

ECSN-Test

April 9, 2019

1 ECSN Test

```
In [1]: from StarKiller.initialization import starkiller_initialize
        from StarKiller.interfaces import EosType
        from StarKiller.interfaces import BurnType
        from StarKiller.eos import Eos
        from StarKiller.network import Network
        import numpy as np

In [2]: probin_file = "probin_ecsn"

In [3]: starkiller_initialize(probin_file)

In [4]: helmholtz = Eos()
        ecsn = Network()

In [5]: def get_eps_nuc_eos(burn_state):
        ecsn.rhs(burn_state)
        print(burn_state.state)

        eos_state = burn_state.to_eos_type()
        helmholtz.evaluate(eos_state.eos_input_rt, eos_state)
        print(eos_state.state)

        Hnuc = burn_state.state.ydot[ecsn.net_ienuc]
        print("Energy generation rate: {:.09e}".format(Hnuc))

        aion = ecsn.ActualNetworkModule.aion
        zion = ecsn.ActualNetworkModule.zion

        #  $dX/dt = dY/dt * A_{ion}$ 
        omegadot = burn_state.state.ydot[:ecsn.nspec_evolve] * aion
        print("omegadot = {}".format(omegadot))

        cp = eos_state.state.cp
        print("cp = {:.05e}".format(cp))

        dpdt = eos_state.state.dpdt
```

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print("dpdt = {:.05e}".format(dpdt))

dpdx = eos_state.state.dpdx
print("dpdx = {}".format(dpdx))

dhdx = eos_state.state.dhdx
print("dhdx = {}".format(dhdx))

print("cp * dpdx/dpdt = {}".format(cp * dpdx/dpdt))
print("cp * dpdx/dpdt * wdot = {:.09e}".format(np.dot(cp * dpdx/dpdt, omegadot)))
print("dhdx = {}".format(dhdx))
print("dhdx * wdot = {:.09e}".format(np.dot(dhdx, omegadot)))

dHcompdx = (cp * dpdx/dpdt - dhdx)
print("dHcompdx = {}".format(dHcompdx))

Hcomp = np.dot(dHcompdx, omegadot)
print("Composition energy generation: {:.09e}".format(Hcomp))

dedx = eos_state.state.dedx
print("dedx = {}".format(dedx))

de = -np.dot(dedx, omegadot)
print("eps_nuc_eos = dedx * wdot (cf. MESA) = {:.09e}".format(de))

dabardX = (eos_state.state.abar/aion) * (aion - eos_state.state.abar)
dzbardX = (eos_state.state.abar/aion) * (zion - eos_state.state.zbar)

dabardt = np.dot(dabardX, omegadot)
dzbardt = np.dot(dzbardX, omegadot)

print("dabar/dt = {:.09e}".format(dabardt))
print("dzbar/dt = {:.09e}".format(dzbardt))

print("sum omegadot = {:.16e}".format(np.sum(omegadot)))
print("sum X = {:.16e}".format(np.sum(burn_state.state.xn)))

Htot = Hnuc + Hcomp
print("Hnuc + Hcomp (Maestro): {:.9e}".format(Htot))

```

1.1 Test 1 from Josiah

In [6]: burn_state_1 = BurnType()

```

burn_state_1.state.rho = 7607783959.50421e0
burn_state_1.state.t = 983559309.749412e0
burn_state_1.state.xn[ecsn.species_map["h1"]] = 0.0
burn_state_1.state.xn[ecsn.species_map["he4"]] = 1.14998095787427E-18

```

```

burn_state_1.state.xn[ecsn.species_map["o16"]] = 0.5955320774
burn_state_1.state.xn[ecsn.species_map["o20"]] = 0.203902681
burn_state_1.state.xn[ecsn.species_map["f20"]] = 1.17278643621995E-07
burn_state_1.state.xn[ecsn.species_map["ne20"]] = 0.19753136
burn_state_1.state.xn[ecsn.species_map["mg24"]] = 0.0
burn_state_1.state.xn[ecsn.species_map["al27"]] = 0.0
burn_state_1.state.xn[ecsn.species_map["si28"]] = 0.0027259815
burn_state_1.state.xn[ecsn.species_map["p31"]] = 0.0
burn_state_1.state.xn[ecsn.species_map["s32"]] = 0.0

```

In [7]: get_eps_nuc_eos(burn_state_1)

