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Title: (U) Energy-Dependent Perturbations of Scattering Cross Sections Using the PERT Card in MCNP6.2

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SUBJECT: (U) Energy-Dependent Perturbations of Scattering Cross Sections Using the PERT Card in MCNP6.2

I. Introduction

The PERT card is used for first- and second-order perturbations of material densities, isotope densities, and isotope cross sections in the MCNP6.2 Monte Carlo code.¹ Using the PERT card for first- and second-order sensitivities is straightforward.² Reference 2 only looked at density perturbations with no energy dependence. This report looks at the sensitivity of a response to scattering cross sections as a function of energy and finds that there is a bug in the PERT capability.

The SENSMSG multigroup neutron sensitivity code^{3,4} was recently given the capability of computing sensitivities to user-specified reactions whose cross sections are available in a user-supplied NJOY output file.⁵ SENSMSG uses the PARTISN multigroup discrete ordinates code⁶ for the transport. The NJOY-reaction capability is similar to that of SUSD3D (Refs. 7 and 8), which also uses PARTISN for the multigroup transport.

The PERT bug was identified by comparing MCNP6.2 outputs with SENSMSG outputs.

The next section of this report describes the test problem. Section III presents the MCNP6.2 PERT bug and proposes a solution. Section IV is a summary and conclusions. The SENSMSG and MCNP input files are listed in the appendix.

II. Test Problem

The test problem used in this report is a one-dimensional sphere with two materials. The geometry is a simplified version of the BeRP ball reflected with polyethylene.⁹ The materials are defined in Table I and dimensions are shown there and in Figure 1. The α -Pu of Table I is a simplification of the material specification given in Ref. 9 in which the impurities were replaced with natural gallium.

Table I. Materials and Geometry of the Test Problem.

Index	Material	Composition (Weight Fraction)	Density (g/cm ³)	Outer Radius (cm)
1	α -Pu	²³⁹ Pu 9.38039E-01; ²⁴⁰ Pu 5.94112E-02; ⁶⁹ Ga 1.51515E-03; ⁷¹ Ga 1.03465E-03	19.6	3.794
2	Polyethylene	C (nat.) 8.56299E-01; ¹ H 1.43701E-01	0.95	7.604

This experiment measured neutron and gamma-ray leakage and subcritical multiplication in Ref. 9. Here we use the system's total neutron leakage.

Figure 1. Cross-section of the spherical geometry. Scales in centimeters.

The calculations used ENDF/B-VIII.0 cross sections. The MCNP6.2 calculations used ZAID extension 00c. PARTISN calculations used LIBNAME = mt80. Because the multigroup cross sections do not include $S(\alpha,\beta)$ scattering, the Monte Carlo calculations were also done without $S(\alpha,\beta)$ scattering.

PARTISN version 8.31.37 was used with S_{256} quadrature, P_3 scattering, and a convergence criterion (PARTISN's `epsi`) of $1\text{E-}6$. These parameters were set on the SENSMSG input line. The fine mesh spacing was 0.005 cm for both regions. The calculations used 36 processors.

PARTISN calculations used 250 energy groups. The 250-energy-group structure from the NDI was used for the MCNP source and tallies, including PERT cards.

Table II compares the MCNP and PARTISN results for the total leakage. The difference of -4.6% (with respect to MCNP) is due to the lack of self-shielding in the multigroup cross sections. (Thomas Saller [CCS-2] confirmed this with a 261-group library based on ENDF/B-VII.1.¹⁰)

Table II. Calculated Leakage.

Code	Energy Treatment	Leakage (neutrons/s)
MCNP6.2	Continuous	$1.91962\text{E}+06 \pm 0.03\%$
PARTISN	Multigroup	$1.8303897\text{E}+06$

III. MCNP PERT Bug

III.A. Problem

Figure 2 compares the sensitivity of the neutron leakage to the Pu-239 elastic scattering cross section computed using MCNP6.2 (with PERT cards) and SENSMSG. Figure 3 is the same for the Pu-239 inelastic scattering cross section, which is the sum of MF 6, MT 51 through 91. For SENSMSG, “sum” means the sum of the Legendre scattering moments. Also, for each energy group, the sensitivity is the sum of outgoing channels.

