TNSolver Command Summary

```
Begin Solution Parameters

  title                         = (S ...)
  type                          = {<steady>|transient}
  units                         = {<SI>|US}
  T units                       = {<C>|K|F|R}
  nonlinear convergence         = {<1.0E-9>|(R)}
  maximum nonlinear iterations  = {<100>|(I)}
  begin time                    = {<0.0>|(R)}
  end time                      = (R)
  time step                     = (R)
  number of time steps          = (I)
  print interval                = {<1>|(I)}
  Stefan-Boltzmann              = {<5.6704E-8 W/m^2-K^4>|1.714e-9 Btu/hr-ft^2-R^4}
  gravity                       = {<9.80665 m/s^2>|32.174 ft/s^2}
  graphviz output               = {<no>|yes}
  plot functions                = {<no>|yes}

End Solution Parameters

Begin Nodes

! label  material  volume
   (S)     (S)      (R)

! label  density*specific heat  volume
   (S)          (R)              (R)

End Nodes

Begin Conductors

! label    type       nd_i  nd_j  parameters
   (S)  conduction    (S)   (S)   (R) (R) (R)      ! k, L, A
   (S)  conduction    (S)   (S)   (S) (R) (R)      ! material, L, A
   (S)  cylindrical   (S)   (S)   (R) (R) (R) (R)  ! k, ri, ro, L
   (S)  cylindrical   (S)   (S)   (S) (R) (R) (R)  ! material, ri, ro, L
   (S)  spherical     (S)   (S)   (R) (R) (R)      ! k, ri, ro
   (S)  spherical     (S)   (S)   (S) (R) (R)      ! material, ri, ro

   (S)  convection    (S)   (S)   (R) (R)          ! h, A
   (S)  IFCduct       (S)   (S)   (S) (R) (R) (R)  ! material, velocity, Dh, A
   (S)  EFCcyl        (S)   (S)   (S) (R) (R) (R)  ! material, velocity, D, A
   (S)  EFCdiamond    (S)   (S)   (S) (R) (R) (R)  ! material, velocity, D, A
   (S)  EFCimpjet     (S)   (S)   (S) (R) (R) (R) (R) ! material, velocity,
                                                      ! D, H, r
   (S)  EFCplate      (S)   (S)   (S) (R) (R) (R) (R) ! material, velocity,
                                                      ! Xbegin, Xend, A
   (S)  EFCsphere     (S)   (S)   (S) (R) (R)      ! material, velocity, D
   (S)  INCvenc       (S)   (S)   (S) (R) (R) (R)  ! material, W, H, A
   (S)  ENChcyl       (S)   (S)   (S) (R) (R)      ! material, D, A
   (S)  ENChplatedown (S)   (S)   (S) (R) (R)      ! material, L=A/P, A
   (S)  ENChplateup   (S)   (S)   (S) (R) (R)      ! material, L=A/P, A
   (S)  ENCiplatedown (S)   (S)   (S) (R) (R) (R) (R) ! material, H, L=A/P,
                                                      ! angle, A
   (S)  ENCiplateup   (S)   (S)   (S) (R) (R) (R) (R) ! material, H, L=A/P,
                                                      ! angle, A
   (S)  ENCsphere     (S)   (S)   (S) (R)          ! material, D
   (S)  ENCvplate     (S)   (S)   (S) (R) (R)      ! material, L, A
   (S)  FCuser        (S)   (S)   (S) (S) (R ...) (R) ! function, material,
                                                      ! parameters, A
   (S)  NCuser        (S)   (S)   (S) (S) (R ...) (R) ! function, material,
                                                      ! parameters, A

   (S)  surfrad       (S)   (S)   (R) (R)          ! emissivity, A
   (S)  radiation     (S)   (S)   (R) (R)          ! script-F, A

   (S)  advection     (S)   (S)   (S) (R) (R)      ! material, velocity, A
   (S)  outflow       (S)   (S)   (S) (R) (R)      ! material, velocity, A

End Conductors

Begin Boundary Conditions

! type       parameter  node(s)
