NREL
NATIONAL RENEWABLE ENERGY LABORATORY

SAM Parabolic Trough Updates

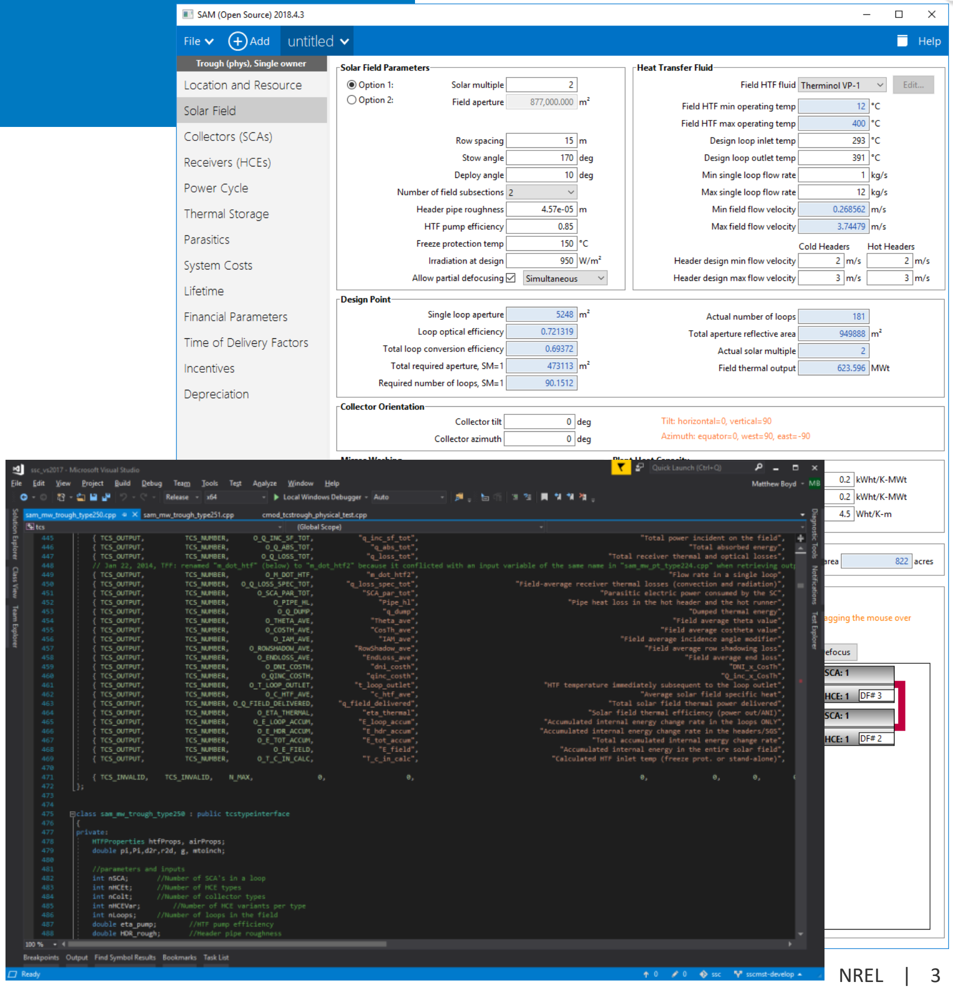
Matthew Boyd
2018-Oct

Photo: 3M

- Bug Fixes
- Script Templates
- Pipe Sizing and Custom Losses
- Interconnects
- Flex hose modeling
- Decoupled Collection and Generation
- Simplify UDPC, Testing and Documentation

Bug Fixes

- Header sizing algorithm considers all sections when progressively downsizing the diameters
- Internal energy of the inlet, outlet, and crossover piping (IOCOP) now fully accounted for
- Runner pressure drop calculation accurately counts expansions and contractions
- Calculation of thermal energy storage (TES) and steam generator system (SGS) piping volumes now more precise



- Bug Fixes
- **Script Templates**
- Pipe Sizing and Custom Losses
- Interconnects
- Flex hose modeling
- Decoupled Collection and Generation
- Simplify UDPC, Testing and Documentation

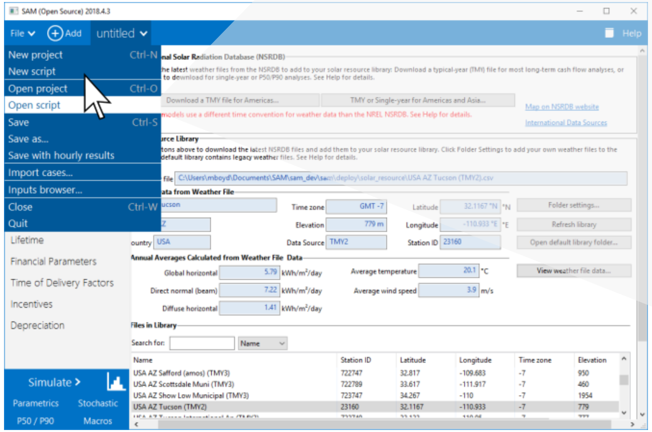
Script Templates

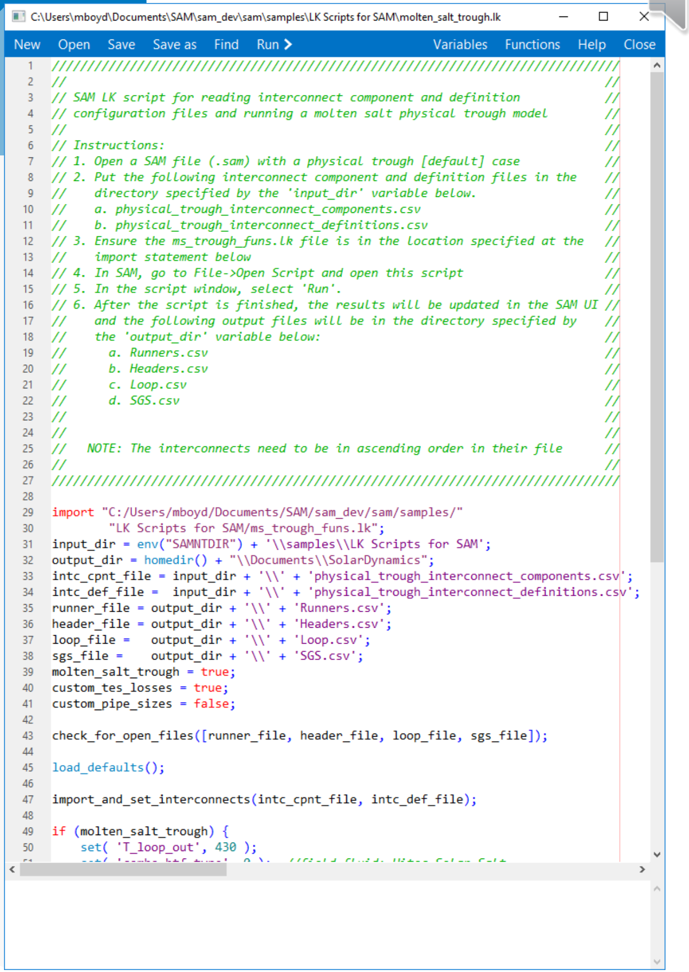
- Script templates added for implementing the new advanced features listed here
- Located in:

  /sam/samples/LK Scripts for SAM/

  molten_salt_trough.lk *(main script)*

  ms_trough_funs.lk *(helper functions)*





Bug Fixes

Script Templates

Pipe Sizing and Custom Losses

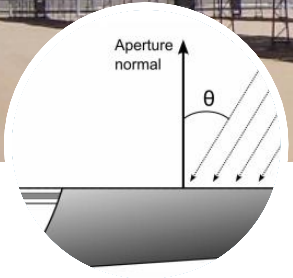
Interconnects

Flex hose modeling

Decoupled Collection and Generation

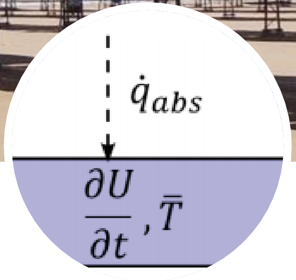
Simplify UDPC, Testing and Documentation

Pipe Sizing and Custom Losses



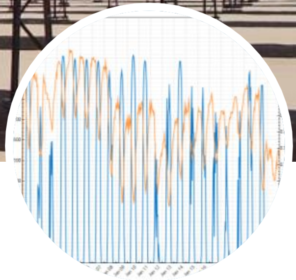
Design Conditions

Calculates (and outputs) HTF properties at design conditions in each pipe section



Steady-State

Model runs until steady-state is achieved



Preliminary

Occurs before yearly simulation

Default

Default is to perform, but can be skipped

Field Design Conditions

Pipe Sizing and Custom Losses

<u>Configurable Advanced Options (Field)</u>

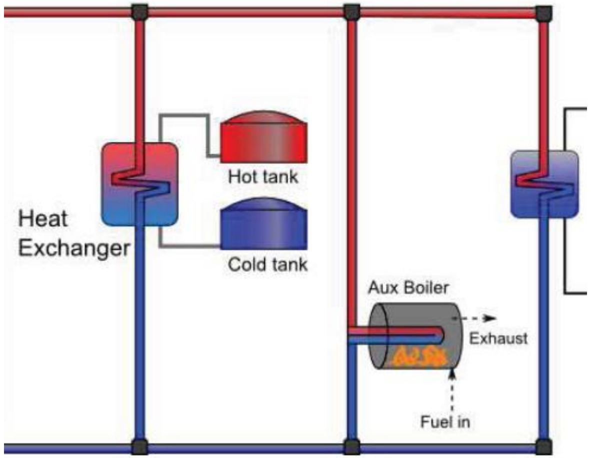
- North/south distance between subfields (northsouth_field_sep)
- Minimum number of runner expansion loops for each constant diameter segment (Min_rnr_xpans)
- Frequency of runner expansion loops (L_rnr_per_xpan)
- Expansion loop lengths (L_xpan_hdr, L_xpan_rnr)
- Maximum number of header diameters (N_max_hdr_diams)
- Location of the first header expansion loop (offset_xpan_hdr)
- Number of collector loops per header expansion loop (N_hdr_per_xpan)


