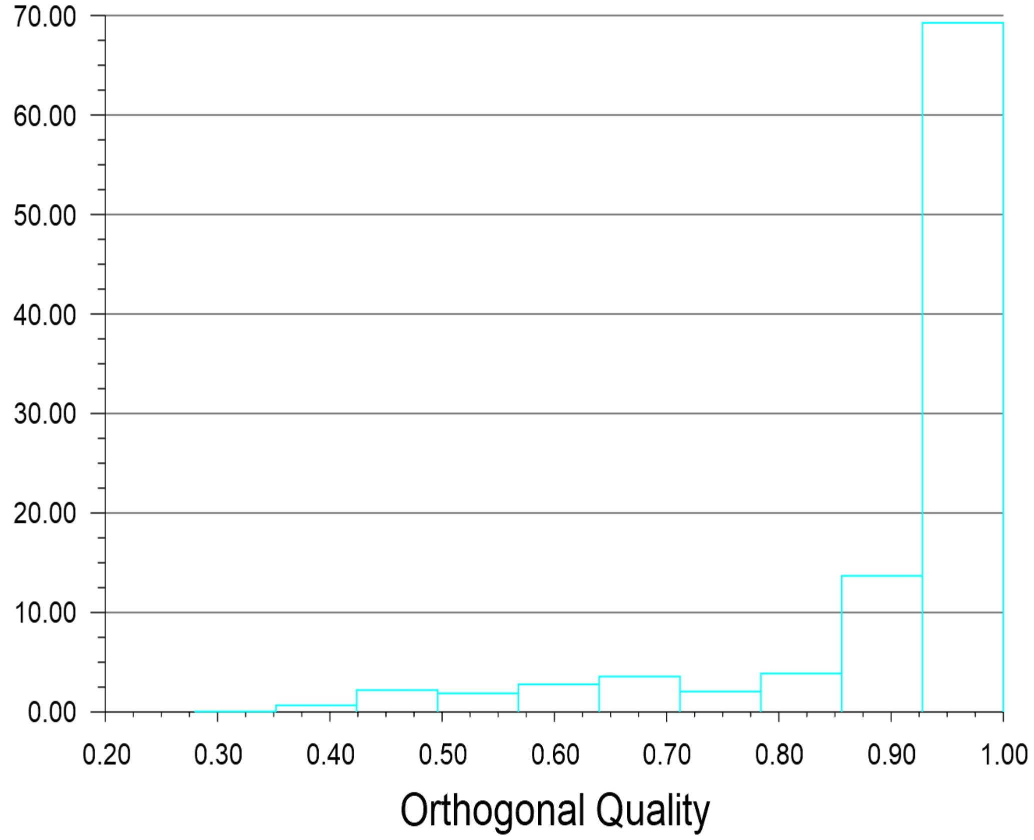
Mesh Quality, cont.

ld-disk-1	Poly Cell	0.39823703	15.807447
silicon-barrel	Poly Cell	0.28002688	53.932512
hd-disk-5	Poly Cell	0.39719451	17.044787
hd-disk-4	Poly Cell	0.39533213	17.626022
hd-disk-3	Poly Cell	0.39916414	17.960018
hd-disk-2	Poly Cell	0.39328678	17.067598
hd-disk-1	Poly Cell	0.39718753	16.875494
hd-mpgd-1	Poly Cell	0.39908895	17.412726
hd-mpgd-2	Poly Cell	0.39888267	17.542956
hd-tof-tracker	Poly Cell	0.28265144	28.984702
drich	Poly Cell	0.38914986	22.331797
hd-emcal	Poly Cell	0.39788475	21.993974
hd-hcal	Poly Cell	0.29857456	22.129507

Orthogonal Quality

A histogram provides a visual representation of the distribution of orthogonal quality values across the mesh. The *x*-axis represents the range of the orthogonal quality values, typically from 0 to 1 and the *y*-axis represents the count of cells within each quality value.

As shown in the figure below, the well-distributed histogram with a high concentration of bars at the higher end (closer to 1) indicates a good mesh quality for the EIC model.



Simulation Setup

Provides information for:

1. Physics data, which includes material properties used for each model component, cell zone conditions, and boundary conditions—velocity and temperature, and heat transfer conditions for inner and outer walls of each element of the model.
2. Solver settings includes the lists of the enabled equations, pseudo-time explicit relaxation factors, and the discretization scheme.

Models

The steady state model assumes that flow conditions and properties remain constant with respect to time, meaning the solution doesn't change over time.

The viscous model allows set parameters for turbulent flow. The Shear Stress Transport (SST) K-ω turbulence model selected is a low-Reynolds-number model, which can handle flows near the wall without needing additional wall functions. This model solves two transport equations, one for turbulent kinetic energy (k) and one for specific dissipation rate of energy (ω).

The surface-to-surface radiation model can account for the radiation exchange in an enclosure of gray-diffuse surfaces. The energy exchange between two surfaces depends in part on their size, separation distance, and orientation.

Model	Settings
Space	3D
Time	steady state
Viscous	SST k-ω turbulence model
Heat transfer	enabled
Radiation	surface-to-surface

Material Properties

Bossinesq approximation was set for the air density as it is recommended for natural convection problems involving small temperature changes. It simplifies the density calculations by assuming the density change is directly proportional to the temperature change.

Fluid				
	air			
Density	boussinesq			
Cp (specific heat)	1006.43 J/(kg K)			
Thermal conductivity	0.0242 W/(m K)			
Viscosity	1.7894e-05 kg/(m s)			
Thermal expansion coefficient	0.0034 K^-1			
Solid				
	silicon	**beryllium**	**carbon fiber**	**aluminum**
Density	2330 kg/m^3	1850 kg/m^3	1750 kg/m^3	2719 kg/m^3
Cp (specific heat)	700 J/(kg K)	1825 J/(kg K)	750 J/(kg K)	871 J/(kg K)
Thermal conductivity	148 W/(m K)	190 W/(m K)	15 W/(m K)	202.4 W/(m K)

Cell Zone Conditions

Defines the properties and behavior of individual fluid or solid volumes, indicates which element is set as solid or fluid, the material assigned for each element, if the element is in motion or static, and if the element is a heat of source for thermal simulation.

Fluid		
	beampipe-air-vol-solid	**enclosure-enclosure**
Material name	air	air
Specify source terms?	no	no
Specify fixed values?	no	no
Frame motion?	no	no
Laminar zone?	no	no
Porous zone?	no	no
3D fan zone?	no	no

Cell Zone Conditions, cont.

Solid					
Detector	Material name	Specify source terms?	Specify fixed values?	Frame motion?	Solid motion?
ld-hcal	aluminum	no	no	no	no
ld-emcal	aluminum	no	no	no	no
ld-pfrich	carbon fiber	no	no	no	no
ld-mpgd-2	carbon fiber	no	no	no	no
ld-mpgd-1	carbon fiber	no	no	no	no
ld-si-disks 1-5	carbon fiber	no	no	no	no
silicon barrel	silicon	no	no	no	no
hd-si-disk 1-5	carbon fiber	no	no	no	no
hd-mpgd-1	carbon fiber	no	no	no	no
hd-mpgd-2	carbon fiber	no	no	no	no
hd-tof-tracker	carbon fiber	no	no	no	no
hd-dRICH	carbon fiber	no	no	no	no
hd-emcal	aluminum	no	no	no	no
hd-hcal	aluminum	no	no	no	no

Boundary Conditions

Provides information about conditions for the beampipe inlet and outlet, such as set velocity, temperature, and pressure, and heat transfer conditions for all walls/surfaces of each model element

	Beampipe Inlet	Beampipe Outlet
Velocity specification method	magnitude, normal to boundary	
Reference frame	absolute	
Velocity magnitude [m/s]	5	
Supersonic/initial gauge pressure [Pa]	0	
Temperature [C]	110	
Turbulence specification method	intensity and viscosity ratio	
Turbulent intensity [%]	5	
Turbulent viscosity ratio	10	
External black body temperature method	boundary temperature	boundary temperature
Internal emissivity	1	1
Participates in view factor calculation?	yes	yes
Flow rate weighting		1

Boundary Conditions, cont.

Beampipe walls	**right-inner**	**left-side-inner**	**mid-sec-inner**	**air-sides**	**right-inner-shadow**	**left-inner-shadow**
Wall thickness [mm]	1	1	3	1	1	1
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	aluminum	aluminum	beryllium	beryllium	aluminum	aluminum
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary	stationary	stationary	stationary
Shear boundary condition	no slip	no slip	no slip	no slip	no slip	no slip
Wall surface roughness	standard	standard	standard	standard	standard	standard
Internal emissivity	0.15	0.15	0.18	0.18	0.15	0.15
Wall roughness height [mm]	0	0	0	0	0	0

Boundary Conditions, cont.

Beampipe walls, cont.	**right-inner**	**left-side-inner**	**mid-sec-inner**	**air-sides**	**right-inner-shadow**	**left-inner-shadow**
Wall roughness constant	0.5	0.5	0.5	0.5	0.5	0.5
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes	yes	yes	yes
Faces per surface cluster	1	1	1	1	1	1
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

Enclosure walls	outer	right	left
Wall thickness [mm]	0	0	0
Heat generation rate [W/m^3]	0	0	0
Material name	aluminum	aluminum	aluminum
Thermal BC type	convection	heat flux	heat flux
Heat flux [W/m^2]		0	0
Convective heat transfer coefficient [W/(m^2 K)]	10		
Free stream temperature [C]	20		
Enable shell conduction?	no	no	no
Wall motion	stationary	stationary	stationary
Shear boundary condition	no slip	no slip	no slip
Wall surface roughness	standard	standard	standard

Boundary Conditions, cont.

Enclosure walls, cont.	outer	right	left
Internal emissivity	0.15	1	1
Wall roughness height [mm]	0	0	0
Wall roughness constant	0.5	0.5	0.5
Radiation BC type	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes
Faces per surface cluster	1	1	1
Convective augmentation factor	1	1	1

Boundary Conditions, cont.

LD-HCAL walls	side	outer	inner	side-shadow	outer-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	aluminum	aluminum	aluminum	aluminum	aluminum	aluminum
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.15	0.15	0.15			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque1	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

LD-EMCAL walls	side	outer	inner	side-shadow	outer-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	aluminum	aluminum	aluminum	aluminum	aluminum	aluminum
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.15	0.15	0.15			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

LD-pfRICH walls	side	outer	inner	side-shadow	outer-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.85	0.85	0.85			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

LD-MPGD2 walls	side	outer	inner	side-shadow	outer-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.85	0.85	0.85			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

LD-MPGD1 walls	side	outer	inner	side-shadow	outer-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.85	0.85	0.85			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

LD-Si-Disks 1–5 walls	side	outer	inner	side-shadow	outer-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.85	0.85	0.85			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

Silicon barrel walls	side	outer	inner	side-shadow	outer-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	silicon	silicon	silicon	silicon	silicon	silicon
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.12	0.12	0.12			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

HD-Si-Disks 1–5 walls	**side**	**outer**	**inner**	**side-shadow**	**outer-shadow**	**inner-shadow**
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.85	0.85	0.85			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

HD-MPGD1 walls	side	outer	inner	side-shadow	outer-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.85	0.85	0.85			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

HD-MPGD2 walls	**side**	**outer**	**inner**	**side-shadow**	**outer-shadow**	**inner-shadow**
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.85	0.85	0.85			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

HD-tof-tracker walls	side	outer	inner	side-shadow	outer-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.85	0.85	0.85			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

HD-dRICH walls	side	outer	inner	side-shadow	outer-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber	carbon fiber
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.85	0.85	0.85			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

HD-EMCAL walls	side	outer	inner	side-shadow	outer-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0	0
Material name	aluminum	aluminum	aluminum	aluminum	aluminum	aluminum
Thermal BC type	coupled	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no	no
Wall motion	stationary	stationary	stationary			
Shear boundary condition	no slip	no slip	no slip			
Wall surface roughness	standard	standard	standard			
Internal emissivity	0.15	0.15	0.15			
Wall roughness height [mm]	0	0	0			
Wall roughness constant	0.5	0.5	0.5			
Radiation BC type	opaque	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes			
Faces per surface cluster	1	1	1			
Convective augmentation factor	1	1	1	1	1	1

Boundary Conditions, cont.

HD-HCAL walls	side	outer	inner	side-shadow	inner-shadow
Wall thickness [mm]	0	0	0	0	0
Heat generation rate [W/m^3]	0	0	0	0	0
Material name	aluminum	aluminum	aluminum	aluminum	aluminum
Thermal BC type	coupled	coupled	coupled	coupled	coupled
Enable shell conduction?	no	no	no	no	no
Wall motion	stationary	stationary	stationary		
Shear boundary condition	no slip	no slip	no slip		
Wall surface roughness	standard	standard	standard		
Internal emissivity	0.15	0.15	0.15		
Wall roughness height [mm]	0	0	0		
Wall roughness constant	0.5	0.5	0.5		
Radiation BC type	opaque	opaque	opaque	opaque	opaque
Participates in view factor calculation?	yes	yes	yes		
Faces per surface cluster	1	1	1		
Convective augmentation factor	1	1	1	1	1

Reference Values

Provides information on the set reference quantities used for computing normalized flow field variables.

Area	1 m^2
Density	1.225 kg/m^3
Enthalpy	0 J/kg
Length	1 mm
Pressure	0 Pa
Temperature	288.16 C
Velocity	1 m/s
Viscosity	1.7894e-05 kg/(m s)
Ratio of specific heats	1.4
Near wall distance for heat transfer coefficient	300
Reference zone	enclosure-enclosure

Solver Settings

Indicates the equations, pseudo time explicit relaxation factors, discretization scheme, and solution limits used for the simulation. Pseudo-time explicit relaxation factors are used to control the under-relaxation of the solution, especially in steady state analysis. Factors are implemented through the pseudo-transient method, which treats a steady state solver as a transient solver with an unstable time-step. This method helps improve solution stability and convergence, particularly when dealing with complex flow conditions or poor mesh quality.

Discretization schemes provide information on the numerical methods used to convert the continuous partial differential equations of fluid dynamics into a system of algebraic equations that can be solved numerically. Schemes determine how the derivatives in the used equations are approximated at discrete points in the mesh.

Equations	
Flow	true
Turbulence	true
Energy	true
Numerics	
Absolute velocity formulation	true

Solver Settings, cont.

Pseudo time explicit relaxation factors	
Density	1
Body forces	1
Turbulent kinetic energy	0.75
Specific dissipation rate	0.75
Turbulent viscosity	1
Energy	0.75
Explicit momentum	0.5
Explicit pressure	0.5
Pressure-velocity coupling	
Type	coupled
Pseudo time method (global time step)	true

Solver Settings, cont.

Discretization Scheme	
Pressure	second order
Momentum	second order upwind
Turbulent kinetic energy	second order upwind
Specific dissipation rate	second order upwind
Energy	second order upwind
Solution Limits	
Minimum absolute pressure [Pa]	1
Maximum absolute pressure [Pa]	5e+10
Minimum static temperature [C]	-272.15
Maximum static temperature [C]	4726.85
Minimum turb. kinetic energy [m^2/s^2]	1e-14
Minimum spec. dissipation rate [s^-1]	1e-20
Maximum turb. viscosity ratio	100000

Run Information

Shows number of computers and cores used in the simulation, the time to read the case and to complete iterations, and the allocated random access memory.

Number of machines	1
Number of cores	6
Case read	102.297 seconds
Iteration	94068.8 seconds
Algebraic MultiGrid	53464.2 seconds
Virtual current memory	23.265 GB
Virtual peak memory	24.4361 GB
Memory per M cell	6.30427

Solution Status

Run Iterations: 7500

Verifies convergence by monitoring parameters such as residuals for the enabled equations.

	Value	Absolute criteria	Convergence status
Continuity	0.0008969181	0.0001	Not Converged
***x*-velocity**	9.351765e-08	0.0001	Converged
***y*-velocity**	1.210729e-07	0.0001	Converged
***z*-velocity**	1.320896e-07	0.0001	Converged
Energy	3.589268e-08	1e-06	Converged
k	2.523355e-06	1e-06	Not Converged
omega	1.004515e-05	0.001	Converged

Report Definitions

Quantify and monitor the maximum and minimum temperatures of each detector

max-temp-enclosure	104.1543	C
min-temp-enclosure	19.7213	C
max-temp-beampipe	110	C
min-temp-beampipe	94.28207	C
max-temp-ld-hcal	43.609	C
min-temp-ld-hcal	40.98714	C
max-temp-ld-hcal-inner-wall	43.6097	C
min-temp-ld-hcal-inner-wall	40.98757	C
max-temp-ld-hcal-outer-wall	43.60262	C
min-temp-ld-hcal-outer-wall	40.98684	C
max-temp-ld-emcal	44.39848	C
min-temp-ld-emcal	42.65622	C
max-temp-ld-emcal-inner-wall	44.40035	C
min-temp-ld-emcal-inner-wall	42.65972	C

Report Definitions, cont.

max-temp-ld-emcal-outer-wall	44.37844	C
min-temp-ld-emcal-outer-wall	42.65566	C
max-temp-ld-pfrich	43.18332	C
min-temp-ld-pfrich	30.37332	C
max-temp-ld-pfrich-inner-wall	43.20483	C
min-temp-ld-pfrich-inner-wall	30.39797	C
max-temp-ld-pfrich-outer-wall	42.85488	C
min-temp-ld-pfrich-outer-wall	30.37203	C
max-temp-ld-mpgd-2	39.60273	C
min-temp-ld-mpgd-2	34.08186	C
max-temp-ld-mpgd-2-inner-wall	39.63705	C
min-temp-ld-mpgd-2-inner-wall	34.09896	C
max-temp-ld-mpgd-2-outer-wall	39.47512	C
min-temp-ld-mpgd-2-outer-wall	34.08001	C

Report Definitions, cont.

max-temp-ld-mpgd-1	38.43433	C
min-temp-ld-mpgd-1	32.58362	C
max-temp-ld-mpgd-1-inner-wall	38.4461	C
min-temp-ld-mpgd-1-inner-wall	32.59982	C
max-temp-ld-mpgd-1-outer-wall	38.3041	C
min-temp-ld-mpgd-1-outer-wall	32.58184	C
max-temp-ld-si-disk-5	39.07116	C
min-temp-ld-si-disk-5	31.66182	C
max-temp-ld-si-disk-5-inner-wall	39.10369	C
min-temp-ld-si-disk-5-inner-wall	31.67608	C
max-temp-ld-si-disk-5-outer-wall	38.91839	C
min-temp-ld-si-disk-5-outer-wall	31.6607	C

Report Definitions, cont.

max-temp-ld-si-disk-4	38.32659	C
min-temp-ld-si-disk-4	32.90764	C
max-temp-ld-si-disk-4-inner-wall	38.35925	C
min-temp-ld-si-disk-4-inner-wall	32.92471	C
max-temp-ld-si-disk-4-outer-wall	38.1737	C
min-temp-ld-si-disk-4-outer-wall	32.90566	C
max-temp-ld-si-disk-3	42.75625	C
min-temp-ld-si-disk-3	38.49385	C
max-temp-ld-si-disk-3-inner-wall	42.76635	C
min-temp-ld-si-disk-3-inner-wall	38.52807	C
max-temp-ld-si-disk-3-outer-wall	42.68218	C
min-temp-ld-si-disk-3-outer-wall	38.48889	C

Report Definitions, cont.

max-temp-ld-si-disk-2	42.53048	C
min-temp-ld-si-disk-2	38.34368	C
max-temp-ld-si-disk-2-inner-wall	42.54052	C
min-temp-ld-si-disk-2-inner-wall	38.38284	C
max-temp-ld-si-disk-2-outer-wall	42.45294	C
min-temp-ld-si-disk-2-outer-wall	38.34039	C
max-temp-ld-si-disk-1	42.24539	C
min-temp-ld-si-disk-1	38.1062	C
max-temp-ld-si-disk-1-inner-wall	42.25518	C
min-temp-ld-si-disk-1-inner-wall	38.14227	C
max-temp-ld-si-disk-1-outer-wall	42.17132	C
min-temp-ld-si-disk-1-outer-wall	38.10101	C

Report Definitions, cont.

max-temp-silicon-barrel	58.93353	C
min-temp-silicon-barrel	58.09703	C
max-temp-silicon-barrel-inner-wall	58.93401	C
min-temp-silicon-barrel-inner-wall	58.09625	C
max-temp-silicon-barrel-outer-wall	58.92886	C
min-temp-silicon-barrel-outer-wall	58.09646	C
max-temp-hd-si-disk-1	41.85189	C
min-temp-hd-si-disk-1	38.1062	C
max-temp-hd-si-disk-1-inner-wall	41.86193	C
min-temp-hd-si-disk-1-inner-wall	37.914	C
max-temp-hd-si-disk-1-outer-wall	41.77343	C
min-temp-hd-si-disk-1-outer-wall	37.87319	C

Report Definitions, cont.

max-temp-hd-si-disk-2	41.91953	C
min-temp-hd-si-disk-2	38.34368	C
max-temp-hd-si-disk-2-inner-wall	41.92962	C
min-temp-hd-si-disk-2-inner-wall	37.83834	C
max-temp-hd-si-disk-2-outer-wall	41.84338	C
min-temp-hd-si-disk-2-outer-wall	37.79696	C
max-temp-hd-si-disk-3	38.95764	C
min-temp-hd-si-disk-3	38.49385	C
max-temp-hd-si-disk-3-inner-wall	38.97012	C
min-temp-hd-si-disk-3-inner-wall	34.52242	C
max-temp-hd-si-disk-3-outer-wall	38.8623	C
min-temp-hd-si-disk-3-outer-wall	34.49313	C

Report Definitions, cont.

max-temp-hd-si-disk-4	37.99893	C
min-temp-hd-si-disk-4	32.90764	C
max-temp-hd-si-disk-4-inner-wall	38.02932	C
min-temp-hd-si-disk-4-inner-wall	28.48043	C
max-temp-hd-si-disk-4-outer-wall	37.78671	C
min-temp-hd-si-disk-4-outer-wall	28.4671	C
max-temp-hd-si-disk-5	39.7625	C
min-temp-hd-si-disk-5	31.66182	C
max-temp-hd-si-disk-5-inner-wall	39.78811	C
min-temp-hd-si-disk-5-inner-wall	27.92736	C
max-temp-hd-si-disk-5-outer-wall	39.6025	C
min-temp-hd-si-disk-5-outer-wall	27.91879	C

Report Definitions, cont.

max-temp-hd-mpgd-1	39.04362	C
min-temp-hd-mpgd-1	27.19875	C
max-temp-hd-mpgd-1-inner-wall	39.06481	C
min-temp-hd-mpgd-1-inner-wall	27.20791	C
max-temp-hd-mpgd-1-outer-wall	38.88571	C
min-temp-hd-mpgd-1-outer-wall	27.19824	C
max-temp-hd-mpgd-2	38.94238	C
min-temp-hd-mpgd-2	27.90031	C
max-temp-hd-mpgd-2-inner-wall	38.96279	C
min-temp-hd-mpgd-2-inner-wall	27.90951	C
max-temp-hd-mpgd-2-outer-wall	38.79904	C
min-temp-hd-mpgd-2-outer-wall	27.89984	C

Report Definitions, cont.

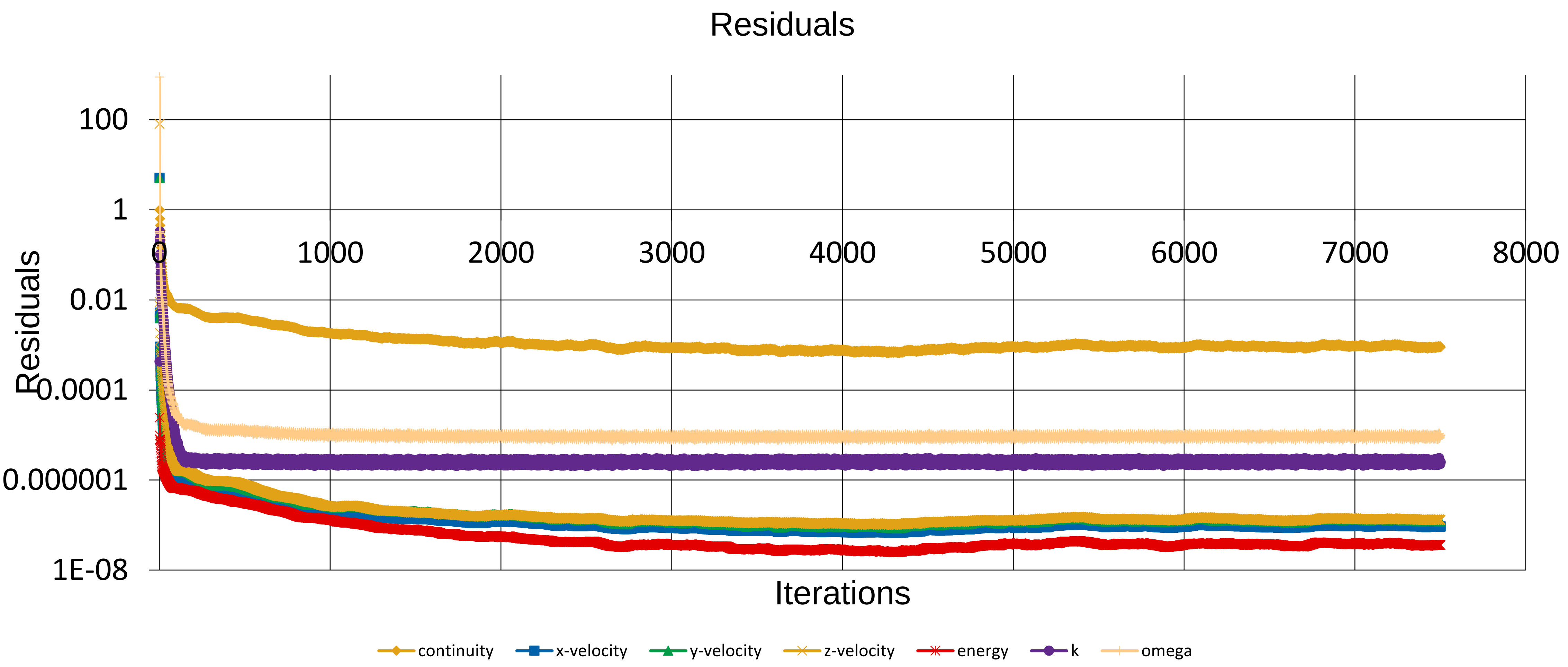
max-temp-hd-tof-tracker	37.33163	C
min-temp-hd-tof-tracker	29.09464	C
max-temp-hd-tof-tracker-inner-wall	37.34683	C
min-temp-hd-tof-tracker-inner-wall	29.10302	C
max-temp-hd-tof-tracker-outer-wall	37.20767	C
min-temp-hd-tof-tracker-outer-wall	29.09417	C
max-temp-hd-drich	40.99634	C
min-temp-hd-drich	26.97333	C
max-temp-hd-drich-inner-wall	41.00073	C
min-temp-hd-drich-inner-wall	26.98803	C
max-temp-hd-drich-outer-wall	40.92822	C
min-temp-hd-drich-outer-wall	26.97286	C

Report Definitions, cont.

max-temp-hd-emcal	39.11662	C
min-temp-hd-emcal	35.20679	C
max-temp-hd-emcal-inner-wall	39.11746	C
min-temp-hd-emcal-inner-wall	35.20757	C
max-temp-hd-emcal-outer-wall	39.10601	C
min-temp-hd-emcal-outer-wall	35.20666	C
max-temp-hd-hcal	38.04856	C
min-temp-hd-hcal	32.3354	C
max-temp-hd-hcal-inner-wall	38.04888	C
min-temp-hd-hcal-inner-wall	32.33532	C
max-temp-hd-hcal-outer-wall	38.04547	C
min-temp-hd-hcal-outer-wall	32.33544	C

Residuals

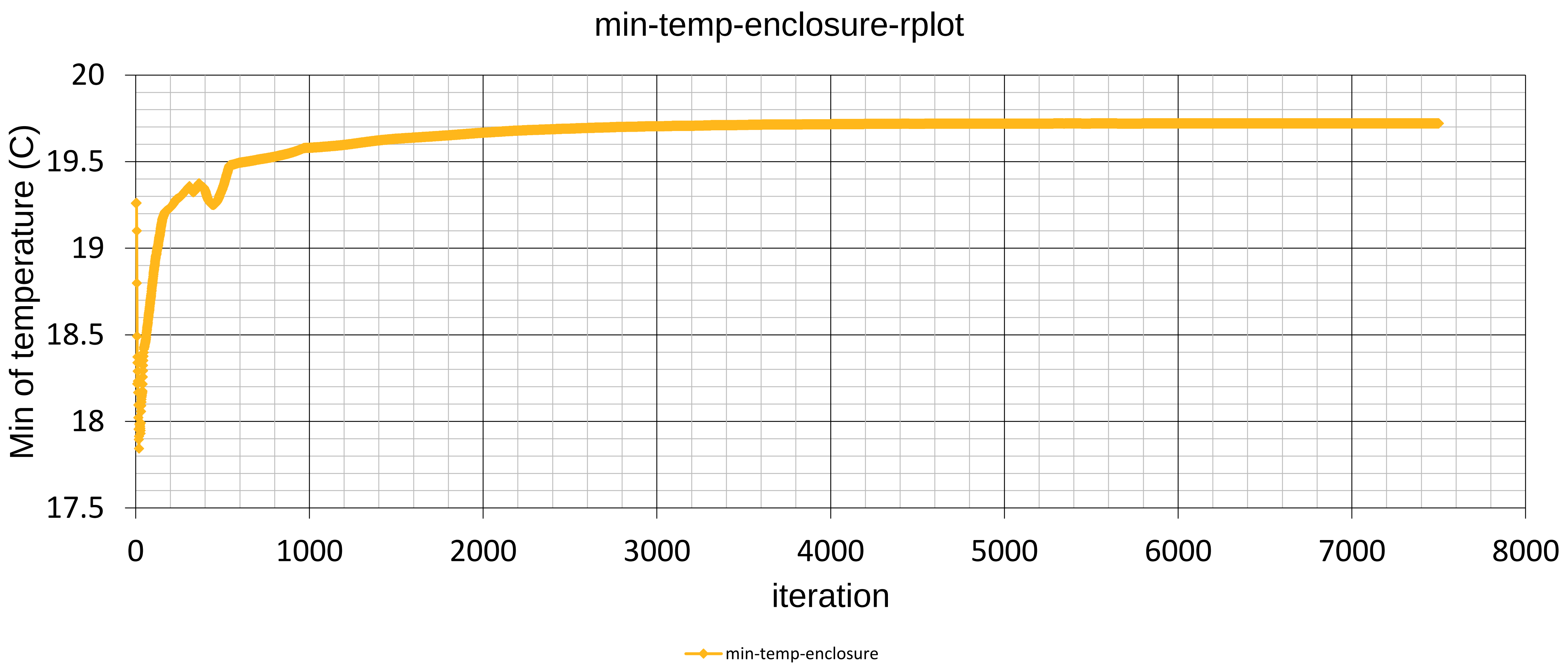
The solver's convergence was determined by monitoring the residual, which when less than 1×10^{-3} for governing equations—continuity, momentum, energy, and turbulence and radiation—terminated the simulation.



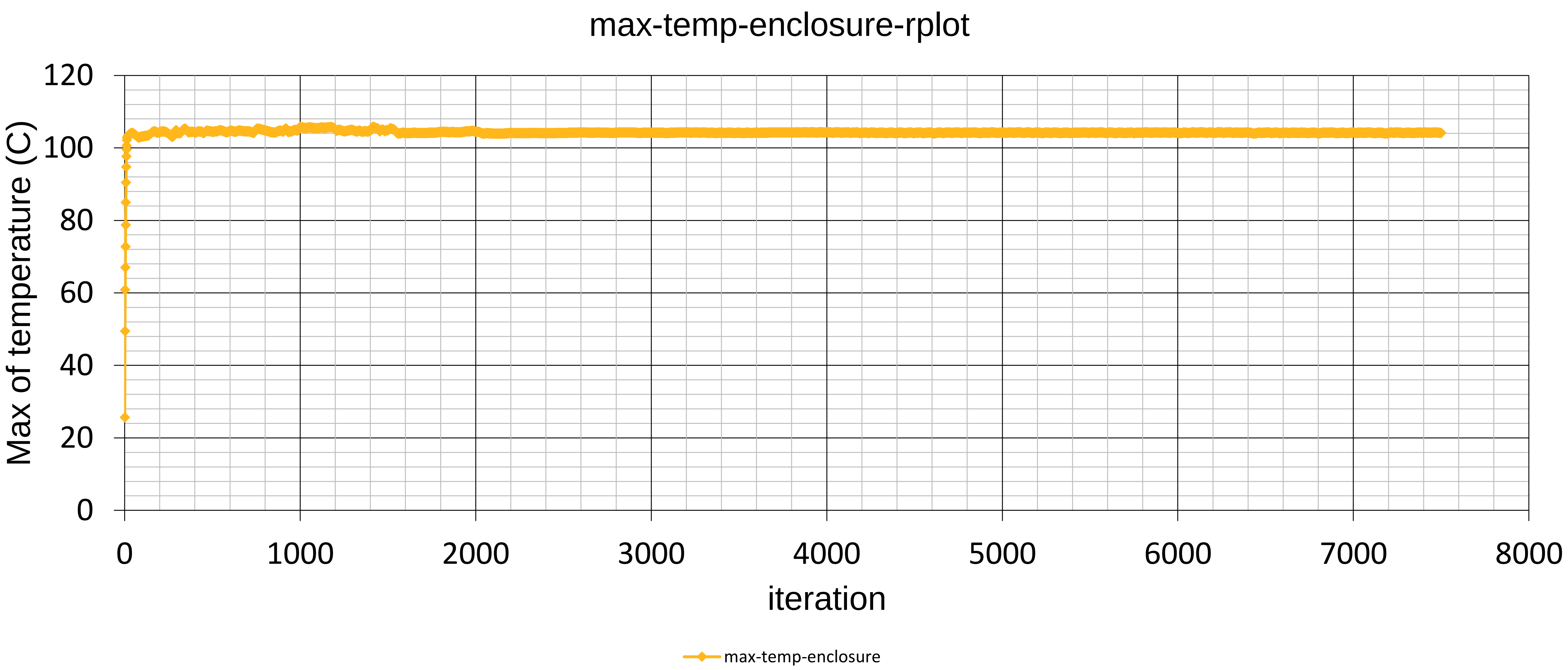
Report Plots

The plot option for the report definitions were enabled for each detector volume to allow an additional point of reference for the monitoring of the convergence in real-time as the solution of the governing equations were iterated.

