

Mechanical Engineering Review Manual

Programmed in
Library Application Card for
HP48GX



CHOTKEH

Mechanical Engineering Review Manual

Programmed in
Library Application Card for
HP48GX/SX

Mechanical Engineering Review Software Package.
Version (6.0)

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TABLE OF CONTENTS

<u>SECTION</u>	<u>DIRECTORY</u>	<u>SUB DIRECTORY(s)</u>	<u>PAGE</u>
<u>ABOUT THE MANUAL AND CALCULATOR</u>			1
<u>1 - COMBUSTION (ENG & SI):</u>			
AIR & EXCESS AIR, REQUIRED	CMBS	AIR	1-1
BINARY COMPOUND EQUATION	CMBS	BI.EQ	1-1
BOILERS & HEATERS	CMBS	HEATR	1-1
HEAT BALANCE	CMBS	HTBAL	1-1
HEAT OF COMBUSTION & HEAT VALUE	CMBS	NTVAL	1-2
HEAT LOSS	CMBS	HTLOS	1-2
IDEAL GAS EQUATIONS	CMBS	I.GAS	1-3
POWER PLANTS	CMBS	PLANT	1-3
STACKS	CMBS	STAK	1-4
GAS PROPERTIES TABLE (In manual only)	CMBS	-	1-5
<u>2 - DUCTS (ENG & SI):</u>			
FLOW PARAMETERS	DUCT	FLOW	2-1
EQUAL FRICTION LOSS DIMENSION	DUCT	EQL.F	2-1
FRICTION LOSS	DUCT	F.LOS	2-1
MINOR LOSS	DUCT	MINOR	2-2
STATIC REGAIN	DUCT	RGAIN	2-2
VELOCITY PRESSURE	DUCT	VEL.P	2-2
<u>3 - ELECTRICITY (ENG+COMMON):</u>			
BATTERIES IN PARALLEL	ELEC	BATT	3-1
CAPACITORS	ELEC	CAPC	3-1
IMPEDANCE	ELEC	IMPD	3-1
INDUCTORS	ELEC	INDC	3-2
KIRCHOFF'S LAW	ELEC	KIRC	3-2
MOTORS:			
- Elevators	ELEC	MOTR/ELEV	3-3
- Power	ELEC	MOTR/POWR	3-3
- Pumps	ELEC	MOTR/PUMP	3-4
POWER	ELEC	POWR	3-4
POWER FACTOR AND PF CORRECTION	ELEC	PFAC	3-5
RESISTORS	ELEC	RESI	3-5
RESONANCE	ELEC	RESO	3-6
TRANSIENTS	ELEC	TRNS	3-6
VOLTAGE DROP	ELEC	VDRP	3-7
<u>4 - ENGINEERING ECONOMICS:</u>			
EQUIVALENT UNIFORM ANNUAL COST	ENEC	ANNU	4-1
BONDS	ENEC	BOND	4-1
CAPITALIZED COST	ENEC	CAPIT	4-1
COMPOUND FACTORS/VALUES	ENEC	FACTR	4-2
DEPRECIATION (DDB, SF, SL, SOYD)	ENEC	DEPRI	4-2
INTEREST RATE/INFLATION	ENEC	INTER	4-3
MORTGAGE	ENEC	MORT	4-4
PRESENT WORTH	ENEC	PW	4-4
RATE OF RETURN	ENEC	ROR	4-5

TABLE OF CONTENTS

<u>SECTION</u>	<u>DIRECTORY</u>	<u>SUB DIRECTORY(s)</u>	<u>PAGE</u>
<u>5 - FANS (ENG & SI):</u>			
AIR PRESS. & TEMP. AT ALTITUDES	FANS	ALTIT	5-1
DENSITY OF AIR	FANS	DENSI	5-1
EFFICIENCY	FANS	EFFI	5-1
HORSEPOWER:			
- Air	FANS	HP/AIR	5-2
- Brake	FANS	HP/BRAK	5-2
LAWS EQUATIONS	FANS	LAW	5-3
PRESSURE	FANS	PRESS	5-3
SIMILARITY EQUATIONS	FANS	SIMIL	5-4
SYSTEM'S CHARACTERISTICS CURVE	FANS	CURVE	5-5
<u>6 - GEARS (ENG & COMMON):</u>			
BEVEL GEARS:			
- Load	GEAR	BEVEL/LOAD	6-1
- Stress	GEAR	BEVEL/STRES	6-1
SPUR GEARS:			
- Diametral pitch	GEAR	SPUR/DIA.P	6-1
- Load	GEAR	SPUR/LOAD	6-1
- Stress	GEAR	SPUR/STRES	6-1
GENERAL EQUATIONS:			
- Horsepower	GEAR	GNRL/HRSP	6-2
- Load transmitted	GEAR	GNRL/LOAD	6-2
- Torque	GEAR	GNRL/TORQ	6-2
- Velocity	GEAR	GNRL/VELO	6-2
TABLES OF VALUES AND FACTORS:			
- Deformation Factor	GEAR	TABLE/DEFOR	6-3
- Error values	GEAR	TABLE/EROR	6-3
- Fatigue Factor	GEAR	TABLE/FATIG	6-3
- Form Factor (Lewis)	GEAR	TABLE/FORM	6-3
- Surface Endurance Limit	GEAR	TABLE/ENDU	6-3
<u>7 - HEAT TRANSFER</u>			
COEFFICIENT OF HEAT TRANSFER	HIT.TR	UCOEF	7-1
FILM COEFFICIENT	HIT.TR	FILMC	7-1
HEAT EXCHANGERS	HIT.TR	HIT.EX	7-1
HEAT FLOW THROUGH:			
- Films	HIT.TR	HIT.FL/FILM	7-2
- Pipes	HIT.TR	HIT.FL/PIPE	7-3
- Slabs	HIT.TR	HIT.FL/SLAB	7-3
IDEAL GAS	HIT.TR	IDEAL	7-4
INTERPOLATION	HIT.TR	INTRP	7-4
RADIANT HEAT FLOW:			
- Radiation	HIT.TR	RADIA	7-4
- Thermocouple	HIT.TR	RADIA/COUPL	7-4
REYNOLDS NUMBER	HIT.TR	REYN	7-5
STEAM PARAMETERS	HIT.TR	STIM	7-5
TRANSIENT HEAT FLOW	HIT.TR	TRNS	7-5
PROPERTIES OF WATER (Tables in manual)			7-9,10

