Report on GasDynamics

Generated by MTT using :
(mtt -u -q -q GasDynamics rep pdf)

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Part I

GasDynamics

Chapter 1

LeakyCylinder

1.1 LeakyCylinder_abg.tex

MTT command:

```
mtt LeakyCylinder abg tex
```

The acausal bond graph of system **LeakyCylinder** is displayed in Figure 1.1 (on page 10) and its label file is listed in Section 1.1.1 (on page 9). The subsystems are listed in Section 1.1.2 (on page 12).

This example roughly corresponds to the Example in section 12.4.3 (Fig. 12.17) of Karnopp, Margolis and Rosenberg (1990). It is a pseudo bond graph representation based on the "thermal accumulator" of section 12.4.1 and the "isentropic nozzle" of section 12.4.2 of that book.

[Notes added by PJG 10 June 03.

1. The parameters/states used in the simulation (odeso) are meaningless at the moment.

2. The steady-state parameters (sspar.r) need to be calculated; at the moment, the state mattrices (sm) are in terms of the steady-state states.

]

1.1.1 Summary information

System LeakyCylinder::Pseudo bond graph model of compressible gas dynamics This example roughly corresponds to the Example in section 12.4.3 (Fig. 12.17) of Karnopp, Margolis and Rosenberg (1990). It is a pseudo bond graph representation based on the "thermal acummulator" of section 12.4.1 and the "isentropic nozzle" of section 12.4.2 of that book.