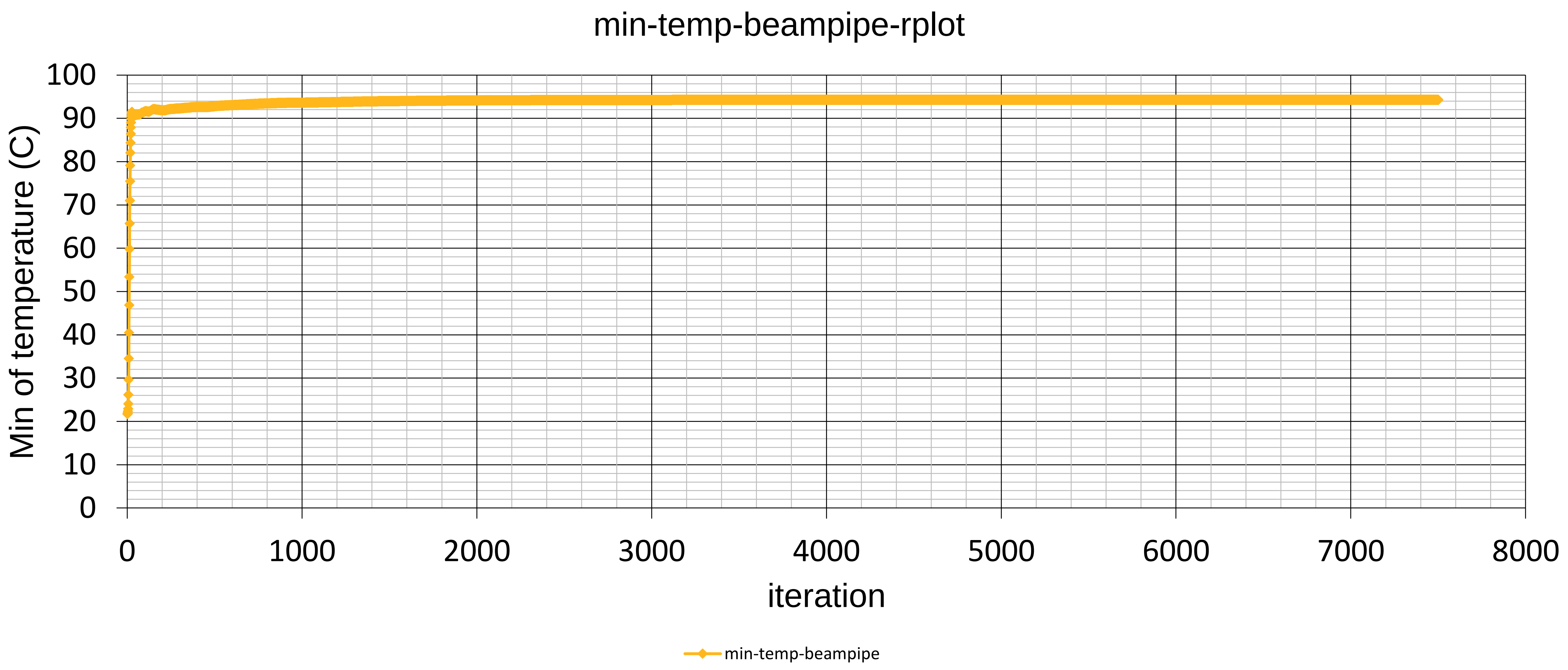
min-temp-enclosure-rplot



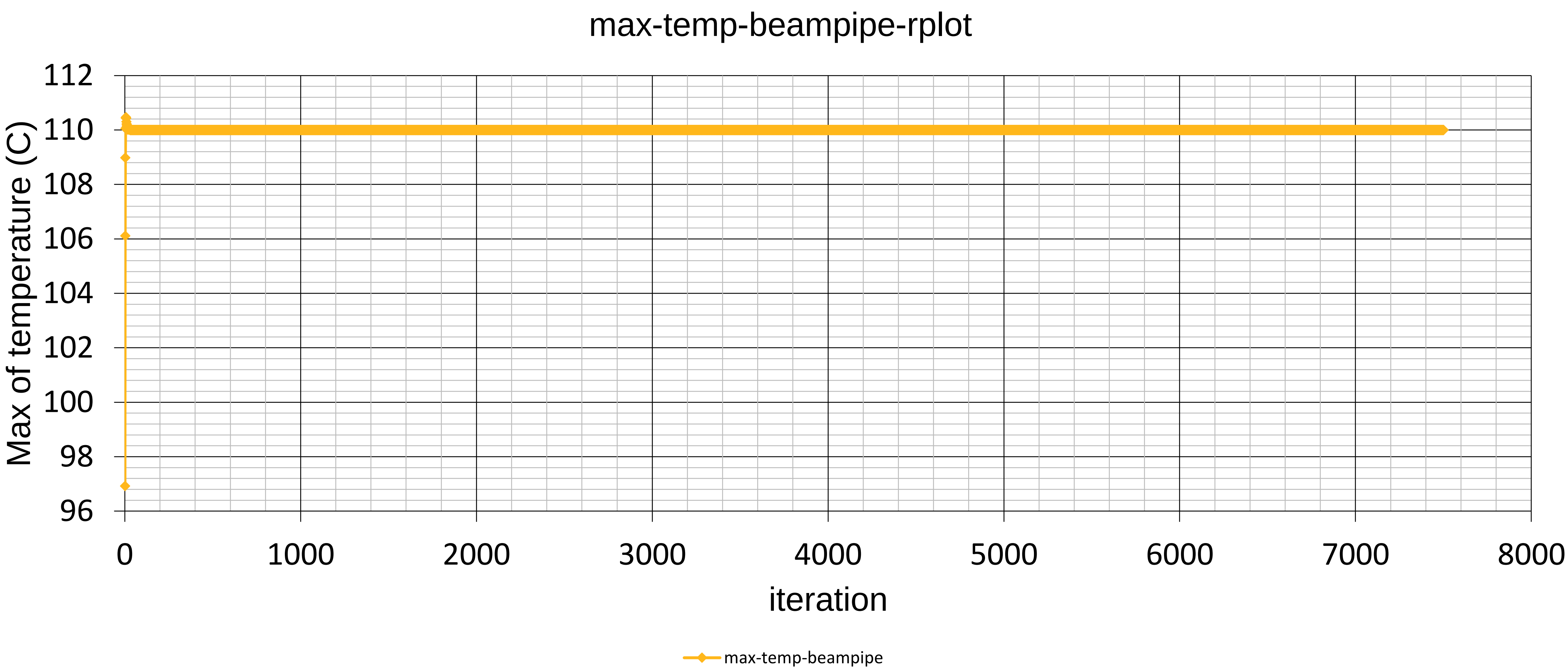
max-temp-enclosure-rplot



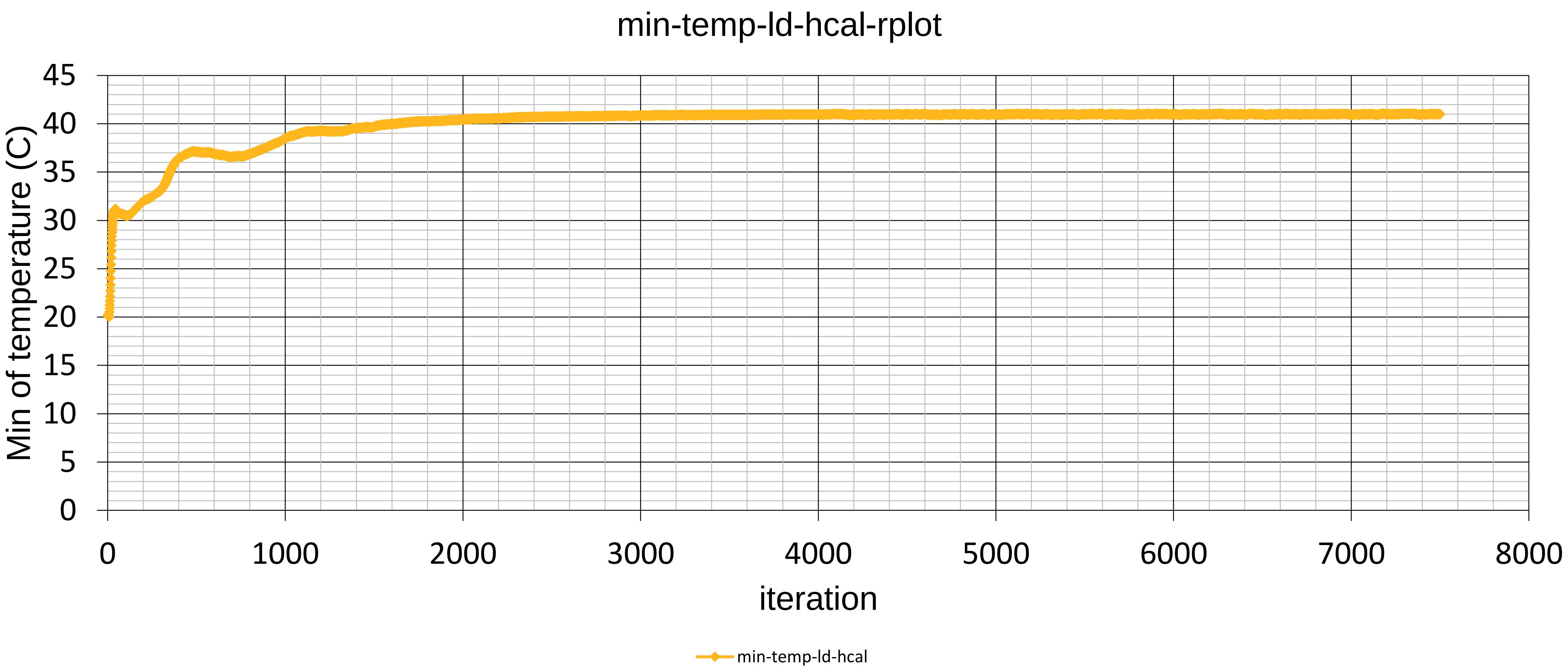
min-temp-beampipe-rplot



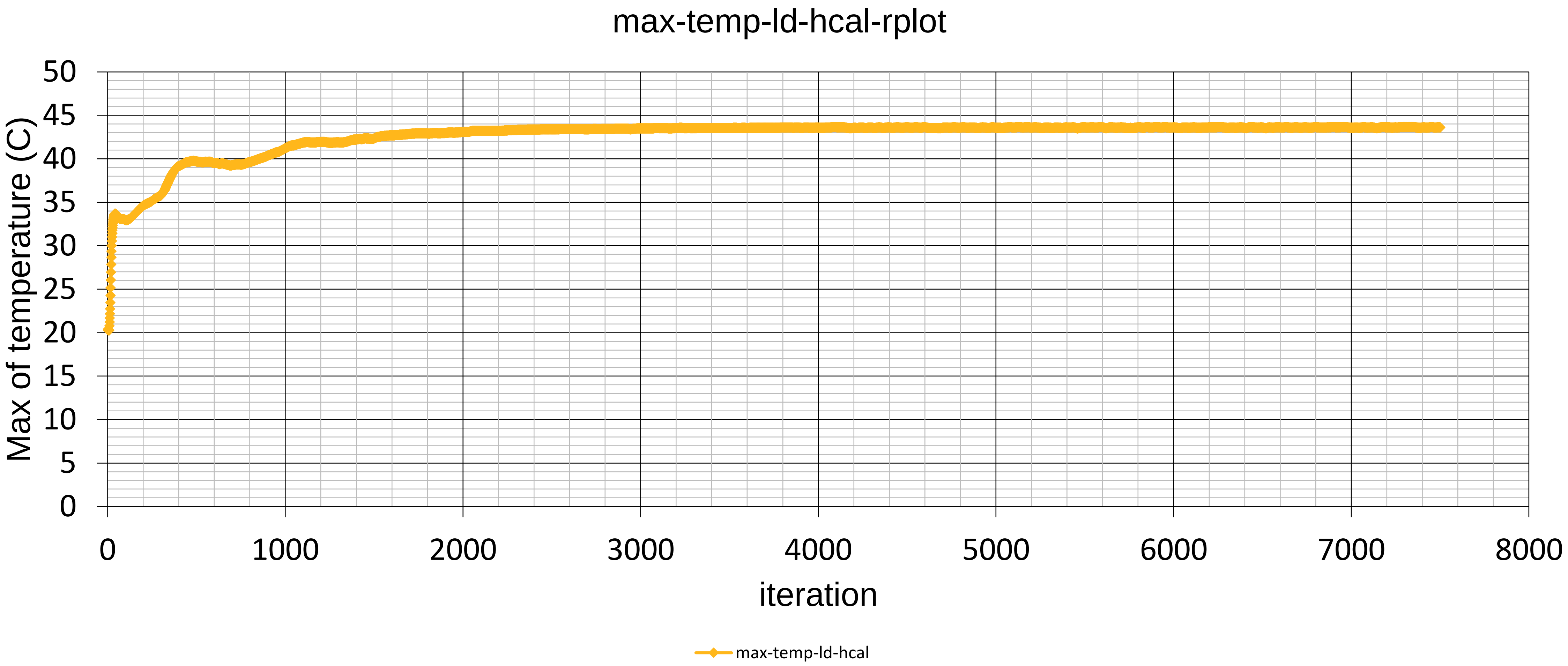
max-temp-beampipe-rplot



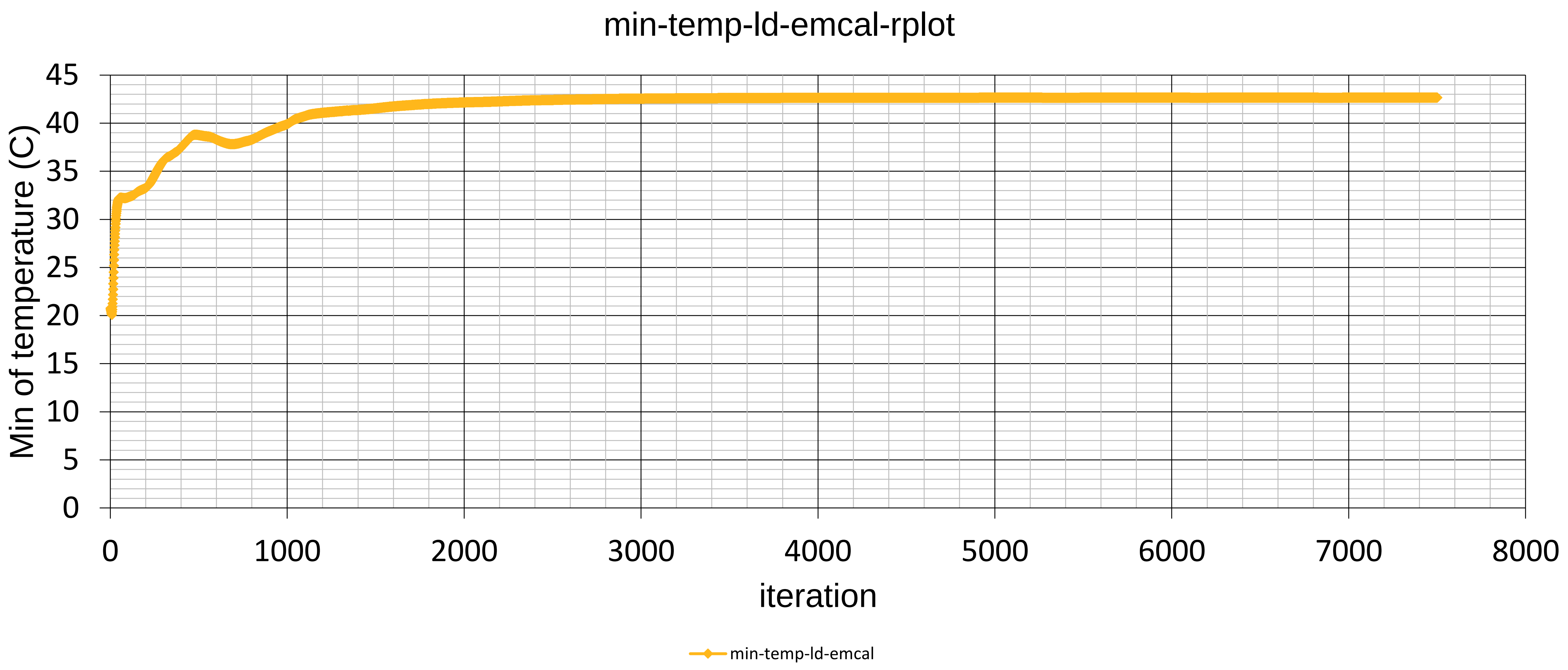
min-temp-ld-hcal-rplot



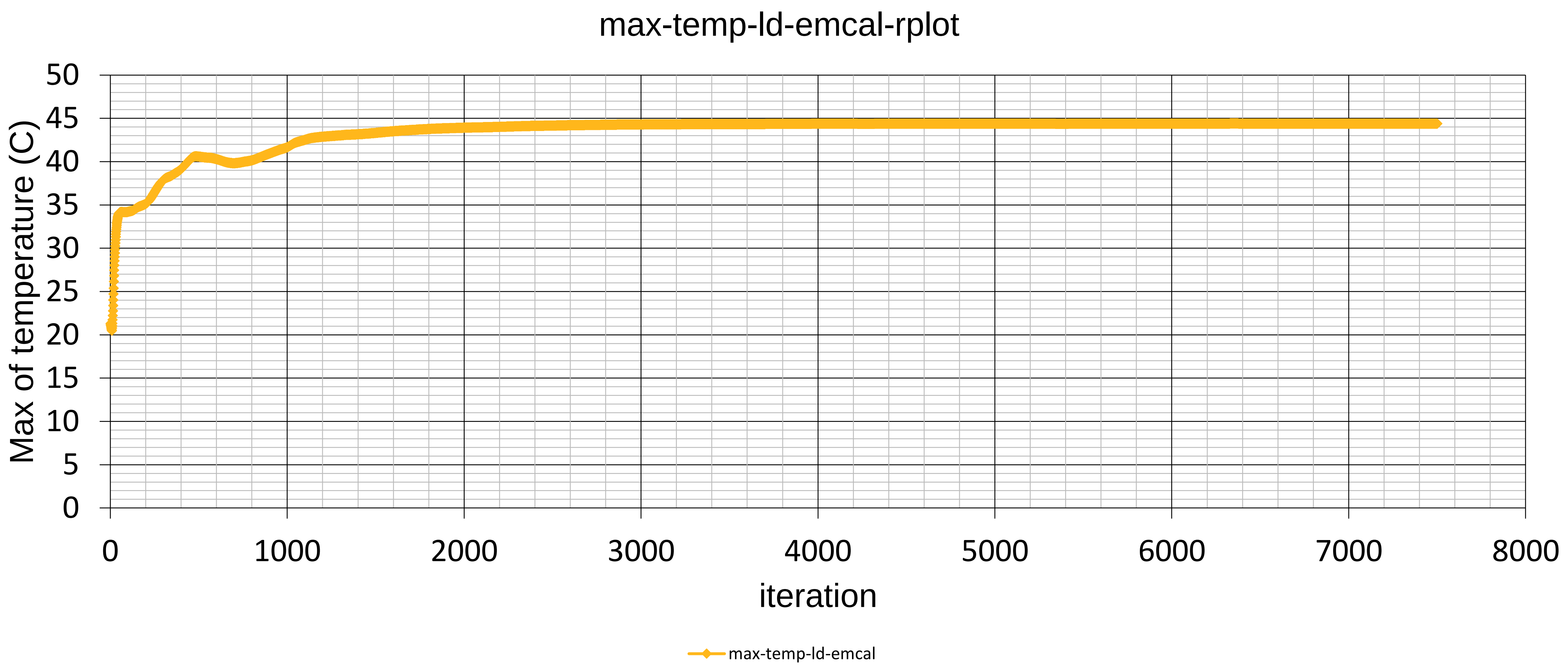
max-temp-ld-hcal-rplot



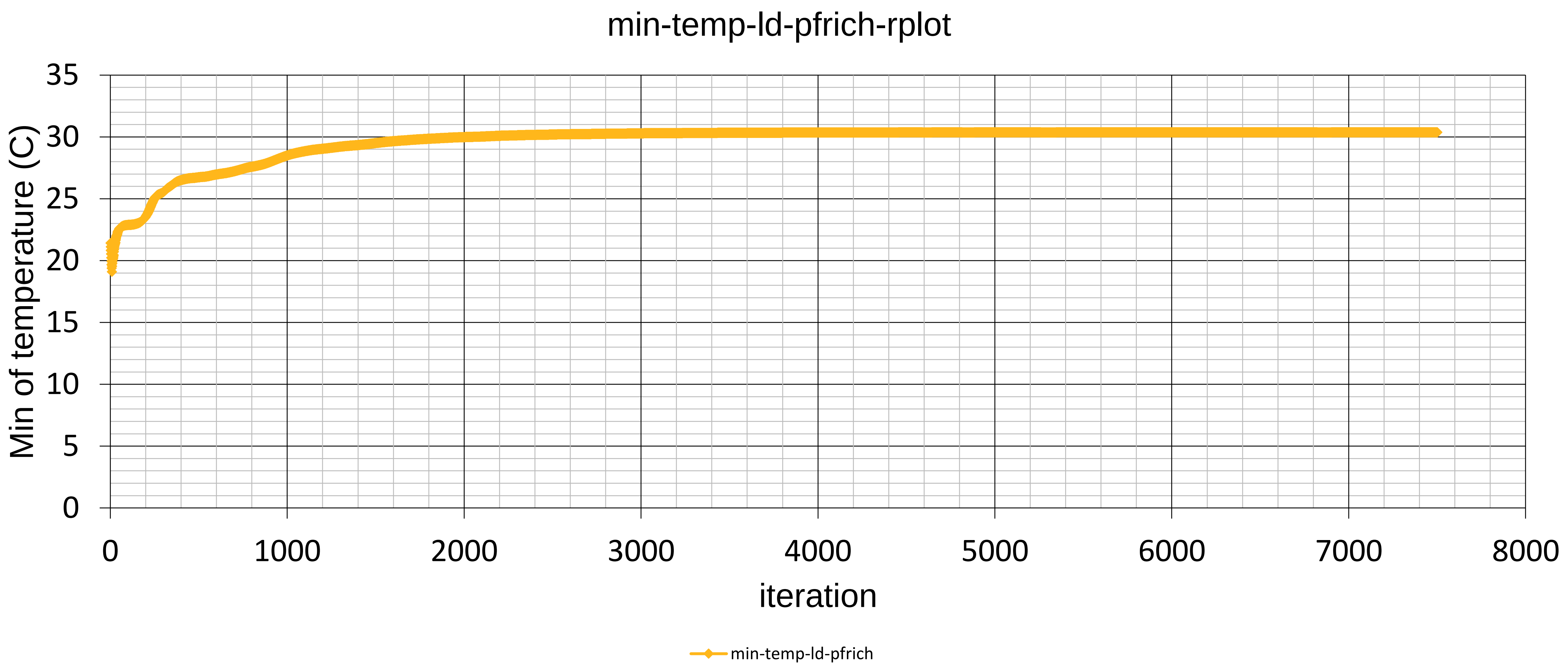
min-temp-ld-emcal-rplot



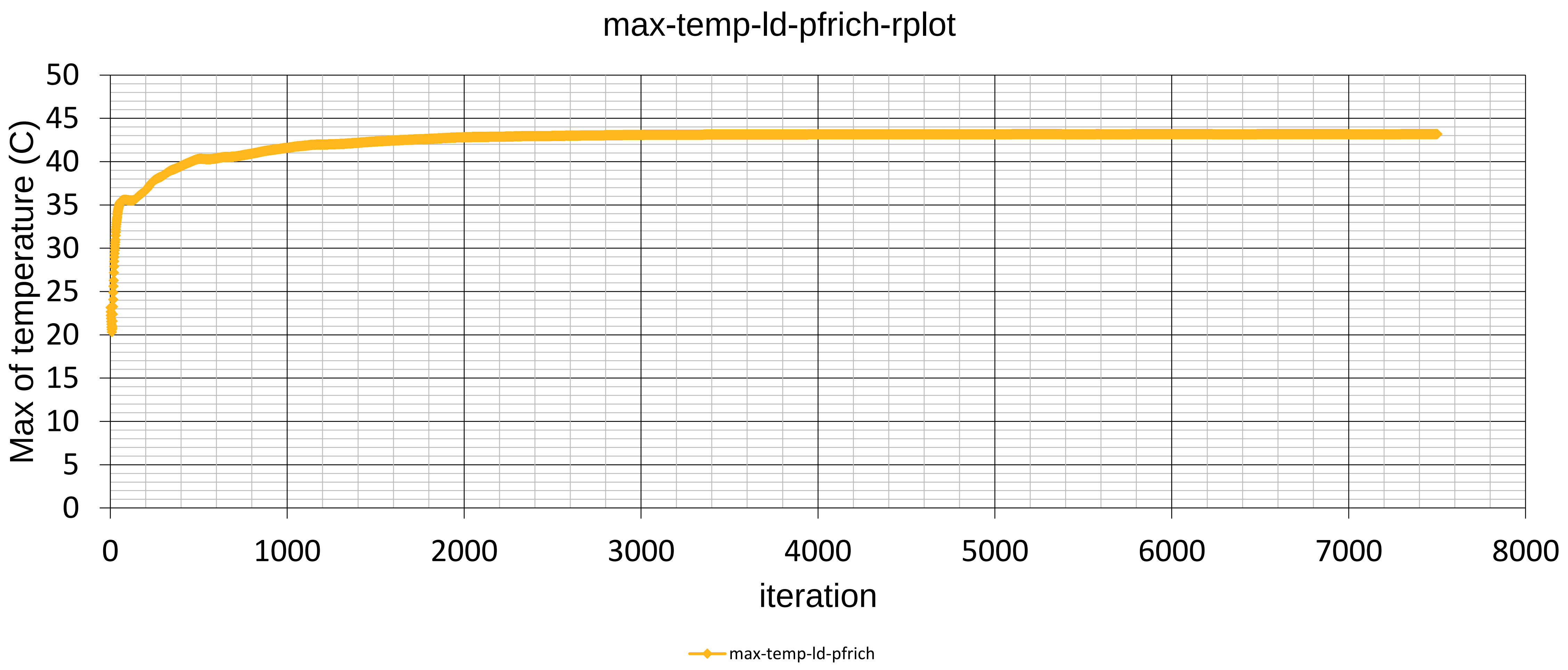
max-temp-ld-emcal-rplot



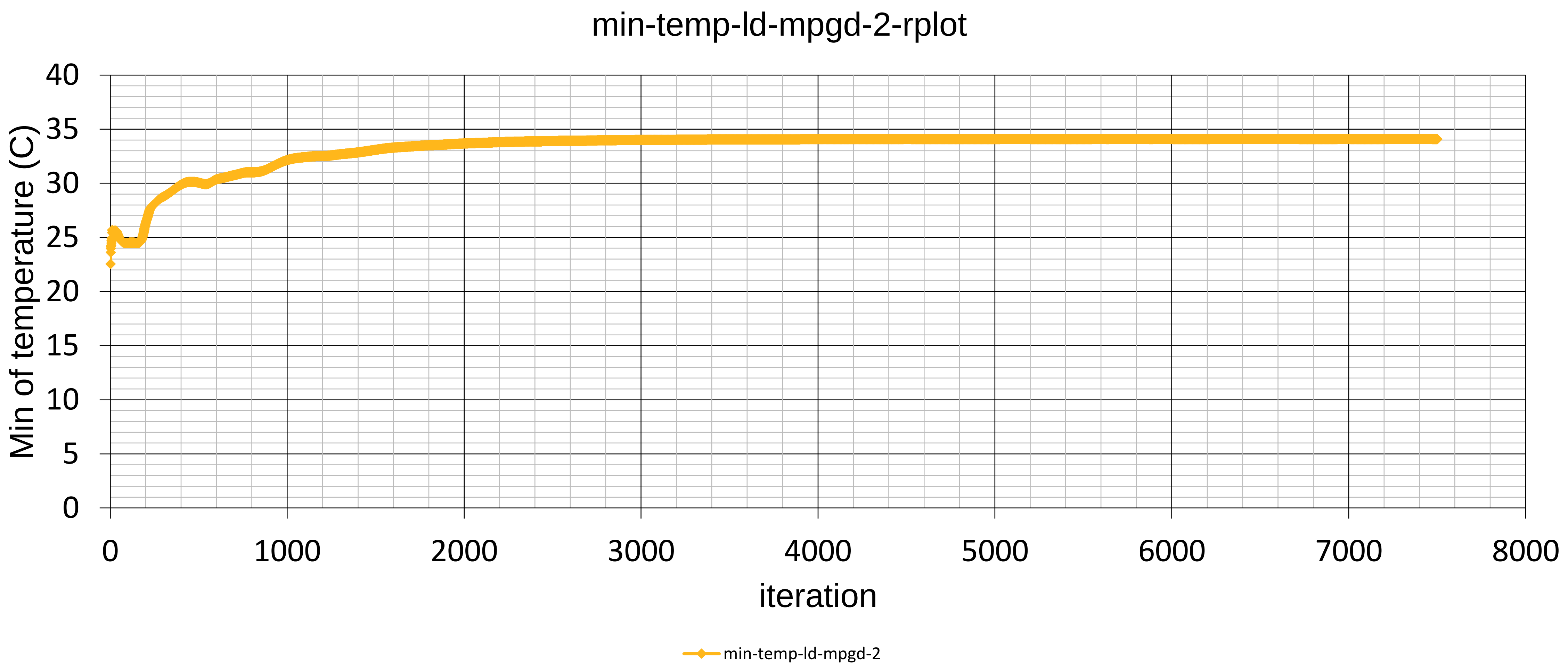
min-temp-ld-pfrich-rplot



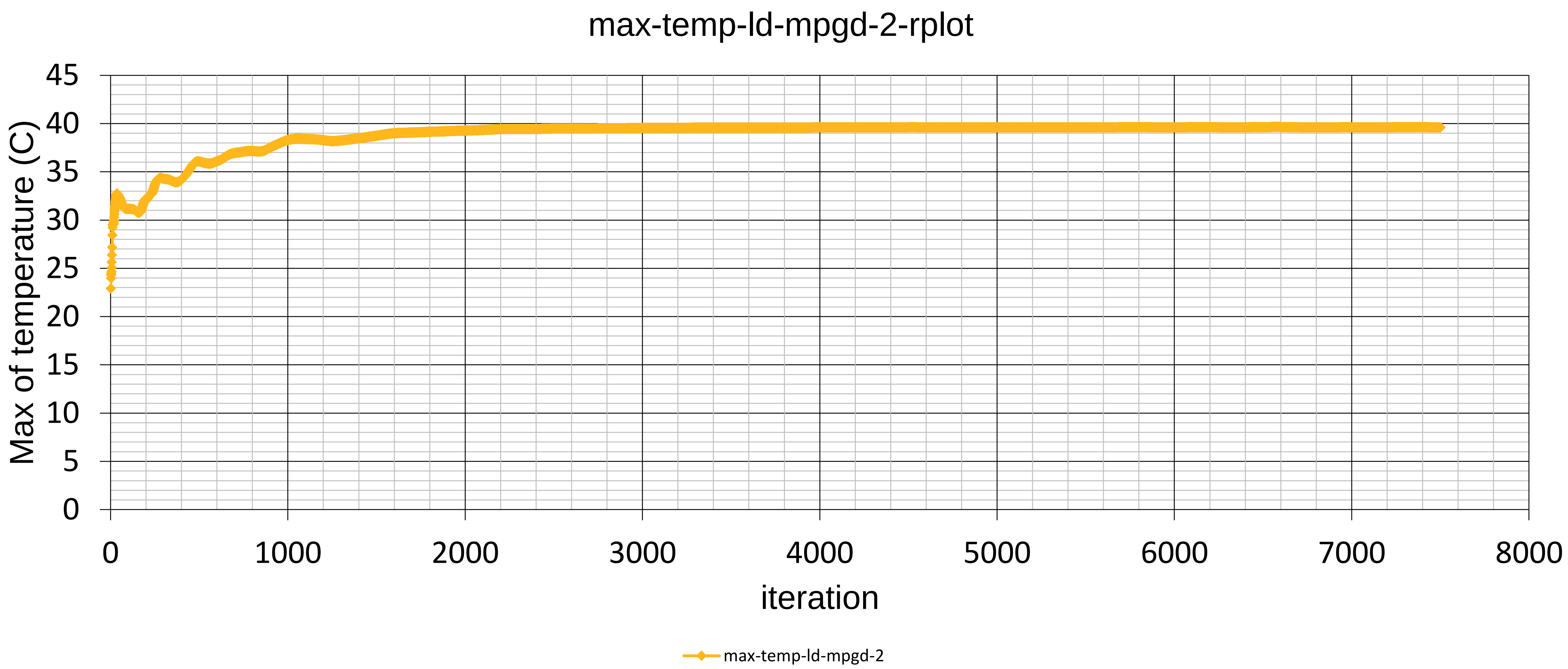
max-temp-ld-pfrich-rplot



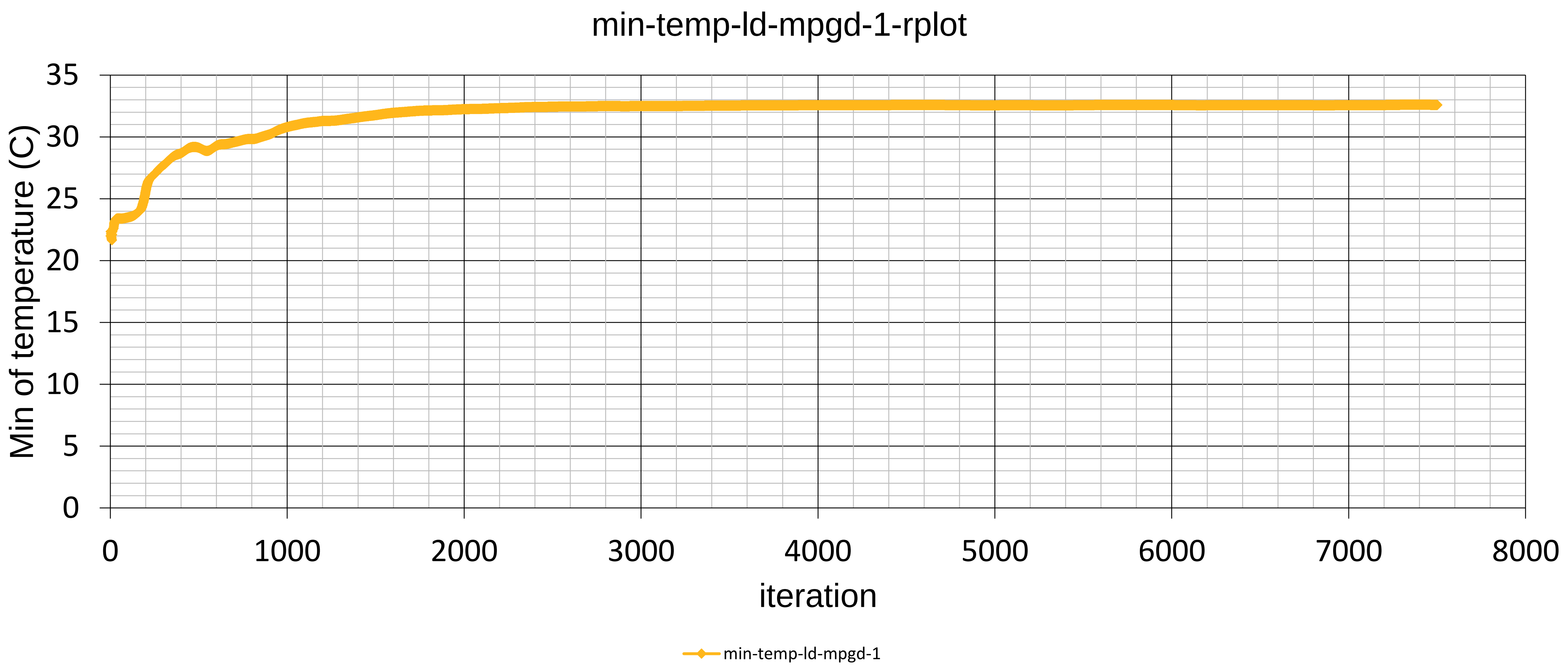
min-temp-ld-mpgd-2-rplot



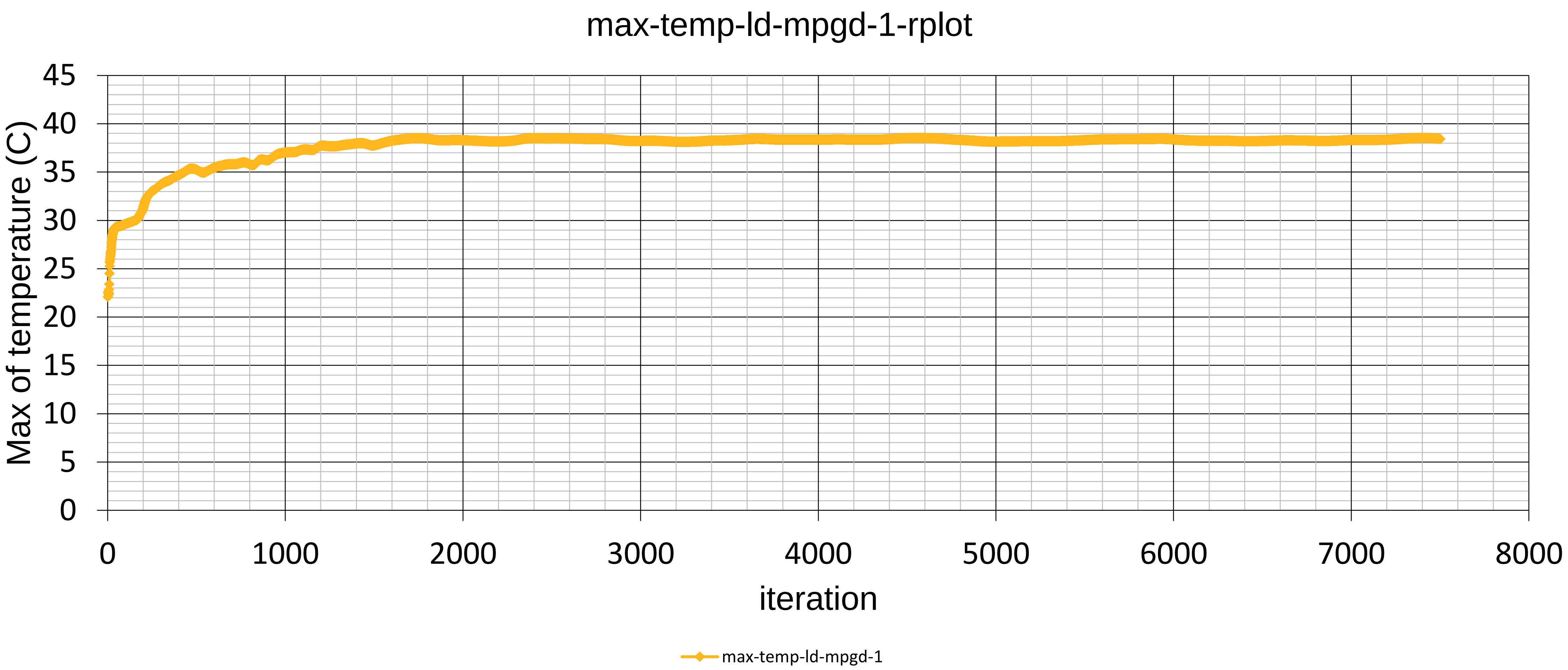
max-temp-ld-mpgd-2-rplot



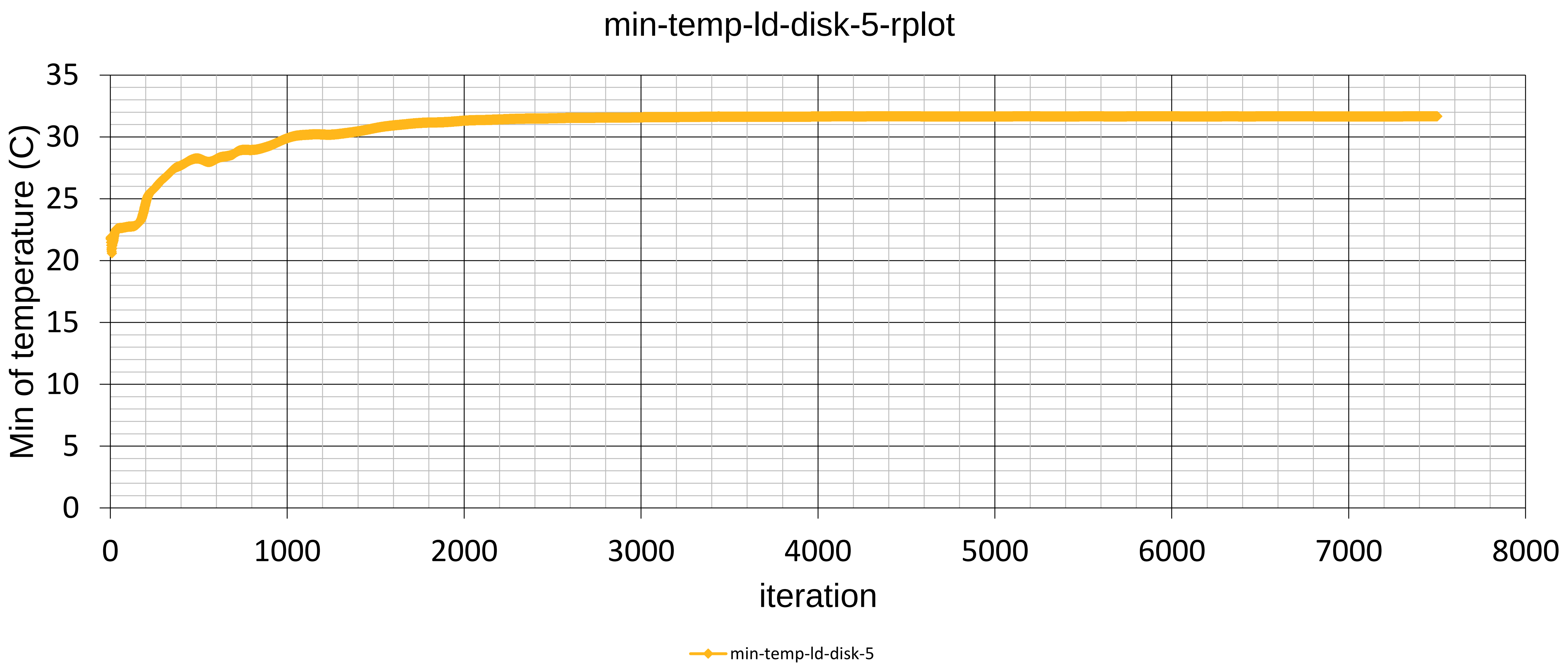
min-temp-ld-mpgd-1-rplot



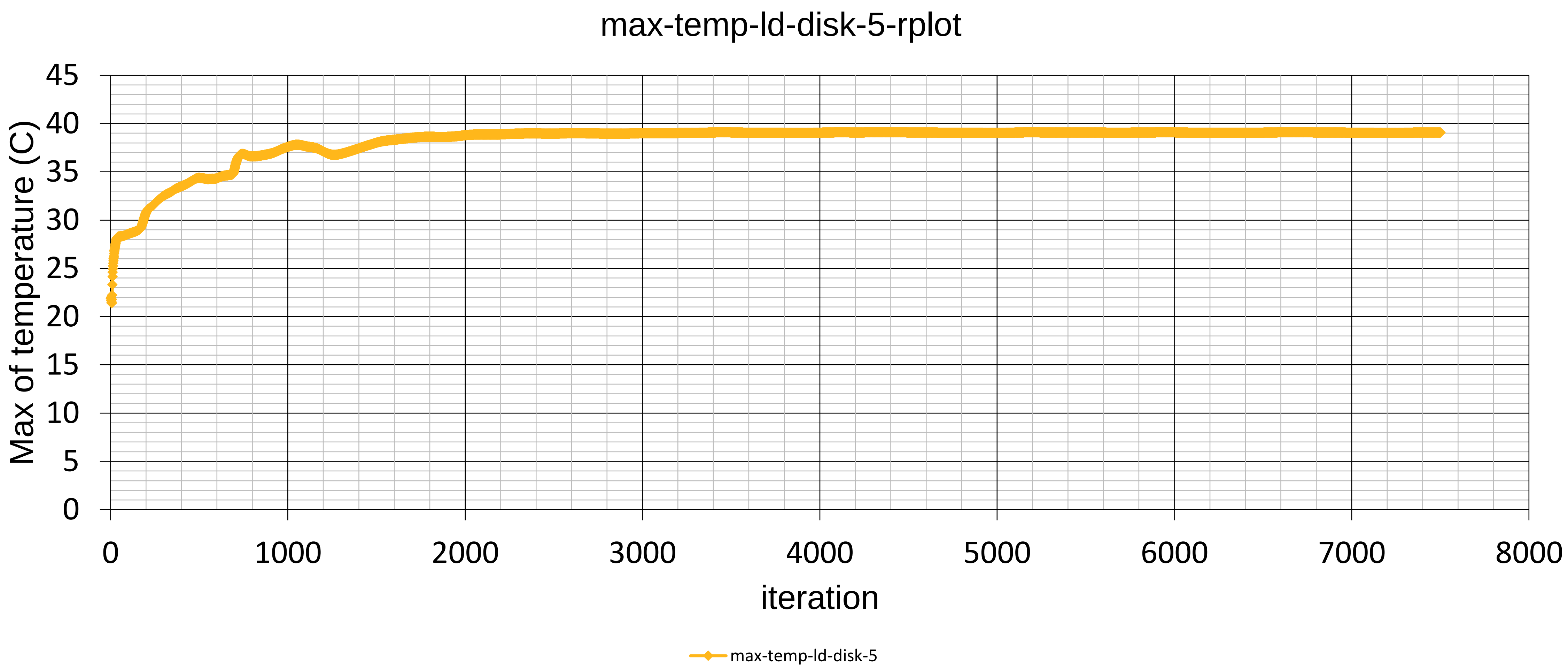
max-temp-ld-mpgd-1-rplot



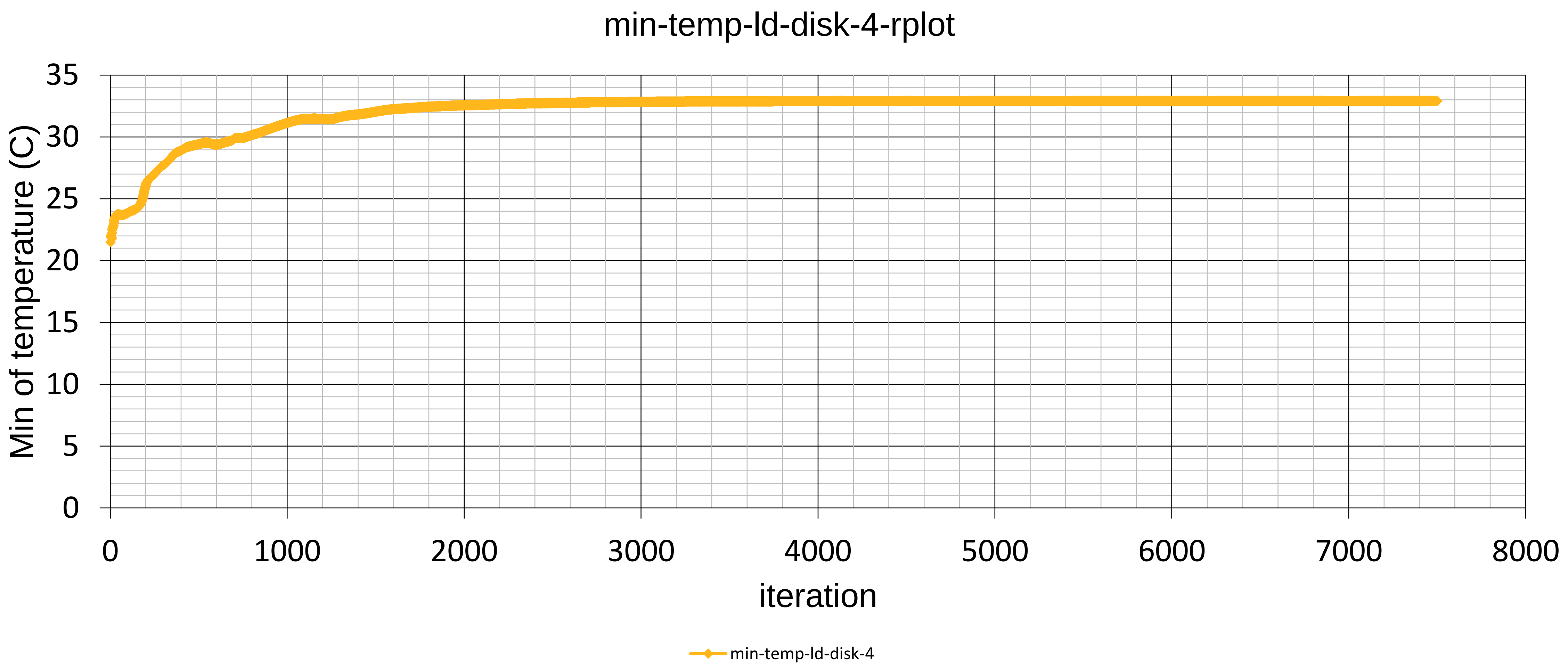
min-temp-ld-si-disk-5-rplot



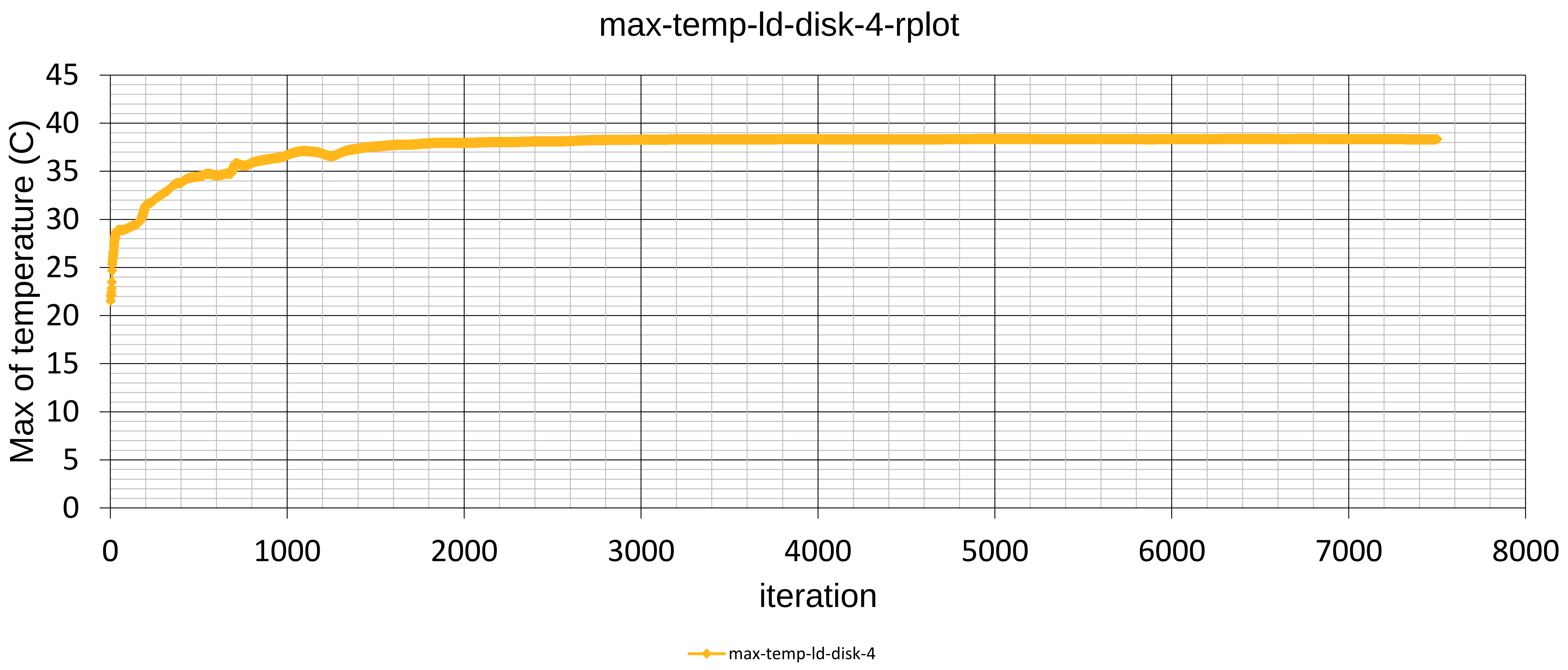
max-temp-ld-si-disk-5-rplot