TABLE OF CONTENTS

<u>SECTION</u>	<u>DIRECTORY</u>	<u>SUB DIRECTORY(s)</u>	<u>PAGE</u>
<u>8 - HVAC:</u>			
ATMOSPHERIC AIR	HVAC	AIR/ATMO	8-1
AIR FLOW RATE	HVAC	AIR/FLOW	8-1
AIR MIXTURE PROPERTIES	HVAC	AIR/MIXTR	8-2
BYPASS FACTOR	HVAC	BYPAS	8-3
CHILLERS	HVAC	CHILR	8-3
COEFFICIENT OF HEAT TRANSFER	HVAC	UCOEF	8-3
COILS	HVAC	COIL	8-3
ENERGY EFFICIENCY RATIO	HVAC	EER	8-3
EXCHANGERS (Air Washers, Cooling Towers, Sprayers)	HVAC	AIR/SPRAY	8-4
FUEL CONSUMPTION	HVAC	FUEL	8-4
HEAT:			
- Heat added	HVAC	HEAT/ADD	8-5
- Heat gained	HVAC	HEAT/GAIN	8-5
- Heat loss	HVAC	HEAT/LOSS	8-6
HUMIDIFIER	HVAC	HUMID	8-6
IDEAL GAS EQUATION	HVAC	IDEAL	8-6
INTERPOLATION	HVAC	INTRP	8-6
ROOM SENSIBLE HEAT RATIO	HVAC	RSHR	8-6
STEAM AND WATER MIXTURE	HVAC	STIM	8-6
TONS OF REFRIGERATION	HVAC	TONR	8-6
<u>9 - HYDRAULIC MACHINES (ENG & SI):</u>			
AFFINITY	HYDM	AFFIN	9-1
BERNOULLI EQUATIONS	HYDM	BERN	9-1
FRICTION FACTOR (Moody's Chart)	HYDM	FRIC.F	9-2
FRICTION HEAD	HYDM	FRIC.H	9-2
HEAD	HYDM	HEAD	9-3
PIPES (Area, Flow rate, Velocity)	HYDM	PIPE	9-3
PUMPS:			
- Head added by	HYDM	PUMP/HEAD	9-4
- Horsepower	HYDM	PUMP/HP	9-4
- Net Positive Suction Head	HYDM	PUMP/NPSH	9-5
- Resistance Head	HYDM	PUMP	9-5
- Specific Speed	HYDM	PUMP/SPC.S	9-5
REYNOLDS NUMBER	HYDM	REYN	9-5
TURBINES HORSEPOWER	HYDM	TURB/HP	9-5
<u>10 - POWER CYCLE (ENG & SI)</u>			
COMPRESSORS:			
- Displacement	PCYCL	COMP/DISP	10-1
- Enthalpy	PCYCL	COMP	10-2
- Power	PCYCL	COMP/POWR	10-2
- Work	PCYCL	COMP	10-2
EFFICIENCY:			
- Carnot	PCYCL	EFFI/CARNO	10-3
- Compressor	PCYCL	EFFI/COMP	10-3
- Gas turbine	PCYCL	EFFI	10-3
- Internal Combustion Engines	PCYCL	EFFI/ENGN	10-3
- Steam turbine	PCYCL	EFFI	10-3
- System	PCYCL	EFFI/SYST	10-4
GAS EQUATIONS	PCYCL	GAS	10-4

TABLE OF CONTENTS

<u>SECTION</u>	<u>DIRECTORY</u>	<u>SUB DIRECTORY(s)</u>	<u>PAGE</u>
<u>10 - POWER CYCLE, Continued (ENG & SI):</u>			
GAS TURBINES:			
- Combustors	PCYCL	G.TURB/CMBS	10-4
- Enthalpy	PCYCL	G.TURB	10-4
- Power	PCYCL	G.TURB/POWR	10-5
- Work	PCYCL	G.TURB/WORK	10-5
INTERPOLATION	PCYCL	INTRP	10-5
INTERNAL COMBUSTION ENGINES:			
- Car	PCYCL	ENGN/CAR	10-5
- Engine displacement	PCYCL	ENGN/DISP	10-6
- Fuel Consumption	PCYCL	ENGN/FC	10-6
- Indicated horsepower	PCYCL	ENGN/IHP	10-6
- Specific Fuel Consumption	PCYCL	ENGN/SFC	10-7
- Volume clearance	PCYCL	ENGN	10-7
REFRIGERATION (ENG & Common)			
- Cooling capacity	PCYCL	REFRI/CAPAC	10-7
- Coefficient Of Performance	PCYCL	REFRI/COP	10-7
- Condenser	PCYCL	REFRI/COND	10-7
- Energy Efficiency Ratio	PCYCL	REFRI/EER	10-7
- Evaporators	PCYCL	REFRI/EVAP	10-7
STEAM TURBINES:			
- Boiler/Heat Exchanger	PCYCL	S.TURB/COMS	10-8
- Enthalpy	PCYCL	S.TURB/ENTH	10-8
- Mixture of steam and water	PCYCL	S.TURB/MIXT	10-8
- Power	PCYCL	S.TURB/POWR	10-8
- Pre-Heater	PCYCL	S.TURB/PREHT	10-8
- Pump-feeder	PCYCL	S.TURB/PUMP	10-9
- Rate of Heat and steam	PCYCL	S.TURB/RATE	10-9
- Work	PCYCL	S.TURB/WORK	10-9
<u>11 - SCREWS:</u>			
ACME SCREWS	SCRW	ACME	11-1
SQUARE SCREWS	SCRW	SQUR	11-1
MISCELLANEOUS:			
- Bearing pressure	SCRW	MSCL	11-1
- Stress	SCRW	MSCL	11-1
<u>12 - SPRINGS:</u>			
COIL SPRING			
- Critical load/frequency	SPRIN	COIL/CRTIC	12-1
- Deflection	SPRIN	COIL/DFLEC	12-1
- Diameter, mean	SPRIN	COIL/DIAM	12-1
- Length	SPRIN	COIL/LNTH	12-1
- Load/Force	SPRIN	COIL/LOAD	12-1
- Number of active coils	SPRIN	COIL/NUMB	12-1
- Wire diameter	SPRIN	COIL/WIRE	12-1
CONSTANT/RATE:			
- Equivalent Spring Constant	SPRIN	CONS/EQUIV	12-1
- spring Constant	SPRIN	CONS/RATE	12-2
SHEAR STRESS	SPRIN	SHEAR	12-2
WORK	SPRIN	WORK	12-2
<u>13 - WELDING:</u>			
LOAD	WELD	LOAD	13-1
STRESS	WELD	STRS	13-1

TABLE OF CONTENTS

<u>SECTION</u>	<u>DIRECTORY</u>	<u>SUB DIRECTORY(s)</u>	<u>PAGE</u>
<u>14 - AIR AND STEAM TABLES:</u>			
INTRODUCTION, GUIDELINES, AND EXAMPLES	--	--	14-1
AIR:			
- Enthalpy	AIR	ENTH	14-5
- Entropy	AIR	ENTR	14-5
- Internal Energy	AIR	ENRG	14-5
- Pressure Ratio	AIR	PR	14-5
- Volume Ratio	AIR	VR	14-5
SATURATED STEAM, WITH TEMPERATURE:			
- Absolute Pressure	SAT.T	ABS.P	14-5
- Specific Volume	SAT.T	SPC.V	14-5
- Enthalpy	SAT.T	ENTH	14-5
- Entropy	SAT.T	ENTR	14-5
SATURATED STEAM, WITH PRESSURE:			
- Temperature	SAT.P	TEMP	14-6
- Specific Volume	SAT.P	SPC.V	14-6
- Enthalpy	SAT.P	ENTH	14-6
- Entropy	SAT.P	ENTR	14-6
- Internal Energy	SAT.P	ENRG	14-6
SUPER HEATED STEAM:			
- Specific Volume	SUPHT	SPC.V	14-6
- Enthalpy	SUPHT	ENTH	14-6
- Entropy	SUPHT	ENTR	14-6
 <u>15 - PSYCHOMETRIC CHART:</u>			
INTRODUCTION, GUIDELINES, AND EXAMPLES	--	--	15-1
WET BULB TEMPERATURE	PSYCH	WET.B	15-1
RELATIVE HUMIDITY	PSYCH	REL.H	15-1
ENTHALPY	PSYCH	ENTH	15-1
SPECIFIC HUMIDITY	PSYCH	SPC.H	15-1
SPECIFIC VOLUME	PSYCH	SPC.V	15-1
DEW POINT	PSYCH	DEW.P	15-1
TABLE OF PROPERTIES	--	--	15-2

ABOUT THE MANUAL AND CALCULATOR

This manual contains over 670 engineering fundamental equations all of which are programmed into a 256 K plug-in Application Library ROM Card for the use by HP48GX. HP48SX may used with two (2) cards or the 256 K card inserting in slot (1) for text materials or slot (2) for the tables described below:

It also includes the Air Tables, Steam Tables, and Psychometric Charts, containing over 600 equations.

