COIL PROGRAM

An invaluable tool for process and plant engineers as well as boiler designers!

Predict the performance of an existing boiler heat transfer component or design a new one such as:

- Superheater (plain tube or finned)
- HRSG or boiler evaporator(plain tube or finned)
- economizer(plain or finned and steaming or non-steaming)
- tubular air heater(gas to gas exchanger, single or multi-pass)
- air cooled condenser(air or cold fluegas outside tubes, steam condensing inside tubes)
- fluid heater or cooler(therminol, dowtherm or industrial fluids inside tubes and air/fluegas outside plain or finned tubes)

The tubes can be plain, solid or serrated finned, in inline or staggered arrangement or in parallel or counter flow. Flue gas or air flows outside tubes and the fluid such as water, steam, thermal fluid is inside the tubes. In the case of tubular air heater, either air or fluegas can be inside the tubes. If the component has two or more different tube or fin types or sections, then one can run one section behind the other as discussed below. Examples illustrate these above points. Economizer could be non- steaming or steaming. Condensing economizer is not considered in this version as also direct radiation from external sources.

Applications

Plant engineers can check if their existing superheater, economizer or evaporator or air heater, fluid heater coil is performing as predicted or needs modification or if it is under-performing . They may also perform simulation studies to see what happens at different gas inlet or fluid inlet conditions. One may also use the program to design a new coil. For example if the estimated duty of a superheater or economizer or evaporator is less than that stated by the boiler supplier, one may check if the design or surface area is reasonable. One may the program to check if there is fouling on gas side or steam side. One may vary the fouling factors on gas side or tube side to simulate field test data such as exit gas temperature or tube wall temperatures and check if fouling is heavy or whether the component is under surfaced. From the maximum tube wall temperature prediction, one can check if there is tube side fouling or if the tube side fluid velocity is a concern. These points are explained in the examples provided.

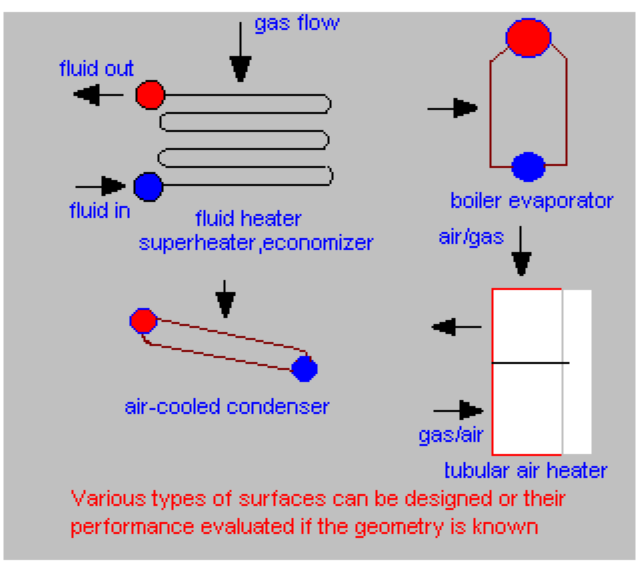


Fig 1 alongside shows the typical coils that may be evaluated by this program.

1.Superheater
2.Economizer
3.Air heater (with gas analysis of both fluids known)
4.Air heater with tube side fluid analysis unknown.(Properties such as specific heat, viscosity, conductivity, MW are required)
5.Liquid heater/cooler (such as therminol,dowtherm,oil heated by waste fluegases)
6.Boiler evaporator/condenser

Example 1:A plant engineer wants to check the performance of an existing economizer. Gas temperature entering an economizer is 300C and flue gas flow is 100,000 kg/h. Gas analysis is % volume CO_2=3,H_2O=6.6,N_2=76,O_2=14.4. . Tube geometry is shown in column E of Fig 3 for case 1 data. 80,000 kg/h of water at 45 kg/cm2a and at 110C enters the coil. Determine the duty and exit fluegas and water temperatures. 51 mm OD finned tubes in inline arrangement are used