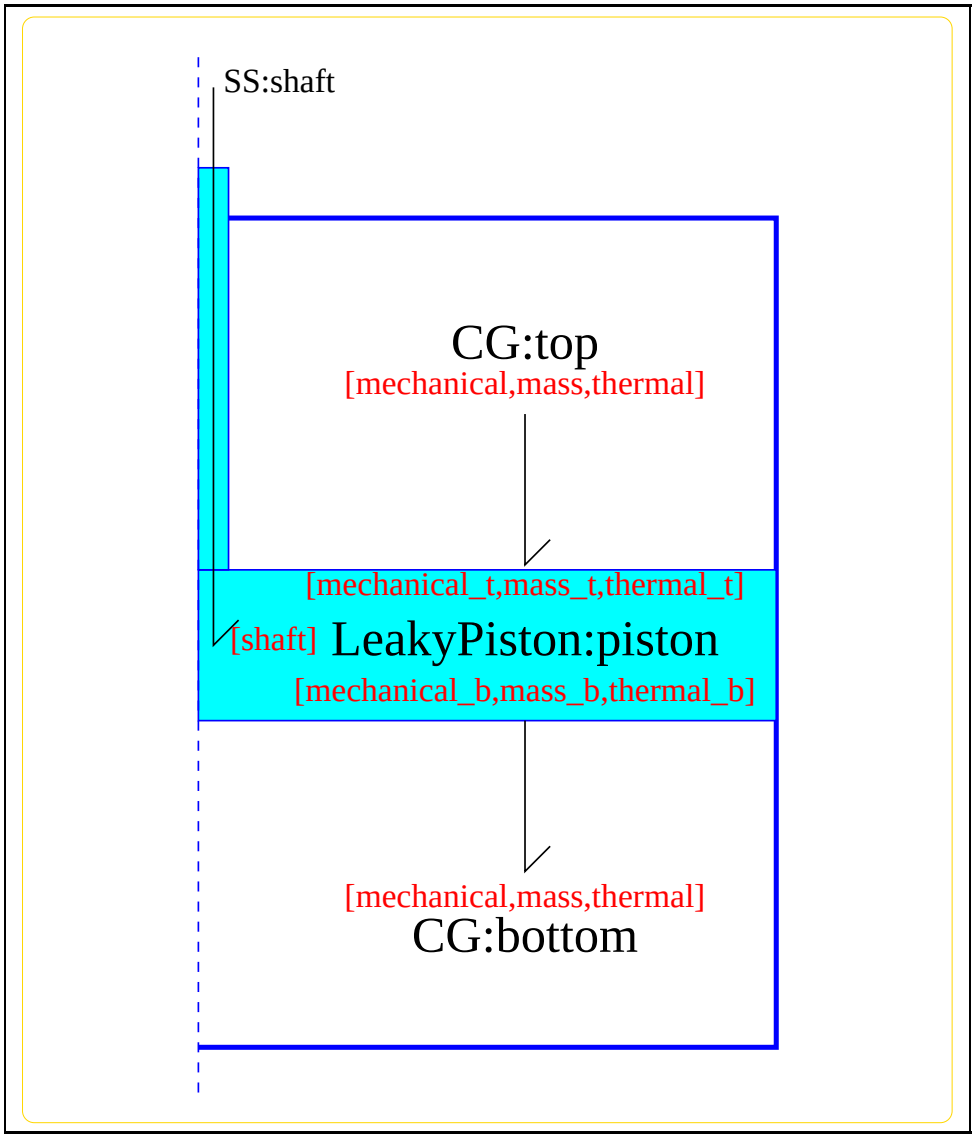

Figure 1.1: System **LeakyCylinder**: acausal bond graph

Interface information:

This component has no ALIAS declarations

Variable declarations:

This component has no PAR declarations

Units declarations:

This component has no UNITs declarations

The label file: LeakyCylinder_lbl.txt

```
%SUMMARY LeakyCylinder: Pseudo bond graph model of compressible gas dyna

%DESCRIPTION This example roughly corresponds to the Example in
%DESCRIPTION section 12.4.3 (Fig. 12.17) of Karnopp, Margolis and Rosenb
%DESCRIPTION (1990). It is a pseudo bond graph representation based on t
%DESCRIPTION "thermal acummulator" of section 12.4.1 and the "isentropic
%DESCRIPTION nozzle" of section 12.4.2 of that book.

%% Label file for system LeakyCylinder (LeakyCylinder_lbl.txt)

% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% Version control history
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% $Id: LeakyCylinder_lbl.txt,v 1.2 2000/05/20 16:39:39 peterg Exp $
% %% $Log: LeakyCylinder_lbl.txt,v $
% %% Revision 1.2  2000/05/20 16:39:39  peterg
% %% New SS format
% %%
% %% Revision 1.1  1998/03/04 09:56:05  peterg
% %% Initial revision
% %%
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% Each line should be of one of the following forms:
% a comment (ie starting with %)
% Component-name CR_name arg1,arg2,..argn
% blank
```

```
% Component type CG
bottom none c_v;r
top none c_v;r

% Component type LeakyPiston
piston none m_p;a_b;a_t;gamma;r;0

% Component type SS
shaft SS external,external
```

1.1.2 Subsystems

- CG: C component for compressible gas dynamics (2) No subsystems.
- LeakyPiston: Leaky piston sub model (1)
  - Piston: simple model of the piston (2)
  - RG: R component for compressible gas dynamics: isentropic nozzle (1)

1.1.3 CG

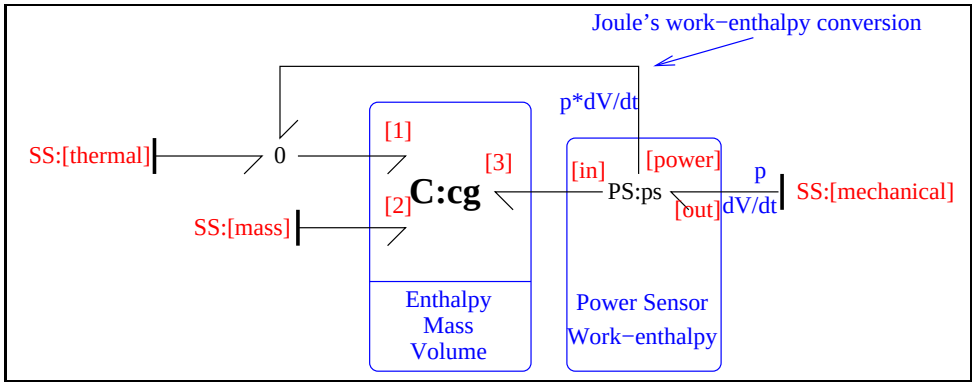

Figure 1.2: System **CG**: acausal bond graph

The acausal bond graph of system **CG** is displayed in Figure 1.2 (on page 12) and its label file is listed in Section 1.1.3 (on page 13). The subsystems are listed in Section 1.1.3 (on page 14).

