LA-UR-12-22751
Approved for public release; distribution is unlimited.

Title: Surrogate Guderley Test Problem Definition

Author(s): Ramsey, Scott D.
Shashkov, Mikhail J.

Intended for: Report

Surrogate Guderley Test Problem Definition

General: The surrogate Guderley problem (SGP) is a ‘spherical shock tube’ (or ‘spherical driven implosion’) designed to ease the notoriously subtle initialization of the true Guderley problem, while still maintaining a high degree of fidelity. In this problem (similar to the Guderley problem), an infinitely strong shock wave forms and converges in one-dimensional (1D) cylindrical or spherical symmetry through a polytropic gas with arbitrary adiabatic index γ, uniform density ρ_0, zero velocity, and negligible pre-shock pressure and specific internal energy (SIE). This shock proceeds to focus on the point or axis of symmetry at $r = 0$ (resulting in ostensibly infinite pressure, velocity, etc.) and reflect back out into the incoming perturbed gas.

Processes Modeled/Principal Code Features Tested: This problem tests the integration of the conservation lows for coupled converging-diverging flow of a compressible polytropic gas.

Benchmark Type: There is no known general solution to this problem, but there is evidence that certain portions of the flow field limit to (and thus may be compared to) the Guderley converging/diverging shock wave solution.

Initial and Boundary Conditions: This problem is initialized as two concentric spherical regions in a $\gamma = 1.4$ gas with arbitrary specific heat.

Parameter	**Inner spherical region**	**Outer spherical region**
Inner radius	0.0	4.0
Outer radius	4.0	10.0
Density	1.0	6.0
SIE	1.0e-10	0.06
Velocity	0.0	0.0

Any self-consistent set of units (e.g., cgs, ‘HE’) may be used in this problem, as the behavior of interest (see below) is scale-invariant, as is the case with the Guderley problem.
A symmetric/reflective boundary condition is enforced at the inner ($r = 0$) boundary, while the behavior of the outer boundary ($r = 10.0$) is typically arbitrary.

Recommended Test Problem Parameters: An SGP can be constructed for any Guderley problem, including those using 1D cylindrical symmetry and/or different values of the adiabatic index. These problems are taken as possible variants of the canonical SGP, which uses the parameters defined above. Additionally, it is recommended that a vacuum, free surface, or ‘freeze’ boundary condition be applied at $r = 10.0$, and that the problem be run to $t = 20.0$.

Canonical surrogate Guderley problem output: The SGP limits to the true Guderley solution as the converging/reflected shocks are in the vicinity of $r = 0$. Therefore, if the motivation for using this problem is to evaluate a compressible flow solver’s simulation of a Guderley-like solution, all observation and analysis should be conducted within a truncated 'analysis domain' defined by $r < r_t$:

Time	**Analysis domain**
$t = 12$	$r_t < 1.6$
$t = 13$	$r_t < 1.5$
$t = 14$	$r_t < 1.0$
$t = 15$	$r_t < 1.0$
$t = 16$	$r_t < 1.0$
$t = 17$	$r_t < 1.0$
$t = 18$	$r_t < 0.9$

The flow behavior outside of the analysis domain is irrelevant to the development and evolution of the Guderley-like solution. Moreover, the comparatively large values of the problem initial interface ($r = 4.0$) and outer radius ($r = 10.0$) are selected to ensure that boundary-driven waves do not pollute the solution of interest in the analysis domain.

Within the analysis domain, possible system response quantities of interest include:

- Snapshots of density, velocity, pressure, and SIE as a function of position,
- Time-histories of density, velocity, pressure, and SIE at specified locations,
- Space-time trajectories of the converging and diverging shock waves,
- The time at which the converging shock reaches $r = 0.0$: $t = 14.05$.

Some references describing the development and application of the Guderley problem and the SGP are provided below, as are example state variable profile snapshots for selected times (two for converging flow and two for diverging flow).

References

1. G. GUDERLEY, “Starke kugelige und zylinderische Verdichtungsstöße in der Nähe des Kugelmittelpunktes bzw. der Zylinderasche,” *Luftfahrtforschung* **19**, 302-312 (1942).

2. K. STANYUKOVICH, *Unsteady Motion of Continuous Media*, Pergammon Press, New York (1970).

3. R. LAZARUS, “Self-Similar Solutions for Converging Shocks and Collapsing Cavities,” *SIAM J. Numer. Anal.* **18**, 316-371 (1981).