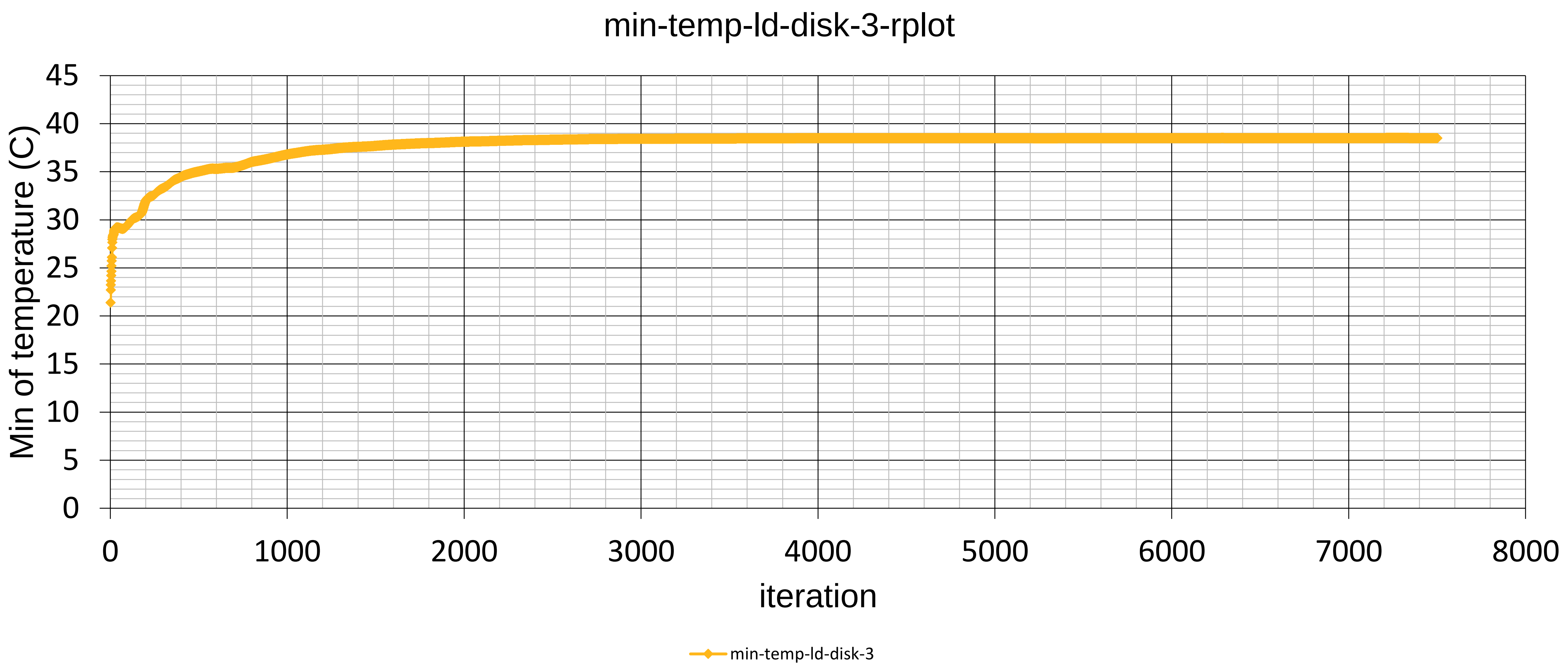
min-temp-ld-si-disk-4-rplot



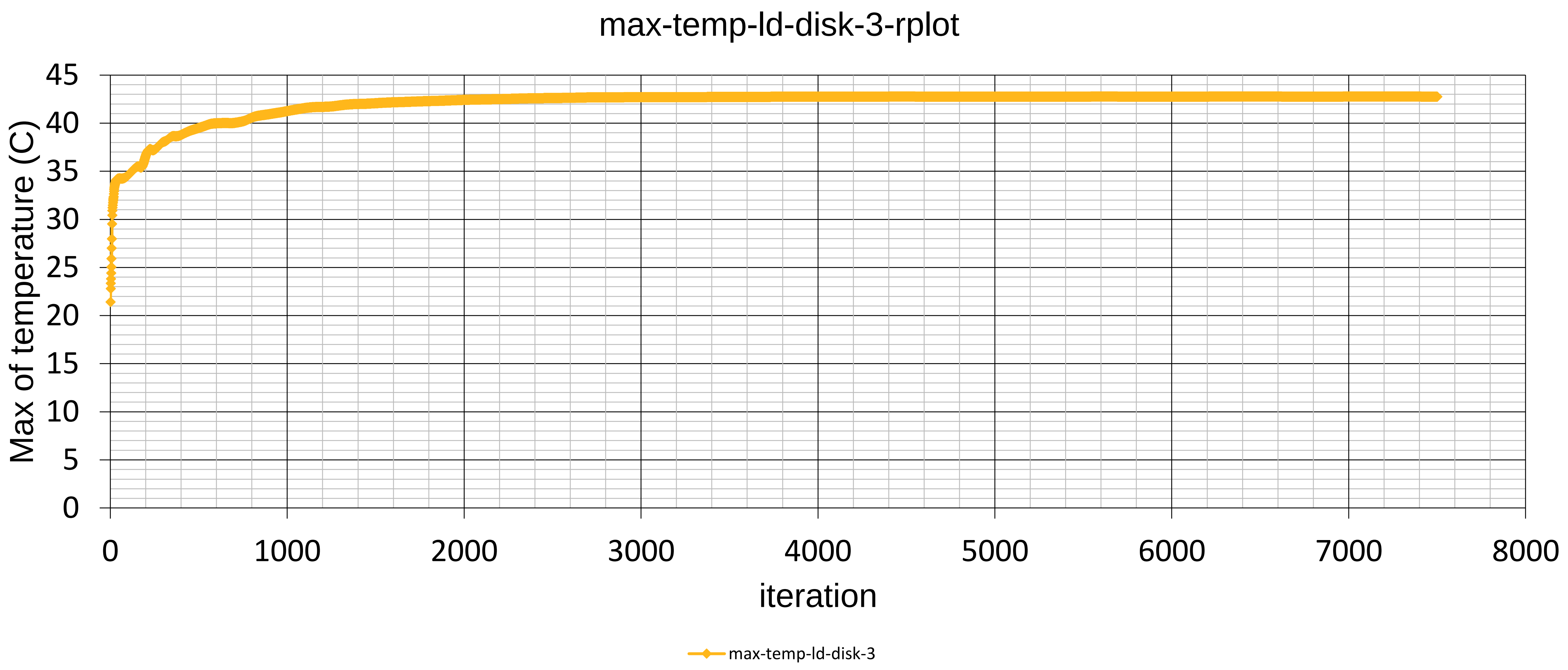
max-temp-ld-si-disk-4-rplot



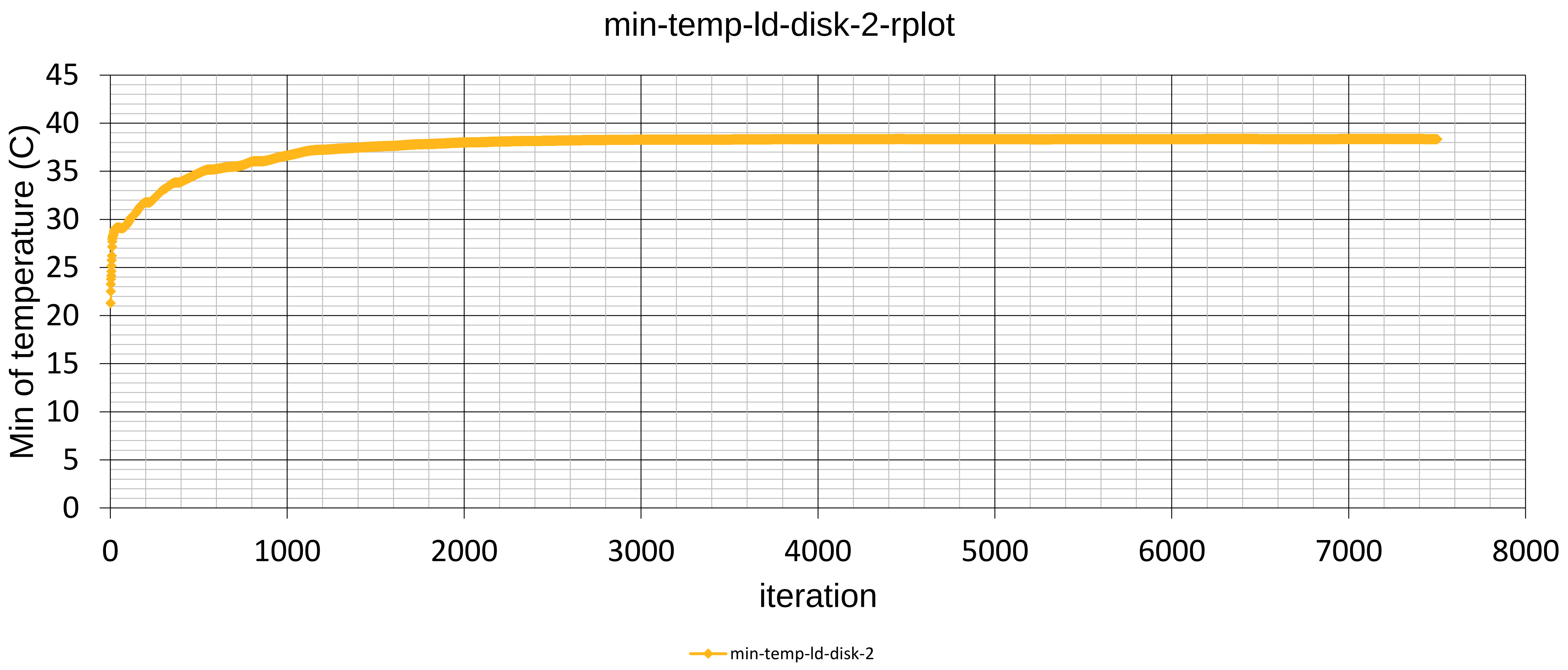
min-temp-ld-si-disk-3-rplot



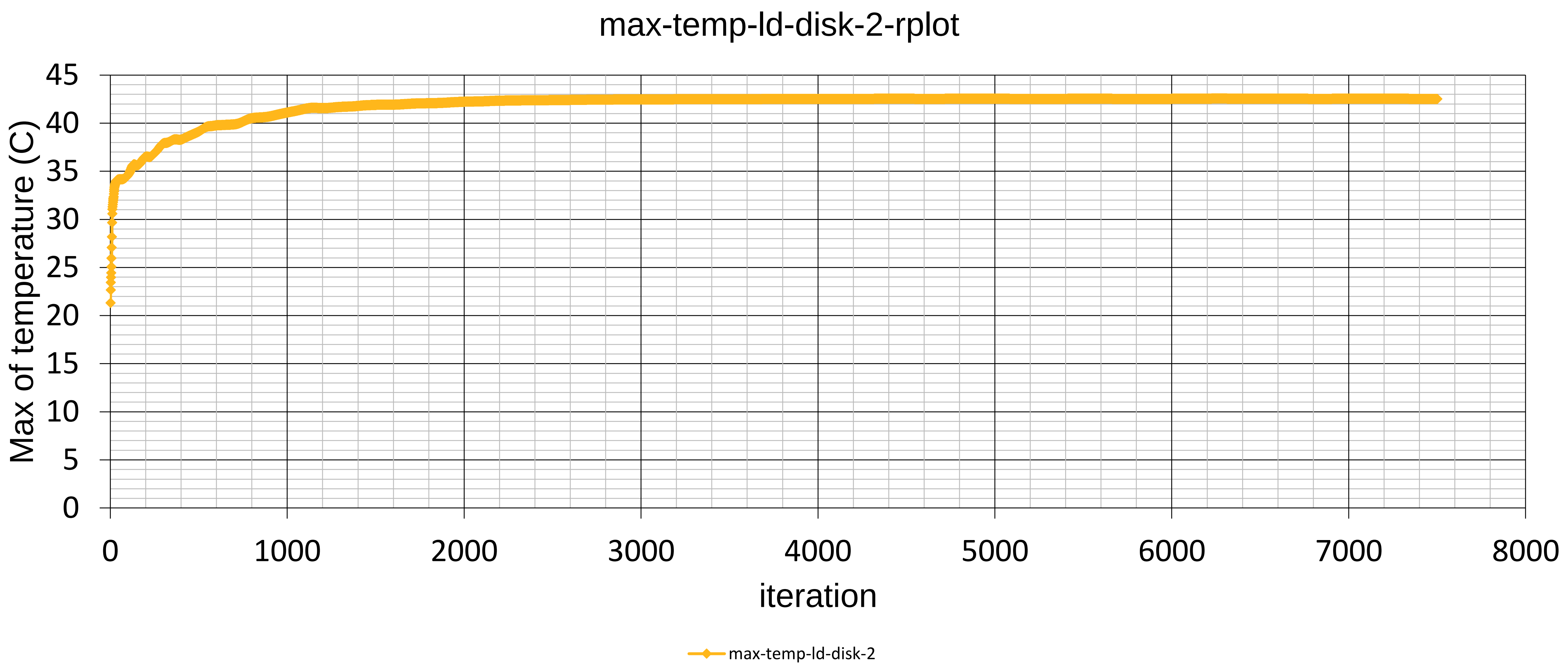
max-temp-ld-si-disk-3-rplot



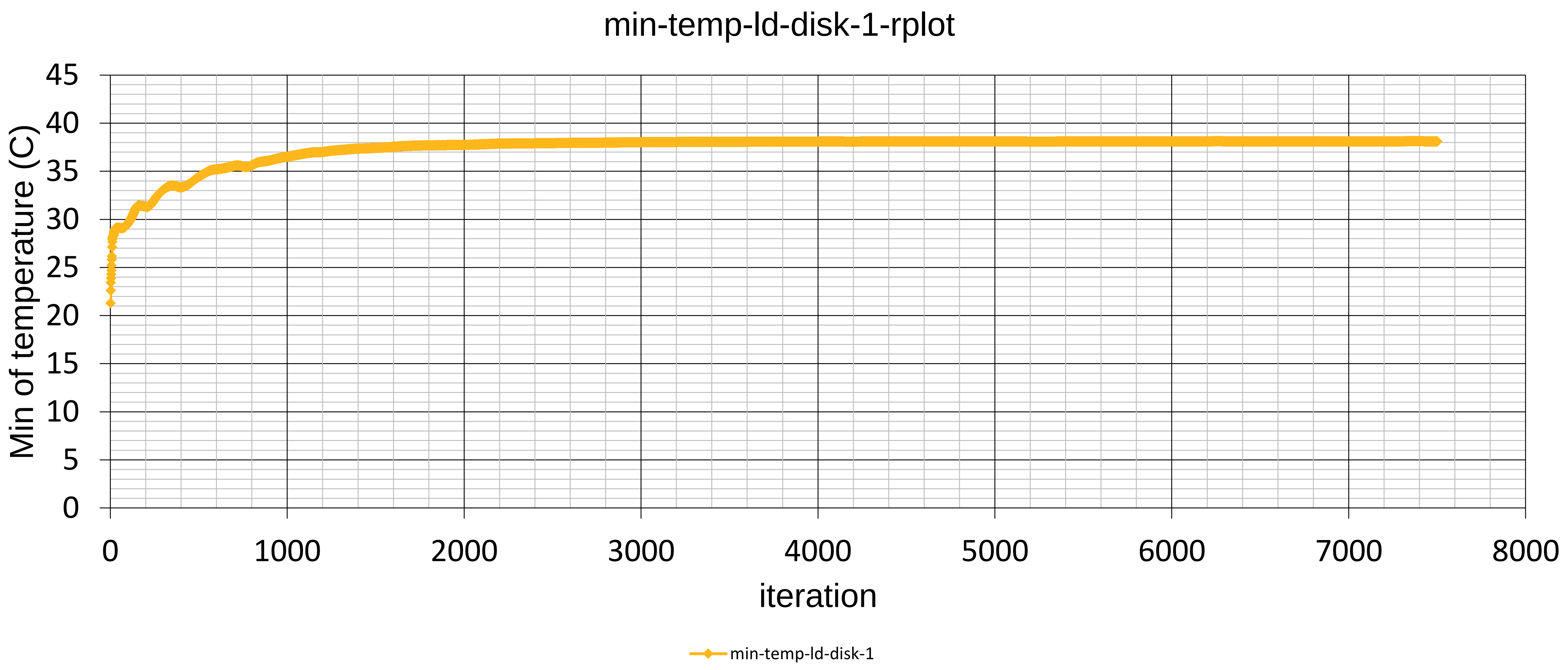
min-temp-ld-si-disk-2-rplot



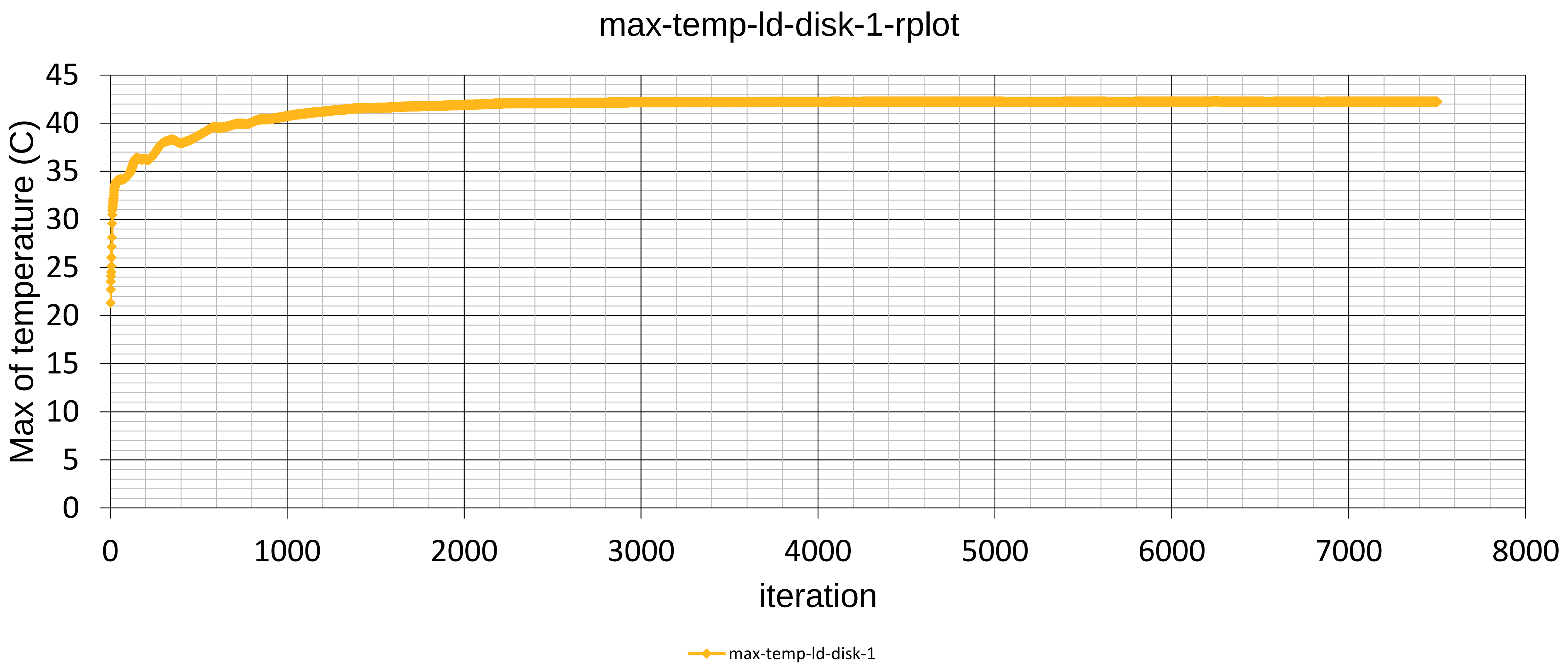
max-temp-ld-si-disk-2-rplot



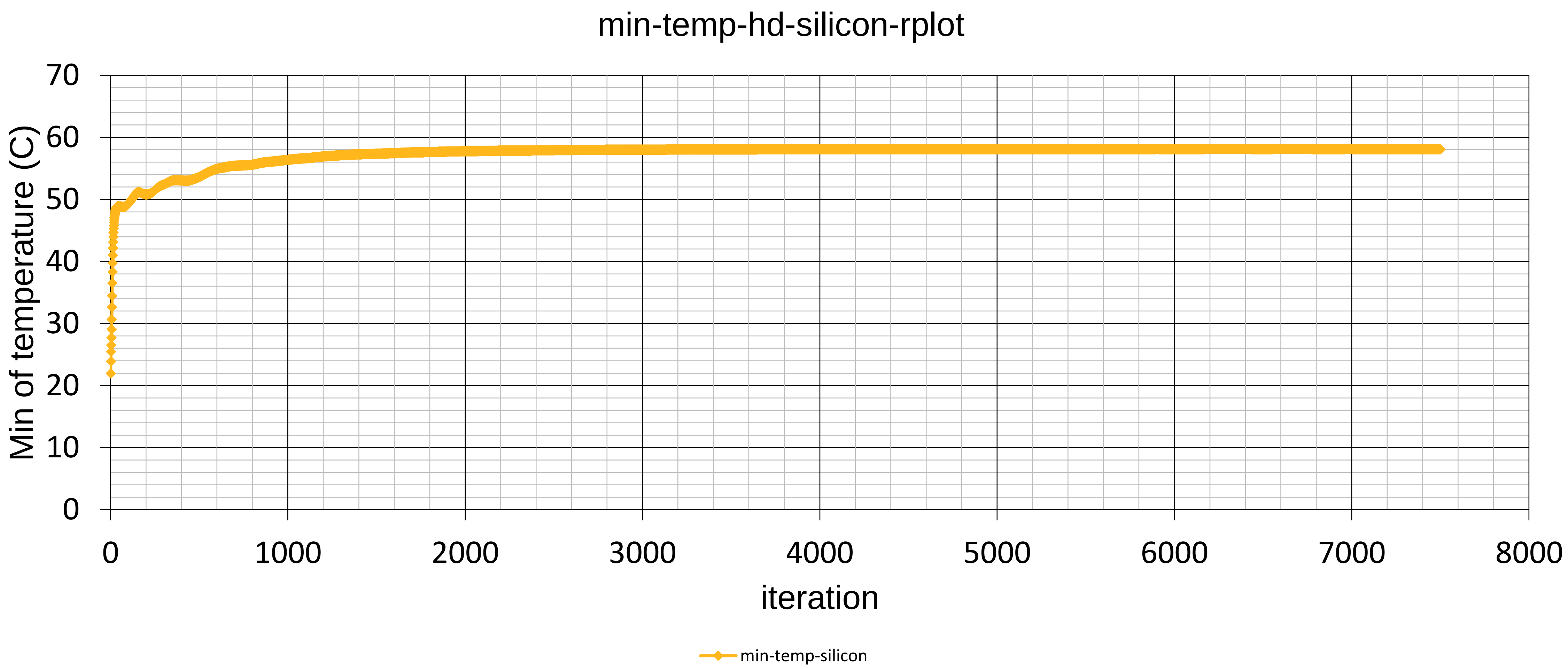
min-temp-ld-si-disk-1-rplot



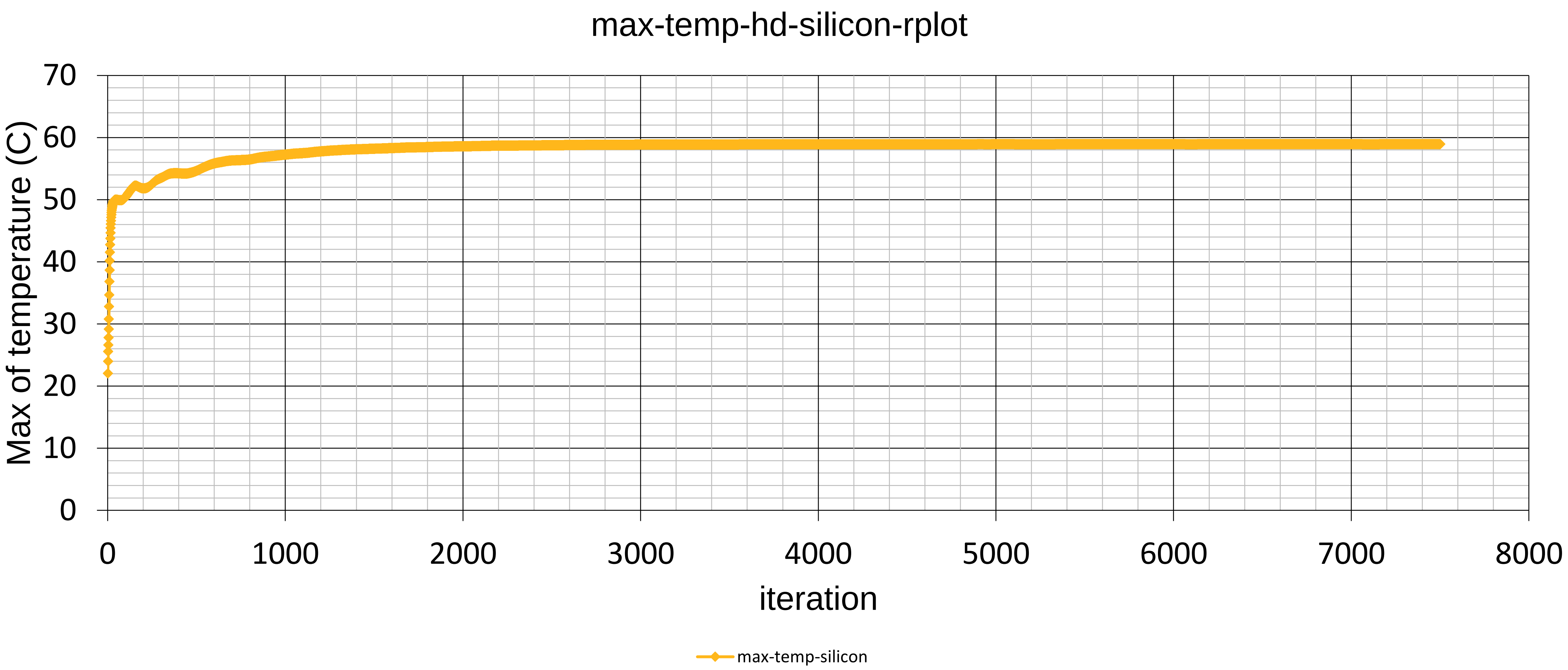
max-temp-ld-si-disk-1-rplot



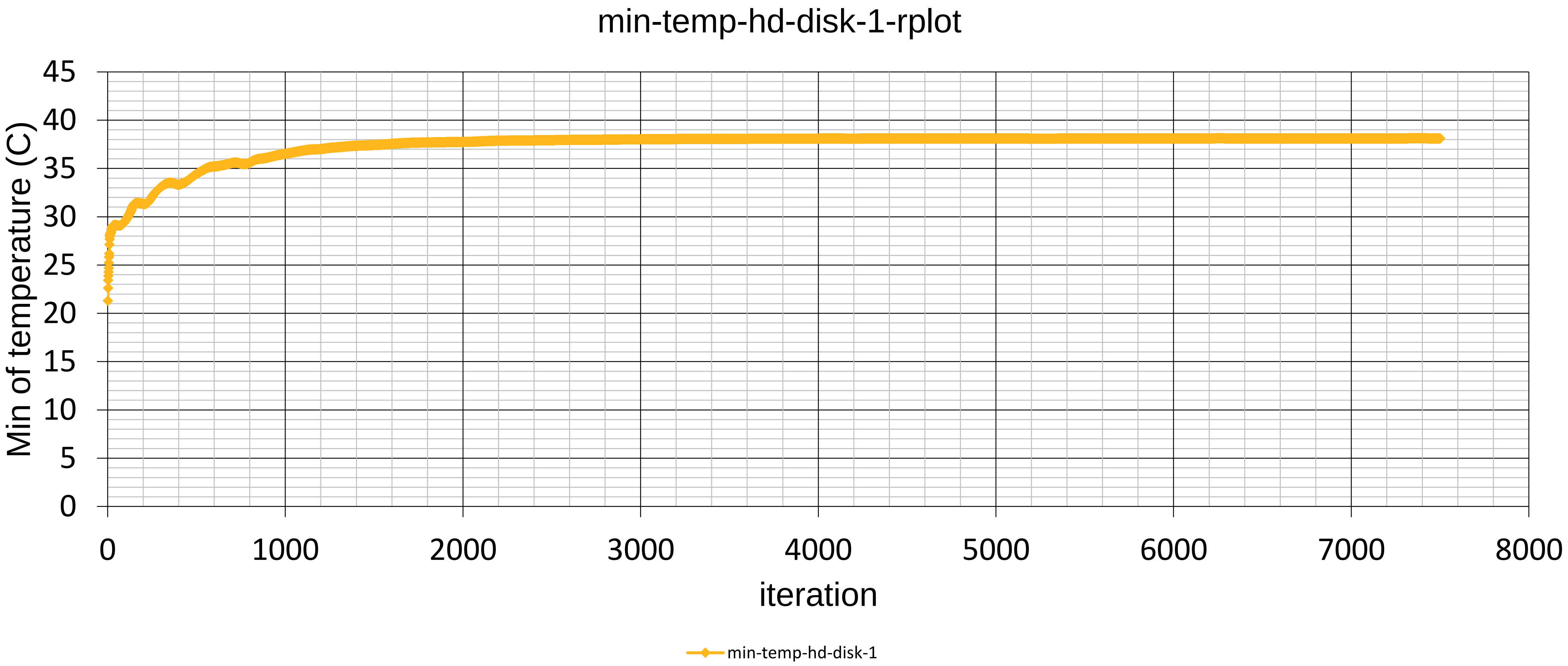
min-temp-silicon-barrel-rplot



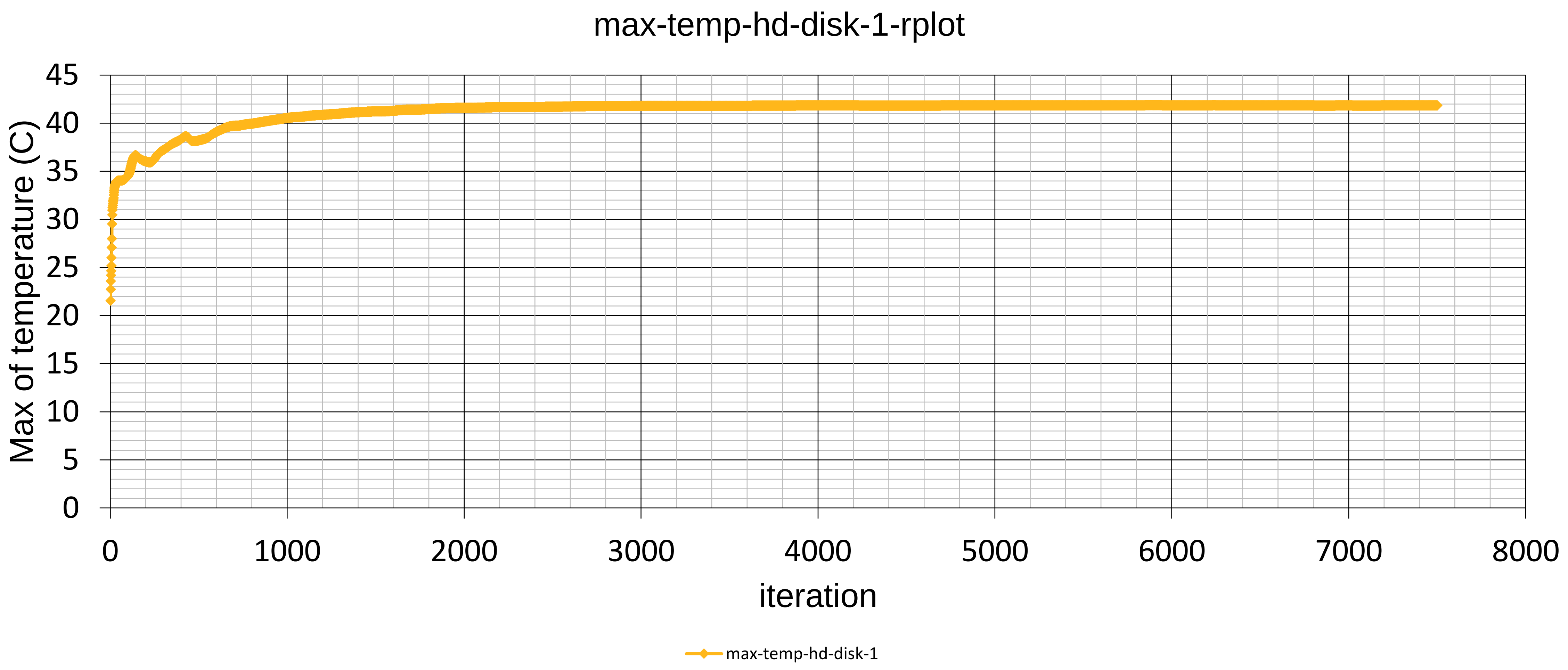
max-temp-silicon-barrel-rplot



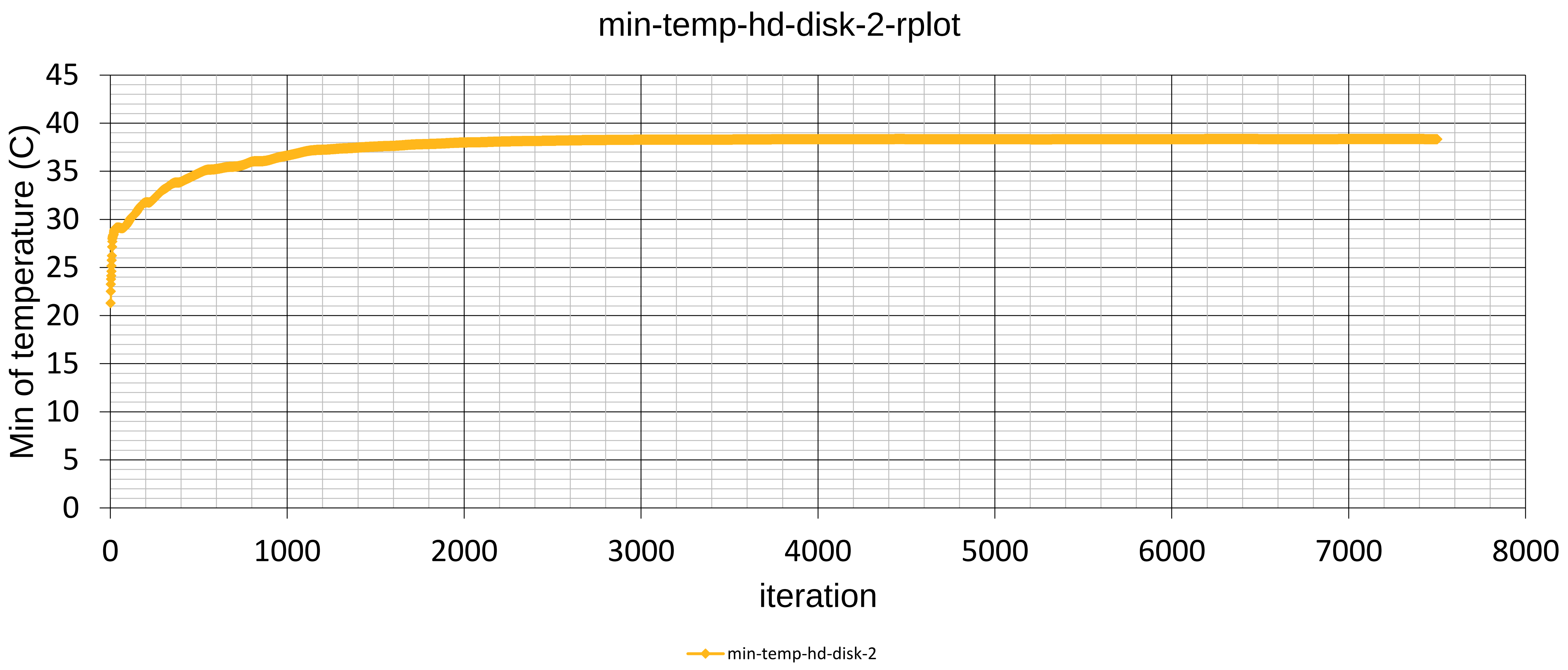
min-temp-hd-si-disk-1-rplot



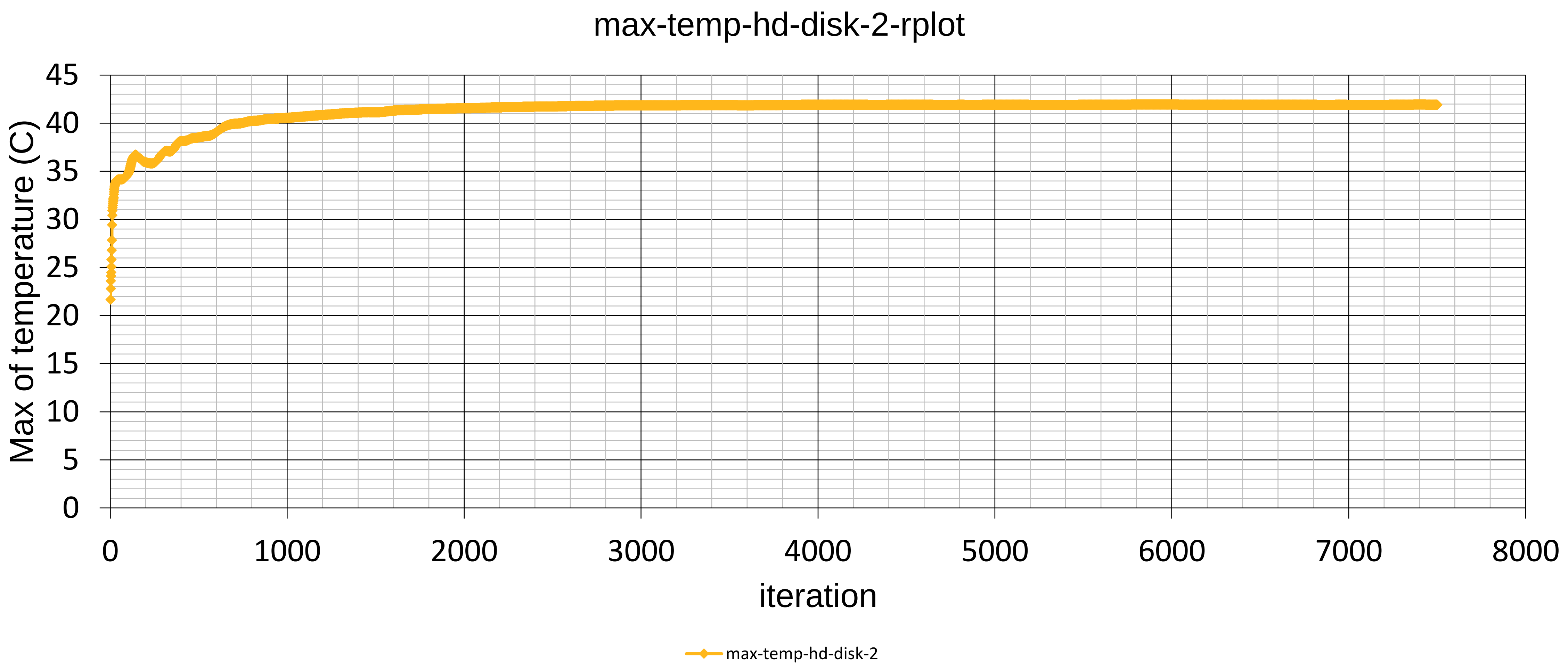
max-temp-hd-si-disk-1-rplot



min-temp-hd-si-disk-2-rplot



max-temp-hd-si-disk-2-rplot



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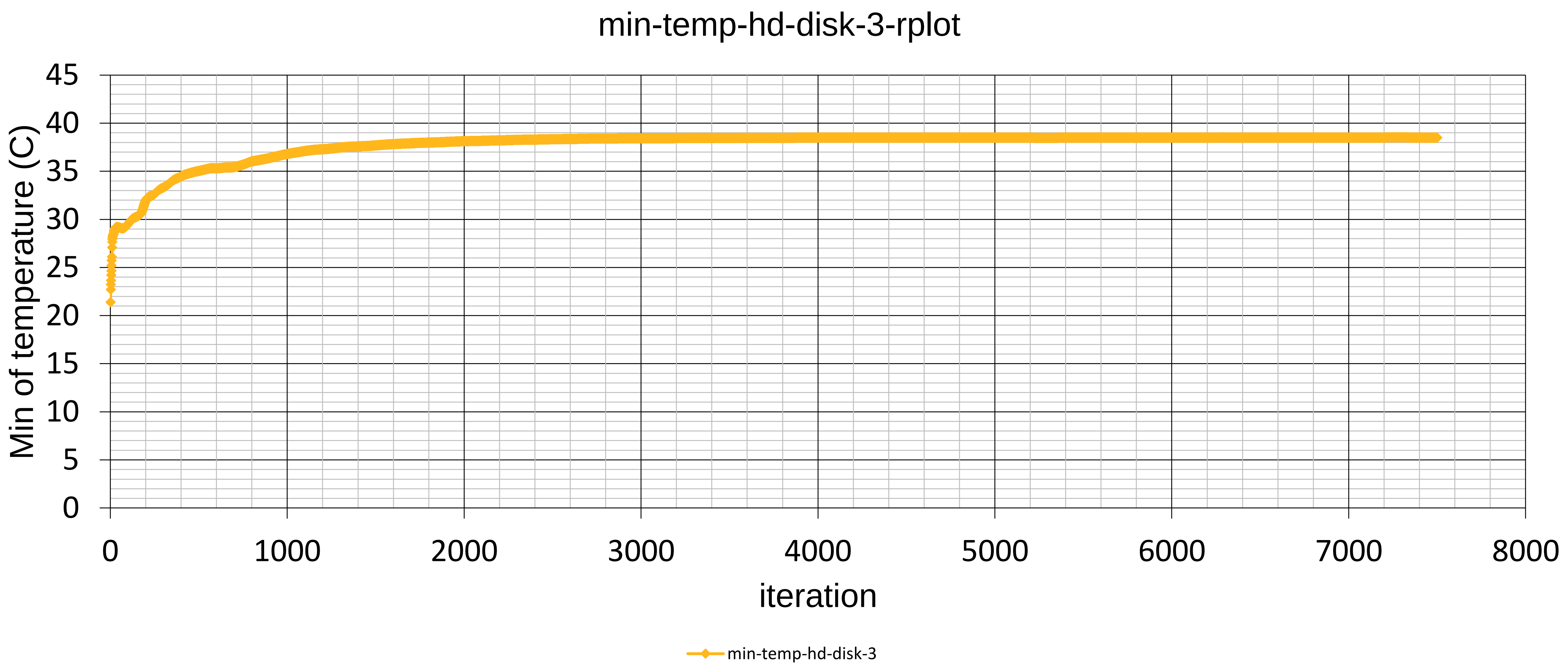
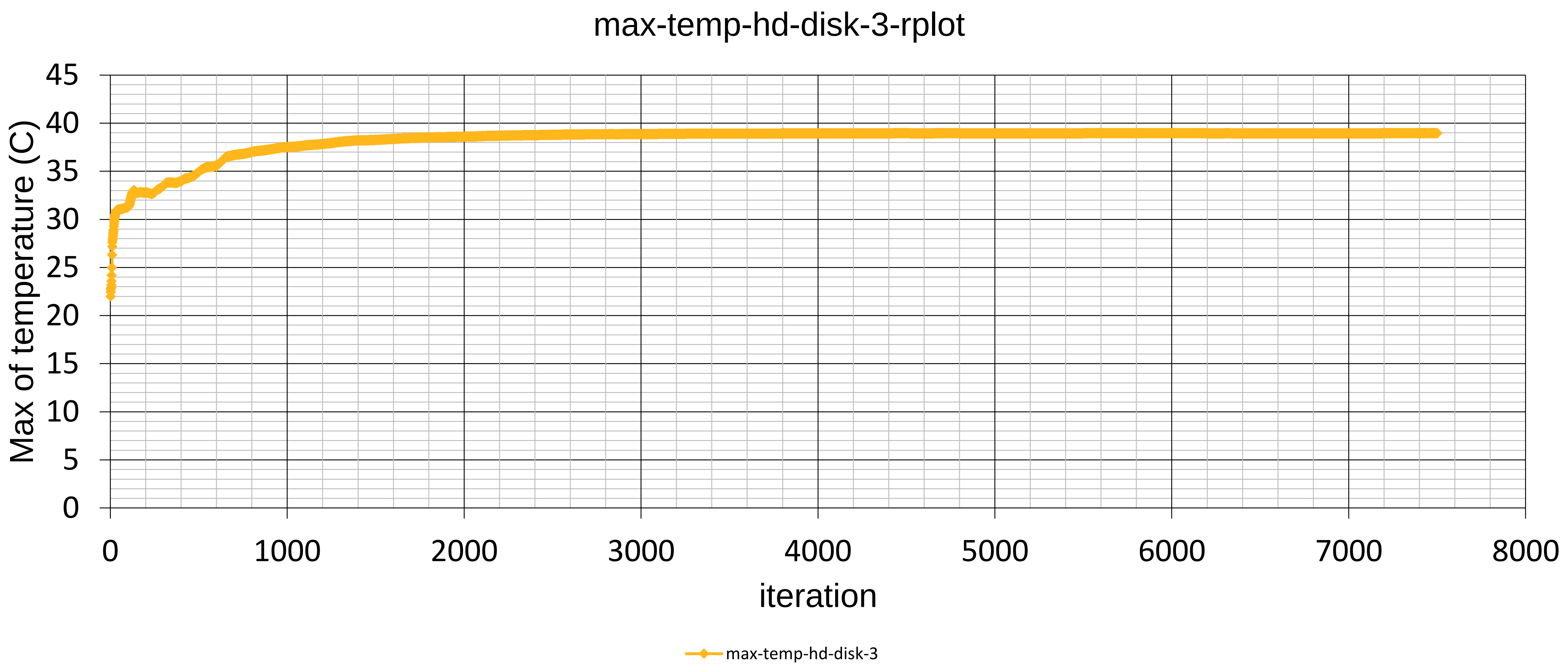
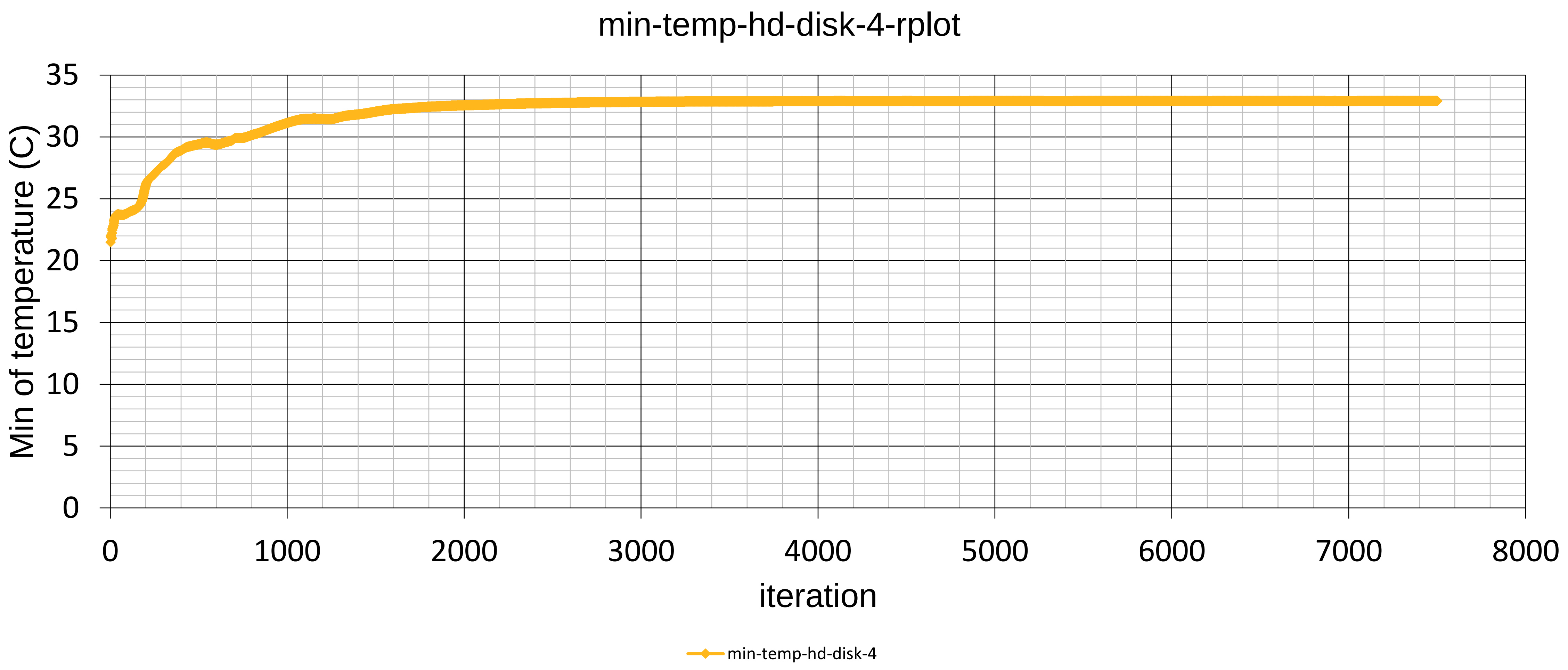