  fixed_T    (R)        (S ...)  ! T
  heat_flux  (R) (R)    (S ...)  ! q, A

End Boundary Conditions

Begin Sources

! type   parameter(s)    node(s)
  qdot   (R)             (S ...)  ! q̇, uses node volume: Q = q̇V
  Qsrc   (R)             (S ...)  ! Q
  tstatQ (R) (S) (R) (R) (S ...)  ! Q, thermostat node, Ton, Toff

End Sources

Begin Initial Conditions

! Initial T  node(s)
     (R)     all      ! apply to all nodes in the model
     (R)     (S ...)
  read restart = (S)  ! read T from restart file

End Initial Conditions
```

```
Begin Radiation Enclosure

! label emiss  area  view factors
   (S)   (R)   (R)   (R ...)

End Radiation Enclosure

Begin Functions

  Begin Constant (S)  ! function name
    (R)
  End Constant (S)

  Begin Time {Table|Spline} (S)  ! function name
!  time value
    (R)  (R)
    ...
    (R)  (R)
  End Time {Table|Spline} (S)

  Begin Polynomial (S)  ! function name
    (R ...)             ! a0 a1 a2 ...
    range = (R) (R)     ! range begin and end
  End Polynomial (S)

  Begin Composite (S)  ! function name
    (S ...)            ! list of function names
  End Composite (S)

End Functions

Begin Material (S)   ! material name

  State = (S)  ! {gas|liquid|solid}, required for all materials

  Density = {(R)|ideal gas}  ! ideal gas: ρ = P/RT
  Density {Table|Spline}
!    T  density
    (R)  (R)
    ...
    (R)  (R)
  End Density {Table|Spline}
  Density Polynomial
    (R ...)          ! a0 a1 a2 ...
    range = (R) (R)  ! range begin and end
  End Density Polynomial

  Conductivity = (R)
  Conductivity {Table|Spline}
!    T    k
    (R)  (R)
    ...
    (R)  (R)
  End Conductivity {Table|Spline}
  Conductivity Polynomial
    (R ...)          ! a0 a1 a2 ...
    range = (R) (R)  ! range begin and end
  End Conductivity Polynomial

  {Specific Heat|c_v} = (R)  ! constant volume specific heat
  {Specific Heat|c_v} {Table|Spline}
!    T   c_v
    (R)  (R)
    ...
    (R)  (R)
  End {Specific Heat|c_v} {Table|Spline}
  {Specific Heat|c_v} Polynomial
    (R ...)          ! a0 a1 a2 ...
    range = (R) (R)  ! range begin and end
  End {Specific heat|c_v} Polynomial

  c_p = (R)  ! constant pressure specific heat
  c_p {Table|Spline}
!    T   c_p
    (R)  (R)
    ...
    (R)  (R)
  End c_p {Table|Spline}
  c_p Polynomial
    (R ...)          ! a0 a1 a2 ...
    range = (R) (R)  ! range begin and end
  End c_p Polynomial

  Viscosity = (R)   ! dynamic viscosity: μ
  Viscosity {Table|Spline}
!    T  viscosity, μ
    (R)  (R)
    ...
    (R)  (R)
  End Viscosity {Table|Spline}
  Viscosity Polynomial
    (R ...)          ! a0 a1 a2 ...
    range = (R) (R)  ! range begin and end
  End Viscosity Polynomial

  Beta = {(R)|ideal gas}  ! thermal expansion coefficient,
                          ! ideal gas: β = 1/T
  Beta {Table|Spline}
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!    T   beta, β
    (R)  (R)
    ...
    (R)  (R)
  End Beta {Table|Spline}
  Beta Polynomial
    (R ...)          ! a0 a1 a2 ...
    range = (R) (R)  ! range begin and end
  End Beta Polynomial

  Pr = (R)                ! Prandtl number, Pr = c_p μ/k
  Pr {Table|Spline}
!    T   Pr, Pr = c_p μ/k
    (R)  (R)
    ...
    (R)  (R)
  End Pr {Table|Spline}
  Pr Polynomial
    (R ...)          ! a0 a1 a2 ...
    range = (R) (R)  ! range begin and end
  End Pr Polynomial

  gas constant = (R)  ! gas constant for use with ideal gas: R = R̂/M

  reference = (S ...)

End Material (S)
```