Summary information

System CG::C component for compressible gas dynamics Port [Thermal]: Temperature/Enthalpy pseudo bond Port [Mass]: Pressure/mass-flow pseudo bond Port [Mechanical]: Pressure/volume flow energy bond

Parameter 1: c_v (specific heat at constant volume) Parameter 2: R (universal gas constant) Based on Karnopp, Margolis and Rosenberg: Section 12.4.

Interface information:

This component has no ALIAS declarations

Variable declarations:

This component has no PAR declarations

Units declarations:

This component has no UNITs declarations

The label file: CG_lbl.txt

```
%SUMMARY CG: C component for compressible gas dynamics
%DESCRIPTION Port [Thermal]: Temperature/Enthalpy pseudo bond
%DESCRIPTION Port [Mass]: Pressure/mass-flow pseudo bond
%DESCRIPTION Port [Mechanical]: Pressure/volume flow energy bond
%DESCRIPTION
%DESCRIPTION Parameter 1: c_v (specific heat at constant volume)
%DESCRIPTION Parameter 2: R   (universal gas constant)
%DESCRIPTION Based on Karnopp, Margolis and Rosenberg: Section 12.4.


%% Label file for system CG (CG_lbl.txt)

% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% Version control history
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% $Id: CG_lbl.txt,v 1.3 2000/12/27 16:34:35 peterg Exp $
% %% $Log: CG_lbl.txt,v $
% %% Revision 1.3  2000/12/27 16:34:35  peterg
% %% *** empty log message ***
% %%
```

```
% %% Revision 1.2  1998/03/04 12:06:06  peterg
% %% Renamed CR from GasAccumulator to CG
% %%
% %% Revision 1.1  1997/11/21  17:06:34  peterg
% %% Initial revision
% %%
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% Each line should be of one of the following forms:
% a comment (ie starting with %)
% Component-name CR_name arg1,arg2,..argn
% blank



% Component type C
cg CG $1,$2

% Component type PS
ps lin effort,1

% Component type SS
[mass] SS external,external
[mechanical] SS external,external
[thermal] SS external,external
```

Subsystems

No subsystems.

1.1.4 LeakyPiston

The acausal bond graph of system **LeakyPiston** is displayed in Figure 1.3 (on page 15) and its label file is listed in Section 1.1.4 (on page 14). The subsystems are listed in Section 1.1.4 (on page 17).

Summary information

System LeakyPiston::Leaky piston sub model ¡Detailed description here¿

Interface information:

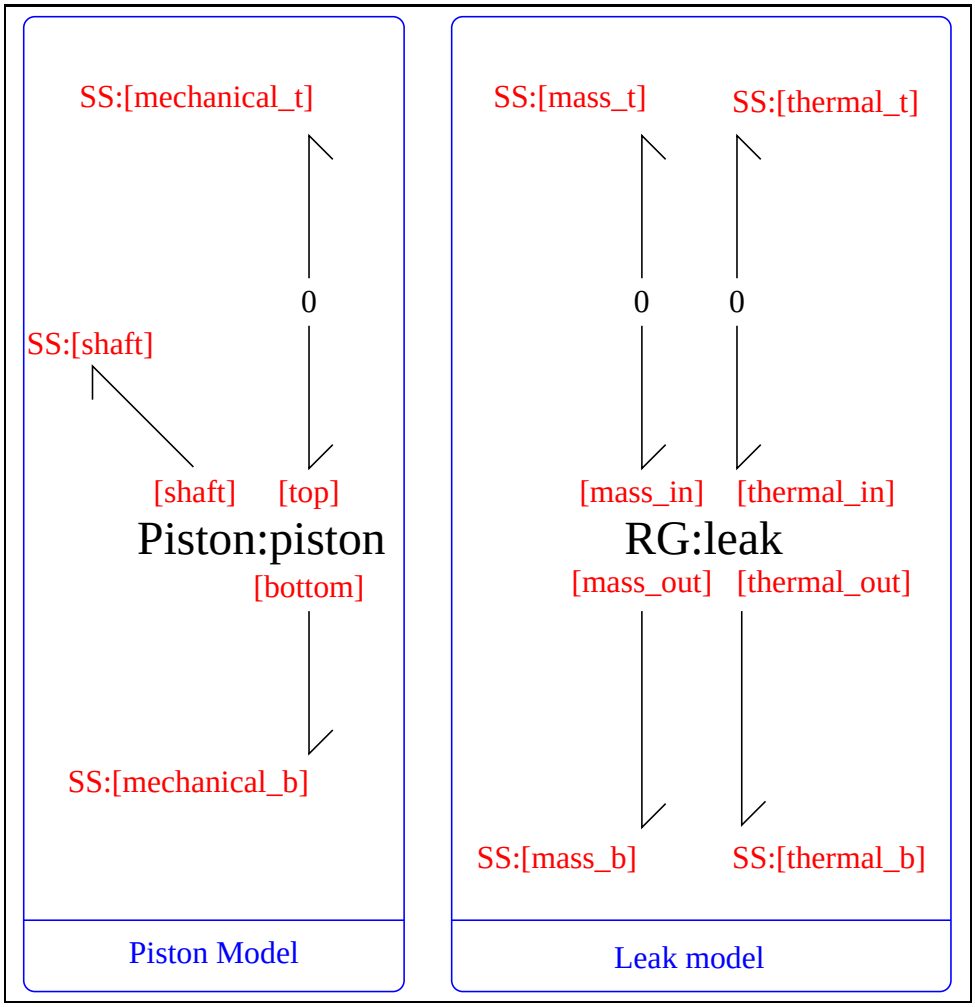

Figure 1.3: System **LeakyPiston**: acausal bond graph

This component has no ALIAS declarations

Variable declarations:

This component has no PAR declarations

Units declarations:

This component has no UNITs declarations

The label file: LeakyPiston_lbl.txt

```
%SUMMARY LeakyPiston: Leaky piston sub model
%DESCRIPTION <Detailed description here>
%% Label file for system LeakyPiston (LeakyPiston_lbl.txt)

% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% Version control history
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% $Id: LeakyPiston_lbl.txt,v 1.2 2003/01/06 21:22:52 geraint Ex
% %% $Log: LeakyPiston_lbl.txt,v $
% %% Revision 1.2  2003/01/06 21:22:52  geraint
% %% Updated SS entries.
% %%
% %% Revision 1.1  1998/03/04 10:00:11  peterg
% %% Initial revision
% %%
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% Each line should be of one of the following forms:
% a comment (ie starting with %)
% Component-name CR_name arg1,arg2,..argn
% blank



% Component type Piston
piston lin $1;$2;$3

% Component type RG
leak lin $4;$5;$6
```

```
% Component type SS
[mass_b] SS external,external
[mass_t] SS external,external
[mechanical_b] SS external,external
[mechanical_t] SS external,external
[shaft] SS external,external
[thermal_b] SS external,external
[thermal_t] SS external,external
```

Subsystems

- Piston: simple model of the piston (2) No subsystems.
- RG: R component for compressible gas dynamics: isentropic nozzle (1) No subsystems.

1.1.5 Piston

The acausal bond graph of system **Piston** is displayed in Figure 1.4 (on page 18) and its label file is listed in Section 1.1.5 (on page 17). The subsystems are listed in Section 1.1.5 (on page 19).

The two **TF** components convert pressure to force. The **I** component represents piston inertia.

Summary information

System Piston::simple model of the piston Inludes inertia and pressure effects.

Interface information:

This component has no ALIAS declarations

Variable declarations:

This component has no PAR declarations

Units declarations:

This component has no UNITs declarations

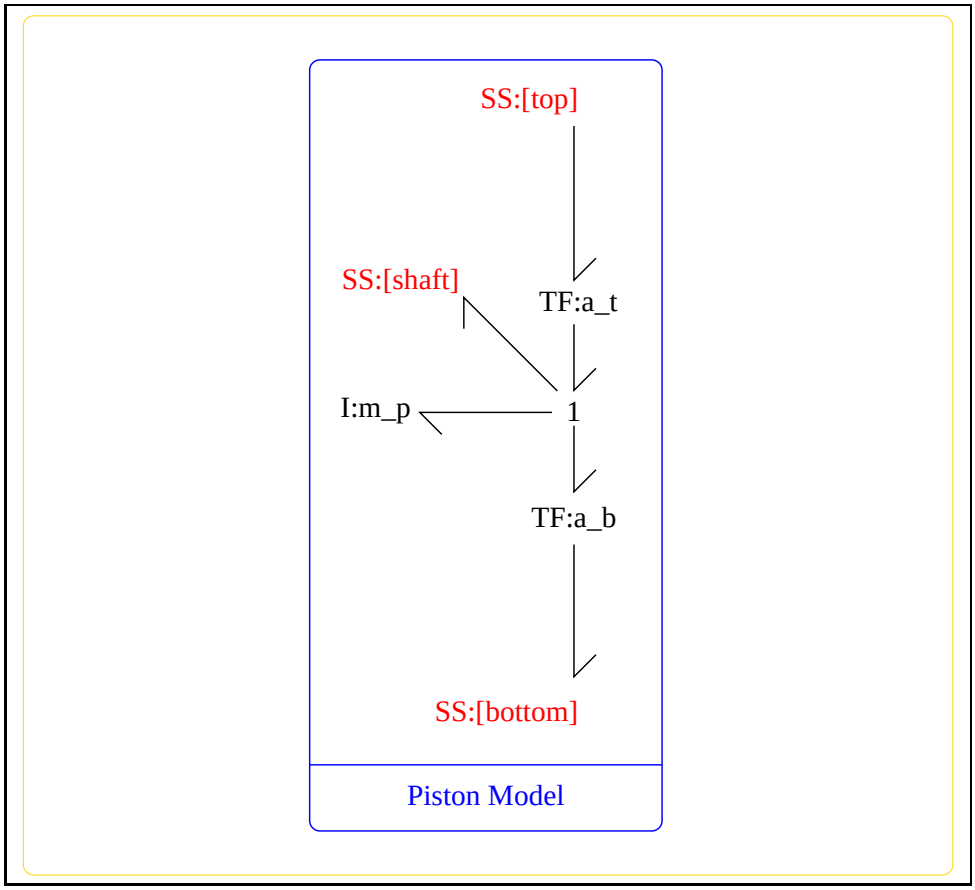

Figure 1.4: System **Piston**: acausal bond graph

The label file: Piston_lbl.txt

```
%SUMMARY Piston: simple model of the piston
%DESCRIPTION Inludes inertia and pressure effects.
%% Label file for system Piston (Piston_lbl.txt)

% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% Version control history
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% $Id: Piston_lbl.txt,v 1.2 2003/01/06 21:22:53 geraint Exp $
% %% $Log: Piston_lbl.txt,v $
% %% Revision 1.2  2003/01/06 21:22:53  geraint
% %% Updated SS entries.
% %%
% %% Revision 1.1  1998/03/04 10:01:38  peterg
% %% Initial revision
% %%
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% Each line should be of one of the following forms:
% a comment (ie starting with %)
% Component-name CR_name arg1,arg2,..argn
% blank



% Component type I
m_p lin flow,$1

% Component type SS
[bottom] SS external,external
[shaft] SS external,external
[top] SS external,external

% Component type TF
a_b lin flow,$2
a_t lin effort,$3
```

Subsystems

No subsystems.

1.1.6 RG

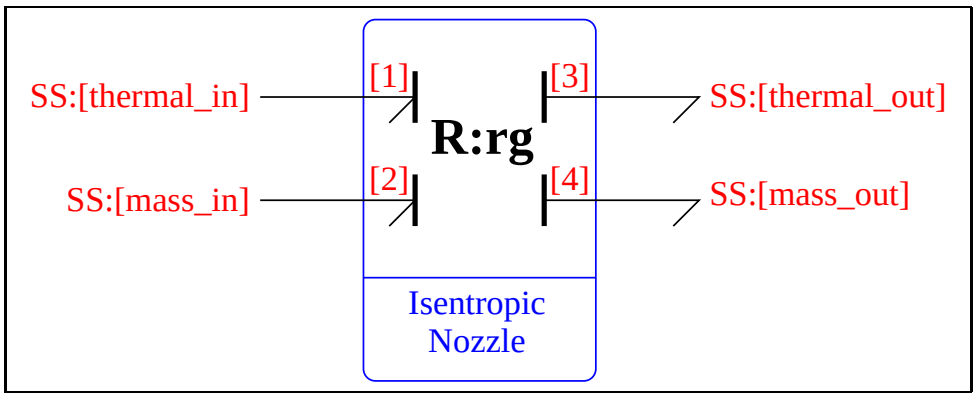

Figure 1.5: System **RG**: acausal bond graph

The acausal bond graph of system **RG** is displayed in Figure 1.5 (on page 20) and its label file is listed in Section 1.1.6 (on page 20). The subsystems are listed in Section 1.1.6 (on page 22).