This upgraded version also makes it possible to use the International System (SI) too.

HOW TO USE THE CALCULATOR:

1. The key board:

There are three (3) types of distinctive function keys in HP48:

- 1.1 The hard keys with their functions showed on the face of the keys. They are activated by pressing the key. Throughout this manual, they are identified by bold letters and underlined, like **ENTER**, **NXT**, **SIN**, **EVAL**, **ON**, etc.
- 1.2 The same hard keys with their colored functions showed at the top of the keys. To activate the function, the corresponding color coded  or  must be pressed prior to the subject key. They are identified by underlined symbols (not bold), like LIBRARY, MENU, PREV, POLAR, etc.
- 1.3 The soft keys or screen menu keys. There are six (6) blank (white) keys located at the bottom of the screen. To activate the menu item, press the corresponding soft key. The screen menu items (Directories, Sub-directories, and Equation's name) are identified with plain capital letters (no bold no underline), like PUMP, HYDM, FANS, EXPR =, THER, etc.

2. Useful keys and their functions:

The user must ensure to use the implied  or  key, as needed.

ARG To get back to the last arguments. This symbol is only underlined, means the corresponding  key must be pressed first.

CLEAR To clear the screen. Use of  is not necessary.

CMD In HP48GX, to copy the last operation to stack.
In HP48GX, to select and display the last four (4) operations.

EDIT To edit the object on level 1.

ABOUT THE MANUAL AND CALCULATOR

<u>ENTER</u>	To enter the data. Or to duplicate the object on level 1
EXPR=	To calculate a complex number. May need to be followed by <u>NUM</u> to get the answer. This symbol is neither bold nor underlined, means that this is a screen menu item. To activate, press the corresponding soft (white blank) key.
<u>HOME</u>	To return back to HOME directory.
<u>LIBRARY</u>	To get to the Library to use the Application Card.
<u>MENU</u>	To get back to previous menu.
<u>NUM</u>	To find the numeric value of the answer/object.
NXEQ are	To rotate the list of related equations written under one name. The name of these equations followed by $\rightarrow$, i.e. HP$\rightarrow$, FLO$\rightarrow$, Δs$\rightarrow$, etc.
<u>NXT</u>	To go to the next page of the screen menu.
<u>OFF</u>	To turn the calculator off.
<u>ON</u>	To turn the calculator on.
<u>ON</u>	To cancel, exit the command, or get off the existing mode.
<u>POLAR</u>	To turn the Rectangular coordinate to Polar coordinate. Press <u>POLAR</u> once more to get back to Rectangular mode.
<u>PREV</u>	To return back to the previous page of screen menu.
<u>PURG(E)</u>	To purge the selected variable(s).
<u>REVIEW</u>	For HP48SX only, to view the current equation and corresponding variables. Press <u>ON</u> to get off.
<u>SPC</u>	To create space between the keyed-in data.
<u>SWAP</u>	Two swap the objects in level one (1) and level two (2). Use of $\leftrightarrow$ is not necessary.

ABOUT THE MANUAL AND CALCULATOR

- UP To get back to one (1) level higher directory.
- ↪ VIEW For HP48GX only, to view the current equation and corresponding variables.
Press ON to get off.
- () Use to identify/enter the value as a complex number. The real and the imaginary part must be separated by "**comma**" or "**SPC**". When writing the expression, use "**comma**" only. But you may use either of them when entering components of complex numbers inside parenthesis.
-  This hard key is located above the SIN key. By pressing this (Tick Mark) key the HP48 calculator will turn to a regular calculator. Enter any numerical expression and press EVAL for answer. Also use when writing an equation or an expression.
- Δ The symbol of angle, to be used when entering the complex numbers in Polar coordinates.
- α Use to turn the calculator to alphabetical mode. If the key pressed twice, the calculator will stay in this mode. Press again when typing is finished. The key may also be pressed and hold during the typing. Then release, when typing is over.

3. How to identify the name, retrieve, and solve the equation:

- 3.1 In the solution part of every problem, in Problems and Solutions Book, following statement is used to refer to the subject equation, i.e. using DARCY equation to calculate the friction head with the given flow rate in **gpm**, which is in English System (**ENG**).
- " Refer to equation (16) **GPM** (HYDM/FRIC.H/DARCY/ENG)." (16) is the number and **GPM** is the name of the equation. HYDM is the main directory for Hydraulic Machines, FRIC.H Sub-directory for Friction Head, DARCY is for Darcy equation, and ENG is for English system. Therefore after getting to LIBRARY, press HYDM FRIC.H DARCY ENG GPM.
- Now, by knowing what to look for, get to LIBRARY.
- 3.2 LIBRARY To get to the Library. You should see the menu on the screen.
- 3.3 Look up for the subject directory on the screen menu. You have to go to the subject directory first. If not found, press NXT. When found, press the corresponding soft key.

ABOUT THE MANUAL AND CALCULATOR

- 3.4 Follow the same instruction for sub-directory(s). In few occasions there are more than two (2) sub-directories prior to equation's name.
- 3.5 Find the **equation/expression** name and press the corresponding soft key. The equations with their names followed by $\rightarrow$, contain more than one equation. See NXEQ in page 2.
- 3.6 You should see the equation's variables listed on the screen menu and the equation, in whole or in part, at the top of the screen. If there are more than six (6) variables in the equation, press NXT to see the rest.
- 3.7 The "EXPR=" symbol is the last on the screen menu. If the equation has more than five (5) variables, press NXT.

NOTE: Throughout the manual, the equation's **directory/sub-directory** names are shown in parenthesis at the right side of the subject's title.

- 3.8 Enter the variable's value: Key in the value and press the corresponding variable's soft key. You should see the variables symbol and its entered value at the top of the screen. If not correct, enter the correct value again. When finished, press $\leftarrow$ and unknown variable's soft key. The answer will appear.

The holders of HP48GX may also use the solver's screen feature. Press $\rightarrow$ SOLVE ENTER. Highlight the variables and input the values. Then highlight the unknown variable and press SOLVE soft key. If the known variable's value needed to be calculated or unit conversion feature must be used, the user must quit the screen and get back, when the calculation or conversion was performed. This is a time consuming process. Press ON to quit the screen.

IMPORTANT NOTE: For the equations with complex numbers, which are programmed in the expression form (only in ELECTRICITY SECTION), you will not find the unknown's symbol on the screen. You have to press EXPR= (on the screen menu) and then NUM, if necessary.