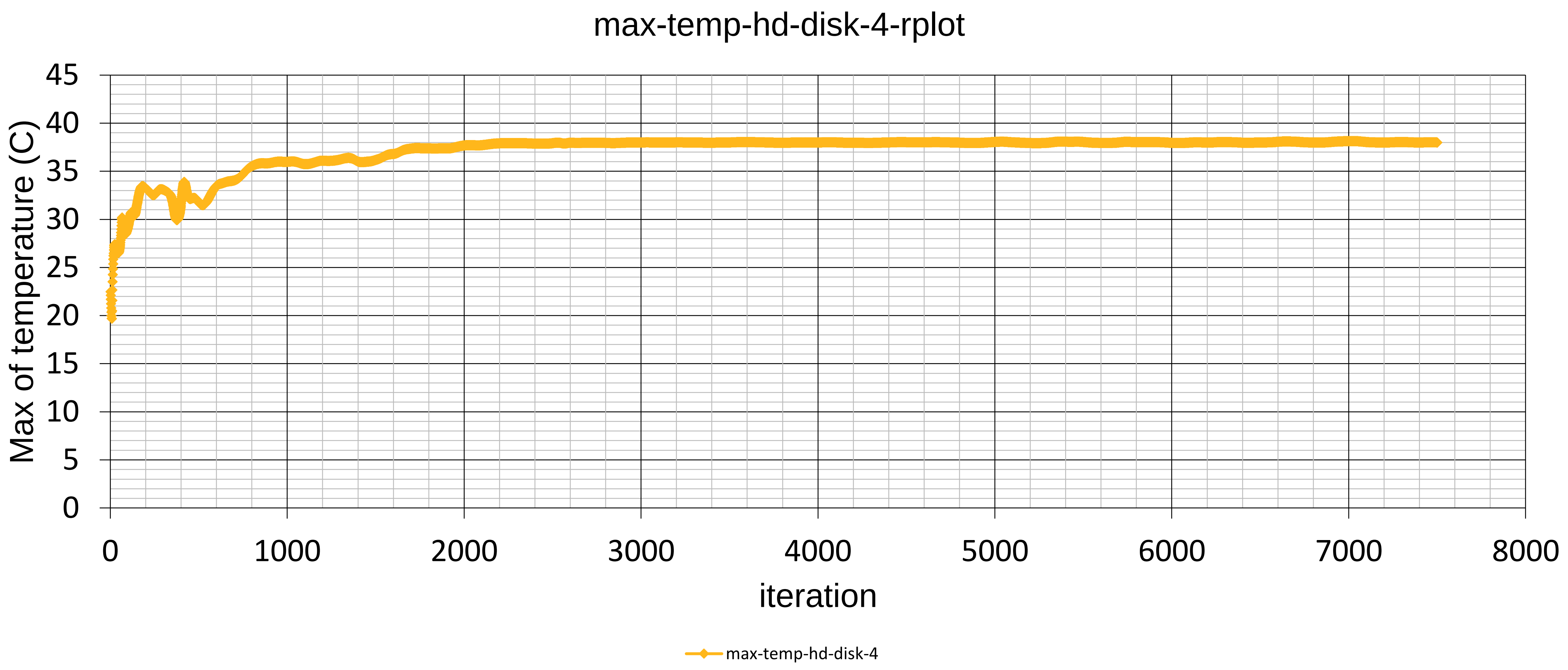
max-temp-hd-si-disk-3-rplot



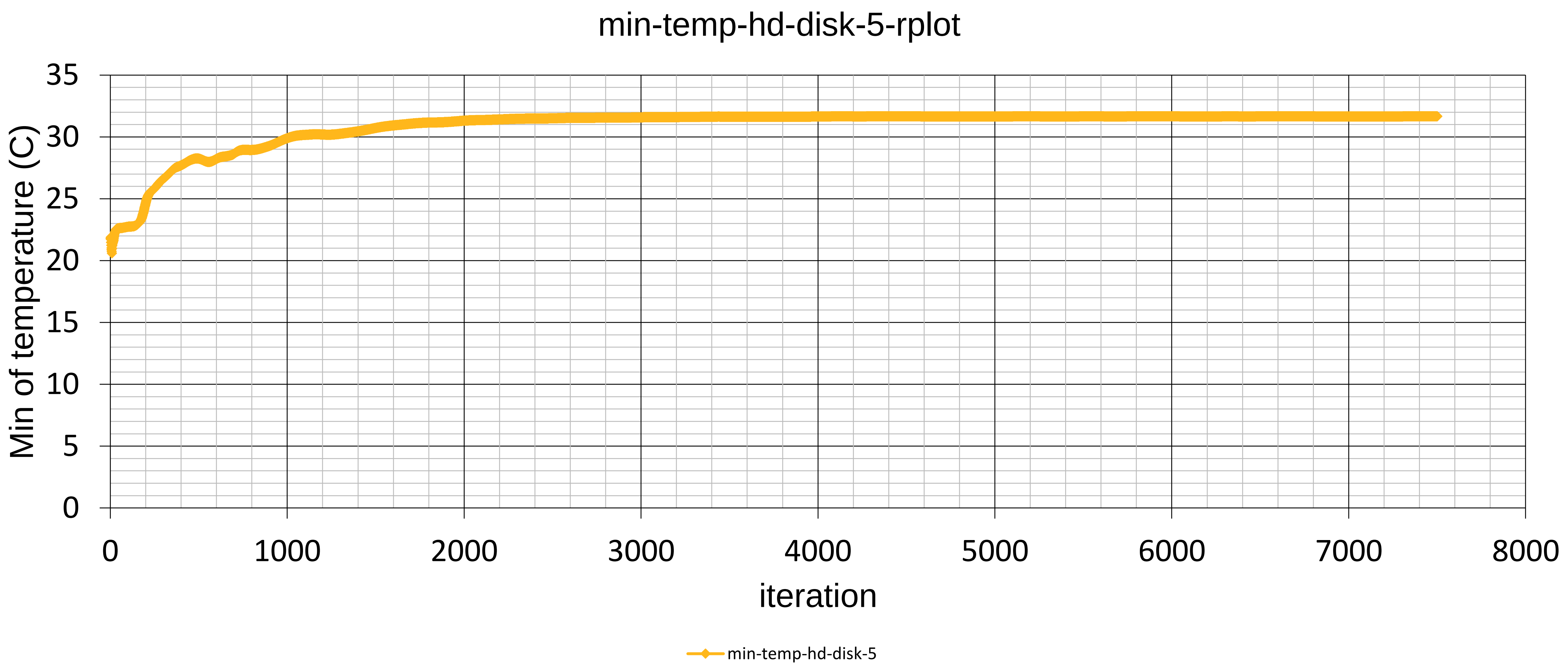
min-temp-hd-si-disk-4-rplot



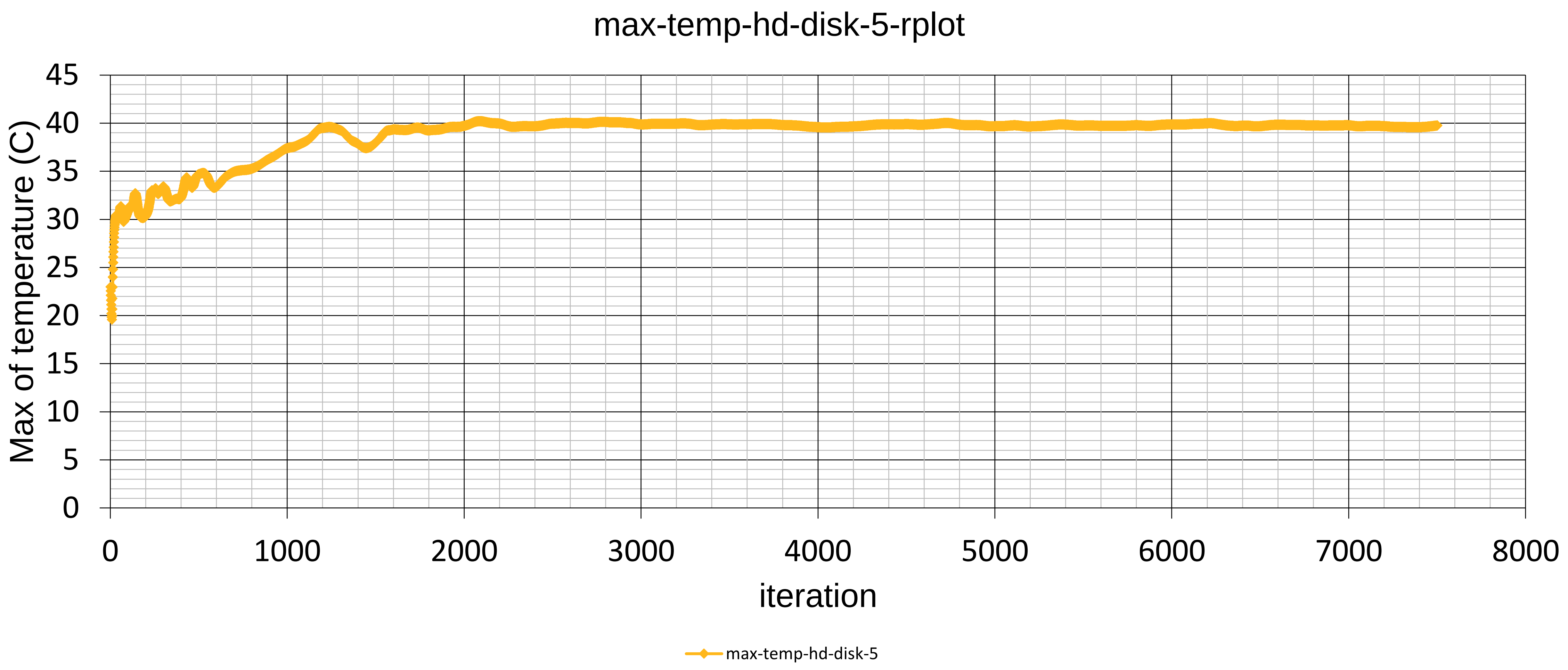
max-temp-hd-si-disk-4-rplot



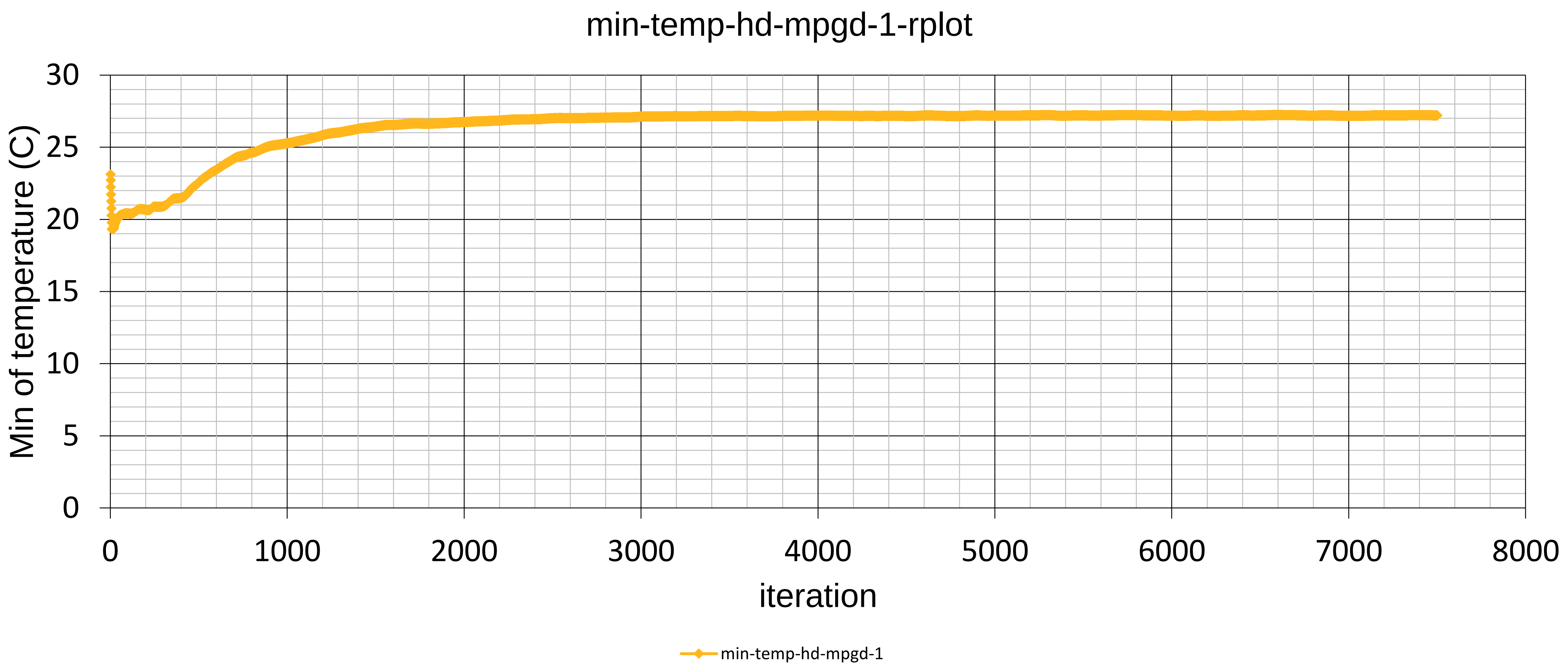
min-temp-hd-si-disk-5-rplot



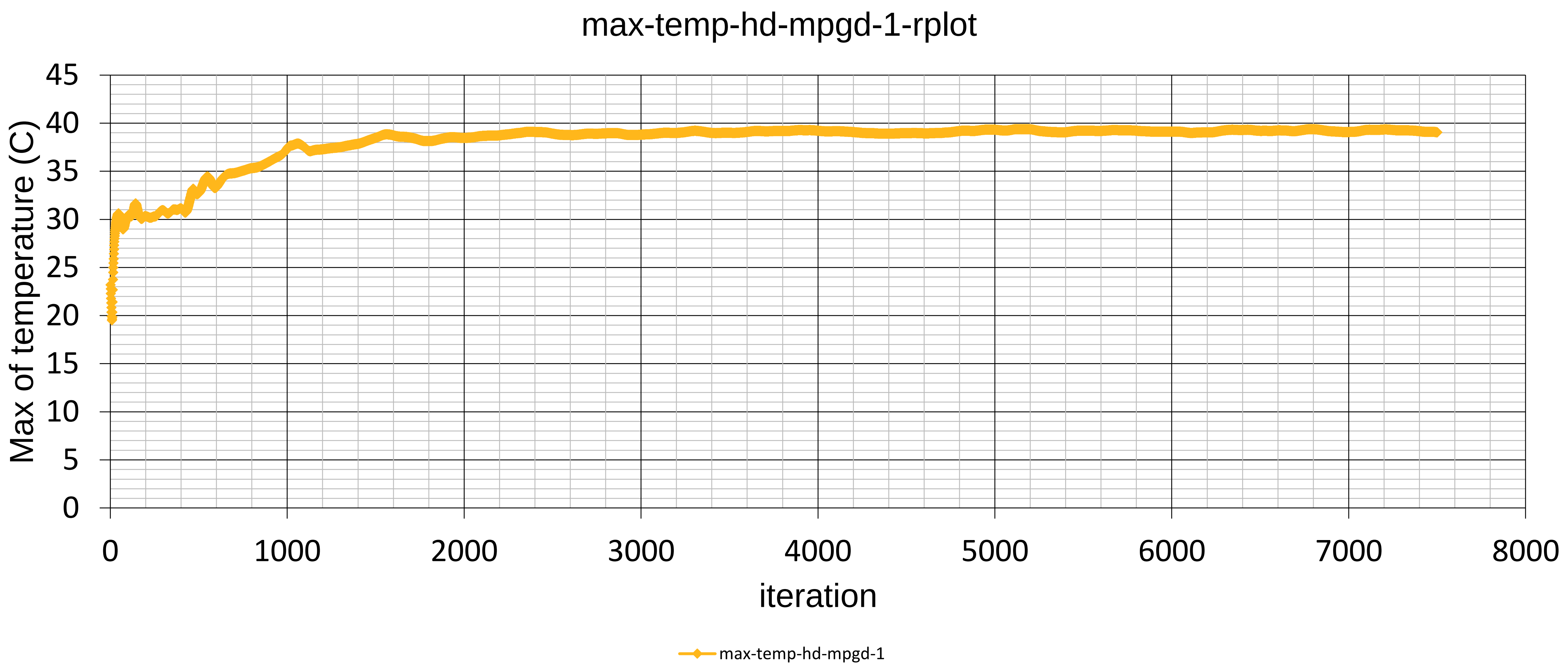
max-temp-hd-si-disk-5-rplot



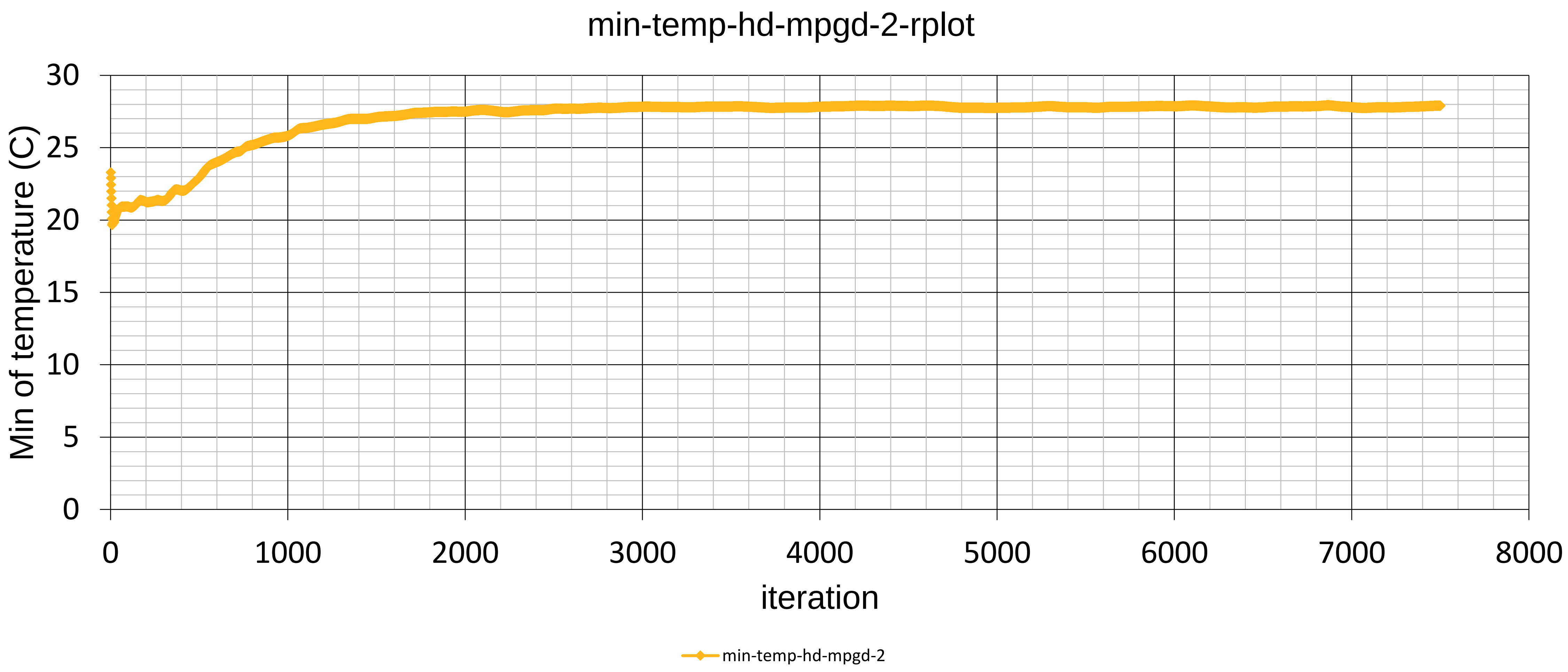
min-temp-hd-mpgd-1-rplot



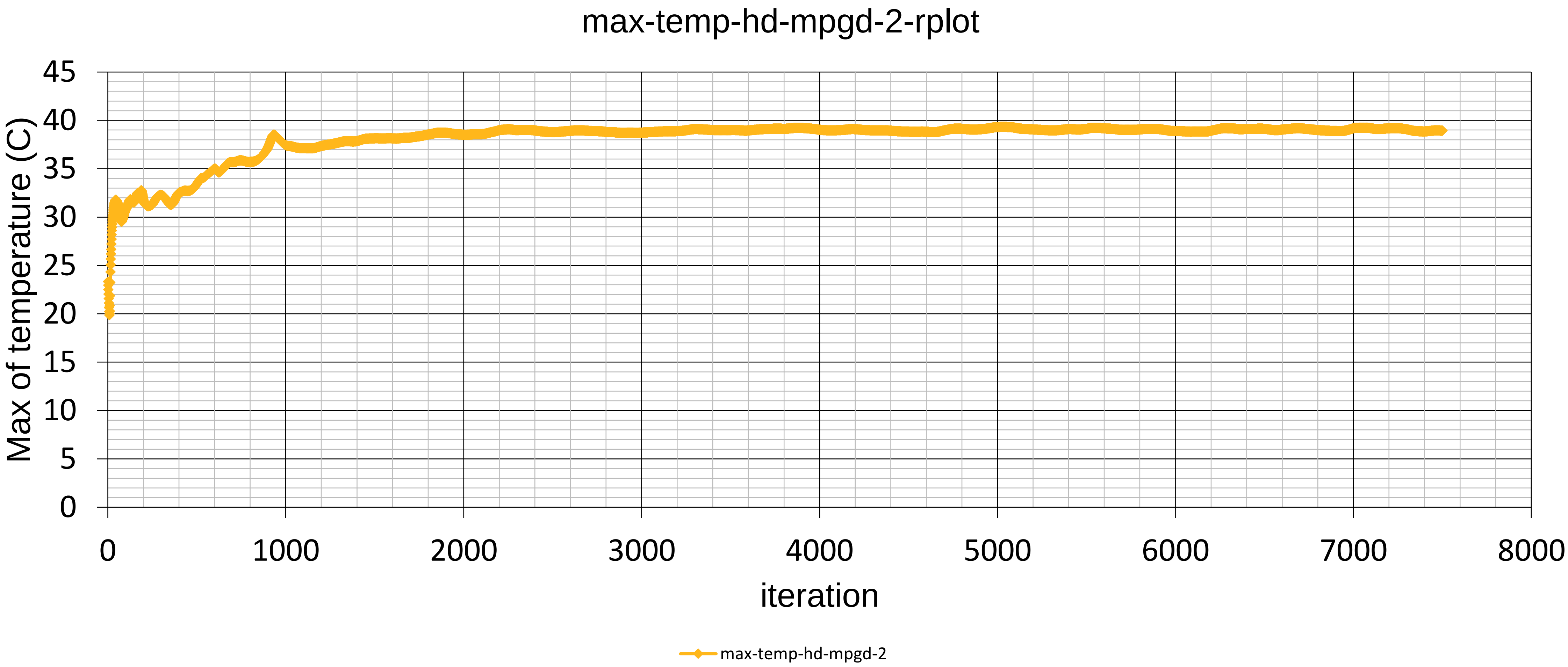
max-temp-hd-mpgd-1-rplot



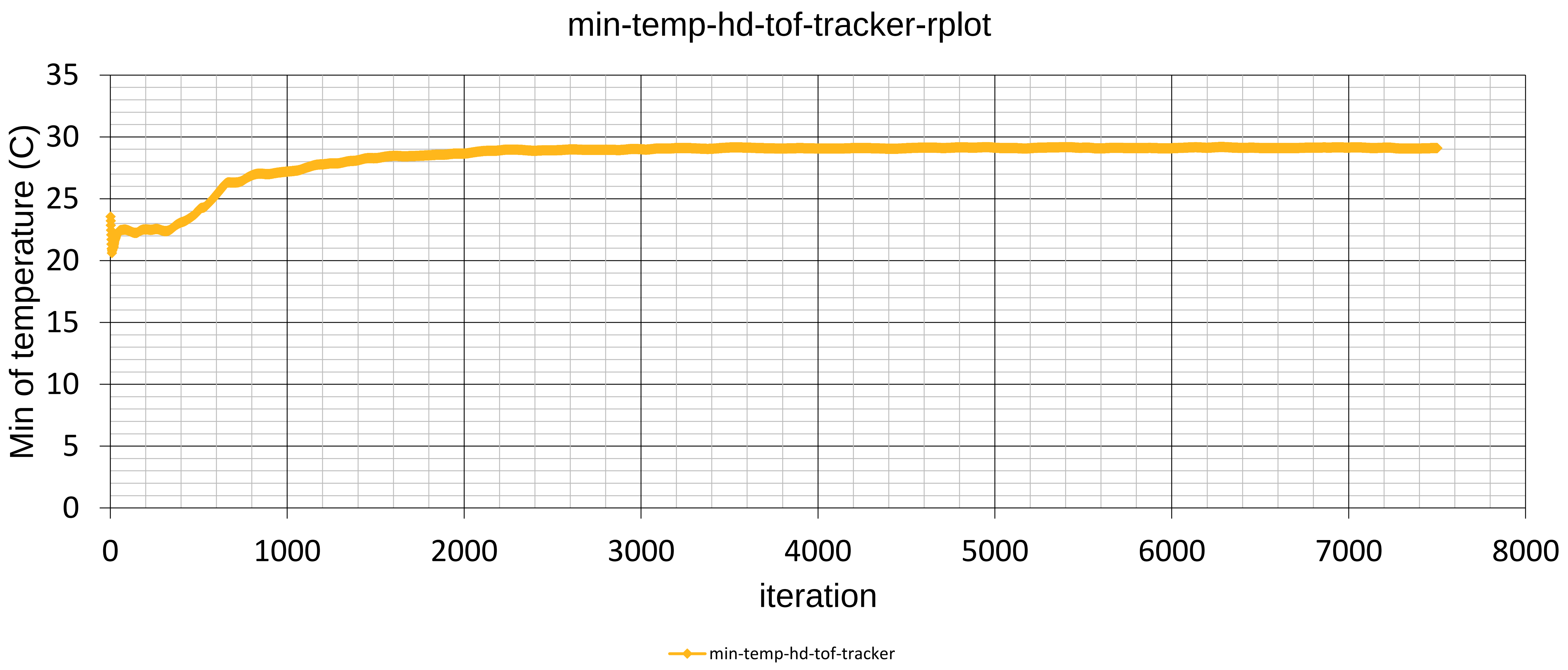
min-temp-hd-mpgd-2-rplot



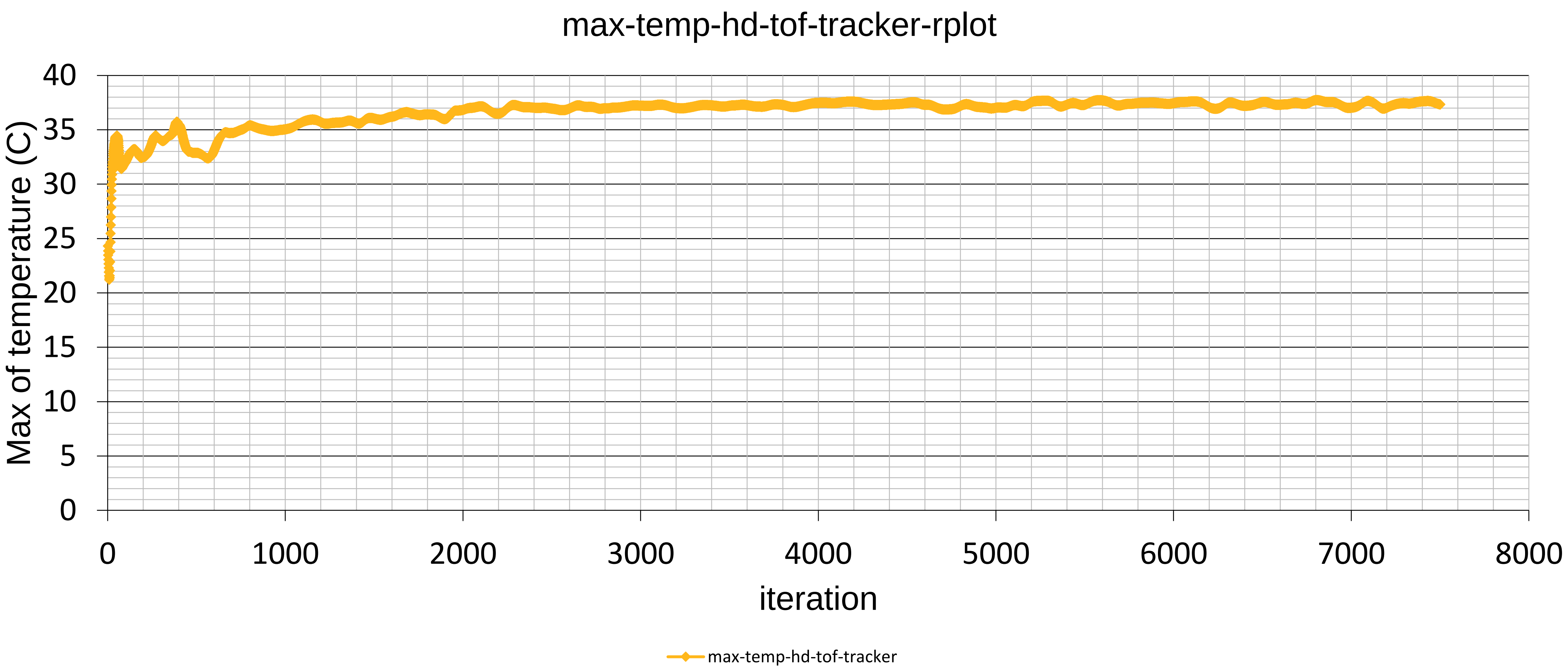
max-temp-hd-mpgd-2-rplot



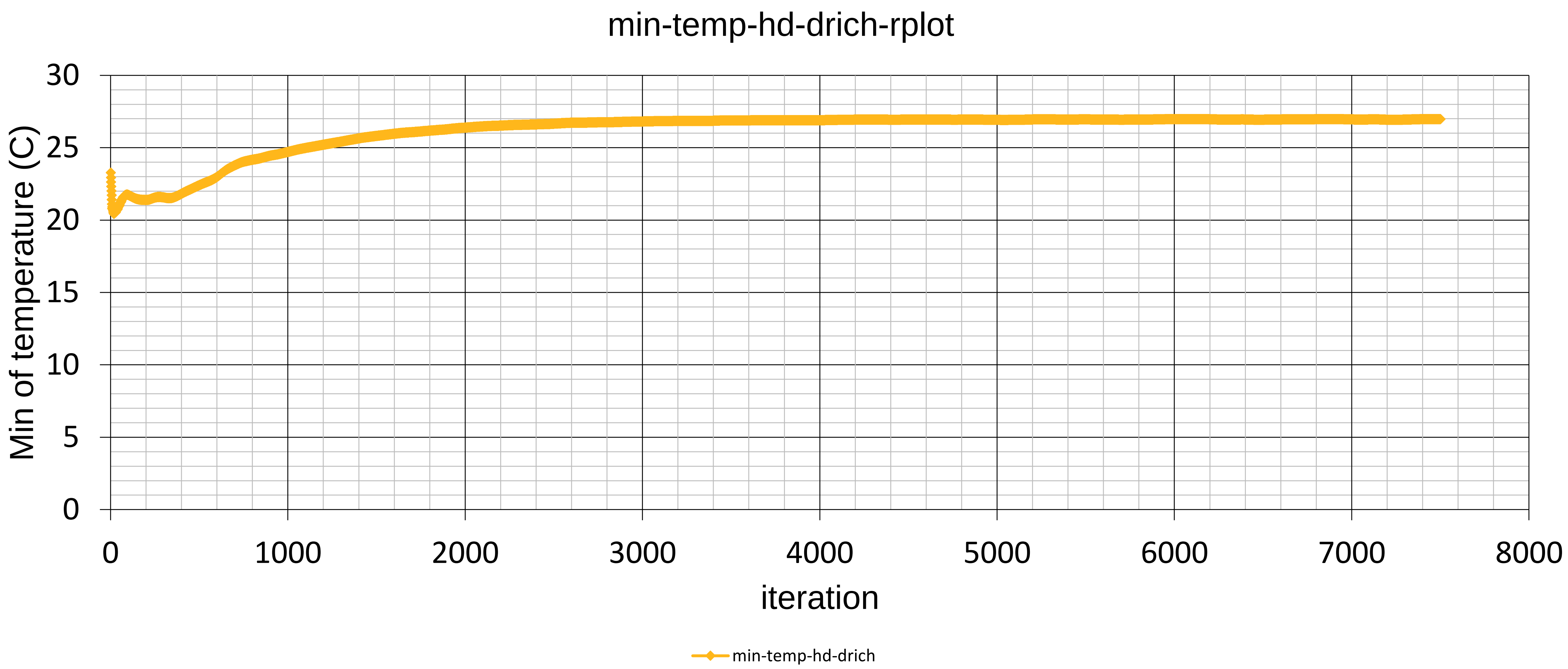
min-temp-hd-tof-tracker-rplot



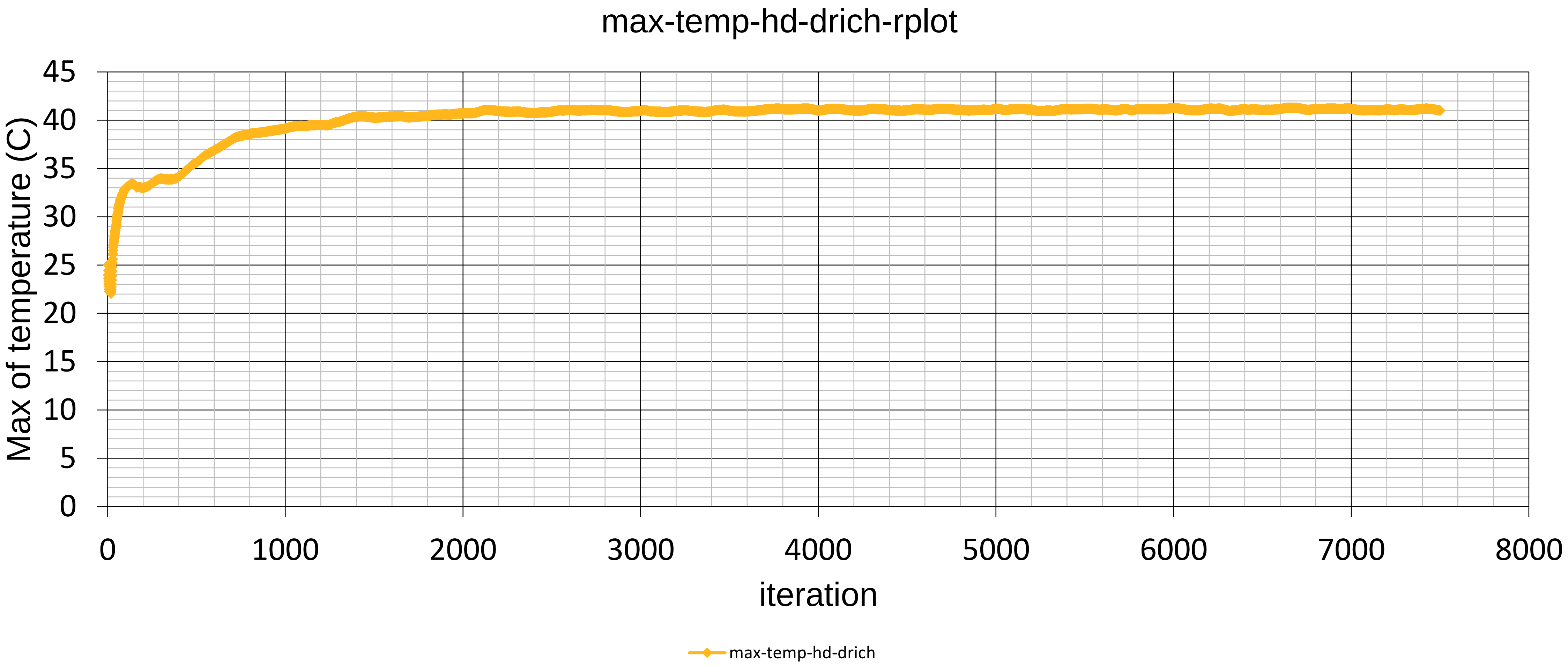
max-temp-hd-tof-tracker-rplot



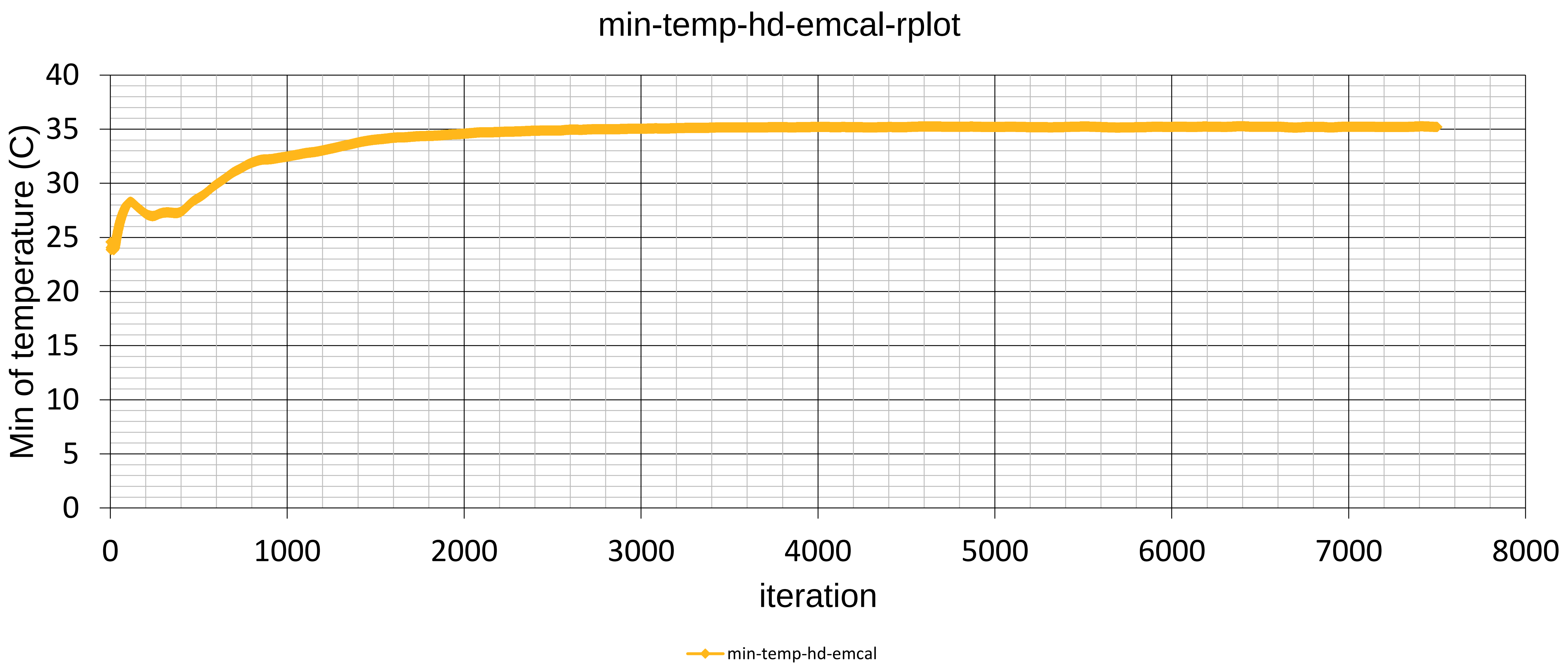
min-temp-hd-drich-rplot



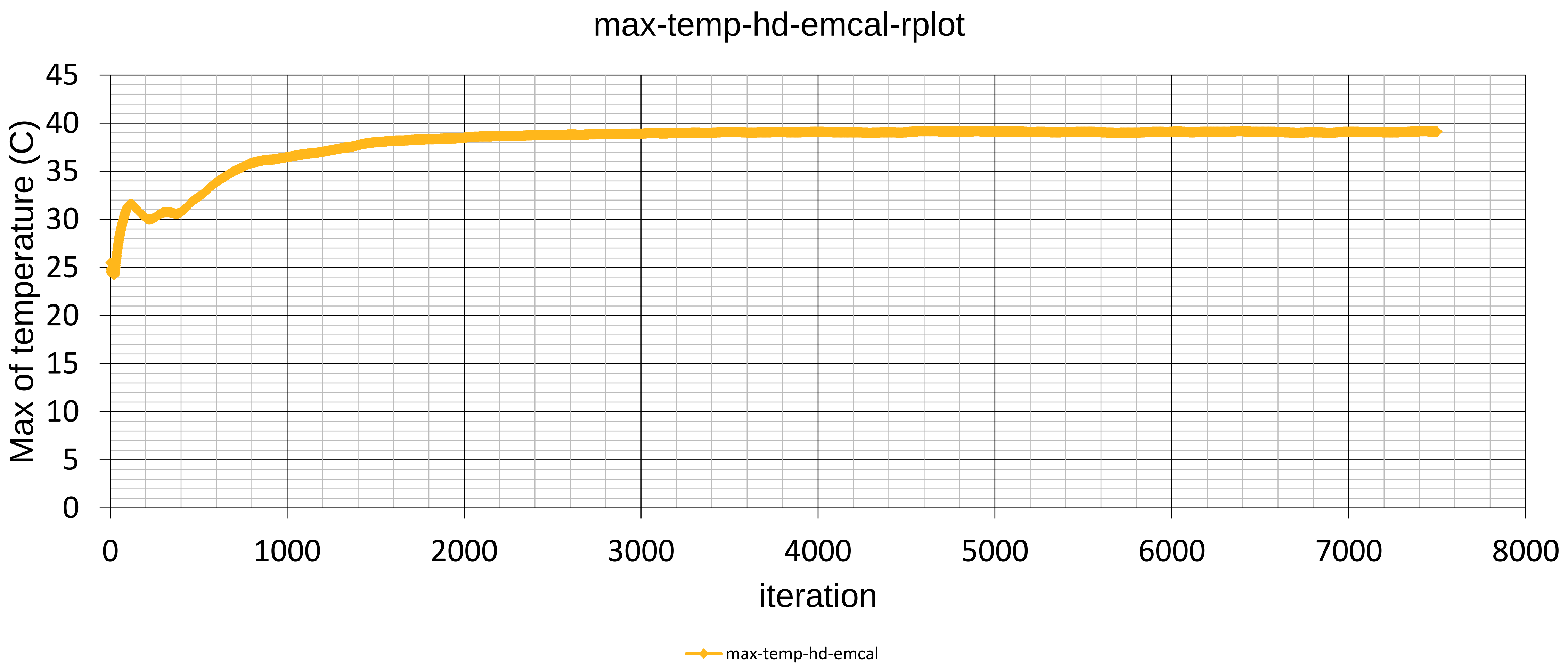
max-temp-hd-drich-rplot



min-temp-hd-emcal-rplot

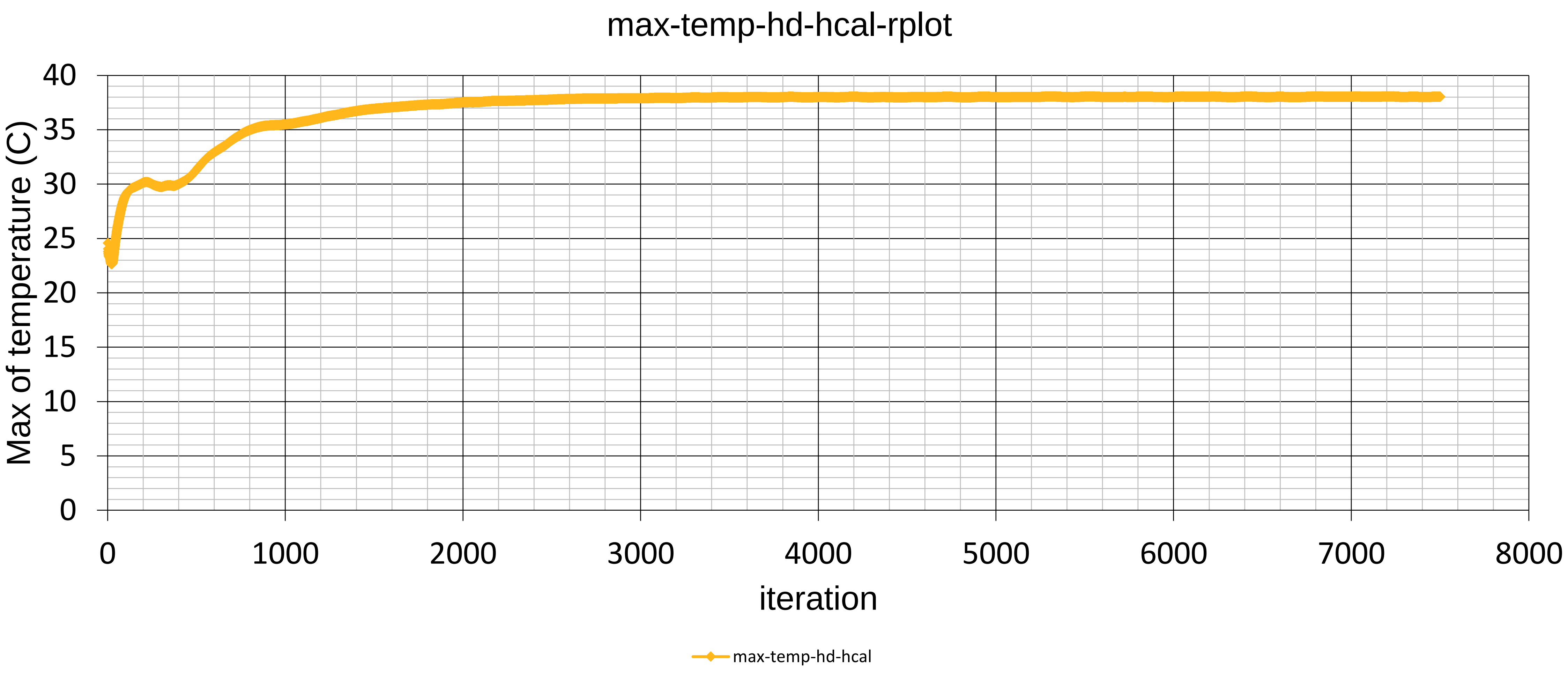


max-temp-hd-emcal-rplot



min-temp-hd-hcal-rplot

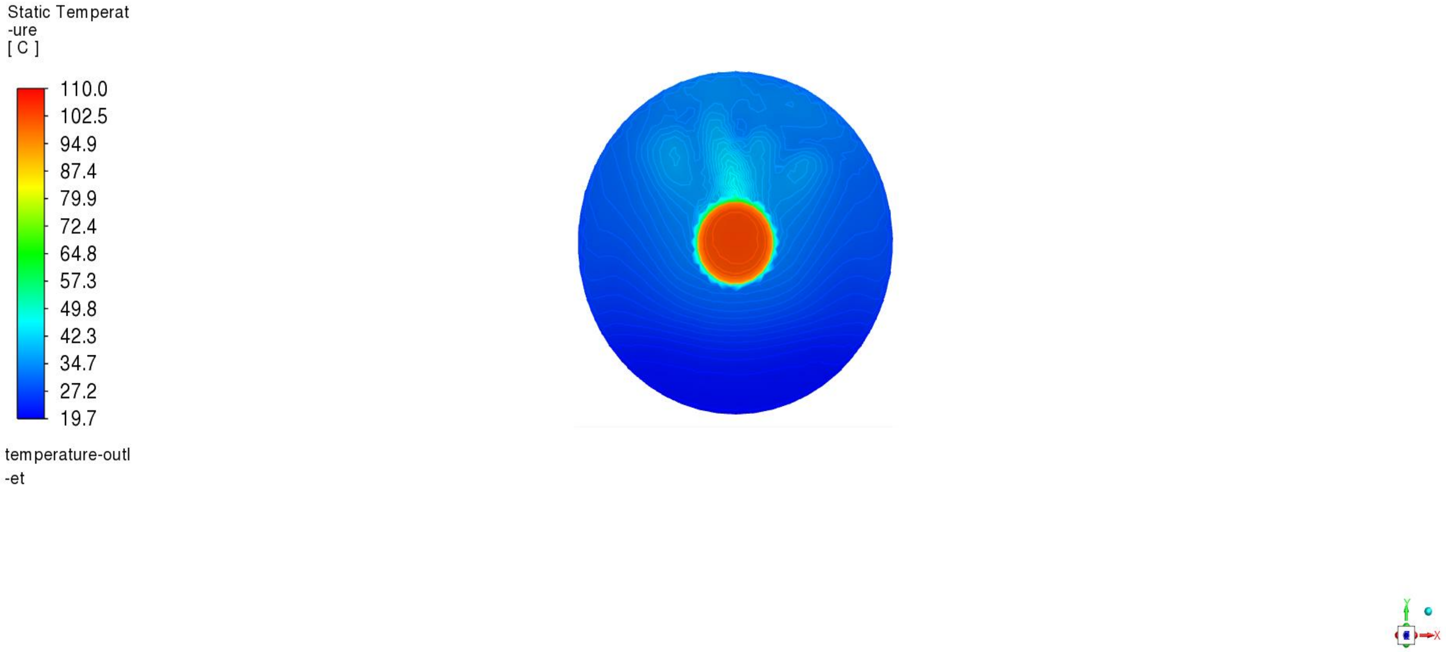
max-temp-hd-hcal-rplot



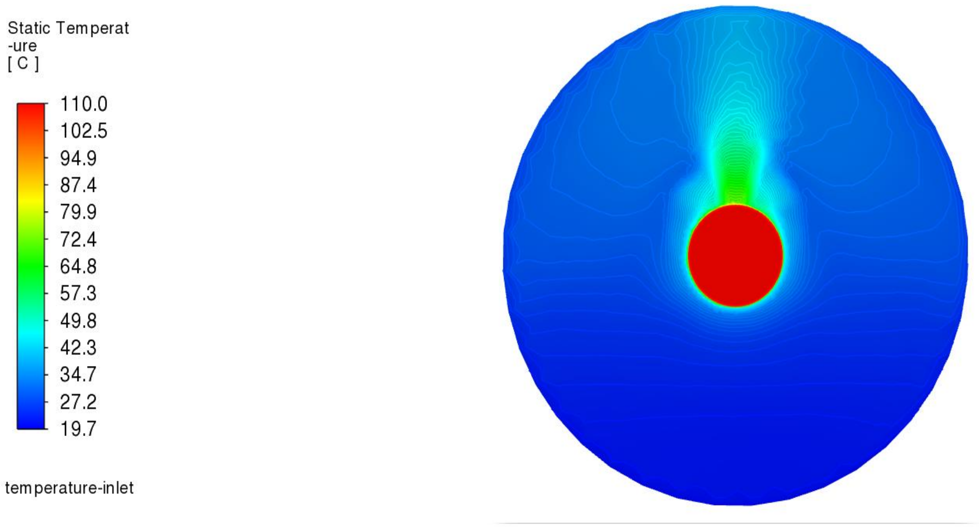
Contour Plots

The plots show the distribution of temperature, allowing the identification of the high temperature areas and the gradient of the heat transfer between the beampipe air flow and detectors.