FADEL SENNA/AFP/AFP/GETTY IMAGES

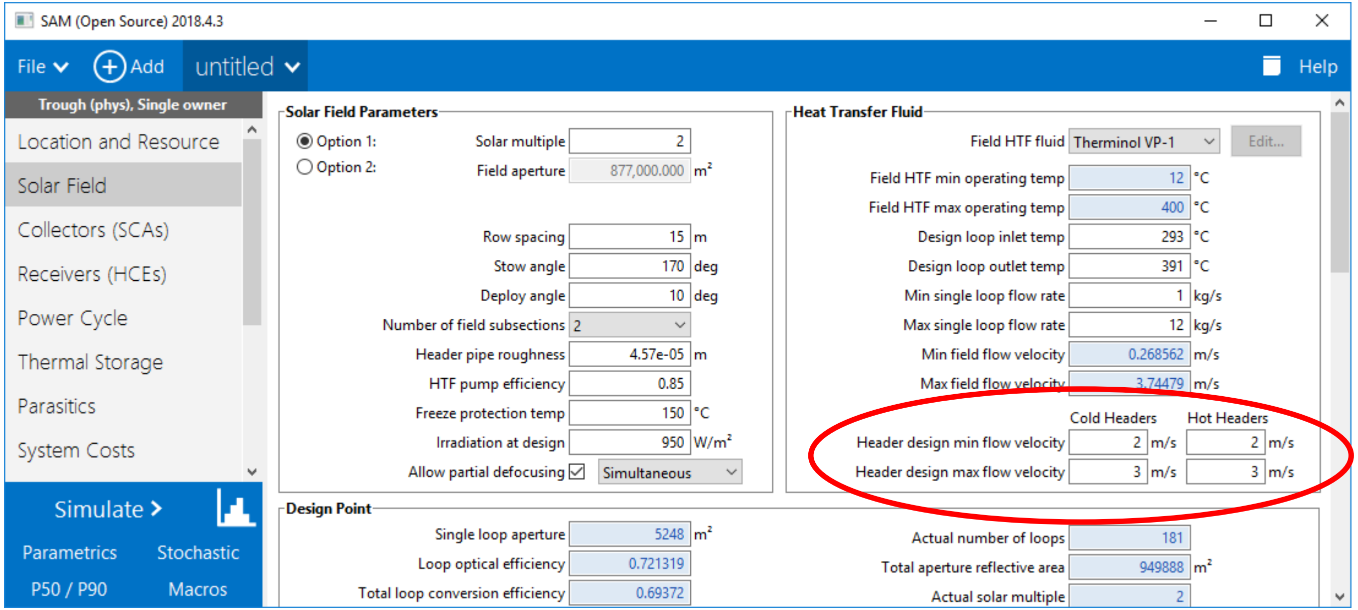
Pipe Sizing and Custom Losses

<u>Configurable Advanced Options (TES/PB)</u>

- Bypass valve operation during field recirculation (has_hot_tank_bypass)
    - Bypass just hot tank and feed into cold tank (=true)
    - Bypass both tanks and rest of TES/PB (=false)
- Minimum HTF temperature that may enter the hot tank (T_tank_hot_inlet_min)
- Length of runner pipe in and around the power block (L_rnr_pb)
- Lengths of the TES/PB piping (sgs_lengths)
- Design-point velocity for sizing the TES/PB pipe diameters (V_tes_des)
- Minor losses of TES/PB pipe fittings (k_tes_loss_coeffs)
- Pressure drop within the steam generator system (DP_SGS)



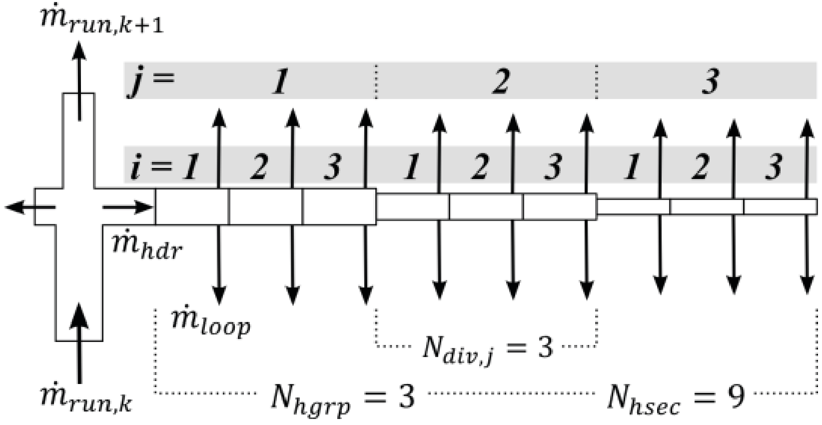
Pipe Sizing and Custom Losses



- Separate design velocities added for sizing hot and cold headers

Pipe Sizing and Custom Losses

- Runner and header diameter sizing algorithm revamped:
  - More robust in edge cases
  - Preferentially selects smaller diameter (cheaper) pipes for out-of-range cases
  - Diameter limit less restrictive for hot (costlier) than cold header pipes



Pipe Sizing and Custom Losses

<u>Custom TES/SGS Pressure Drops</u>

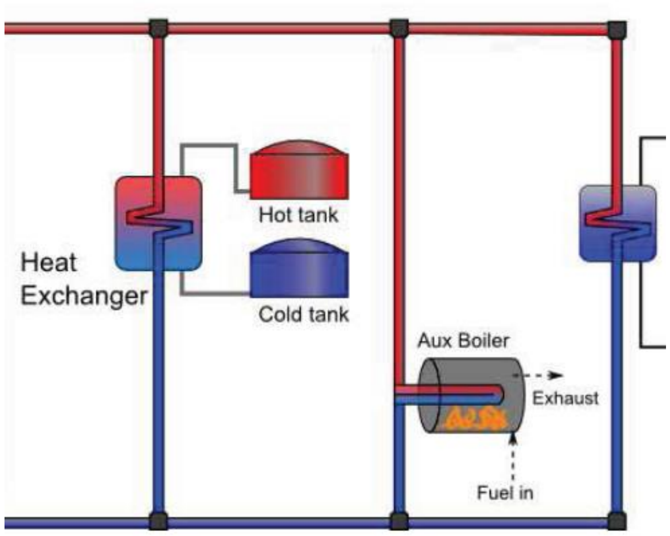
- Default is to use pumping coefficients (kJ/kg)
- New advanced option to calculate using:
  - Darcy–Weisbach equation

    $$\Delta P = f \times U^2 \times L \times \rho / (2 \times D)$$

  - Minor pressure losses

    $$\Delta P = K \times U^2 \times \rho / 2$$

    with minor loss coefficients (k) for each section as input parameters



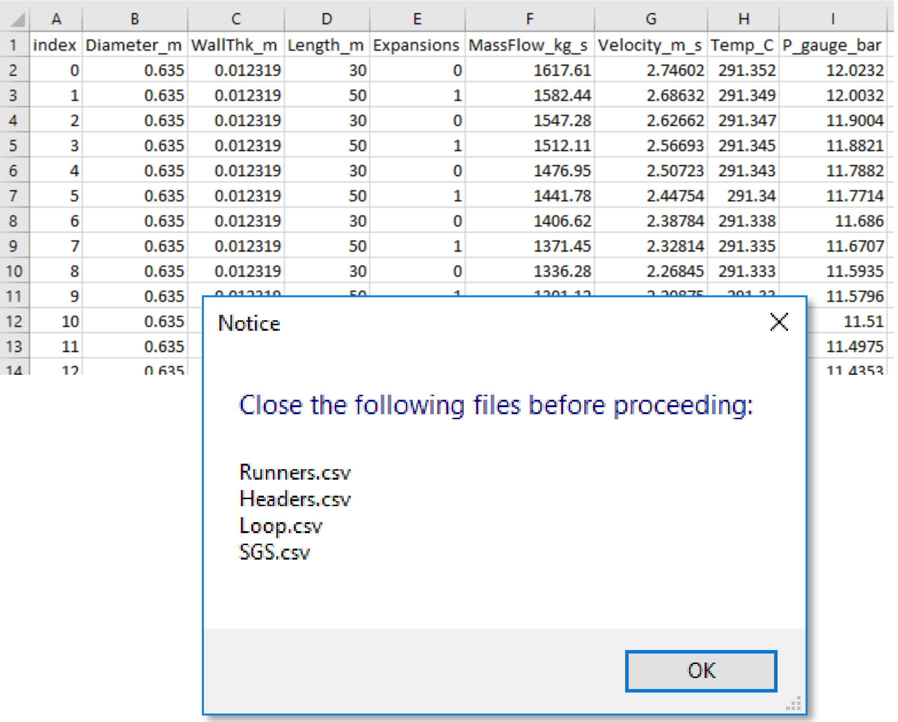
Pipe Sizing and Custom Losses

- Reporting all applicable SGS, runner, header, and loop:
  - Lengths
  - Diameters
  - Wall thicknesses
  - Number of expansion loops

Pipe Sizing and Custom Losses

- If using script templates:
  - Outputting:
    - SGS.csv
    - Runners.csv
    - Headers.csv
    - Loop.csv

  - Pre-simulation checks for open, unwritable output files to avoid wasted simulation time



	A	B	C	D	E	F	G	H	I
1	index	Diameter_m	WallThk_m	Length_m	Expansions	MassFlow_kg_s	Velocity_m_s	Temp_C	P_gauge_bar
2	0	0.635	0.012319	30	0	1617.61	2.74602	291.352	12.0232
3	1	0.635	0.012319	50	1	1582.44	2.68632	291.349	12.0032
4	2	0.635	0.012319	30	0	1547.28	2.62662	291.347	11.9004
5	3	0.635	0.012319	50	1	1512.11	2.56693	291.345	11.8821
6	4	0.635	0.012319	30	0	1476.95	2.50723	291.343	11.7882
7	5	0.635	0.012319	50	1	1441.78	2.44754	291.34	11.7714
8	6	0.635	0.012319	30	0	1406.62	2.38784	291.338	11.686
9	7	0.635	0.012319	50	1	1371.45	2.32814	291.335	11.6707
10	8	0.635	0.012319	30	0	1336.28	2.26845	291.333	11.5935
11	9	0.635							11.5796
12	10	0.635							11.51
13	11	0.635							11.4975
14	12	0.635							11.4353

