

# TGT-CALC-103-009

---

Be Isolation Window  
Dave Meekins

## Model description and assumptions

The following beam parameters were used:

- Beam current is 30 microA
- Raster 2x2 mm
- Heat deposited by beam is ~3 W

The flange is directly attached to a heat sink that is cooled with chilled water at 10 C  
The face of the flange in contact with the sink is held at 10 C

### Geometry

**TABLE 2**  
**Model (B4) > Geometry**

Object Name	Geometry
State	Fully Defined
<b>Definition</b>	
Source	D:\meekins\Google Drive\JLAB\Hall A\Trtium\Calculations\ANSYS\Be window\TGT-103-1002-0003-beam.stp
Type	Step
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
<b>Bounding Box</b>	
Length X	6.9088e-002 m
Length Y	6.9088e-002 m
Length Z	1.27e-002 m
<b>Properties</b>	
Volume	3.8239e-005 m <sup>3</sup>
Mass	0.10847 kg
Scale Factor Value	1.
<b>Statistics</b>	
Bodies	3
Active Bodies	3
Nodes	33161
Elements	14564
Mesh Metric	None
<b>Basic Geometry Options</b>	

Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	No
Parameters	Yes
Parameter Key	DS
Attributes	No
Named Selections	No
Material Properties	No
<b>Advanced Geometry Options</b>	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	No
Compare Parts On Update	No
Attach File Via Temp File	Yes
Temporary Directory	C:\Users\meekins\AppData\Local\Temp
Analysis Type	3-D
Mixed Import Resolution	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

**TABLE 3**  
**Model (B4) > Geometry > Parts**

Object Name	<i>TGT-103-1002-0002-beam</i>	<i>TGT-103-1002-0002-solid</i>	<i>TGT-103-1002-0001</i>
State	Meshed		
<b>Graphics Properties</b>			
Visible	Yes		
Transparency	1		
<b>Definition</b>			
Suppressed	No		
Stiffness Behavior	Flexible		
Coordinate System	Default Coordinate System		
Reference Temperature	By Environment		
<b>Material</b>			
Assignment	Beryllium		2219 (UNS A92219)
Nonlinear Effects	Yes		
Thermal Strain Effects	Yes		
<b>Bounding Box</b>			
Length X	2.24e-003 m	2.7546e-002 m	6.9088e-002 m
Length Y	2.24e-003 m	2.7546e-002 m	6.9088e-002 m
Length Z	2.032e-004 m		1.27e-002 m
<b>Properties</b>			
Volume	8.0077e-010 m <sup>3</sup>	1.0216e-007 m <sup>3</sup>	3.8136e-005 m <sup>3</sup>
Mass	1.4813e-006 kg	1.8899e-004 kg	0.10828 kg

Centroid X	-4.8307e-003 m	-4.8311e-003 m	
Centroid Y	-3.3873e-003 m		
Centroid Z	-9.1583e-003 m	-3.1593e-003 m	
Moment of Inertia Ip1	4.5908e-013 kg·m <sup>2</sup>	7.5067e-009 kg·m <sup>2</sup>	3.6538e-005 kg·m <sup>2</sup>
Moment of Inertia Ip2	4.5908e-013 kg·m <sup>2</sup>	7.5067e-009 kg·m <sup>2</sup>	3.6543e-005 kg·m <sup>2</sup>
Moment of Inertia Ip3	9.0808e-013 kg·m <sup>2</sup>	1.5012e-008 kg·m <sup>2</sup>	7.0397e-005 kg·m <sup>2</sup>
<b>Statistics</b>			
Nodes	342	10477	22342
Elements	42	1446	13076
Mesh Metric	None		

## Coordinate Systems

**TABLE 4**  
**Model (B4) > Coordinate Systems > Coordinate System**

Object Name	<i>Global Coordinate System</i>
State	Fully Defined
<b>Definition</b>	
Type	Cartesian
Coordinate System ID	0.
<b>Origin</b>	
Origin X	0. m
Origin Y	0. m
Origin Z	0. m
<b>Directional Vectors</b>	
X Axis Data	[ 1. 0. 0. ]
Y Axis Data	[ 0. 1. 0. ]
Z Axis Data	[ 0. 0. 1. ]

## Connections

**TABLE 5**  
**Model (B4) > Connections**

Object Name	<i>Connections</i>
State	Fully Defined
<b>Auto Detection</b>	
Generate Automatic Connection On Refresh	Yes
<b>Transparency</b>	
Enabled	Yes

**TABLE 6**  
**Model (B4) > Connections > Contacts**

Object Name	<i>Contacts</i>
State	Fully Defined
<b>Definition</b>	
Connection Type	Contact
<b>Scope</b>	
Scoping Method	Geometry Selection

Geometry	All Bodies
<b>Auto Detection</b>	
Tolerance Type	Slider
Tolerance Slider	0.
Tolerance Value	2.4632e-004 m
Use Range	No
Face/Face	Yes
Face/Edge	No
Edge/Edge	No
Priority	Include All
Group By	Bodies
Search Across	Bodies
<b>Statistics</b>	
Connections	2
Active Connections	2

**TABLE 7**  
**Model (B4) > Connections > Contacts > Contact Regions**

Object Name	<i>Contact Region</i>	<i>Contact Region 2</i>
State	Fully Defined	
<b>Scope</b>		
Scoping Method	Geometry Selection	
Contact	1 Face	2 Faces
Target	1 Face	2 Faces
Contact Bodies	TGT-103-1002-0002-beam	TGT-103-1002-0002-solid
Target Bodies	TGT-103-1002-0002-solid	TGT-103-1002-0001
<b>Definition</b>		
Type	Bonded	
Scope Mode	Automatic	
Behavior	Program Controlled	
Trim Contact	Program Controlled	
Trim Tolerance	2.4632e-004 m	
Suppressed	No	
<b>Advanced</b>		
Formulation	Program Controlled	
Detection Method	Program Controlled	
Elastic Slip Tolerance	Program Controlled	
Thermal Conductance	Program Controlled	
Pinball Region	Program Controlled	
<b>Geometric Modification</b>		
Contact Geometry Correction	None	
Target Geometry Correction	None	

## Mesh

**TABLE 8**  
**Model (B4) > Mesh**

Object Name	<i>Mesh</i>
-------------	-------------

State	Solved
<b>Display</b>	
Display Style	Body Color
<b>Defaults</b>	
Physics Preference	Mechanical
Relevance	0
<b>Sizing</b>	
Use Advanced Size Function	Off
Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	3.5415e-003 m
<b>Inflation</b>	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
<b>Patch Conforming Options</b>	
Triangle Surface Mesher	Program Controlled
<b>Patch Independent Options</b>	
Topology Checking	No
<b>Advanced</b>	
Number of CPUs for Parallel Part Meshing	Program Controlled
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries For Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
<b>Defeaturing</b>	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Automatic Mesh Based Defeaturing	On
Defeaturing Tolerance	Default
<b>Statistics</b>	
Nodes	33161
Elements	14564
Mesh Metric	None

## Steady-State Thermal (B5)

**TABLE 9**  
**Model (B4) > Analysis**

Object Name	<i>Steady-State Thermal (B5)</i>
State	Solved
<b>Definition</b>	
Physics Type	Thermal
Analysis Type	Steady-State
Solver Target	Mechanical APDL
<b>Options</b>	
Generate Input Only	No

**TABLE 10**  
**Model (B4) > Steady-State Thermal (B5) > Initial Condition**

Object Name	<i>Initial Temperature</i>
State	Fully Defined
<b>Definition</b>	
Initial Temperature	Uniform Temperature
Initial Temperature Value	10. °C

