

Brief User's Guide to SIMULATE: FORTRAN Code for Time-Dependent Simulation of Tamped Fission Core

See at the end of this document for BARECOREVALS: Time-Dependent Simulation of Bare Core Only; No tamper

July 2014; modified March 2015

SIMULATE

The program comprises 3 main sections:

- (1) Computation of bare threshold critical mass and radius
- (2) Computation of tamped threshold critical mass and radius for a tamper of specified outer radius; also computes tamper mass
- (3) Time-dependent simulation for tamped super-criticality for specified core mass (> tamped threshold critical mass) and tamper outer radius specified in (2).
[Well, OK, you need the answer to (2) before doing this part!]

The user must provide a short four-line file of parameters, CRITVLAS. The four lines are

$$\begin{aligned} &\rho_{core}, A_{core}, \sigma_{fiss}^{core}, \sigma_{scatt}^{core}, \nu \\ &\rho_{tamp}, A_{tamp}, \sigma_{scatt}^{tamp}, R_{tamp} \\ &M_{core} \\ &\gamma, N_{neuts}, t_{start}, dt \end{aligned}$$

These are:

core density (gr/cm³), core atomic weight (gr/mol), core fission cross-section (bn), core scattering cross-section (bn), neutrons per fission

tamper density (gr/cm³), tamper atomic weight (gr/mol), tamper scattering cross-section (bn), tamper outer radius (meters)

core mass (kg)

gas/radiation pressure constant, number of initial neutrons, starting time (seconds), timestep (seconds)

For the *Little Boy* simulation of section 2.5.12 of the book, here is CRITVALS:

18.71, 235.04, 1.235, 4.566, 2.637

14.8, 195.84, 6.587, 0.18
64.0
0.333333333, 1, 1.0D-08, 5.0D-10

The energy per fission and average neutron energy are programmed in as 180 MeV and 2 MeV; these could be changed as desired. A kiloton is programmed as 4.2×10^{12} Joules. The output goes to a file named SIMULATION-RESULTS. A duplicate file named SIMULATION-PLOT is formatted for quick reading-in of the time-dependent simulation output into a spreadsheet. The program runs until second criticality is reached ($\alpha = 0$).

This program uses a bisection routine for root-finding; this is adopted from program RTBIS on p. 247 of William H. Press, Brian T. Flannery, Saul A. Teukolsy, and William T. Vetterling, *Numerical recipes: The Art of Scientific Computing* (Cambridge UP, 1986)

Copied below is (partial) output for the *Little Boy* simulation. Yield (last column) is in kilotons.

INPUT AND DERIVED CORE PARAMETERS

CORE DENSITY 18.71 gr/cm³
CORE ATOMIC WT 235.04 gr/mol
CORE FISSION, SCATT SIGMAS 1.235 4.566 barns
NEUTRONS PER FISSION 2.637
FISSION AND NEUTRON ENERGY 180.0 2.0 MEV

CORE NUMBER DENSITY 4.794 10²⁸ M⁻³
NEUTRON VELOCITY 1.956 10⁷ m/sec
TAU 8.635 nanosec
CORE FISSION MFP 16.891 cm
CORE TOTAL MFP 3.596 cm
BARE CORE D-VALUE 3.517 cm
CORE ETA VALUE 0.682 No units

BARE THRESHOLD CRITICALITY

BARE THRESH RADIUS 8.366 cm
BARE THRESH MASS 45.90 kg

TAMPED THRESHOLD CRITICALITY

TAMPER DENSITY 14.80 gr/cm³
TAMPER ATOMIC WT 195.84 gr/mol
TAMPER SCATT SIGMA 6.587 barns
TAMPER NUMBER DENSITY 4.551 10²⁸ M⁻³
TAMPER OUTER RADIUS 18.00 cm
TAMPER LAMBDA 3.336 cm
THRESHOLD CRITICAL TAMPED RADIUS 6.170 cm
THRESHOLD CRITICAL TAMPED MASS 18.41 kg
TAMPER MASS FOR OUTER RADIUS 346.99 kg

TAMPED SUPER-CRITICALITY

CORE MASS 64.00 kg
CORE RADIUS 9.347 cm
TAMPER MASS 310.92 kg

ALPHA 0.5485055
INITIAL NEUTRONS 1.