Pipe Sizing and Custom Losses

- If setting advanced parameter flag option, output files become input files for custom:
  - Diameters
  - Wall thicknesses
  - Lengths

	A	B	C	D	E	F	G	H	I
1	index	Diameter_m	WallThk_m	Length_m	Expansions	MassFlow_kg_s	Velocity_m_s	Temp_C	P_gauge_bar
2	0	0.635	0.012319	30	0	1617.61	2.74602	291.352	12.0232
3	1	0.635	0.012319	50	1	1582.44	2.68632	291.349	12.0032
4	2	0.635	0.012319	30	0	1547.28	2.62662	291.347	11.9004
5	3	0.635	0.012319	50	1	1512.11	2.56693	291.345	11.8821
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7	5	0.635	0.012319	50	1	1441.78	2.44754	291.34	11.7714
8	6	0.635	0.012319	30	0	1406.62	2.38784	291.338	11.686
9	7	0.635	0.012319	50	1	1371.45	2.32814	291.335	11.6707
10	8	0.635	0.012319	30	0	1336.28	2.26845	291.333	11.5935
11	9	0.635	0.012319	50	1	1301.12	2.20875	291.33	11.5796
12	10	0.635	0.012319	30	0	1265.95	2.14906	291.327	11.51
13	11	0.635	0.012319	50	1	1230.79	2.08936	291.325	11.4975
14	12	0.635	0.012319	30	0	1195.62	2.02966	291.322	11.4353

Custom for all files: SGS.csv, Runners.csv, Headers.csv, Loop.csv

- Flags:
  - For field: *custom_sf_pipe_sizes*
  - For TES/PB: custom_sgs_pipe_sizes

- Bug Fixes
- Script Templates
- Pipe Sizing and Custom Losses
- **Interconnects**
- Flex hose modeling
- Decoupled Collection and Generation
- Simplify UDPC, Testing and Documentation

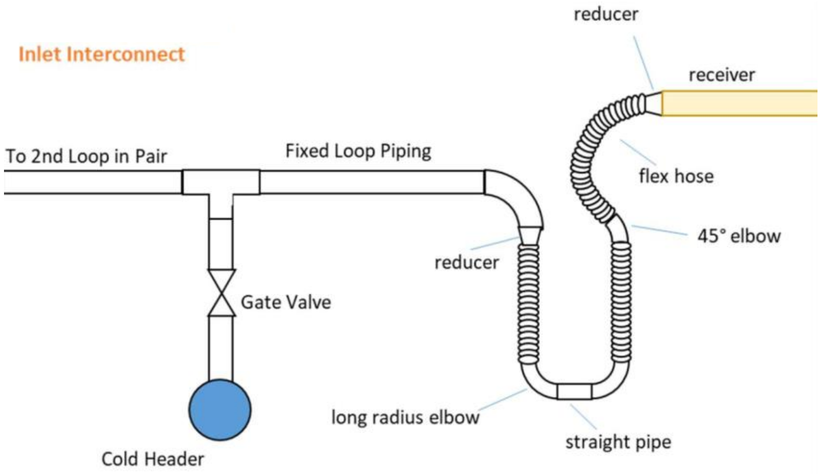
Interconnects

- Configurable interconnects have been added as an advanced option at the:
  - inlet
  - outlet
  - crossover
  - connections between solar collector assemblies (SCAs)
- Exposes hard coded component sizes and associated losses
- Using defaults will replicate the original hard coded values and respective calculated outputs

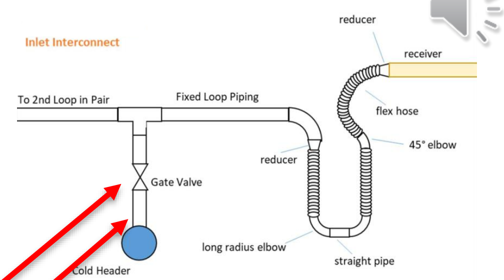
Interconnects

- Pressure losses modeled according to component type:
    - Fitting *(minor loss coeffs.)*
    - Pipe *(Darcy–Weisbach)*
    - Flex hose *(empirical model)*

- Heat losses modeled according to component geometry:
    - Global heat loss coefficient
    - Fitting heat losses neglected



Interconnects



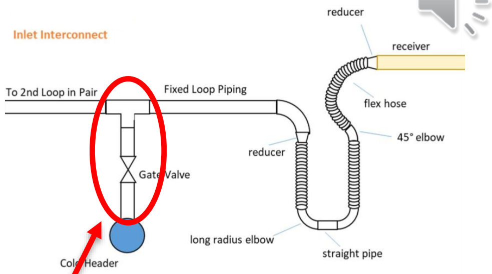
/sam/samples/LK Scripts for SAM/

- physical_trough_interconnect_components.csv

defines library of individual components

	A	B	C	D	E	F
1	Name	Component Description	Minor Loss Coefficient	Flow Diameter	Length	Type
2	Units	-	-	m	m	flag:[0=fitting | 1=pipe | 2=flex_hose]
3	[0]	intc_cpnt	cpnt_K	cpnt_D	cpnt_L	cpnt_type
4	e1	Expansion 1	0.15	0.085	0	0
5	c1	Contraction 1	0.05	0.085	0	0
6	l1	Elbow 1, long	0.6	0.085	0	0
7	l2	Elbow 2, long	0.6	0.0635	0	0
8	l3	Elbow 3, 45 deg	0.42	0.0635	0	0
9	v1	Valve 1, gate	0.19	0.085	0	0
10	t1	Tee 1	0.9	0.085	0	0
11	p1	Pipe 1	0	0.0635	0.5	1
12	p2	Pipe 2	0	0.085	2	1
13	p3	Pipe 3	0	0.0635	1	1
14	f1	Flex hose 1	0	0.0635	1	2
15	w1	Weldolet 1	0.9	0.085	0	0

Interconnects



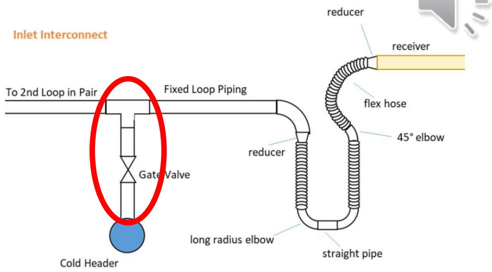
/sam/samples/LK Scripts for SAM/

- physical_trough_interconnect_components.csv
- physical_trough_interconnect_definitions.csv

defines assemblies of components (interconnects)

	A	B	C	D
1	Name	Interconnect Description	Number of Components	Components
2	Units	-	-	-
3	[0]	intc_desc	intc_n_cpnts	intc_cpnts
4	I#0	Interconnect #0	5	w1-p3-v1-p3-t1
5	I#1	Interconnect #1	11	p2-l1-c1-f1-l2-p1-l2-f1-l3-f1-e1
6	I#2	Interconnect #2	11	c1-f1-l3-f1-l2-p1-l2-f1-l3-f1-e1
7	I#3	Interconnect #3	11	c1-f1-l3-f1-l2-p1-l2-f1-l3-f1-e1
8	I#4	Interconnect #4	11	c1-f1-l3-f1-l2-p1-l2-f1-l3-f1-e1
9	I#5	Interconnect #5	11	c1-f1-l3-f1-l2-p1-l2-f1-l3-f1-e1
10	I#6	Interconnect #6	11	c1-f1-l3-f1-l2-p1-l2-f1-l3-f1-e1
11	I#7	Interconnect #7	11	c1-f1-l3-f1-l2-p1-l2-f1-l3-f1-e1
12	I#8	Interconnect #8	11	c1-f1-l3-f1-l2-p1-l2-f1-l3-f1-e1
13	I#9	Interconnect #9	11	c1-f1-l3-f1-l2-p1-l2-f1-e1-l1-p2
14	I#10	Interconnect #10	5	t1-p3-v1-p3-w1

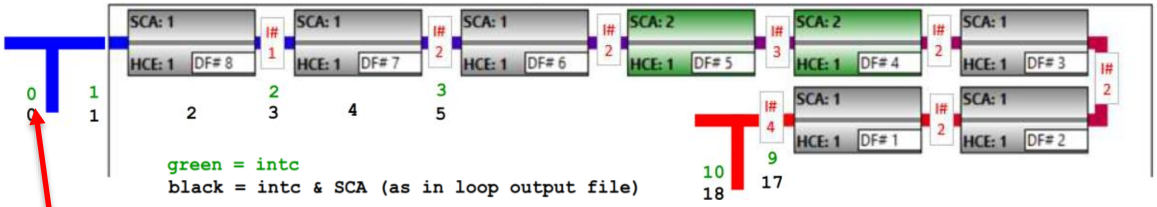
Interconnects



/sam/samples/LK Scripts for SAM/

- physical_trough_interconnect_components.csv
- physical_trough_interconnect_definitions.csv

	A	B	
1	Name	Interconnect Description	Nu
2	Units	-	-
3	[0]	intc_desc	int
4	I#0	Interconnect #0	
5	I#1	Interconnect #1	
6	I#2	Interconnect #2	
7	I#3	Interconnect #3	
8	I#4	Interconnect #4	
9	I#5	Interconnect #5	
10	I#6	Interconnect #6	
11	I#7	Interconnect #7	
12	I#8	Interconnect #8	
13	I#9	Interconnect #9	
14	I#10	Interconnect #10	



Numbers correspond to locations in the loop (in green)

- Bug Fixes
- Script Templates
- Pipe Sizing and Custom Losses
- Interconnects
- **Flex hose modeling**
- Decoupled Collection and Generation
- Simplify UDPC, Testing and Documentation