**TABLE 11**  
**Model (B4) > Steady-State Thermal (B5) > Analysis Settings**

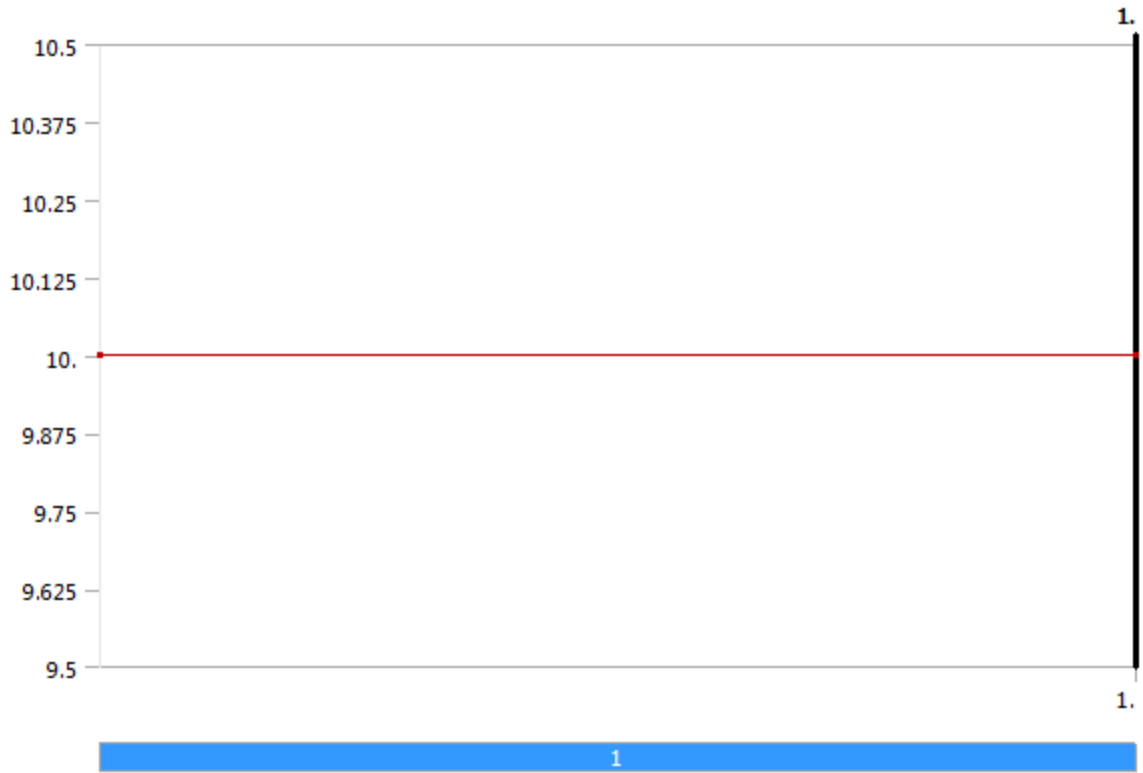
Object Name	<i>Analysis Settings</i>
State	Fully Defined
<b>Step Controls</b>	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
<b>Solver Controls</b>	
Solver Type	Program Controlled
Solver Pivot Checking	Program Controlled
<b>Radiosity Controls</b>	
Radiosity Solver	Program Controlled
Flux Convergence	1.e-004
Maximum Iteration	1000.
Solver Tolerance	0.1 W/m <sup>2</sup>
Over Relaxation	0.1
Hemicube Resolution	10.
<b>Nonlinear Controls</b>	
Heat Convergence	Program Controlled
Temperature Convergence	Program Controlled
Line Search	Program Controlled
<b>Output Controls</b>	
Calculate Thermal Flux	Yes
General Miscellaneous	No
Store Results At	All Time Points

Analysis Data Management	
Solver Files Directory	D:\meekins\Google Drive\JLAB\Hall A\Trtium\Calculations\ANSYS\Be window\Be_window_files\dp0\SYSMECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Delete Unneeded Files	Yes
Nonlinear Solution	Yes
Solver Units	Active System
Solver Unit System	mks

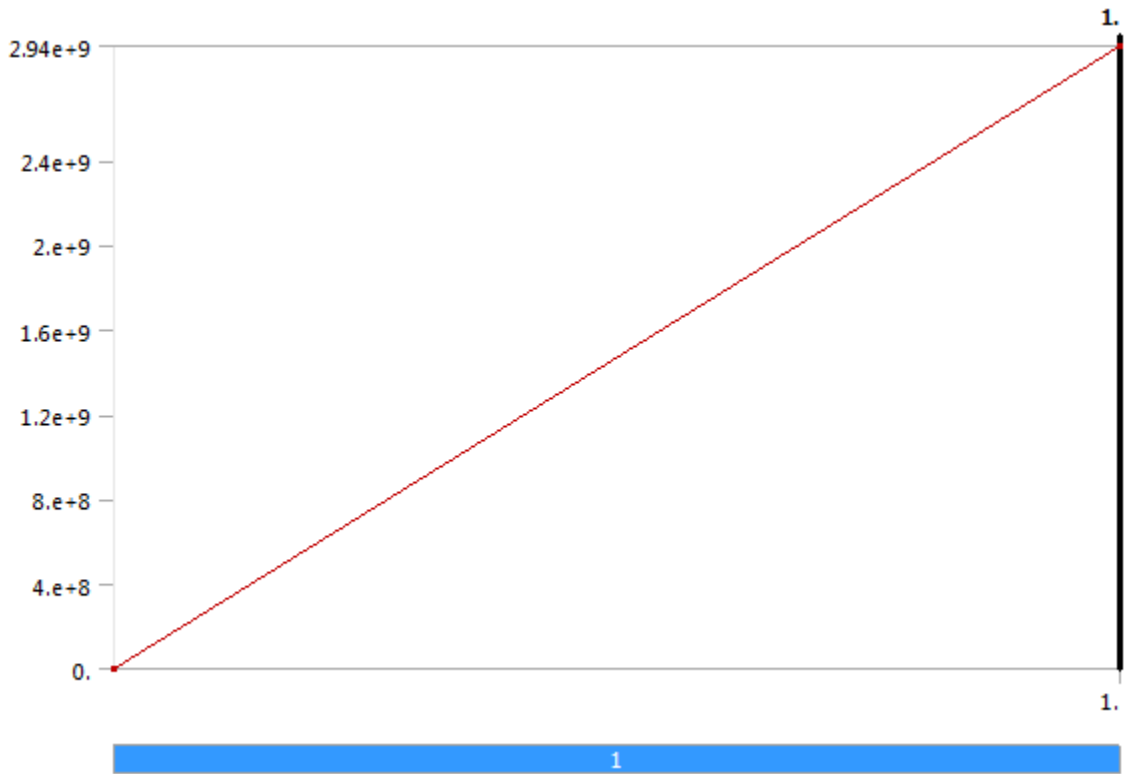
**TABLE 12**  
**Model (B4) > Steady-State Thermal (B5) > Loads**

Object Name	<i>Temperature</i>	<i>Internal Heat Generation</i>
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	1 Face	1 Body
Definition		
Type	Temperature	Internal Heat Generation
Magnitude	10. °C (ramped)	2.94e+009 W/m <sup>3</sup> (ramped)
Suppressed	No	

**FIGURE 1**  
**Model (B4) > Steady-State Thermal (B5) > Temperature**



**FIGURE 2**  
**Model (B4) > Steady-State Thermal (B5) > Internal Heat Generation**





## Solution (B6)

**TABLE 13**  
**Model (B4) > Steady-State Thermal (B5) > Solution**

Object Name	<i>Solution (B6)</i>
State	Solved
<b>Adaptive Mesh Refinement</b>	
Max Refinement Loops	1.
Refinement Depth	2.
<b>Information</b>	
Status	Done
<b>Post Processing</b>	
Calculate Beam Section Results	No

**TABLE 14**  
**Model (B4) > Steady-State Thermal (B5) > Solution (B6) > Solution Information**

Object Name	<i>Solution Information</i>
State	Solved
<b>Solution Information</b>	
Solution Output	Solver Output
Update Interval	2.5 s
Display Points	All
<b>FE Connection Visibility</b>	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

**TABLE 15**  
**Model (B4) > Steady-State Thermal (B5) > Solution (B6) > Results**

Object Name	<i>Temperature</i>
State	Solved
<b>Scope</b>	
Scoping Method	Geometry Selection
Geometry	All Bodies
<b>Definition</b>	
Type	Temperature
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
<b>Results</b>	
Minimum	10. °C
Maximum	36.346 °C
Minimum Occurs On	TGT-103-1002-0001

Maximum Occurs On	TGT-103-1002-0002-beam
Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	3

