APPENDIX B

SIZING COMPONENTS

Component Name	Component	Section
APU	Auxiliary Power Unit	B1
BØIL	Boiler	B2
CNTRL	System Control	B3
CØMP	Compressor	B4
CØND	Condenser	B5
DSEP	Dust Separator	B6
EJECT	Ejector	B7
EVAP	Evaporator	B8
FAN	Fan	B9
HEATER	Resistance Heater	B10
HX	Heat Exchanger	B11
INIT	Initialization	B12
INSLTN	Insulation	B13
LINE	Line	B14
MISC	Miscellaneous Operations	B15
PUMP	Pump	B16
RIN	Ram Air Inlet	B17
RØUT	Ram Air Outlet	B18
TURB	Turbine	B19
VALVE	Valve	B20
VCØMP	Vapor Cycle Compressor	B21
WSEP	Water Separator	B22

Notes: 1. Data card fields which refer to the parameter table are indicated by brackets, [ ].

2. A card column specified by a single value represents the righthand column of a four column integer data field. Data values punched in these fields must be right justified.

Sizing Component APU

Auxiliary Power Unit

Purpose: This component will compute weight, cost units, reliability index, development risk factor, fuel flow rate, and volume for APU. The available APU types are:

IAPUT	Type
1	bleed air extraction with or without shaft power extraction
2	shaft power extraction only

Equations:

1. Weight:

   For IAPUT = 1:

$$Wt = \frac{0.398\,(EHP)_{ECS}}{(4.215 \times 10^{-4})(EHP)_T + 0.159}$$

   bare

   For IAPUT = 2:

$$Wt = \frac{0.398\,(EHP)_{ECS}}{(6.29 \times 10^{-4})(EHP)_T + 0.253}$$

   where

$$(EHP)_{ECS} = (HP)_{shaft} + W\,C_p\,T_{out}\left[1 - \left(\frac{P_{out}}{P_{in}}\right)^{\frac{1-\gamma}{\gamma}}\right]/42.42$$

$$(EHP)_T = (EHP)_{ECS} + (HP)_{other\ system}$$

2. Cost Units:

$$CU = 7.3(EHP)_{ECS}$$

3. Reliability Index:

$$RI = 0.24971$$

4. Development Risk Factor:

$$DR = 1.15$$

5. Weight Standard Error:

   For IAPUT = 1:

$$Wt_d = 0.1809\ Wt$$

   For IAPUT = 2:

$$Wt_d = 0.3241\ Wt$$

6. Installation Weight Factor:

$$Wt_i = 1.5126\ Wt$$

7. Fuel Flow Rate:

For IAPUT = 1:

$$W_{fu} = [1.5 - 1.158 \times 10^{-3}(EHP)_T](EHP)_{ECS}$$

For IAPUT = 2:

$$W_{fu} = [1.55 - 2.43 \times 10^{-3}(EHP)_T](EHP)_{ECS}$$

8. Volume:

For IAPUT = 1:

$$V = \frac{(EHP)_{ECS}}{(1.343 \times 10^{-5})(EHP)_T + 2.95 \times 10^{-3}}$$

For IAPUT = 2:

$$V = \frac{(EHP)_{ECS}}{(9.919 \times 10^{-6})(EHP)_T + 6.83 \times 10^{-3}}$$

Restrictions:

1. This component can only be used for fluid type 2.

Notes:

1. The component printout consists of weight, cost units, reliability index, development risk factor, and the following items:

   W - flow rate
   PI - inlet pressure
   PØ - outlet pressure
   TI - inlet temperature
   TØ - outlet temperature
   HI - inlet humidity
   HØ - outlet humidity
   FT - fluid type
   FN - fluid properties table relative number

   } for APU with bleed air extraction by ECS

   SHAFT - shaft number
   SHP - shaft horsepower

   } for APU with shaft power extraction by ECS

   VØL - volume
   WTBT - total bare weight

EHPT - total equivalent horsepower

FC - fuel flow rate (lb/hr)

2. The value of volume is stored in general argument 71.

Sizing Component APU

Data Card Format

Card Column	Symbol	Value
1-3	CN	APU component name
8	CC	change code
12	NC	card number
16	NL	leg number = 0 without bleed air extraction by ECS > 0 with bleed air extraction by ECS
20	NSI	inlet station number (not required if NL = 0)
24	NSØ	outlet station number (not required if NL = 0)
28	NST	shaft number = 0 without shaft power extraction by ECS > 0 with shaft power extraction by ECS
32	[WTM]	weight multiplier (optional)
36	[CUM]	cost unit multiplier (optional)
40	[RI]	reliability index (optional)
44	[DRM]	development risk factor multiplier (optional)
48	IAPUT	APU type = 1 bleed air extraction with or without shaft power extraction = 2 shaft power extraction only
52	[ØEHP]	equivalent horsepower required by other systems

SECTION XIX

B2 - REPLACEMENT

SIZING COMPONENT BØIL

Boiler

Purpose: This component will compute core dimensions, weight, cost units, reliability index, development risk factor, core volume, and the required expendable coolant weight for boilers. The available types of boilers are:

IBT	Type
1	integral boiler
2	boiler with separate storage tank

Equations:

1. Weight:
   (a) Core Weight:
   The same equations for heat exchanger core weight are applicable to the boiler core. (See HX component)
   (b) Boiler Weight (dry):
   For IBT = 1:
   $$Wt = Wt_{core} + 3.4722 \times 10^{-4} \rho_{metal} (V + V_{liquid})^{2/3}$$
   for IBT = 2:
   $$Wt = Wt_{core} + 3.0382 \times 10^{-4} \rho_{metal} V_{liquid}^{2/3}$$
2. Cost Units:
   $CU = 29.7 + 2.72\ Wt$
3. Reliability Index:
   $RI = 0.02165$
4. Development Risk Factor:
   If the average pressure is less than or equal to 314.7 psi:
   $DR = 1.15$
   If the average pressure is greater than 314.7 psi:
   $$DR = 1.15 \left[1.0 + \left(\frac{P_{av} - 314.7}{283.0}\right)^2\right]$$
5. Weight Standard Error:
   $Wt_d = 0.12\ Wt$

6. Installation Weight Factor:

$$Wt_i = 0.205\ Wt$$

7. Core dimensions (if not specified):

Core dimensions L_H, L_C, and L_N are obtained iteratively by the generalized Newton Raphson method from the following three equations:

$$L_N = r_a\ L_C$$

$$\Delta P_H = \frac{Re_H^{\ 2}\ \mu_H^{\ 2}(1 + \psi_H^{\ 2})}{1029.568\ r_{hH}^{\ 2}\ \rho_{1H}}\ \left[\frac{f_H\ L_H\ N_{PH}(\rho_{1H}/\rho_{2H} + 1)}{2r_{hH}(1 + \psi_H^{\ 2})} + \frac{\rho_{1H}}{\rho_{2H}} - 1\right]$$

$$\varepsilon = 1 - e^{-NTU}$$

where

$$r_a = \text{aspect ratio } (L_N/L_C)$$

$$= 1.0$$

$\psi = \dfrac{\text{free flow area}}{\text{frontal area}}$

$$NTU = \frac{\eta_{OH} j_H L_H N_{PH}}{r_{hH}\ Pr_H^{\ 2/3}}$$

$$\psi_H = \frac{b_H\ \beta_H\ r_{hH}\ N_H}{(b_H + b_C + 2\ t_{SP})N_H + b_C + 2\ t_{SP}}$$

$$Re_H = \frac{0.8 r_{hH}\ W_H\ N_{PH}}{\mu_H\ L_C\ L_N\ \psi_H}$$

$$\eta_{OH} = 1 - (A_F/A)_H\ \left[1 - \frac{\tanh\ (m_H\ \ell_{eH})}{m_H\ \ell_{eH}}\right]$$

$$m_H = \left[\frac{1800\ C'_{pH}\ \mu_H\ Re_H\ j_H\ (1 + t_{FH}/\xi_H)}{r_{hH}\ t_{FH}\ PR_H^{\ 2/3}\ k_H}\right]^{1/2}$$

$$SHR = (T_{in} - \bar{T}_{out})/(T_{in} - T_{out})$$

$$C'_{pH} = C_{pH} \cdot SHR$$

8. Core Volume:

$$V = L_H\ L_C\ L_N$$

9. Cold Side Liquid Volume:

$$V_{liquid} = 1728\ W\ C_p\ (T_{in} - T_{out})/(H_{fg}\ \rho_{sat})\tau$$

10. Volume of hot side liquid inside the core:

$$V_{LH} = \psi_H V$$

Required Tables:

- Table ID (IFH, 31 and IFGC, 31) - fin geometry (hot side and cold side), refer to HX component for table description.

f - Table ID (IFH, 32) - fin friction factor (hot side), refer to HX component for table description.

j - Table ID (IFH, 33) - fin Colburn modulus (hot side), refer to HX component for table description.

t_{SP} - Table ID (ITSP, 34) - separation plate thickness, refer to HX component for table description.

- Table ID (IMH, 20) - hot side fin material properties.
- Table ID (IMC, 20) - cold side fin material properties.
- Table ID (IMSP, 20) - separation plate material properties.
- Table ID (IMW, 20) - storage tank wall material properties.

Restrictions:

1. This component is used for sizing plate fin boilers.
2. This component can only be used for fluid types 1 and 2 on the hot side.
3. The core dimensions L_H, L_C, L_N must either be all specified by the user or be all unspecified.

Notes:

1. Two consecutive data cards are required, BØIL1 and BØIL2. The BØIL1 card must precede the BØIL2 card.
2. The same table relative number is used for the fin geometry table, the fin friction factor table, and the fin Colburn modulus table of the hot side.
3. Hot side fluid properties are evaluated at average temperature, $T_{ave} = (T_{in} + T_{out})/2$, and average pressure, $P_{ave} = (P_{in} + P_{out})/2$.
4. The component printout consists of boiler weight, cost units, reliability index, development risk factor, and the following items:

$$\left.\begin{array}{l} \text{W - flow rate} \\ \text{PI - inlet pressure} \\ \text{PØ - outlet pressure} \end{array}\right\} \text{hot side}$$

$$\left.\begin{array}{ll}
\text{TI} & \text{- inlet temperature} \\
\text{TØ} & \text{- outlet temperature} \\
\text{HI} & \text{- inlet humidity} \\
\text{HØ} & \text{- outlet humidity} \\
\text{FT} & \text{- fluid type} \\
\text{FN} & \text{- fluid properties table relative} \\
 & \quad \text{number}
\end{array}\right\} \text{hot side}$$

LH - hot side flow length

LC - cold side flow length

LN - no flow length

VØL - core volume

WTC - core weight

EWT - expendable coolant weight

EFF - effectiveness (not printed if core dimensions are specified)

NTU - number of heat transfer units (not printed if core dimensions are specified)

VL - volume of hot side liquid inside the core (not printed if hot side is a gas)

5. Four performance map options are available. They are

   Option 0 - no maps

   Option 1 - print maps

   Option 2 - punch maps

   Option 3 - print and punch maps

   The map produced will consist of effectiveness versus hot side flow rate, and $\sigma\Delta P$ (if a gas) or ΔP (if a liquid) of hot side versus hot side flow rate.

6. If core dimensions are not specified by the user and the iteration dump option is selected, the following information is printed:

   (a) State Variables (S.V.) - the two values printed are L_H and L_C, respectively.

   (b) Error Variables (E.V.) - the two values printed are the difference of the calculated and the given hot side pressure drops, and the difference of the calculated and the given effectiveness, respectively.

(c) The four values printed after the error variables are Re_H, NTU, ε, and η_{OH}, respectively.

7. The convergence limits for pressure drop and effectiveness are 0.01 and 0.0001, respectively. The upper and the lower limits for the state variables are 100.0 and 0.1, respectively.

8. Values of L_H, L_C, L_N, V, and V_{LH} are stored in general arguments 71, 72, 73, 74, and 75, respectively.

Sizing Component BØIL

Data Card Format

1. BØIL1 Data Card

Card Column	Symbol	Value
1-5	CN	BØIL1 component name
8	CC	change code
12	NC	card number
16	NL	leg number, hot side
20	NSI	inlet station number, hot side
24	NSØ	outlet station number, hot side
28	[WTM]	weight multiplier (optional)
32	[CUM]	cost unit multiplier (optional)
36	[RI]	reliability index (optional)
40	[DRM]	development risk factor multiplier (optional)
44	[BT]	boiling temperature of cold side liquid
48	[DENS]	cold side liquid density at boiling temperature
52	[HFG]	heat of vaporization of cold side liquid
56	[TIME]	boiler usage time
60	[WTE]	extra cold side liquid weight
64	IBT	boiler type = 1 integral boiler = 2 boiler with separate storage tank
68	MAP	performance map options = 0 no maps = 1 print maps = 2 punch maps = 3 print and punch maps

2. BØIL2 Data Card

Card Column	Symbol	Value
1-5	CN	BØIL2 component name
8	CC	change code
12	NC	card number
16	[LH]	core flow length, hot side = 0 computed > 0 user specified
20	[LC]	core flow length, cold side = 0 computed > 0 user specified
24	[LN]	no flow length = 0 computed > 0 user specified
28	NPH	number of passes, hot side
32	IMH	fin material properties table relative number, hot side (type 20)
36	IMC	fin material properties table relative number, cold side (type 20)
40	IFH	fin variable tables relative number, hot side (types 31, 32, 33)
44	IFGC	fin geometry table relative number, cold side (type 31)
48	IMSP	separation plate material properties table relative number (type 20)
52	ITSP	separation plate thickness table relative number (type 34)
56	IMW	storage tank wall material properties table relative number (type 20)

B3

Sizing Component CNTRL

System Control

Purpose: This component will compute weight, cost units, reliability index, development risk factor, and volume for system control. The available control types are:

ICT	Type
1	temperature control, electronic, fighter or light bomber
2	temperature control, electronic, cargo or heavy bomber
3	temperature control, pneumatic or electro-pneumatic
4	cabin pressure control, fighter or light bomber
5	cabin pressure control, cargo or heavy bomber

Equations:

1. Weight:

For ICT = 1 & 2:

$$Wt = [\frac{NIA\emptyset}{3} + Wt_{selector} + 0.2 \text{ (number of sensors)}] K_T K_P$$