There is a large mismatch, including a negative peak at $5\text{E-}08$ MeV for the MCNP calculations.

Figure 2. Sensitivity of the total leakage to Pu-239 elastic scattering. The PERT capability has a bug.

Figure 3. Sensitivity of the total leakage to Pu-239 inelastic scattering. The PERT capability has a bug.

III.B. Diagnosis and Solution

Variable `eg0` is defined in `tskcom` as the “Energy of the particle before last collision”. It is used in subroutine `pert_difop_dtrack` to help determine if the particle energy is within the boundaries set on the PERT card. The current particle energy is also used.

The problem is that `eg0` is not reset when a particle terminates. When a particle comes from the source or the bank, `eg0` still has the value that it had in the last collision. When the particle comes from the source, there is no problem in `pert_difop_dtrack` because `iexp` (“IEX from previous collision” defined in `pblcom`) is 0. However, when a particle is banked due to a collision, it comes out with a non-zero `iexp`, and `eg0` is used. But `eg0` has a value corresponding to the last thing that happened in the code, which likely has nothing to do with the particle that came from the bank.

Figure 4(a) is a snippet from an event log showing a neutron bouncing around in the plutonium (cell 1) and polyethylene (cell 2) before terminating by escape. Then a neutron comes from the bank into the plutonium (cell 1). This snippet also has `eg0` printed at the end of subroutine `eventp`. The neutron from the bank has the same `eg0` that the previous neutron had when it escaped. Perturbations using this value of `eg0` score in the wrong bin.

We think that when a neutron comes from the bank, it should have `eg0` equal to the value it had when the neutron went into the bank. Thus `eg0` should be a banked variable.

We modified MCNP to use `eg0` as `sparm(1)` (thank you whoever put in those spares all those centuries ago!). Everywhere we found “`eg0 =`” (`charged_particle_history.F90`, `chg_pl_lcaopt.F90`, `electr.F90`, `electron_history.F90`, `history_neutral_high.F90`, `hstory.F90`, `neu_pl_lcaopt.F90`, `single_event_electrons.F90`, and `xs_calc.F90`), we added the line

```
pbl%r%spare(1) = eg0
```

We don’t know if this is the right thing to do in all cases.

In subroutine `unbank_particle`, after “`call gpbl_unbank`”, we added
`eg0 = pbl%r%spare(1)`

For good measure, in subroutine `startp`, after “`enddo SAMPLE_SRC`”, we initialized `eg0` with
`eg0 = 0.d0`
`pbl%r%spare(1) = eg0`

We don’t know if that’s the right place to do it. Maybe it should be done in subroutine `neutron_photon_history` where `pbl%i%iexp` is set to 0.

Variable `eg0` is used a lot in charged particle tracking and we don’t know how this proposed solution affects that. However, none of the regular regression problems had any changes.

Figure 4(b) is a snippet from the same point in the event log as Figure 4(a). It shows that the neutron from the bank has the correct value of `eg0`, that of the neutron when it went into the bank.

Figure 5 and Figure 6 show that PERT and SENSMSG sensitivities of Pu-239 elastic and inelastic scattering agree when the PERT bug is fixed as discussed above.