Solution: By entering the data in metric units as shown in Fig 2,selecting Metric units and "economizer" as coil type and clicking the RUN button we get the performance as shown in Fig 2 under case 1 results. It shows the exit fluegas temperature as 154C and exit water temperature as 156C. The results show fluegas and water side pressure drop,velocities,maximum tube wall temperature and fin tip temperatures. The heat transfer coefficients are also shown.The duty is 3.73 MM kcal/h or 4337 kW.(Appropriate units for Metric and British data are shown in the last two columns)

Now one can compare the exit gas temperature from field data and compare with that predicted here. If the difference is significant then one has to review the design for surfacing, check for fouling or ensure gas and water flow measurements are reasonably accurate. Generally water side measurements can be taken as more reliable than fluegas side measurements. The plant engineer can also input the design conditions and check the duty and exit fluid temperatures and compare it with the proposal data offered by the economizer supplier before buying the unit. By doing this check, poor designs can be challenged. The program is a good source for verifying the design of various coils. Process engineers hitherto have been taking the design information from boiler suppliers for granted.

The program also shows a message "Economizer steaming ** %" in case the economizer steams. One may change the tube geometry (design) to avoid steaming economizers. Pl see my latest book for methods to avoid or minimize the consequences of steaming in economizer.

Example 2 is for a superheater of a HRSG heating 70,000 kg/h of saturated steam (option 1) . Pressure is 50 kg/cm2a at exit. If zero is inputted for saturated steam temperature, the program computes the saturation temperature and hence no need to refer to steam tables for saturation temperature. Tube geometry and gas data are entered as before.

The results show the tube wall temperature, fin tip temperature, gas and steam side pressure drops, gas and steam side velocities. The Performance can thus be checked at any set of gas or steam conditions. Results can be compared with field data and if they vary significantly, analyze the design for adequacy of surfacing or fouling effects if any. If tube wall temperature is say much higher with gas inlet temperature nearly the same, then it is likely there is fouling on tube side.

Example 3: This is an evaporator module with finned tubes (option 6). Data is in British units. One can obtain the exit gas temperature and duty if inlet gas conditions and steam pressure are inputted. If necessary one may also add another module ahead of this section (in case the evaporator has several types of fin geometries). In high gas temperature applications the first few rows of the evaporator can be bare, the next few with low-finned tubes and rest with high fin density rubes and so on). Input the gas exit temperature of the first section as inlet gas temperature for the next section and so on. The heat transfer coefficient inside the tubes is an input. As it is typically much higher than the gas side coefficient, it does not affect the performance. A suggested value of 2000 Btu/ft^2hF is used here. My new book," Steam Generators and Waste Heat Boilers" may be referred to for heat transfer correlations in boiling or condensation.

Example 4: This is an air heater heated by steam or one can call it an air-cooled condenser. Air at 80F is used to condense steam. Saturated steam at a given pressure enters the unit and is condensed. The duty, amount of steam condensed and heated air temperature are all shown. The heat transfer coefficient inside the tubes is an estimate and as it is typically much higher than the gas side coefficient, it does not affect the performance. Finned tubes are suggested as tube side coefficient is much higher than the gas side.

Example 5: This is plain tube tubular air heater(option 3) with fluegas heating air and the analysis of fluegas is known. The Gas data refers to the medium outside the tubes. Here it is flue gas at 300ºC.The tube geometry for each pass and the number of passes are inputted. Here it is a two-pass air heater. The tube side flow and analysis are also inputted as shown. The performance is shown under case 5. The air is heated from 30 to 173C and flue gas is cooled from 300 to 186C. The exit fluid temperatures, fluid velcocities, pressure drop are all shown. One may change the configuration and rerun it if it is a new exchanger or check the field data with those predicted if it is an existing unit.