For ICT = 3:

$$Wt = (0.5D + 1.75) K_T K_P$$

For ICT = 4:

$$Wt = 6.0$$

For ICT = 5:

$$Wt = 0.096W + 51.45$$

2. Cost Units:

For ICT = 1:

$$CU = [14.6 + 0.545 (NIA\emptyset)] Wt K_T K_P$$

For ICT = 2:

$$CU = [14.85 + 1.04 (NIA\emptyset)] Wt K_T K_P$$

For ICT = 3:

$$CU = (2.48D + 13.6) K_T K_P$$

For ICT = 4:

$$CU = 49.5$$

For ICT = 5:

$$CU = (6.45 + 0.0176W) Wt$$

3. Reliability Index:

For ICT = 1 & 2:

$$RI = 0.04628 + 0.03781 \text{ (number of sensors)}$$

For ICT = 3:

$$RI = 0.00582 + 0.03781 \text{ (number of sensors)}$$

For ICT = 4 & 5:

$$RI = 0.24448$$

4. Development Risk Factor:

$$DR = 1.0$$

5. Weight Standard Error:

For ICT = 1, 2, and 3:

$$Wt_d = 0.41 \; Wt$$

For ICT = 4 & 5:

$$Wt_d = 0.24 \; Wt$$

6. Installation Weight Factor:

$$Wt_i = 0.205 \; Wt$$

7. Volume:

For ICT = 1 & 2:

$$V = [11.43 \text{ (NIAØ)} + 25.71] \; K_T \; K_P$$

For ICT = 3:

$$V = (40.0D + 20.0) \; K_T \; K_P$$

For ICT = 4:

$$V = 250.0$$

For ICT = 5:

$$V = 8.065W + 5671.0$$

8. Thrust Recovery (for ICT = 5):

$$\text{Thrust} = 6.587 \times 10^{-4} \; W_j \; \bar{c} \left[\frac{\left(\frac{P_{cabin}}{P_{ambient}}\right)^{\frac{\gamma-1}{\gamma}} - 1}{\gamma - 1} \right]^{1/2}$$

where

$\bar{c}$ = the speed of sound at the nozzle exit

$$W_j = W - \frac{31.82(C_D A) \; P_{cabin}}{\sqrt{T_{cabin}}}$$

Restrictions:

1. This component can only be used for fluid type 2 if ICT = 5

Notes:

1. Temperature control sizing method applies to water separator anti-ice control, vapor cycle control, and other controls which modulate flow.
2. For ICT = 5, this component has an option to compute the thrust recovery.
3. The component printout consists of weight, cost units, reliability index, development risk factor, and the following items:

   VØL - volume

   ICT - control type

   THRC - thrust recovery (for ICT = 5 and if thrust recovery option is used only)

Sizing Component CNTRL

Data Card Format

Card Column	Symbol	Value
1-5	CN	CNTRL component name
8	CC	change code
12	NC	card number
16	[WTM]	weight multiplier (optional)
20	[CUM]	cost unit multiplier (optional)
24	[RI]	reliability index (optional)
28	[DRM]	development risk factor multiplier (optional)
32	ICT	control type
		= 1 temperature control, electronic, fighter or light bomber
		= 2 temperature control, electronic, cargo or heavy bomber
		= 3 temperature control, pneumatic or electro-pneumatic
		= 4 cabin pressure control, fighter or light bomber
		= 5 cabin pressure control, cargo or heavy bomber
if ICT = 1 & 2		
36	[KT]	technical weighing factor
40	[KP]	requirements weighing factor
44	[WTS]	selector weight
48	NSR	number of sensors
52	NIAØ	number of inputs and outputs
if ICT = 3		
36	[KT]	technical weighing factor
40	[KP]	requirements weighing factor
44	[D]	control valve diameter
if ICT = 4		
no additional data required.		
if ICT = 5		
36	NL	cabin leg number

Card Column	Symbol	Value
40	NS	cabin outlet station number = 0 no thrust recovery > 0 thrust recovery computed
44	[CDA]	effective leakage area (not required if NS = 0)

Sizing Component CØMP

Compressor

Purpose: This component will compute weight, cost units, reliability index, development risk factor, volume, wheel diameter and/or shaft speed for an air cycle compressor (centrifugal or axial). It will also compute weight, cost units, volume, efficiency, and input horsepower for drives. The available types of drives are:

IDT	Type
0	drive not to be sized
1	turbine
2	electric motor, AC
3	electric motor, DC
4	hydraulic motor
5	shaft, engine, or APU

Equations:

1. Weight:

For compressor:

$$Wt_{comp} = 0.4D^2$$

$100^{5/6} = 46.4$

$50^{5/6} = 26.1$ ... $= 22.6$

$2.3 \times 10^5 / 23{,}500^{1.25} = .790$

For drive (IDT = 2):

$$Wt_{drive} = 2.0 + 2.3 \times 10^5\ HP^{5/6}/N_{drive}^{1.25}$$

For drive (IDT = 3):

$$Wt_{drive} = 1.5 + 3.83 \times 10^5\ HP^{5/6}/N_{drive}^{1.25}$$

For drive (IDT = 4 and N < 20,000 rpm):

$$Wt_{drive} = K(DPR)^{1/2}$$

where $DRP = 139.094\ HP/N$

$K = 11.37$ if $DPRL \leq DPR \leq DPRU$

$K = 24.1158$ if $DPR > DPRU$

$K = 12.0615$ if $DPR < DPRL$

$$DPRL = e^{-(1.519 + 3.784 \times 10^{-4} N)}$$

$$DPRU = e^{(2.706 - 3.453 \times 10^{-4} N)}$$

For drive (IDT = 4 and N $\geq$ 20,000 rpm):

$$Wt_{drive} = 2.0113\ (HP)^{1/2}$$

For drive (IDT = 5):

$$Wt_{drive} = Wt_{comp}$$

2. Cost Units:

For compressor:

$$CU = 5.5\ Wt_{comp}$$

For drive (IDT = 2):

$$CU = 4.0 + 0.6\ Wt_{drive}$$

For drive (IDT = 3):

$$CU = 3.0 + Wt_{drive}$$

For drive (IDT = 4):

$$CU = 17.0 + 4.57\ Wt_{drive}$$

For drive (IDT = 5):

$$CU = 0.0$$

3. Reliability Index (for compressor and drive):

$$RI = 0.06793$$

4. Development Risk Factor (for compressor and drive):

If $T_{out} \leq 1460°R$, $U \leq 1500$ ft/sec, and $N \leq 60{,}000$ rpm:

$$DR = 1.0$$

If $T_{out} > 1460°R$, $U > 1500$ ft/sec, and $N > 60{,}000$ rpm:

$$DR = \left[1 + \left(\frac{T_{out} - 1460}{1000}\right)^2\right]\left[1 + \left(\frac{U - 1500}{707}\right)^2\right]$$

$$\left[1 + \left(\frac{N - 60{,}000}{42{,}500}\right)^2\right]$$

5. Weight Standard Error:

For compressor:

$$Wt_d = 0.164\ Wt_{comp}$$

For drive (IDT = 2):

$$Wt_d = 0.111\ Wt_{drive}$$

For drive (IDT = 3):

$$Wt_d = 0.259\ Wt_{drive}$$

For drive (IDT = 4 & 5):

$$Wt_d = 0.2\ Wt_{drive}$$

6. Installation Weight Factor (for compressor):

$$Wt_i = 0.205\ Wt_{comp}$$

7. Volume:

For compressor:

$$V_{comp} = 0.6666667\ D^4$$

For drive (IDT = 2 and 3):

$$V_{drive} = 10\ Wt_{dr}$$

For drive (IDT = 4):

$$V_{drive} = 20\ Wt_{drive}$$

8. Efficiency:

For compressor:

$$\eta_{ad} = T_{in}\ [(P_{out}/P_{in})^{\frac{\gamma-1}{\gamma}} - 1]/(\bar{T}_{out} - T_{in})$$

For drive (IDT = 2):

$$\eta = K_1\ (1 - 0.281/HP^{0.169})$$

where

$K_1 = 1.02$ $(11{,}000 \text{ rpm} \leq N \leq 22{,}000 \text{ rpm})$

$K_1 = 1.0$ $(7{,}200 \text{ rpm} \leq N < 11{,}000 \text{ rpm})$

$K_1 = 0.98$ $(N < 7{,}200 \text{ rpm})$

For drive (IDT = 3):

$$\eta = K_2\ (1 - 0.281/HP^{0.169})$$

where $K_2 = f(N)$, and is found by first order interpolation with the following data points:

K_2	N(rpm)
1.04	22,000
1.02	11,500
1.0	7,500
0.98	5,500

For drive (IDT = 4):

$$\eta = 0.82$$

9. Horsepower:

For compressor:

$$HP = 0.02356\ W\ C_p\ (\bar{T}_{out} - T_{in})$$

For drives:

$$HP_{in} = HP/\eta$$

10. Wheel Diameter (if not specified):

$$D = 12\ D_s\ Q^{1/2}/H^{1/4}$$

where

$D_s = f\ (N_s, \eta_{ad})$ (N_s - D_s - η_{ad} table)

$$Q = W/\rho_{in}$$

$$H = 778\ C_p\ T_{in}\ [(P_{out}/P_{in})^{\frac{\gamma-1}{\gamma}} - 1]$$

$$N_s = NQ^{1/2}/H^{3/4}$$

11. Shaft Speed (if not specified):

$$N = N_s\ H^{3/4}/Q^{1/2}$$

where N_s is found iteratively from a N_s - D_s - η_{ad} table by the generalized Newton-Raphson method.

12. Tip Speed:

$$U = 0.004363\ D\ N$$

Required Tables:

(N_s - D_s - η_{ad}) - Table ID (ND,36) - 3 or 33 dimensional, the first independent variable is N_s (argument type 0; argument relative number 59), the second independent variable is η_{ad} (argument type 0; argument relative number 60), and the dependent variable is D_s.

Restrictions:

1. This component can only be used for fluid type 2.

Notes:

1. If both shaft speed and wheel diameter are not specified, the built in limiting shaft speed is used for wheel diameter calculation. If this results in an excessive tip speed (a warning message "tip speed exceeds limiting value" is printed), the built in limiting tip speed is used to determine the wheel diameter and shaft speed iteratively by the generalized Newton-Raphson method.

2. The shaft speed of an AC electric motor drive is defined in the following manner:

motor speed (N_{drive})	compressor speed (N)
5,500	$N < 7,200$
7,500	$7,200 \leq N < 11,000$
11,500	$11,000 \leq N < 22,000$

3. If the compressor shaft speed exceeds 22,000 rpm for IDT = 2 & 3, an error message "shaft speed too high for motor drive" is printed. The drive sizing is then bypassed.
4. If the compressor speed exceeds 20,000 rpm for IDT = 4, the drive is sized based on a 20,000 rpm geared unit. A message "hydraulic motor geared" is then printed.
5. The drive is not sized for IDT = 0 & 1.
6. The component printout consists of compressor weight, cost units, reliability index, development risk factor, and the following items:

W - flow rate
PI - inlet pressure
PØ - outlet pressure
TI - inlet temperature
TØ - outlet temperature
HI - inlet humidity
HØ - outlet humidity
FT - fluid type
FN - fluid properties table relative number
D - wheel diameter
VØL - volume
N - shaft speed
EFF - efficiency
HP - horsepower
U - tip speed
NS - specific speed
DS - specific diameter

If a drive is sized, additional printout consists of drive type and the following items:

EFF - drive efficiency

HP - drive input horsepower

WT - drive weight

CU - drive cost unit

VØL - drive volume (if IDT $\neq$ 5)

7. If iteration is employed and the iteration dump option is selected, the following information is printed for each iteration:
   (a) State Variable (S.V.) - specific speed
   (b) Error Variable (E.V.) - If the conditions described in Note 1 occur, the printed value is the difference of the calculated tip speed and the limiting tip speed. If the wheel diameter is specified, the printed value is the difference of the calculated and the known specific diameter.
8. The convergence limit is 0.001. The upper and the lower limits for the state variable are 10,000 and 1.0,respectively.
9. The values of the wheel diameter and the compressor volume are stored in the general arguments 71 and 72,respectively. If rotational speed is determined, it will be stored in general argument (80 + NST).
10. The built in limiting rotational speed and the limiting tip speed are 60,000 rpm and 1500 ft/sec, respectively. Users may override this by specifying a different value with a CØMMØN card.

Sizing Component CØMP

Data Card Format

Card Column	Symbol	Value
1-5	CN	CØMP component name
8	CC	change code
12	NC	card number
16	NL	leg number
20	NSI	inlet station number
24	NSØ	outlet station number
28	NST	shaft number
32	[WTM]	weight multiplier (optional)
36	[CUM]	cost unit multiplier (optional)
40	[RI]	reliability index (optional)
44	[DRM]	development risk factor multiplier (optional)
48	[D]	wheel diameter = 0 computed > 0 user specified
52	ND	N_s - D_s - η_{ad} table relative number (type 36)
56	ICT	compressor type = 1 high pressure ratio = 2 low pressure ratio
60	-	
64	IDT	drive type = 0 drive not to be sized = 1 turbine = 2 electric motor, AC = 3 electric motor, DC = 4 hydraulic motor = 5 shaft, engine or APU

Sizing Component CØND

Condenser

Purpose: This component will compute core dimensions, weight, cost units, reliability index, development risk factor, and core volume for vapor cycle condensers.

Equations:

1. Weight:

   (a) Core Weight:

   The same equations for heat exchanger core weight are applicable to the condenser core weight calculation. (See HX subroutine. Note that variables with subscript H (hot side) refer to refrigerant side, and those with subscript C (cold side) refer to heat sink side.)