cell	x	y	z	u	v	w	erg	wgt	nhc	nrn
...										
nnf	1 -1.762-01	-5.716-02	-1.719-01	-6.444-01	6.827-01	3.444-01	1.348+00	2.687-03 n npa=	1	7 118
eg0=	7.803673E-01									
nnf	1 -1.762-01	-5.716-02	-1.719-01	6.338-01	-3.769-01	-6.754-01	1.083+00	2.687-03 n npa=	1	7 120
eg0=	7.803673E-01									
col	1 -1.762-01	-5.716-02	-1.719-01	-4.723-01	8.113-01	3.445-01	5.807+00	2.687-03 94239.00c r= 18: 3		7 124
eg0=	7.803673E-01									
sur	2 -1.975+00	3.032+00	1.140+00	-4.723-01	8.113-01	3.445-01	5.807+00	2.687-03 surf=	1	125
eg0=	5.806766E+00									
col	2 -3.067+00	4.909+00	1.937+00	4.619-01	8.792-01	-1.170-01	5.297+00	2.687-03 6012.00c r=	2	8 132
eg0=	5.806766E+00									
sur	3 -1.870+00	7.187+00	1.634+00	4.619-01	8.792-01	-1.170-01	5.297+00	2.687-03 surf=	2	133
eg0=	5.297297E+00									
ter	3 -1.870+00	7.187+00	1.634+00	4.619-01	8.792-01	-1.170-01	5.297+00	2.687-03 escape		133
eg0=	5.297297E+00									
bank	1 -1.762-01	-5.716-02	-1.719-01	6.338-01	-3.769-01	-6.754-01	1.083+00	2.687-03 n (n,xn,f)		120 133
eg0=	5.297297E+00									
col	1 1.094+00	-8.123-01	-1.525+00	9.631-01	2.602-01	6.862-02	1.078+00	2.672-03 94239.00c r=	2	9 142
eg0=	1.082633E+00									
col	1 3.336+00	-2.066-01	-1.365+00	9.373-01	3.482-01	1.568-02	1.078+00	2.657-03 94239.00c r=	2	10 149
eg0=	1.077765E+00									

(a)

cell	x	y	z	u	v	w	erg	wgt	nhc	nrn
...										
nnf	1 -1.762-01	-5.716-02	-1.719-01	-6.444-01	6.827-01	3.444-01	1.348+00	2.687-03 n npa=	1	7 118
eg0=	7.803673E-01									
nnf	1 -1.762-01	-5.716-02	-1.719-01	6.338-01	-3.769-01	-6.754-01	1.083+00	2.687-03 n npa=	1	7 120
eg0=	7.803673E-01									
col	1 -1.762-01	-5.716-02	-1.719-01	-4.723-01	8.113-01	3.445-01	5.807+00	2.687-03 94239.00c r= 18: 3		7 124
eg0=	7.803673E-01									
sur	2 -1.975+00	3.032+00	1.140+00	-4.723-01	8.113-01	3.445-01	5.807+00	2.687-03 surf=	1	125
eg0=	5.806766E+00									
col	2 -3.067+00	4.909+00	1.937+00	4.619-01	8.792-01	-1.170-01	5.297+00	2.687-03 6012.00c r=	2	8 132
eg0=	5.806766E+00									
sur	3 -1.870+00	7.187+00	1.634+00	4.619-01	8.792-01	-1.170-01	5.297+00	2.687-03 surf=	2	133
eg0=	5.297297E+00									
ter	3 -1.870+00	7.187+00	1.634+00	4.619-01	8.792-01	-1.170-01	5.297+00	2.687-03 escape		133
eg0=	5.297297E+00									
bank	1 -1.762-01	-5.716-02	-1.719-01	6.338-01	-3.769-01	-6.754-01	1.083+00	2.687-03 n (n,xn,f)		120 133
eg0=	7.803673E-01									
col	1 1.094+00	-8.123-01	-1.525+00	9.631-01	2.602-01	6.862-02	1.078+00	2.672-03 94239.00c r=	2	9 142
eg0=	1.082633E+00									
col	1 3.336+00	-2.066-01	-1.365+00	9.373-01	3.482-01	1.568-02	1.078+00	2.657-03 94239.00c r=	2	10 149
eg0=	1.077765E+00									

(b)

Figure 4. Event log snippets. (a) From unmodified MCNP6.2 showing eg0 is the last value from an unrelated history. (b) From modified MCNP6.2 showing eg0 has the correct value.

Figure 5. Sensitivity of the total leakage to Pu-239 elastic scattering when the PERT bug is fixed.

Figure 6. Sensitivity of the total leakage to Pu-239 inelastic scattering when the PERT bug is fixed.