Example 6: In the case of fluid heater(option 5), the fluid (therminol,dowtherm or any fluid/oil),once you select the liquid heater/cooler button, input boxes for specific heat, viscosity, thermal conductivity and density appear and the data are inputted along with flow and inlet temperature. After selecting the units "British" and clicking the RUN button, results appear as shown in case 6.One can modify the fin geometry or tube length, pitch or any tube geometry data to obtain reasonable gas and fluid side pressure drops, size and heat flux.

EXCEL PROGRAM available which runs in win XP, win 7 or win 8. Pl email for a FREE Demo program. One time fee of $ 450 for up to two users.

Reference: "Steam Generators and Waste Heat Boilers for process and Plant engineers". See my web site.

Contact: email: **v_ganapathy@yahoo.com** for more information and a FREE demo program.

FIG 2

COIL PROGRAM

GAS DATA		COIL DATA		FLUID DATA	
gas flow	100000	tubeOD	51	fluid flow	80000
gas temp in	300	tube ID	44	pressure	45
gas press	1.03	fin density	197	temp in	110
vol % CO2	3	fin height	15	fouling ftr	0.0002
H2O	6.6	fin thick	1.5		
N2	76	serration	4		
O2	14.4	conductivity	30		
SO2	0	tr pitch	101		
HCL	0	long pitch	101		
H2S		tubes/row	24		
H2		no deep	12		
CO	0	eff length	4		
CH4		no streams	12		
SO3		arrangement	0		
fouling ftr	0.0002	configuration	1		
heat loss	1	correction ftr	1.1		
case no	1	no passes	1		

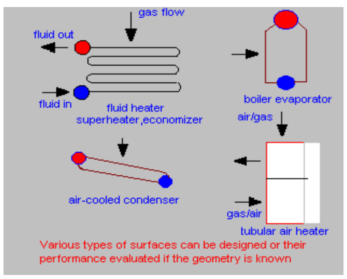
Data for Case 1: Economizer **METRIC UNITS**

◯ British ◯ Metric ◯ select units

UNITS

	Metric	British
flow	kg/h	lb/h
pressure	kg/cm2a	psia
temp	C	F
fouling ftr	m2hC/kcal	ft2hF/Btu
sp heat	kcal/kgC	btu/lbF
viscosity	kg/mh	lb/fth
th cond	kcal/mhC	btu/fthF
ht tr coefft	kcal/m2hC	Btu/ft2hF
density	kg/m3	lb/ft3
duty	MM kcal/h	MM Btu/h
gas velocity	m/s	ft/s
gas pr drop	mm wc	in wc
surface area	m2	ft2
tube dia	mm	in wc
spacings	mm	in
fin density	fins/m	fins/in
fin height,thick	mm	in

◯ 1.superheater
◯ 2.economizer
◯ 3.air heater(flue gas analysis known)
◯ 4.air heater (no fluegas analysis)
◯ 5.liquid heater/cooler
◯ 6.condenser/boiling