   (b) Condenser Weight:

$$Wt = 3.23126\ Wt_{core}/(V)^{0.118}$$

2. Cost Units:

   $CU = 29.7 + 2.72\ Wt$

3. Reliability Index:

   $RI = 0.00306$

4. Development Risk Factor:

   If the average pressure is less than or equal to 314.7 psi:

   $DR = 1.0$

   If the average pressure is greater than 314.7 psi:

   $DR = 1.0 + [(P_{ave} - 314.7)/283.0]^2$

5. Weight Standard Error:

   $Wt_d = 0.12\ Wt$

6. Installation Weight Factor:

   $Wt_i = 0.205\ Wt$

7. Core Dimensions (if not specified):

   Core dimensions L_R, L_S, and L_N are obtained iteratively by the generalized Newton Raphson method from the following three equations:

$$L_R = 6.0 + 0.08\ L_N + (0.96\ L_N + 0.0064\ L_N^{\,2})^{1/2}$$

$$\Delta P_S = \frac{Re_S^2\ \mu_S^2\ (1 + \psi_S^2)}{1029.568\ r_{hS}^{\,2}\ \rho_{1S}} \left[\frac{f_S\ L_S\ N_{PS}(\rho_{1S}/\rho_{2S} + 1)}{2\ r_{hS}\ (1 + \psi_S^2)} + \frac{\rho_{1S}}{\rho_{2S}} - 1\right]$$

$$\varepsilon = 1 - e^{-NTU}$$

where

$$NTU = \frac{L_R\ L_S\ L_N}{(WC_p)_S\ [\overset{4.0}{0.8}\ (\frac{r_h^{\,2}\ P_r^{\,2/3}}{C_p\ \mu\ Re\ j\ \psi\ \eta_o})_S + (\frac{r_h}{h\ \psi})_R]}$$

$$h_R = 0.023148\ \text{Btu/min in.}^2\,{}^\circ\text{F}$$

$$\psi_S = \frac{b_S\ \beta_S\ r_{hS}}{b_S + b_R + 2t_{SP}}$$

$$\psi_R = \frac{b_R\ \beta_R\ r_{hR}}{b_S + b_R + 2t_{SP}}$$

$$Re_S = \frac{0.8 r_{hS}\ W_S\ N_{PS}}{\mu_S\ L_R\ L_N\ \psi_S}$$

$$\eta_{oS} = 1 - (A_F/A)_S\ [1 - \frac{\tanh\ (m_S\ \ell_{eS})}{m_S\ \ell_{eS}}]$$

$$m_S = [\frac{1800\ C_{pS}\ \mu_S\ Re_S\ j_S\ (1 + t_{FS}/\xi_S)}{r_{hS}\ t_{FS}\ Pr_S^{\,2/3}\ h_S}]^{1/2}$$

8. Core Volume:

$$V = L_R\ L_S\ L_N$$

9. Volume of heat sink liquid inside the core:

$$V_{LS} = \psi_S\ V$$

Required Tables:

- Table ID (IFS, 31 and IFGR,31) - fin geometry (heat sink side and refrigerant side), refer to HX component for table description.

f - Table ID (IFS,32) - fin friction factor (heat sink side), refer to HX component for table description.

j - Table ID (IFS,33) - fin Colburn modulus (heat sink side), refer to HX component for table description.

t_{SP} - Table ID (ITSP,34) - separation plate thickness, refer to HX component for table description.

- Table ID (IMS,20) - heat sink side fin material properties.
- Table ID (IMR,20) - refrigerant side fin material properties.
- Table ID (IMSP,20) - separation plate material properties.

Restrictions:

1. This component is used for sizing plate fin cross flow vapor cycle condensers.
2. This component can only be used for fluid types 1 and 2 on the heat sink side.
3. The core dimensions (L_R, L_S, L_N) must either be all specified by the user or be all unspecified.

Notes:

1. Two consecutive data cards are required, CØND1 and CØND2. CØND1 card must precede CØND2 card.
2. The same table relative number is used for the fin geometry table, the fin friction factor table, and the fin Colburn modulus table of the heat sink side.
3. Heat sink side fluid properties are evaluated at average temperature, $T_{ave} = (T_{in} + T_{out})/2$, and average pressure, $P_{ave} = (P_{in} + P_{out})/2$.
4. The component printout consists of condenser weight, cost units, reliability index, development risk factor, and the following items:

W - flow rate		
PI - inlet pressure	}	heat sink side
PØ - outlet pressure		

TI - inlet temperature
TØ - outlet temperature
HI - inlet humidity
HØ - outlet humidity
FT - fluid type
FN - fluid properties table relative number

(TI through FN: heat sink side)

LS - heat sink side flow length
LR - refrigerant side flow length
LN - no flow length
VØL - core volume
WTC - core weight
EFF - effectiveness (not printed if core dimensions are specified)
NTU - number of heat transfer units (not printed if core dimensions are specified)
VL - volume of heat sink liquid inside the core (not printed if heat sink is a gas)

5. Four performance map options are available. They are
   Option 0 - no maps
   Option 1 - print maps
   Option 2 - punch maps
   Option 3 - print and punch maps

   The maps produced will consist of effectiveness versus heat sink flow rate, and $\sigma\Delta P$ (if a gas) or ΔP (if a liquid) of heat sink side versus heat sink flow rate.

6. If core dimensions are not specified by the user and the iteration dump option is selected, the following information is printed for each iteration:
   (a) State Variables (S.V.) - the values printed are L_S and L_N, respectively.
   (b) Error Variables (E.V.) - the two values printed are the difference of the calculated and the given heat sink side pressure drops, and the difference of the calculated and the given effectivenesses, respectively.

(c) The four values printed after the error variables are Re_S, NTU, ε, and η_{oS}, respectively.

7. The convergence limits for pressure drop and effectiveness are 0.01 and 0.0001, respectively. The upper and the lower limits for the state variables are 100.0 and 0.1, respectively.
8. The dry air rated heat sink outlet temperature is used for effectiveness calculation.
9. Values of L_S, L_R, L_N, V, V_{LS}, and Wt are stored in general arguments 71, 72, 73, 74, 75, and 76, respectively.

Sizing Component CØND

Data Card Format

1. CØND1 Data Card

Card Column	Symbol	Value
1-5	CN	CØND1 component name
8	CC	change code
12	NC	card number
16	NLS	leg number, heat sink side
20	NSIS	inlet station number, heat sink side
24	NSØS	outlet station number, heat sink side
28	NSØR	outlet station number, refrigerant side
32	[WTM]	weight multiplier (optional)
36	[CUM]	cost unit multiplier (optional)
40	[RI]	reliability index (optional)
44	[DRM]	development risk factor multiplier (optional)
48	MAP	performance map options = 0 no maps = 1 print maps = 2 punch maps = 3 print and punch maps

2. CØND2 Data Card

Card Column	Symbol	Value
1-5	CN	CØND2 component name
8	CC	change code
12	NC	card number
16	[LS]	core flow length, heat sink side = 0 computed > 0 user specified
20	[LR]	core flow length, refrigerant side = 0 computed > 0 user specified
24	[LN]	no flow length = 0 computed > 0 user specified
28	NPS	number of passes, heat sink side
32	IMS	fin material properties table relative number, heat sink side (type 20)
36	IMR	fin material properties table relative number, refrigerant side (type 20)
40	IFS	fin variable table relative number, heat sink side (types 31, 32, 33)
44	IFGR	fin geometry table relative number, refrigerant side (type 31)
48	IMSP	separation plate material properties table relative number (type 20)
52	ITSP	separation plate thickness table relative number (type 34)

Sizing Component DSEP

Dust Separator

Purpose: This component will compute weight, cost units, reliability index, development risk factor, and volume for dust separators. The available dust separator types are:

IDT	Type
1	static
2	self-cleaning, high pressure

Equations:

1. Weight:

   For IDT = 1:

   $Wt = 0.195\ W^{0.79}$

   For IDT =2:

   $Wt = 0.5 + 0.0346\ W$

2. Cost Units:

   For IDT = 1:

   $CU = 5.4 + 0.71\ Wt$

   For IDT = 2:

   $CU = 9.11 + 1.07\ Wt$

3. Reliability Index:

   $RI = 0.04135$

4. Development Risk Factor:

   $DR = 1.0$

5. Weight Standard Error:

   For IDT = 1:

   $Wt_d = 0.04\ Wt$

   For IDT = 2:

   $Wt_d = 0.1225\ Wt$

6. Installation Weight Factor:

   $Wt_i = 0.205\ Wt$

7. Volume:

   For IDT = 1:

   $V = 7.3\ Wt^{1.28}$

   For IDT = 2:

   $V = 19.0\ Wt^{1.5}$

Restrictions:

1. This component can only be used for fluid type 2.

Notes:

1. The component printout consist of weight, cost units, reliability index, development risk factor, and the following items:

   W - flow rate

   PI - inlet pressure

   PØ - outlet pressure

   TI - inlet temperature

   TØ - outlet temperature

   HI - inlet humidity

   HØ - outlet humidity

   FT - fluid type

   FN - fluid properties table relative number

   VØL - volume

2. The value of volume is stored in general argument 71.

Sizing Component DSEP

Data Card Format

Card Column	Symbol	Value
1-4	CN	DSEP component name
8	CC	change code
12	NC	card number
16	NL	leg number
20	NSI	inlet station number
24	NSØ	outlet station number
28	[WTM]	weight multiplier (optional)
32	[CUM]	cost unit multiplier (optional)
36	[RI]	reliability index (optional)
40	[DRM]	development risk factor multiplier (optional)
44	IDT	dust separator type = 1 static = 2 self-cleaning, high pressure

Sizing Component EJECT

Ejector

Purpose: This component will compute weight, cost units, reliability index, development risk factor, effective nozzle area, and volume for an ejector assembly, which includes a mixing tube, high pressure tubing, and nozzles.

Equations:

1. Weights:

   $Wt = 20.0\ (2.5\ B + 2)\ t\ \rho/1728$

2. Cost Units:

   $CU = 17.96 + 5.36\ Wt^{0.64} + 0.139\ Wt^{1.65}$

3. Reliability Index:

   $RI = 0.00177$

4. Development Risk Factor:

   $DR = 1.0$

5. Weight Standard Error:

   $Wt_d = 0.25\ Wt$

6. Installation Weight Factor:

   $Wt_i = 0.205\ Wt$

7. Volume:

   $V = 38.6\ B$

8. Effective Nozzle Area:

   If flow is choked:

   $$A = (W/28.3725)\left[\gamma\ P_{in}\ \rho_{in}\left(\frac{2}{1+\gamma}\right)^{\frac{\gamma+1}{\gamma-1}}\right]^{1/2}$$

   If flow is not choked:

   $$A = (W/40.1248)\left(\frac{\gamma}{\gamma-1}\ P_{in}\ \rho_{in}\right)^{1/2}\left[(P_{out}/P_{in})^{\frac{2}{\gamma}} - (P_{out}/P_{in})^{\frac{\gamma+1}{\gamma}}\right]^{1/2}$$

9. Number of Single - Nozzle Ejector Modules:

$\frac{A}{0.0371}$	0.0 ~ 3.0	3.0 ~ 5.0	5.0 ~ 7.0	7.0 ~ 9.0	etc
B	2	4	6	8	etc

Required Tables:

- Table ID (IMT,20) - mixing tube material properties.

Restrictions:

1. This component can only be used for fluid type 2.

Notes:

1. The component printout consists of weight, cost units, reliability index, development risk factor, and the following items:

   W - primary flow rate

   PI - primary flow inlet pressure

   PØ - primary flow outlet pressure

   TI - primary flow inlet temperature

   TØ - primary flow outlet temperature

   HI - primary flow inlet humidity

   HØ - primary flow outlet humidity

   FT - primary flow fluid type

   FN - primary flow fluid properties table relative number

   AN - effective nozzle area

   VØL - volume

2. The value of volume is stored in general argument 71.

Sizing Component EJECT

Data Card Format

Card Column	Symbol	Value
1-5	CN	EJECT component name
8	CC	change code
12	NC	card number
16	NL	leg number, primary flow
20	NSI	inlet station number, primary flow
24	NSØ	outlet station number, primary flow
28	[WTM]	weight multiplier (optional)
32	[CUM]	cost unit multiplier (optional)
36	[RI]	reliability index (optional)
40	[DRM]	development risk factor multiplier (optional)
44	[THK]	mixing tube wall thickness
48	IMT	material properties table relative number (type 20)

Sizing Component EVAP
Evaporator

Purpose: This component will compute core dimensions, weight, cost units, reliability index, development risk factor, and core volume for vapor cycle evaporators.

Equations:

1. Weight:

   (a) Core Weight:

   The same equations for heat exchanger core weight are applicable to the evaporator core weight calculation. (See HX component.) Note that variables with subscript C (cold side) refer to refrigerant side, and those with subscript H (hot side) refer to heat source side.

   (b) Evaporator Weight:

$$Wt = 3.23126\, Wt_{core}/(V)^{0.118}$$

2. Cost Units:

   $CU = 29.7 + 2.72\ Wt$

3. Reliability Index:

   $RI = 0.00216$

4. Development Risk Factor:

   If the average pressure is less than or equal to 314.7 psi:

   $DR = 1.2$

   If the average pressure is greater than 314.7 psi:

$$DR = 1.2\ [1.0 + (\frac{P_{ave} - 314.7}{283})^2]$$

5. Weight Standard Error:

   $Wt_d = 0.12\ Wt$

6. Installation Weight Factor:

   $Wt_i = 0.205\ Wt$

7. Core Dimensions (if not specified):

   Core dimensions L_R, L_S and L_N are obtained iteratively by the generalized Newton Raphson method from the following three equations:

$$L_R = 3.0 + 0.18\ L_N + (1.08\ L_N + 0.0324\ L_N^2)^{1/2}$$

$$\Delta P_S = \frac{Re_S^2\ \mu_S^2\ (1 + \psi_S^2)}{1029.568\ r_{hS}^2\ \rho_{1S}} \left[\frac{f_S\ L_S\ N_{PS}(\rho_{1S}/\rho_{2S} + 1)}{2\ r_{hS}\ (1 + \psi_S^2)} + \frac{\rho_{1S}}{\rho_{2S}} - 1\right]$$

$$\varepsilon = 1 - e^{-NTU}$$

where

$$NTU = \frac{L_R\ L_S\ L_N}{(WC_p)_S \left[0.8 \left(\frac{r_h^2\ Pr^{2/3}}{C_p\ \mu\ Re\ j\ \psi\ \eta_o}\right)_S + \left(\frac{r_h}{h\ \psi}\right)_R\right]}$$

$h_R = 0.017361$ Btu/min in^2 °F $=$ ~~[illegible]~~ 150. BTU/hr ft^2 °F

$$\psi_S = \frac{b_S\ \beta_S\ r_{hS}}{b_S + b_R + 2t_{SP}}$$

$$\psi_R = \frac{b_R\ \beta_R\ r_{hR}}{b_S + b_R + 2t_{SP}}$$

$$Re_S = \frac{0.8 r_{hS}\ W_S\ N_{PS}}{\mu_S\ L_R\ L_N\ \psi_S}$$

$$\eta_{oS} = 1 - (A_F/A)_S \left[1 - \frac{\tanh\ (m_S\ \ell_{eS})}{m_S\ \ell_{eS}}\right]$$

$$m_S = \left[\frac{1800\ C_{pS}\ \mu_S\ Re_S\ j_S\ (1 + t_{FS}/\xi_S)}{r_{hS}\ t_{FS}\ Pr_S^{2/3}\ k_S}\right]^{1/2}$$

8. Core Volume:

$V = L_R\ L_S\ L_N$

9. Volume of heat source liquid inside the core:

$V_{LS} = \psi_S\ V$

Required Tables:

- Table ID (IFS,31 and IFGR,31) - fin geometry (heat source side and refrigerant side), refer to HX component for table description.

f - Table ID (IFS,32) - fin friction factor (heat source side), refer to HX component for table description.

j - Table ID (IFS,33) - fin Colburn modulus (heat source side), refer to HX component for table description.

t_{SP} - Table ID (ITSP,34) - separation plate thickness, refer to HX component for table description.