```

<burn_t>{
  rho : 7607783959.50421,
  t : 983559309.749412,
  e : 2.490743133790312e+18,
  xn : array([0.00000000e+00, 1.14998096e-18, 5.95532077e-01, 2.03902681e-01,
            1.17278644e-07, 1.97531360e-01, 0.00000000e+00, 0.00000000e+00,
            2.72598150e-03, 0.00000000e+00, 0.00000000e+00]),
  cv : 14444247.553061701,
  cp : 14486626.878325198,
  y_e : 0.47945583462538965,
  eta : 87.75746182063078,
  cs : 1099451413.7881703,
  dx : 0.0,
  abar : 17.42469332287015,
  zbar : 8.354370880208164,
  t_old : 6.91452328486113e-310,
  dcvdt : 4.6613249073456e-310,
  dcpdt : 4.66132490734757e-310,
  ydot : array([ 1.16695205e-11, -7.26850364e-12, -4.11345965e-11,  5.79382894e-11,
                7.42255606e-12, -5.81959032e-11,  2.16734518e-12,  0.00000000e+00,
                4.23112889e-12,  1.16695205e-11,  5.05156388e-16, -3.95207429e+01,
                -5.72522257e+08]),
  jac : array([[4.66132491e-310, 4.66132491e-310, 5.30498948e-313,
                0.00000000e+000, 6.91451145e-310, 1.38338381e-322,
                4.94065646e-324, 6.91455022e-310, 6.91452328e-310,
                1.01855798e-312, 2.54639621e-313, 6.91455065e-310,
                8.27578359e-313],
              [4.24400499e-314, 6.91455635e-310, 2.96439388e-323,
                1.97626258e-323, 0.00000000e+000, 6.91455065e-310,
                2.47032823e-323, 0.00000000e+000, 4.66132491e-310,
                1.48539705e-313, 2.96439388e-323, 4.94065646e-324,
                4.24399158e-314],
              [0.00000000e+000, 4.94065646e-324, 4.66132491e-310,
                1.23516411e-322, 0.00000000e+000, 1.48539705e-313,
                1.38338381e-322, 0.00000000e+000, 0.00000000e+000,
                4.66132491e-310, 1.23516411e-322, 1.48539839e-313,

```

4.66132491e-310],
 [0.00000000e+000, 1.48219694e-323, 4.66132491e-310,
 4.66132491e-310, 4.88059032e-313, 0.00000000e+000,
 6.91455065e-310, 8.27578359e-313, 0.00000000e+000,
 4.66132491e-310, 4.66132491e-310, 4.66839074e-313,
 5.43472210e-323],
 [4.94065646e-324, 1.23516411e-322, 0.00000000e+000,
 6.91455635e-310, 2.96439388e-323, 2.47032823e-323,
 4.24399158e-314, 1.48219694e-323, 1.28457068e-322,
 2.33419663e-313, 6.91455635e-310, 1.23516411e-322,
 2.12200857e-314],
 [4.94065646e-324, 4.66132491e-310, 1.06099924e-313,
 4.94065646e-324, 4.66132491e-310, 1.23516411e-322,
 0.00000000e+000, 4.66132491e-310, 4.66132491e-310,
 0.00000000e+000, 4.94065646e-324, 4.66132491e-310,
 1.28457068e-322],
 [4.66132491e-310, 6.91455562e-310, 0.00000000e+000,
 1.97626258e-323, 4.66132491e-310, 4.66132491e-310,
 4.66839074e-313, 3.16202013e-320, 4.66132491e-310,
 0.00000000e+000, 2.96439388e-323, 6.91451135e-310,
 4.66132491e-310],
 [1.27319748e-313, 9.88131292e-324, 1.48219694e-323,
 1.23516411e-322, 0.00000000e+000, 6.91455635e-310,