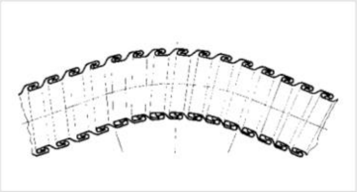
Flex Hoses

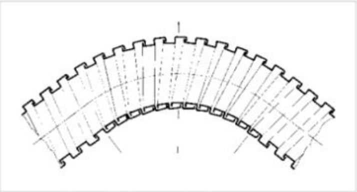
<u>Flex Hoses</u>

- Added as an advanced modeling option
- Pressure drop dependent on:
  - Type
  - Size
  - Flex radius and angle

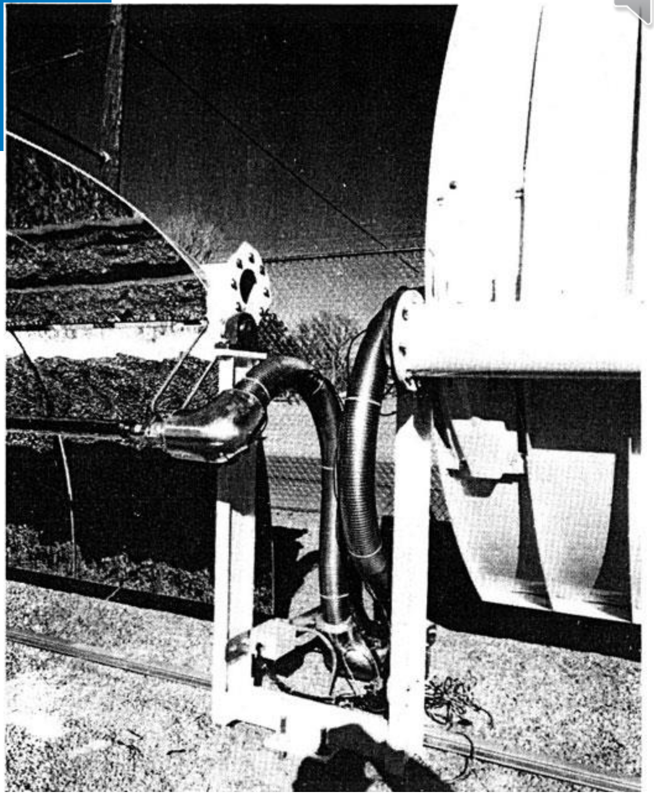
- Formulation a modification of Darcy-Weisbach equation that accounts for bending:

$$\Delta p = \left[f\left(\frac{L}{D}\right) + \zeta_b\right]\left(\frac{\rho}{2}\right)V^2$$





Courtesy: Witzenmann GmbH



Courtesy: Sandia National Laboratories

Flex Hoses

Types

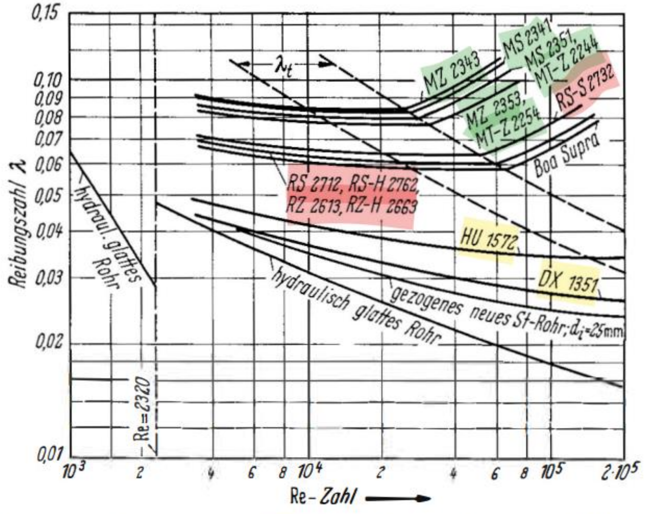
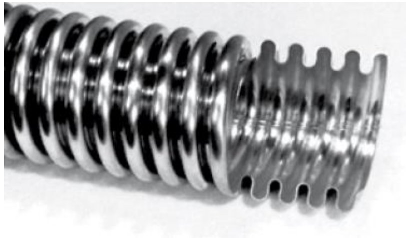


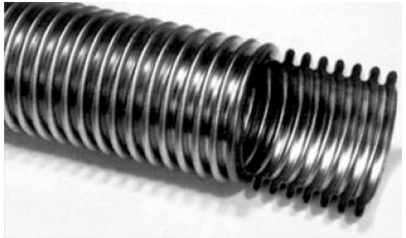
Figure 7. Friction numbers of winding and corrugated hoses (2/W 25); Winding hoses DX, HU, corrugated hoses RZ, RS, helical hoses MT, MZ, MS (factory picture)

Gropp, R., Pforzheim, 1974. Flow Resistance of flexible metallic lines

Helical
(helically corrugated)

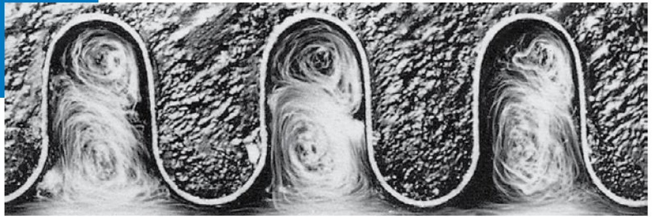


Corrugated
(annular)



Winding
(stripwound)

Flex Hoses

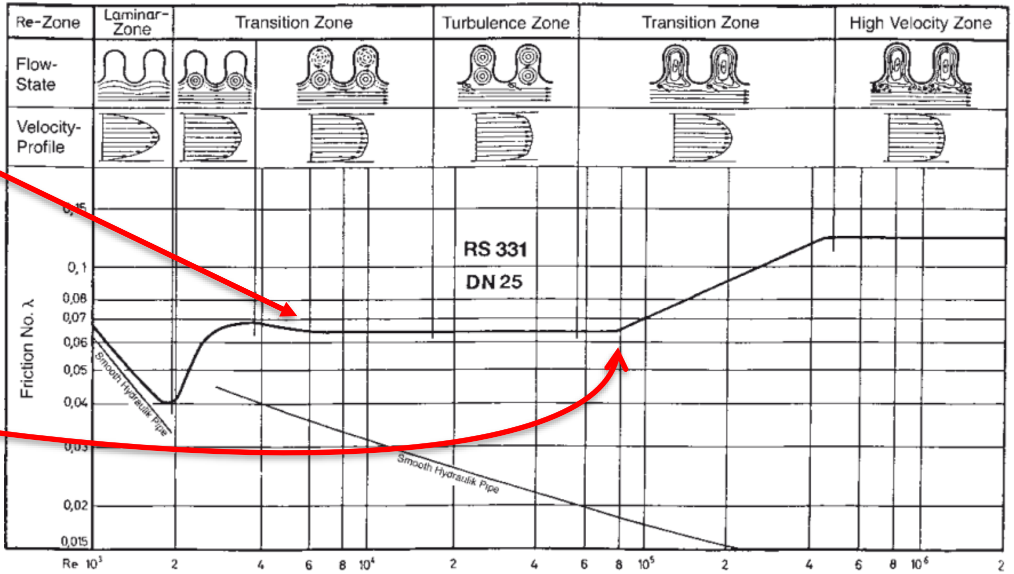


Courtesy: Witzenmann GmbH

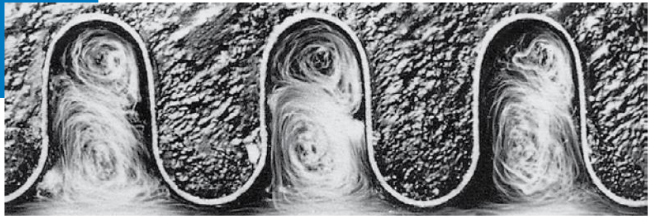
Flow Regimes

- Quickly enters fully rough zone (near constant ff)

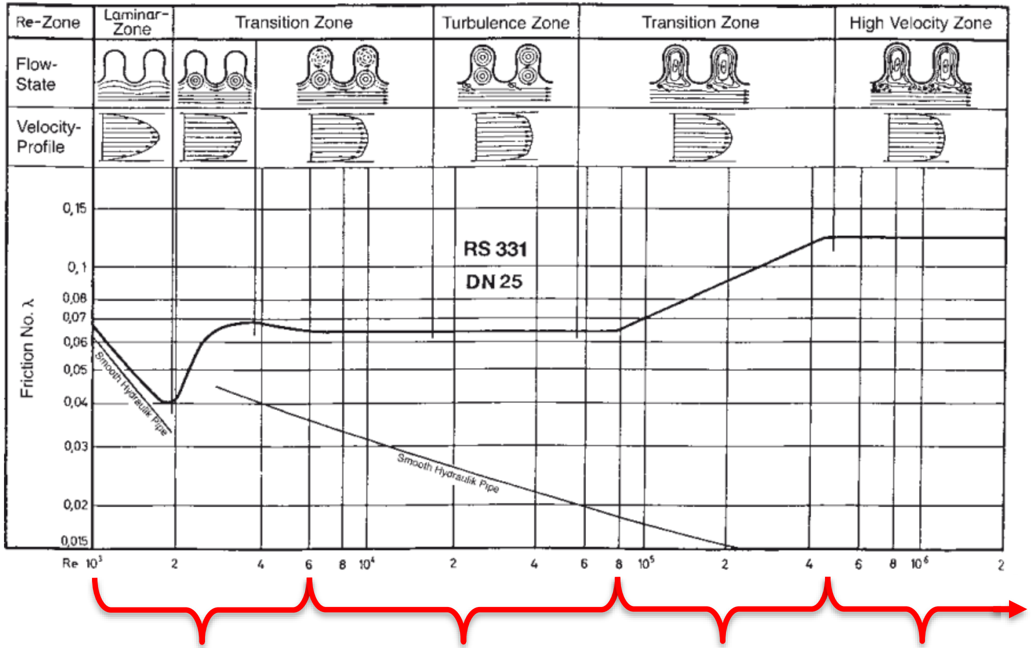
- At higher Reynold's numbers, enters additional, higher friction factor zones instead of staying constant



Flex Hoses



Courtesy: Witzenmann GmbH



Modeling of Friction Factor (*ff*)