- Table ID (IMS,20) - heat source side fin material properties.
- Table ID (IMR,20) - refrigerant side fin material properties.
- Table ID (IMSP,20) - separation plate material properties.

Restrictions:

1. This component is used for sizing plate fin cross flow vapor cycle evaporators.
2. This component can only be used for fluid types 1 and 2 on the heat source side.
3. The core dimensions (L_R, L_S, L_N) must either be all specified by the user or be all unspecified.

Notes:

1. Two consecutive data cards are required, EVAP1 and EVAP2. The EVAP1 card must precede the EVAP2 card.
2. The same table relative number is used for the fin geometry table, the fin friction factor table, and the fin Colburn modulus table of the heat source side.
3. Heat source side fluid properties are evaluated at average temperature, $T_{ave} = (T_{in} + T_{out})/2$, and average pressure, $P_{ave} = (P_{in} + P_{out})/2$.
4. The component printout consists of evaporator weight, cost units, reliability index, development risk factor, and the following items:

W	- flow rate	heat source side
PI	- inlet pressure	
PØ	- outlet pressure	
TI	- inlet temperature	
TØ	- outlet temperature	
HI	- inlet humidity	
HØ	- outlet humidity	
FT	- fluid type	
FN	- fluid properties table relative number	

LS - heat source side flow length

LR - refrigerant side flow length

LN - no flow length

VØL - core volume

WTC - core weight

EFF - effectiveness (not printed if core dimensions are specified)

NTU - number of heat transfer units (not printed if core dimensions are specified)

VL - volume of heat source liquid inside the core (not printed if heat source is a gas)

5. Four performance map options are available. They are

   Option 0 - no maps

   Option 1 - print maps

   Option 2 - punch maps

   Option 3 - print and punch maps

   The maps produced will consist of effectiveness versus heat source flow rate, and $\sigma\Delta P$ (if a gas) or ΔP (if a liquid) of heat source side versus heat source flow rate.

6. If core dimensions are not specified by the user and the iteration dump option is selected, the following information is printed for each iteration:

   (a) State Variables (S.V.) - the two values printed are L_S and L_N, respectively.

(b) Error Variables (E.V.) - the two values printed are the difference of the calculated and the given heat source side pressure drops, and the difference of the calculated and the given effectivenesses, respectively.

(c) The four values printed after the error variables are Re_S, NTU, ε, and η_{oS}, respectively.

7. The convergence limits for pressure drop and effectiveness are 0.01 and 0.0001, respectively. The upper and the lower limits for state variables are 100.0 and 0.1, respectively.
8. The dry air rated heat source outlet temperature is used for effectiveness calculation.
9. Values of L_S, L_R, L_N, V, V_{LS}, and Wt are stored in general arguments 71, 72, 73, 74, 75, and 76, respectively.

Sizing Component EVAP

Data Card Format

1. EVAP1 Data Card

Card Column	Symbol	Value
1-5	CN	EVAP1 component name
8	CC	change code
12	NC	card number
16	NLS	leg number, heat source side
20	NSIS	inlet station number, heat source side
24	NSØS	outlet station number, heat source side
28	NSØR	outlet station number, refrigerant side
32	[WTM]	weight multiplier (optional)
36	[CUM]	cost unit multiplier (optional)
40	[RI]	reliability index (optional)
44	[DRM]	development risk factor multiplier (optional)
48	MAP	performance map options = 0 no maps = 1 print maps = 2 punch maps = 3 print and punch maps

2. EVAP2 Data Card

Card Column	Symbol	Value
1-5	CN	EVAP2 component name
8	CC	change code
12	NC	card number
16	[LS]	core flow length, heat source side = 0 computed > 0 user specified
20	[LR]	core flow length, refrigerant side = 0 computed > 0 user specified
24	[LN]	no flow length = 0 computed > 0 user specified
28	NPS	number of passes, heat source side
32	IMS	fin material properties table relative number, heat source side (type 20)
36	IMR	fin material properties table relative number, refrigerant side (type 20)
40	IFS	fin variable table relative number, heat source side (types 31, 32, 33)
44	IFGR	fin geometry table relative number, refrigerant side (type 31)
48	IMSP	separation plate material properties table relative number (type 20)
52	ITSP	separation plate thickness table relative number (type 34)

Sizing Component FAN

Fan

Purpose: This component will compute weight, cost units, reliability index, blade tip diameter, and volume for a fan (including a drive). The available types of drives are:

IDT	Type
2	electric motor, AC
3	electric motor, DC
4	hydraulic motor
6	tip turbine

Equations:

1. Weight:

   For IDT = 2 & 3:

   $Wt = 0.26\ D^2$

   For IDT = 4:

   $Wt = 0.178\ D^2$

   For IDT = 6:

   $Wt = 0.109\ D_E^2$

   where D_E = effective blade tip diameter

2. Cost Units:

   For IDT = 2:

   $CU = 14.29 + 0.46\ Wt$

   For IDT = 3:

   $CU = 4.87 + 0.76\ Wt$

   For IDT = 4:

   $CU = 58.587 + 1.725\ Wt$

   For IDT = 6:

   $CU = 5.5\ Wt$

3. Reliability Index:

   For IDT = 2 & 3:

   $RI = 0.00546$

   For IDT = 4:

   $RI = 0.01162$

   For IDT = 6:

   $RI = 0.00707$

4. Development Risk Factor:

$DR = 1.0$

5. Weight Standard Error:

For IDT = 2 & 3:

$Wt_d = 0.25\ Wt$

For IDT = 4:

$Wt_d = 0.109\ Wt$

For IDT = 6:

$Wt_d = 0.199\ Wt$

6. Installation Weight Factor:

$Wt_i = 0.205\ Wt$

7. Volume:

For IDT = 2, 3 & 4:

$V = 1.3\ D^3$

For IDT = 6:

$V = 0.8666667\ {D_E}^3$

8. Blade Tip Diameter (if not specified):

$$D = 16.8\ \left(\frac{W}{\rho N}\right)^{1/3} \tag{1}$$

9. Effective Blade Tip Diameter (for IDT = 6):

$$D_E = D + 2\ h \tag{2}$$

The effective blade tip diameter is found interatively by the generalized Newton Raphson method from Equation (1), Equation (2), turbine $N_s - D_s - \eta_{ad}$ table, and turbine $N_s - h/D - \eta_{ad}$ table.

10. Fan Horsepower:

$HP = 0.02356\ W\ C_p\ (T_{out} - T_{in})$

11. Fan Adiabatic Efficiency:

$$\eta_{ad} = \frac{T_{in}\ [(P_{out}/P_{in})^{\frac{\gamma-1}{\gamma}} - 1]}{T_{out} - T_{in}}$$

Required Tables (for IDT = 6 only):

(N_s - D_s - η_{ad}) - Table ID (ITS,37) - 3 or 33 dimensional, the first independent variable is N_s (argument type 0; argument relative number 59), the second independent variable is η_{ad} (argument type 0; argument relative number 60), and the dependent variable is D_s.

(N_s - h/D - η_{ad}) - Table ID (ITS,38) - 3 or 33 dimensional, the first independent variable is N_s (argument type 0; argument relative number 59), the second independent variable is η_{ad} (argument type 0, argument relative number 60), and the dependent variable is h/D.

Restrictions:

1. This component can only be used for fluid type 2.
2. Shaft speed must be specified for IDT = 2, 3, & 4. For IDT = 6, the effective blade tip diameter and shaft speed must be either both specified or both unspecified.

Notes:

1. The component printout consists of weight, cost units, reliability index, development risk factor, and the following items:

W - flow rate
PI - inlet pressure
PØ - outlet pressure
TI - inlet temperature
TØ - outlet temperature
HI - inlet humidity
HØ - outlet humidity
FT - fluid type
FN - fluid properties table relative number
D - blade tip diameter (if IDT = 2, 3, & 4) or effective blade tip diameter (if IDT = 6)
VØL - volume
N - shaft speed
EFF - fan adiabatic efficiency
HP - fan fluid horsepower

Additional printout consists of drive type and the following items:

EFF - drive efficiency

HP - drive input horsepower

for IDT = 6 only:

- W - turbine flow rate
- PI - turbine inlet pressure
- PØ - turbine outlet pressure
- TI - turbine inlet temperature
- TØ - turbine outlet temperature
- HI - turbine inlet humidity
- HØ - turbine outlet humidity
- FT - fluid type
- FN - fluid properties table relative number

2. If iteration is employed and the iteration dump option is selected, the following information is printed for each iteration:
   (a) State Variable (S.V.) - specific speed.
   (b) Error Variable (E.V.) - the difference of the calculated turbine wheel diameter and the calculated effective fan blade tip diameter.
3. The convergence limit is 0.001. The upper and lower limits for the state variable are 1000.0 and 1.0 respectively.
4. The values of the blade tip diameter (or effective blade tip diameter) and the volume are stored in general argument 71 and 72, respectively.
5. For IDT = 6, the limiting rotational speed and the limiting tip speed are 60,000 rpm and 1,500 ft/sec, respectively. Users may override this by specifying a different value with a CØMMØN card.

Sizing Component FAN

Data Card Format

Card Column	Symbol	Value
1-3	CN	FAN component name
8	CC	change code
12	NC	card number
16	NLF	fan leg number
20	NSIF	fan inlet station number
24	NSØF	fan outlet station number
28	NST	shaft number
32	[WTM]	weight multiplier (optional)
36	[CUM]	cost unit multiplier (optional)
40	[RI]	reliability index
44	[DRM]	development risk factor multiplier (optional)
48	[D]	fan tip diameter (if IDT = 2, 3, & 4) or turbine tip diameter (if IDT = 6) = 0 computed > 0 user specified
52	IDT	drive type = 2 electric motor, AC = 3 electric motor, DC = 4 hydraulic motor = 6 tip turbine
56	NLT	turbine leg number (not required if IDT ≠ 6)
60	NSIT	turbine inlet station number (not required if IDT ≠ 6)
64	NSØT	turbine outlet station number (not required if IDT ≠ 6)
68	ITS	turbine sizing characteristic table relative number (types 37 & 38, not required if IDT ≠ 6)

Sizing Component HEATER

Resistance Heater

Purpose: This component will compute weight, cost units, reliability index, development risk factor, volume, and flow length for resistance heaters.

Equations:

1. Weight:

   $Wt = \rho V/1728$

   where

   $\rho = 20.0 \qquad (V \leq 794.3\ in^3)$

   $\rho = 374.11/V^{0.4384} \qquad (V > 794.3\ in^3)$

2. Cost Units:

   $CU = 2.08\ Wt$

3. Reliability Index:

   $RI = 0.01109$

4. Development Risk Factor:

   $DR = 1.0$

5. Weight Standard Error:

   $Wt_d = 0.12\ Wt$

6. Installation Weight Factor:

   $Wt_i = 0.205\ Wt$

7. Volume:

   $V = 1.21444\ WC_p\ (\overline{T}_{out} - T_{in})$

8. Flow Length (if not specified and the performance map is required: The flow length L is obtained iteratively by the generalized Newton Raphson method from the following equation:

$$\Delta P = \frac{Re^2\ \mu^2\ (1 + \psi^2)}{1029.568\ r_h^{\ 2}\ \rho_1} \left[\frac{Lf\ (\rho_1/\rho_2 + 1)}{2r_h\ (1 + \psi^2)} + \frac{\rho_1}{\rho_2} - 1\right]$$

where

$$Re = 0.8\ r_h\ W\ L/(\mu\ V\ \psi)$$

$$\psi = \frac{b\ \beta\ r_h}{b + b' + 0.012}$$

b' = heater element height

Required Tables (if the map option is not 0):

- Table ID (IF,31) - fin geometry, refer to HX component for table description.

f - Table ID (IF,32) - fin friction factor, refer to HX component for table description.

Restriction:

1. This component can only be used for fluid type 2.

Notes:

1. The same table relative number is used for the fin geometry table and the fin friction factor table.
2. Fluid properties are evaluated at average temperature, $T_{ave} = (T_{in} + T_{out})/2$, and average pressure, $P_{ave} = (P_{in} + P_{out})/2$.
3. The component printout consists of weight, cost units, reliability index, development risk factor, and the following items:

   W - flow rate

   PI - inlet pressure

   PØ - outlet pressure

   TI - inlet temperature

   TØ - outlet temperature

   HI - inlet humidity

   HØ - outlet humidity

   FT - fluid type

   FN - fluid properties table relative number

   VØL - volume

   L - flow length (if the map option is not 0)
4. If iteration is employed and the iteration dump option is selected, the following information is printed for each iteration:

   (a) State Variable (S.V.) - flow length

   (b) Error Variable (E.V.) - the difference of the calculated and the given pressure drops.

   (c) RE - Reynolds number
5. The convergence limit is 0.01. The upper and the lower limits of the state variables are 100.0 and 0.1 respectively.

6. Four performance map options are available. They are:

   Option 0 - no map

   Option 1 - print map

   Option 2 - punch map

   Option 3 - print and punch map.

   The maps produced will give values of $\sigma\Delta P$ versus flow rate.

7. The values of the flow length and the volume are stored in general arguments 71 and 72, respectively.

Sizing Component HEATER

Data Card Format

Card Column	Symbol	Value
1-6	CN	HEATER component name
8	CC	change code
12	NC	card number
16	NL	leg number
20	NSI	inlet station number
24	NSØ	outlet station number
28	[WTM]	weight multiplier (optional)
32	[CUM]	cost unit multiplier (optional)
36	[RI]	reliability index (optional)
40	[DRM]	development risk factor multiplier (optional)
44	[L]	flow length (not required if MAP = 0) = 0 computed > 0 user specified
48	[IHEL]	heater element height (not required if MAP = 0)
52	IF	fin variable tables relative number (types 31 and 32, not required if MAP = 0)
56	MAP	performance map options = 0 no map = 1 print map = 2 punch map = 3 print and punch map

SECTION XX

B11 - REPLACEMENT

SIZING COMPONENT HX

Heat Exchanger

Purpose: This component will compute core dimensions, weight, cost units, reliability index, development risk factor, and core volume for heat exchangers.