 1.06099790e-313, 0.00000000e+000, 9.88131292e-324,
 2.47032823e-323, 1.23516411e-322, 4.94065646e-324,
 4.66132491e-310],
 [6.91455065e-310, 1.48219694e-323, 4.94065646e-324,
 4.66132491e-310, 0.00000000e+000, 4.94065646e-324,
 4.66132491e-310, 1.28457068e-322, 2.47032823e-323,
 4.94065646e-324, 4.66132491e-310, 4.66839074e-313,
 4.94065646e-324],
 [4.94065646e-324, 8.48798317e-314, 4.66132491e-310,
 6.91455635e-310, 1.27319875e-313, 2.47032823e-323,
 6.91451135e-310, 4.66132491e-310, 8.39911598e-323,
 4.66132491e-310, 6.91455022e-310, 8.89318163e-323,
 4.66839074e-313],
 [1.48539839e-313, 6.91451145e-310, 1.38338381e-322,
 1.27319747e-313, 1.97626258e-323, 1.23516411e-322,
 1.27319747e-313, 4.66132491e-310, 6.91451145e-310,
 1.38338381e-322, 4.94065646e-324, 6.91451135e-310,
 1.06099790e-313],
 [1.48219694e-323, 2.96439388e-323, 6.91455065e-310,
 1.97626258e-323, 4.94065646e-324, 4.66132491e-310,
 4.66839074e-313, 4.94065646e-324, 1.27319875e-313,
 6.91455065e-310, 2.96439388e-323, 7.58884832e-320,
 4.66132491e-310],
 [1.23516411e-322, 2.12200857e-314, 4.94065646e-324,
 8.39911598e-323, 4.66132491e-310, 6.91455022e-310,

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        8.89318163e-323, 4.66839074e-313, 0.00000000e+000,
        4.94065646e-324, 1.27319748e-313, 0.00000000e+000,
        0.00000000e+000]]),
self_heat : 25856,
i : 6,
j : 26,
k : 0,
n_rhs : -1280125512,
n_jac : 21966,
time : 4.6613249074211e-310,
success : 2}
<eos_t>{
rho : 7607783959.50421,
t : 983559309.749412,
p : 6.87649058595149e+27,
e : 2.490743133790312e+18,
h : 3.3946187725511716e+18,
s : 46493486.57937405,
xn : array([0.00000000e+00, 1.14998096e-18, 5.95532077e-01, 2.03902681e-01,
1.17278644e-07, 1.97531360e-01, 0.00000000e+00, 0.00000000e+00,
2.72598150e-03, 0.00000000e+00, 0.00000000e+00]),
aux : array([], dtype=float64),
dpdt : 5.482451265458468e+16,
dpdr : 1.2052571947699988e+18,
dedt : 14444247.553061701,
dedr : 117877656.67151032,
dhdt : 21650618.41564302,
dhdr : 157492550.78698152,
dsdt : 0.014685690440713491,
dsdr : -0.0009472365278694044,
dpde : 3795594921.3127203,
dpdr_e : 7.578413597713697e+17,
cv : 14444247.553061701,
cp : 14486626.878325198,
xne : 2.196634277233492e+33,
xnp : 0.0,
eta : 87.75746182063078,
pele : 6.958956124711135e+27,
ppos : 0.0,
mu : 1.668408683623596e-257,
mu_e : 2.085697842808241,
y_e : 0.47945583462538965,
dedx : array([ 4.33966224e+18, 2.88111110e+17, 1.47145182e+17, -5.59790031e+17,
-2.11021289e+17, 1.37747453e+17, 1.31482301e+17, -1.17194771e+15,
1.27007192e+17, 1.19026957e+16, 1.23650860e+17]),
dpdx : array([ 1.19073140e+28, 8.14581090e+26, 3.98775309e+26, -1.51484702e+27,
-5.71896050e+26, 3.71054924e+26, 3.52574667e+26, -6.93324382e+24,
3.39374483e+26, 2.75321273e+25, 3.29474346e+26]),