- *Re* < 6000:
  - Normal pipe
  - Laminar *ff* = 64 / *Re*
  - Turbulent transition = Colebrook (iterative)
- *Re* >= 6000
  - Annular corrugated with average characteristics
  - Simple model (*Re* vs. *D*)
  - Linear log-log (*ff* vs. *Re*)

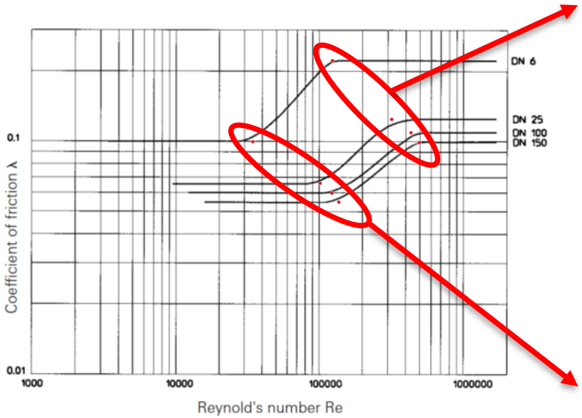
Modeled as: normal pipe | constant | linear (log-log) | constant

Flex Hoses

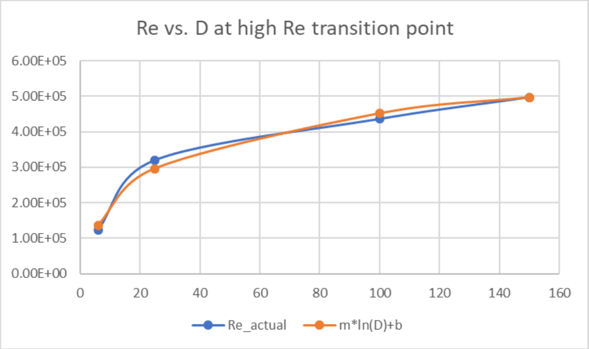
Flex Hose Modeling

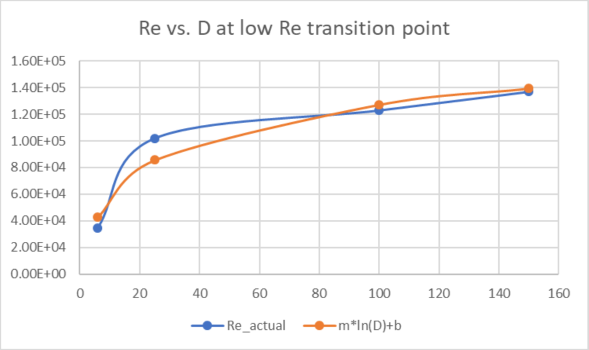
- *Re* transition points as function of diameter
  - Data from corrugated hose model RS331
  - Model form:

$$Re = m \cdot ln(D) + b$$

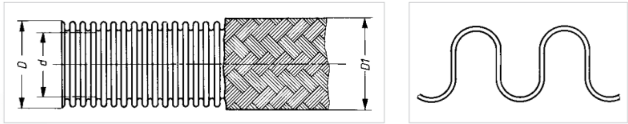


Courtesy: Witzenmann GmbH





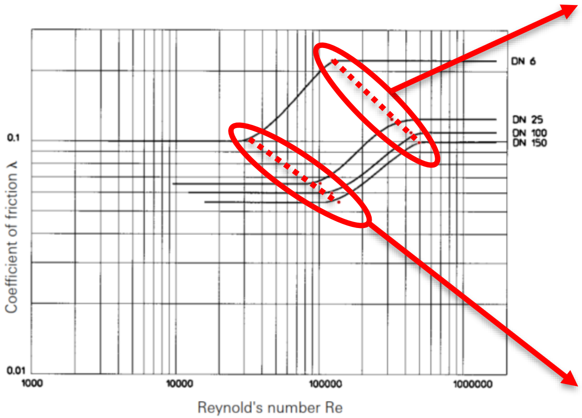
RS 330 / 331



Flex Hoses

<u>Flex Hose Modeling</u>

- *ff* transition points as function of *Re*
  - Linear log-log
  - Two models
    - at low trans.
    - at high trans.



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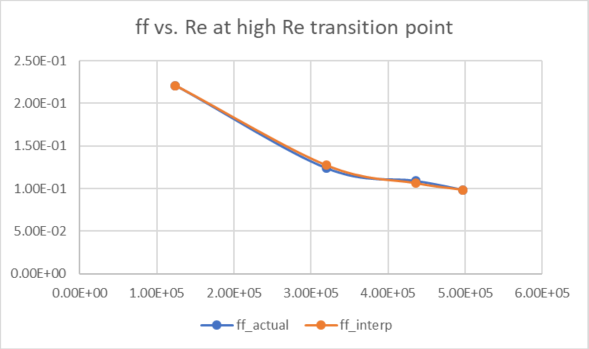
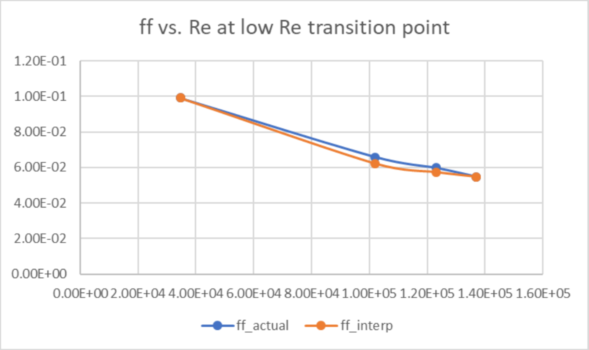
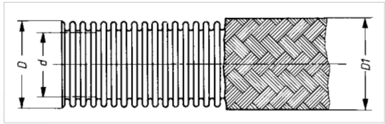




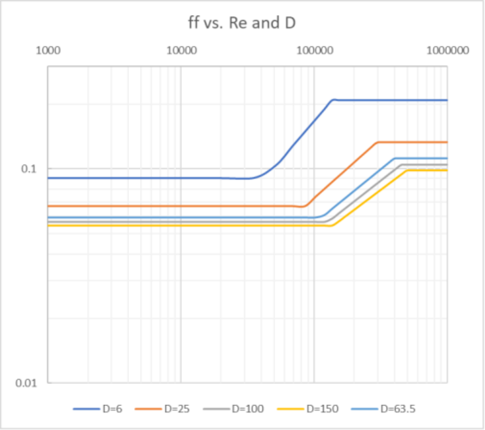
RS 330 / 331

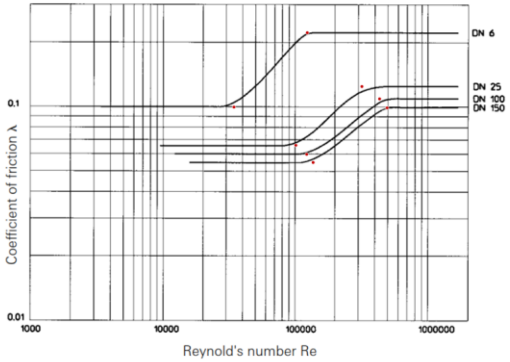


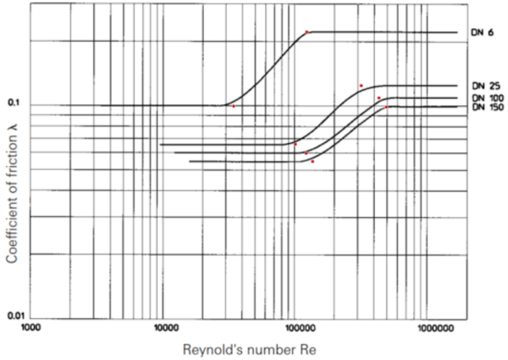
Flex Hoses

<u>Flex Hose Modeling</u>

- Results
  - Good fit
  - Plot includes one known implemented diameter of 2.5” (63.5 mm)







Courtesy: Witzenmann GmbH

Flex Hoses

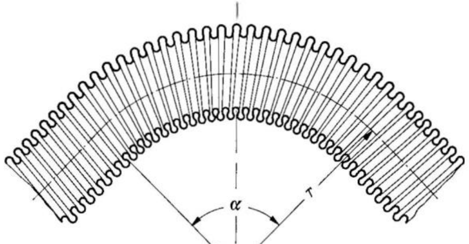


Figure 8. Bent metal hose (factory picture)

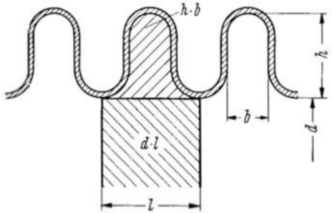


Figure 6. Relative roughness of metal hoses (factory picture)

Flex Hose Modeling

- Bending effects
  - Not implemented
  - Possible future feature
  - Determination of *in situ* hose angles is the more difficult task

$$\Delta p = \left[f\left(\frac{L}{D}\right) + \zeta_b \right] \left(\frac{\rho}{2}\right) V^2$$

$$\zeta_b = \zeta \frac{\alpha}{180°}$$

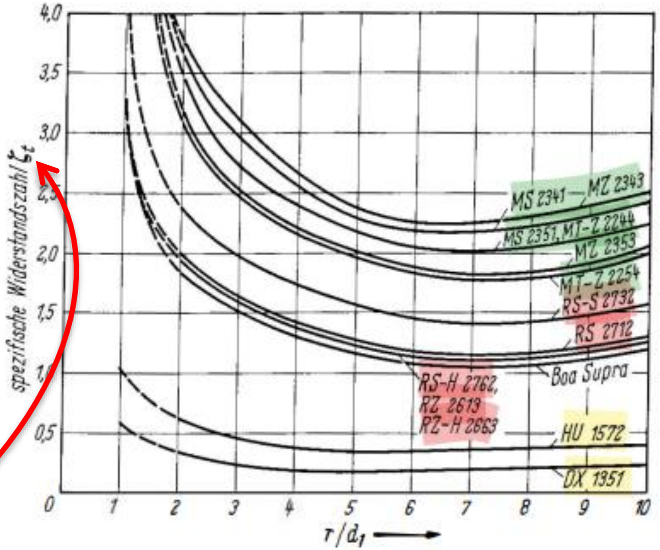
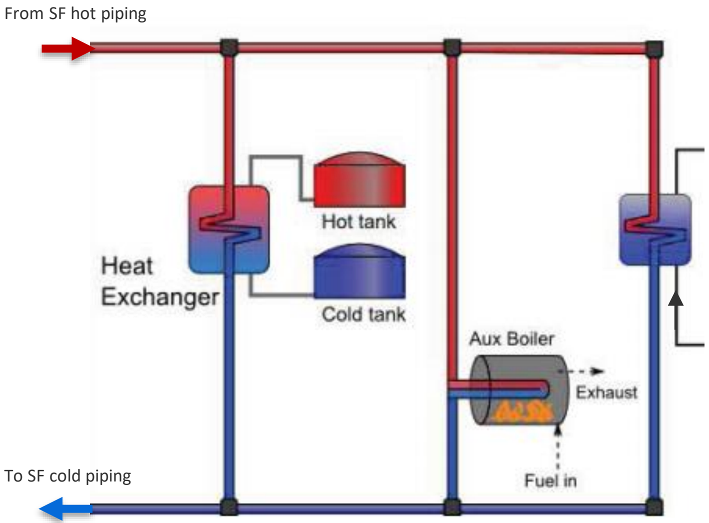