IV. Summary and Future Work

There is a bug in the MCNP6.2 PERT capability that affects energy-dependent perturbations. It is not known if this bug affects energy-dependent tallies. A simple fix is provided.

The SENSMSG and MCNP input files are listed in the appendix.

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XCP-5 File
XCP-7 File

APPENDIX

INPUT FILES FOR THE TEST PROBLEM

SENSMG Input File

```
simple BeRP ball, 38.1 mm reflector, no steel or NO
sphere lkg
mt80
2 / no of materials
1 94239 -9.38039E-01 94240 -5.94113E-02 31069 -1.51516E-03 31071 -1.03465E-03 / simple BeRP
2 6012 -8.56299E-01 1001 -1.43701E-01 / HDPE, C2H4
-19.6 -0.95 / densities
2 / no of shells
3.794 7.604 / radii
1 2 / material nos
0 / number of edit points
0 / number of reaction-rate ratios
45 / number of njoy reactions
94239 6 2 / zaid, mf, mt
94239 6 221 / zaid, mf, mt
94239 6 51 / zaid, mf, mt
94239 6 52 / zaid, mf, mt
94239 6 53 / zaid, mf, mt
94239 6 54 / zaid, mf, mt
94239 6 55 / zaid, mf, mt
94239 6 56 / zaid, mf, mt
94239 6 57 / zaid, mf, mt
94239 6 58 / zaid, mf, mt
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94239 6 85 / zaid, mf, mt
94239 6 86 / zaid, mf, mt
94239 6 87 / zaid, mf, mt
94239 6 88 / zaid, mf, mt
94239 6 89 / zaid, mf, mt
94239 6 90 / zaid, mf, mt
94239 6 91 / zaid, mf, mt
94239 6 16 / zaid, mf, mt
94239 6 17 / zaid, mf, mt
```

MCNP Input File

```
simplified berp ball
c
1 1 4.966933870E-02 -1 imp:n=1
2 3 1.224090259E-01 -2 1 imp:n=1
3 0 2 imp:n=0

1 so 3.794
2 so 7.604

m1
94239.00c 4.631643975E-02
94240.00c 2.921241629E-03
31069.00c 2.594682660E-04
31071.00c 1.721890521E-04

m2
94239.00c 9.263287950E-02
94240.00c 2.921241629E-03
31069.00c 2.594682660E-04
31071.00c 1.721890521E-04

m3
6012.00c 4.083550385E-02
1001.00c 8.157352203E-02
sdef pos=0. 0. erg=d2 rad=d1 wgt=2.78389E+05
sil 0. 3.794
spl -21 2
# si002 sp002
h d
0 0
1.39E-10 0
2.43741E-10 1.18987E-12
4.01861E-10 2.09435E-12
6.62557E-10 4.60578E-12
1.09237E-09 9.73049E-12
1.80102E-09 2.04727E-11
2.96937E-09 4.34132E-11
4.89567E-09 9.1868E-11
8.07159E-09 1.94722E-10
1.25015E-08 3.4211E-10
2.06115E-08 7.94171E-10
3.39827E-08 1.68132E-09
5.6028E-08 3.55923E-09
9.23745E-08 7.53494E-09
0.000000152 1.58622E-08
1.72578E-07 6.32385E-09
1.95557E-07 7.52079E-09
2.21595E-07 9.0715E-09
2.511E-07 1.09424E-08
2.84533E-07 1.31988E-08
3.22419E-07 1.59214E-08
3.65348E-07 1.92042E-08
0.000000414 2.31682E-08
4.69116E-07 2.79389E-08
5.31579E-07 3.37054E-08
6.02357E-07 4.06553E-08
6.8256E-07 4.90403E-08
7.73442E-07 5.9154E-08
8.76425E-07 7.13534E-08
9.93119E-07 8.60679E-08
0.00000113 1.07585E-07
1.27519E-06 1.21462E-07
1.44498E-06 1.51055E-07
1.63738E-06 1.8221E-07
1.85539E-06 2.19779E-07
2.10243E-06 2.65106E-07
2.38237E-06 3.19787E-07
2.69958E-06 3.85733E-07
0.00000306 4.66583E-07
3.46633E-06 5.59936E-07
3.92786E-06 6.7697E-07
4.45085E-06 8.16594E-07
5.04348E-06 9.85008E-07
```