```

```

dhdx : array([ 4.34886659e+18,  2.88740781e+17,  1.47453435e+17, -5.60961007e+17,
              -2.11463364e+17,  1.38034278e+17,  1.31754841e+17, -1.17730710e+15,
               1.27269528e+17,  1.19239780e+16,  1.23905544e+17]),
gam1 : 1.3373448286956426,
cs : 1099451413.7881703,
abar : 17.42469332287015,
zbar : 8.354370880208164,
dpda : -5.2622655581624275e+26,
dpdz : 1.0823157183836253e+27,
deda : -1.9440978481690643e+17,
dedz : 4.003155009345395e+17,
conductivity : 4.11e-321}
Energy generation rate: -5.725222567e+08
omegadot = [ 1.16695205e-11 -2.90740146e-11 -6.58153544e-10  1.15876579e-09
              1.48451121e-10 -1.16391806e-09  5.20162842e-11  0.00000000e+00
              1.18471609e-10  3.61755137e-10  1.61650044e-14]
cp = 1.44866e+07
dpdt = 5.48245e+16
dpdx = [ 1.19073140e+28  8.14581090e+26  3.98775309e+26 -1.51484702e+27
          -5.71896050e+26  3.71054924e+26  3.52574667e+26 -6.93324382e+24
          3.39374483e+26  2.75321273e+25  3.29474346e+26]
dhdx = [ 4.34886659e+18  2.88740781e+17  1.47453435e+17 -5.60961007e+17
          -2.11463364e+17  1.38034278e+17  1.31754841e+17 -1.17730710e+15
          1.27269528e+17  1.19239780e+16  1.23905544e+17]
cp * dpdx/dpdt = [ 3.14634469e+18  2.15241901e+17  1.05370916e+17 -4.00277586e+17
                  -1.51115701e+17  9.80461836e+16  9.31630287e+16 -1.83201476e+15
                  8.96750609e+16  7.27498770e+15  8.70590851e+16]
cp * dpdx/dpdt * wdot = -6.211677313e+08
dhdx = [ 4.34886659e+18  2.88740781e+17  1.47453435e+17 -5.60961007e+17
          -2.11463364e+17  1.38034278e+17  1.31754841e+17 -1.17730710e+15
          1.27269528e+17  1.19239780e+16  1.23905544e+17]
dhdx * wdot = -8.705208662e+08
dHcompdx = [-1.20252190e+18 -7.34988800e+16 -4.20825188e+16  1.60683420e+17
              6.03476628e+16 -3.99880947e+16 -3.85918119e+16 -6.54707656e+14
              -3.75944671e+16 -4.64899032e+15 -3.68464585e+16]
Composition energy generation: 2.493531349e+08
dedx = [ 4.33966224e+18  2.88111110e+17  1.47145182e+17 -5.59790031e+17
          -2.11021289e+17  1.37747453e+17  1.31482301e+17 -1.17194771e+15
          1.27007192e+17  1.19026957e+16  1.23650860e+17]
eps_nuc_eos = dedx * wdot (cf. MESA) = 8.687036959e+08
dabar/dt = 3.491671084e-09
dzbar/dt = -4.743475369e-10
sum omegadot = -2.0731264589208190e-27
sum X = 9.9969221717864365e-01
Hnuc + Hcomp (Maestro): -3.231691217e+08