Equations:

1. Weight:

(a) Core Weight:

If $\rho_{SP} < 460$:

$$Wt_{core} = \frac{\rho_{FH}V_H + \rho_{FC}V_C + \rho_{SP}t_{SP}L_CL_H\ (N_HN_{SH} + N_CN_{SC} + 1.0)}{1728}$$

If $\rho_{SP} \geq 460$:

$$Wt_{core} = \frac{\rho_{FH}V_H + \rho_{FC}V_C + \rho_{SP}t_{SP}L_CL_H\ (N_HN_{SH} + N_CN_{SC} + 1.0)}{1728}$$

$$+ 6.44 \times 10^{-4}\ L_CL_H\ (N_HN_{SH} + N_CN_{SC} + 1.0)$$

where

$$N_H = \frac{L_N - b_C - 2t_{SP}}{b_H + b_C + 2t_{SP}}$$

$$N_C = N_H + 1$$

$$V_H = N_H\ [b_H - (N_{SH} - 1)\ t_{SP}]\ L_C\ L_H$$

$$V_C = N_C\ [b_C - (N_{SC} - 1)\ t_{SP}]\ L_C\ L_H$$

$$\rho_F = \frac{t_Fp\rho_{metal}\,[B + 1/p - (9 - 2\pi)t_F]}{B} \quad \text{- rectangular fin}$$

$$\rho_F = \frac{t_Fp\rho_{metal}\ [B + (\pi - 2)/2p - t_F]}{B} \quad \text{- rounded fin}$$

$$\rho_F = \frac{t_Fp\rho_{metal}\ [S + 3t_F\phi]}{B} \quad \text{- triangular fin}$$

$$B = \frac{b - (N_S - 1)\ t_{SP}}{N_S}$$

$$\emptyset = 2 \cos^{-1} \left(\frac{3t_F}{a + 3t_F}\right)$$

$$a = \frac{-1 + 6p^2 t_F B + (1 - 12 p^2 t_F + p^2 B^2)^{1/2}}{1/(3t_F) - 12p^2 t_F}$$

$$S = 1/(p \cos(\emptyset/2)) - 6t_F p (B + 2a)$$

(b) Heat Exchanger Weight:

$$Wt = 3.23126\ Wt_{core} / (V)^{0.118}$$

2. Cost Units:

$CU = 2.08\ Wt$

3. Reliability Index:

$RI = 0.00256$ (gas/gas HX)

$RI = 0.00328$ (gas/liquid HX)

$RI = 0.00106$ (liquid/liquid HX)

4. Development Risk Factor:

For gas/gas HX:

$DR = 1.0$ ($T \leq 1760°R$, $P \leq 314.7$ psi)

$DR = 1.0 + \left(\frac{T - 1760}{425}\right)^2 + \left(\frac{P - 314.7}{283}\right)^2$ ($T > 1760°R$, $P > 314.7$ psi)

For gas/liquid or liquid/liquid HX:

$DR = 1.0$ ($P \leq 314.7$ psi)

$DR = 1.0 + \left(\frac{P - 314.7}{283}\right)^2$ ($P > 314.7$ psi)

5. Weight Standard Error:

$Wt_d = 0.12\ Wt$

6. Installation Weight Factor:

$Wt_i = 0.205\ Wt$

7. Core Dimensions (if not specified):

Core dimensions L_H, L_C and L_N are obtained iteratively by the generalized Newton Raphson method from the following three equations:

$$\Delta P_H = \frac{Re_H^2\ \mu_H^2\ (1+\psi_H^2)}{1029.568\ r_{hH}^2\ \rho_{1H}}\ \left[\frac{f_H\ L_H\ N_{PH}\ (\rho_{1H}/\rho_{2H}+1)}{2r_{hH}\ (1+\psi_H^2)} + \frac{\rho_{1H}}{\rho_{2H}} - 1\right]$$

$$\Delta P_C = \frac{Re_C^2\ \mu_C^2\ (1+\psi_C^2)}{1029.568\ r_{hC}^2\ \rho_{1C}}\ \left[\frac{f_C\ L_C\ N_{PC}\ (\rho_{1C}/\rho_{2C}+1)}{2r_{hC}\ (1+\psi_C^2)} + \frac{\rho_{1C}}{\rho_{2C}} - 1\right]$$

$\varepsilon = f\ (NTU,\ CC)$ (heat transfer effectiveness table)

where

$$NTU = r_{hH}\ W_H\ L_H\ N_{PH}/[(WC_p')_{min}\ \psi_H\ \mu_H\ Re_H$$

$$\left(\frac{r_{hH}^2\ Pr_H^{2/3}}{\eta_{OH}\ C_{pH}'\ \mu_H\ \psi_H\ j_H\ Re_H} + \frac{r_{hC}^2\ Pr_C^{2/3}}{\eta_{OC}\ C_{pC}'\ \mu_C\ \psi_C\ j_C\ Re_C}\right)]$$

$CC = (WC_p')_{min}/(WC_p')_{max}$ (both fluids mixed or both fluids unmixed)

$CC = (WC_p')_{mixed}/(WC_p')_{unmixed}$ (one fluid mixed)

$$\psi_H = \frac{b_H\ \beta_H\ r_{hH}\ N_H}{(b_H + b_C + 2t_{SP})\ N_H + b_c + 2t_{SP}}$$

$$\psi_C = \frac{b_C\ \beta_C\ r_{hC}\ N_C}{(b_H + b_C + 2t_{SP})\ N_H + b_c + 2t_{SP}}$$

$$Re_H = \frac{0.8\ r_{hH}\ W_H\ N_{PH}}{\mu_H\ L_C\ L_N\ \psi_H}$$

$$Re_C = \frac{0.8\ r_{hC}\ W_C\ N_{PC}}{\mu_C\ L_H\ L_N\ \psi_C}$$

$$\eta_{OH} = 1 - \left(\frac{A_F}{A}\right)_H \left[1 - \frac{\tanh\ (m_H\ \ell_{eH})}{m_H\ \rho_{eH}}\right]$$

$$\eta_{OC} = 1 - \left(\frac{A_F}{A}\right)_C \left[1 - \frac{\tanh\,(m_C\,\ell_{eC})}{m_C\,\ell_{eC}}\right]$$

$$m_H = \left[\frac{1800C'_{pH}\,\mu_H\,Re_H\,j_H\,(1 + t_{FH}/\xi_H)}{r_{hH}\,t_{FH}\,Pr_H^{2/3}\,k_H}\right]^{1/2}$$

$$m_C = \left[\frac{1800C'_{pC}\,\mu_C\,Re_C\,j_C\,(1 + t_{FC}/\xi_C)}{r_{hC}\,t_{FC}\,Pr_C^{2/3}\,k_C}\right]^{1/2}$$

$$SHR_H = (T_{H_{in}} - \bar{T}_{H_{out}})/(T_{H_{in}} - T_{H_{out}})$$

$$SHR_C = (T_{C_{in}} - \bar{T}_{C_{out}})/(T_{C_{in}} - T_{C_{out}})$$

$$C'_{pH} = C_{pH} \cdot SHR$$

$$C'_{pC} = C_{pC} \cdot SHR$$

8. Core Volume:

   $V = L_H\,L_C\,L_N$

9. Volume of liquid inside the core:

   $V_{LH} = \psi_H\,V$

   $V_{LC} = \psi_C\,V$

Required Tables:

- Table ID (IF1, 31 and IF2, 31) - fin geometry (side 1 and side 2), -1 dimensional, 9 table values are in the following order:

  A_F/A - fin area/total area

  p - fin pitch

  b - stack height

  r_h - hydraulic radius

  t_F - fin thickness

β - total heat transfer area/volume of one side

ξ - effective length in flow direction

FS - fin shape code

= 1.0 rectangular fin

= 2.0 rounded fin

= 3.0 triangular fin

N_S - number of sandwiches

= 1.0 single

= 2.0 double

= 3.0 triple

etc.

f - Table ID (IF1, 32 and IF2, 32) - fin friction factor (side 1 and side 2), 2 dimensional, the independent variable is Reynolds number (argument type 0; argument relative number 21), and the dependent variable is friction factor.

j - Table ID (IF1, 33 and IF2, 33) - fin Colburn modulus (side 1 and side 2), 2 dimensional, the independent variable is Reynolds number (argument type 0; argument relative number 21), and the dependent variable is Colburn modulus.

ε - Table ID (IEF, 5) - heat transfer effectiveness, 3 or 33 dimensional, the first independent variable is NTU (argument type 0; argument relative number 55), the second independent variable is $(WC_p)_{min}/(WC_p)_{max}$ or $(WC_p)_{mixed}/(WC_p)_{unmixed}$ (argument type 0; argument relative number 56), and the dependent variable is heat transfer effectiveness.

t_{SP} - Table ID (ITSP, 34) - separation plate thickness.

- Table ID (IM1, 20) - side 1 fin material properties.
- Table ID (IM2, 20) - side 2 fin material properties
- Table ID (IMSP, 20) - separation plate material properties.

Restrictions:

1. This component is used for sizing a plate fin cross flow heat exchanger.
2. The component can only be used for fluid types 1 and 2.
3. The core dimensions (L_H, L_C, L_N) must either be all specified by the user or be all unspecified.

Notes:

1. Three consecutive data cards are required, HX, HX1 and HX2. The HX card must precede HX1 and HX2 cards.
2. For each side of the heat exchanger, the same table relative number is used for the fin geometry table, the fin friction factor table and the fin Colburn modulus table.
3. Fluid properties are evaluated at average temperature, $T_{ave} = (T_{in} + T_{out})/2$, and average pressure, $P_{ave} = (P_{in} + P_{out})/2$.
4. The component printout consists of heat exchanger weight, cost units, reliability index, development risk factor, and the following items:

W	- flow rate	hot side and cold side
PI	- inlet pressure	hot side and cold side
PØ	- outlet pressure	hot side and cold side
TI	- inlet temperature	hot side and cold side
TØ	- outlet temperature	hot side and cold side
HI	- inlet humidity	hot side and cold side
HØ	- outlet humidity	hot side and cold side
FT	- fluid type	hot side and cold side
FN	- fluid properties table relative number	hot side and cold side
LH	- hot side flow length	
LC	- cold side flow length	
LN	- no flow length	
VØL	- core volume	
WTC	- core weight	
EFF	- heat transfer effectiveness (not printed if core dimensions are specified)	

NTU - number of heat transfer units (not printed if core dimensions are specified)

VLH - volume of hot side liquid inside the core (not printed if hot side fluid is a gas)

VLC - volume of cold side liquid inside the core (not printed if cold side fluid is a gas)

5. Four performance map options are available. They are:

Option 0 - no maps

Option 1 - print maps

Option 2 - punch maps

Option 3 - print and punch maps

The maps produced will consist of the following:

(a) side 1 temperature effectiveness versus flow rates for side 1 and side 2.

(b) side 1 and side 2 $\sigma\Delta P$ (for gas) or ΔP (for liquid) versus flow rate.

6. If core dimensions are not specified by the user and the iteration dump option is selected, the following information is printed for each iteration:

(a) State Variables (S.V.) - the three values printed are L_H, L_C, and L_N, respectively.

(b) Error Variables (E.V.) - the three values printed are the difference of the calculated and the given hot side pressure drops, the difference of the calculated and the given cold side pressure drops, and the difference of the calculated and the given heat transfer effectiveness, respectively.

(c) The six values printed after the error variables are Re_H, Re_C, NTU, ε, η_{OH}, and η_{OC}, respectively.

7. The convergence limits for pressure drops and heat transfer effectiveness are 0.001 and 0.0001, respectively. The upper and lower limits for state variables are 100.0 and 0.1, respectively.

8. Values of L_H, L_C, L_N, V, V_{LH}, and V_{LC} are stored in general arguments 71, 72, 73, 74, 75 and 76, respectively.

Sizing Component HX

Data Cards Format

1. HX Data Card

Card Column	Symbol	Value
1-2	CN	HX component name
8	CC	change code
12	NC	card number
16	[WTM]	weight multiplier (optional)
20	[CUM]	cost unit multiplier (optional)
24	[RI]	reliability index (optional)
28	[DRM]	development risk factor multiplier (optional)
32	[LN]	no flow length = 0 computed > 0 user specified
36	IMSP	separation plate material table relative number (type 20)
40	ITSP	separation plate thickness table ~~relative number (type 34)~~
44	IEF	effectiveness table relative number (type 5)
48	MAP	performance map options = 0 no maps = 1 print maps = 2 punch maps = 3 print and punch maps
52	IFLT	flow type = 1 both sides unmixed = 2 both sides mixed = 3 side 1 mixed, side 2 unmixed = 4 side 1 unmixed, side 2 mixed

1 - 6061 Aluminum
2 - AISI 347 steel
3 - Brazed Nickel
4 - Magnesium
8 - Inconel 600

# of passes +1
any # 2 thru 7 (crossflow thru 6 passes)

rel 55 56

ϵ vs. NTU and $\frac{(WC_p)_{min}}{(WC_p)_{max}}$

p 73

1 - Al (.012")
2 - Steel/Nickel (.006)

20x10x10

2. HX1 Data Card

Card Column	Symbol	Value
1-3	CN	HX1 component name
8	CC	change code
12	NC	card number
16	NL1	leg number, side 1
20	NSI1	inlet station number, side 1
24	NSØ1	outlet station number, side 1
28	[L1]	core flow length, side 1 = 0 computed > 0 user specified
32	NP1	number of passes, side 1
36	IM1	fin material properties table relative number, side 1 (type 20)
40	IF1	fin variable tables relative number, side 1 (types 31, 32, 33)

1 aluminum 6061
2 stainless 347
3 nickel (brazed)
8 inconel 600

3. HX2 Data Card

Card Column	Symbol	Value
1-3	CN	HX2 component name
8	CC	change code
12	NC	card number
16	NL2	leg number, side 2
20	NSI2	inlet station number, side 2
24	NSØ2	outlet station number, side 2
28	[L2]	core flow length, side 2 = 0 computed > 0 user specified
32	NP2	number of passes, side 2
36	IM2	fin material properties table relative number, side 2 (type 20)
40	IF2	fin variable tables relative number, side 2 (types 31, 32, 33)

Sizing Component INIT

Initialization

Purpose: This component is used to initialize a known component value. The available types of values are:

ITYP	Value
1	weight
2	cost units
3	reliability index
4	development risk factor
5	weight standard error
6	electrical power
7	shaft power
8	hydraulic power
9	bleed air extraction
10	fuel flow rate (lb/hr)
11	drag
12	expendable coolant weight

Equations:

For ITYP = 1, 2, 3, and 6 through 12

$$(\quad)_{system} = (\quad)_{system} + \text{Value}$$

For ITYP = 4

$$DR_{system} = DR_{system} \times \text{Value}$$

For ITYP = 5

$$(Wt_d)^2_{system} = (Wt_d)^2_{system} + (\text{Value})^2$$

Notes:

1. This component may be used to define an additional system development risk factor.
2. This component must be used to define bleed air extraction if system penalty calculation is required.
3. The component printout consists of initialization type and value.