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6.47595E-06	1.43316E-06
7.33822E-06	1.72874E-06
0.00000832	2.0956E-06
9.42245E-06	2.5049E-06
0.000010677	3.03391E-06
1.20987E-05	3.65988E-06
1.37096E-05	4.41439E-06
0.000015535	5.3248E-06
1.76035E-05	6.42308E-06
1.99473E-05	7.74732E-06
0.0000226	9.33351E-06
2.56129E-05	1.12846E-05
2.90232E-05	1.35973E-05
3.28876E-05	1.64015E-05
3.72665E-05	1.97838E-05
4.22285E-05	2.3864E-05
4.78512E-05	2.87855E-05
5.42225E-05	3.47216E-05
0.0000614	4.16302E-05
0.000069623	5.07709E-05
7.88932E-05	6.09377E-05
8.93978E-05	7.35051E-05
0.000101301	8.86631E-05
0.000114789	0.000106947
0.000130073	0.000129002
0.000147392	0.000155605
0.000167	0.000187526
0.000189255	0.000226567
0.000214454	0.000273087
0.000243008	0.000329399
0.000275364	0.000397326
0.000312029	0.00047927
0.000353575	0.000578087
0.000400653	0.000697295
0.000454	0.000841088
0.000514449	0.001014501
0.000582947	0.001223689
0.000660565	0.001475991
0.000748518	0.001780321
0.000848182	0.002147384
0.000961117	0.002590129
0.00108909	0.003124136
0.001235	0.003792233
0.00139842	0.004520833
0.00158461	0.005481524
0.0017956	0.006611632
0.00203468	0.007974195
0.0023056	0.009617794
0.00261259	0.01159959
0.00296045	0.013989372
0.00335	0.016667335
0.00380129	0.020550878
0.00430743	0.024537572
0.00488095	0.029589716
0.00553084	0.035681932
0.00626727	0.043026848
0.00710174	0.051879886
0.00804733	0.062553216
0.00912	0.075502497
0.010333	0.090836521
0.0117088	0.109601298
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0.0193045	0.231229206
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0.0248	0.3370903
0.0280879	0.402726759
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0.125881	3.664528262
0.142642	4.385274903
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0.184	6.508871793
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0.266491	5.494747891
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0.303	6.87571612
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0.467706	11.47244021
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1.53355	17.71119576
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1.63246	18.16625617
1.68427	18.35553634
1.738	18.62079657
1.7929	18.58583654
1.84981	18.79345673
1.90853	18.88499681
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8.29029	0.759993976
8.55345	0.624039055
8.82497	0.507918452
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9.39413	0.327294691
9.69233	0.258958231
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10.25	0.127557614
10.5	0.10135669
10.75	0.080455962
11	0.063802737
11.25	0.050548745
11.5	0.040011516
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15	0.00139772
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15.5	0.00085649
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erg=1.94969E-01 2.07543E-01 method=2
pert130:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.07543E-01 2.20929E-01 method=2
pert131:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.20929E-01 2.35177E-01 method=2
pert132:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.35177E-01 2.50345E-01 method=2
pert133:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.50345E-01 2.66491E-01 method=2
pert134:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.66491E-01 2.83678E-01 method=2
pert135:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.83678E-01 3.03000E-01 method=2
pert136:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.03000E-01 3.21449E-01 method=2
pert137:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.21449E-01 3.42181E-01 method=2
pert138:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.42181E-01 3.64250E-01 method=2
pert139:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.64250E-01 3.87742E-01 method=2
pert140:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.87742E-01 4.12749E-01 method=2
pert141:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=4.12749E-01 4.39369E-01 method=2
pert142:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=4.39369E-01 4.67706E-01 method=2
pert143:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=4.67706E-01 5.00000E-01 method=2
pert144:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=5.00000E-01 5.29981E-01 method=2
pert145:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=5.29981E-01 5.64161E-01 method=2
pert146:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=5.64161E-01 6.00547E-01 method=2
pert147:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=6.00547E-01 6.39279E-01 method=2
pert148:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=6.39279E-01 6.80509E-01 method=2
pert149:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=6.80509E-01 7.24398E-01 method=2
pert150:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=7.24398E-01 7.71117E-01 method=2
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erg=7.71117E-01 8.23000E-01 method=2
pert152:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=8.23000E-01 8.73790E-01 method=2
pert153:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=8.73790E-01 9.30145E-01 method=2
pert154:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=9.30145E-01 9.90134E-01 method=2