- 3.9 If you have to retrieve another equation in the same sub-directory, press MENU and continue as directed above. Otherwise press LIBRARY for other directories.

ABOUT THE MANUAL AND CALCULATOR

- 3.10 After you retrieved the equation, if you observed any inconsistency between the variables in the equation and the ones on the screen menu, first ensure that you retrieved the right equation. If the answer is yes, refer to NOTE 3 below.

NOTE 1:

Except for the complex number contained equations/expressions, every equation can be solved for any variable in the equation, if the rest are known.

NOTE 2:

When using CHOTKEH's Library Card, stay in HOME directory. To use the calculator's built-in EQ-LB, other Library cards, or to write new equations/programs, a new directory, i.e. EQLB, should be created and used for this purpose.

For HP48GX: Press  type EQLB press  MEMORY DIR CRDIR.

For HP48SX: Press  type EQLB press  MEMORY CRDIR.

Press VAR, EQLB will appear on the screen menu. Press the corresponding soft key, the { HOME EQLB } will appear at the top of the screen, which means that the calculator is in EQLB directory. Use EQ-LB or write your own equations in this directory. To get back to HOME, press  UP.

NOTE 3:

Do not enter the variable's value accompanied with the unit sign, i.e. for L=2 feet, enter 2 not 2_ft. The variables' value must all be numeric and consistent. If by error the values are followed by unit signs or the values are represented by an expression, etc., you may get the "Bad Guess" error message or may lose the variable on the menu. This situation may also occur if any of the EQ-LB equations are solved in HOME directory. If that happened:

- Purge the variable: key in  type variable's name press PURG(E). If did not work:
- Press VAR press  twice type CLVAR press ENTER. This process will purge all variables in the current directory. If did not work:
- Press ON A F keys simultaneously and release. Press soft key under NO. This will re-set the calculator and clears the entire memory. If you have any equation or Directory you want to hold. This is not a right approach.

NOTE 4:

Although enough care has been taken in compiling the contents of this manual, writing the programs, and problems and solutions, the preparer assumes no responsibility resulting from any error or omission in this manual, program, or problems and solutions. The contents of this manual and the associated application card is subject to change without prior notice.

NOTE 5:

For installation of Application Library Card, refer to Hewlett Packard HP48 User's Guide or FAQ sheet.

COMBUSTION

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>AIR: (CMBS/AIR)</u>		
<u>Mass of combustion air: (CMBS/AIR/MASS)</u>		
(01) Liquid fuel	$m_a = m_f (34.34 (\frac{W.C}{3} + W.H2 + \frac{W.S2}{8}) - W.O2) (1 + XAIR)$	<i>LIQID</i>
(02) Solid fuel	$m_a = m_f * 34.34 (\frac{W.C}{3} + W.H2 + \frac{W.S2}{8} - \frac{W.O2}{8}) (1 + XAIR)$	<i>SOLID</i>
(03) Volume of combustion air for Natural Gas (NG)		<i>VOLU</i>
	$V_a = \frac{V_{so}}{100} (9.52MET\% + 7.14H2S\% + 2.38(H2\% + CO\%) - 4.785O2\% + 14.29ET\% + 16.67H\% + 23.82PRO\% + 30.96BUT\%)$	
(04) Excess air	$XAIR = \frac{V.O2 - .5V.CO}{.264V.N2 - V.O2 + .5V.CO}$	<i>EXAIR</i>

(05) Binary Compound Equation	$W_1 = W_2 \frac{NA_1}{NA_2} * \frac{AW_1}{AW_2}$	<i>BI.EQ</i>
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BOILERS/HEATERS: (CMBS/HEATR)

Amount of heated water: (CMBS/HEATR/WATR)

(06) English system	$m_w = \frac{m_f * HV * \eta}{t_{out} - t_{in}}$	<i>ENG</i>
(07) SI system	$m_w = \frac{m_f * HV * \eta}{4186.8(t_{out} - t_{in})}$	<i>SI</i>
(08) Amount of generated steam	$m_{st} = \frac{m_f * HV * \eta}{h_{st} - hf_w}$	<i>STIM</i>
(09) Amount of heated air	$m_a = \frac{m_f * HV * \eta}{cp_a(t_{out} - t_{in})}$	<i>AIR</i>

HEAT BALANCE: (CMBS/HTBAL)

(10) English system	$m_f * HV(1 - \eta) + m_a * cp_a(t_{sup} - t_{amb}) = m_g * cp_g(t_g - t_{amb}) + 970 * m_{H_2O}$	<i>ENG</i>
(11) SI system	$m_f * HV(1 - \eta) + m_a * cp_a(t_{sup} - t_{amb}) = m_g * cp_g(t_g - t_{amb}) + 2.256EE6 * m_{H_2O}$	<i>SI</i>

COMBUSTION

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>HEAT OF COMBUSTION/VALUE (GROSS OR HIGH HEAT): (CMBS/HTVAL)</u>		
<u>Coal: (CMBS/HTVAL/COAL)</u>		
Dulong's formula for coal, 2% to 3% accuracy compared to calorimeter values.		
(12) English system	$HV = 14093 * W.C + 60958 (W.H_2 - \frac{W.O_2}{8}) + 3983 * W.S_2$	ENG
(13) SI system	$HV = 3.278EE7 * W.C + 1.418EE8 (W.H_2 - \frac{W.O_2}{8}) + 9.246EE6 * W.S_2$	SI
(14) Fuel Oil: Look up table for approximate heating value of: Fuel oil No. 1, No. 2, No. 4, No. 5L, No. 5H, and No. 6		F.OIL
(15) Gaseous fuels: Look up table for approximate heating value of: Butane (C4H10), Ethane (C2H6), Ethylene (C2H4), Methane (CH4), Natural Gas, Propane (C3H8), CO, H2, H2S		GAS
(16) Solid fuels: Look up table for heating value of Carbon (C) and Sulfur (S)		SOLID
<u>HEAT LOSS: (CMBS/HTLOS)</u>		
(17) In dry flue gas	$q = m_g * c_{p_g} (t_g - t_{amb})$	FLUE
<u>In incomplete combustion: (CMBS/HTLOS/INCOMP)</u>		
(18) English Units	$q = \frac{9746 * W.C + V.CO}{V.CO_2 + V.CO}$	ENG
(19) SI Units	$q = \frac{2.267EE7 * W.C + V.CO}{V.CO_2 + V.CO}$	SI
<u>In carbon left in fuel ash: (CMBS/HTLOS/CARB)</u>		
(20) English Units	$q = \frac{14093 * m_{ash} * C_{ash}}{m_f}$	ENG
(21) SI Units	$q = \frac{3.278EE7 * m_{ash} * C_{ash}}{m_f}$	SI
<u>In water vapor: (CMBS/HTLOS/VAPOR)</u>		
(22) Existed in the air	$q = H_s * m_{da} (hg_g - hg_a)$	IN AIR
(23) Formed as a product	$q = 9 * H_2 (hg_g - h_f)$	PRDCT

COMBUSTION

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>IDEAL GAS LAW: (CMBS/I.GAS)</u>		
(24) With the given mass	$p \cdot V = m \cdot R \cdot T$	MASS
<u>With the given mole: (CMBS/I.GAS/MOLE)</u>		
(25) English Units	$p \cdot V = 1545.3 \cdot n \cdot T$	ENG
(26) SI Units	$p \cdot V = 8314 \cdot n \cdot T$	SI