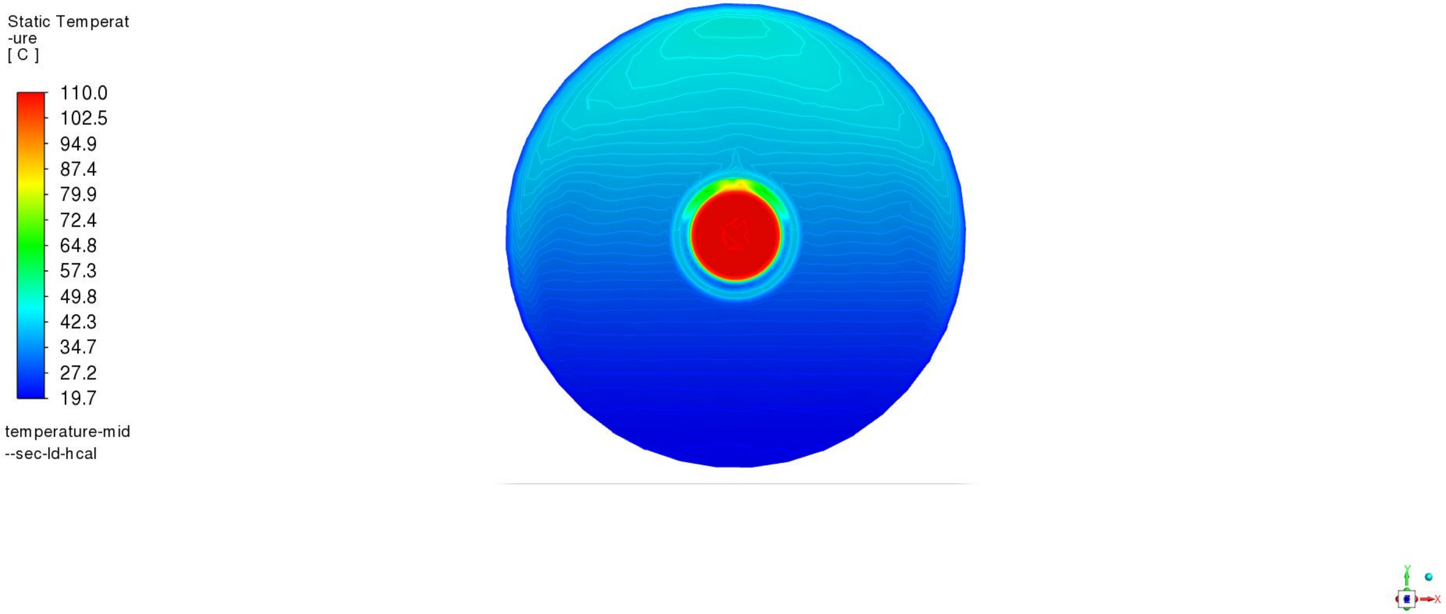
temperature-outlet



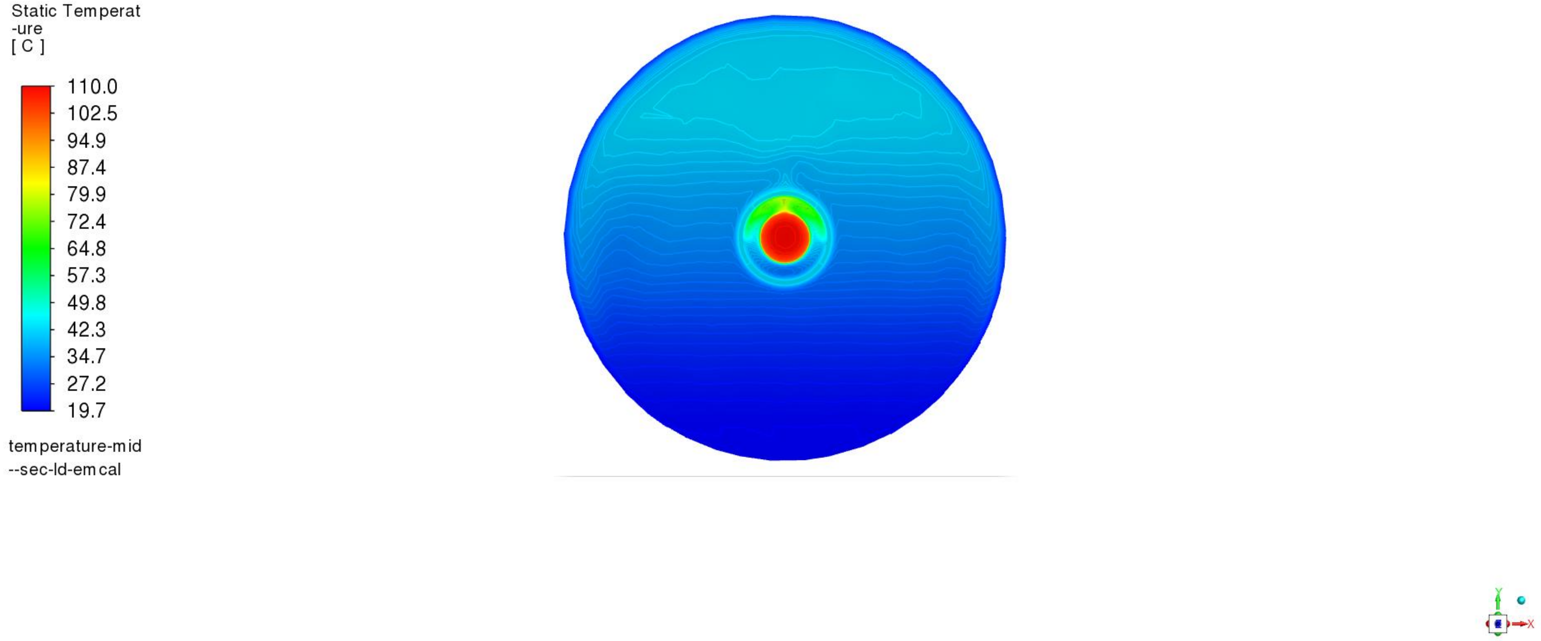
temperature-inlet



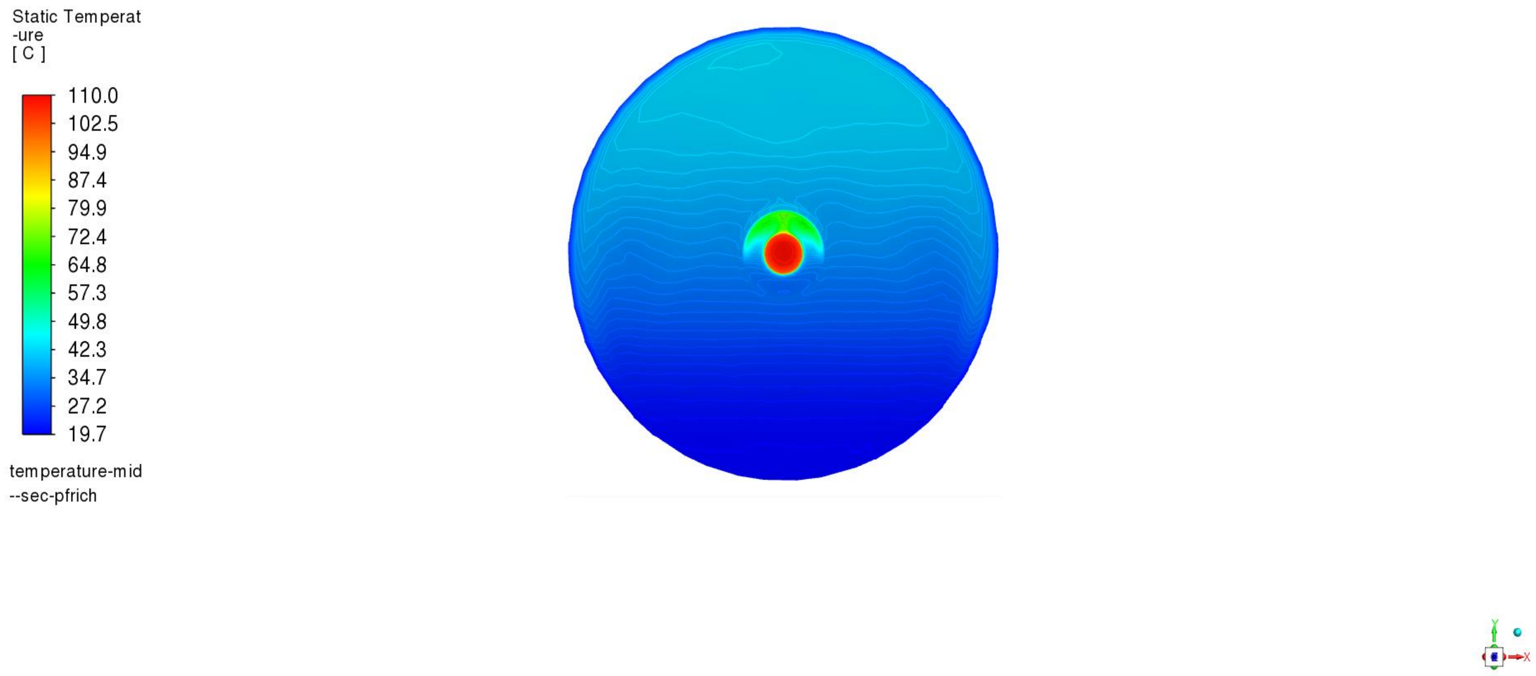
temperature-mid-sec-ld-hcal



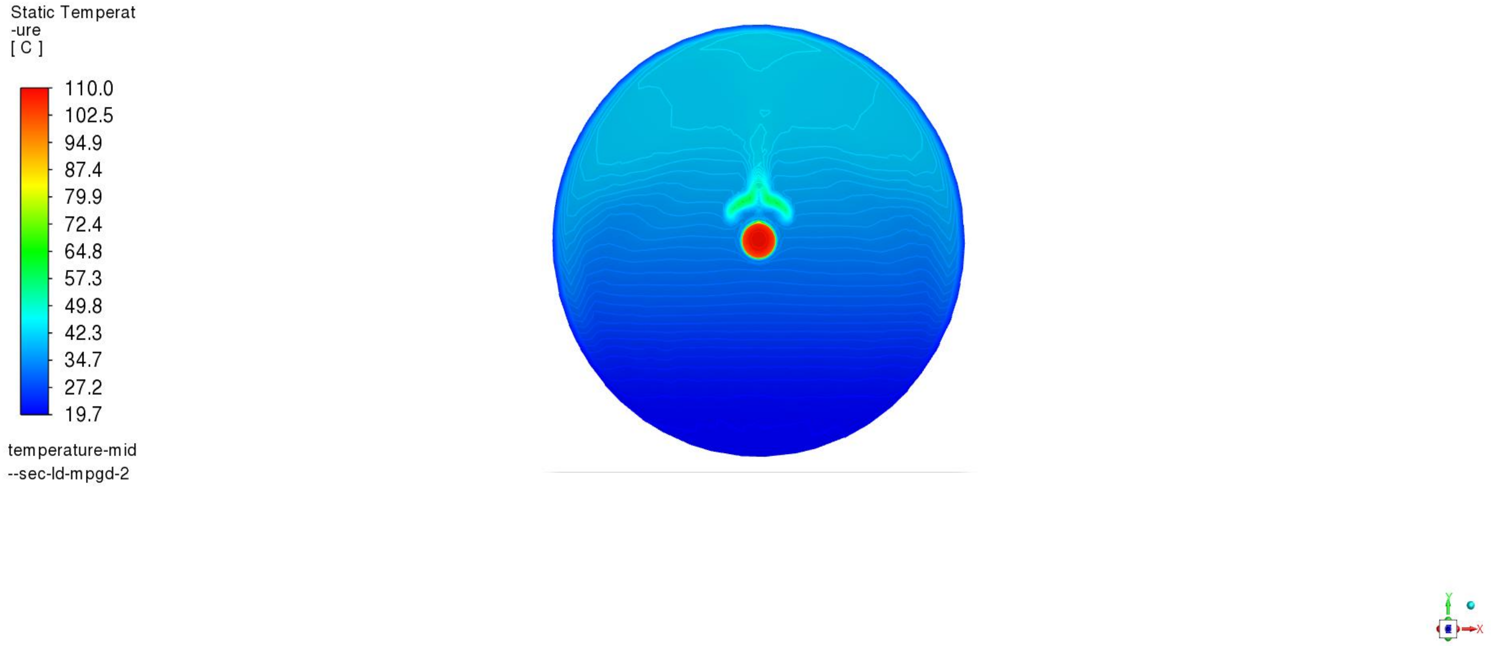
temperature-mid-sec-ld-emcal



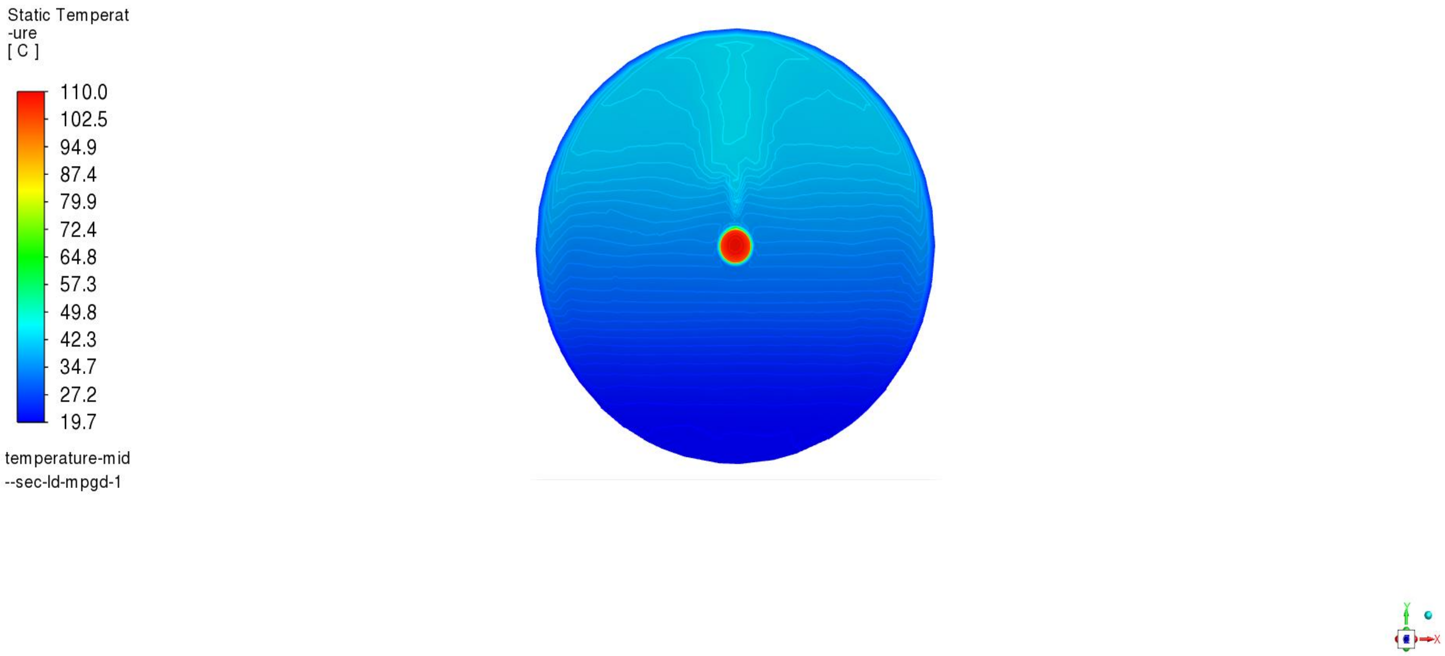
temperature-mid-sec-pfrich



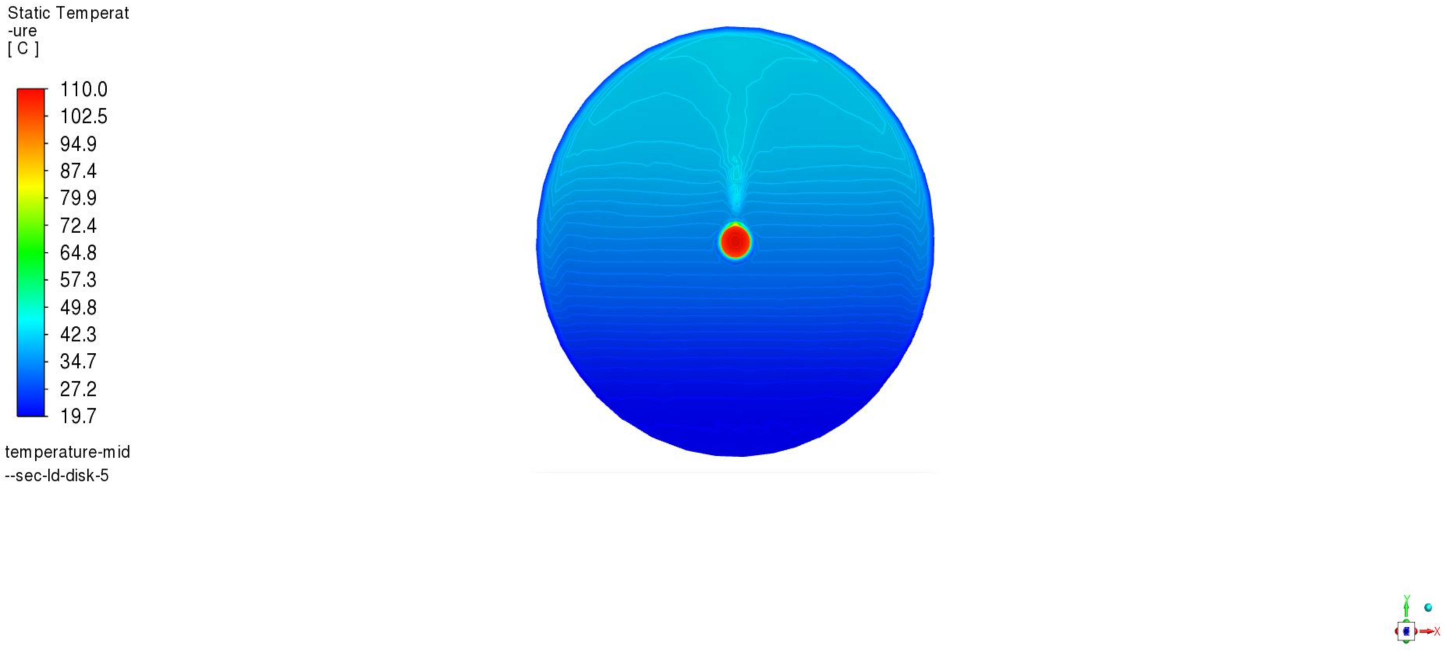
temperature-mid-sec-ld-mpgd-2



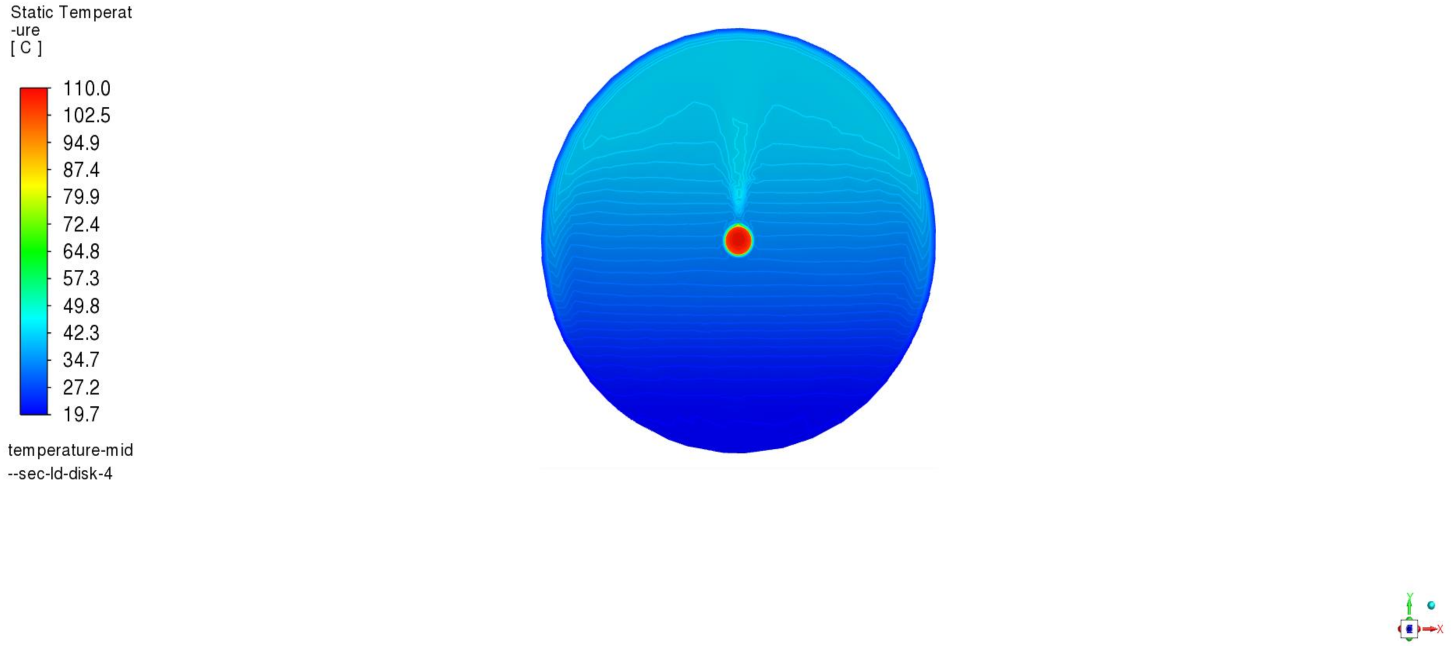
temperature-mid-sec-ld-mpgd-1



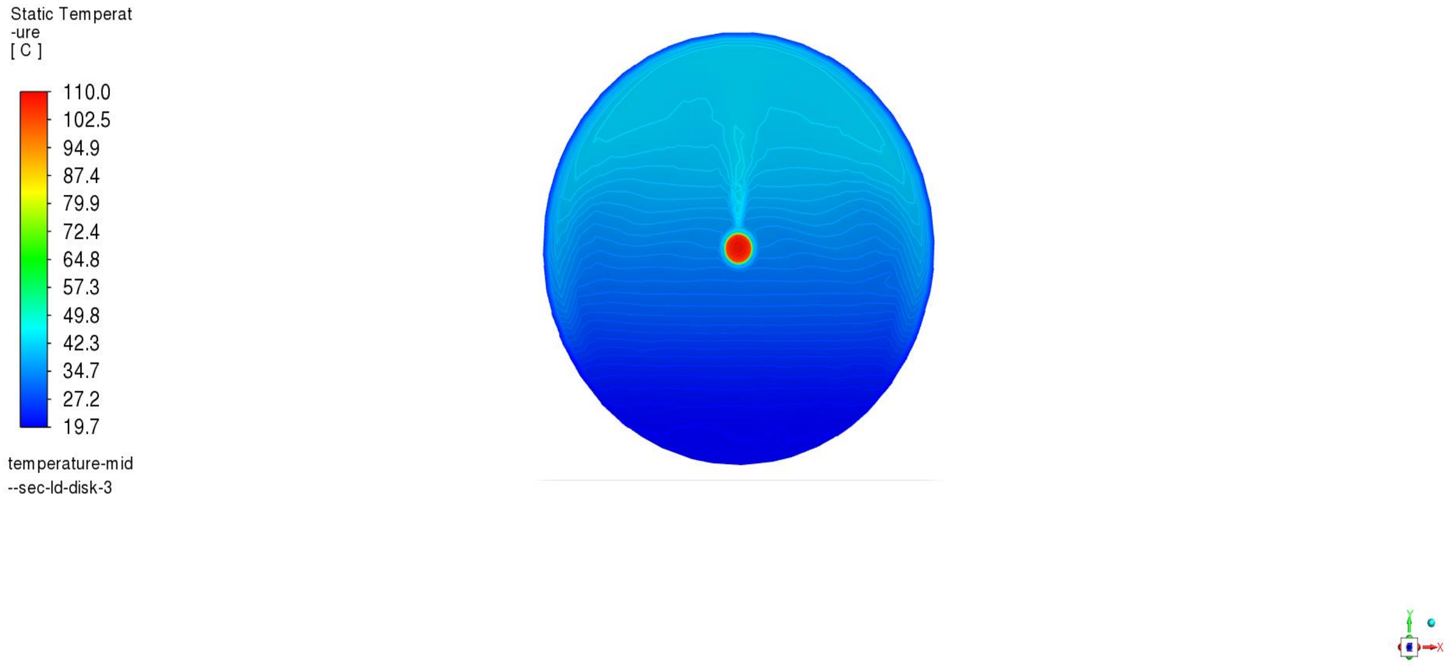
temperature-mid-sec-ld-disk-5



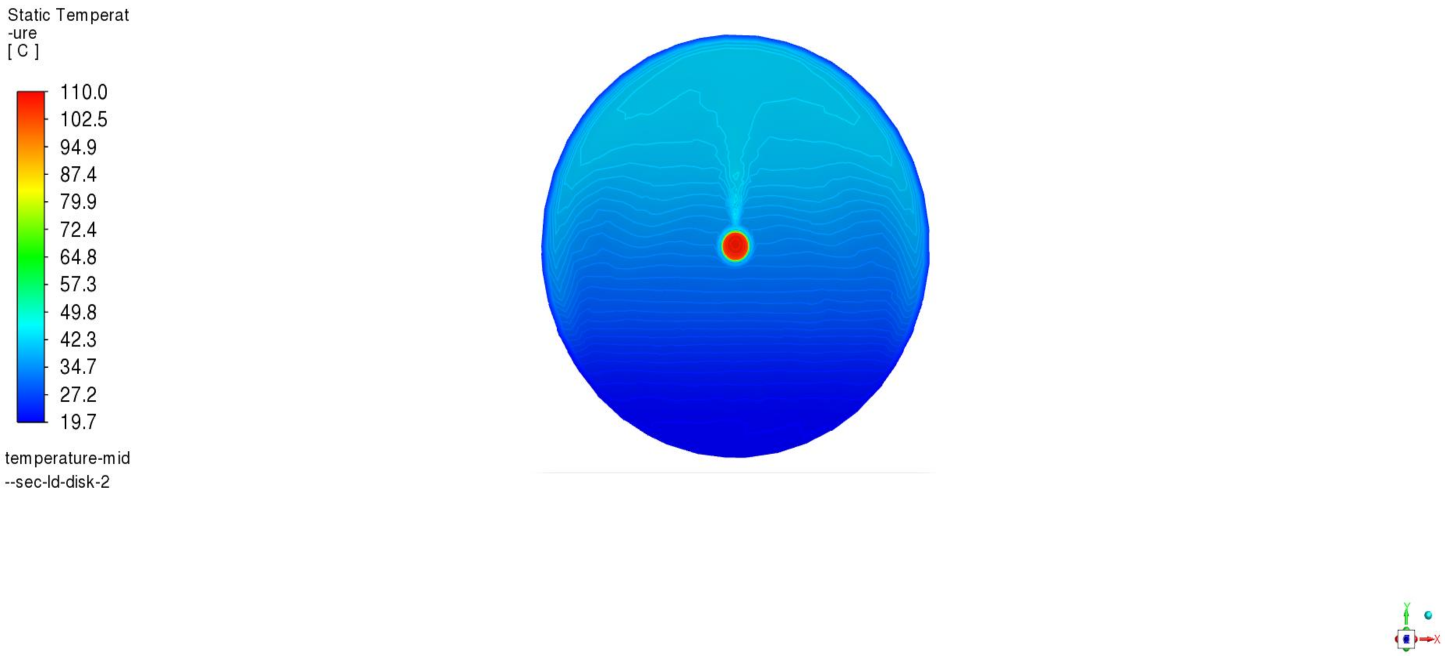
temperature-mid-sec-ld-disk-4



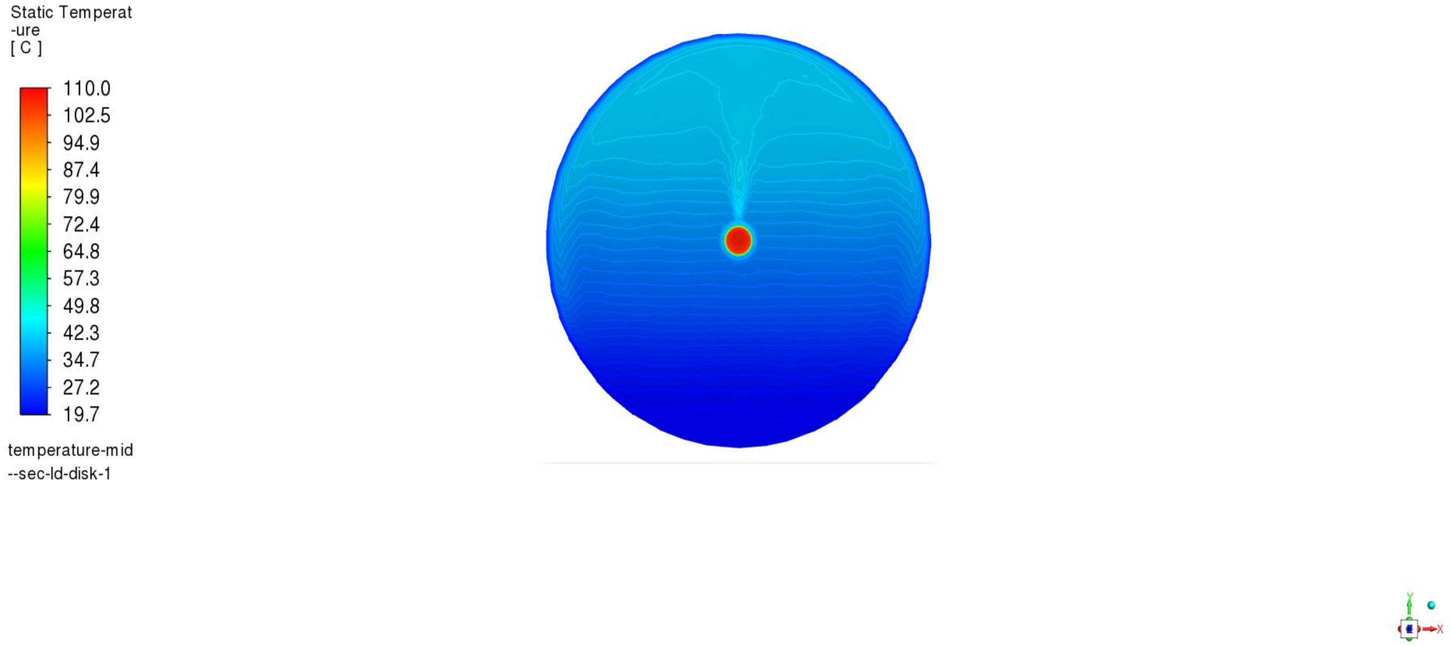
temperature-mid-sec-ld-disk-3



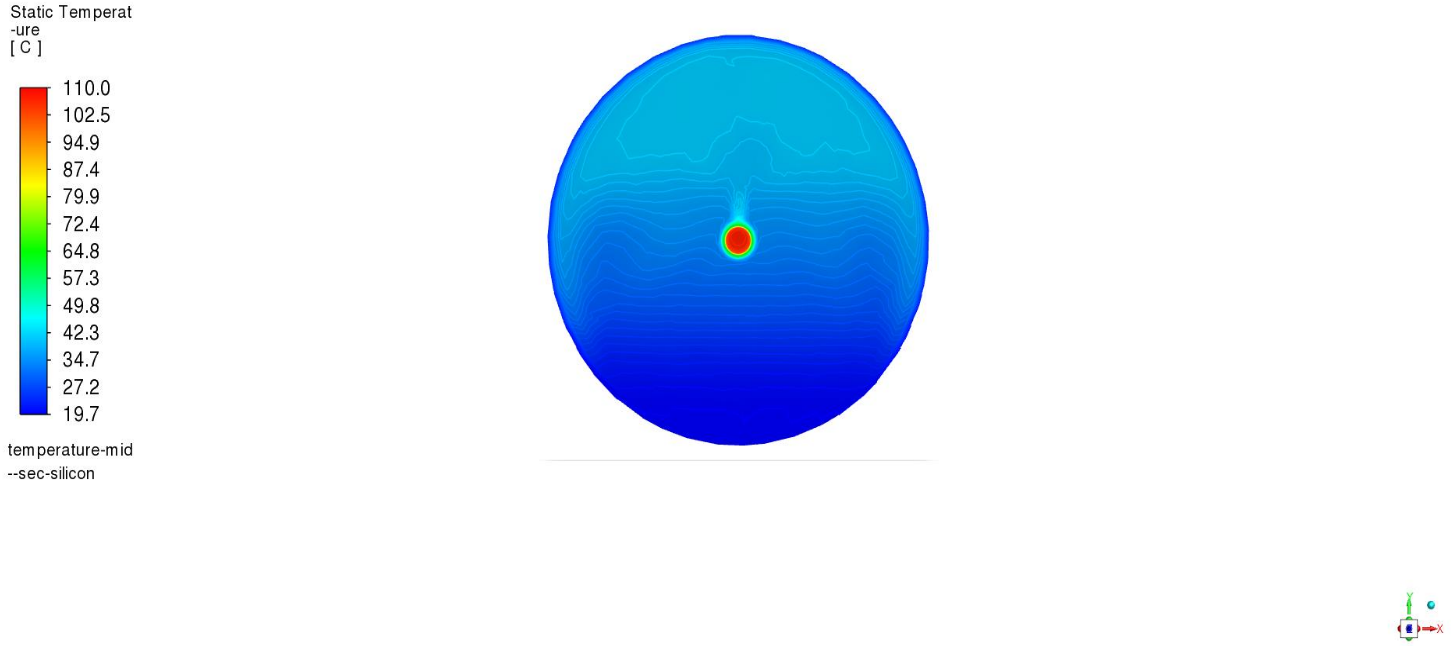
temperature-mid-sec-ld-disk-2



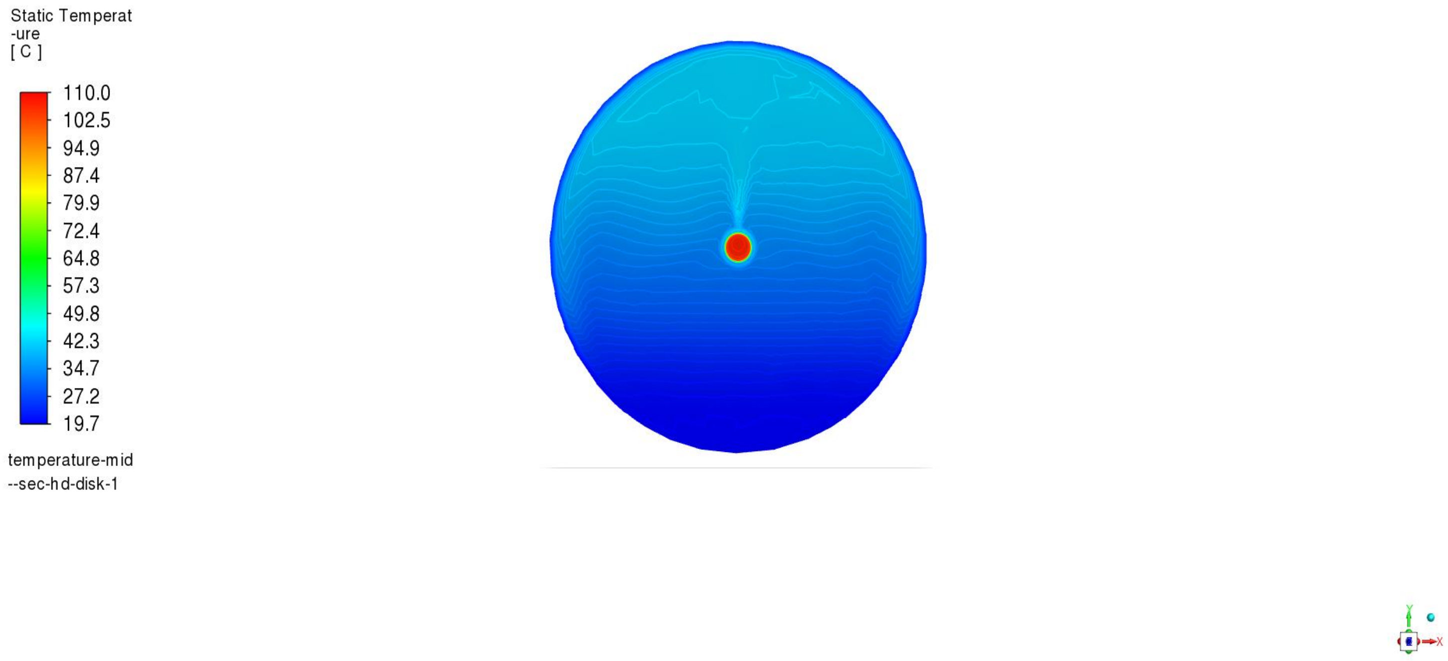
temperature-mid-sec-ld-disk-1



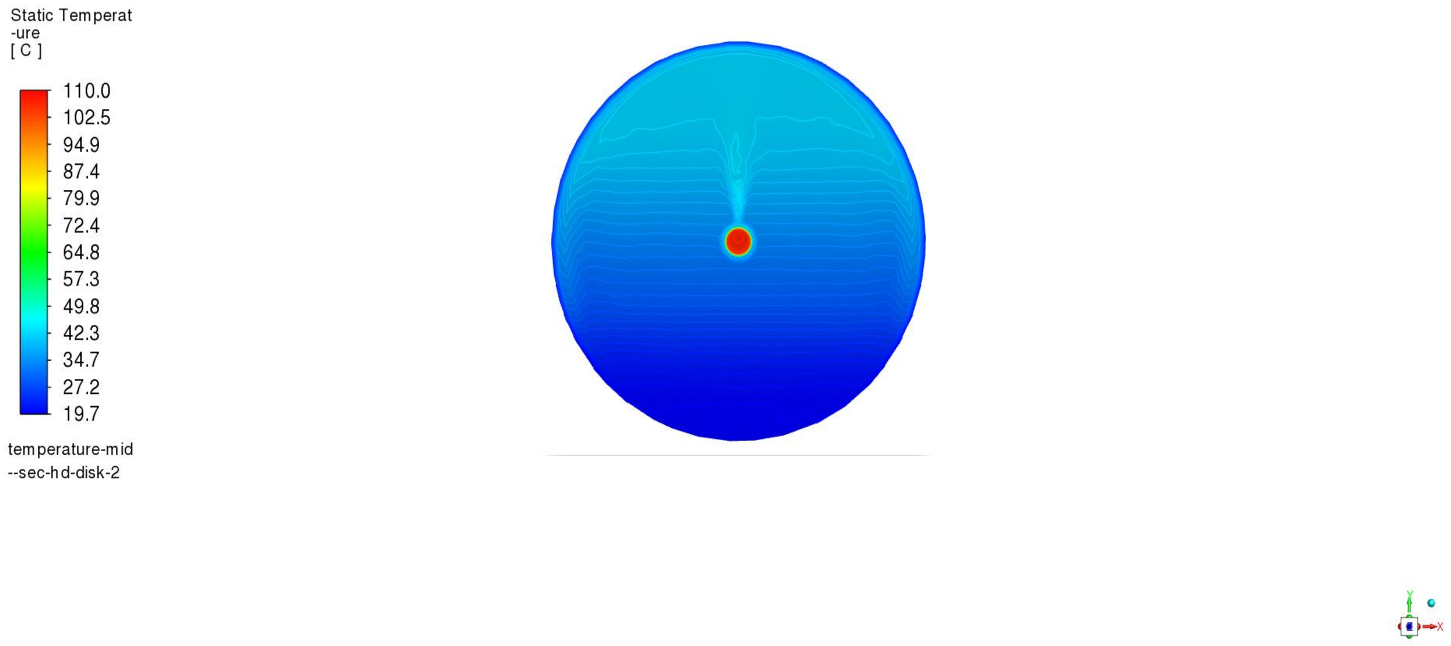
temperature-mid-sec-silicon-barrel