**FIGURE 3**

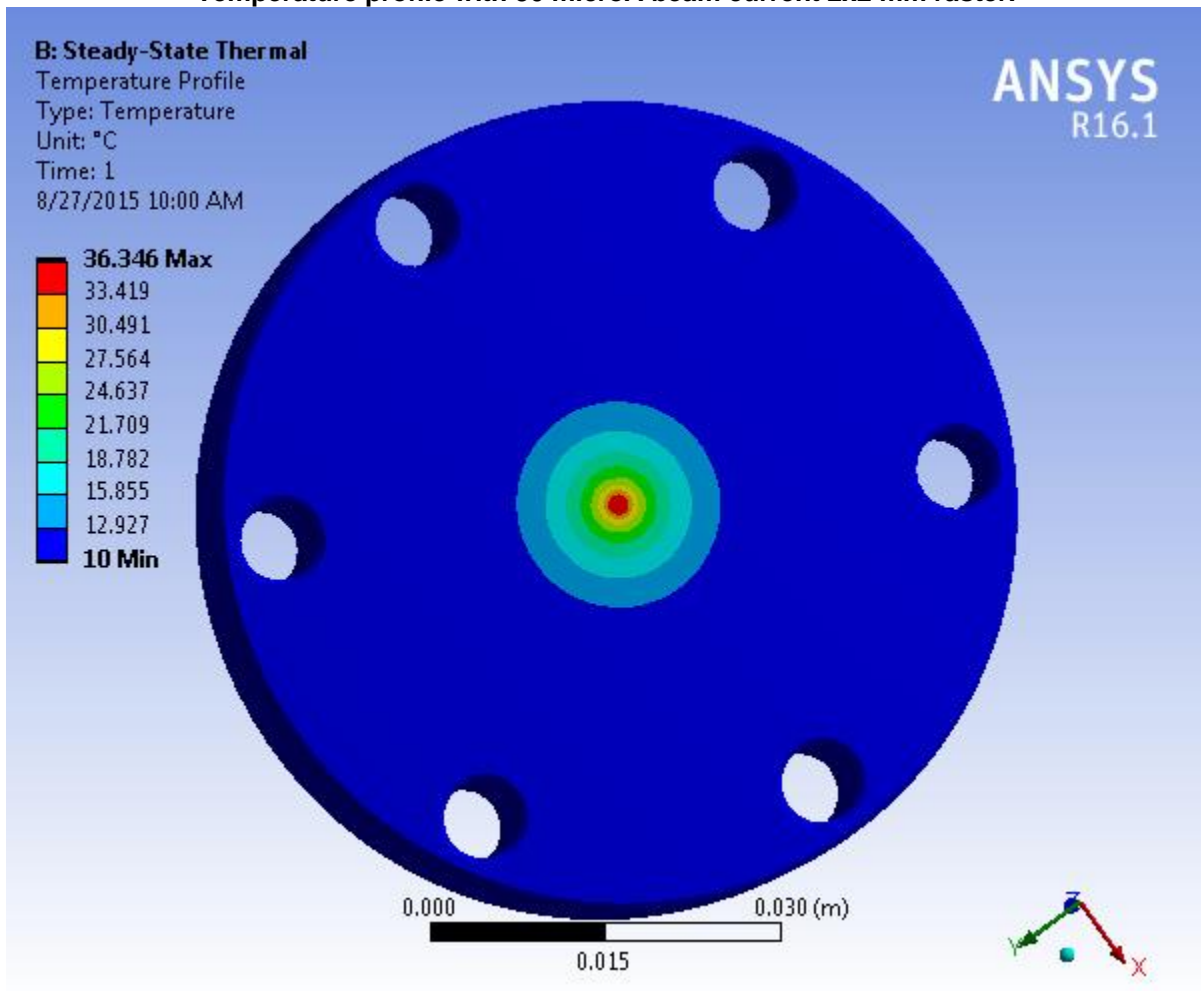
**TABLE 16**

**Model (B4) > Steady-State Thermal (B5) > Solution (B6) > Temperature**

Time [s]	Minimum [°C]	Maximum [°C]
1.	10.	36.346

**FIGURE 4**

**Model (B4) > Steady-State Thermal (B5) > Solution (B6) > Temperature > Temperature Profile**  
 Temperature profile with 30 microA beam current 2x2 mm raster.



## Material Data

*Beryllium*

**TABLE 17**  
**Beryllium > Density**

Density kg m <sup>-3</sup>	Temperature C
1857.1	-273.15
1857.1	-260.29
1857.1	-247.43
1857.1	-234.57
1857.1	-221.72
1857.1	-208.86
1857.1	-196
1857.1	-183.14
1857.1	-170.28
1856.9	-157.42
1856.7	-144.56
1856.4	-131.71
1856.1	-118.85
1855.8	-105.99
1855.4	-93.13
1854.9	-80.271
1854.4	-67.413
1853.9	-54.554
1853.3	-41.695
1852.7	-28.837
1852	-15.978
1851.3	-3.1197
1850.6	9.7389
1849.8	22.597
1849.1	35.456
1848.2	48.315
1847.4	61.173
1846.5	74.032
1845.6	86.89
1844.7	99.749
1843.8	112.61
1842.8	125.47
1841.8	138.32
1840.8	151.18
1839.8	164.04
1838.7	176.9
1837.7	189.76
1836.6	202.62
1835.5	215.48
1834.3	228.33
1833.1	241.19
1832	254.05
1830.8	266.91
1829.6	279.77
1828.5	292.63
1827.3	305.49

1826.1	318.34
1824.9	331.2
1823.7	344.06
1822.4	356.92
1821.2	369.78
1820	382.64
1818.7	395.5
1817.5	408.36
1816.2	421.21
1814.9	434.07
1813.7	446.93
1812.4	459.79
1811.1	472.65
1809.8	485.51
1808.5	498.37
1807.2	511.22
1805.8	524.08
1804.5	536.94
1803.2	549.8
1801.8	562.66
1800.5	575.52
1799.1	588.38
1797.8	601.23
1796.4	614.09
1795	626.95
1793.6	639.81
1792.3	652.67
1790.9	665.53
1789.5	678.39
1788	691.24
1786.6	704.1
1785.2	716.96
1783.8	729.82
1782.3	742.68
1780.9	755.54
1779.5	768.4
1778	781.25
1776.5	794.11
1775.1	806.97
1773.6	819.83
1772.1	832.69
1770.7	845.55
1769.2	858.41
1767.7	871.26
1766.2	884.12
1764.7	896.98
1763.2	909.84
1761.6	922.7

1760.1	935.56
1758.6	948.42
1757.1	961.27
1755.5	974.13
1754	986.99
1752.4	999.85

**TABLE 18**  
**Beryllium > Tensile Yield Strength**

Tensile Yield Strength Pa	Temperature C
2.73e+008	19.85
2.7205e+008	25.709
2.7107e+008	31.567
2.7007e+008	37.426
2.6904e+008	43.284
2.6799e+008	49.143
2.6692e+008	55.002
2.6582e+008	60.86
2.647e+008	66.719
2.6356e+008	72.577
2.6239e+008	78.436
2.6121e+008	84.294
2.6e+008	90.153
2.5877e+008	96.012
2.5752e+008	101.87
2.5625e+008	107.73
2.5496e+008	113.59
2.5365e+008	119.45
2.5233e+008	125.3
2.5098e+008	131.16
2.4962e+008	137.02
2.4824e+008	142.88
2.4684e+008	148.74
2.4543e+008	154.6
2.44e+008	160.46
2.4255e+008	166.31
2.4109e+008	172.17
2.3962e+008	178.03
2.3813e+008	183.89
2.3662e+008	189.75
2.3511e+008	195.61
2.3358e+008	201.47
2.3203e+008	207.32
2.3048e+008	213.18
2.2891e+008	219.04
2.2733e+008	224.9
2.2574e+008	230.76
2.2414e+008	236.62
2.2253e+008	242.48

2.2091e+008	248.33
2.1928e+008	254.19
2.1764e+008	260.05
2.16e+008	265.91
2.1434e+008	271.77
2.1268e+008	277.63
2.1101e+008	283.49
2.0933e+008	289.34
2.0765e+008	295.2
2.0596e+008	301.06
2.0427e+008	306.92
2.0257e+008	312.78
2.0086e+008	318.64
1.9915e+008	324.5
1.9744e+008	330.36
1.9573e+008	336.21
1.9401e+008	342.07
1.9229e+008	347.93
1.9057e+008	353.79
1.8884e+008	359.65
1.8712e+008	365.51
1.8539e+008	371.37
1.8366e+008	377.22
1.8194e+008	383.08
1.8021e+008	388.94
1.7849e+008	394.8
1.7676e+008	400.66
1.7504e+008	406.52
1.7332e+008	412.38
1.716e+008	418.23
1.6989e+008	424.09
1.6818e+008	429.95
1.6647e+008	435.81
1.6477e+008	441.67
1.6307e+008	447.53
1.6138e+008	453.39
1.5969e+008	459.24
1.5801e+008	465.1
1.5634e+008	470.96
1.5467e+008	476.82
1.5301e+008	482.68
1.5136e+008	488.54
1.4971e+008	494.4
1.4808e+008	500.25
1.4645e+008	506.11
1.4483e+008	511.97
1.4323e+008	517.83
1.4163e+008	523.69

1.4004e+008	529.55
1.3847e+008	535.41
1.3691e+008	541.26
1.3535e+008	547.12
1.3381e+008	552.98
1.3229e+008	558.84
1.3078e+008	564.7
1.2928e+008	570.56
1.2779e+008	576.42
1.2632e+008	582.27
1.2486e+008	588.13
1.2342e+008	593.99
1.22e+008	599.85

**TABLE 19**  
**Beryllium > Tensile Ultimate Strength**

Tensile Ultimate Strength Pa	Temperature C
4.54e+008	19.85
4.5313e+008	25.709
4.5215e+008	31.567
4.5108e+008	37.426
4.499e+008	43.284
4.4864e+008	49.143
4.4727e+008	55.002
4.4582e+008	60.86
4.4428e+008	66.719
4.4264e+008	72.577
4.4092e+008	78.436
4.3912e+008	84.294
4.3723e+008	90.153
4.3527e+008	96.012
4.3322e+008	101.87
4.311e+008	107.73
4.289e+008	113.59
4.2663e+008	119.45
4.2428e+008	125.3
4.2187e+008	131.16
4.1939e+008	137.02
4.1684e+008	142.88
4.1423e+008	148.74
4.1155e+008	154.6
4.0882e+008	160.46
4.0603e+008	166.31
4.0318e+008	172.17
4.0027e+008	178.03
3.9731e+008	183.89
3.943e+008	189.75
3.9124e+008	195.61
3.8814e+008	201.47

3.8499e+008	207.32
3.8179e+008	213.18
3.7855e+008	219.04
3.7528e+008	224.9
3.7196e+008	230.76
3.6861e+008	236.62
3.6522e+008	242.48
3.618e+008	248.33
3.5835e+008	254.19
3.5487e+008	260.05
3.5136e+008	265.91
3.4783e+008	271.77
3.4428e+008	277.63
3.407e+008	283.49
3.371e+008	289.34
3.3349e+008	295.2
3.2986e+008	301.06
3.2622e+008	306.92
3.2256e+008	312.78
3.1889e+008	318.64
3.1522e+008	324.5
3.1154e+008	330.36
3.0785e+008	336.21
3.0416e+008	342.07
3.0047e+008	347.93
2.9678e+008	353.79
2.9309e+008	359.65
2.8941e+008	365.51
2.8573e+008	371.37
2.8206e+008	377.22
2.784e+008	383.08
2.7475e+008	388.94
2.7112e+008	394.8
2.675e+008	400.66
2.639e+008	406.52
2.6032e+008	412.38
2.5676e+008	418.23
2.5322e+008	424.09
2.4971e+008	429.95
2.4623e+008	435.81
2.4277e+008	441.67
2.3934e+008	447.53
2.3595e+008	453.39
2.3259e+008	459.24
2.2926e+008	465.1
2.2598e+008	470.96
2.2273e+008	476.82
2.1952e+008	482.68