POWER PLANT: (CMBS/PLANT)

Condenser (CMBS/PLANT/CONDN)

Flow Of Cooling Water: (CMBS/PLANT/CONDN/FLOW)

(27) English System	$cfs = \frac{q_{in} - 3413 \frac{kW}{\eta_{GEN}}}{224640 \Delta t}$	ENG
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(28) SI System	$lps = \frac{q_{in} - 3.6EE6 \frac{kW}{\eta_{GEN}}}{1.507EE7 \cdot \Delta t}$	SI
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Temperature Difference: (CMBS/PLANT/CONDN/ ΔT)

(29) English System	$\Delta t = \frac{q_{in} - \frac{3413 kW}{\eta_{GEN}}}{224640 \cdot cfs}$	ENG
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(30) SI System	$\Delta t = \frac{q_{in} - \frac{3.6EE6 kW}{\eta_{GEN}}}{1.507EE7 \cdot lps}$	SI
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Power Generated: (CMBS/PLANT/POWR)

(31) English System	$kW = \frac{q_{in} - q_{out}}{3413} \eta_{GEN}$	ENG
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(32) SI System	$kW = \frac{q_{in} - q_{out}}{3.6EE6} \eta_{GEN}$	SI
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COMBUSTION

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>STACK: (CMBS/STAK)</u>		
(33) Area	$area = \frac{V}{v_a}$	AREA
<u>Stack Effect: (CMBS/STAK/EFFECT)</u>		
(34) English Units	$effect = \frac{P \cdot H}{R} \left(\frac{1}{T_a} - \frac{1}{T_g} \right)$	ENG
(35) SI Units	$effect = \frac{9.8146 P \cdot H}{R} \left(\frac{1}{T_a} - \frac{1}{T_g} \right)$	SI
(36) Head	$head = H \left(\frac{T_g}{T_a} - 1 \right)$	HEAD
<u>Velocity of gas: (CMBS/STAK/VELO)</u>		
(37) Velocity of gas, actual	$v_a = c_v \left(2g \cdot H \left(\frac{T_g}{T_a} - 1 \right) \right)^{.5}$	ACTU
(38) Velocity of gas, ideal	$v_i = \left(2g \cdot H \left(\frac{T_g}{T_a} - 1 \right) \right)^{.5}$	IDEAL

COMBUSTION

GAS PROPERTIES (14.7 psia, 68 oF; 1 atm, 20 oC)

GAS	SYMBL	MW	R ENG/SI	cp ENG/SI	cv ENG/SI	k	DENS ENG/SI
Acetylene	C2H2	26	59.4/ 320	.350/1465	.2737/1145	1.3	.0675/1.0812
Air	---	29	53.3/ 287	.240/1005	.1714/ 718	1.4	.0752/1.2046
Ammonia	NH3	17	91.0/ 490	.523/2190	.4064/1702	1.32	.0441/.7064
Carb. diox.	CO2	44	35.1/ 189	.205/858	.1599/ 669	1.28	.1142/1.8293
Carb. monox.	CO	28	55.2/ 297	.243/1017	.1721/ 721	1.40	.0726/1.1629
Chlorine	CL2	71	21.8/ 117	.115/481	.0865/ 362	1.33	.1839/2.9458
Ethane	C2H6	30	51.3/ 276	.422/1767	.357/1495	1.18	.0781/1.2510
Ethylene	C2H4	28	55.1/ 296	.400/1675	.3292/1378	1.22	.0728/1.1661
Freon (R-12)	CCL2F2	121	12.6/ 68	---	---	1.13	.3182/5.0971
Helium	He	4	386.3/2078	1.25/ 5234	.754/ 3157	1.66	.0104/.1666
Hydrogen	H2	2	766.8/4126	3.42/14319	2.435/10195	1.41	.0052/0.0833
Methane	CH4	16	96.4/ 519	.593/ 2483	.4692/1964	1.32	.0416/0.6664
Nitrogen	N2	28	55.2/ 297	.247/ 1034	.1761/737	1.40	.0726/1.1629
Oxygen	O2	32	48.3/ 260	.217/ 909	.1549/649	1.40	.0830/1.3295
Propane	C3H8	44	35.0/ 188	.404/ 1691	.360/1507	1.12	.1145/1.8341
Hydrog. Sulf.	SH2	34	45.2/ 243	---	---	---	.0887/1.4208
Sulf. diox.	SO2	64	24.0/ 129	.154/ 645	.123/515	1.26	.1670/2.6751
Steam	H2O	18	85.8/ 462	.460/1926	.360/1507	1.28	---

COMBUSTION

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT (ENG, SI)</u>
<u>A</u>	Stack's section area; <u>ft²</u> , <u>m²</u> (1 ft ² =0.0929 m ²).
<u>AW</u>	Atomic Weight of element; <u>None</u> .
<u>Cash</u>	Percent of Carbon in ash; <u>decimal</u> .
<u>cpa</u>	Air specific heat at constant pressure; <u>BTU/lbm-oR</u> , <u>J/kg.K</u> (1 BTU/lbm-oR=4186.8 J/kg.K).
<u>cpg</u>	Flue gas mean spec. heat at constant pressure; <u>BTU/lb-oR</u> , <u>J/kg.K</u> (1 BTU/lb-R=4186.8 J/kg.K).
<u>Cv</u>	Coefficient of velocity; <u>None</u> .
<u>effect</u>	Stack Effect; <u>psf</u> , <u>Pa</u> (1 psf=47.88 Pa).
<u>H</u>	Height of stack; <u>ft</u> , <u>m</u> (1 ft=0.3048 m).
<u>head</u>	Head of stack gases; <u>ft</u> , <u>m</u> (1 ft=0.3048 m).
<u>hf</u>	Enthalpy of sat. water at primary air temp; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm=2326 J/kg 1 BTU=1055 J).
<u>hfw</u>	Enthalpy of sat. water entering the boiler; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm=2326 J/kg 1 BTU=1055 J).
<u>hga</u>	Enthalpy of sat. steam at primary air temp; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm=2326 J/kg 1 BTU=1055 J).
<u>hgg</u>	Enthalpy of sat. steam at flue gas temp; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm=2326 J/kg 1 BTU=1055 J).
<u>Hs</u>	Specific Humidity; <u>lbw/lbda</u> , <u>kgw/kgda</u> (1 lb=0.4536 kg).
<u>hst</u>	Enthalpy of generated steam.; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm=2326 J/kg 1 BTU=1055 J).
<u>HV</u>	Heating Value of fuel; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm=2326 J/kg 1 BTU=1055 J).
<u>HV.C</u>	Carbon's Heating Value; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm=2326 J/kg 1 BTU=1055 J).
<u>HV.F</u>	Fuel Oil's Heating Value; <u>BTU/gal</u> , <u>kJ/L</u> (1 BTU/gal=0.2787 kJ/L).
<u>HV.G</u>	Gaseous Fuel's Heating Value; <u>BTU/ft³</u> , <u>kJ/m³</u> (1 BTU/ft ³ =37.26 kJ/m ³).
<u>HV.S</u>	Solid Fuel's Heating Value; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm=2326 J/kg 1 BTU=1055 J).
<u>ma</u>	Mass of combustion air; <u>lbm</u> , <u>kg</u> (1 lbm=0.4536 kg).
<u>mash</u>	Mass of ash; <u>lbm</u> , <u>kg</u> (1 lbm=0.4536 kg).
<u>mda</u>	Mass of dry air; <u>lbm</u> , <u>kg</u> (1 lbm=0.4536 kg).
<u>mf</u>	Mass of fuel; <u>lbm</u> , <u>kg</u> (1 lbm=0.4536 kg).
<u>mg</u>	Mass of flue gas; <u>lbm</u> , <u>kg</u> (1 lbm=0.4536 kg).
<u>mst</u>	Mass of steam; <u>lbm</u> , <u>kg</u> (1 lbm=0.4536 kg).
<u>mw</u>	Mass of water; <u>lbm</u> , <u>kg</u> (1 lbm=0.4536 kg).
<u>n</u>	Number of moles; <u>pmole</u> , <u>kgmole</u> .
<u>NA</u>	Number of atoms of element used in reaction; <u>None</u> .
<u>p</u>	Pressure; <u>psf</u> , <u>Pa</u> (1 psf=47.88 Pa).

