Table 1. An example of sensitivity analysis

j	Parameter (p_j) Symbol	Nominal Value	Units	$\frac{\partial F}{\partial p_j}$	$\Delta p_j^{(*)}$	ΔF_j
1	c_f	2.0×10^{-6}	\$/kJ	7.7378×10^{4}	2.0×10^{-7}	1.5476×10^{-2}
2	c_e	8.33×10^{-6}	\$/kJ	2.3541×10^{2}	8.33×10^{-7}	1.9610×10^{-4}
3	b_{11}	740.	$\$/(kW)^{0.8}$	3.7912×10^{-5}	74.	2.8055×10^{-3}
4	b_{12}	0.8	-	2.8941×10^{-1}	0.08	2.3153×10^{-2}
5	b_{21}	3000.	$\$/(kW)^{0.7}$	7.2855×10^{-6}	300.	2.1857×10^{-3}
6	b_{22}	0.7	-	2.1645×10^{-1}	0.07	1.5152×10^{-2}
7	b_{31}	217.	$\$/m^2$	1.2885×10^{-5}	21.7	2.7961×10^{-4}
8	b_{32}	577.	\$/(kg/s)	5.7447×10^{-6}	57.7	3.3147×10^{-4}
9	b_{41}	378.	$\$/(kW)^{0.71}$	6.4086×10^{-7}	37.8	2.4225×10^{-5}
10	b_{42}	0.71	-	1.1835×10^{-3}	0.071	8.4029×10^{-5}
11	f_m	1.06	-	5.3079×10^{-2}	0.106	5.6264×10^{-3}
12	C	18.2	%	3.0914×10^{-3}	1.82	5.6264×10^{-3}
$\Delta F_{max} = 7.0940\times10^{-2}$				$\Delta F_{prob} = 1.0813\times10^{-3}$		

(*) for $\Delta p_j/p_j = 0,10$

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APPENDIX A

Expressions for the Functions of Fig. 2 and 3

The essergy flows related to the environment are:

$$y_{1,1} = \dot{\varepsilon}_f^{ch}, \qquad y_{3,2} = \dot{M}_w v_w (P_a - P_b)/\eta_{Mw},$$
$$y_{4,1} = \dot{W}_4 = \dot{M}(h_4 - h_3)/\eta_{M4}, \qquad y_{2,1} = \dot{W} = \eta_{M2}\dot{M}(h_1 - h_2).$$

Other essergy flows are:

$$y_{1,2} = \dot{M}v_4(P_4 - P_1), \qquad y_{2,1} = \dot{M}(\psi_1 - \psi_2), \qquad y_{3,1} = \dot{M}(\psi_2 - \psi_3),$$
$$y_{4,1} = \dot{M}(\psi_4 - \psi_3), \qquad \dot{\Psi}_t = \dot{\Psi}_3 + y_{4,1} - y_{1,2} = \dot{M}[\psi_4 - v_4(P_4 - P_1)],$$
$$y_{1,1} = \dot{\Psi}_1 - \dot{\Psi}_t = \dot{M}[\psi_1 - \psi_4) + v_4(P_4 - P_1)],$$

where ψ is the flow essergy per unit mass:

$$\psi = h - h_0 - T_0(s - s_0) \quad \text{and} \quad \dot{\Psi} = \dot{M}\psi.$$

The negentropy flows are:

$$y_{3,1} = \dot{S}_2 - \dot{S}_3 \rightarrow y_{3,1} = \dot{M}T_0(s_2 - s_3),$$
$$y_{1,3} = \dot{S}_1 - \dot{S}_4 \rightarrow y_{1,3} = \dot{M}T_0(s_1 - s_4),$$
$$y_{2,2} = \dot{S}_2 - \dot{S}_1 \rightarrow y_{2,2} = \dot{M}T_0(s_2 - s_1),$$
$$y_{4,2} = \dot{S}_4 - \dot{S}_3 \rightarrow y_{4,2} = \dot{M}T_0(s_4 - s_3),$$

where:

$$\dot{S}_i = -\dot{M}s_i (i = 1, 2, 3, 4).$$

The last forms of $y_{3,1}, y_{1,3}, y_{2,2}$, and $y_{4,2}$ are obtained by multiplying negentropy flows by the reference temperature T_0 and changing the sign. This convenient procedure is used in order to obtain all functions as positive quantities in the same units.

APPENDIX B

Cost Functions

The following equations have been derived in Ref. 5 by using information from several sources (e.g. Refs. 11–14):

$$Z_1 = \zeta_{11} y_{1,1}^{b_{12}} g_p g_{1\eta} g_{1T}, \qquad Z_2 = \zeta_{21} y_{2,1}^{b_{22}} g_{2\eta} g_{2T},$$
$$Z_3 = T_2(\zeta_{31} n_3 R_3 + \zeta_{32}/c_{pw}) y_{3,1}/[T_0(T_b - T_a)],$$
$$Z_4 = \zeta_{41} y_{4,1}^{b_{42}} f_{4m} g_{4\eta}, \qquad \Gamma_{0,k} = c_k y_{0,k} \quad (k = 1, 2, 3),$$

where:

$$\zeta_{ri} = (C/3.6 \times 10^5 N)\phi_r b_{ri}, \qquad g_p = \exp[(P_1 - \bar{P}_1)/b_{13}],$$
$$g_{1\eta} = 1 + [(0,45 - \bar{\eta}_{II1})/(0,45 - \eta_{II})]^{b_{14}},$$
$$g_{rT} = 1 + b_{r5}\exp[(T_1 - \bar{T}_1)/b_{r6}](r = 1, 2),$$
$$g_{r\eta} = 1 + [(1 - \bar{\eta}_{IIr})/(1 - \eta_{IIr})]^{b_{r3}}(r = 2, 4).$$

Z_1 – Boiler

Z_2 – ST

Z_3 – Condenser

Z_4 – pump