2.1636e+008	488.54
2.1325e+008	494.4
2.1018e+008	500.25
2.0716e+008	506.11
2.0419e+008	511.97
2.0127e+008	517.83
1.9841e+008	523.69
1.956e+008	529.55
1.9285e+008	535.41
1.9017e+008	541.26
1.8754e+008	547.12
1.8498e+008	552.98
1.8248e+008	558.84
1.8005e+008	564.7
1.7769e+008	570.56
1.754e+008	576.42
1.7319e+008	582.27
1.7105e+008	588.13
1.6899e+008	593.99
1.67e+008	599.85

**TABLE 20**  
**Beryllium > Isotropic Secant Coefficient of Thermal Expansion**

Coefficient of Thermal Expansion C <sup>-1</sup>	Temperature C
4.3702e-006	-273.15
4.5673e-006	-260.29
4.7881e-006	-247.43
5.0324e-006	-234.57
5.3003e-006	-221.72
5.5918e-006	-208.86
5.9603e-006	-196
6.325e-006	-183.14
6.6767e-006	-170.28
7.0156e-006	-157.42
7.3422e-006	-144.56
7.6568e-006	-131.71
7.9598e-006	-118.85
8.2517e-006	-105.99
8.5329e-006	-93.13
8.804e-006	-80.271
9.0656e-006	-67.413
9.3181e-006	-54.554
9.5623e-006	-41.695
9.7987e-006	-28.837
1.0028e-005	-15.978
1.0251e-005	-3.1197
1.0469e-005	9.7389
1.0681e-005	22.597
1.089e-005	35.456

1.1096e-005	48.315
1.1299e-005	61.173
1.1501e-005	74.032
1.1696e-005	86.89
1.1888e-005	99.749
1.2077e-005	112.61
1.2265e-005	125.47
1.245e-005	138.32
1.2632e-005	151.18
1.2812e-005	164.04
1.2989e-005	176.9
1.3163e-005	189.76
1.3333e-005	202.62
1.3498e-005	215.48
1.3657e-005	228.33
1.381e-005	241.19
1.3941e-005	254.05
1.4073e-005	266.91
1.42e-005	279.77
1.4323e-005	292.63
1.4442e-005	305.49
1.4557e-005	318.34
1.4669e-005	331.2
1.4778e-005	344.06
1.4883e-005	356.92
1.4985e-005	369.78
1.5084e-005	382.64
1.5181e-005	395.5
1.5275e-005	408.36
1.5367e-005	421.21
1.5457e-005	434.07
1.5545e-005	446.93
1.5631e-005	459.79
1.5716e-005	472.65
1.5799e-005	485.51
1.588e-005	498.37
1.596e-005	511.22
1.604e-005	524.08
1.6117e-005	536.94
1.6194e-005	549.8
1.6271e-005	562.66
1.6346e-005	575.52
1.642e-005	588.38
1.6494e-005	601.23
1.6568e-005	614.09
1.6641e-005	626.95
1.6713e-005	639.81
1.6785e-005	652.67

1.6857e-005	665.53
1.6928e-005	678.39
1.6999e-005	691.24
1.707e-005	704.1
1.7141e-005	716.96
1.7211e-005	729.82
1.7281e-005	742.68
1.7351e-005	755.54
1.7421e-005	768.4
1.749e-005	781.25
1.7559e-005	794.11
1.7628e-005	806.97
1.7696e-005	819.83
1.7765e-005	832.69
1.7832e-005	845.55
1.7899e-005	858.41
1.7966e-005	871.26
1.8032e-005	884.12
1.8097e-005	896.98
1.8161e-005	909.84
1.8225e-005	922.7
1.8288e-005	935.56
1.8349e-005	948.42
1.8409e-005	961.27
1.8469e-005	974.13
1.8526e-005	986.99
1.8582e-005	999.85
Reference Temperature C	
19.85	

**TABLE 21**  
**Beryllium > Specific Heat**

Specific Heat J kg <sup>-1</sup> C <sup>-1</sup>	Temperature C
0.56717	-257.56
3.1422	-241.98
18.35	-226.39
38.773	-210.81
82.632	-195.22
159.34	-179.63
269.04	-164.05
400.4	-148.46
544.35	-132.88
694.42	-117.29
845.33	-101.71
992.91	-86.12
1134.2	-70.534
1267.3	-54.948
1391.5	-39.362
1507.4	-23.776

1616.4	-8.1904
1721.4	7.3955
1811.2	22.981
1891.7	38.567
1963.8	54.153
2028.6	69.739
2087	85.325
2139.6	100.91
2187.4	116.5
2230.9	132.08
2270.8	147.67
2307.7	163.25
2342	178.84
2374.1	194.43
2404.4	210.01
2433.2	225.6
2460.6	241.18
2486.9	256.77
2512	272.36
2536.1	287.94
2558.9	303.53
2580.6	319.11
2598.4	334.7
2617	350.28
2635.4	365.87
2653.8	381.46
2672.1	397.04
2690.3	412.63
2708.4	428.21
2726.4	443.8
2744.3	459.39
2762.2	474.97
2779.9	490.56
2797.6	506.14
2815.1	521.73
2832.6	537.31
2850	552.9
2867.3	568.49
2884.5	584.07
2901.6	599.66
2918.6	615.24
2935.6	630.83
2952.4	646.42
2969.2	662
2985.8	677.59
3002.4	693.17
3018.9	708.76
3035.3	724.34

3051.6	739.93
3067.8	755.52
3083.9	771.1
3100	786.69
3115.9	802.27
3131.8	817.86
3147.6	833.45
3163.2	849.03
3178.8	864.62
3194.3	880.2
3209.7	895.79
3225	911.38
3240.3	926.96
3255.4	942.55
3270.5	958.13
3285.4	973.72
3300.3	989.3
3315.1	1004.9
3329.8	1020.5
3344.4	1036.1
3358.9	1051.6
3373.3	1067.2
3387.6	1082.8
3401.9	1098.4
3416	1114
3430.1	1129.6
3444.1	1145.2
3457.9	1160.7
3471.7	1176.3
3485.4	1191.9
3499	1207.5
3512.6	1223.1
3526	1238.7
3539.3	1254.3
3552.6	1269.8

**TABLE 22**  
**Beryllium > Isotropic Thermal Conductivity**

Thermal Conductivity W m <sup>-1</sup> C <sup>-1</sup>	Temperature C
177.84	-272.15
2699.5	-258.02
4496.2	-243.89
4498.9	-229.76
3242.8	-215.62
2057	-201.49
1388.6	-187.36
991.82	-173.23
762.72	-159.1
604.33	-144.97

495.99	-130.84
421.9	-116.71
370.27	-102.57
332.79	-88.443
303.95	-74.312
280.51	-60.18
260.86	-46.049
244.42	-31.918
231.03	-17.786
220.4	-3.6551
211.42	10.476
201.64	24.608
194.04	38.739
187.72	52.87
181.87	67.002
176.46	81.133
171.46	95.264
166.83	109.4
162.55	123.53
158.59	137.66
154.92	151.79
151.53	165.92
148.38	180.05
145.46	194.18
142.75	208.31
140.23	222.45
137.87	236.58
135.67	250.71
133.6	264.84
131.66	278.97
129.82	293.1
128.09	307.23
126.43	321.37
124.85	335.5
123.34	349.63
121.88	363.76
120.47	377.89
119.11	392.02
117.77	406.15
116.47	420.28
115.19	434.42
113.93	448.55
112.68	462.68
111.45	476.81
110.23	490.94
109.02	505.07
107.82	519.2
106.62	533.33

105.43	547.47
104.24	561.6
103.06	575.73
101.88	589.86
100.72	603.99
99.556	618.12
98.405	632.25
97.266	646.39
96.138	660.52
95.025	674.65
93.927	688.78
92.847	702.91
91.786	717.04
90.746	731.17
89.729	745.3
88.736	759.44
87.769	773.57
86.829	787.7
85.917	801.83
85.034	815.96
84.182	830.09
83.359	844.22
82.566	858.36
81.803	872.49
81.068	886.62
80.361	900.75
79.679	914.88
79.021	929.01
78.384	943.14
77.763	957.27
77.156	971.41
76.557	985.54
75.962	999.67
75.363	1013.8
74.755	1027.9
74.129	1042.1
73.477	1056.2
72.791	1070.3
72.058	1084.5
71.269	1098.6
70.412	1112.7
69.472	1126.8

**TABLE 23**  
**Beryllium > Isotropic Resistivity**

Resistivity ohm m	Temperature C
3.32e-010	-272.15
3.341e-010	-257.01
3.4708e-010	-241.87