COMBUSTION

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT</u>
<u>P</u>	Pressure; <u>psi</u> , <u>Pa</u> (1 psi=6894.76 Pa).
<u>q</u>	Heat loss; <u>BTU</u> , <u>J</u> (1 BTU=1055 J).
<u>R</u>	Specific heat constant; <u>ft-lbf/lbm-oR</u> , <u>J/kg.K</u> (1 ft-lbf/lbm-oR=5.3803 J/kg.K).
<u>Ta</u>	Outside air temperature; <u>oR</u> , <u>K</u> .
<u>tamb</u>	Ambient temperature; <u>oF</u> , <u>oC</u> .
<u>tg</u>	Average temperature of stack gas; <u>oF</u> , <u>oC</u> .
<u>Tg</u>	Average temperature of stack gas; <u>oR</u> , <u>K</u> .
<u>tin</u>	Temperature of fluid entering the boiler/heater; <u>oF</u> , <u>oC</u> .
<u>tout</u>	Temperature of fluid leaving the boiler/heater; <u>oF</u> , <u>oC</u> .
<u>tsup</u>	Temperature of supply air to the boiler; <u>oF</u> , <u>oC</u> .
<u>V</u>	Flow quantity; <u>ft3/s</u> , <u>m3/s</u> (1 ft3/s=.0283 m3/s).
<u>Va</u>	Volume of air; <u>ft3</u> , <u>m3</u> (1 ft3=.0283 m3).
<u>V.CO</u>	Volumetric fraction of Carbon Monoxide; <u>decimal</u> .
<u>V.CO2</u>	Volumetric fraction of Carbon Dioxide; <u>decimal</u> .
<u>V.N2</u>	Volumetric fraction of Nitrogen; <u>decimal</u> .
<u>VNG</u>	Volume of natural gas; <u>ft3</u> , <u>m3</u> (1 ft3=.0283 m3).
<u>V.O2</u>	Volumetric fraction of Oxygen; <u>decimal</u> .
<u>va</u>	Actual velocity of flue gas; <u>fps</u> , <u>m/s</u> (1 ft/s=.3048 m/s).
<u>vi</u>	Ideal velocity of flue gas; <u>fps</u> , <u>m/s</u> (1 ft/s=.3048 m/s).
<u>W.C</u>	Gravimetric (weight) fraction of Carbon in fuel; <u>decimal</u> .
<u>W.H2</u>	Gravimetric (weight) fraction of Hydrogen; <u>decimal</u> .
<u>W.O2</u>	Gravimetric (weight) fraction of Oxygen; <u>decimal</u> .
<u>W.S2</u>	Gravimetric (weight) fraction of Sulfur; <u>decimal</u> .
<u>XAIR</u>	Excess air; <u>decimal</u> .
<u>η</u>	Efficiency; <u>decimal</u> .
<u>ηGEN</u>	Efficiency of generating system; <u>decimal</u> .

DUCTS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>DUCT'S FLOW PARAMETERS: (DUCT/FLOW)</u>		
<u>English Units: (DUCT/FLOW/ENG)</u>		
(01) Diameter	$d = 13.541 \left(\frac{cfm}{fpm} \right)^{.5}$	<i>DIAM</i>
(02) Flow quantity	$cfm = 5.4545E-3 * fpm * d^2$	<i>FLOW</i>
(03) Velocity	$fpm = 183.35 * \frac{cfm}{d^2}$	<i>VELO</i>
<u>SI Units: (DUCT/FLOW/SI)</u>		
(04) Diameter	$d = 35.6824 \left(\frac{lps}{mps} \right)^{.5}$	<i>DIAM</i>
(05) Flow quantity	$lps = 7.854E-4 * mps * d^2$	<i>FLOW</i>
(06) Velocity	$fpm = 1274.2366 * \frac{lps}{d^2}$	<i>VELO</i>

EQUAL FRICTION LOSS DIMENSION: (DUCT/EQL.F)

(07) Diameter (d), rectangular to round	$d = \frac{1.3(a+b)^{.625}}{(a+b)^{.25}}$	<i>D</i>
(08) Shorter side (a), round to rectangular	$a = \frac{d(R+1)^{.25}}{1.3 * R^{.625}}$	<i>A</i>
(09) Long side (b), round to rectangular	$b = \frac{d * R^{.375} (R+1)^{.25}}{1.3}$	<i>B</i>

FRICTION LOSS: (DUCT/F.LOS)

English Units: (DUCT/F.LOS/ENG)

(10) With flow quantity (FQ) & diameter (D)	$P_f = \frac{1.2326EE-3 * L_e * cfm^{1.82}}{d^{4.86}}$	<i>FQ&D</i>
(11) With velocity (V) & diameter (D)	$P_f = \frac{.027 L_e}{d^{1.22}} \left(\frac{fpm}{1000} \right)^{1.82}$	<i>V&D</i>
(12) With velocity (V) & flow quantity (FQ)	$P_f = \frac{3.9EE-9 * L_e * fpm^{2.43}}{cfm^{.61}}$	<i>V&FQ</i>

SI Units: (DUCT/F.LOS/SI)

(13) With flow quantity (FQ) & diameter (D)	$P_f = \frac{26530176 * L_e * lps^{1.82}}{d^{4.86}}$	<i>FQ&D</i>
(14) With velocity (V) & diameter (D)	$P_f = \frac{17013061 * L_e}{d^{1.22}} \left(\frac{mps}{1000} \right)^{1.82}$	<i>V&D</i>
(15) With velocity (V) & flow quantity (FQ)	$P_f = \frac{.756474 * L_e * mps^{2.43}}{lps^{.61}}$	<i>V&FQ</i>

DUCTS

DESCRIPTION

FORMULA

NAME

MINOR LOSS: (DUCT/M.LOS)

(16) English Units:

$$P_m = C_m \left(\frac{fpm}{4005} \right)^2$$

ENG

(17) SI Units:

$$P_m = 0.60116 * C_m * mps^2$$

SI

STATIC REGAIN: (DUCT/REGAIN)

English Units: (DUCT/REGAIN/ENG)

(18) With the given velocity

$$P_{sx} = \frac{C_{sx} (fpm_1^2 - fpm_2^2)}{4005^2}$$

VELO

(19) With the given flow (FQ) and diameter (D)

$$P_{sx} = \frac{C_{sx}}{477.14} \left(\frac{cfm_1^2}{d_1^4} - \frac{cfm_2^2}{d_2^4} \right)$$