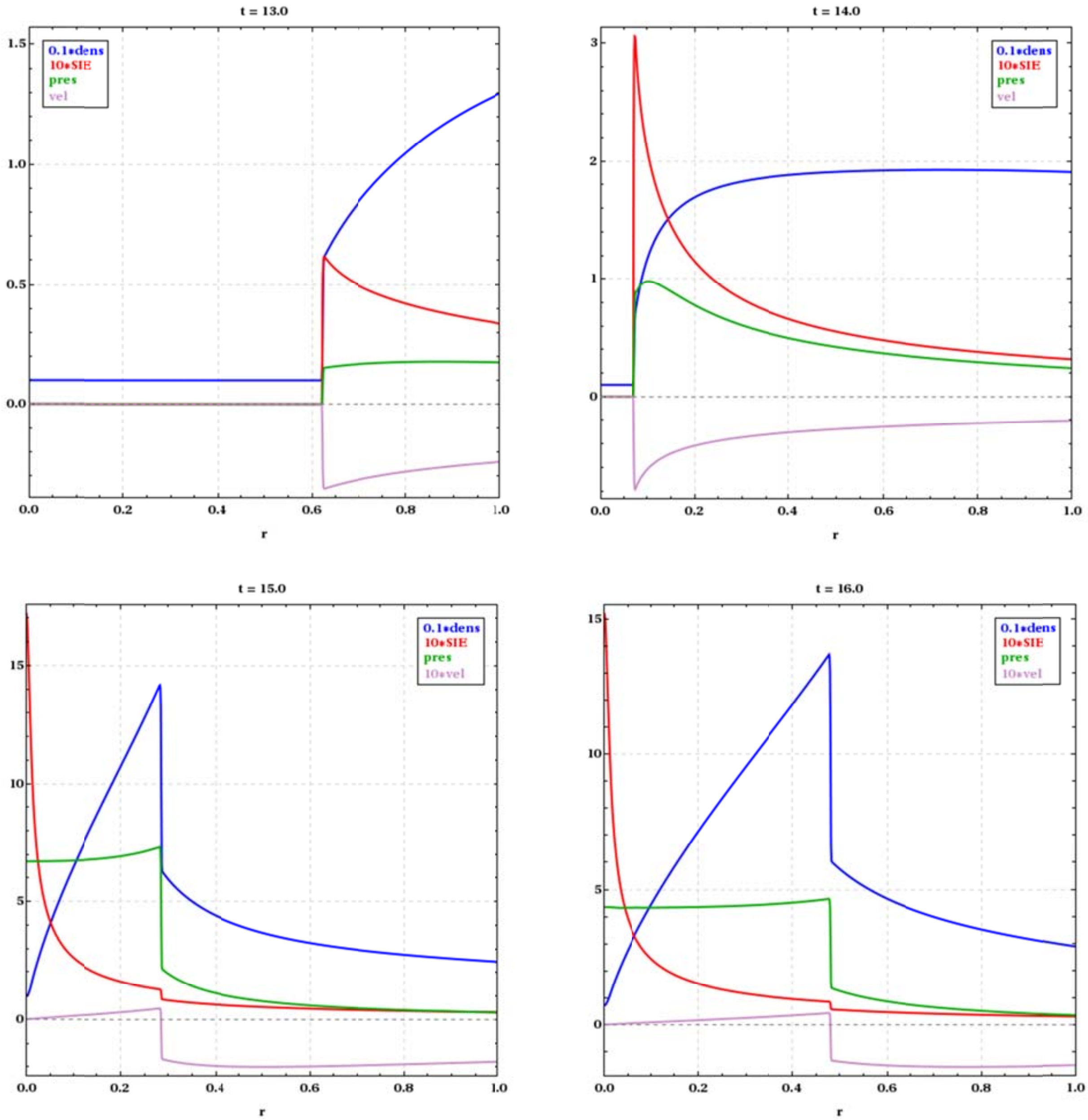
4. S. RAMSEY, J. KAMM, and J. BOLSTAD, “The Guderley Problem Revisited,” *Int. J. Comput. Fluid Dyn.* **26**, 79-99 (2012).

5. S. RAMSEY, “Preliminary Results for Converging Shock Wave Problems,” Los Alamos National Laboratory unclassified report (2012).

6. S. RAMSEY, “Preliminary Results for Converging Shock Wave Problems,” Los Alamos National Laboratory unclassified presentation (2012).

7. S. RAMSEY and M. SHASHKOV, “Evaulation of Converging Shock Wave Problems Using the xRAGE Compressible Flow Solver,” Los Alamos National Laboratory unclassified report (2012).

Figures


t = 13.0
0.1*dens
10*SIE
pres
vel
r
t = 14.0
0.1*dens
10*SIE
pres
vel
r
t = 15.0
0.1*dens
10*SIE
pres
10*vel
r
t = 16.0
0.1*dens
10*SIE
pres
10*vel
r