3.9004e-010	-226.73
4.8622e-010	-211.58
6.8278e-010	-196.44
1.0433e-009	-181.3
1.6312e-009	-166.16
2.5098e-009	-151.02
3.7424e-009	-135.88
5.3973e-009	-120.74
7.5481e-009	-105.59
1.0017e-008	-90.453
1.2784e-008	-75.312
1.5827e-008	-60.17
1.9125e-008	-45.029
2.2657e-008	-29.887
2.6403e-008	-14.746
3.034e-008	0.39545
3.4449e-008	15.537
3.8708e-008	30.678
4.3097e-008	45.82
4.7593e-008	60.961
5.2176e-008	76.103
5.6825e-008	91.244
6.1519e-008	106.39
6.6237e-008	121.53
7.0958e-008	136.67
7.5661e-008	151.81
8.0324e-008	166.95
8.492e-008	182.09
8.9747e-008	197.23
9.4591e-008	212.38
9.9453e-008	227.52
1.0433e-007	242.66
1.0923e-007	257.8
1.1416e-007	272.94
1.191e-007	288.08
1.2406e-007	303.22
1.2905e-007	318.37
1.3406e-007	333.51
1.3909e-007	348.65
1.4415e-007	363.79
1.4923e-007	378.93
1.5434e-007	394.07
1.5948e-007	409.21
1.6464e-007	424.36
1.6984e-007	439.5
1.7506e-007	454.64
1.8032e-007	469.78
1.856e-007	484.92



1.9092e-007	500.06
1.9627e-007	515.2
2.0165e-007	530.34
2.0707e-007	545.49
2.1252e-007	560.63
2.1801e-007	575.77
2.2353e-007	590.91
2.2909e-007	606.05
2.3469e-007	621.19
2.4033e-007	636.33
2.46e-007	651.48
2.5172e-007	666.62
2.5748e-007	681.76
2.6328e-007	696.9
2.6912e-007	712.04
2.7501e-007	727.18
2.8094e-007	742.32
2.8691e-007	757.47
2.9293e-007	772.61
2.99e-007	787.75
3.0511e-007	802.89
3.1128e-007	818.03
3.1749e-007	833.17
3.2375e-007	848.31
3.3006e-007	863.46
3.3642e-007	878.6
3.4283e-007	893.74
3.493e-007	908.88
3.5582e-007	924.02
3.6239e-007	939.16
3.6902e-007	954.3
3.757e-007	969.45
3.8244e-007	984.59
3.8924e-007	999.73
3.961e-007	1014.9
4.0301e-007	1030
4.0998e-007	1045.2
4.1702e-007	1060.3
4.2411e-007	1075.4
4.3127e-007	1090.6
4.3849e-007	1105.7
4.4577e-007	1120.9
4.5312e-007	1136
4.6053e-007	1151.1
4.6801e-007	1166.3
4.7555e-007	1181.4
4.8316e-007	1196.6
4.9084e-007	1211.7

4.9859e-007	1226.8
-------------	--------

**TABLE 24**  
**Beryllium > Isotropic Elasticity**

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
-180.15	2.949e+011	0.33	2.8912e+011	1.1087e+011
-170.76	2.9455e+011	0.33	2.8877e+011	1.1073e+011
-161.36	2.942e+011	0.33	2.8843e+011	1.106e+011
-151.97	2.9384e+011	0.33	2.8808e+011	1.1047e+011
-142.57	2.9349e+011	0.33	2.8774e+011	1.1034e+011
-133.18	2.9314e+011	0.33	2.8739e+011	1.102e+011
-123.79	2.9279e+011	0.33	2.8705e+011	1.1007e+011
-114.39	2.9244e+011	0.33	2.867e+011	1.0994e+011
-105	2.9209e+011	0.33	2.8636e+011	1.0981e+011
-95.605	2.9173e+011	0.33	2.8601e+011	1.0967e+011
-86.211	2.9138e+011	0.33	2.8567e+011	1.0954e+011
-76.817	2.9103e+011	0.33	2.8532e+011	1.0941e+011
-67.423	2.9068e+011	0.33	2.8498e+011	1.0928e+011
-58.029	2.9033e+011	0.33	2.8463e+011	1.0915e+011
-48.635	2.8997e+011	0.33	2.8429e+011	1.0901e+011
-39.241	2.8962e+011	0.33	2.8394e+011	1.0888e+011
-29.847	2.8927e+011	0.33	2.836e+011	1.0875e+011
-20.453	2.8891e+011	0.33	2.8325e+011	1.0861e+011
-11.059	2.8856e+011	0.33	2.829e+011	1.0848e+011
-1.6652	2.8821e+011	0.33	2.8255e+011	1.0835e+011
7.7288	2.8785e+011	0.33	2.8221e+011	1.0821e+011
17.123	2.8749e+011	0.33	2.8186e+011	1.0808e+011
26.517	2.8714e+011	0.33	2.8151e+011	1.0795e+011
35.911	2.8678e+011	0.33	2.8116e+011	1.0781e+011
45.305	2.8642e+011	0.33	2.8081e+011	1.0768e+011
54.698	2.8606e+011	0.33	2.8046e+011	1.0754e+011
64.092	2.8571e+011	0.33	2.801e+011	1.0741e+011
73.486	2.8534e+011	0.33	2.7975e+011	1.0727e+011
82.88	2.8498e+011	0.33	2.794e+011	1.0714e+011
92.274	2.8462e+011	0.33	2.7904e+011	1.07e+011
101.67	2.8426e+011	0.33	2.7868e+011	1.0686e+011
111.06	2.8389e+011	0.33	2.7833e+011	1.0673e+011
120.46	2.8353e+011	0.33	2.7797e+011	1.0659e+011
129.85	2.8316e+011	0.33	2.7761e+011	1.0645e+011
139.24	2.8279e+011	0.33	2.7725e+011	1.0631e+011
148.64	2.8242e+011	0.33	2.7689e+011	1.0617e+011
158.03	2.8205e+011	0.33	2.7652e+011	1.0604e+011
167.43	2.8168e+011	0.33	2.7616e+011	1.059e+011
176.82	2.8131e+011	0.33	2.7579e+011	1.0576e+011
186.21	2.8093e+011	0.33	2.7543e+011	1.0561e+011
195.61	2.8056e+011	0.33	2.7506e+011	1.0547e+011
205	2.8018e+011	0.33	2.7469e+011	1.0533e+011
214.4	2.798e+011	0.33	2.7432e+011	1.0519e+011
223.79	2.7942e+011	0.33	2.7394e+011	1.0505e+011

233.18	2.7904e+011	0.33	2.7357e+011	1.049e+011
242.58	2.7865e+011	0.33	2.7319e+011	1.0476e+011
251.97	2.7827e+011	0.33	2.7281e+011	1.0461e+011
261.37	2.7788e+011	0.33	2.7243e+011	1.0447e+011
270.76	2.7749e+011	0.33	2.7205e+011	1.0432e+011
280.15	2.771e+011	0.33	2.7166e+011	1.0417e+011
289.55	2.767e+011	0.33	2.7128e+011	1.0402e+011
298.94	2.7631e+011	0.33	2.7089e+011	1.0388e+011
308.33	2.7591e+011	0.33	2.705e+011	1.0373e+011
317.73	2.7551e+011	0.33	2.7011e+011	1.0358e+011
327.12	2.7511e+011	0.33	2.6971e+011	1.0342e+011
336.52	2.747e+011	0.33	2.6932e+011	1.0327e+011
345.91	2.743e+011	0.33	2.6892e+011	1.0312e+011
355.3	2.7389e+011	0.33	2.6852e+011	1.0297e+011
364.7	2.7348e+011	0.33	2.6811e+011	1.0281e+011
374.09	2.7306e+011	0.33	2.6771e+011	1.0266e+011
383.49	2.7265e+011	0.33	2.673e+011	1.025e+011
392.88	2.7223e+011	0.33	2.6689e+011	1.0234e+011
402.27	2.7181e+011	0.33	2.6648e+011	1.0218e+011
411.67	2.7138e+011	0.33	2.6606e+011	1.0202e+011
421.06	2.7096e+011	0.33	2.6564e+011	1.0186e+011
430.46	2.7053e+011	0.33	2.6522e+011	1.017e+011
439.85	2.7009e+011	0.33	2.648e+011	1.0154e+011
449.24	2.6966e+011	0.33	2.6437e+011	1.0138e+011
458.64	2.6922e+011	0.33	2.6394e+011	1.0121e+011
468.03	2.6878e+011	0.33	2.6351e+011	1.0105e+011
477.43	2.6834e+011	0.33	2.6308e+011	1.0088e+011
486.82	2.6789e+011	0.33	2.6264e+011	1.0071e+011
496.21	2.6744e+011	0.33	2.622e+011	1.0054e+011
505.61	2.6699e+011	0.33	2.6176e+011	1.0037e+011
515	2.6653e+011	0.33	2.6131e+011	1.002e+011
524.4	2.6608e+011	0.33	2.6086e+011	1.0003e+011
533.79	2.6561e+011	0.33	2.6041e+011	9.9855e+010
543.18	2.6515e+011	0.33	2.5995e+011	9.968e+010
552.58	2.6468e+011	0.33	2.5949e+011	9.9504e+010
561.97	2.6421e+011	0.33	2.5903e+011	9.9326e+010
571.37	2.6373e+011	0.33	2.5856e+011	9.9148e+010
580.76	2.6325e+011	0.33	2.5809e+011	9.8968e+010
590.15	2.6277e+011	0.33	2.5762e+011	9.8786e+010
599.55	2.6229e+011	0.33	2.5714e+011	9.8604e+010
608.94	2.618e+011	0.33	2.5666e+011	9.842e+010
618.33	2.613e+011	0.33	2.5618e+011	9.8234e+010
627.73	2.6081e+011	0.33	2.5569e+011	9.8048e+010
637.12	2.6031e+011	0.33	2.552e+011	9.7859e+010
646.52	2.598e+011	0.33	2.5471e+011	9.767e+010
655.91	2.5929e+011	0.33	2.5421e+011	9.7479e+010
665.3	2.5878e+011	0.33	2.5371e+011	9.7286e+010
674.7	2.5827e+011	0.33	2.532e+011	9.7092e+010