Figure 9. Specific resistance coefficients ζt of winding and corrugated hoses (NW 25): Winding hoses DX, HU, corrugated hoses RZ, RS, helical hoses MT, MZ, MS (factory picture)

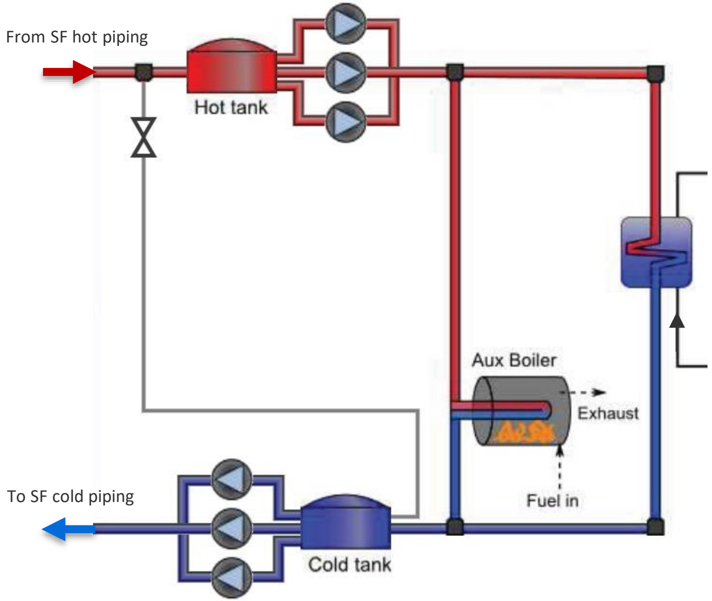
Gropp, R., Pforzheim, 1974. Flow Resistance of flexible metallic lines

- Bug Fixes
- Script Templates
- Pipe Sizing and Custom Losses
- Interconnects
- Flex hose modeling
- **Decoupled Collection and Generation**
- Simplify UDPC, Testing and Documentation

Decoupled Collection and Generation



Default (parallel) storage tank configuration

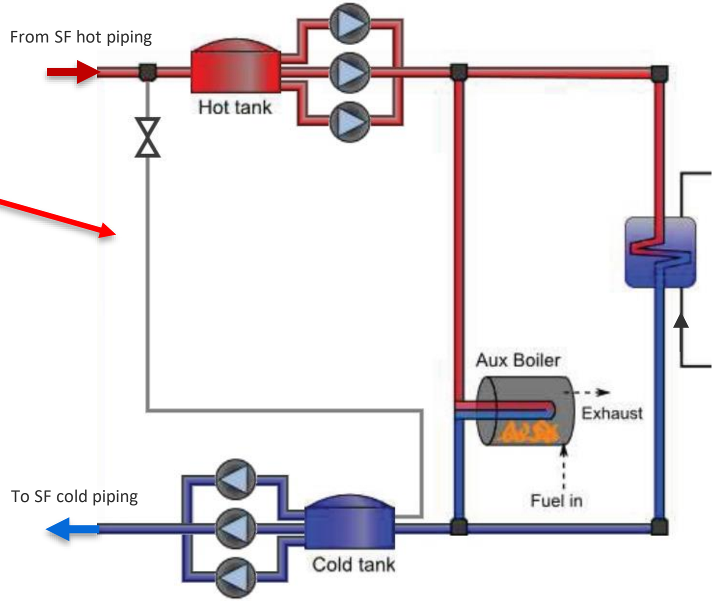


New series storage tank option

Decoupled Collection and Generation

<u>TES in Series with Field</u>

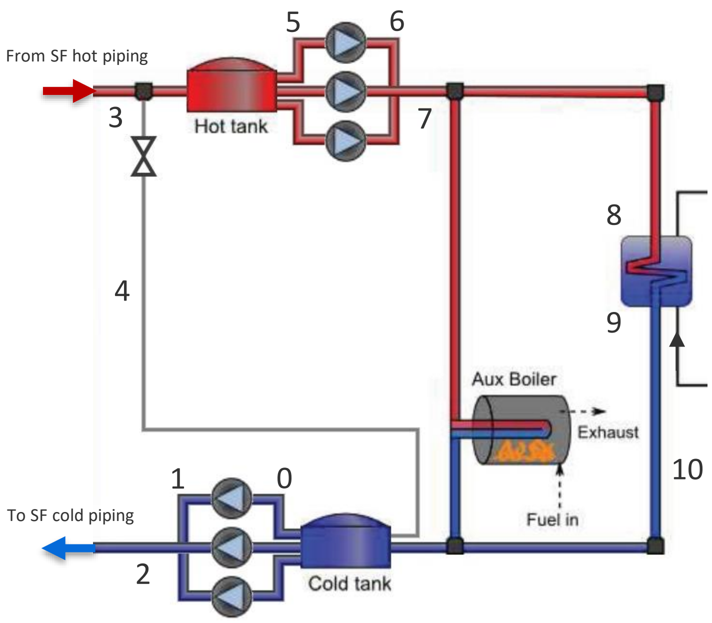
- *tanks_in_parallel* = true
- *has_hot_tank_bypass* = true
    - Field HTF circulates through cold tank (instead of straight back to field) when *T_tank_hot_inlet_min* is not met
- Field and TES/PB are now effectively decoupled



New series storage tank option

Decoupled Collection and Generation

Number	From	To
0	Cold thermal storage tank	Individual solar field (SF) pump inlet
1	Individual SF pump discharge	SF pump discharge header
2	SF pump discharge header	SF runners
3	SF runners	Hot thermal storage tank
4	SF runners	Cold thermal storage tank
5	Steam generator system (SGS) pump suction header	Individual SGS pump inlet
6	Individual SGS pump discharge	SGS pump discharge header
7	SGS pump discharge header	Steam generator supply header
8	Steam generator supply header	Inter-steam generator piping
9	Inter-steam generator piping	Steam generator outlet header
10	Steam generator outlet header	Cold thermal storage tank



New series storage tank option

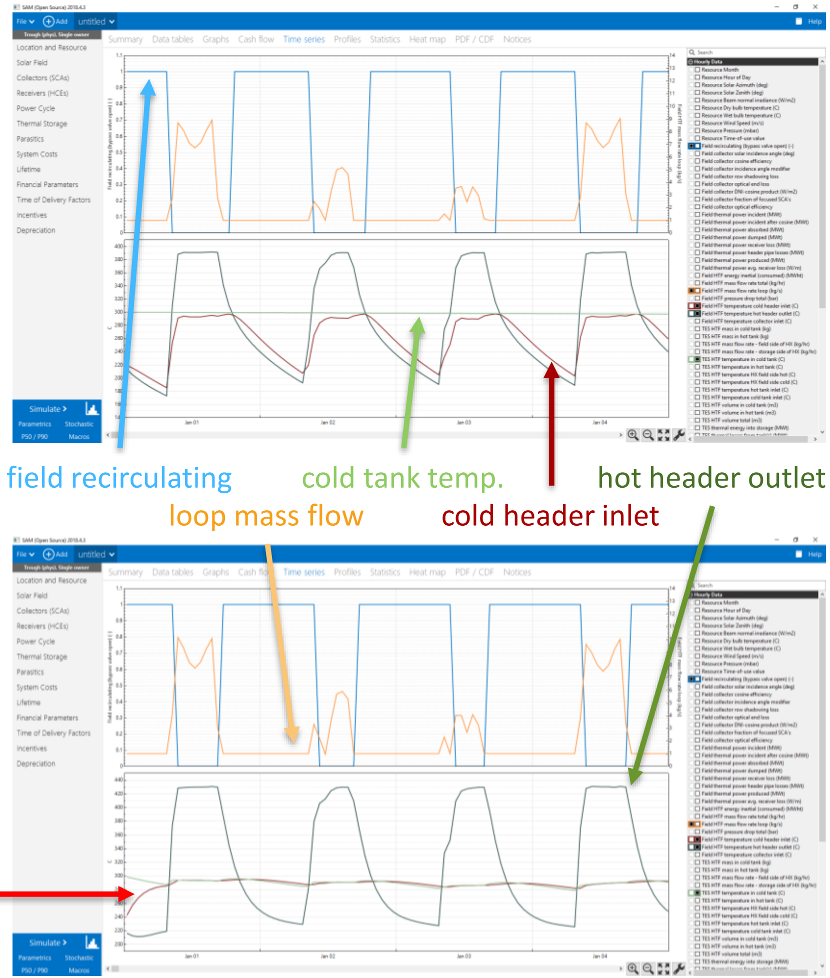
Decoupled Collection and Generation

Example behavior of:

Field in parallel with TES

vs.