RESULTS	case no	1	2	3	4	5	6		
	GAS SIDE							METRIC	BRITISH
	gas flow	100000	100000	276000	100000	50000	100000	kg/h	lb/h
	gas temp in	300	550	900	80	300	650	ºC	ºF
	gas temp out	154	435	588	243	186	468	ºC	ºF
	sp heat	0.2593	0.2738	0.2684	0.2444	0.2782	0.2539	kcal/kgC	btu/lbF
	heat loss	1	1	1	1	1	1	%	%
	duty	3.73	3.10	22.86	3.93	1.57	4.57	MM Kcal/h	MM Btu/h
	ov ht tr coefft	26.36	54.73	5.75	2.84	38.85	6.19	kcal/m2hC	Btu/ft2hF
	tube side coefft	7296	2468	2000.00	2000	81	298.04	kcal/m2hC	Btu/ft2hF
	convective	33.51	121.41	7.23	3.28	92.91	9.12	kcal/m2hC	Btu/ft2hF
	non luminous	0.85	2.35	0.33	0.03	1.44	0.06	kcal/m2hC	Btu/ft2hF
	LMTD	84	199	245	167	141	161	ºC	ºF
	max gas velocity	11.9	22	54.9	10	22	36	m/s	ft/s
	gas pr drop	16.00	39.29	0.67	0.06	135	0.49	mm wc	in wc
	gas pressure	1.03	1	14.50	14.5	1	14.50	kg/cm^2a	psia
	coil type	economzr	superhtr	evap/condı	evap/cond	air/gas xch	liquid exchanger		
	TUBE SIDE								
	tube side flow	80000	70000	22744	4480	45000	80000	kg/h	lb/h
	temp in	110	265	467	341	30	350.0	ºC	ºF
	temp out	156	319	467	341	173	438	ºC	ºF
	pr drop	0.5233	1.2106	0.0000	0.0000	0.0189	6.91	kg/cm2	psi
	tube side press	45	51	500	120	1	200	kg/cm2a	psia
	wall temp in	116	311	478	335	125	372	ºC	ºF
	wall temp out	175	382	509	325	250	478	ºC	ºF
	fin temp in	124	396	507	321	125	404	ºC	ºF
	fin temp out	200	497	609	287	250	534	ºC	ºF
	tube side vel	1.29	28.4	28.40	28.4	31.2	5	m/s	ft/s
	surf area	1681	286	16189	8289	287	4597	m^2	ft2
	tube OD	51	38	2	2	51	2	mm	in
	tube ID	44	32	1.738	1.77	43	1.77	mm	in
	fin density	197	78	5	4	0	2	fins/m	fins/in
	fin height	15	19	0.76	0.75	0	0.75	mm	in
	fin thick	1.5	1.5	0.059	0.05	0	0.05	mm	in
	serration	4	0	0.172	0.157	0	0.157	mm	in
	fin conduct	30	30	25	25	0	25	kcal/mhC	btu/fthF
	tr pitch	101	100	4.25	4	70	4	mm	in
	long pitch	101	80	4	4	60	4	mm	in
	tubes/row	24	18	24	24	20	18		
	no deep	12	8	8	6	15	12		
	eff length	4	3	14	12	3	8	m	ft
	no streams	12	36	24	144	300	6		
	arrangement	0	1	0	0	0	0		
	configuration	1	1	1	1	1	1		
	correction ftr	1.1	1.1	1.1	1.1	1.1	1.1		
	no passes	1	1	1	1	2	1		

FIG 3

INPUT DATA SHEETS FOR ALL EXAMPLES

COIL PROGRAM

GAS DATA		COIL DATA		FLUID DATA	
gas flow	100000	tubeOD	51	fluid flow	80000
gas temp in	300	tube ID	44	pressure	45
gas press	1.03	fin density	197	temp in	110
vol % CO2	3	fin height	15	fouling ftr	0.0002
H2O	6.6	fin thick	1.5		
N2	76	serration	4		
O2	14.4	conductivity	30		
SO2	0	tr pitch	101		
HCL	0	long pitch	101		
H2S		tubes/row	24		
H2		no deep	12		
CO	0	eff length	4		
CH4		no streams	12		
SO3		arrangement	0		
fouling ftr	0.0002	configuratio	1		
heat loss	1	correction ft	1.1		
case no	1	no passes	1		

Data for Case 1: Economizer **METRIC UNITS**

COIL PROGRAM

GAS DATA		COIL DATA		FLUID DATA	
gas flow	100000	tubeOD	38	fluid flow	70000
gas temp in	550	tube ID	32	pressure	50
gas press	1	fin density	78	temp in	0
vol % CO2	3	fin height	19	fouling ftr	0.0002
H2O	6.6	fin thick	1.5		
N2	76	serration	0		
O2	14.4	conductivity	30		
SO2	0	tr pitch	100		
HCL	0	long pitch	80		
H2S		tubes/row	24		
H2		no deep	8		
CO	0	eff length	3		
CH4		no streams	24		
SO3		arrangement	1		
fouling ftr	0.0002	configuratio	1		
heat loss	1	correction ft	1.1		
case no	2	no passes	1		