684.09	2.5775e+011	0.33	2.5269e+011	9.6897e+010
693.49	2.5722e+011	0.33	2.5218e+011	9.67e+010
702.88	2.5669e+011	0.33	2.5166e+011	9.6501e+010
712.27	2.5616e+011	0.33	2.5114e+011	9.6301e+010
721.67	2.5562e+011	0.33	2.5061e+011	9.61e+010
731.06	2.5508e+011	0.33	2.5008e+011	9.5896e+010
740.46	2.5454e+011	0.33	2.4955e+011	9.5691e+010
749.85	2.5399e+011	0.33	2.4901e+011	9.5485e+010

## 2219 (UNS A92219)

**TABLE 25**  
**2219 (UNS A92219) > Density**

Density kg m <sup>-3</sup>	Temperature C
2873.1	-251.15
2873.2	-243.18
2873.3	-235.21
2873.2	-227.24
2873	-219.27
2872.7	-211.3
2872.3	-203.33
2871.8	-195.36
2871.2	-187.39
2870.6	-179.42
2869.9	-171.45
2869.1	-163.48
2868.2	-155.51
2867.3	-147.54
2866.3	-139.57
2865.2	-131.6
2864.2	-123.63
2863	-115.67
2861.9	-107.7
2860.6	-99.726
2859.4	-91.756
2858.1	-83.786
2856.8	-75.817
2855.5	-67.847
2854.1	-59.877
2852.7	-51.908
2851.4	-43.938
2849.9	-35.968
2848.5	-27.998
2847.1	-20.029
2845.6	-12.059
2844.2	-4.0894
2842.7	3.8803
2841.2	11.85

2839.7	19.82
2838.2	27.789
2836.7	35.759
2835.2	43.729
2833.7	51.698
2832.2	59.668
2830.6	67.638
2829.1	75.608
2827.5	83.577
2826	91.547
2824.4	99.517
2822.8	107.49
2821.2	115.46
2819.6	123.43
2817.9	131.4
2816.3	139.37
2814.6	147.33
2813	155.3
2811.3	163.27
2809.6	171.24
2807.9	179.21
2806.2	187.18
2804.5	195.15
2802.8	203.12
2801.1	211.09
2799.3	219.06
2797.6	227.03
2795.8	235
2794.1	242.97
2792.3	250.94
2790.5	258.91
2788.7	266.88
2786.9	274.85
2785.1	282.82
2783.3	290.79
2781.5	298.76
2779.7	306.73
2777.8	314.7
2776	322.67
2774.1	330.64
2772.2	338.61
2770.4	346.58
2768.5	354.55
2766.6	362.52
2764.7	370.49
2762.8	378.46
2760.9	386.43
2759	394.4

2757.1	402.37
2755.2	410.33
2753.2	418.3
2751.3	426.27
2749.4	434.24
2747.4	442.21
2745.5	450.18
2743.5	458.15
2741.5	466.12
2739.6	474.09
2737.6	482.06
2735.6	490.03
2733.6	498
2731.6	505.97
2729.6	513.94
2727.6	521.91
2725.6	529.88
2723.6	537.85

**TABLE 26**  
**2219 (UNS A92219) > Tensile Yield Strength**

Tensile Yield Strength Pa	Temperature C
7.5291e+007	19.85
7.4996e+007	24.922
7.4695e+007	29.995
7.4389e+007	35.067
7.4078e+007	40.14
7.3761e+007	45.212
7.3439e+007	50.285
7.3111e+007	55.357
7.2778e+007	60.43
7.2439e+007	65.502
7.2094e+007	70.575
7.1745e+007	75.647
7.1389e+007	80.72
7.1029e+007	85.792
7.0662e+007	90.864
7.0291e+007	95.937
6.9913e+007	101.01
6.9531e+007	106.08
6.9142e+007	111.15
6.8749e+007	116.23
6.8349e+007	121.3
6.7945e+007	126.37
6.7534e+007	131.44
6.7119e+007	136.52
6.6698e+007	141.59
6.6271e+007	146.66
6.5686e+007	151.73

6.4866e+007	156.81
6.4084e+007	161.88
6.334e+007	166.95
6.2635e+007	172.02
6.1969e+007	177.1
6.134e+007	182.17
6.075e+007	187.24
6.0199e+007	192.31
5.9685e+007	197.39
5.9211e+007	202.46
5.8186e+007	207.53
5.661e+007	212.6
5.5119e+007	217.68
5.3706e+007	222.75
5.2366e+007	227.82
5.1091e+007	232.89
4.9874e+007	237.97
4.871e+007	243.04
4.7591e+007	248.11
4.651e+007	253.18
4.5462e+007	258.26
4.4439e+007	263.33
4.3434e+007	268.4
4.2442e+007	273.47
4.1455e+007	278.55
4.0467e+007	283.62
3.947e+007	288.69
3.8459e+007	293.76
3.7427e+007	298.84
3.6367e+007	303.91
3.5272e+007	308.98
3.4136e+007	314.05
3.2952e+007	319.13
3.1714e+007	324.2
3.0414e+007	329.27
2.9046e+007	334.34
2.7604e+007	339.42
2.6081e+007	344.49
2.4469e+007	349.56
2.2763e+007	354.63
2.0956e+007	359.71
1.9041e+007	364.78
1.7012e+007	369.85

**TABLE 27**  
**2219 (UNS A92219) > Tensile Ultimate Strength**

Tensile Ultimate Strength Pa	Temperature C
1.7067e+008	19.85
1.6999e+008	24.922

1.6931e+008	29.995
1.6864e+008	35.067
1.6796e+008	40.14
1.6729e+008	45.212
1.6661e+008	50.285
1.6593e+008	55.357
1.6526e+008	60.43
1.6458e+008	65.502
1.639e+008	70.575
1.6323e+008	75.647
1.6255e+008	80.72
1.6187e+008	85.792
1.612e+008	90.864
1.6052e+008	95.937
1.5954e+008	101.01
1.5734e+008	106.08
1.5487e+008	111.15
1.5209e+008	116.23
1.4901e+008	121.3
1.4559e+008	126.37
1.4183e+008	131.44
1.377e+008	136.52
1.332e+008	141.59
1.2829e+008	146.66
1.2298e+008	151.73
1.1723e+008	156.81
1.1104e+008	161.88
1.0438e+008	166.95
9.7247e+007	172.02
8.973e+007	177.1
8.7017e+007	182.17
8.4356e+007	187.24
8.1755e+007	192.31
7.9223e+007	197.39
7.6767e+007	202.46
7.4394e+007	207.53
7.2109e+007	212.6
6.9918e+007	217.68
6.7822e+007	222.75
6.5826e+007	227.82
6.393e+007	232.89
6.2136e+007	237.97
6.0444e+007	243.04
5.8852e+007	248.11
5.7357e+007	253.18
5.5958e+007	258.26
5.465e+007	263.33
5.3428e+007	268.4



5.2286e+007	273.47
5.1217e+007	278.55
5.0214e+007	283.62
4.9268e+007	288.69
4.8369e+007	293.76
4.7506e+007	298.84
4.6668e+007	303.91
4.5842e+007	308.98
4.5015e+007	314.05
4.4172e+007	319.13
4.3298e+007	324.2
4.2376e+007	329.27
4.139e+007	334.34
4.032e+007	339.42
3.9148e+007	344.49
3.7854e+007	349.56
3.6416e+007	354.63
3.4812e+007	359.71
3.302e+007	364.78
3.1014e+007	369.85

**TABLE 28**  
**2219 (UNS A92219) > Isotropic Secant Coefficient of Thermal Expansion**

Coefficient of Thermal Expansion C <sup>-1</sup>	Temperature C
1.4313e-005	-251.15
1.4837e-005	-243.18
1.5331e-005	-235.21
1.5798e-005	-227.24
1.6238e-005	-219.27
1.6652e-005	-211.3
1.7042e-005	-203.33
1.7408e-005	-195.36
1.7752e-005	-187.39
1.8075e-005	-179.42
1.8378e-005	-171.45
1.8662e-005	-163.48
1.8928e-005	-155.51
1.9177e-005	-147.54
1.9409e-005	-139.57
1.9627e-005	-131.6
1.983e-005	-123.63
2.002e-005	-115.67
2.0198e-005	-107.7
2.0364e-005	-99.726
2.0519e-005	-91.756
2.0664e-005	-83.786
2.08e-005	-75.817
2.0927e-005	-67.847
2.1047e-005	-59.877