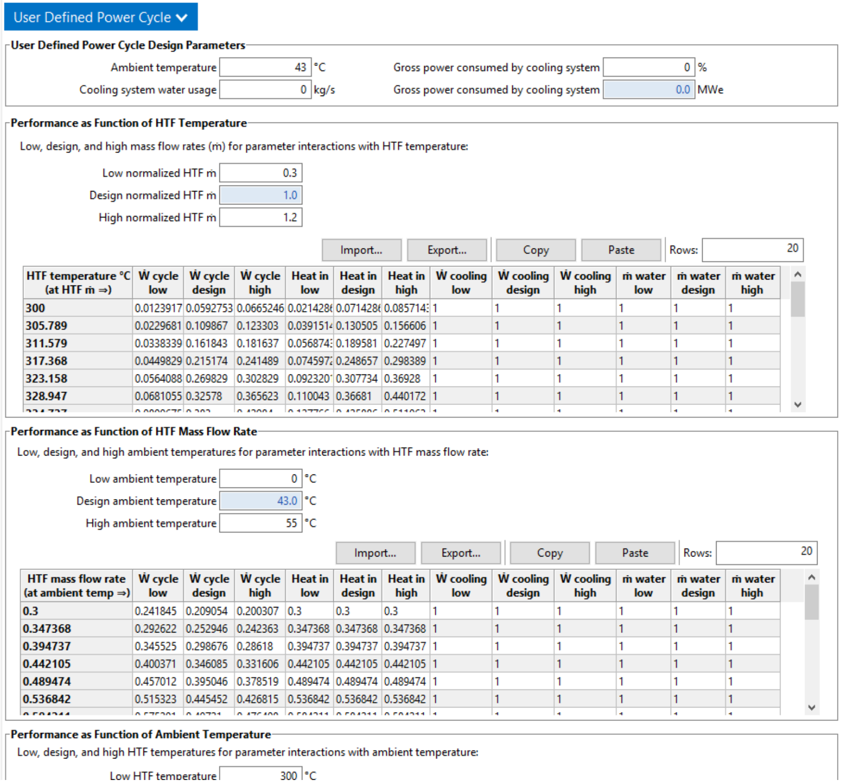
Field in series with TES



Cold-tank a thermal reservoir, keeping field HTF at a higher temperature

- Bug Fixes
- Script Templates
- Pipe Sizing and Custom Losses
- Interconnects
- Flex hose modeling
- Decoupled Collection and Generation
- **Simplify UDPC, Testing and Documentation**

Simplify UDPC



User Defined Power Cycle

User Defined Power Cycle Design Parameters

Ambient temperature: 43 °C
Cooling system water usage: 0 kg/s
Gross power consumed by cooling system: 0 %
Gross power consumed by cooling system: 0.0 MWe

Performance as Function of HTF Temperature

Low, design, and high mass flow rates (m) for parameter interactions with HTF temperature:

Low normalized HTF ṁ: 0.3
Design normalized HTF ṁ: 1.0
High normalized HTF ṁ: 1.2

Import... Export... Copy Paste Rows: 20

HTF temperature °C (at HTF ṁ ⇒)	Ẇ cycle low	Ẇ cycle design	Ẇ cycle high	Heat in low	Heat in design	Heat in high	Ẇ cooling low	Ẇ cooling design	Ẇ cooling high	ṁ water low	ṁ water design	ṁ water high
300	0.0123917	0.0592753	0.0665246	0.021428	0.071428	0.085714	1	1	1	1	1	1
305.789	0.0229681	0.109867	0.123303	0.039151	0.130505	0.156606	1	1	1	1	1	1
311.579	0.0338339	0.161843	0.181637	0.056874	0.189581	0.227497	1	1	1	1	1	1
317.368	0.0449829	0.215174	0.241489	0.074597	0.248657	0.298389	1	1	1	1	1	1
323.158	0.0564088	0.269829	0.302829	0.092320	0.307734	0.36928	1	1	1	1	1	1
328.947	0.0681055	0.32578	0.365623	0.110043	0.36681	0.440172	1	1	1	1	1	1

Performance as Function of HTF Mass Flow Rate

Low, design, and high ambient temperatures for parameter interactions with HTF mass flow rate:

Low ambient temperature: 0 °C
Design ambient temperature: 43.0 °C
High ambient temperature: 55 °C

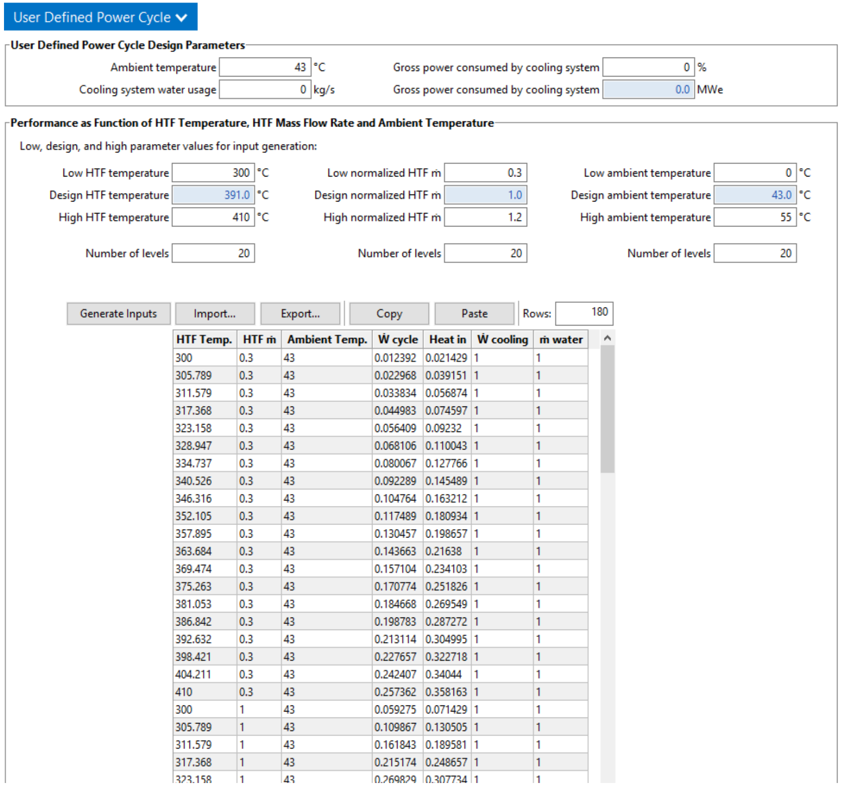
Import... Export... Copy Paste Rows: 20

HTF mass flow rate (at ambient temp ⇒)	Ẇ cycle low	Ẇ cycle design	Ẇ cycle high	Heat in low	Heat in design	Heat in high	Ẇ cooling low	Ẇ cooling design	Ẇ cooling high	ṁ water low	ṁ water design	ṁ water high
0.3	0.241845	0.209054	0.200307	0.3	0.3	0.3	1	1	1	1	1	1
0.347368	0.292622	0.252946	0.242363	0.347368	0.347368	0.347368	1	1	1	1	1	1
0.394737	0.345525	0.298676	0.28618	0.394737	0.394737	0.394737	1	1	1	1	1	1
0.442105	0.400371	0.346085	0.331606	0.442105	0.442105	0.442105	1	1	1	1	1	1
0.489474	0.457012	0.395046	0.378519	0.489474	0.489474	0.489474	1	1	1	1	1	1
0.536842	0.515323	0.445452	0.426815	0.536842	0.536842	0.536842	1	1	1	1	1	1

Performance as Function of Ambient Temperature

Low, design, and high HTF temperatures for parameter interactions with ambient temperature:

Low HTF temperature: 300 °C



User Defined Power Cycle

User Defined Power Cycle Design Parameters

Ambient temperature: 43 °C
Cooling system water usage: 0 kg/s
Gross power consumed by cooling system: 0 %
Gross power consumed by cooling system: 0.0 MWe

Performance as Function of HTF Temperature, HTF Mass Flow Rate and Ambient Temperature

Low, design, and high parameter values for input generation:

Low HTF temperature: 300 °C
Design HTF temperature: 391.0 °C
High HTF temperature: 410 °C
Number of levels: 20

Low normalized HTF ṁ: 0.3
Design normalized HTF ṁ: 1.0
High normalized HTF ṁ: 1.2
Number of levels: 20

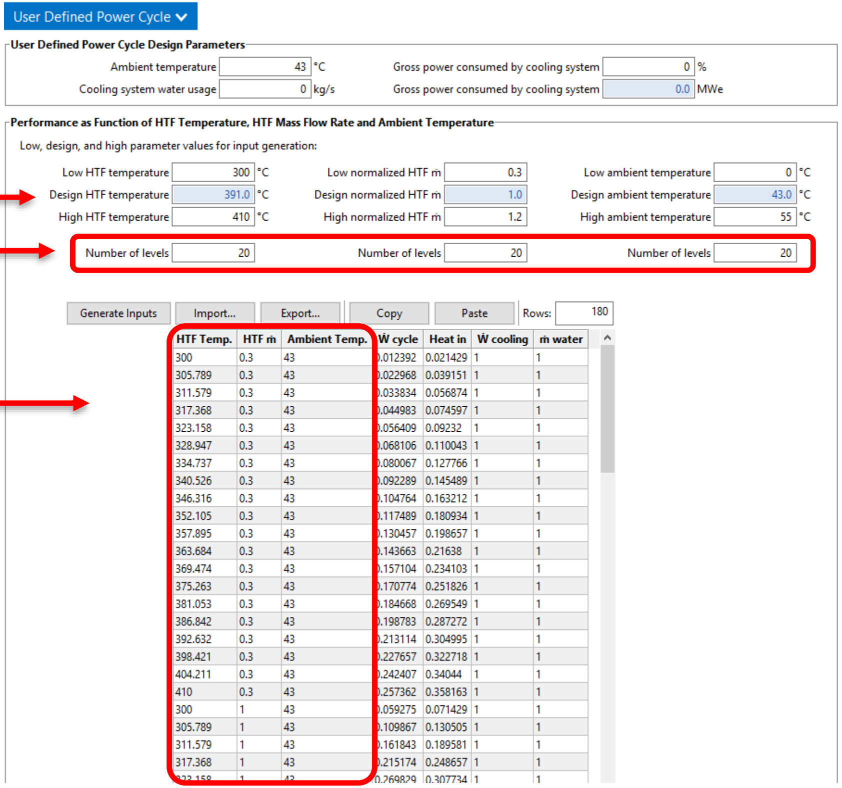
Low ambient temperature: 0 °C
Design ambient temperature: 43.0 °C
High ambient temperature: 55 °C
Number of levels: 20