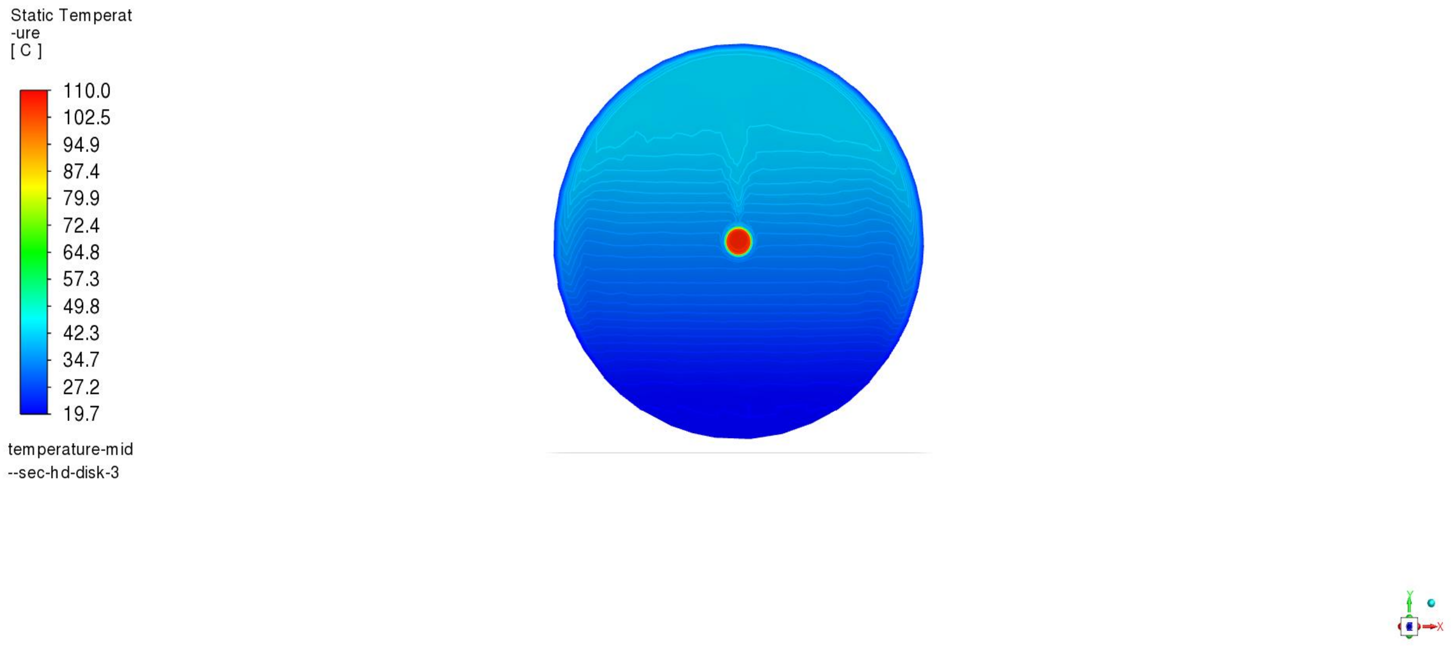
temperature-mid-sec-hd-disk-1



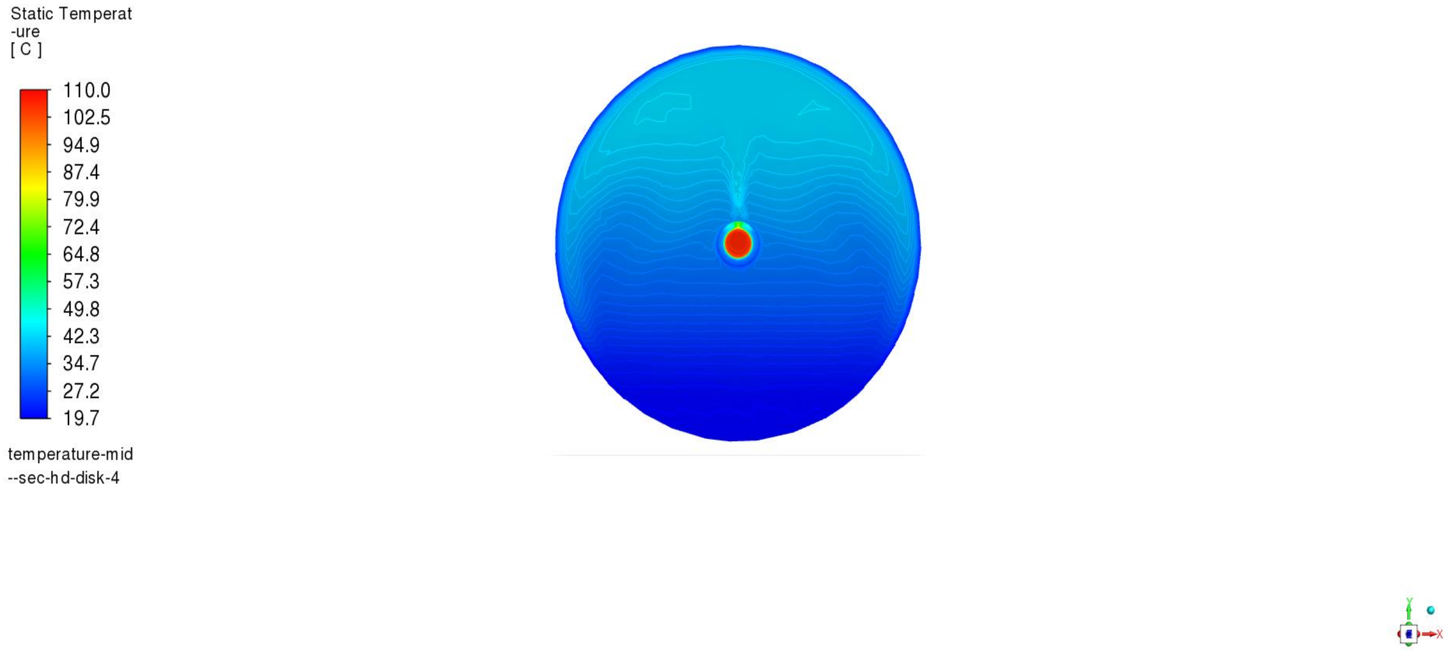
temperature-mid-sec-hd-disk-2



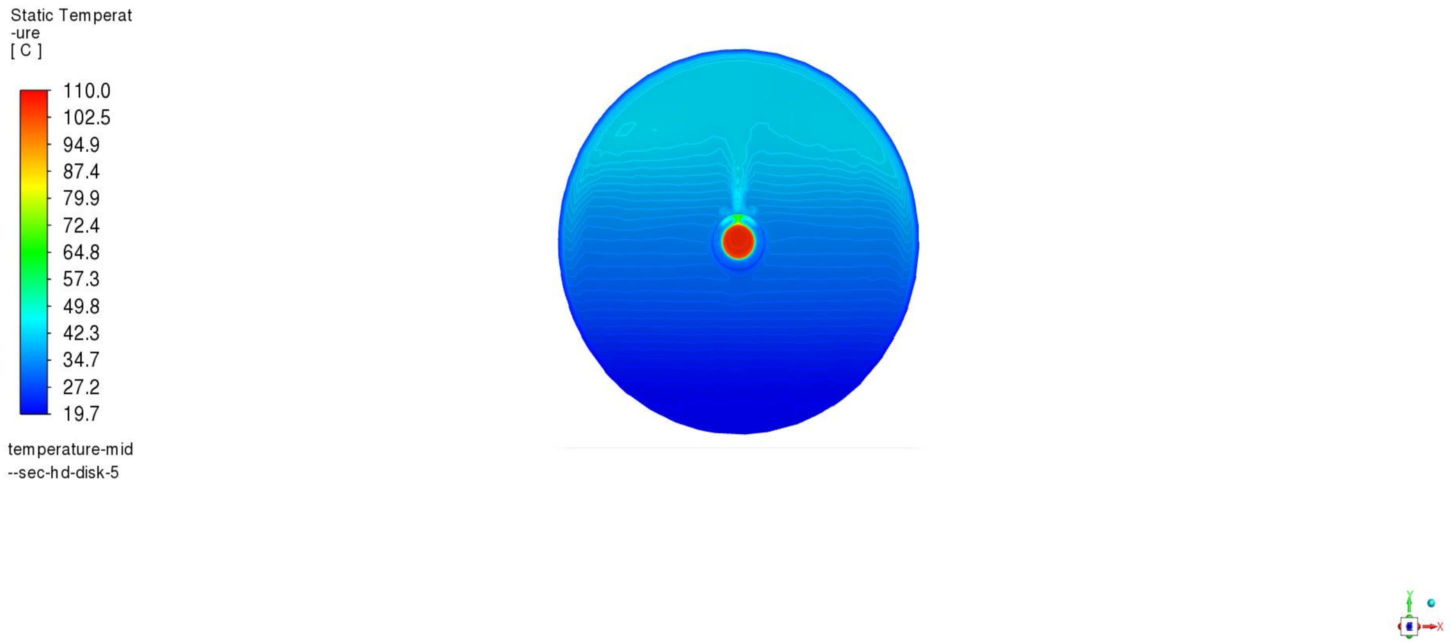
temperature-mid-sec-hd-disk-3



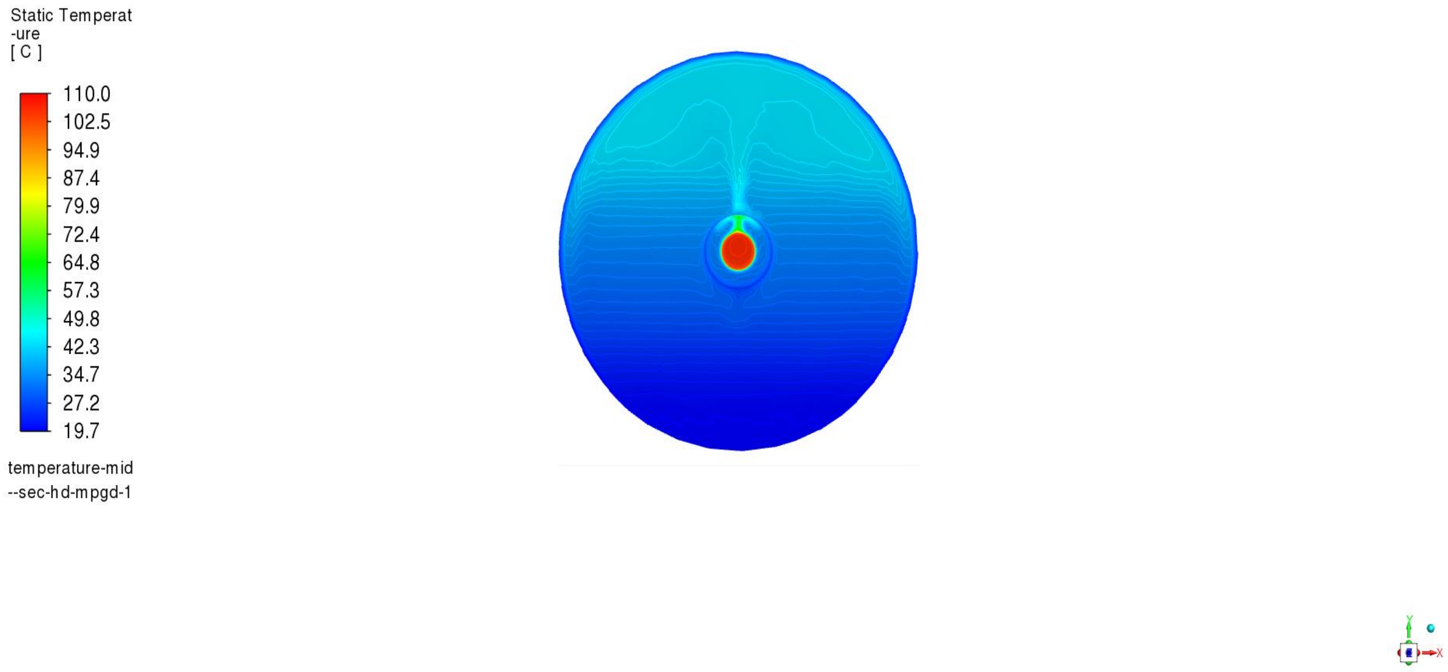
temperature-mid-sec-hd-disk-4



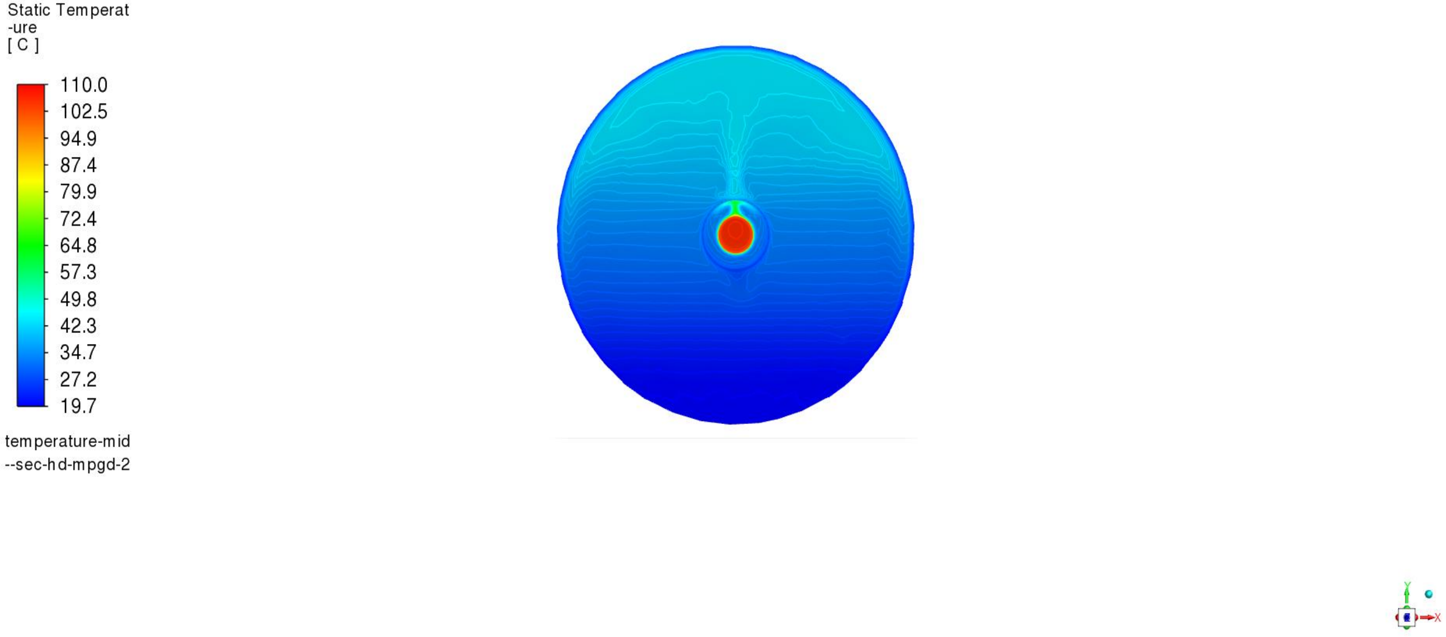
temperature-mid-sec-hd-disk-5



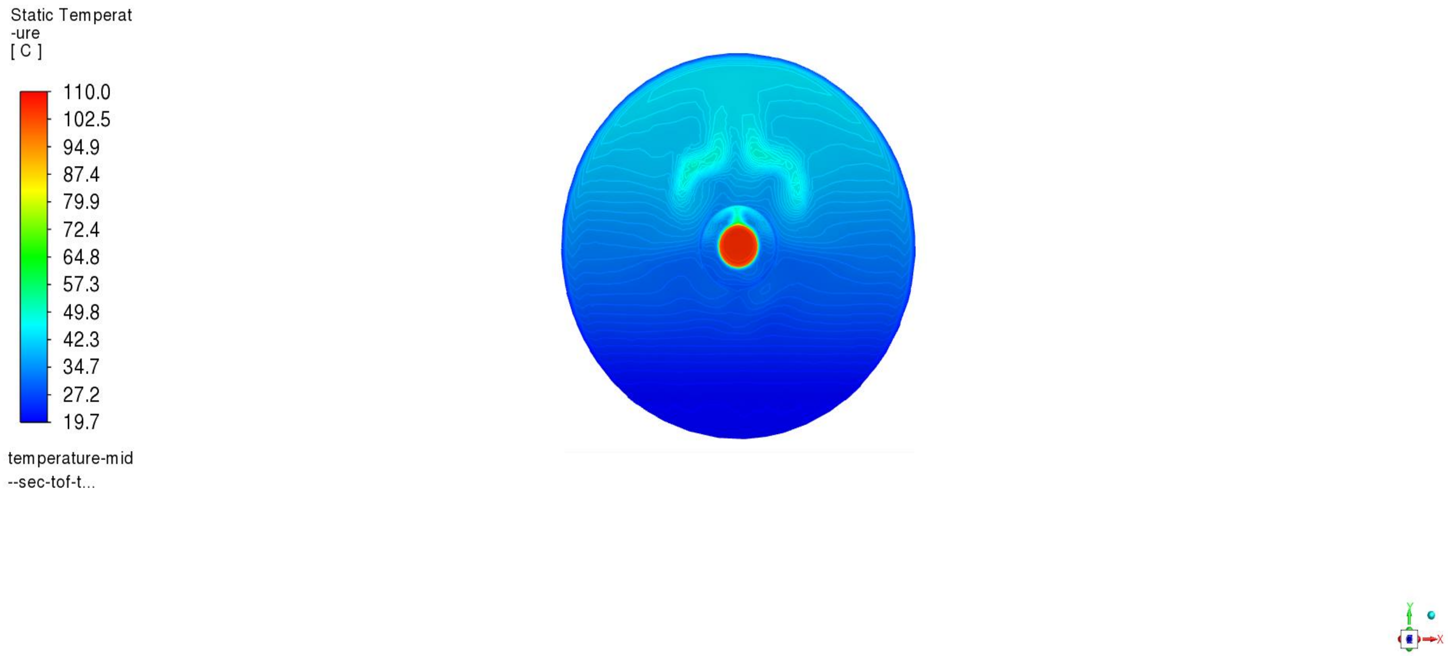
temperature-mid-sec-hd-mpgd-1



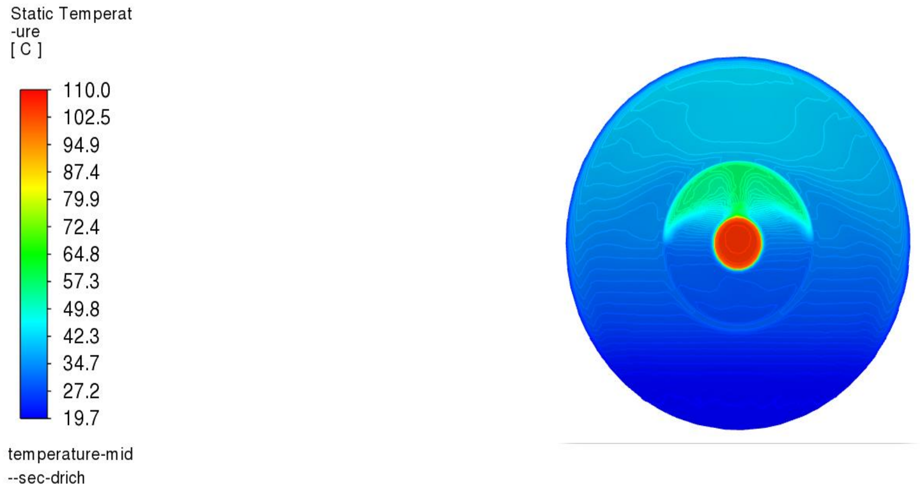
temperature-mid-sec-hd-mpgd-2



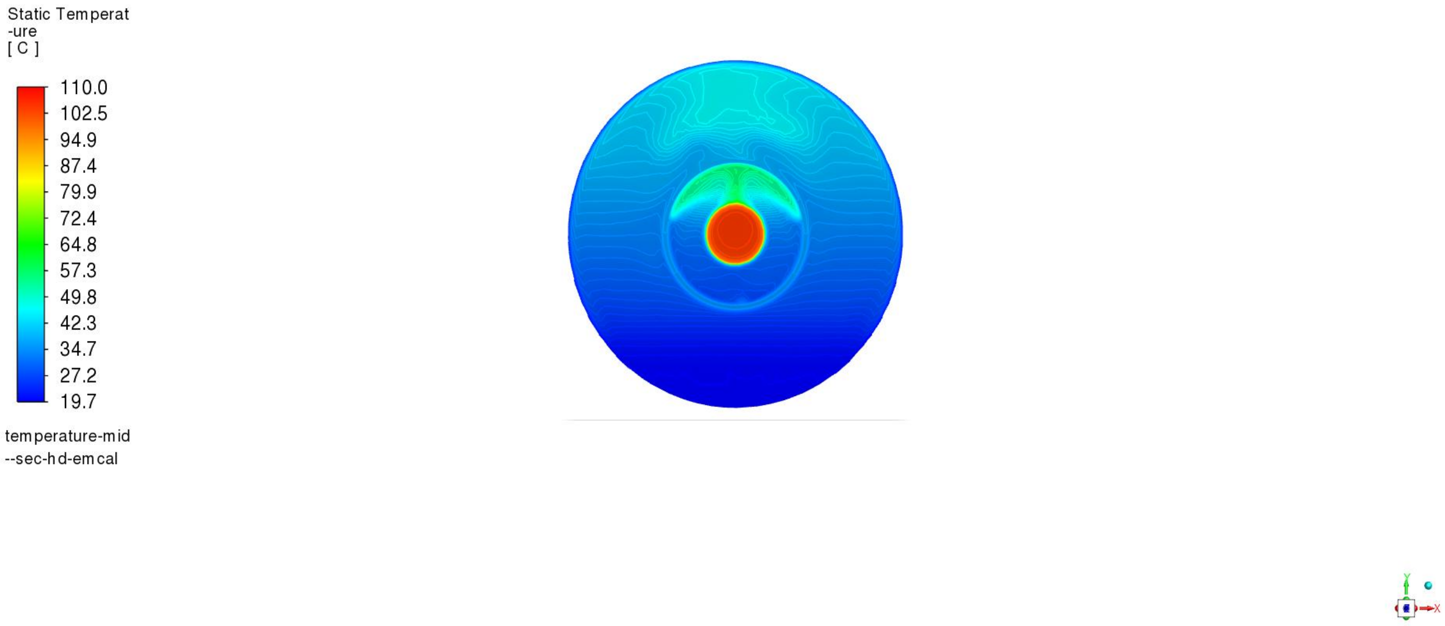
temperature-mid-sec-tof-tracker



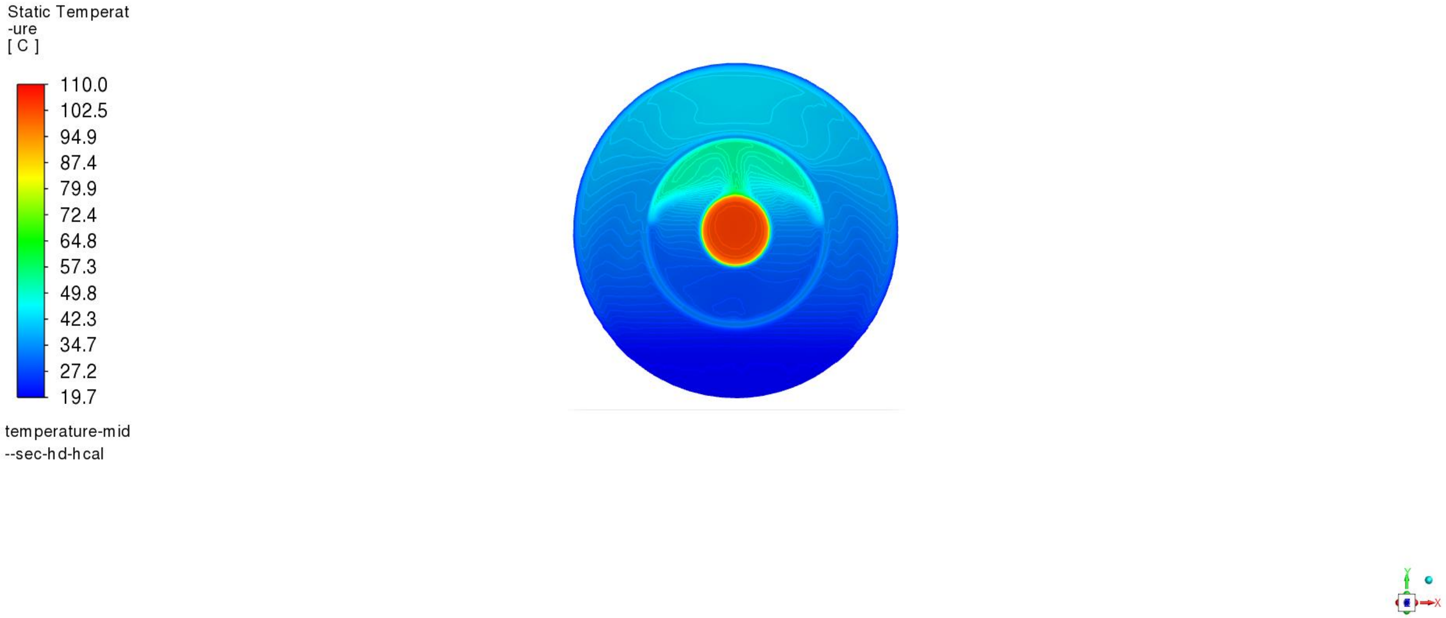
temperature-mid-sec-drich



temperature-mid-sec-hd-emcal



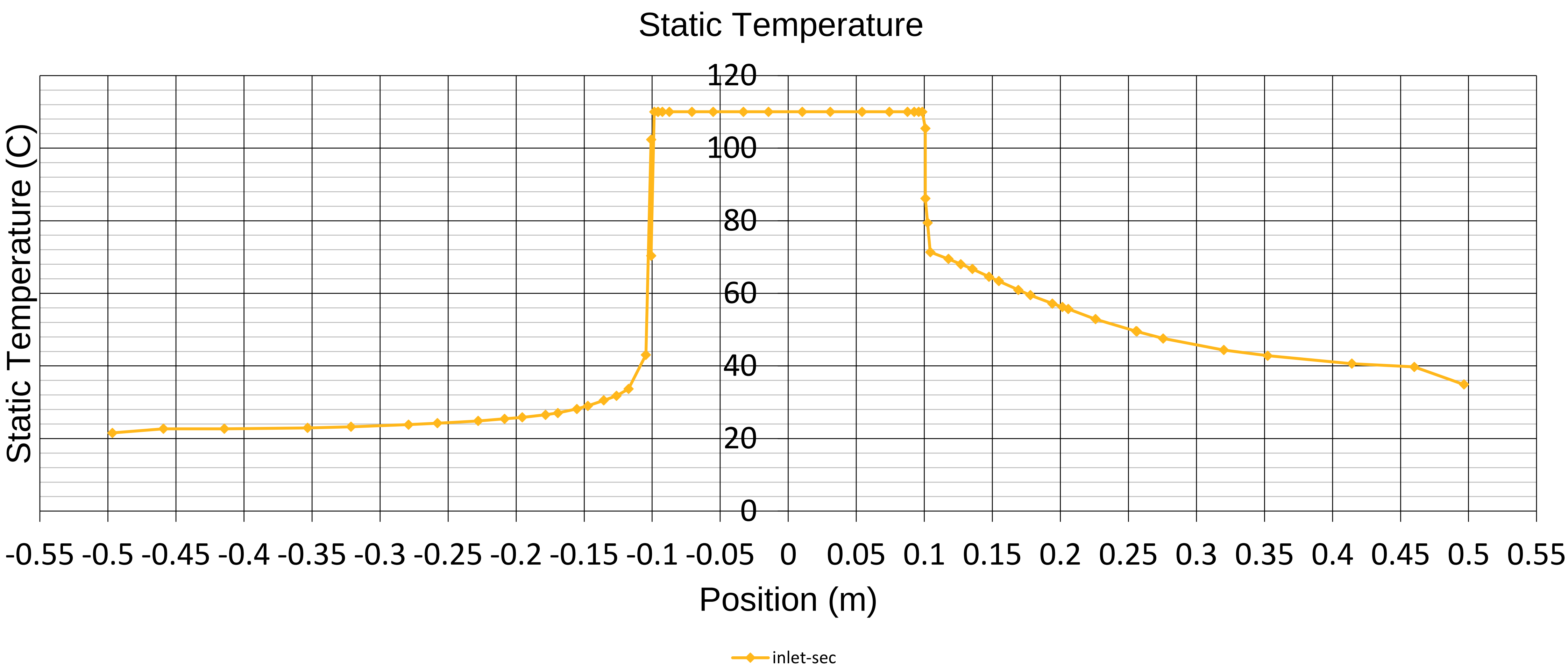
temperature-mid-sec-hd-hcal



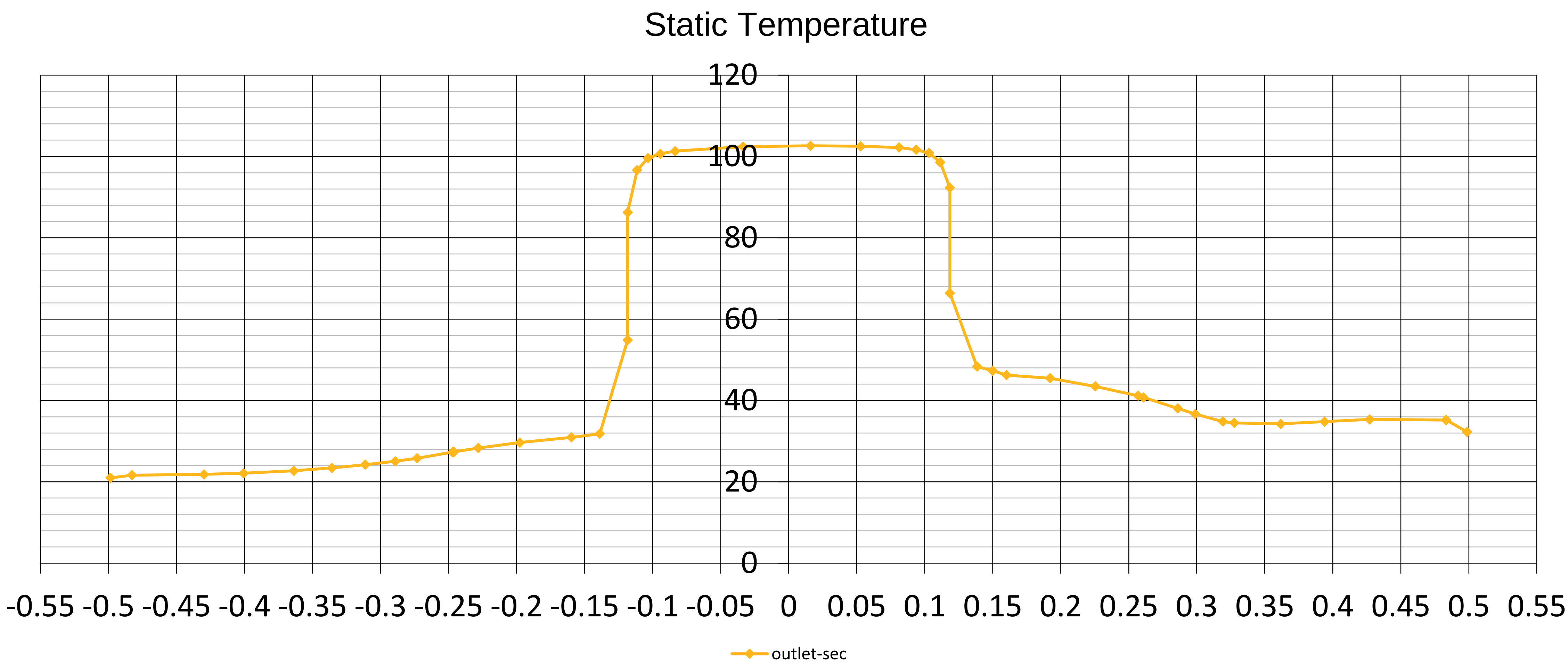
XY Plots

Show each detector’s mid-section, and the beampipe’s inlet and outlet sections. These plots allow the rough estimation of the detector's diameter.