Command Description Character Symbols

{}	list of valid parameters
<>	default parameter in the list of parameters
|	separator for the list of valid parameters
(I)	single integer number
(I ...)	list of integer numbers
(R)	single real number
(R ...)	list of real numbers
(S)	single character string
(S ...)	list of character strings

Units

	SI	US
t	s	hr
L, D	m	ft
A	m^2	ft^2
V	m^3	ft^3
ρ	kg/m^3	lb_m/ft^3
c_v, c_p	$J/kg \cdot K$	$Btu/lb_m \cdot {}^\circ R$
k	$W/m \cdot K$	$Btu/hr \cdot ft \cdot {}^\circ R$
μ	$kg/m \cdot s$	$lb_m/ft \cdot hr$
h	$W/m^2 \cdot K$	$Btu/hr \cdot ft^2 \cdot {}^\circ R$
T	$C = K - 273.15$	${}^\circ F = {}^\circ R - 459.67$
Q	W	Btu/hr
q	W/m^2	$Btu/hr \cdot ft^2$
$\dot{q}$	W/m^3	$Btu/hr \cdot ft^3$
u, v, w	m/s	ft/hr

Dimensionless Numbers

$$\mathrm{Pr} = \frac{\text{viscous diffusion rate}}{\text{thermal diffusion rate}} = \frac{c_p \mu}{k} = \frac{\nu}{\alpha} = \frac{\mu/\rho}{k/(\rho c_p)}$$

$$\mathrm{Nu}_L = \frac{\text{convective heat transfer}}{\text{conductive heat transfer}} = \frac{hL}{k}$$

$$\mathrm{Re}_L = \frac{\text{inertial forces}}{\text{viscous forces}} = \frac{\rho u L}{\mu} = \frac{uL}{\nu}$$

$$D_h = \frac{4 \times \text{cross-sectional area}}{\text{wetted perimeter}} = \frac{4A_c}{P}$$

$$\mathrm{Gr}_L = \frac{g\rho^2 \beta L^3 \Delta T}{\mu^2} = \frac{g\beta L^3 \Delta T}{\nu^2}$$

$$\mathrm{Ra}_L = \mathrm{Gr}_L \mathrm{Pr} = \frac{c_p \rho^2 g \beta L^3 \Delta T}{\mu k} = \frac{g\beta L^3 \Delta T}{\nu \alpha}$$

$$\mathrm{Bi} = \frac{hL_c}{k} < 0.1 \qquad L_c = \frac{V}{A} \qquad \mathrm{Fo} = \frac{\alpha t}{L_c^2} = \frac{kt}{\rho c L_c^2}$$

Conversion Factors

$1\, s$	$=$	$0.0002777778\, hr$
$1\, m$	$=$	$3.28084\, ft$
$1\, kg$	$=$	$2.204623\, lb_m$
$1\, K$	$=$	$1.8\, {}^\circ R$
C	$=$	$\frac{5}{9}({}^\circ F - 32)$
$1\, J$	$=$	$0.00094781712\, BTU$
$1\, W$	$=$	$3.412142\, BTU/hr$

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Quantity	SI	Multiply by	US
time, t	s	$\times 0.000277778 =$	hr
length, L	m	$\times 3.2808399 =$	ft
area, A	m^2	$\times 10.76391 =$	ft^2
volume, V	m^3	$\times 35.314667 =$	ft^3
temperature, T	K	$\times 1.8 =$	$^\circ R$
density, ρ	$\frac{kg}{m^3}$	$\times 0.062427961 =$	$\frac{lb_m}{ft^3}$
thermal conductivity, k	$\frac{W}{m \cdot K}$	$\times 0.57778932 =$	$\frac{Btu}{hr \cdot ft \cdot {}^\circ R}$
specific heat, c_v, c_p	$\frac{J}{kg \cdot K}$	$\times 0.0002388459 =$	$\frac{Btu}{lb_m \cdot {}^\circ R}$
viscosity, μ	$Pa \cdot s$ or $\frac{N \cdot s}{m^2}$	$\times 2419.0883 =$	$\frac{lb_m}{ft \cdot hr}$
thermal expansion, β	$\frac{1}{K}$	$\times 0.555556 =$	$\frac{1}{{}^\circ R}$
convection coefficient, h	$\frac{W}{m^2 \cdot K}$ or $\frac{J}{s \cdot m^2 \cdot K}$	$\times 0.17611018 =$	$\frac{Btu}{hr \cdot ft^2 \cdot {}^\circ R}$
heat flux, q	$\frac{W}{m^2}$ or $\frac{J}{s \cdot m^2}$	$\times 0.31699833 =$	$\frac{Btu}{hr \cdot ft^2}$
rate of heat transfer, $Q = qA$	watt (W) or $\frac{J}{s}$	$\times 3.4121416 =$	$\frac{Btu}{hr}$

Practical Values

Temperature		Velocity		Pressure	
F	C	mph	m/s	psi	Pa
0.0	-17.8	1.0	0.44704	1.0	6,894.8
32.0	0.0	5.0	2.2352	5.0	34,473.8
70.0	21.1	10.0	4.4704	14.696	101,325.0
100.0	37.8	20.0	8.9408	50.0	344,737.9
212.0	100.0	50.0	22.352	100.0	689,475.7
		100.0	44.704		

Parameters Replaceable by Functions

`Nodes`	
	ρC and V
`Boundary Conditions`	
`fixed_T`	T_b
`heat_flux`	q and A
`Sources`	
`qdot`	$\dot{q}$
`Qsrc`	Q

Material Property Library

material	Notes
air	At atmospheric pressure, 101.325 kPa
water	
steel	AISI 1010
fir	Perpendicular to the grain