pert155:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
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erg=1.05399E+00 1.12197E+00 method=2
pert157:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=1.12197E+00 1.19433E+00 method=2
pert158:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=1.19433E+00 1.27136E+00 method=2
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erg=1.44064E+00 1.48637E+00 method=2
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erg=1.63246E+00 1.68427E+00 method=2
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pert169:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=1.79290E+00 1.84981E+00 method=2
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erg=1.84981E+00 1.90853E+00 method=2
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erg=1.90853E+00 1.96912E+00 method=2
pert172:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=1.96912E+00 2.03162E+00 method=2
pert173:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.03162E+00 2.09611E+00 method=2
pert174:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.09611E+00 2.16265E+00 method=2
pert175:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.16265E+00 2.23200E+00 method=2
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erg=2.23200E+00 2.30213E+00 method=2
pert177:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
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pert180:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.52840E+00 2.60866E+00 method=2
pert181:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.60866E+00 2.69146E+00 method=2
pert182:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
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erg=2.77690E+00 2.86500E+00 method=2
pert184:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.86500E+00 2.95599E+00 method=2
pert185:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=2.95599E+00 3.04983E+00 method=2
pert186:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.04983E+00 3.14664E+00 method=2
pert187:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.14664E+00 3.24652E+00 method=2
pert188:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.24652E+00 3.34958E+00 method=2
pert189:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.34958E+00 3.45591E+00 method=2
pert190:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.45591E+00 3.56561E+00 method=2
pert191:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.56561E+00 3.68000E+00 method=2

pert192:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.68000E+00 3.79557E+00 method=2
pert193:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=3.79557E+00 3.91606E+00 method=2
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erg=3.91606E+00 4.04037E+00 method=2
pert195:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=4.04037E+00 4.16862E+00 method=2
pert196:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
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erg=4.57833E+00 4.72367E+00 method=2
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erg=4.87361E+00 5.02832E+00 method=2
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erg=5.02832E+00 5.18793E+00 method=2
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erg=5.18793E+00 5.35261E+00 method=2
pert204:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=5.35261E+00 5.52252E+00 method=2
pert205:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
erg=5.52252E+00 5.69783E+00 method=2
pert206:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
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erg=9.39413E+00 9.69233E+00 method=2
pert223:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
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pert224:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
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pert226:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
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pert251:n cell=1 mat=2 rho=9.598577845E-02 rxn=2
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pert601:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=0.00000E+00 1.39000E-10 method=2
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erg=1.39000E-10 2.43741E-10 method=2
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erg=2.43741E-10 4.01861E-10 method=2
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pert605:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=6.62557E-10 1.09237E-09 method=2
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erg=1.09237E-09 1.80102E-09 method=2
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erg=2.96937E-09 4.89567E-09 method=2
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erg=8.07159E-09 1.25015E-08 method=2
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erg=1.25015E-08 2.06115E-08 method=2
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erg=3.39827E-08 5.60280E-08 method=2
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erg=1.52000E-07 1.72578E-07 method=2
pert617:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
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erg=1.95557E-07 2.21595E-07 method=2
pert619:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=2.21595E-07 2.51100E-07 method=2
pert620:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=2.51100E-07 2.84533E-07 method=2
pert621:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
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pert622:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
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pert623:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=3.65348E-07 4.14000E-07 method=2
pert624:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
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pert625:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=4.69116E-07 5.31579E-07 method=2
pert626:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
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pert629:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
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erg=8.76425E-07 9.93119E-07 method=2
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erg=1.13000E-06 1.27519E-06 method=2
pert633:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.27519E-06 1.44498E-06 method=2
pert634:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
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pert635:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
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pert636:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
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pert637:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
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pert638:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=2.38237E-06 2.69958E-06 method=2
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erg=2.69958E-06 3.06000E-06 method=2
pert640:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
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pert796:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=4.16862E+00 4.30095E+00 method=2
pert797:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=4.30095E+00 4.43747E+00 method=2
pert798:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=4.43747E+00 4.57833E+00 method=2
pert799:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=4.57833E+00 4.72367E+00 method=2