Sizing Component INIT

Data Card Format

Card Column	Symbol	Value
1-4	CN	INIT component name
8	CC	change code
12	NC	card number
16	ITYP	type of initialized value = 1 weight = 2 cost unit = 3 reliability index = 4 development risk factor = 5 weight standard error = 6 electrical power = 7 shaft power = 8 hydraulic power = 9 bleed air extraction = 10 fuel flow rate = 11 drag = 12 expendable coolant weight
20	[VALUE]	initialized value

Sizing Component INSLTN

Insulation

Purpose: This component will compute weight, cost units, reliability index, development risk factor, and insulation thickness for ducting and compartment insulation. The available insulation types and insulation methods are:

INT	Insulation Type
1	bleed air line
2	conditioned air distribution line
3	compartment

INM	Insulation Method
1	wrap around (for INT = 1 & 2)
	blanket (for INT = 3)
2	integral blanket (for INT = 1 & 2)
	blanket with air gap (for INT = 3)
3	removable blanket with radiation reflector (for INT = 1)
4	air gap radiation shield (for INT = 1)

Equations:

1. Weight:

For INT = 1 and INM = 1 & 3:

$$Wt = L\ [(1.9667 \times 10^{-3}\ \rho_i\ D\ + 7.0 \times 10^{-4}\ \rho_i$$
$$+ 7.7 \times 10^{-2})(t - 0.25) + 4.25 \times 10^{-4}\ \rho_i\ D$$
$$+ 0.01\ D\ + 2.0833 \times 10^{-4}\ \rho_i + 1.59167 \times 10^{-2})] \quad (1)$$

For INT = 1 and INM = 2:

$$Wt = L[(5.5 \times 10^{-3}\ t + 5.8833 \times 10^{-3})\ D$$
$$- 0.015\ t - 5.8333 \times 10^{-4}] \quad (2)$$

For INT = 1 and INM = 4:

$$Wt = L[(6.0667 \times 10^{-3}\ D + 8.6 \times 10^{-3})\ (t - 0.25) + 2.35 \times 10^{-3}\ D + 1.0667 \times 10^{-3})] \qquad (3)$$

For INT = 2 and INM = 1:

$$Wt = L\ (D + t)(6.1078 \times 10^{-4} + 1.0917 \times 10^{-3}\ t) \qquad (4)$$

For INT = 2 and INM = 2:

$$Wt = L\ [(D + t)\ (9.725 \times 10^{-3} + 1.275 \times 10^{-3}\ t) - 4.8625 \times 10^{-3}\ D\ ] \qquad (5)$$

For INT = 3:

$$Wt = A\ [3.646 \times 10^{-4}\ t\ /\ CF + 5.104 \times 10^{-4}] \qquad (6)$$

2. Cost Units:

For INT = 1:

$$CU = L\ [0.009583t\ (D + t) + 0.04425]$$

For INT = 2:

$$CU = 0.002378\ DL$$

For INT = 3:

$$CU = A\ (6.944 \times 10^{-4} + 7.9167 \times 10^{-4}\ t)$$

3. Reliability Index:

$$RI = 0.00001$$

4. Development Risk Factor:

$$DR = 1.0$$

5. Weight Standard Error:

For INT = 1 and INM = 1 & 3:

$$Wt_d = 0.055\ Wt$$

For INT = 1 and INM = 2:

$Wt_d = 0.149\ Wt$

For INT = 1 and INM = 4:

$Wt_d = 0.167\ Wt$

For INT = 2:

$Wt_d = 0.15\ Wt$

For INT = 3:

$Wt_d = 0.15\ Wt$

6. Installation Weight Factor:

$Wt_i = 0.205\ Wt$

7. Thickness (if not specified):

For INT = 1 and INM = 1 & 2:

$$t_{calc} = 0.045\ (T_D - 460)\ /\ (T_S - 0.2\ T_D - 416)$$

For INT = 1 and INM = 3:

$$t_{calc} = 0.064\ (T_D - 460)\ /\ (T_S - 0.2\ T_D - 416)$$

For INT = 1 and INM = 4:

$$t_{calc} = 0.06\ (T_D - 460)\ /\ (T_S - 0.2\ T_D - 416)$$

For INT = 1 and all INM

$$t = t_{calc} \quad \text{if } 0 < t_{calc} \leq 1$$

$$t = 1 \quad \text{if } t_{calc} \leq 0 \text{ or } t_{calc} > 1$$

For INT = 2:

$$t = \frac{D}{2}\,(e^{c} - 1)$$

where

$$c = 2\pi\ k_i\ \left(\frac{T_{in} + T_{out}}{2} - T_A\right)\ /\ (q/L)$$

$$\frac{q}{L} = 60\ W\ C_p\ (T_{in} - T_{out})/L$$

For INT = 3:

$$t = 12\ \ (LF)\ k_i\ (T_S - T_C)\ /\ (q_T/A)$$

where

LF = heat leak factor

= 2.625

$$q_T/A = q_c/A + q_r/A$$

$$= 1.5\ \left(\frac{P_A}{14.7}\right)^{1/2} (T_C - T_A) + 0.9\ (1.714 \times 10^{-9})(T_C^{\ 4} - T_A^{\ 4})$$

Required Tables:

- Table ID(IMT,20) - insulation material properties.

Restrictions:

1. Equation (1) applies only to line diameters greater than 1.5 inches.
2. Equation (2) applies only to 3 pcf insulation with a 0.006 inch thick stainless steel outer cover and a 0.002 inch thick aluminum radiation reflector.
3. Equation (3) applies only to line diameters approximately one inch or greater.
4. Equation (4) applies only to 0.6 pcf insulation with 0.125 lb per square yard cover sheets.
5. Equation (5) applies only to 0.6 pcf insulation with 5 ounces per square yard cover sheets.

Notes:

1. The insulation weights for flange clamps and expansion bellows are included in the installation weight factor.
2. The component printout consists of weight, cost units, reliability index, development risk factor, and the following item:
   THK - insulation thickness or air gap size
3. The insulation material properties table input is always required although it is not always required in the computation. For INT = 1 and INM = 4, the user may input a dummy material properties table.
4. The insulation conductivity, k_i, is evaluated at an average temperature of insulation inner and outer surfaces. The insulation density, ρ_i, is constant. C_p is evaluated at the inlet temperature, T_{in}.

Sizing Component INSLTN

Data Card Format

Card Column	Symbol	Value
1-6	CN	INSLTN component name
8	CC	change code
12	NC	card number
16	[WTM]	weight multiplier (optional)
20	[CUM]	cost unit multiplier (optional)
24	[RI]	reliability index (optional)
28	[DRM]	development risk factor multiplier (optional)
32	INT	insulation type = 1 bleed air line = 2 distribution line = 3 compartment
36	INM	insulation method = 1 wrap around (for INT = 1 & 2) blanket (for INT = 3) = 2 integral blanket (for INT = 1 & 2) blanket with air gap (for INT= 3) = 3 removable blanket with radiation reflector (for INT = 1) = 4 air gap radiation shield (for INT = 1)
If INT = 1		
40	[THK]	insulation thickness or air gap size = 0 computed > 0 user specified
44	[D]	line outer diameter
48	[L]	line length
52	[TD]	line temperature (not required if [THK] > 0) = 0 use fluid inlet temperature > 0 user specified
56	NSI	inlet station number (not required if [THK] > 0 or [TD] > 0)
60	[TS]	insulation outer surface temperature (not required if [THK] > 0)
64	-	
68	IMT	insulation material properties table relative number (type 20)

If INT = 2

40	[THK]	insulation thickness = 0 computed > 0 user specified
44	[D]	line outer diameter
48	[L]	line length
52	[TA]	abmient temperature (not required if [THK] > 0)
56	NL	leg number
60	NSI	inlet station number
64	NSØ	outlet station number
68	IMT	insulation material properties table relative number (type 20)

If INT = 3

40	[THK]	insulation thickness = 0 computed > 0 user specified
44	[A]	insulation area
48	[PC]	compartment pressure (not required if [THK] > 0)
52	[TC]	compartment temperature (not required if [THK] > 0)
56	[TW]	compartment wall temperature (not required if [THK] > 0)
60	[TS]	insulation outer surface temperature (not required if [THK] > 0)
64	[CF]	compression factor
68	IMT	insulation material properties table relative number (type 20)

B14

Sizing Component LINE

Line

Purpose: This component will compute weight, cost units, reliability index, development risk factor, and inside diameter for lines. The available types of lines are:

ILT	Type
1	high pressure bleed line, aluminum
2	high pressure bleed line, steel
3	low pressure distribution or ram air line
4	refrigeration package line
5	liquid coolant line, aluminum

Equations:

1. Weight:

   .035×.34 ≈ .0119 DL

   For ILT = 1:

   $$Wt = 0.34\ D\ t\ L$$

   For ILT = 2:

   $$Wt = (2.4\ D + 1.25)\ t\ L$$

   For ILT = 3:

   $$Wt = 0.0137\ D\ L \qquad (D \leq 3.5)$$

   $$Wt = (0.0179\ D - 0.0147)\ L \qquad (D > 3.5)$$

   For ILT = 4:

   $$Wt = 0.7\ (2.4\ D + 1.25\ )\ t\ L$$

   For ILT = 5:

   $$Wt = 0.3071\ (D + t)\ t\ L$$

2. Cost Units:

   For ILT = 1 & 5:

   $$CU = (0.0097\ D + 0.0191)\ L$$

   For ILT = 2 & 4:

   $$CU = (0.103\ D + 0.026)\ L \qquad (D \leq 2.5)$$

   $$CU = (0.231\ D - 0.295)\ L \qquad (D > 2.5)$$

   For ILT = 3:

   $$CU = (0.011\ D + 0.0295)\ L \qquad (D \leq 3.5)$$

   $$CU = (0.0254\ D - 0.0233)\ L \qquad (D > 3.5)$$

3. Reliability Index:

For ILT = 1, 2 & 4:

$$RI = 0.01164$$

For ILT = 3:

$$RI = 0.00291$$

For ILT = 5:

$$RI = 0.00285$$

4. Development Risk Factor:

$$DR = 1.0$$

5. Weight Standard Error:

$$Wt_d = 0.15\ Wt + 0.158\ Wt_i$$

6. Installation Weight:

For ILT = 1, 2, & 3:

$$Wt_i = 3.45 \times 10^{-4}\ (D\ L)^{1.58}$$

For ILT = 4 & 5:

$$Wt_i = 0.0$$

7. Liquid Volume (for ILT = 5 only):

$$V = \frac{\pi}{4} D^2 L$$

8. Inside Diameter (if not specified):

$$\Delta P = 1.008 \times 10^{-3} \left(\frac{4\ f\ L}{D} + C\ K_t\right) \frac{W^2}{\rho\ D^4} - \frac{\rho\ Z}{1728}$$

where

Z = inlet elevation - outlet elevation

The above equation is solved for inside diameter iteratively by the generalized Newton Raphson method.

9. Wall Thickness (if not specified):

For ILT = 1:

$t = 0.035 \qquad (D \leq 3.5)$

$t = 0.042 \qquad (D > 3.5)$

For ILT = 2 & 4:

$$t = 0.00677\ D + 0.00322$$

For ILT = 5:

$t = 0.01 \qquad (D \leq 1.0)$

$t = 0.028 \qquad (D > 1.0)$

For ILT = 3:

Wall thickness is not required.

Required Tables (if inside diameter is not specified):

f - Table ID(IF,3) - friction factor

K_t - Table ID (IKT,2) - bend pressure loss factor

Restrictions:

1. This component can only be used for fluid types 1 (if ILT = 1) or 2 (if ILT ≠ 1)

Notes:

1. The component printout consists of weight, cost units, reliability index, development risk factor, and the following items:

   W - flow rate
   PI - inlet pressure
   PØ - outlet pressure
   TI - inlet temperature
   TØ - outlet temperature
   HI - inlet humidity
   HØ - outlet humidity
   FT - fluid type
   FN - fluid properties table relative number
   D - inside diameter
   THK - wall thickness (for ILT ≠ 3 only)
   V - velocity
   M - Mach number (for ILT ≠ 5 only)
   VL - liquid volume (for ILT = 5 only)

2. If a line inside diameter is not specified and the iteration dump option is selected, the following information is printed for each iteration:

   (a) State Variable (S.V.) - line inside diameter.
   (b) Error Variable (E.V.) - the difference of the calculated and the given pressure drops.
   (c) RE - Reynolds number.

3. The convergence limit is 0.01. The upper and lower limits for the state variable are 10.0 and 0.1, respectively.
4. The values of inside diameter, velocity, Mach number, and liquid volume are stored in general arguments 71, 72, 73, and 74, respectively.
5. Reynolds number is available in general argument 21, and diameter is available in general argument 57, for the f and K_t table lookup.
6. If diameter is not specified, the f or the K_t term can be optional, but not both.

Sizing Component LINE

Data Card Format

Card Column	Symbol	Value
1-4	CN	LINE component name
8	CC	change code
12	NC	card number
16	NL	leg number
20	NSI	inlet station number
24	NSØ	outlet station number
28	[WTM]	weight multiplier (optional)
32	[CUM]	cost unit multiplier (optional)
36	[RI]	reliability index (optional)
40	[DRM]	development risk factor multiplier (optional)
44	[D]	inside diameter = 0 computed > 0 user specified
48	[L]	line length
52	[THK]	wall thickness (not required if ILT = 3) = 0 computed > 0 user specified
56	[Z]	difference in elevation between line inlet and outlet
60	IF	friction factor table relative number (type 3, optional)
64	[C]	correction factor for loss of bends other than 90° (optional)
68	IKT	90° bend pressure loss factor table relative number (type 2, optional)
72	ILT	line type = 1 high pressure bleed line, aluminum = 2 high pressure bleed line, steel = 3 low pressure distribution or ram air line = 4 refrigeration package line = 5 liquid coolant line, aluminum

Sizing Component MISC
Miscellaneous Operations

Purpose: This component will compute any value desired using basic mathematical expressions. The result of the operation may be a general argument or a parameter table value. Variables one and two may be a general argument, a flow rate, a pressure, a temperature, a humidity, a parameter table value or a table lookup value.

Options: The operations which are a function of one variable are: equality, absolute value, square root, base ten logarithm, natural logarithm, ten to a power, and e to a power. The operations which are a function of two variables are: addition, subtraction, multiplication, division, the minimum of two variables, the maximum of two variables, variable one to the variable two power, average value, and a code which indicates that variable one is either less than, equal to, or greater than variable two.