2.116e-005	-51.908
2.1266e-005	-43.938
2.1366e-005	-35.968
2.1462e-005	-27.998
2.1553e-005	-20.029
2.1639e-005	-12.059
2.1723e-005	-4.0894
2.1804e-005	3.8803
2.1882e-005	11.85
2.1959e-005	19.82
2.2034e-005	27.789
2.2109e-005	35.759
2.2187e-005	43.729
2.2267e-005	51.698
2.2347e-005	59.668
2.2428e-005	67.638
2.251e-005	75.608
2.2592e-005	83.577
2.2674e-005	91.547
2.2756e-005	99.517
2.2839e-005	107.49
2.2922e-005	115.46
2.3006e-005	123.43
2.3089e-005	131.4
2.3173e-005	139.37
2.3257e-005	147.33
2.3341e-005	155.3
2.3425e-005	163.27
2.3509e-005	171.24
2.3594e-005	179.21
2.3678e-005	187.18
2.3763e-005	195.15
2.3847e-005	203.12
2.3932e-005	211.09
2.4016e-005	219.06
2.41e-005	227.03
2.4184e-005	235
2.4268e-005	242.97
2.4352e-005	250.94
2.4436e-005	258.91
2.4519e-005	266.88
2.4603e-005	274.85
2.4686e-005	282.82
2.4768e-005	290.79
2.4851e-005	298.76
2.4933e-005	306.73
2.5015e-005	314.7
2.5096e-005	322.67

2.5177e-005	330.64
2.5257e-005	338.61
2.5337e-005	346.58
2.5417e-005	354.55
2.5495e-005	362.52
2.5574e-005	370.49
2.5652e-005	378.46
2.5729e-005	386.43
2.5806e-005	394.4
2.5882e-005	402.37
2.5957e-005	410.33
2.6031e-005	418.3
2.6105e-005	426.27
2.6178e-005	434.24
2.6251e-005	442.21
2.6322e-005	450.18
2.6393e-005	458.15
2.6463e-005	466.12
2.6532e-005	474.09
2.66e-005	482.06
2.6667e-005	490.03
2.6733e-005	498
2.6798e-005	505.97
2.6862e-005	513.94
2.6926e-005	521.91
2.6988e-005	529.88
2.7049e-005	537.85
Reference Temperature C	
19.85	

**TABLE 29**  
**2219 (UNS A92219) > Specific Heat**

Specific Heat J kg <sup>-1</sup> C <sup>-1</sup>	Temperature C
76.253	-240.15
125.77	-232.29
173.68	-224.43
219.93	-216.57
264.5	-208.72
307.34	-200.86
348.44	-193
387.77	-185.14
425.31	-177.28
461.07	-169.42
495.02	-161.56
527.18	-153.71
557.56	-145.85
586.16	-137.99
613	-130.13
638.11	-122.27

661.52	-114.41
683.25	-106.55
703.36	-98.695
721.89	-90.837
738.89	-82.978
754.41	-75.12
768.52	-67.261
781.29	-59.403
792.79	-51.544
803.1	-43.685
812.31	-35.827
820.49	-27.968
827.76	-20.11
833.13	-12.251
837.79	-4.3924
842.41	3.4662
847	11.325
851.54	19.183
856.06	27.042
860.53	34.901
864.98	42.759
869.38	50.618
873.75	58.476
878.08	66.335
882.38	74.193
886.64	82.052
890.86	89.911
895.05	97.769
899.2	105.63
903.31	113.49
907.39	121.34
911.43	129.2
915.44	137.06
919.41	144.92
923.34	152.78
927.24	160.64
931.1	168.5
934.92	176.36
938.71	184.21
942.46	192.07
946.18	199.93
949.86	207.79
953.5	215.65
957.11	223.51
960.68	231.37
964.21	239.22
967.71	247.08
971.18	254.94

974.6	262.8
977.99	270.66
981.34	278.52
984.66	286.38
987.94	294.23
991.19	302.09
994.4	309.95
997.57	317.81
1000.7	325.67
1003.8	333.53
1006.9	341.39
1009.9	349.24
1012.9	357.1
1015.8	364.96
1018.8	372.82
1021.6	380.68
1024.5	388.54
1027.3	396.4
1030.1	404.25
1032.8	412.11
1035.5	419.97
1038.2	427.83
1040.8	435.69
1043.4	443.55
1046	451.41
1048.5	459.26
1051	467.12
1053.4	474.98
1055.8	482.84
1058.2	490.7
1060.5	498.56
1062.8	506.42
1065.1	514.27
1067.3	522.13
1069.5	529.99
1071.7	537.85

**TABLE 30**  
**2219 (UNS A92219) > Isotropic Thermal Conductivity**

Thermal Conductivity W m <sup>-1</sup> C <sup>-1</sup>	Temperature C
44.794	-225.15
47.431	-219.85
50.012	-214.54
52.538	-209.24
55.01	-203.94
57.428	-198.63
59.794	-193.33
62.108	-188.03
64.372	-182.73

66.587	-177.42
68.752	-172.12
70.87	-166.82
72.941	-161.51
74.965	-156.21
76.945	-150.91
78.88	-145.6
80.771	-140.3
82.619	-135
84.426	-129.7
86.192	-124.39
87.917	-119.09
89.603	-113.79
91.25	-108.48
92.859	-103.18
94.431	-97.877
95.967	-92.574
97.468	-87.271
98.933	-81.968
100.36	-76.665
101.76	-71.362
103.13	-66.059
104.46	-60.756
105.77	-55.453
107.04	-50.15
108.28	-44.847
109.5	-39.544
110.68	-34.241
111.84	-28.938
112.97	-23.635
114.08	-18.332
115.16	-13.029
116.21	-7.7258
117.24	-2.4227
118.25	2.8803
119.23	8.1833
120.2	13.486
121.14	18.789
122.06	24.092
122.95	29.395
123.83	34.698
124.69	40.002
125.54	45.305
126.36	50.608
127.16	55.911
127.95	61.214
128.73	66.517
129.48	71.82

130.23	77.123
130.95	82.426
131.67	87.729
132.37	93.032
133.05	98.335
133.73	103.64
134.39	108.94
135.04	114.24
135.68	119.55
136.31	124.85
136.92	130.15
137.53	135.46
138.13	140.76
138.72	146.06
139.31	151.37
139.88	156.67
140.45	161.97
141.01	167.27
141.56	172.58
142.11	177.88
142.65	183.18
143.19	188.49
143.72	193.79
144.24	199.09
144.76	204.4
145.28	209.7
145.8	215
146.31	220.3
146.82	225.61
147.32	230.91
147.83	236.21
148.33	241.52
148.83	246.82
149.33	252.12
149.83	257.43
150.33	262.73
150.83	268.03
151.32	273.33
151.82	278.64
152.32	283.94
152.82	289.24
153.32	294.55
153.82	299.85

**TABLE 31**  
**2219 (UNS A92219) > Isotropic Elasticity**

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
-273.15	8.1033e+010	0.32387	7.6678e+010	3.0605e+010
-265.34	8.1038e+010	0.32391	7.6701e+010	3.0606e+010

-257.53	8.102e+010	0.32398	7.6714e+010	3.0597e+010
-249.73	8.0981e+010	0.32407	7.6716e+010	3.058e+010
-241.92	8.092e+010	0.32418	7.6708e+010	3.0555e+010
-234.11	8.0841e+010	0.32431	7.669e+010	3.0522e+010
-226.3	8.0744e+010	0.32446	7.6664e+010	3.0482e+010
-218.49	8.0629e+010	0.32463	7.6628e+010	3.0435e+010
-210.69	8.0499e+010	0.32481	7.6583e+010	3.0381e+010
-202.88	8.0353e+010	0.32501	7.653e+010	3.0322e+010
-195.07	8.0194e+010	0.32521	7.6469e+010	3.0257e+010
-187.26	8.0022e+010	0.32543	7.6399e+010	3.0187e+010
-179.45	7.9837e+010	0.32566	7.6322e+010	3.0112e+010
-171.64	7.9641e+010	0.32589	7.6236e+010	3.0033e+010
-163.84	7.9435e+010	0.32613	7.6144e+010	2.995e+010
-156.03	7.9219e+010	0.32637	7.6044e+010	2.9863e+010
-148.22	7.8995e+010	0.32662	7.5937e+010	2.9773e+010
-140.41	7.8762e+010	0.32687	7.5823e+010	2.968e+010
-132.6	7.8522e+010	0.32713	7.5703e+010	2.9584e+010
-124.8	7.8276e+010	0.32738	7.5576e+010	2.9485e+010
-116.99	7.8024e+010	0.32763	7.5442e+010	2.9384e+010
-109.18	7.7766e+010	0.32788	7.5303e+010	2.9282e+010
-101.37	7.7503e+010	0.32813	7.5157e+010	2.9178e+010
-93.564	7.7237e+010	0.32838	7.5006e+010	2.9072e+010
-85.756	7.6967e+010	0.32862	7.4848e+010	2.8965e+010
-77.948	7.6693e+010	0.32885	7.4686e+010	2.8857e+010
-70.14	7.6417e+010	0.32908	7.4518e+010	2.8748e+010
-62.332	7.6139e+010	0.32931	7.4344e+010	2.8639e+010
-54.524	7.5859e+010	0.32953	7.4166e+010	2.8528e+010
-46.716	7.5577e+010	0.32974	7.3983e+010	2.8418e+010
-38.908	7.5294e+010	0.32995	7.3795e+010	2.8307e+010
-31.099	7.501e+010	0.33014	7.3602e+010	2.8196e+010
-23.291	7.4726e+010	0.33033	7.3405e+010	2.8085e+010
-15.483	7.4441e+010	0.33052	7.3204e+010	2.7974e+010
-7.6753	7.4156e+010	0.33069	7.2999e+010	2.7864e+010
0.13283	7.3871e+010	0.33086	7.279e+010	2.7753e+010
7.9409	7.3586e+010	0.33102	7.2578e+010	2.7643e+010
15.749	7.3301e+010	0.33117	7.2362e+010	2.7533e+010
23.557	7.3016e+010	0.33131	7.2142e+010	2.7423e+010
31.365	7.2732e+010	0.33145	7.192e+010	2.7313e+010
39.173	7.2448e+010	0.33158	7.1695e+010	2.7204e+010
46.981	7.2164e+010	0.33171	7.1467e+010	2.7095e+010
54.789	7.188e+010	0.33183	7.1236e+010	2.6986e+010
62.597	7.1597e+010	0.33194	7.1003e+010	2.6877e+010
70.406	7.1313e+010	0.33205	7.0768e+010	2.6768e+010
78.214	7.1029e+010	0.33216	7.0531e+010	2.6659e+010
86.022	7.0744e+010	0.33226	7.0292e+010	2.6551e+010
93.83	7.0459e+010	0.33236	7.0051e+010	2.6442e+010
101.64	7.0173e+010	0.33246	6.9809e+010	2.6332e+010
109.45	6.9886e+010	0.33257	6.9565e+010	2.6222e+010