temp-vs-pos-inlet-sec

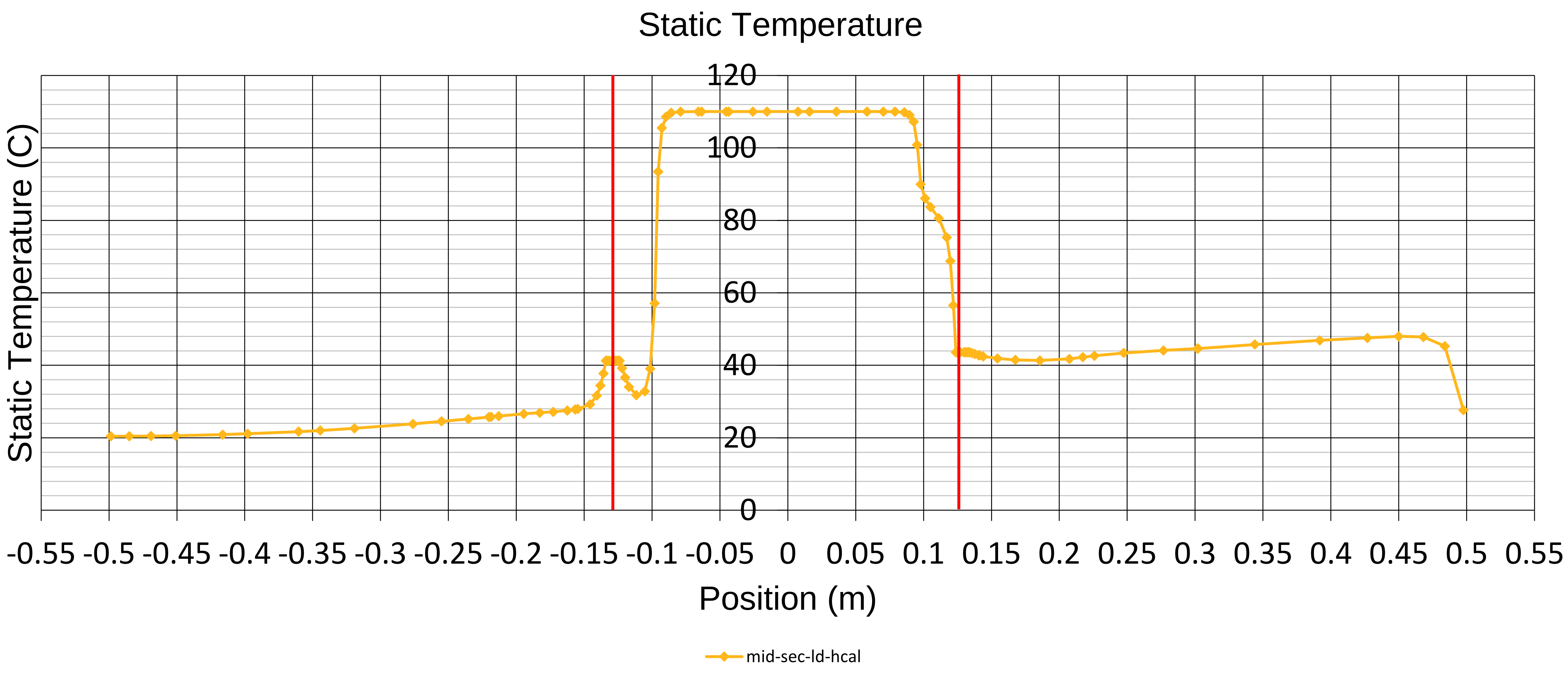


temp-vs-pos-outlet-sec



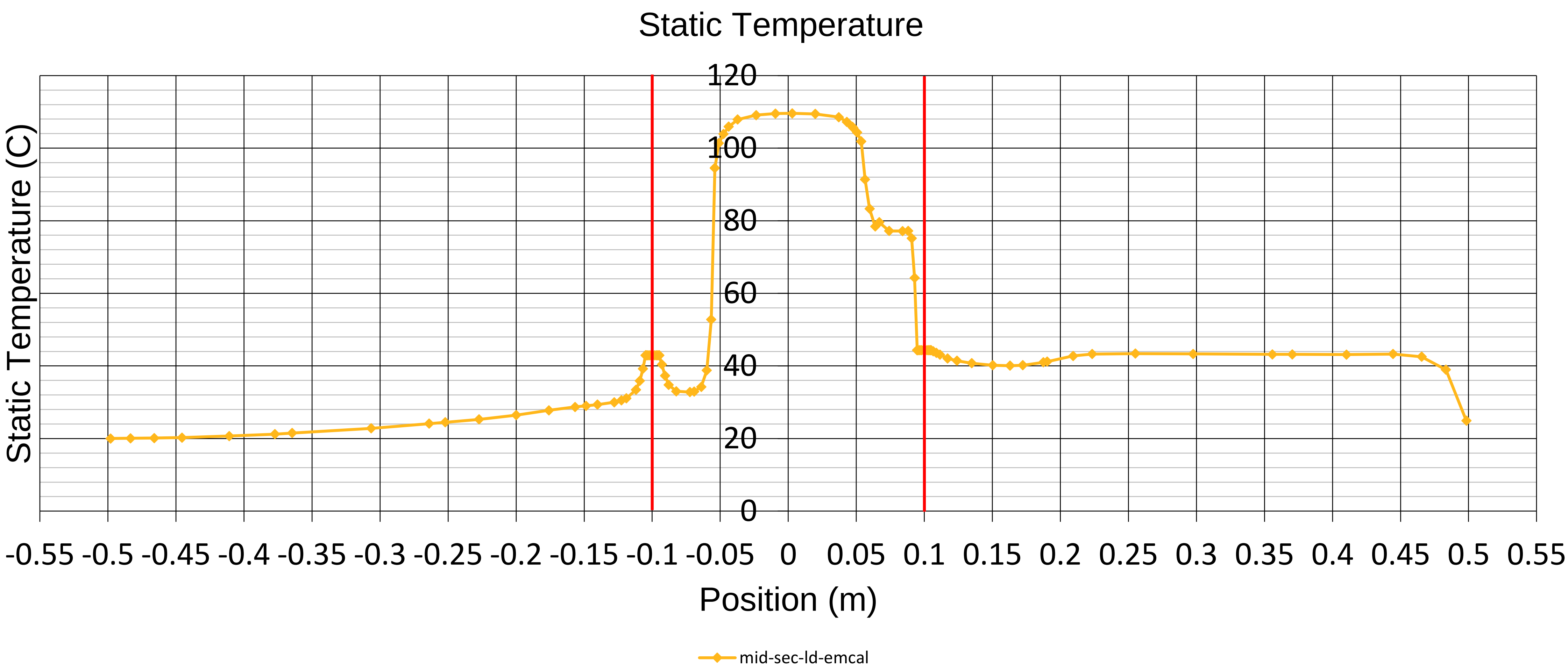
temp-vs-pos-mid-sec-ld-hcal

Detector ⌀ = 0.248 m



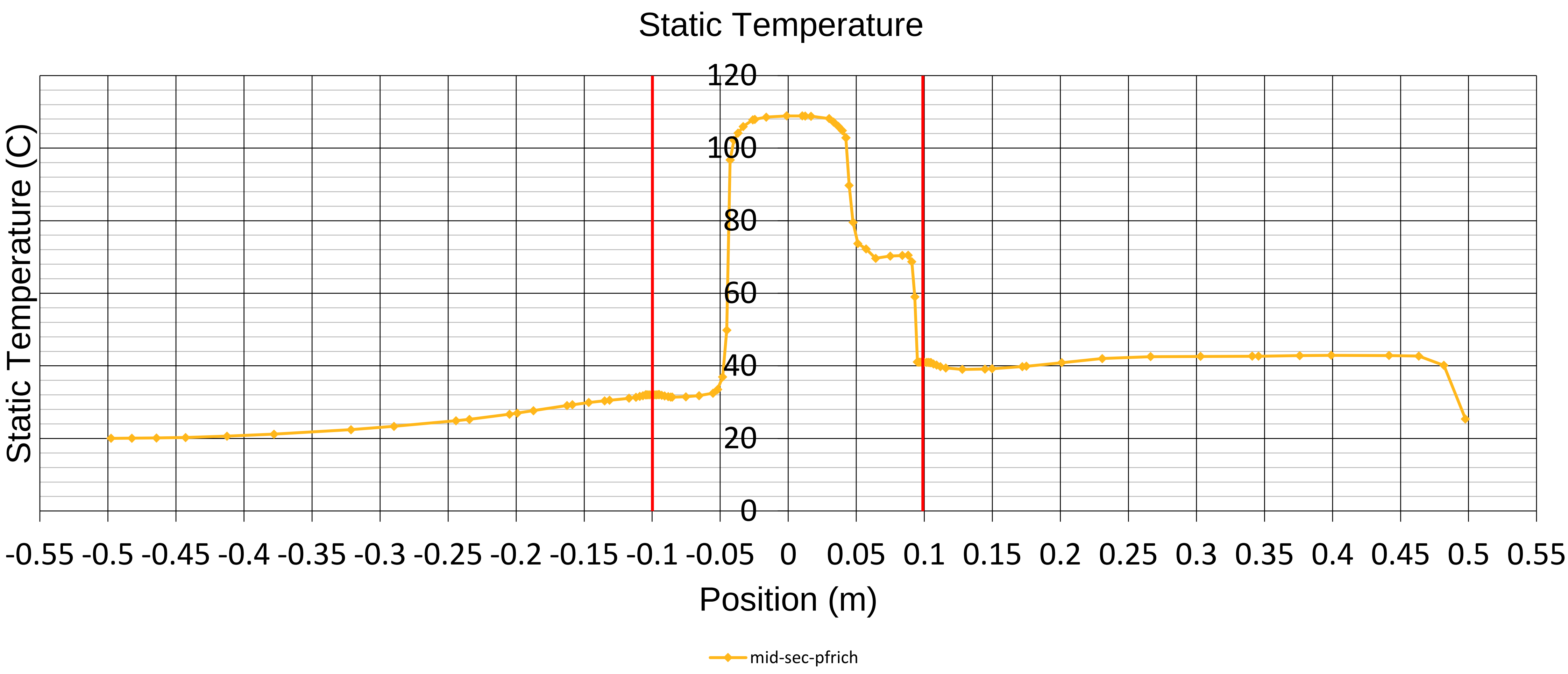
temp-vs-pos-mid-sec-ld-emcal

Detector ⌀ = 0.190 m



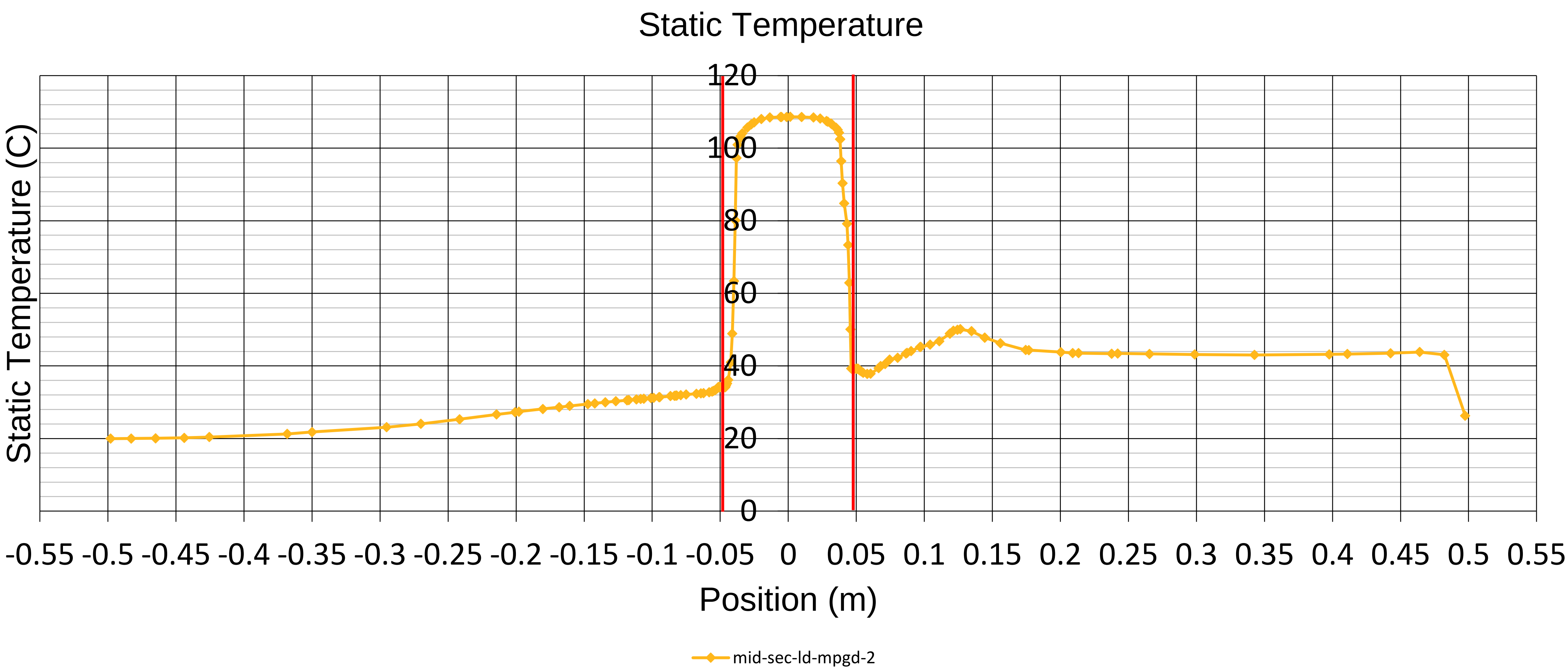
temp-vs-pos-mid-sec-pfrich

Detector ⌀ = 0.190 m



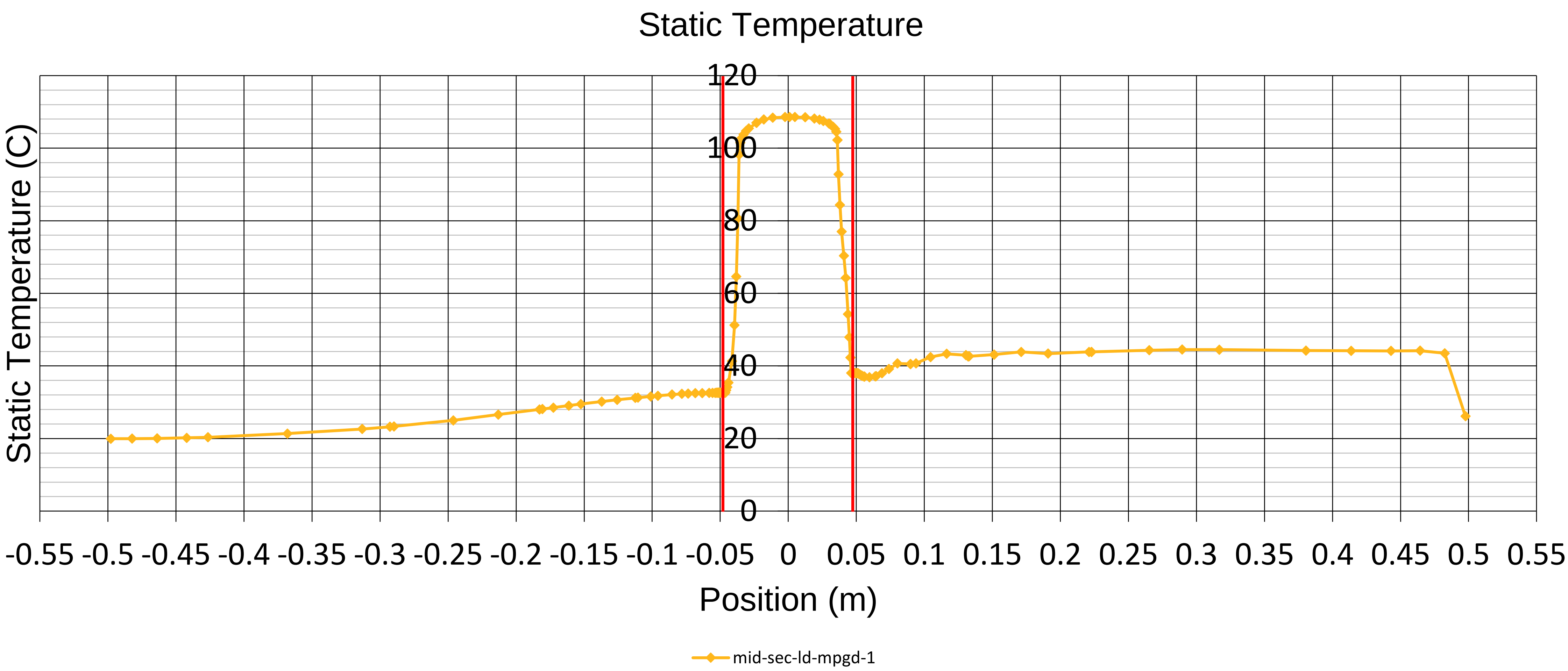
temp-vs-pos-mid-sec-ld-mpgd-2

Detector ⌀ = 0.0927 m



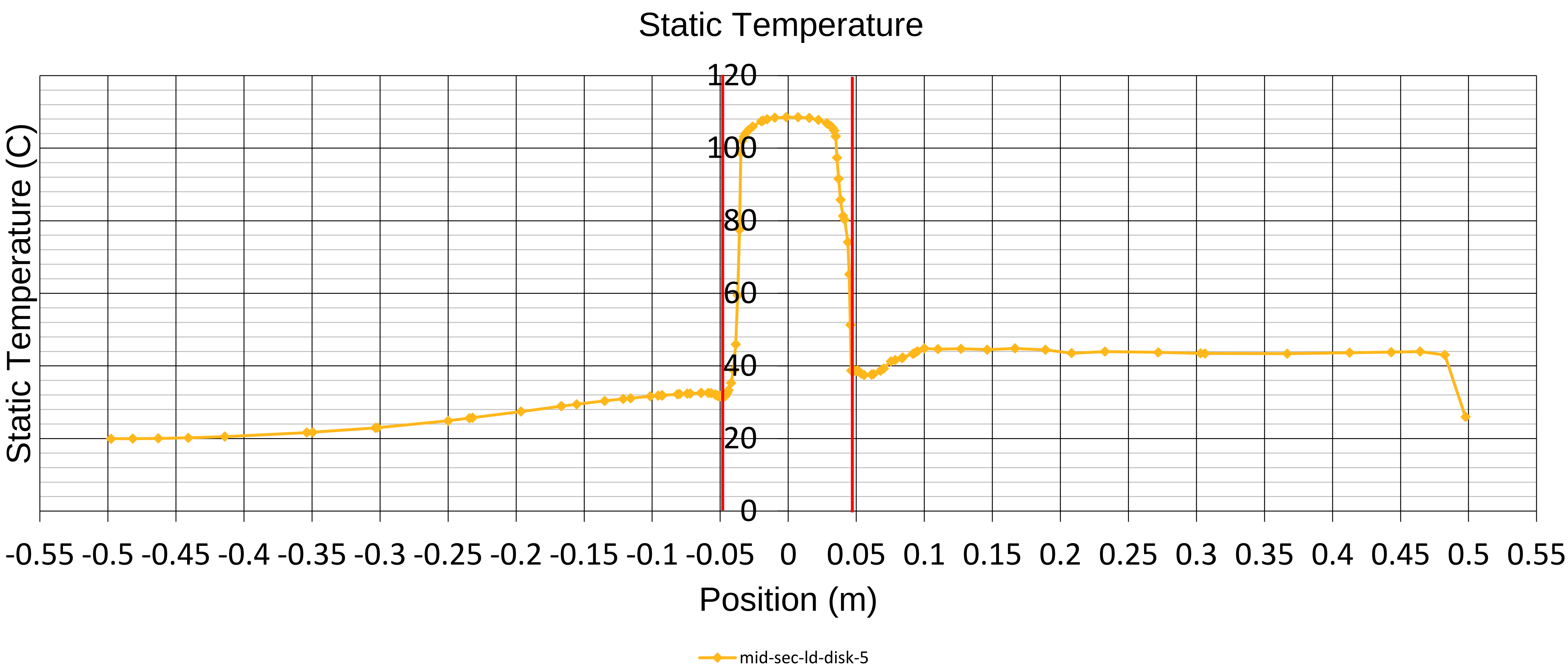
temp-vs-pos-mid-sec-ld-mpgd-1

Detector ⌀ = 0.0927 m



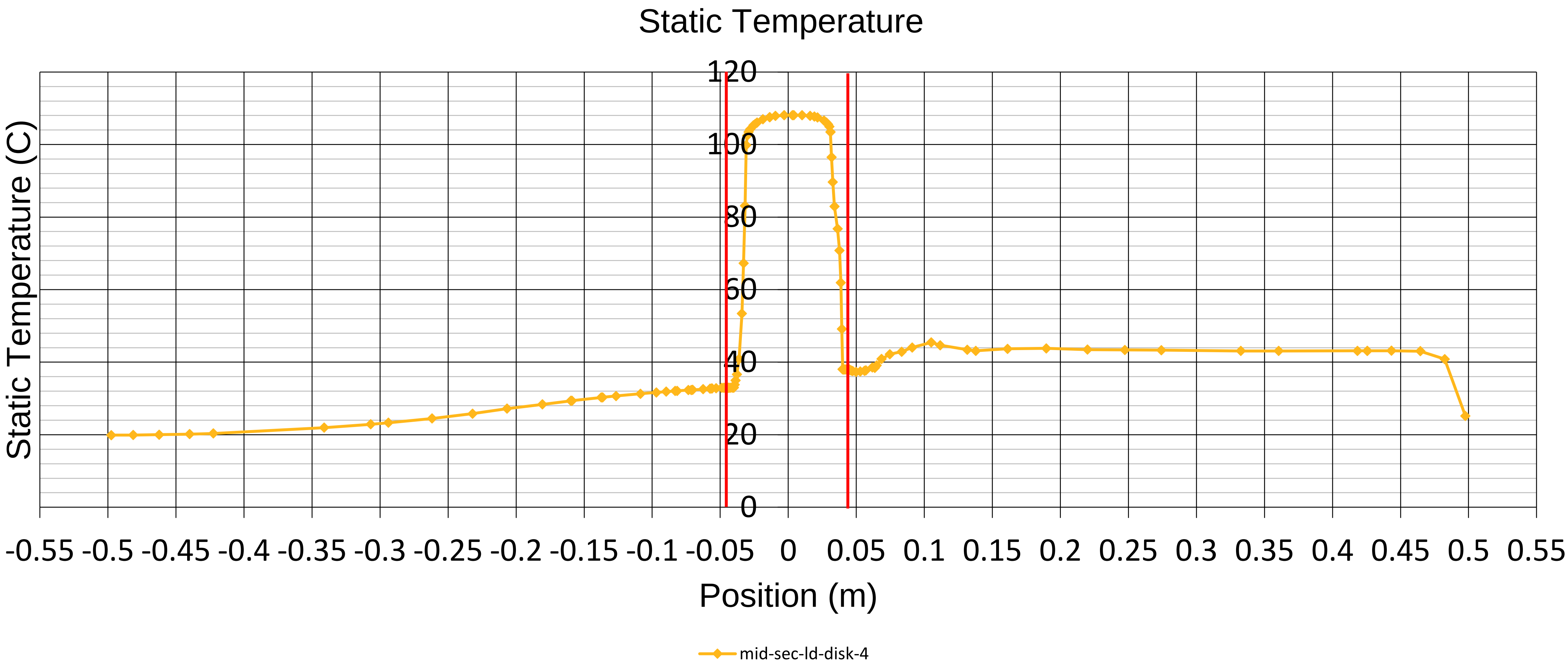
temp-vs-pos-mid-sec-ld-disk-5

Detector ⌀ = 0.0927 m



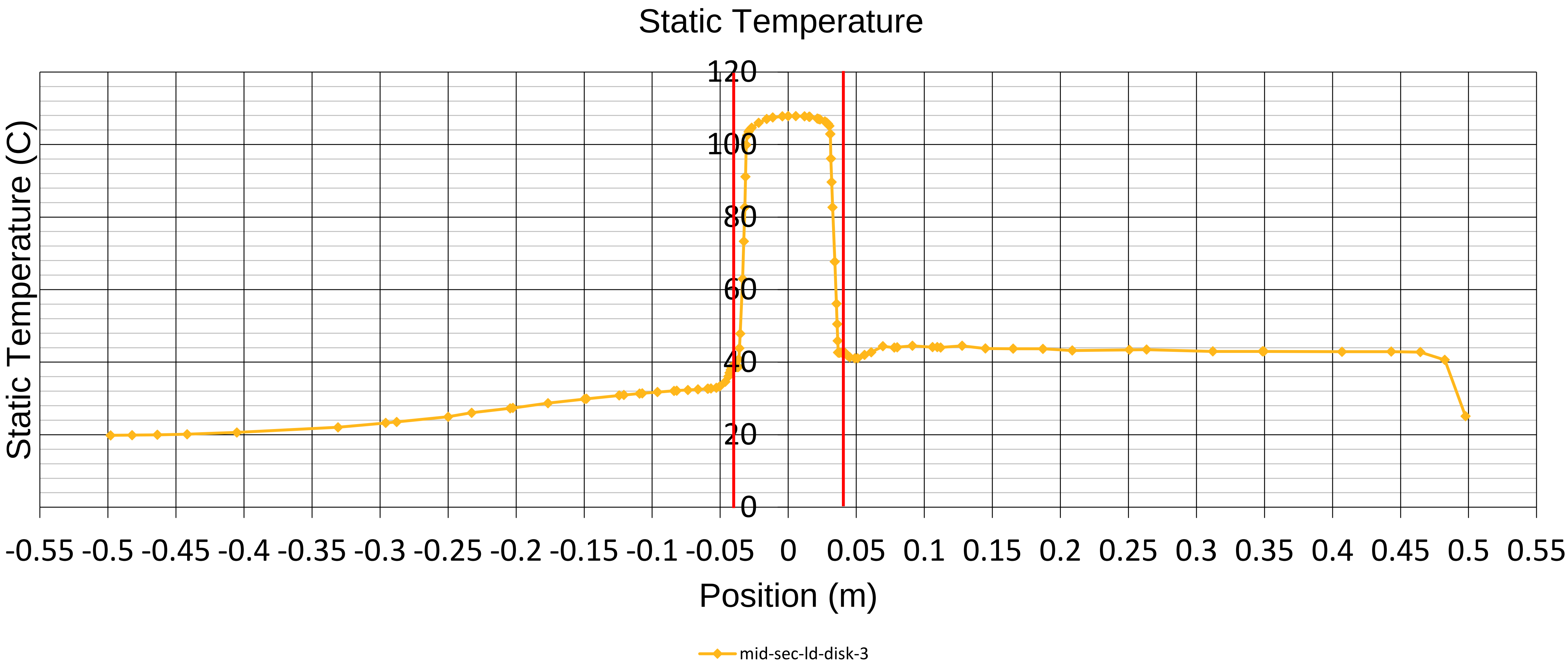
temp-vs-pos-mid-sec-ld-disk-4

Detector ⌀ = 0.08012 m



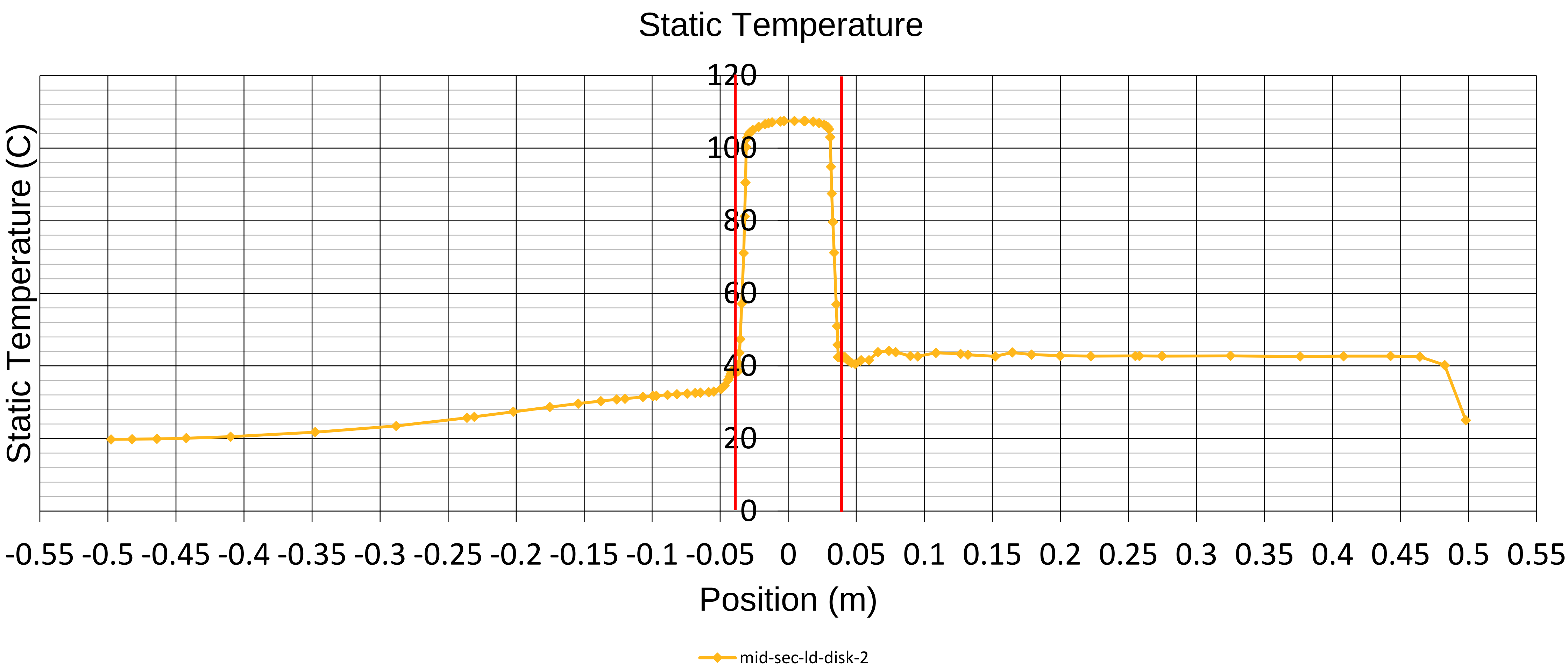
temp-vs-pos-mid-sec-ld-disk-3

Detector ⌀ = 0.07352 m



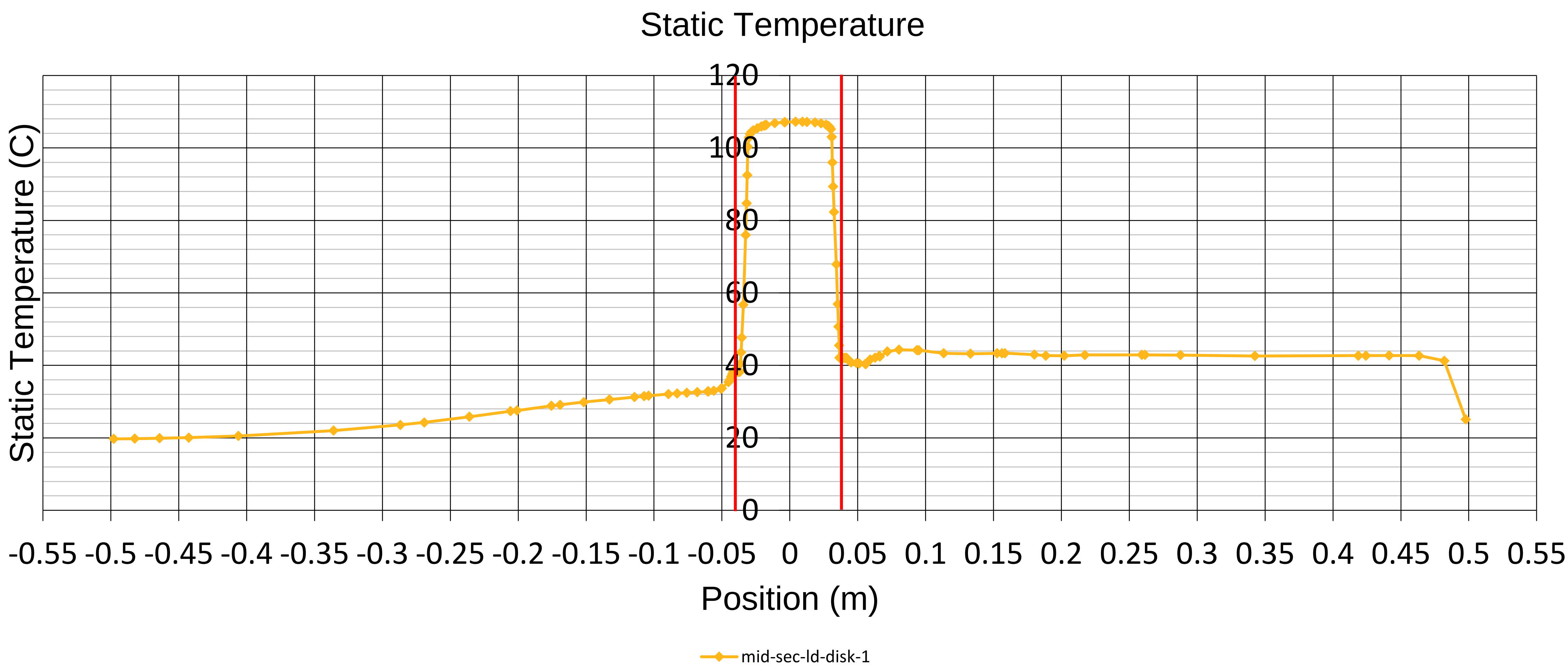
temp-vs-pos-mid-sec-ld-disk-2

Detector ⌀ = 0.07352 m



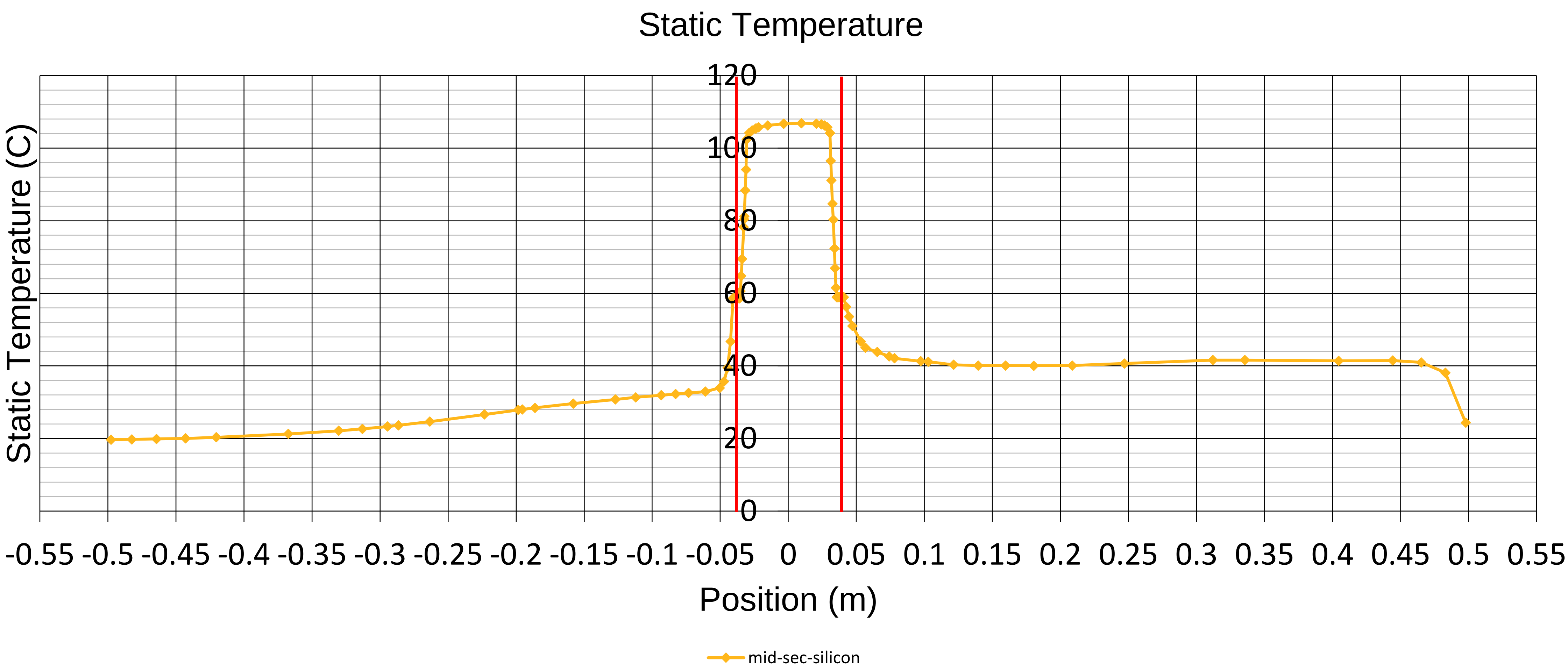
temp-vs-pos-mid-sec-ld-disk-1

Detector ⌀ = 0.07352 m



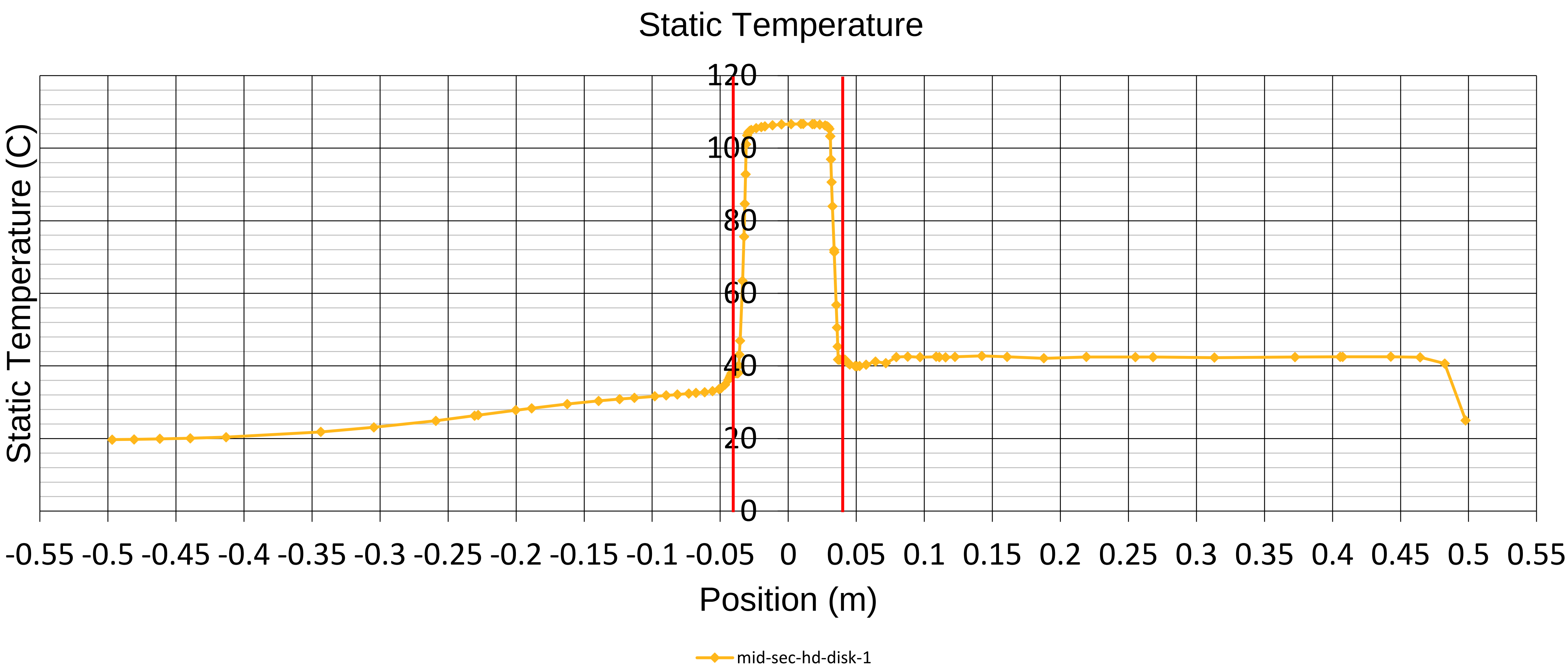
temp-vs-pos-mid-sec-silicon-barrel

Detector ⌀ = 0.072 m



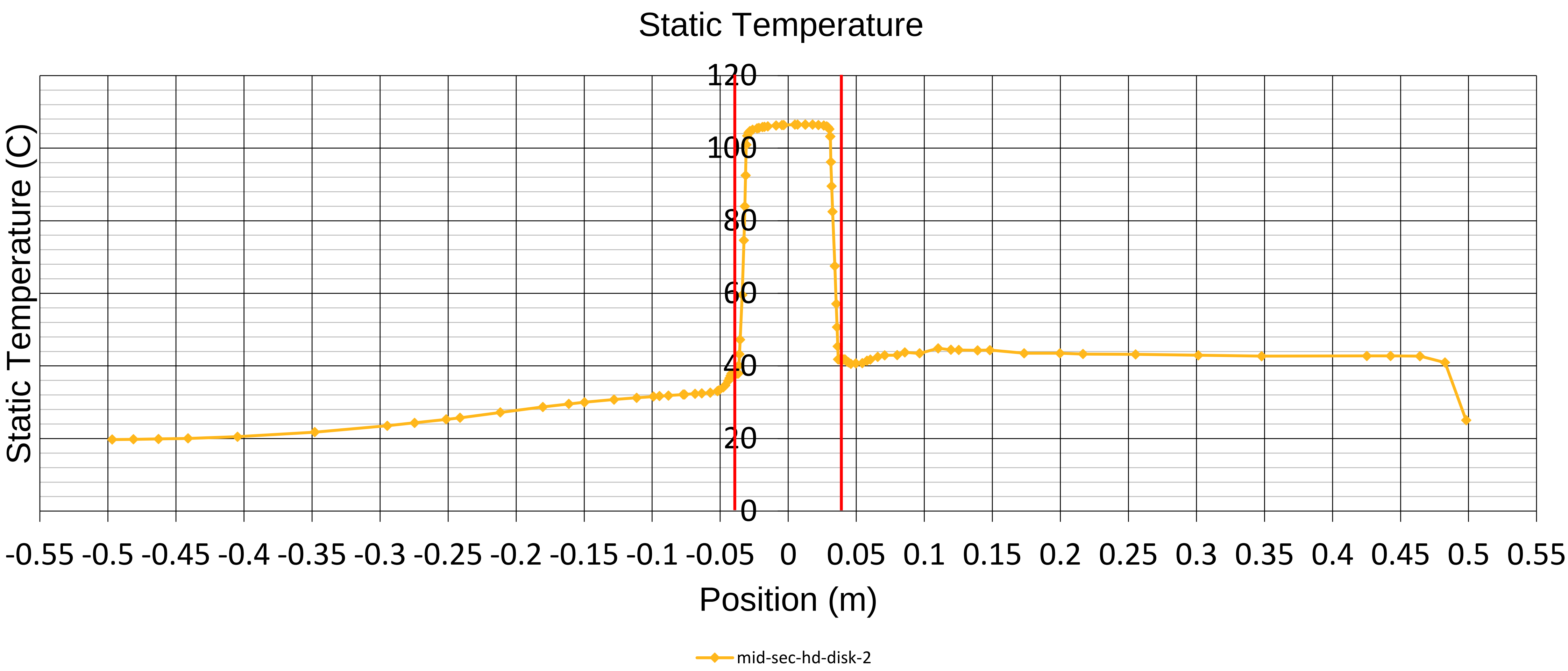
temp-vs-pos-mid-sec-hd-disk-1

Detector ⌀ = 0.07352 m



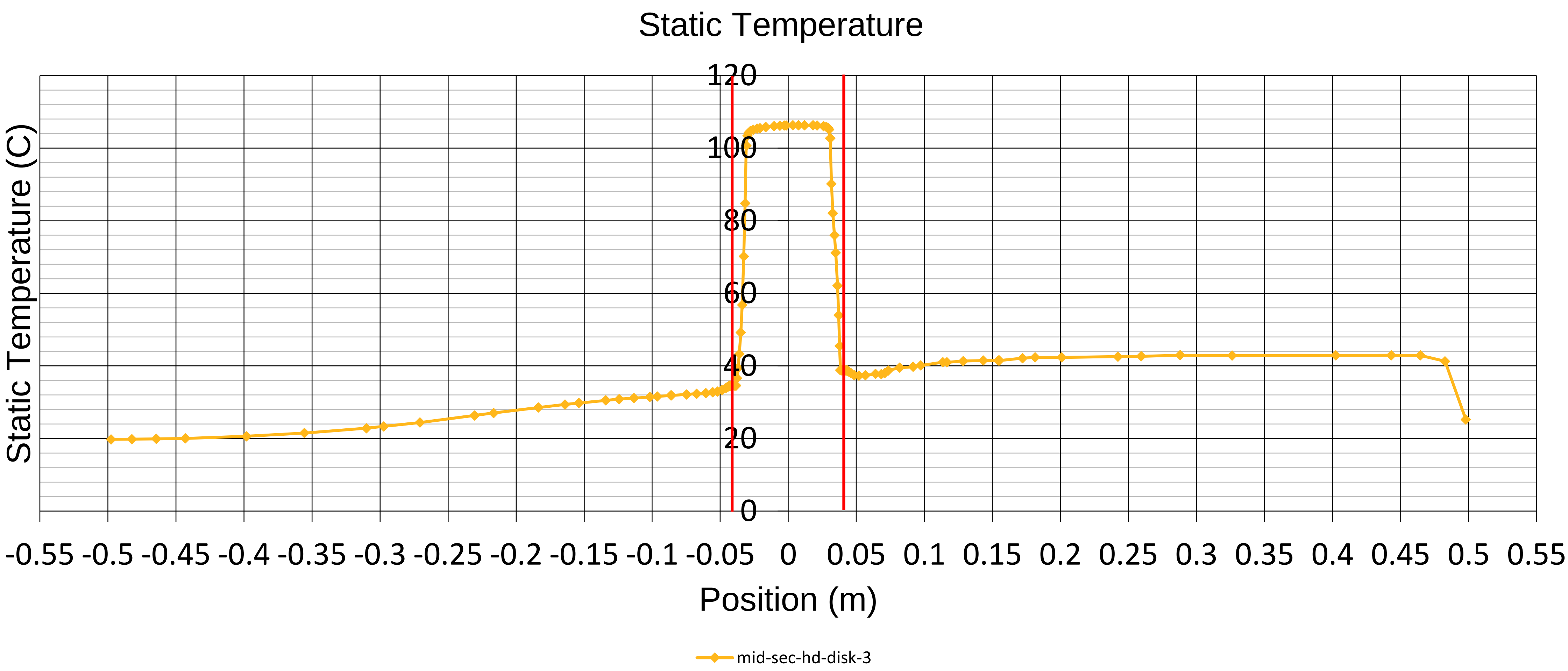
temp-vs-pos-mid-sec-hd-disk-2

Detector ⌀ = 0.07352 m



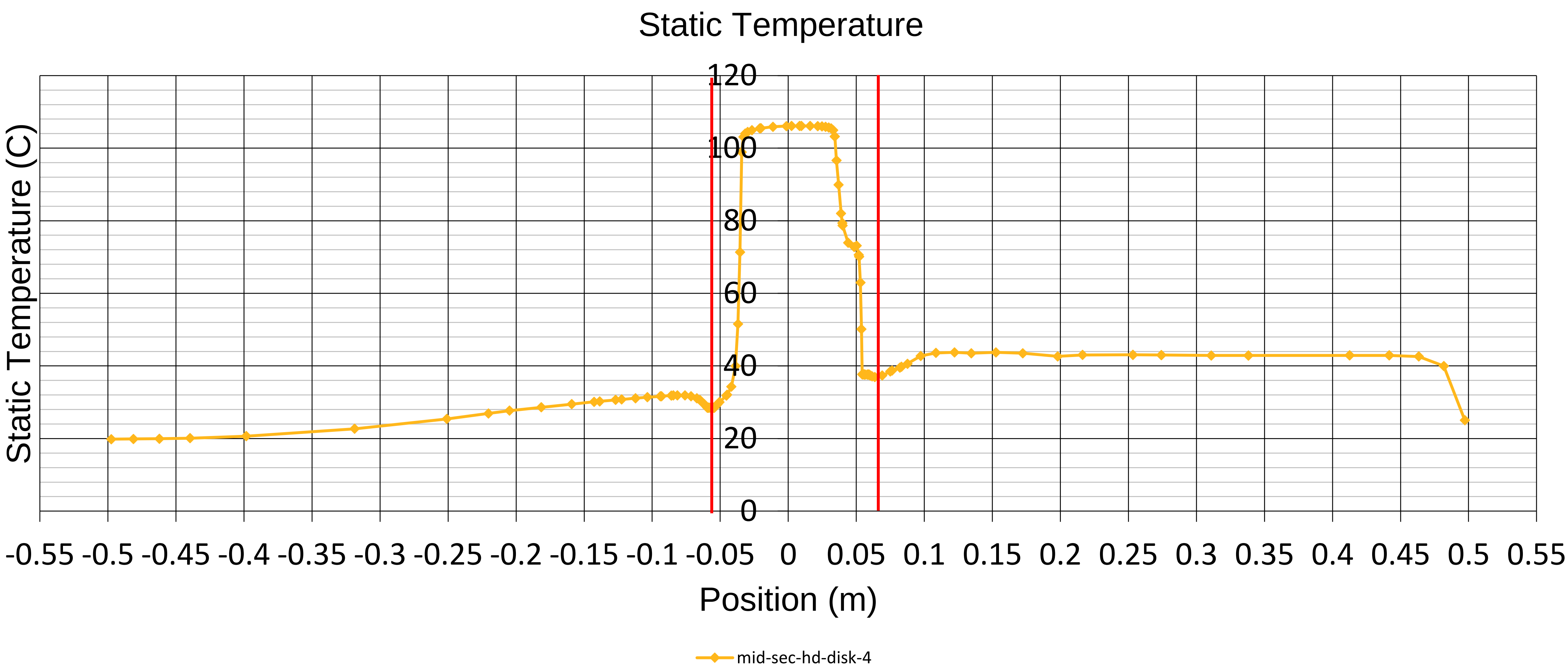
temp-vs-pos-mid-sec-hd-disk-3

Detector ⌀ = 0.07684 m



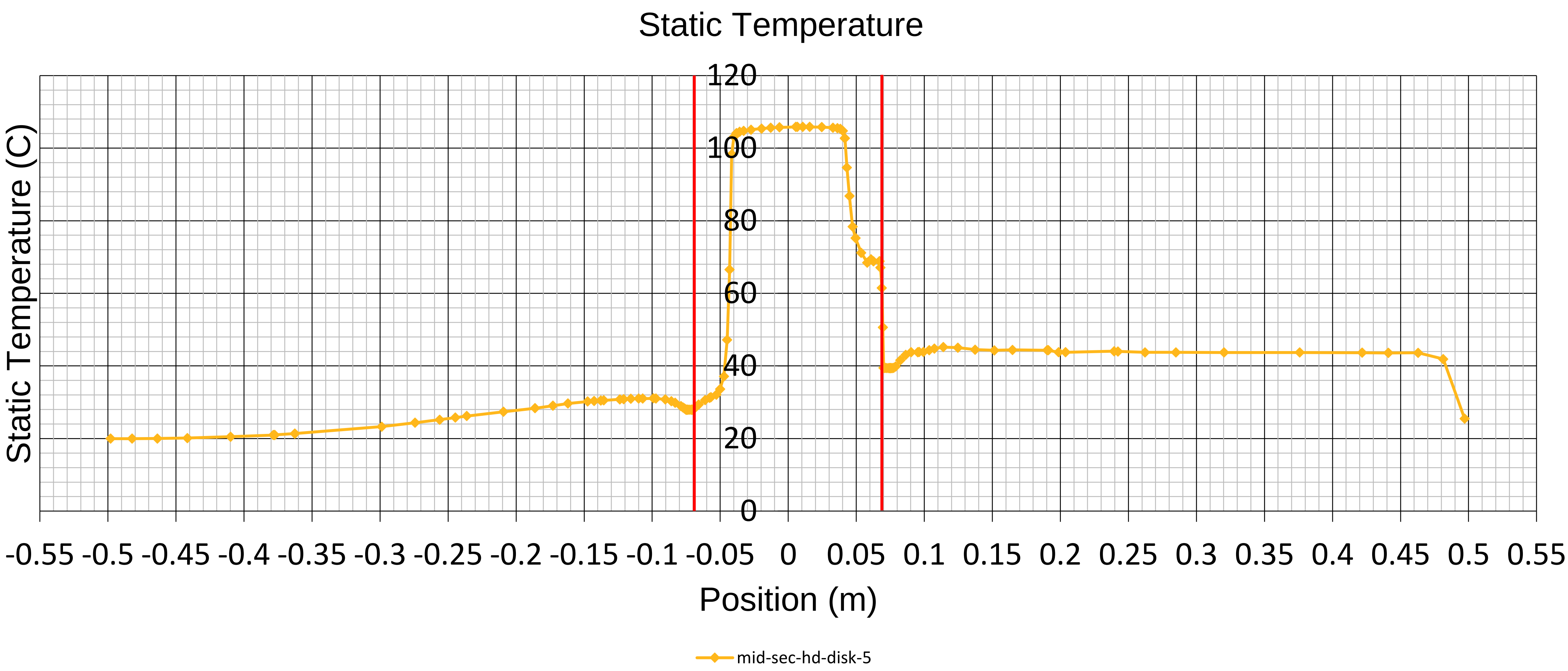
temp-vs-pos-mid-sec-hd-disk-4

Detector ⌀ = 0.10886 m



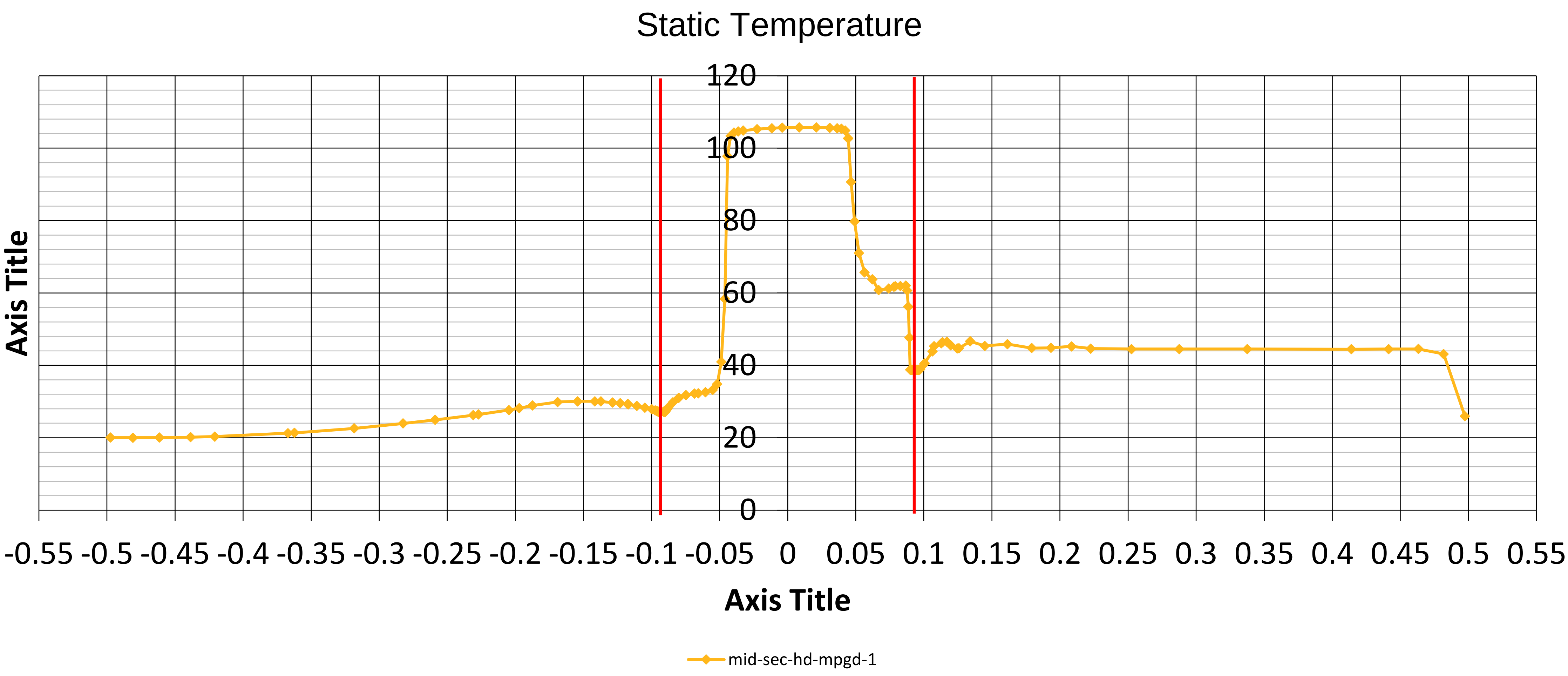
temp-vs-pos-mid-sec-hd-disk-5

Detector ⌀ = 0.14028 m



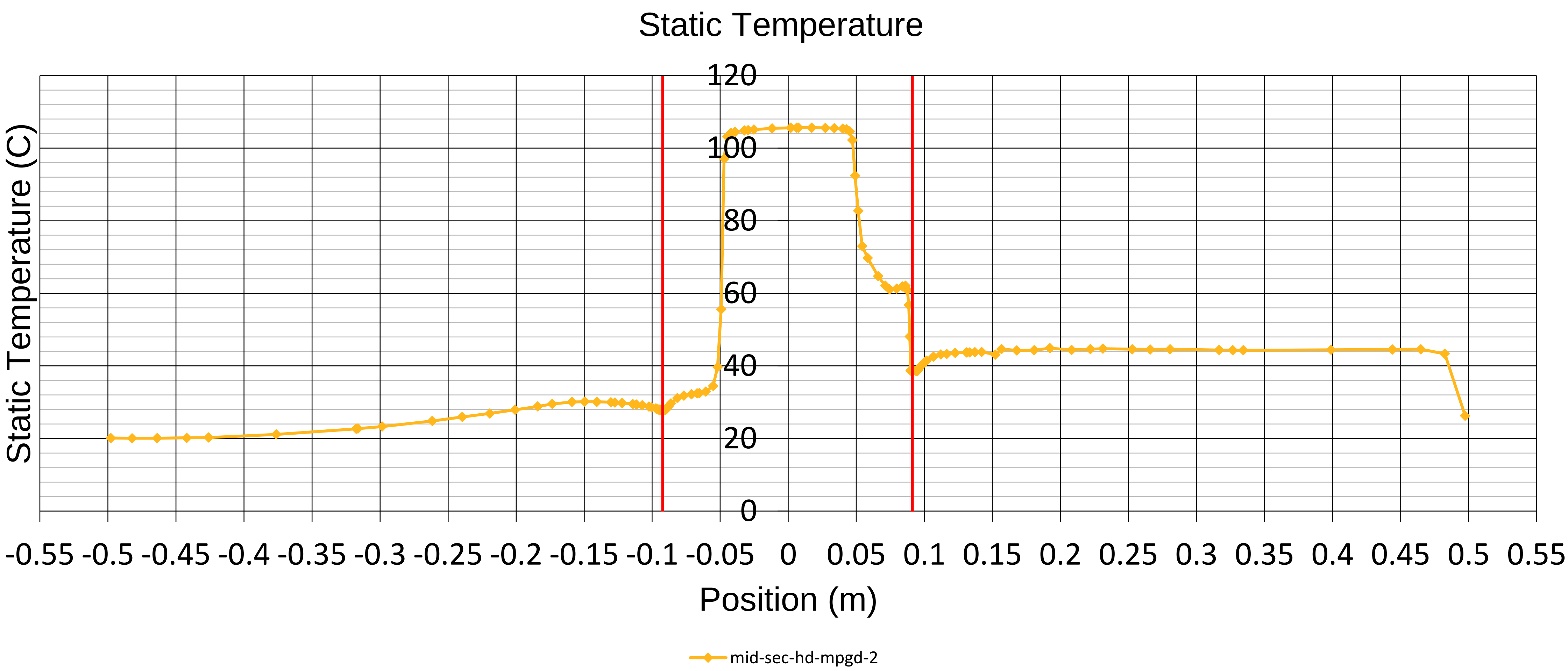
temp-vs-pos-mid-sec-hd-mpgd-1

Detector ⌀ = 0.18 m



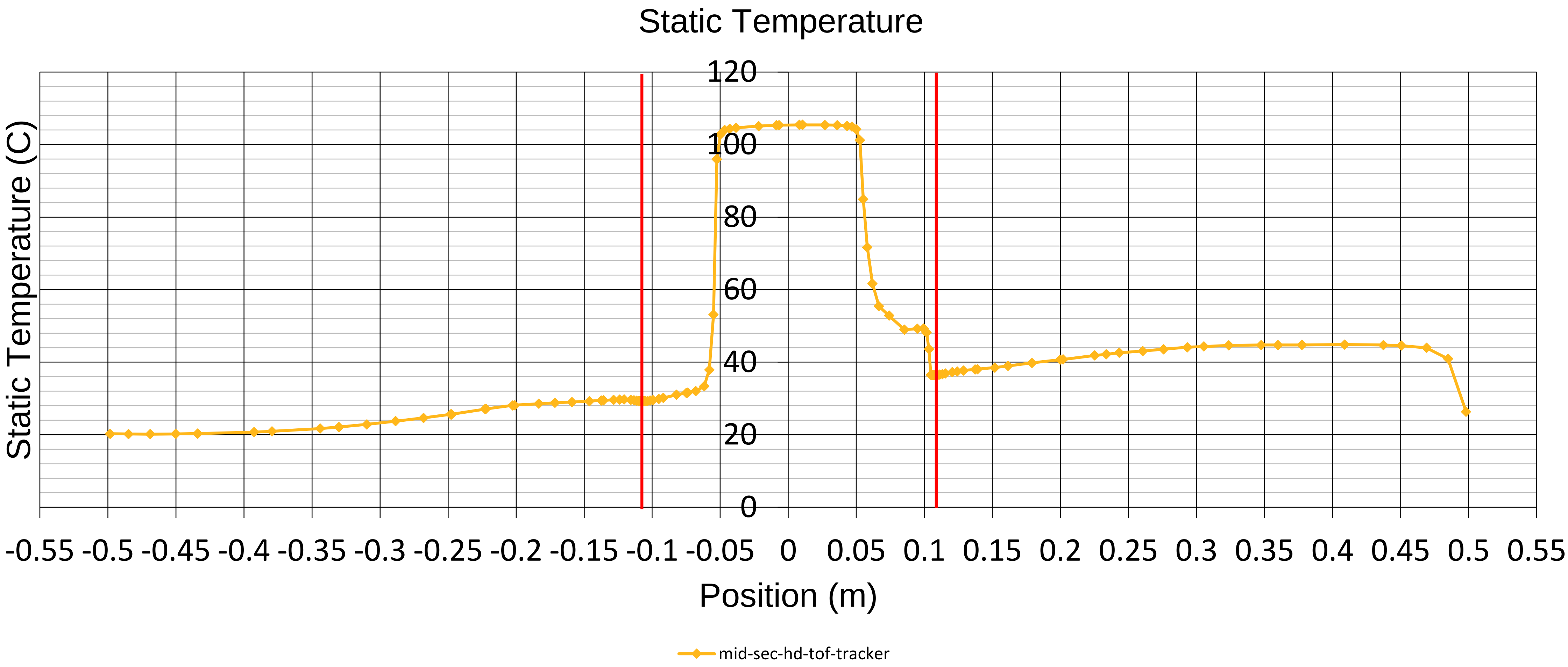
temp-vs-pos-mid-sec-hd-mpgd-2