DIAM

SI Units: (DUCT/REGAIN/SI)

(20) With the given velocity

$$P_{sx} = 0.60116 * C_{sx} (mps_1^2 - mps_2^2)$$

VELO

(21) With flow (FQ) and diameter (D)

$$P_{sx} = 974608 * C_{sx} \left(\frac{1ps_1^2}{d_1^4} - \frac{1ps_2^2}{d_2^4} \right)$$

DIAM

VELOCITY PRESSURE: (DUCT/VEL.P)

(22) English Units

$$P_v = \left(\frac{fpm}{4005} \right)^2$$

ENG

(23) SI Units:

$$P_v = 0.60116 * mps^2$$

SI

DUCTS

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT (ENG, SI)</u>
<u>a</u>	Short side of duct; <u>in</u> , <u>mm</u> (1 in = 25.4 mm)
<u>b</u>	Long side of duct; <u>in</u> , <u>mm</u> (1 in = 25.4 mm)
<u>cm</u>	Coefficient of Minor loss; <u>None</u> .
<u>csr</u>	Coefficient of Static Regain; <u>None</u> .
<u>d</u>	Diameter; <u>in</u> , <u>mm</u> (1 in = 25.4 mm)
<u>fpm</u>	Velocity in foot per minute (1 fpm = 196.85 mps)
<u>gpm</u>	Flow quantity in cubic foot per minute (1 cfm = 0.47195 lps)
<u>Le</u>	Length, equivalent; <u>ft</u> , <u>m</u> (1 ft = 0.3048 m)
<u>lps</u>	Flow quantity in liter per second (1 lps = 2.11887 cfm)
<u>mps</u>	Velocity in meter per second (1 mps = 0.00508 fpm)
<u>Pf</u>	Friction loss; <u>inH2O</u> , <u>Pa</u> , (1 inH2o = 248.84 Pa)
<u>Pm</u>	Minor pressure loss; <u>inH2o</u> , (1 inH2o = 248.84 Pa)
<u>Psr</u>	Static Pressure Regain; <u>inH2o</u> , (1 inH2o = 248.84 Pa)
<u>Pv</u>	Velocity pressure; <u>inH2o</u> , (1 inH2o = 248.84 Pa)
<u>R</u>	Aspect Ratio (b/a); <u>None</u> .

ELECTRICITY

DESCRIPTION

FORMULA

NAME

BATTERIES IN PARALLEL: (ELEC/BATT)

(01) Current through battery #1

$$I_1 = \frac{V_1 - V_2 + I \cdot R_2}{R_1 + R_2}$$

AMP→

(02) Current through battery #2

$$I_2 = \frac{V_2 - V_1 + I \cdot R_1}{R_1 + R_2}$$

CAPACITORS: (ELEC/CAPC)

Equivalent Capacitance:

(03) Parallel, 2 or 3

$$C_e = C_1 + C_2 + C_3$$

CEP

(04) Series, 2

$$C_e = \frac{C_1 \cdot C_2}{C_1 + C_2}$$

CES2

(05) Series, 3

$$C_e = \frac{C_1 \cdot C_2 \cdot C_3}{C_1 \cdot C_2 + C_1 \cdot C_3 + C_2 \cdot C_3}$$

CES3

(06) Capacitive Reactance

$$X_c = \frac{1}{2\pi \cdot f \cdot C}$$

XFC

(07) Capacitive Reactance

$$X_c = \frac{V}{I}$$

XVI

(08) Capacitive Reactance

$$X_c = \frac{1}{\omega \cdot C}$$

XωC

IMPEDANCE: (ELEC/IMPD)

(09) Magnitude

$$Z = \frac{V}{I}$$

MAG

Magnitude of R, L, and C in Parallel (ELEC/IMPD/PARA)

(10) R & C

$$Z = \frac{R \cdot X_c}{\sqrt{R^2 + X_c^2}}$$

RC

(11) R & L

$$Z = \frac{R \cdot X_L}{\sqrt{R^2 + X_L^2}}$$

RL

(12) L & C

$$Z = \frac{X_L \cdot X_c}{X_L - X_c}$$

LC

ELECTRICITY

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
(13) R , L, & C	$Z = \frac{R * X_L * X_C}{\sqrt{X_L^2 * X_C^2 + R^2 (X_L - X_C)^2}}$	RLC
<u>Magnitude of R, L, and C in Series (ELEC/IMPD/SERI)</u>		
(14) R & C	$Z = \sqrt{R^2 + X_C^2}$	RC
(15) R & L	$Z = \sqrt{R^2 + X_L^2}$	RL
(16) L & C	$Z = X_L - X_C$	CL
(17) R , L, & C	$Z = \sqrt{R^2 + (X_L - X_C)^2}$	RLC

INDUCTOR: (ELEC/INDC)

Equivalent Inductance:

(18) Parallel, 2	$L_{\bullet} = \frac{L_1 * L_2}{L_1 + L_2}$	LEP2
(19) Parallel, 3	$L_{\bullet} = \frac{L_1 * L_2 * L_3}{L_1 * L_2 + L_1 * L_3 + L_2 * L_3}$	LEP3
(20) Series, 2 or 3	$L_{\bullet} = L_1 + L_2 + L_3$	LES
(21) Inductive Reactance	$X_L = 2 \pi * f * L$	XFL
(22) Inductive Reactance	$X_L = \frac{V}{I}$	XVI
(23) Inductive Reactance	$X_L = L * \omega$	XWL

KIRCHOFF'S LAW: (ELEC/KIRC)

Two (2) MESH network: (ELEC/KIRC/LOOP2)

The format of the equations resulted from applying the Kirchoff's Law, are as follow:

$$\begin{cases} A_1 I_1 + B_1 I_2 = C_1 \\ A_2 I_1 + B_2 I_2 = C_2 \end{cases}$$

(24) Current in MESH #1	$I_1 = \text{EXPR} = \frac{C_1 B_2 - B_1 C_2}{A_1 B_2 - A_2 B_1}$	I1
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ELECTRICITY

DESCRIPTION

FORMULA

NAME

(25) Current in MESH #2	$I_2 = \text{EXPR} = \frac{C_1 A_2 - A_1 C_2}{A_2 B_1 - A_1 B_2}$	I2
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Three (3) MESH network: (ELEC/KIRC/LOOP3)

The format of the equations, resulted from applying the Kirchoff's Law, are as follow:

$$\begin{cases} A_1 I_1 + B_1 I_1 + C_1 I_3 = D1 \\ A_2 I_1 + B_2 I_1 + C_2 I_3 = D2 \\ A_3 I_1 + B_3 I_1 + C_3 I_3 = D3 \end{cases}$$

Current in MESH #1

(26)	$I_1 = \text{EXPR} = \frac{(C_3 B_2 - C_2 B_3) (C_2 D_1 - C_1 D_2) - (C_2 B_1 - C_1 B_2) (C_3 D_2 - C_2 D_3)}{(C_3 B_2 - C_2 B_3) (C_2 A_1 - C_1 A_2) - (C_2 B_1 - C_1 B_2) (C_3 A_2 - C_2 A_3)}$	I1
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Current in MESH #2