TIME(mu)	ALPHA	R(CORE)	RHO	R(TAMP)	LOG(FISSRATE)	LOG(PRESS)	YIELD
0.0100	0.54851	9.347	18.710	18.000	8.340	-9.513	0.00
0.0105	0.54851	9.347	18.710	18.000	8.353	-9.205	0.00
0.0110	0.54851	9.347	18.710	18.000	8.367	-9.022	0.00
0.0115	0.54851	9.347	18.710	18.000	8.381	-8.890	0.00
0.0120	0.54851	9.347	18.710	18.000	8.395	-8.786	0.00
0.0125	0.54851	9.347	18.710	18.000	8.409	-8.699	0.00
0.0130	0.54851	9.347	18.710	18.000	8.422	-8.625	0.00
0.0135	0.54851	9.347	18.710	18.000	8.436	-8.560	0.00
0.0140	0.54851	9.347	18.710	18.000	8.450	-8.502	0.00
0.0145	0.54851	9.347	18.710	18.000	8.464	-8.449	0.00
0.0150	0.54851	9.347	18.710	18.000	8.478	-8.400	0.00
0.0155	0.54851	9.347	18.710	18.000	8.491	-8.355	0.00

(several hundred lines omitted)

1.0560	0.07457	11.917	9.029	18.859	9.975	15.366	11.77
1.0565	0.07205	11.929	9.000	18.864	9.905	15.365	11.77
1.0570	0.06952	11.942	8.972	18.869	9.836	15.363	11.77
1.0575	0.06698	11.955	8.943	18.874	9.767	15.362	11.77
1.0580	0.06443	11.967	8.915	18.879	9.697	15.361	11.77
1.0585	0.06187	11.980	8.887	18.885	9.628	15.359	11.77
1.0590	0.05931	11.993	8.858	18.890	9.559	15.358	11.77
1.0595	0.05673	12.005	8.830	18.895	9.490	15.357	11.77
1.0600	0.05414	12.018	8.802	18.900	9.422	15.355	11.77
1.0605	0.05154	12.031	8.774	18.905	9.353	15.354	11.77
1.0610	0.04893	12.044	8.746	18.910	9.284	15.352	11.77
1.0615	0.04631	12.057	8.718	18.916	9.216	15.351	11.77
1.0620	0.04368	12.069	8.690	18.921	9.147	15.350	11.77
1.0625	0.04103	12.082	8.663	18.926	9.079	15.348	11.77
1.0630	0.03838	12.095	8.635	18.931	9.011	15.347	11.77
1.0635	0.03572	12.108	8.607	18.937	8.943	15.345	11.77
1.0640	0.03305	12.121	8.579	18.942	8.875	15.344	11.77
1.0645	0.03036	12.134	8.552	18.947	8.807	15.343	11.77
1.0650	0.02767	12.147	8.524	18.953	8.739	15.341	11.77
1.0655	0.02496	12.160	8.497	18.958	8.671	15.340	11.77
1.0660	0.02225	12.173	8.470	18.963	8.604	15.338	11.77
1.0665	0.01952	12.186	8.442	18.969	8.536	15.337	11.77
1.0670	0.01678	12.200	8.415	18.974	8.469	15.336	11.77
1.0675	0.01403	12.213	8.388	18.980	8.402	15.334	11.77
1.0680	0.01127	12.226	8.361	18.985	8.334	15.333	11.77
1.0685	0.00850	12.239	8.334	18.991	8.267	15.331	11.77
1.0690	0.00572	12.252	8.307	18.996	8.200	15.330	11.77
1.0695	0.00293	12.266	8.280	19.002	8.133	15.329	11.77
1.0700	0.00012	12.279	8.253	19.007	8.067	15.327	11.77
1.0705	0.00000	12.292	8.226	19.013	8.064	15.326	11.77

FINAL CORE VELOCITY (km/s) 267.19

BARECOREVALS

This runs similarly to SIMULATE. The CRITVALS file is now called BARECOREVALS, and has only 3 lines:

$$\rho_{core}, A_{core}, \sigma_{fiss}^{core}, \sigma_{scatt}^{core}, \nu$$
$$M_{core}$$
$$\gamma, N_{neuts}, t_{start}, dt$$

For a 64-kg untamped *Little Boy* simulation:

18.71, 235.04, 1.235, 4.566, 2.637
64.0
0.333333333, 1, 1.0D-08, 5.0D-10