Data for case 2: superheater **METRIC UNITS**

COIL PROGRAM

GAS DATA		COIL DATA		FLUID DATA	
gas flow	276000	tubeOD	2		
gas temp in	900	tube ID	1.738	pressure	600
gas press	14.5	fin density	5	temp in	230
vol % CO2	3	fin height	0.76	fouling ftr	0.001
H2O	6.6	fin thick	0.059		
N2	76	serration	0.172		
O2	14.4	conductivity	25		
SO2	0	tr pitch	4.25	ht coefft	2000
HCL	0	long pitch	4		
H2S		tubes/row	24		
H2		no deep	8		
CO	0	eff length	14		
CH4		no streams	24		
SO3		arrangement	0		
fouling ftr	0.001	configuratio	1		
heat loss	1	correction ft	1.1		
case no	3	no passes	1		

Data for Case 3: evaporator **British units**

COIL PROGRAM

GAS DATA		COIL DATA		FLUID DATA	
gas flow	100000	tubeOD	2		
gas temp in	80	tube ID	1.77	pressure	120
gas press	14.5	fin density	4	temp in	0
vol % CO2	0	fin height	0.75	fouling ftr	0.001
H2O	1	fin thick	0.05		
N2	78	serration	0.157		
O2	21	conductivity	25		
SO2	0	tr pitch	4	ht coefft	2000
HCL	0	long pitch	4		
H2S		tubes/row	24		
H2		no deep	6		
CO	0	eff length	12		
CH4		no streams	144		
SO3		arrangement	0		
fouling ftr	0.001	configuratio	1		
heat loss	1	correction ft	1.1		
case no	4	no passes	1		

Data for case 4: air cooled condenser -British units

COIL PROGRAM

GAS DATA		COIL DATA		FLUID DATA	
gas flow	50000	tubeOD	51	fluid flow	45000
gas temp in	300	tube ID	43	pressure	1
gas press	1	fin density	0	temp in	30
vol % CO2	8	fin height	0	fouling ftr	0.0002
H2O	18	fin thick	0		
N2	71	serration	0		
O2	3	conductivity	0		
SO2	0	tr pitch	70		
HCL	0	long pitch	60		
H2S		tubes/row	20		
H2		no deep	15	co2	0
CO	0	eff length	3	h2o	1
CH4		no streams	300	n2	78
SO3		arrangement	0	o2	21
fouling ftr	0.0002	configuratio	1	so2	
heat loss	1	correction ft	1.1	hcl	
case no	5	no passes	2	h2s	
				h2	
				co	
				ch4	
				so3	

Data for case 5: tubular air heater Metric

COIL PROGRAM

GAS DATA		COIL DATA		FLUID DATA	
gas flow	100000	tubeOD	2	fluid flow	80000
gas temp in	650	tube ID	1.77	pressure	200
gas press	14.5	fin density	2	temp in	350
vol % CO2	0	fin height	0.75	fouling ftr	0.001
H2O	1	fin thick	0.05	avg sp ht	0.65
N2	78	serration	0.157	avg visco:	0.6
O2	21	conductivity	25	avg th co	0.05
SO2	0	tr pitch	4	ht coefft	0
HCL	0	long pitch	4	density	45
H2S		tubes/row	18		
H2		no deep	12		
CO	0	eff length	8		
CH4		no streams	6		
SO3		arrangement	0		
fouling ftr	0.001	configuratio	1		
heat loss	1	correction ft	1.1		
case no	6	no passes	1		

Data for case 6: Fluid heater British units