Equations:

if IØPR $\leq$ 0

$$VX = f\ (V1)$$

if IØPR > 0

$$VX = f\ (V1,\ V2)$$

Notes:

1. The component printout consists of the following items:

VX	- result variable value	
IVXT	- result variable type	
IVXN	- result variable relative number	
IØPR	- operation code	
V1	- variable value	variable one
IV1T	- variable type	variable one
IV1N	- variable relative number	variable one
V2	- variable value	variable two (printed if IØPR > 0)
IV2T	- variable type	variable two (printed if IØPR > 0)
IV2N	- variable relative number	variable two (printed if IØPR > 0)

Sizing Component MISC

Data Card Format

Card Column	Symbol	Value
1-4	CN	MISC component name
8	CC	change code
12	NC	card number
16	IVXT	result type = 0 - general argument = -1 - parameter value
20	NVX	result relative number If IVXT = 0 - general argument number = -1 - parameter index
24	IV1T	variable one type = 0 - general argument = 1 - flow rate = 2 - pressure = 3 - temperature = 4 - humidity = -1 - parameter value = -2 - table (type 99)
28	NV1	variable one relative number if IV1T = 0 - general argument relative number = 1 - leg number = 2 - } station number = 3 - } station number = 4 - } station number = -1 - parameter index = -2 - table relative number (type 99)
32	IØPR	operation if IØPR > 0 VX = f(V1, V2) = 1 - V1 + V2 = 2 - V1 - V2 = 3 - V1 x V2 = 4 - V1 ÷ V2 = 5 - minimum value (V1, V2) = 6 - maximum value (V1, V2) = 7 - $V1^{V2}$ = 8 - (V1 + V2)/2

$$
\begin{aligned}
= 9 - & \ 0 \text{ if } V1 = V2 \\
& \ 1 \text{ if } V1 > V2 \\
& -1 \text{ if } V1 < V2
\end{aligned}
$$

if IØPR = 0

VX = V1

if IØPR < 0 VX = f(V1)

$= -1 - |V1|$
$= -2 - \sqrt{V1}$
$= -3 - \log V1$
$= -4 - \ln V1$
$= -5 - 10^{V1}$
$= -6 - e^{V1}$

36	IV2T	variable two type (same as IV1T)
40	NV2	variable two relative number (same as NV1)

Sizing Component PUMP

Pump

Purpose: This component will compute weight, cost units, reliability index, development risk factor, and volume for a pump package. It will also compute the efficiency and the horsepower for a pump and its drive. The available pump types are:

IPT	Type
1	vane or gear
2	centrifugal

Equations:

1. Weight:

   For pump and motor:

   For IPT = 1:

   $Wt_p = 2.1$ $\qquad$ ($DPR < 0.088$ in^3/rev)

   $Wt_p = 10.63\ (DPR)^{2/3}$ $\qquad$ ($DPR \geq 0.088$ in^3/rev)

   For IPT = 2:

   $Wt_p = 2.1$ $\qquad$ ($DPR < 0.028$ in^3/rev)

   $Wt_p = 22.92\ (DPR)^{2/3}$ $\qquad$ ($DPR \geq 0.028$ in^3/rev)

   where

   $$DPR = 1728\ W/(\rho^{.87}\ N^{.51})$$

   For reservoir:

   $$Wt_r = 0.131\ V_f^{2/3}$$

   where

   $$V_f = Wt_{liquid}\ (1/\rho_{high\ temp} - 1/\rho_{low\ temp})$$

   $$Wt_{liquid} = \rho_{in}\ V_{liquid}$$

   For filter:

   $$Wt_{filter} = 0.55 + 0.9575\ W/\rho$$

   For pump package:

   $$Wt = 1.125\ (Wt_p + Wt_r + Wt_{filter}) + Wt_{liquid}$$

2. Cost Units:

   $$CU = 81.2 + 1.05\ (Wt_p + Wt_r + Wt_{filter})$$

3. Reliability Index:

   $$RI = 0.04016$$

4. Development Risk Factor:

   $$DR = 1.0$$

5. Weight Standard Error:

$$Wt_d = (0.0361\ Wt_P^{\,2} + 0.0551\ Wt_r^{\,2} + 0.0441\ Wt^2_{filter})^{1/2}$$

6. Installation Weight Factor:

$$Wt_i = 0.205\ (Wt_P + Wt_r + Wt_{filter})$$

7. Volume:

$$V = 33.04\ (Wt_P + Wt_r + Wt_{filter})$$

8. Horsepower:

(a) Fluid horsepower:

$$HP_f = 4.3636 \times 10^{-3}\ (P_{out} - P_{in})\ W/\rho_{in}$$

(b) Shaft Horsepower:

$$HP_S = HP_f + WC_P\ (T_{out} - T_{in})/42.416$$

9. Efficiency:

$$\eta = HP_f/HP_S$$

Restrictions:

1. This component can only be used for fluid type 1.
2. This component is used for sizing an electric motor driven pump only.
3. Shaft speed must be specified by the user.

Notes:

1. Refer to sizing subroutine CØMP for drive type,and equations (DC motor) for drive efficiency and horsepower.
2. The volumetric change of the total amount of liquid in the liquid loop is computed at a high temperature of 710°R and a low temperature of 395°R.
3. The component printout consists of weight (including weight of liquid in the liquid loop subsystem), cost units, reliability index, and development risk factor of the pump package, and the following items:

W - flow rate
PI - inlet pressure
PØ - outlet pressure
TI - inlet temperature
TØ - outlet temperature
HI - inlet humidity
HØ - outlet humdiity

FT - fluid type

FN - fluid properties table relative number

WTP - weight of pump and motor

WTR - weight of reservoir

WTL - weight of filter

VØL - volume of the pump package

N - shaft speed

EFF - pump efficiency

HP - pump shaft horsepower

Additional printout consists of drive type and the following items:

EFF - drive efficiency

HP - drive input horsepower

4. The value of package volume is stored in general argument 71.

Sizing Component PUMP

Data Card Format

Card Column	Symbol	Value
1-4	CN	PUMP component name
8	CC	change code
12	NC	card number
16	NL	leg number
20	NSI	inlet station number
24	NSØ	outlet station number
28	NST	shaft number
32	[WTM]	weight multiplier (optional)
36	[CUM]	cost unit multiplier (optional)
40	[RI]	reliability index (optional)
44	[DRM]	development risk factor multiplier (optional)
48	[VL]	liquid volume in the whole liquid loop
52	IPT	pump type = 1 vane or gear = 2 centrifugal

Sizing Component RIN
Ram Air Inlet

Purpose: This component will compute weight, cost units, reliability index, development risk factor, inlet area, diffuser exit area, volume, and drag for inlets. The available inlet types are:

INLT	Type
1	flush inlet
2	scoop inlet
3	nose inlet
4	engine duct inlet

Equations:

1. Weight:

   $Wt = \rho\ t_e\ (8\ A_I + S)/1728$

   where t_e is the effective wall thickness of inlet and diffuser.

2. Cost Units:

   $CU = 13.0 + 0.139\ Wt^{1.65}$

3. Reliability Index:

   $RI = 0.0001$

4. Development Risk Factor:

   $DR = 1.0$

5. Weight Standard Error:

   $Wt_d = 0.25\ Wt$

6. Installation Weight Factor:

   $Wt_i = 0.205\ Wt$

7. Inlet Area:

   For INLT = 1:

   $$A_I = \frac{3.6823\ W}{\rho_\infty\ V_\infty} \quad \text{(for flight condition, } V_\infty > 0\text{)}$$

   $$A_I = \frac{W\sqrt{T_\infty}}{8.9376\ P_\infty} \quad \text{(for sea level static condition, } V_\infty = 0\text{)}$$

For INLT = 2:

$$A_I = \frac{3.4286\ W}{\rho_\infty\ V_\infty} \quad \text{(for subsonic flight condition)}$$

$$A_I = \frac{3\ W}{\rho_\infty\ V_\infty} \quad \text{(for supersonic flight condition)}$$

$$A_I = \frac{W\sqrt{T_\infty}}{8.9376\ P_\infty} \quad \text{(for sea level static condition)}$$

For INLT = 3:

$$A_I = \frac{3\ W}{\rho_\infty\ V_\infty} \quad \text{(for flight condition)}$$

$$A_I = \frac{W\sqrt{T_\infty}}{8.9376\ P_\infty} \quad \text{(for sea level static condition)}$$

For INLT = 4:

$$A_I = \frac{2.4\ W}{0.3\ \rho_I\ c_I}$$

where c_I is the speed of sound at the inlet.

8. Diffuser Exit Area:

$$A_D = \frac{2.4\ W}{0.15\ \rho_D\ c_D}$$

where c_D is the speed of sound at the diffuser exit.

9. Diffuser Surface Area:

$$S = \frac{A_D - A_I}{0.10453}$$

10. Volume:

$$V = 1.89\ A_I^{1.5} + \frac{(\sqrt{A_D} - \sqrt{A_I})(A_I + A_D + \sqrt{A_I\ A_D})}{0.5589}$$

11. Drag:

$$D = \frac{W\ V_\infty}{1932}$$

Required Tables:

- Table ID (IM,20) - material properties

Restrictions:

1. This component can only be used for fluid type 2.

Notes:

1. An inlet consists of an inlet section and a diffuser.
2. The outlet station refers to the station at the end of the mixing section.
3. The component printout consists of weight, cost units, reliability index, development risk factor, and the following items:

   W - flow rate
   PI - free stream pressure
   PØ - outlet pressure
   TI - free stream temperature
   TØ - outlet temperature
   HI - free stream humidity
   HØ - outlet humidity
   FT - fluid type
   FN - fluid properties table relative number
   AI - inlet area
   AD - diffuser exit area
   VØL - volume
   DRAG - inlet drag
4. If S < 0.0, the diffuser is not sized. A message is printed, and A_D is set to zero.
5. The free stream fluid, free stream pressure, temperature, Mach number, and velocity must be defined.
6. The values of volume and inlet area are stored in general argument 71 and 72, respectively.

Sizing Component RIN

Data Card Format

Card Column	Symbol	Value
1-3	CN	RIN component name
8	CC	change code
12	NC	card number
16	NL	leg number
20	NSØ	mixing section outlet station number
24	[WTM]	weight multiplier (optional)
28	[CUM]	cost unit multiplier (optional)
32	[RI]	reliability index (optional)
36	[DRM]	development risk factor multiplier (optional)
40	[AI]	inlet area = 0 computed > 0 user specified
44	[THK]	effective wall thickness
48	IM	material properties table relative number (type 20)
52	INLT	inlet type = 1 flush inlet = 2 scoop inlet = 3 nose inlet = 4 engine duct inlet

Sizing Component RØUT
Ram Air Outlet

Purpose: This component will compute weight, cost units, reliability index, development risk factor, outlet area, and volume for an outlet of a ram air duct.

Equations:

1. Weight:

   $$Wt = 4.5\ \rho\ t_e\ (1.0 + 1.69\ A_0^{1/2} + 1.2\ A_0)$$

2. Cost Units:

   $$CU = 13.0 + 0.139\ Wt^{1.65}$$

3. Reliability Index:

   $$RI = 0.00010$$

4. Development Risk Factor:

   $$DR = 1.0$$

5. Weight Standard Error:

   $$Wt_d = 0.25\ Wt$$

6. Installation Weight Factor:

   $$Wt_i = 0.205\ Wt$$

7. Volume

   $$V = 0.85\ A_0^{1.5}$$

8. Outlet Area:

   $$A_0 = (W/40.1248C_D)\left(\frac{\gamma}{\gamma-1}\ P_0\ \rho_0\right)^{1/2} \left[(PR)^{\frac{2}{\gamma}} - (PR)^{\frac{\gamma+1}{\gamma}}\right]^{1/2}$$

   $$PR = P_{ambient}/P_0$$

Required Table:

- Table ID (IM,20) - material properties

Restriction:

1. This component can only be used for fluid type 2.

Notes:

1. The component printout consists of weight, cost units, reliability index, development risk factor, and the following items:

W - flow rate

PI - inlet pressure

PØ - outlet pressure

TI - inlet temperature

TØ - outlet temperature

HI - inlet humidity

HØ - outlet humidity

FT - fluid type

FN - fluid properties table relative number

AØ - outlet area

VØL - volume

2. The values of volume and outlet area are stored in general arguments 71 and 72 respectively.

Sizing Component RØUT

Data Card Format

Card Column	Symbol	Value
1-4	CN	RØUT component name
8	CC	change code
12	NC	card number
16	NL	leg number
20	NSI	inlet station number
24	NSØ	outlet station number
28	[WTM]	weight multiplier (optional)
32	[CUM]	cost unit multiplier (optional)
36	[RI]	reliability index (optional)
40	[DRM]	development risk factor multiplier (optional)
44	[AØ]	outlet area = 0 computed > 0 user specified
48	[THK]	effective wall thickness
52	IM	material properties table relative number (table 20)
56	[CD]	discharge coefficient (not required if [AØ] > 0)

Sizing Component TURB

Turbine

Purpose: This component will compute weight, cost units, reliability index, development risk factor, volume, wheel diameter and/or shaft speed for an air cycle turbine (centrifugal or axial).

Equations:

1. Weight:
   $Wt = 0.4\ D^2$
2. Cost Units:
   $CU = 5.5\ Wt$
3. Reliability Index:
   $RI = 0.0$
4. Development Risk Factor:
   $DR = 1.0$
5. Weight Standard Error:
   $Wt_d = 0.164\ Wt$
6. Installation Weight Factor:
   $Wt_i = 0.205\ Wt$
7. Volume:
   $V = 0.6666667\ D^4$
8. Efficiency:
   $$\eta_{ad} = (T_{in} - \overline{T}_{out})/[T_{in}\ \{1.0 - (P_{out}/P_{in})^{\frac{\gamma-1}{\gamma}}\}]$$
9. Horsepower:
   $HP = 0.02356\ WC_p\ (T_{in} - \overline{T}_{out})$
10. Wheel Diameter (if not specified):
    $D = 12\ D_s\ Q^{1/2}/H^{1/4}$
    where
    $D_s = f\ (N_s, \eta_{ad})$ $(N_s - D_s - \eta_{ad}$ table)
    $Q = W/\rho_{in}$

$$H = 778\, C_p\, T_{in}\, [1.0 - (P_{out}/P_{in})^{\frac{\gamma-1}{\gamma}}]$$

$$N_s = N\, Q^{1/2}/H^{3/4}$$

11. Shaft speed (if not specified):

$$N = N_s\, H^{3/4}/Q^{1/2}$$

where N_s is found iteratively from $N_s - D_s - \eta_{ad}$ table by the generalized Newton Raphson method.

12. Tip speed:

$$U = 0.004363\, D\, N$$

Required Tables:

$(N_s - D_s - \eta_{ad})$ - Table ID (ND,37) - 3 or 33 dimensional, the first independent variable is N_s (argument type 0; argument relative number 59), the second independent variable is η_{ad} (argument type 0; argument relative number 60), and the dependent variable is D_s.