```

1.2 Test 2 from Josiah

In [8]: `burn_state_2 = BurnType()`

```
burn_state_2.state.rho = 8346403698.95185e0
burn_state_2.state.t = 656536305.140964e0
burn_state_2.state.xn[ecsn.species_map["h1"]] = 0.0
burn_state_2.state.xn[ecsn.species_map["he4"]] = 8.89957317703129E-23
burn_state_2.state.xn[ecsn.species_map["o16"]] = 0.5999942706e0
burn_state_2.state.xn[ecsn.species_map["o20"]] = 0.3926652894e0
burn_state_2.state.xn[ecsn.species_map["f20"]] = 0.000000002e0
burn_state_2.state.xn[ecsn.species_map["ne20"]] = 0.0073364571e0
burn_state_2.state.xn[ecsn.species_map["mg24"]] = 0.0
burn_state_2.state.xn[ecsn.species_map["al27"]] = 0.0
burn_state_2.state.xn[ecsn.species_map["si28"]] = 3.518236231242E-06
burn_state_2.state.xn[ecsn.species_map["p31"]] = 0.0
burn_state_2.state.xn[ecsn.species_map["s32"]] = 0.0
```

In [9]: `get_eps_nuc_eos(burn_state_2)`

```
<burn_t>{
  rho : 8346403698.95185,
  t : 656536305.140964,
  e : 2.4366503017450455e+18,
  xn : array([0.00000000e+00, 8.89957318e-23, 5.99994271e-01, 3.92665289e-01,
            2.00000000e-09, 7.33645710e-03, 0.00000000e+00, 0.00000000e+00,
            3.51823623e-06, 0.00000000e+00, 0.00000000e+00]),
  cv : 13444158.983137527,
  cp : 13470518.44019436,
  y_e : 0.46073323962811563,
  eta : 133.98527882572262,
  cs : 1086123519.6557314,
  dx : 0.0,
  abar : 17.391348207658748,
  zbar : 8.012772201215236,
  t_old : 6.91452328486113e-310,
  dcvdt : 4.66132490582783e-310,
  dcpdt : 4.6613249058298e-310,
  ydot : array([ 3.75545872e-17, -2.13349498e-17, -1.35886276e-16,  1.24835159e-12,
                1.35222972e-13, -1.38354101e-12,  5.60711361e-19,  0.00000000e+00,
                1.33342876e-17,  3.75545872e-17,  4.90756421e-25,  3.57280937e-62,
                -1.61389226e+07]),
  jac : array([[4.66132491e-310, 4.66132491e-310, 5.30498948e-313,
                0.00000000e+000, 6.91451145e-310, 4.24399160e-314,
                4.94065646e-324, 6.91451135e-310, 1.48539705e-313,
                1.01855798e-312, 0.00000000e+000, 6.91455065e-310,
                8.27578359e-313],
              [6.01334510e-154, 6.91455635e-310, 2.96439388e-323,
                1.97626258e-323, 2.12201147e-314, 6.91455360e-310,
```