Generate Inputs Import... Export... Copy Paste Rows: 180

HTF Temp.	HTF ṁ	Ambient Temp.	Ẇ cycle	Heat in	Ẇ cooling	ṁ water
300	0.3	43	0.012392	0.021429	1	1
305.789	0.3	43	0.022968	0.039151	1	1
311.579	0.3	43	0.033834	0.056874	1	1
317.368	0.3	43	0.044983	0.074597	1	1
323.158	0.3	43	0.056409	0.09232	1	1
328.947	0.3	43	0.068106	0.110043	1	1
334.737	0.3	43	0.080067	0.127766	1	1
340.526	0.3	43	0.092289	0.145489	1	1
346.316	0.3	43	0.104764	0.163212	1	1
352.105	0.3	43	0.117489	0.180934	1	1
357.895	0.3	43	0.130457	0.198657	1	1
363.684	0.3	43	0.143663	0.21638	1	1
369.474	0.3	43	0.157104	0.234103	1	1
375.263	0.3	43	0.170774	0.251826	1	1
381.053	0.3	43	0.184668	0.269549	1	1
386.842	0.3	43	0.198783	0.287272	1	1
392.632	0.3	43	0.213114	0.304995	1	1
398.421	0.3	43	0.227657	0.322718	1	1
404.211	0.3	43	0.242407	0.34044	1	1
410	0.3	43	0.257362	0.358163	1	1
300	1	43	0.059275	0.071429	1	1
305.789	1	43	0.109867	0.130505	1	1
311.579	1	43	0.161843	0.189581	1	1
317.368	1	43	0.215174	0.248657	1	1
323.158	1	43	0.269829	0.307734	1	1

Simplify UDPC

- If the user already has the three tables from before:
  - Six low and high independent values can be input above the table (initially empty)
  - The number of independent values can be chosen, with the total number of rows calculated
  - The HTF Temp., HTF m, and Ambient Temp. columns then populate
  - Serves as:
    - a guide for copy and pasting from their original tables
      OR
    - inputs to their parametric model run

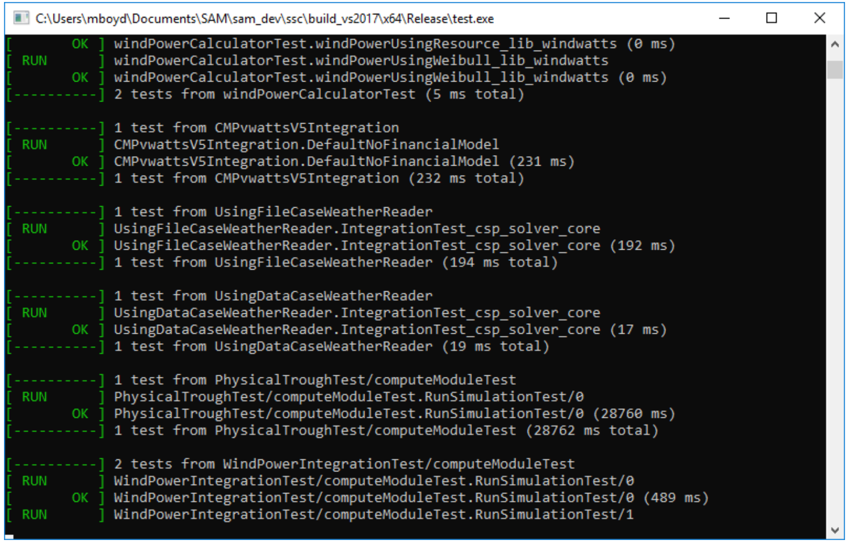


HTF Temp.	HTF ṁ	Ambient Temp.	Ẇ cycle	Heat in	Ẇ cooling	ṁ water
300	0.3	43	.012392	0.021429	1	1
305.789	0.3	43	.022968	0.039151	1	1
311.579	0.3	43	.033834	0.056874	1	1
317.368	0.3	43	.044983	0.074597	1	1
323.158	0.3	43	.056409	0.09232	1	1
328.947	0.3	43	.068106	0.110043	1	1
334.737	0.3	43	.080067	0.127766	1	1
340.526	0.3	43	.092289	0.145489	1	1
346.316	0.3	43	.104764	0.163212	1	1
352.105	0.3	43	.117489	0.180934	1	1
357.895	0.3	43	.130457	0.198657	1	1
363.684	0.3	43	.143663	0.21638	1	1
369.474	0.3	43	.157104	0.234103	1	1
375.263	0.3	43	.170774	0.251826	1	1
381.053	0.3	43	.184668	0.269549	1	1
386.842	0.3	43	.198783	0.287272	1	1
392.632	0.3	43	.213114	0.304995	1	1
398.421	0.3	43	.227657	0.322718	1	1
404.211	0.3	43	.242407	0.34044	1	1
410	0.3	43	.257362	0.358163	1	1
300	1	43	.059275	0.071429	1	1
305.789	1	43	.109867	0.130505	1	1
311.579	1	43	.161843	0.189581	1	1
317.368	1	43	.215174	0.248657	1	1
[illegible]	1	43	0.269829	0.307734	1	1

Unit Testing

googletest
Google C++ Testing Framework

- A GoogleTest case has been added for the physical trough model
  - Continual, automated value checks for known working code
  - Verify functions perform as designed


C:\Users\mboyd\Documents\SAM\sam_dev\ssc\build_vs2017\x64\Release\test.exe

```
[       OK ] windPowerCalculatorTest.windPowerUsingResource_lib_windwatts (0 ms)
[ RUN      ] windPowerCalculatorTest.windPowerUsingWeibull_lib_windwatts
[       OK ] windPowerCalculatorTest.windPowerUsingWeibull_lib_windwatts (0 ms)
[----------] 2 tests from windPowerCalculatorTest (5 ms total)

[----------] 1 test from CMPvwattsV5Integration
[ RUN      ] CMPvwattsV5Integration.DefaultNoFinancialModel
[       OK ] CMPvwattsV5Integration.DefaultNoFinancialModel (231 ms)
[----------] 1 test from CMPvwattsV5Integration (232 ms total)

[----------] 1 test from UsingFileCaseWeatherReader
[ RUN      ] UsingFileCaseWeatherReader.IntegrationTest_csp_solver_core
[       OK ] UsingFileCaseWeatherReader.IntegrationTest_csp_solver_core (192 ms)
[----------] 1 test from UsingFileCaseWeatherReader (194 ms total)

[----------] 1 test from UsingDataCaseWeatherReader
[ RUN      ] UsingDataCaseWeatherReader.IntegrationTest_csp_solver_core
[       OK ] UsingDataCaseWeatherReader.IntegrationTest_csp_solver_core (17 ms)
[----------] 1 test from UsingDataCaseWeatherReader (19 ms total)

[----------] 1 test from PhysicalTroughTest/computeModuleTest
[ RUN      ] PhysicalTroughTest/computeModuleTest.RunSimulationTest/0
[       OK ] PhysicalTroughTest/computeModuleTest.RunSimulationTest/0 (28760 ms)
[----------] 1 test from PhysicalTroughTest/computeModuleTest (28762 ms total)

[----------] 2 tests from WindPowerIntegrationTest/computeModuleTest
[ RUN      ] WindPowerIntegrationTest/computeModuleTest.RunSimulationTest/0
[       OK ] WindPowerIntegrationTest/computeModuleTest.RunSimulationTest/0 (489 ms)
[ RUN      ] WindPowerIntegrationTest/computeModuleTest.RunSimulationTest/1
```

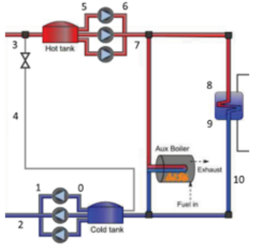
Help File

- SAM Help has been updated:
  - 'Physical Trough Model' section
  - Definitions of new input and output variables
  - For new functionality:
    - Descriptions
    - Equations
    - Diagrams

sgs_lengths [m]

The custom specified thermal energy storage and power block pipe section lengths. The values are utilized if the parameter custom_sgs_pipe_sizes is set to true. The number of length values needs to match the number of pipe sections. Lengths at indices 0, 1, 5 and 6 are the summed lengths of the multiple individual pump sections. The default values are { 0, 90, 100, 120, 0, 0, 0, 0, 80, 120, 80 }, in meters.

Number	From	To
0	Cold thermal storage tank	Individual solar field (SF) pump inlet
1	Individual SF pump discharge	SF pump discharge header
2	SF pump discharge header	SF runners
3	SF runners	Hot thermal storage tank
4	SF runners	Cold thermal storage tank
5	Steam generator system (SGS) pump suction header	Individual SGS pump inlet
6	Individual SGS pump discharge	SGS pump discharge header
7	SGS pump discharge header	Steam generator supply header
8	Steam generator supply header	Inter-steam generator piping
9	Inter-steam generator piping	Steam generator outlet header
10	Steam generator outlet header	Cold thermal storage tank

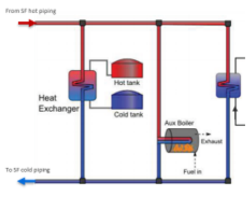


sgs_wallthicks [m]

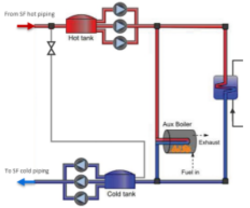
The custom specified thermal energy storage and power block pipe wall thicknesses. The values are utilized if the parameter custom_sgs_pipe_sizes is set to true. The number of wall thickness values needs to match the number of pipe sections.

tanks_in_parallel [-]

Whether the thermal energy storage tank are in parallel with the field or in series with the field. Tanks in series with the field are specific to direct storage systems as in this configuration the field heat transfer fluid passes through the tanks before entering and after leaving the power block. The default value is false.



Default (parallel) storage tank configuration



New series storage tank option

Thank you

www.nrel.gov

Questions -> matthew.boyd@nrel.gov

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