pert800:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=4.72367E+00 4.87361E+00 method=2
pert801:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=4.87361E+00 5.02832E+00 method=2
pert802:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=5.02832E+00 5.18793E+00 method=2
pert803:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=5.18793E+00 5.35261E+00 method=2
pert804:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=5.35261E+00 5.52252E+00 method=2
pert805:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=5.52252E+00 5.69783E+00 method=2
pert806:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=5.69783E+00 5.87870E+00 method=2
pert807:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=5.87870E+00 6.07000E+00 method=2
pert808:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=6.07000E+00 6.25784E+00 method=2
pert809:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=6.25784E+00 6.45649E+00 method=2
pert810:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=6.45649E+00 6.66144E+00 method=2
pert811:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=6.66144E+00 6.87289E+00 method=2
pert812:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=6.87289E+00 7.09106E+00 method=2
pert813:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=7.09106E+00 7.31616E+00 method=2
pert814:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=7.31616E+00 7.54840E+00 method=2
pert815:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=7.54840E+00 7.79000E+00 method=2
pert816:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=7.79000E+00 8.03523E+00 method=2
pert817:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=8.03523E+00 8.29029E+00 method=2
pert818:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=8.29029E+00 8.55345E+00 method=2
pert819:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=8.55345E+00 8.82497E+00 method=2
pert820:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=8.82497E+00 9.10510E+00 method=2
pert821:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=9.10510E+00 9.39413E+00 method=2
pert822:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=9.39413E+00 9.69233E+00 method=2
pert823:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=9.69233E+00 1.00000E+01 method=2
pert824:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.00000E+01 1.02500E+01 method=2
pert825:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.02500E+01 1.05000E+01 method=2
pert826:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.05000E+01 1.07500E+01 method=2
pert827:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.07500E+01 1.10000E+01 method=2
pert828:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.10000E+01 1.12500E+01 method=2
pert829:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.12500E+01 1.15000E+01 method=2
pert830:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.15000E+01 1.17500E+01 method=2
pert831:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.17500E+01 1.20000E+01 method=2
pert832:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.20000E+01 1.22500E+01 method=2
pert833:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.22500E+01 1.25000E+01 method=2
pert834:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.25000E+01 1.27500E+01 method=2
pert835:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.27500E+01 1.30000E+01 method=2
pert836:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.30000E+01 1.32500E+01 method=2

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pert837:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.32500E+01 1.35000E+01 method=2
pert838:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.35000E+01 1.37500E+01 method=2
pert839:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.37500E+01 1.40000E+01 method=2
pert840:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.40000E+01 1.42500E+01 method=2
pert841:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.42500E+01 1.45000E+01 method=2
pert842:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.45000E+01 1.47500E+01 method=2
pert843:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.47500E+01 1.50000E+01 method=2
pert844:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.50000E+01 1.52500E+01 method=2
pert845:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.52500E+01 1.55000E+01 method=2
pert846:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.55000E+01 1.57500E+01 method=2
pert847:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.57500E+01 1.60000E+01 method=2
pert848:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.60000E+01 1.62500E+01 method=2
pert849:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.62500E+01 1.65000E+01 method=2
pert850:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.65000E+01 1.67500E+01 method=2
pert851:n cell=1 mat=2 rho=9.598577845E-02 rxn=51 39I 91
erg=1.67500E+01 1.70000E+01 method=2
nps      6e8
prdmp j 6e7
print
```