Restrictions:

1. This component can only be used for fluid type 2.

Notes:

1. If both shaft speed and wheel diameter are not specified, the built in limiting shaft speed is used for wheel diameter calculation. If this results in an excessive tip speed (a warning message "tip speed exceeds limiting value" is printed), the built in limiting tip speed is used to determine the wheel diameter and shaft speed iteratively by the generalized Newton Raphson method.
2. The component printout consists of weight, cost units, reliability index, development risk factor, and the following items:

   W - flow rate

   PI - inlet pressure

   PØ - outlet pressure

TI - inlet temperature

TØ - outlet temprature

HI - inlet humidity

HØ - outlet humidity

FT - fluid type

FN - fluid properties table relative number

D - wheel diameter

VØL - volume

N - shaft speed

EFF - efficiency

HP - horsepower

U - tip speed

NS - specific speed

DS - specific diameter

3. The reliability index and the development risk factor are accounted for in the component driven by the turbine.
4. If iteration is employed and the iteration dump option is selected, the following information is printed for each iteration:
   (a) State Variable (S.V.) - specific speed
   (b) Error Variable (E.V.) - if the conditions described in Note 1 occur, the printed value is the difference of the calculated tip speed and the limiting tip speed. If the wheel diameter is specified, the printed value is the difference of the calculated and the known specific diameters.
5. The convergence limit is 0.001. The upper and the lower limits for the state variable are 10,000 and 1.0, respectively.
6. The values of the wheel diameter and the compressor volume are stored in the general arguments 71 and 72, respectively. If rotational speed is determined, it will be stored in general argument (80 + NST).
7. The built in limiting rotational speed and the limiting tip speed are 60,000 rpm and 2,000 ft/sec, respectively. Users may override this by specifying a different value with a CØMMØN card.

Sizing Component TURB

Data Card Format

Card Column	Symbol	Value
1-4	CN	TURB component name
8	CC	change code
12	NC	card number
16	NL	leg number
20	NSI	inlet station number
24	NSØ	outlet station number
28	NST	shaft number
32	[WTM]	weight multiplier (optional)
36	[CUM]	cost unit multiplier (optional)
40	[RI]	reliability index (optional)
44	[DRM]	development risk factor multiplier (optional)
48	[D]	wheel diameter = 0 computed > 0 user specified
52	ND	$N_s - D_s - \eta_{ad}$ table relative number (type 37)
56	ITT	turbine type = 1 centrifugal = 2 axial

B20

Sizing Component VALVE

Valve

Purpose: This component will compute weight, cost units, reliability index, development risk factor, and inside diameter for valves.

IVT	Type
1	pneumatic butterfly
2	electric butterfly
3	45° stem poppet
4	60° stem poppet
5	90° stem poppet
6	split flapper check

Equations:

1. Weight:

For IVT = 1 through 6 and fluid type 1: liquid

$Wt = 1.1$

For IVT = 1 and fluid type 2: gas

$Wt = 2.68\ D - 1.0$ (steel)

$Wt = 0.7\ D + 0.35$ (aluminum, $D \leq 2.5$) 2.10lbs@2.5"D

$Wt = 1.26\ D - 1.05$ (aluminum, $D > 2.5$)

For IVT = 2 and fluid type 2:

$Wt = 1.14\ D + 0.9$ (steel)

$Wt = 0.56\ D + 1.1$ (aluminum)

For IVT = 3, 4, 5 and fluid type 2:

$Wt = 2.04\ D + 0.225$ (steel)

$Wt = 0.833\ D - 0.05$ (aluminum)

For IVT = 6 and fluid type 2:

$Wt = 0.625\ D - 0.625$ (steel)

$Wt = 0.33\ D - 0.38$ (aluminum)

2. Cost Units:

For IVT = 1 through 6 and fluid type 1:

$CU = 5.4$

For IVT = 1, 2 and fluid type 2:

$CU = 1.13\ (D\ Wt)^{1.11}$ ($D\ Wt > 17.5$)

$CU = 27.0$ ($D\ Wt \leq 17.5$)

For IVT = 3, 4, 5 and fluid type 2:

$CU = 8.4\ (D\ Wt)^{0.192}$ $(D\ Wt > 0.1)$

$CU = 5.4$ $(D\ Wt \leq 0.1)$

For IVT = 6 and fluid type 2:

$CU = 3.7\ (D\ Wt)^{0.193}$ $(D\ Wt > 0.1)$

$CU = 2.37$ $(D\ Wt \leq 0.1)$

3. Reliability Index:

For IVT = 1 through 6 and fluid type 1:

$RI = 0.00219$

For IVT = 1 and fluid type 2:

$RI = 0.0461$

For IVT = 2 and fluid type 2:

$RI = 0.07649$

For IVT = 3, 4, 5 and fluid type 2:

$RI = 0.05291$

For IVT = 6 and fluid type 2:

$RI = 0.0571$

4. Development Risk Factor:

$DR = 1.0 \quad (T \leq 1460°R,\ P \leq 364.7\ \text{psi})$

$$DR = 1.0 + \left(\frac{T-1460}{450}\right)^2 + \left(\frac{P-364.7}{585}\right)^2$$

$(T > 1460°R,\ P > 364.7\ \text{psi})$

5. Weight Standard Error:

For IVT = 1 through 6 and fluid type 1:

$Wt_d = 0.303\ Wt$ (steel)

$Wt_d = 0.348\ Wt$ (aluminum)

For IVT = 1 and fluid type 2:

$Wt_d = 0.35\ Wt$ (steel)

$Wt_d = 0.339\ Wt$ (aluminum)

For IVT = 2 and fluid type 2:

$Wt_d = 0.201\ Wt$ (steel)

$Wt_d = 0.174\ Wt$ (aluminum)

For IVT = 3, 4, 5 and fluid type 2:

$Wt_d = 0.303\ Wt$ (steel)

$Wt_d = 0.348\ Wt$ (aluminum)

For IVT = 6 and fluid type 2:

$Wt_d = 0.3\ Wt$ (steel)

$Wt_d = 0.359\ Wt$ (aluminum)

6. Installation Weight Factor:

   $Wt_i = 0.0$

7. Diameter (if not specified):

   $$D = [1.008 \times 10^{-3}\ K_t\ W^2/(\rho\ \Delta P)]^{0.25}$$

   where $K_t = 0.43$ for IVT = 1 & 2
   $= 2.74$ for IVT = 3
   $= 3.4$ for IVT = 4
   $= 6.5$ for IVT = 5
   $= 0.68$ for IVT = 6

Restrictions:

1. This component can only be used for fluid types 1 and 2.

Notes:

1. The component printout consists of weight, cost units, reliability index, development risk factor and the following items:

   W - flow rate
   PI - inlet pressure
   PØ - outlet pressure
   TI - inlet temperature
   TØ - outlet temperature
   HI - inlet humidity
   HØ - outlet humidity
   FT - fluid type
   FN - fluid properties table relative number
   D - inside diameter
   KT - pressure loss coefficient
   V - velocity
   M - Mach number (for fluid type 2 only)

2. Steel valve equations are used if inlet temperature is greater than or equal to T_{LM}. Aluminum valve equations are used if it is less than T_{LM}. The built in T_{LM} is 960°R. Users may override this by specifying a different T_{LM} with a CØMMØN card.

3. The minimum weight for IVT = 1 is 0.5. For IVT = 3 through 5, the minimum weight is 0.3. For IVT = 6, it is 0.25.
4. The values of inside diameter, velocity, and Mach number are stored in the general arguments 71, 72, and 73, respectively.

Sizing Component VALVE

Data Card Format

Card Column	Symbol	Value
1-5	CN	VALVE component name
8	CC	change code
12	NC	card number
16	NL	leg number
20	NSI	inlet station number
24	NSØ	outlet station number
28	[WTM]	weight multiplier (optional)
32	[CUM]	cost unit multiplier (optional)
36	[RI]	reliability index (optional)
40	[DRM]	development risk factor multiplier (optional)
44	[D]	inside diameter = 0 computed > 0 user specified
48	IVT	valve type = 1 butterfly, pneumatic = 2 butterfly, electric = 3 poppet, 45° stem = 4 poppet, 60° stem = 5 poppet, 90° stem = 6 check, split flapper

Sizing Component VCØMP
Vapor Cycle Compressor

Purpose: This component will compute weight, cost units, reliability index, and development risk factor for a vapor cycle compressor assembly, which includes the compressor, the drive, refrigerant charge, refrigerant lines, and the receiver. The available types of drives are:

IDT	Type
1	turbine
2	electric motor, AC
3	electric motor, DC
4	hydraulic motor

Equations:

1. Weight:

For compressor:

$$Wt_{comp} = 0.5\ Wt_{drive}$$

For refrigerant charge:

$$Wt_{rc} = \rho\ V_{rc}/1728$$

where

$$V_{rc} = 0.3\ V_{evap} + 0.6\ V_{cond} + 5.184W\ V_{in}$$

V_{in} = specific volume at compressor inlet

For receiver:

$$Wt_{r} = 0.012\ V_{rc}$$

For refrigerant lines:

$$Wt_{line} = (Wt_{drive} + Wt_{comp} + Wt_{evap} + Wt_{cond} + Wt_{r}) \times (0.1 + 0.01\ L)$$

2. Cost Units:

For IDT = 1:

$$CU = 5.5\ Wt_{comp}$$

For IDT = 2 & 3:

$$CU = 34.7 + 17.3\ (Wt_{comp} + Wt_{drive})$$

For IDT = 4

$$CU = 17.0 + 4.88\ (Wt_{comp} + Wt_{drive})$$

3. Reliability Index:

For IDT = 1:

$$RI = 0.02576$$

For IDT = 2 & 3:

$$RI = 0.00873$$

For IDT = 4:

$$RI = 0.02576$$

4. Development Risk Factor:

For IDT = 1:

$$DR = 1.15$$

For IDT = 2, 3, & 4:

$$DR = 1.0$$

5. Weight Standard Error:

For IDT = 1:

$$Wt_d = [(0.164\ Wt_{comp})^2 + (0.12\ Wt_r)^2 + (0.12\ Wt_{rc})^2 + (0.12\ Wt_{line})^2]^{1/2}$$

For IDT = 2:

$$Wt_d = [(0.1665\ Wt_{drive})^2 + (0.12\ Wt_r)^2 + (0.12\ Wt_{rc})^2 + (0.12\ Wt_{line})^2]^{1/2}$$

For IDT = 3:

$$Wt_d = [(0.388\ Wt_{drive})^2 + (0.12\ Wt_r)^2 + (0.12\ Wt_{rc})^2 + (0.12\ Wt_{line})^2]^{1/2}$$

For IDT = 4:

$$Wt_d = [(0.3\ Wt_{drive})^2 + (0.12\ Wt_r)^2 + (0.12\ Wt_{rc})^2 + (0.12\ Wt_{line})^2]^{1/2}$$

6. Installation Weight Factor:

$$Wt_i = 0.205\ (Wt_{drive} + Wt_{comp} + Wt_r)$$

7. Volume:

For IDT = 1

$$V = 0.2\ D^4_{turb}$$

For IDT = 2 & 3:

$$V = 10\ (Wt_{drive} + Wt_{comp})$$

For IDT = 4

$$V = 20\ (Wt_{drive} + Wt_{comp})$$

8. Compressor Horsepower:

$$HP = 0.02356\ W\ (H_{out} - H_{in})$$

9. Compressor Efficiency:

$$\eta = (H_s - H_{in})/(H_{out} - H_{in})$$

Restriction:

1. This component can only be used for fluid type 3.

Notes:

1. Refer to sizing subroutine CØMP section for equations pertinent to drives.
2. The component printout consists of weight, cost units, reliability index, development risk factor, and the following items:

W - flow rate
PI - inlet pressure
PØ - outlet pressure
TI - inlet temperature
TØ - outlet temperature
HI - inlet humidity
HØ - outlet humidity
FT - fluid type
FN - fluid properties table relative number
WTCD - weight of compressor with drive
WTR - weight of receiver
WTRC - weight of refrigerant charge
WTL - weight of refrigerant lines
VØL - volume of compressor with drive
N - shaft speed
EFF - compressor efficiency
HP - compressor fluid horsepower

Additional printout consists of drive type and the following items:

EFF - drive efficiency

HP - drive input horsepower

WT - drive weight

3. The refrigerant charge density is evaluated at 15°F below the compressor inlet temperature.
4. The value of volume is stored in general argument 71.

Sizing Component VCØMP

Data Card Format

Card Column	Symbol	Value
1-5	CN	VCØMP component name
8	CC	change code
12	NC	card number
16	NL	leg number
20	NSI	inlet station number
24	NSØ	outlet station number
28	NST	shaft number
32	[WTM]	weight multiplier (optional)
36	[CUM]	cost unit multiplier (optional)
40	[RI]	reliability index (optional)
44	[DRM]	development risk factor multiplier (optional)
48	[EV]	evaporator core volume
52	[CV]	condenser core volume
56	IDT	types of drives = 1 turbine = 2 electric motor, AC = 3 electric motor, DC = 4 hydraulic motor
60	[D]	turbine wheel diameter (not required if IDT $\neq$ 1)
64	-	
68	[L]	line length between evaporator and condenser
72	[CWT]	condenser weight
76	[EWT]	evaporator weight

Sizing Component WSEP

Water Separator

Purpose: This component will compute weight, cost units, reliability index, development risk factor, and volume for water separators.

Equations:

1. Weight:

   $Wt = 0.0936\ W$

2. Cost Units:

   $CU = 18.82 + 2.08\ Wt$

3. Reliability Index:

   $RI = 0.00285$

4. Development Risk Factor:

   $DR = 1.0$

5. Weight Standard Error:

   $Wt_d = 0.173\ Wt$

6. Installation Weight Factor:

   $Wt_i = 0.205\ Wt$

7. Volume:

   $V = 2.11\ W^{1.5}$

Restrictions:

1. This component can only be used for fluid type 2.

Notes:

1. The component printout consists of weight, cost units, reliability index, development risk factor, and the following items:

   W - flow rate
   PI - inlet pressure
   PØ - outlet pressure
   TI - inlet temperature
   TØ - outlet temperature
   HI - inlet humidity
   HØ - outlet humidity
   FT - fluid type
   FN - fluid properties table relative number
   VØL - volume

2. The value of volume is stored in general argument 71.

Sizing Component WSEP

Data Card Format

Card Column	Symbol	Value
1-4	CN	WSEP component name
8	CC	change code
12	NC	card number
16	NL	leg number
20	NSI	inlet station number
24	NSØ	outlet station number
28	[WTM]	weight multiplier (optional)
32	[CUM]	cost unit multiplier (optional)
36	[RI]	reliability index (optional)
40	[DRM]	development risk factor multiplier (optional)