Summary information

System RG::R component for compressible gas dynamics: isentropic nozzle Port [Thermal_in]: Temperature/Enthalpy pseudo bond Port [Thermal_out]: Temperature/Enthalpy pseudo bond Port [Mass_in]: Pressure/mass-flow pseudo bond Port [Mass_out]: Pressure/mass-flow pseudo bond

Parameter 1: gamma (c_p/c_v) Parameter 2: R (universal gas constant) Parameter 3: A (nozzle cross-section) Based on Karnopp, Margolis and Rosenberg: Section 12.4.

Interface information:

This component has no ALIAS declarations

Variable declarations:

This component has no PAR declarations

Units declarations:

This component has no UNITs declarations

The label file: RG_lbl.txt

```
%SUMMARY RG: R component for compressible gas dynamics: isentropic nozzl
%DESCRIPTION Port [Thermal_in]: Temperature/Enthalpy pseudo bond
%DESCRIPTION Port [Thermal_out]: Temperature/Enthalpy pseudo bond
%DESCRIPTION Port [Mass_in]: Pressure/mass-flow pseudo bond
%DESCRIPTION Port [Mass_out]: Pressure/mass-flow pseudo bond
%DESCRIPTION
%DESCRIPTION Parameter 1: gamma (c_p/c_v)
%DESCRIPTION Parameter 2: R   (universal gas constant)
%DESCRIPTION Parameter 3: A   (nozzle cross-section)
%DESCRIPTION Based on Karnopp, Margolis and Rosenberg: Section 12.4.



%% Label file for system RG (RG_lbl.txt)

% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% Version control history
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% $Id: RG_lbl.txt,v 1.3 2000/05/19 19:52:26 peterg Exp $
% %% $Log: RG_lbl.txt,v $
% %% Revision 1.3  2000/05/19 19:52:26  peterg
% %% New SS form
% %%
% %% Revision 1.2  1998/03/04 12:07:37  peterg
% %% Renamed CR from Isentropic nozzle to RG
% %%
% %% Revision 1.1  1997/11/21 19:18:28  peterg
% %% Initial revision
% %%
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% Each line should be of one of the following forms:
% a comment (ie starting with %)
% Component-name CR_name arg1,arg2,..argn
% blank



% Component type RG
```

```
rg RG $1,$2,$3

% Component type SS
[mass_in] SS external,external
[mass_out] SS external,external
[thermal_in] SS external,external
[thermal_out] SS external,external
```

Subsystems

No subsystems.

1.2 LeakyCylinder_struc.tex

MTT command:

```
mtt LeakyCylinder struc tex
```

List of inputs for system LeakyCylinder			
	Component	System	Repetition
1	shaft	LeakyCylinder__shaft	1

List of outputs for system LeakyCylinder			
	Component	System	Repetition
1	shaft	LeakyCylinder__shaft_2	1

List of states for system LeakyCylinder			
	Component	System	Repetition
1	cg	LeakyCylinder__bottom__cg	1
2	cg	LeakyCylinder__bottom__cg_2	1
3	cg	LeakyCylinder__bottom__cg_3	1
4	cg	LeakyCylinder__top__cg	1
5	cg	LeakyCylinder__top__cg_2	1
6	cg	LeakyCylinder__top__cg_3	1
7	m_p	LeakyCylinder__piston__piston__m_p	1

1.3 LeakyCylinder_sympar.tex

MTT command:

```
mtt LeakyCylinder sympar tex
```

Parameter	System
a_b	LeakyCylinder
a_t	LeakyCylinder
c_v	LeakyCylinder
gamma	LeakyCylinder
m_p	LeakyCylinder
r	LeakyCylinder