2.47032823e-323, 2.12199781e-313, 4.66132491e-310,
 2.96439388e-323, 2.96439388e-323, 4.94065646e-324,
 1.48219694e-323],
 [3.67294518e-062, 1.39642613e-076, 4.66132491e-310,
 1.69759663e-313, 0.00000000e+000, 4.94065646e-324,
 2.12199580e-314, 0.00000000e+000, 0.00000000e+000,
 4.66132491e-310, 1.23516411e-322, 0.00000000e+000,
 4.66132491e-310],
 [3.92639286e+179, 1.48219694e-323, 4.66132491e-310,
 4.66132491e-310, 4.88059032e-313, 1.27319874e-313,
 6.91455065e-310, 8.27578359e-313, 3.41498174e-320,
 4.66132491e-310, 4.66132491e-310, 4.66839074e-313,
 0.00000000e+000],
 [4.94065646e-324, 1.74652330e-076, 4.66132491e-310,
 6.91455635e-310, 6.36598738e-314, 2.47032823e-323,
 4.94065646e-324, 1.27319747e-313, 1.28457068e-322,
 1.58101007e-322, 6.91455635e-310, 1.23516411e-322,
 0.00000000e+000],
 [4.94065646e-324, 4.66132491e-310, 4.66132491e-310,
 2.12199579e-314, 4.66132491e-310, 1.23516411e-322,
 1.26480805e-321, 4.66132491e-310, 4.66132491e-310,
 1.69759790e-313, 4.94065646e-324, 4.66132491e-310,
 1.28457068e-322],
 [4.66132491e-310, 6.91455562e-310, 4.24400625e-314,
 1.97626258e-323, 4.66132491e-310, 4.66132491e-310,
 4.66839074e-313, 0.00000000e+000, 4.66132491e-310,
 0.00000000e+000, 2.96439388e-323, 6.91451135e-310,
 4.66132491e-310],
 [6.01182197e-067, 5.20843611e-090, 1.48219694e-323,
 1.23516411e-322, 3.81959376e-313, 6.91455635e-310,
 1.23516411e-322, 1.69759820e-313, 9.88131292e-324,
 2.47032823e-323, 1.69759663e-313, 4.94065646e-324,
 4.66132491e-310],
 [6.91455360e-310, 1.48219694e-323, 4.94065646e-324,
 4.66132491e-310, 0.00000000e+000, 4.94065646e-324,
 4.66132491e-310, 1.28457068e-322, 2.47032823e-323,
 4.94065646e-324, 4.66132491e-310, 4.66839074e-313,
 4.24399158e-314],
 [6.01346930e-154, 2.62395791e+179, 4.66132491e-310,
 6.91455635e-310, 0.00000000e+000, 2.47032823e-323,
 6.91451135e-310, 4.66132491e-310, 2.12199580e-314,
 4.66132491e-310, 6.91455022e-310, 4.24399159e-314,
 4.66839074e-313],
 [1.36922931e-071, 6.91451145e-310, 1.38338381e-322,
 9.88131292e-324, 1.97626258e-323, 1.23516411e-322,
 4.94065646e-324, 4.66132491e-310, 6.91451145e-310,
 1.38338381e-322, 4.94065646e-324, 6.91451135e-310,
 1.48219694e-323],

```

[1.48219694e-323, 3.24245662e-086, 6.91455360e-310,
 1.97626258e-323, 4.94065646e-324, 4.66132491e-310,
 4.66839074e-313, 4.94065646e-324, 0.00000000e+000,
 6.91455360e-310, 2.96439388e-323, 0.00000000e+000,
 4.66132491e-310],
[3.70155530e-033, 1.39804329e-076, 2.12199579e-313,
 8.39911598e-323, 4.66132491e-310, 6.91455022e-310,
 8.89318163e-323, 4.66839074e-313, 1.26480805e-321,
 4.94065646e-324, 1.38338381e-322, 2.12201615e-314,
 0.00000000e+000]]),
self_heat : 0,
i : 0,
j : 26,
k : 10,
n_rhs : -1280156232,
n_jac : 21966,
time : 4.6613249059033e-310,
success : 2}
<eos_t>{
rho : 8346403698.95185,
t : 656536305.140964,
p : 7.364917477765657e+27,
e : 2.4366503017450455e+18,
h : 3.3190563946459377e+18,
s : 40474438.71911317,
xn : array([0.00000000e+00, 8.89957318e-23, 5.99994271e-01, 3.92665289e-01,
 2.00000000e-09, 7.33645710e-03, 0.00000000e+00, 0.00000000e+00,
 3.51823623e-06, 0.00000000e+00, 0.00000000e+00]),
aux : array([], dtype=float64),
dpdt : 5.73841729147549e+16,
dpdr : 1.1773559024964984e+18,
dedt : 13444158.983137527,
dedr : 105182091.4988295,
dhdt : 20319476.183761463,
dhdr : 140520642.1170612,
dsdt : 0.02047740372903058,
dsdr : -0.0008237460646059265,
dpde : 4268334894.4868603,
dpdr_e : 7.284035110769347e+17,
cv : 13444158.983137527,
cp : 13470518.44019436,
xne : 2.315793919641922e+33,
xnp : 0.0,
eta : 133.98527882572262,
pele : 7.464603358528272e+27,
ppos : 0.0,
mu : 1.668408683623596e-257,
mu_e : 2.1704533426048394,