117.25	6.9597e+010	0.33267	6.9321e+010	2.6112e+010
125.06	6.9306e+010	0.33278	6.9076e+010	2.6001e+010
132.87	6.9013e+010	0.33289	6.8829e+010	2.5889e+010
140.68	6.8717e+010	0.33301	6.8583e+010	2.5775e+010
148.49	6.8418e+010	0.33313	6.8336e+010	2.5661e+010
156.29	6.8115e+010	0.33327	6.8088e+010	2.5544e+010
164.1	6.7808e+010	0.33342	6.7841e+010	2.5426e+010
171.91	6.7496e+010	0.33358	6.7594e+010	2.5306e+010
179.72	6.7178e+010	0.33375	6.7347e+010	2.5184e+010
187.53	6.6854e+010	0.33394	6.71e+010	2.5059e+010
195.33	6.6524e+010	0.33416	6.6854e+010	2.4931e+010
203.14	6.6186e+010	0.33439	6.6609e+010	2.48e+010
210.95	6.5841e+010	0.33465	6.6364e+010	2.4666e+010
218.76	6.5486e+010	0.33493	6.612e+010	2.4528e+010
226.57	6.5121e+010	0.33525	6.5878e+010	2.4385e+010
234.38	6.4746e+010	0.33559	6.5637e+010	2.4239e+010
242.18	6.436e+010	0.33598	6.5397e+010	2.4087e+010
249.99	6.3961e+010	0.3364	6.5159e+010	2.393e+010
257.8	6.3549e+010	0.33686	6.4922e+010	2.3768e+010
265.61	6.3123e+010	0.33736	6.4687e+010	2.36e+010
273.42	6.2682e+010	0.33792	6.4454e+010	2.3425e+010
281.22	6.2224e+010	0.33852	6.4223e+010	2.3244e+010
289.03	6.1749e+010	0.33918	6.3994e+010	2.3055e+010
296.84	6.1256e+010	0.33989	6.3767e+010	2.2859e+010
304.65	6.0744e+010	0.34067	6.3542e+010	2.2654e+010
312.46	6.0211e+010	0.34152	6.3319e+010	2.2441e+010
320.26	5.9656e+010	0.34243	6.3099e+010	2.2219e+010
328.07	5.9077e+010	0.34342	6.2882e+010	2.1988e+010
335.88	5.8475e+010	0.34448	6.2667e+010	2.1746e+010
343.69	5.7847e+010	0.34563	6.2455e+010	2.1494e+010
351.5	5.7192e+010	0.34687	6.2246e+010	2.1232e+010
359.3	5.6509e+010	0.34819	6.204e+010	2.0957e+010
367.11	5.5796e+010	0.34961	6.1837e+010	2.0671e+010
374.92	5.5053e+010	0.35114	6.1637e+010	2.0373e+010
382.73	5.4276e+010	0.35277	6.144e+010	2.0061e+010
390.54	5.3466e+010	0.35451	6.1247e+010	1.9736e+010
398.34	5.262e+010	0.35636	6.1057e+010	1.9397e+010
406.15	5.1737e+010	0.35834	6.0871e+010	1.9044e+010
413.96	5.0815e+010	0.36045	6.0689e+010	1.8676e+010
421.77	4.9853e+010	0.36269	6.0511e+010	1.8292e+010
429.58	4.8849e+010	0.36507	6.0337e+010	1.7893e+010
437.39	4.7801e+010	0.36759	6.0167e+010	1.7477e+010
445.19	4.6709e+010	0.37026	6.0003e+010	1.7044e+010
453	4.5568e+010	0.37309	5.9844e+010	1.6593e+010
460.81	4.4379e+010	0.37608	5.969e+010	1.6125e+010
468.62	4.314e+010	0.37925	5.9542e+010	1.5639e+010
476.43	4.1848e+010	0.38258	5.9401e+010	1.5134e+010
484.23	4.0501e+010	0.38611	5.9267e+010	1.461e+010

492.04	3.9098e+010	0.38982	5.9141e+010	1.4066e+010
499.85	3.7637e+010	0.39373	5.9024e+010	1.3502e+010

**TABLE 32**  
**2219 (UNS A92219) > Multilinear Isotropic Hardening**

Stress Pa	Plastic Strain m m <sup>-1</sup>	Temperature C
5.1428e+008	0	19.85
5.349e+008	3.1579e-003	19.85
5.5378e+008	6.3158e-003	19.85
5.7102e+008	9.4737e-003	19.85
5.8673e+008	1.2632e-002	19.85
6.0102e+008	1.5789e-002	19.85
6.14e+008	1.8947e-002	19.85
6.2577e+008	2.2105e-002	19.85
6.3644e+008	2.5263e-002	19.85
6.4612e+008	2.8421e-002	19.85
6.5492e+008	3.1579e-002	19.85
6.6295e+008	3.4737e-002	19.85
6.7032e+008	3.7895e-002	19.85
6.7713e+008	4.1053e-002	19.85
6.8348e+008	4.4211e-002	19.85
6.895e+008	4.7368e-002	19.85
6.9529e+008	5.0526e-002	19.85
7.0095e+008	5.3684e-002	19.85
7.0659e+008	5.6842e-002	19.85
7.1233e+008	6.e-002	19.85

**TABLE 33**  
**2219 (UNS A92219) > Alternating Stress R-Ratio**

Alternating Stress Pa	Cycles	R-Ratio
2.1695e+008	800	-1
2.162e+008	935.51	-1
2.1533e+008	1094	-1
2.1432e+008	1279.3	-1
2.1318e+008	1496	-1
2.119e+008	1749.4	-1
2.1046e+008	2045.7	-1
2.0888e+008	2392.2	-1
2.0715e+008	2797.4	-1
2.0526e+008	3271.3	-1
2.0321e+008	3825.4	-1
2.0101e+008	4473.4	-1
1.9866e+008	5231.1	-1
1.9615e+008	6117.2	-1
1.9348e+008	7153.4	-1
1.9067e+008	8365.1	-1
1.8771e+008	9782.1	-1
1.8461e+008	11439	-1
1.8137e+008	13377	-1

1.7801e+008	15643	-1
1.7451e+008	18292	-1
1.7091e+008	21391	-1
1.6719e+008	25014	-1
1.6337e+008	29251	-1
1.5947e+008	34206	-1
1.5549e+008	40000	-1
1.5143e+008	46776	-1
1.4733e+008	54699	-1
1.4318e+008	63964	-1
1.39e+008	74799	-1
1.3481e+008	87469	-1
1.3061e+008	1.0229e+005	-1
1.2644e+008	1.1961e+005	-1
1.223e+008	1.3987e+005	-1
1.182e+008	1.6356e+005	-1
1.1418e+008	1.9127e+005	-1
1.1025e+008	2.2367e+005	-1
1.0642e+008	2.6156e+005	-1
1.0273e+008	3.0586e+005	-1
9.9183e+007	3.5767e+005	-1
9.5811e+007	4.1826e+005	-1
9.2634e+007	4.891e+005	-1
8.9676e+007	5.7195e+005	-1
8.6803e+007	6.6883e+005	-1
8.4748e+007	7.8213e+005	-1
8.2758e+007	9.1461e+005	-1
8.0857e+007	1.0695e+006	-1
7.9063e+007	1.2507e+006	-1
7.7399e+007	1.4626e+006	-1
7.4546e+007	2.e+006	-1