Table 1.1: Parameters

1.4 LeakyCylinder_ode.tex

MTT command:

```
mtt LeakyCylinder ode tex
```

$$
\begin{aligned}
\dot{x}_1 &= \frac{(a_b x_1 x_7 r)}{(c_v m_p x_3)} \\
\dot{x}_2 &= 0 \\
\dot{x}_3 &= \frac{(a_b x_7)}{m_p} \\
\dot{x}_4 &= \frac{(a_t x_4 x_7 r)}{(c_v m_p x_6)} \\
\dot{x}_5 &= 0 \\
\dot{x}_6 &= \frac{(a_t x_7)}{m_p} \\
\dot{x}_7 &= \frac{(-a_b x_1 x_6 r + a_t x_3 x_4 r + c_v u_1 x_3 x_6)}{(c_v x_3 x_6)}
\end{aligned}
\tag{1.1}
$$

$$
y_1 = \frac{x_7}{m_p} \tag{1.2}
$$

1.5 LeakyCylinder_ss.tex

MTT command:

```
mtt LeakyCylinder ss tex
```

$$x = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \end{pmatrix} \tag{1.3}$$

$$u = \begin{pmatrix} u_1 \end{pmatrix} \tag{1.4}$$

$$y = \begin{pmatrix} \frac{x_7}{m_p} \end{pmatrix} \tag{1.5}$$

$$\dot{x} = \begin{pmatrix} \frac{(a_b x_1 x_7 r)}{(c_v m_p x_3)} \\ 0 \\ \frac{(a_b x_7)}{m_p} \\ \frac{(a_t x_4 x_7 r)}{(c_v m_p x_6)} \\ 0 \\ \frac{(a_t x_7)}{m_p} \\ \frac{(-a_b x_1 x_6 r + a_t x_3 x_4 r + c_v u_1 x_3 x_6)}{(c_v x_3 x_6)} \end{pmatrix} \tag{1.6}$$

1.6 LeakyCylinder_sm.tex

MTT command:

```
mtt LeakyCylinder sm tex
```

$$A = \begin{pmatrix} \frac{(a_b x_7 r)}{(c_v m_p x_3)} & 0 & \frac{(-a_b x_1 x_7 r)}{(c_v m_p x_3^2)} & 0 & 0 & 0 & \frac{(a_b x_1 r)}{(c_v m_p x_3)} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \frac{a_b}{m_p} \\ 0 & 0 & 0 & \frac{(a_t x_7 r)}{(c_v m_p x_6)} & 0 & \frac{(-a_t x_4 x_7 r)}{(c_v m_p x_6^2)} & \frac{(a_t x_4 r)}{(c_v m_p x_6)} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \frac{a_t}{m_p} \\ \frac{(-a_b r)}{(c_v x_3)} & 0 & \frac{(a_b x_1 r)}{(c_v x_3^2)} & \frac{(a_t r)}{(c_v x_6)} & 0 & \frac{(-a_t x_4 r)}{(c_v x_6^2)} & 0 \end{pmatrix} \tag{1.7}$$

$$B = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \tag{1.8}$$

$$C = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{m_p} \end{pmatrix} \tag{1.9}$$

$$D = \begin{pmatrix} 0 \end{pmatrix} \tag{1.10}$$

1.7 LeakyCylinder_rep.txt

MTT command:

```
mtt LeakyCylinder rep txt
```

```
# Outline report file for system LeakyCylinder (LeakyCylinder_rep.txt)

% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% Version control history
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% %% $Id: LeakyCylinder_rep.txt,v 1.3 2003/08/17 17:02:01 gawthrop Exp $
% %% $Log: LeakyCylinder_rep.txt,v $
% %% Revision 1.3  2003/08/17 17:02:01  gawthrop
```

```
% %% Updated for new MTT
% %%
% %% Revision 1.2  2003/06/11 15:57:57  gawthrop
% %% Updated examples for latest MTT.
% %%
% %% Revision 1.1  2000/12/28 17:44:35  peterg
% %% To RCS
% %%
% %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

mtt LeakyCylinder abg tex
mtt LeakyCylinder struc tex
mtt LeakyCylinder sympar tex
mtt LeakyCylinder ode tex
mtt LeakyCylinder ss tex
mtt LeakyCylinder sm tex
##mtt LeakyCylinder odeso ps

mtt LeakyCylinder rep txt
```

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