```

```

y_e : 0.46073323962811563,
dedx : array([ 4.47058940e+18,  4.09184168e+17,  2.82554706e+17, -4.36864735e+17,
              -8.13759969e+16,  2.74112742e+17,  2.68484765e+17,  1.33695616e+17,
              2.64464783e+17,  1.47456812e+17,  2.61449795e+17]),
dpdx : array([ 1.33454960e+28,  1.23271936e+27,  8.37705760e+26, -1.29517292e+27,
              -2.41900702e+26,  8.11371520e+26,  7.93815360e+26,  3.93961115e+26,
              7.81275246e+26,  4.34228656e+26,  7.71870160e+26]),
dhdx : array([ 4.47671966e+18,  4.09750419e+17,  2.82939506e+17, -4.37459674e+17,
              -8.14871141e+16,  2.74485446e+17,  2.68849405e+17,  1.33876583e+17,
              2.64823662e+17,  1.47656275e+17,  2.61804354e+17]),
gam1 : 1.336872341929589,
cs : 1086123519.6557314,
abar : 17.391348207658748,
zbar : 8.012772201215236,
dpda : -5.650331154459965e+26,
dpdz : 1.211260000488575e+27,
deda : -1.905857130636209e+17,
dedz : 4.088110181833375e+17,
conductivity : 4.11e-321}
Energy generation rate: -1.613892258e+07
omegadot = [ 3.75545872e-17 -8.53397992e-17 -2.17418042e-15  2.49670318e-11
              2.70445944e-12 -2.76708202e-11  1.34570727e-17  0.00000000e+00
              3.73360052e-16  1.16419220e-15  1.57042055e-23]
cp = 1.34705e+07
dpdt = 5.73842e+16
dpdx = [ 1.33454960e+28  1.23271936e+27  8.37705760e+26 -1.29517292e+27
          -2.41900702e+26  8.11371520e+26  7.93815360e+26  3.93961115e+26
          7.81275246e+26  4.34228656e+26  7.71870160e+26]
dhdx = [ 4.47671966e+18  4.09750419e+17  2.82939506e+17 -4.37459674e+17
          -8.14871141e+16  2.74485446e+17  2.68849405e+17  1.33876583e+17
          2.64823662e+17  1.47656275e+17  2.61804354e+17]
cp * dpdx/dpdt = [ 3.13275840e+18  2.89371931e+17  1.96645352e+17 -3.04032451e+17
                   -5.67844354e+16  1.90463580e+17  1.86342399e+17  9.24795147e+16
                   1.83398698e+17  1.01932028e+17  1.81190922e+17]
cp * dpdx/dpdt * wdot = -1.301478750e+07
dhdx = [ 4.47671966e+18  4.09750419e+17  2.82939506e+17 -4.37459674e+17
          -8.14871141e+16  2.74485446e+17  2.68849405e+17  1.33876583e+17
          2.64823662e+17  1.47656275e+17  2.61804354e+17]
dhdx * wdot = -1.873789321e+07
dHcompdx = [-1.34396126e+18 -1.20378488e+17 -8.62941542e+16  1.33427223e+17
              2.47026787e+16 -8.40218653e+16 -8.25070060e+16 -4.13970679e+16
              -8.14249637e+16 -4.57242475e+16 -8.06134319e+16]
Composition energy generation: 5.723105706e+06
dedx = [ 4.47058940e+18  4.09184168e+17  2.82554706e+17 -4.36864735e+17
          -8.13759969e+16  2.74112742e+17  2.68484765e+17  1.33695616e+17
          2.64464783e+17  1.47456812e+17  2.61449795e+17]
eps_nuc_eos = dedx * wdot (cf. MESA) = 1.871242553e+07
dabar/dt = 1.048602276e-14

```

```
dzbar/dt = -4.576791284e-11  
sum omegadot = -4.7384837197298319e-27  
sum X = 9.9999953733623126e-01  
Hnuc + Hcomp (Maestro): -1.041581688e+07
```