Detector ⌀ = 0.18 m



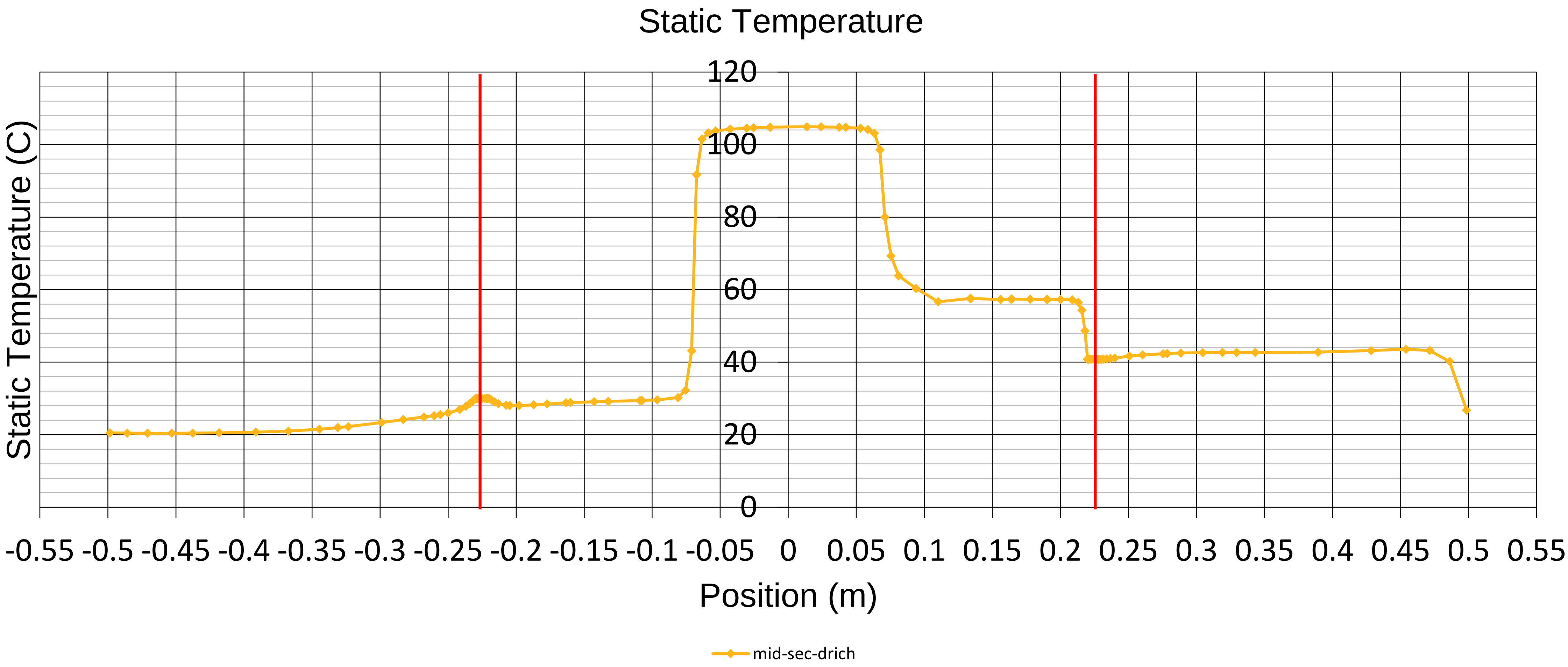
temp-vs-pos-mid-sec-hd-tof-tracker

Detector ⌀ = 0.21 m



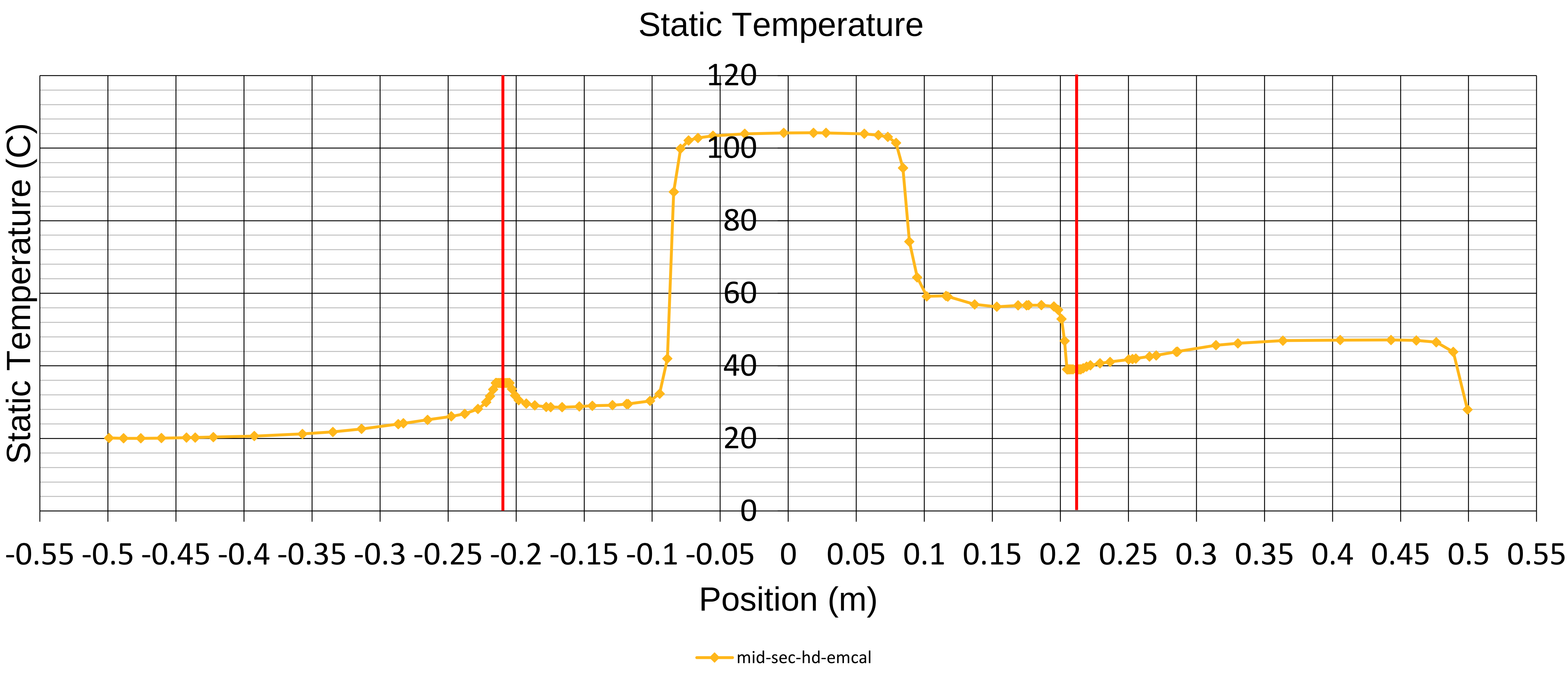
temp-vs-pos-mid-sec-drich

Detector ⌀ = 0.44 m



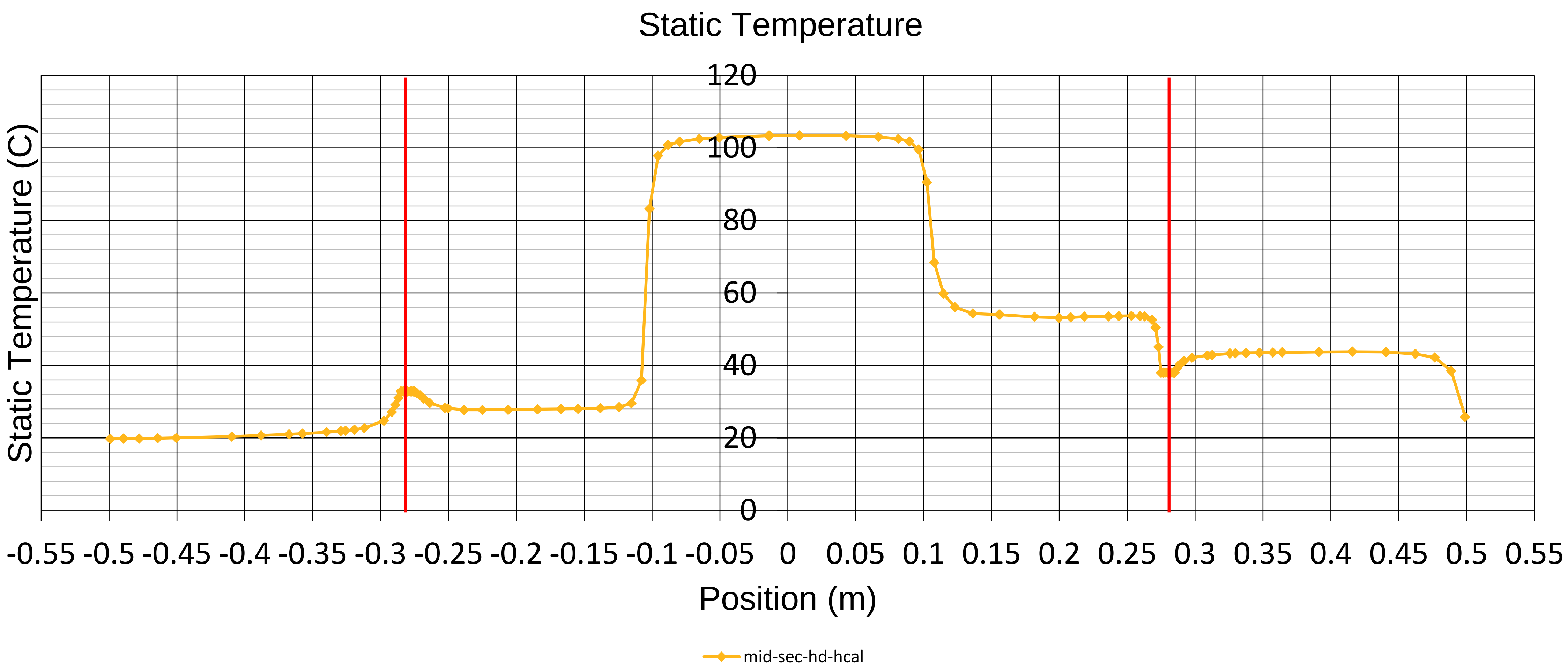
temp-vs-pos-mid-sec-hd-emcal

Detector ⌀ = 0.41 m



temp-vs-pos-mid-sec-hd-hcal

Detector ⌀ = 0.55 m



Conclusions

#	Detector	ID [mm]	OD [mm]	Surface thickness [mm]	Length [mm]	Min temperature [°C]	Max temperature [°C]
1	LD-HCAL	248	268	10	450	40.99	43.61
2	LD-EMCAL	190	210	10	600	42.66	44.40
3	LD-pfRICH	190	210	10	491	30.37	43.18
4	LD-MPGD-2	92.7	102.7	5	25	34.08	39.60
5	LD-MPGD-1	92.7	102.7	5	25	32.58	38.43
6	LD-Si-Disk-5	92.7	102.7	5	25	31.66	39.07
7	LD-Si-Disk-4	80.12	90.12	5	25	32.91	38.33
8	LD-Si-Disk-3	73.52	83.52	5	25	38.49	42.76
9	LD-Si-Disk-2	73.52	83.52	5	25	38.34	42.53
10	LD-Si-Disk-1	73.52	83.52	5	25	38.11	42.25
11	Si Barrel	72	82	5	270	58.10	58.93
12	HD-Si-Disk-1	73.52	83.52	5	25	38.11	41.85
13	HD-Si-Disk-2	73.52	83.52	5	25	38.34	41.92
14	HD-Si-Disk-3	76.84	86.84	5	25	38.49	38.96
15	HD-Si-Disk-4	108.86	118.86	5	25	32.91	38.00
16	HD-Si-Disk-5	140.28	150.28	5	25	31.66	39.76
17	HD-MPGD-1	180	190	5	25	27.20	39.04
18	HD-MPGD-2	180	190	5	25	27.90	38.94
19	HD-TOF-Tracker	210	220	5	80	29.09	37.33
20	HD-dRICH	440	460	10	1270	26.97	41.00
21	HD-EMCAL	410	430	10	300	35.21	39.12
22	HD-HCAL	550	570	10	1400	32.34	38.05

Conclusion

To conclude, the report presents the fluid dynamics and thermal analysis at qualitative and quantitative levels for each model component.

The computed information presented in the report shows the thermal conditions at each detector's inner wall. The resulting maximum temperature at each detector's inner wall under the specific set and presented conditions was calculated and displayed.