(27)	$I_2 = \text{EXPR} = \frac{(A_3 A_2 - A_2 C_3) (A_2 D_1 - A_1 D_2) - (A_2 C_1 - A_1 C_2) (A_3 D_2 - A_2 D_3)}{(A_3 C_2 - A_2 C_3) (A_2 B_1 - A_1 B_2) - (A_2 C_1 - A_1 C_2) (A_3 B_2 - A_2 B_3)}$	I2
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Current in MESH #3

(28)	$I_3 = \text{EXPR} = \frac{(A_3 B_2 - A_2 B_3) (A_2 D_1 - A_1 D_2) - (A_2 B_1 - A_1 B_2) (A_3 D_2 - A_2 D_3)}{(A_3 B_2 - A_2 B_3) (A_2 C_1 - A_1 C_2) - (A_2 B_1 - A_1 B_2) (A_3 C_2 - A_2 C_3)}$	I3
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MOTORS: (ELEC/MOTR)

Elevators: (ELEC/MOTR/ELEV)

(29) Horsepower	$hp = \frac{W \times V}{33000 \times \eta}$	HP
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Power: (ELEC/MOTR/POWER)

(30) Single phase (power in kW)	$kW = \frac{V \times I \times PF \times \eta_M}{1000}$	KW1φ
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(31) Single phase (power in hp)	$hp = \frac{V \times I \times PF \times \eta_M}{745.7}$	HP1φ
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(32) Three phase (power in kW)	$kW = \frac{\sqrt{3} \times V \times I \times PF \times \eta_M}{1000}$	KW3φ
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(33) Three phase (power in hp)	$hp = \frac{\sqrt{3} \times V \times I \times PF \times \eta_M}{745.7}$	HP3φ
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ELECTRICITY

DESCRIPTION

FORMULA

NAME

Pumps: (ELEC/MOTR/PUMP)

(34) Horsepower (flow in gpm)

$$hp = \frac{h \times Q \times SG}{3960 \eta}$$

HP-Q

(35) Horsepower (flow in lb/sec)

$$hp = \frac{h \times M}{550 \eta}$$

HP-M

(36) Horsepower (flow in cfs)

$$hp = \frac{h \times V \times SG}{8.814 \eta}$$

HP-V

Speed:

(37) Rotational speed

$$n = \frac{120 \times f (1 - S)}{P}$$

SPED

Torque:

(38) Torque

$$T = \frac{63025 \times hp}{n}$$

TORQ

POWER: (ELEC/POWR)

Apparent:

(39) Single phase

$$P_a = V \times I$$

AP1φ

(40) Three phase

$$P_a = \sqrt{3} \times V \times I$$

AP3φ

Effective:

(41) Instantaneous

$$P_i = V \times I (\cos \phi + \cos (2\omega \times t + \phi))$$

EFφω

(42) Average, single phase

$$P = V \times I \times PF$$

EF1φ

(43) Average, three phase

$$P = \sqrt{3} \times V \times I \times PF$$

EF3φ

Reactive:

(44) Average, single phase

$$P_r = V \times I \times \sin (A \cos (PF))$$

RE1φ

(45) Average, three phase

$$P_r = \sqrt{3} \times V \times I \times \sin (A \cos (PF))$$

RE3φ

ELECTRICITY

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>POWER FACTOR: (ELEC/PFAC)</u>		
(46) Power Factor	$PF = \cos(\phi)$	ϕ
(47) Power Factor	$PF = \cos\left(\Delta \tan \frac{X}{R}\right)$	$X-R$
(48) Power Factor	$PF = \frac{KW}{KVA}$	$W-VA$
(49) Power Factor (Single phase)	$PF = \frac{1000 \times KW}{V \times I}$	$W-1\phi$
(50) Power Factor (Three phase)	$PF = \frac{1000 \times KW}{\sqrt{3} \times V \times I}$	$W-3\phi$
(51) Power Factor (same load and voltage)	$PF_2 = PF_1 \times \frac{I_1}{I_2}$	$I1-I2$
<u>Power Factor Correction:</u>		
(52) System Power Factor	$PF = \frac{KWR + KWI}{\sqrt{(KWI \times \tan(\Delta \cos(PFI)))^2 + (KWR + KWI)^2}}$	$SYPF$
(53) Capacitors KVAR	$KVAR = (KWR + KWI) \times (\tan(\Delta \cos(PF1)) - \tan(\Delta \cos(PF2)))$	$KVAR$
(54) Capacitors Value	$Cval = \frac{159.15 \times Kvar}{f \times V^2}$	$CVAL$

RESISTORS: (ELEC/RESI)

Equivalent Resistance:

(55) Parallel, 2	$R_e = \frac{R_1 \times R_2}{R_1 + R_2}$	$REP2$
(56) Parallel, 3	$R_e = \frac{R_1 \times R_2 \times R_3}{R_1 \times R_2 + R_1 \times R_3 + R_2 \times R_3}$	$REP3$
(57) Series, 2 or 3	$R_e = R_1 + R_2 + R_3$	RES
(58) Resistance	$R = \frac{\rho \times L}{A \text{ cmil}}$	$RpLA$
(59) Resistance variance with temperature	$R_2 = R_1 (1 + \alpha \times dt)$	$R\Delta T$
(60) Thermal Coefficient of resistant	$\alpha = \frac{R_2 - R_1}{dt \times R_1}$	$R\Delta T$

ELECTRICITY

DESCRIPTION

FORMULA

NAME

RESONANCE: (ELEC/RESO)

(61) Angular velocity	$\omega_r = \sqrt{\frac{1}{L \cdot C}}$	ωRLC
(62) Frequency	$f_r = \frac{\omega_r}{2\pi}$	$FR\omega R$
(63) Frequency	$f_r = \frac{1}{2\pi} \sqrt{\frac{1}{L \cdot C}}$	$FRLC$
(64) Frequency	$f_r = f \sqrt{\frac{X_c}{X_L}}$	$FRFX$
(65) Capacitance	$C_r = \frac{1}{L \cdot \omega^2}$	$CRL\omega$
(66) Capacitance	$C_r = \frac{1}{L(2\pi \cdot f)^2}$	$CRLF$
(67) Inductance	$L_r = \frac{1}{C(2\pi \cdot f)^2}$	$LRCF$
(68) Inductance	$L_r = \frac{1}{C \cdot \omega^2}$	$LRC\omega$

TRANSIENTS: (ELEC/TRNS)

RC Transients: (ELEC/TRNS/RC)

(69) Voltage across the capacitor	$V_{Ct} = V_{Co} \cdot e^{-\frac{t}{R \cdot C}} + V(1 - e^{-\frac{t}{R \cdot C}})$	VCT
(70) Transient current	$i_t = \frac{(V - V_{Co})}{R} \cdot e^{-\frac{t}{R \cdot C}}$	IT
(71) Voltage across the resistor	$V_{Rt} = i_t \cdot R = (V - V_{Co}) \cdot e^{-\frac{t}{R \cdot C}}$	$VRT \rightarrow$

RL Transients: (ELEC/TRNS/RL)

(72) Vol. across inductor	$V_{Lt} = L(di/dt) = -i_o \cdot R \cdot e^{-\frac{R \cdot t}{L}} + V \cdot e^{-\frac{R \cdot t}{L}}$	$VL T \rightarrow$
(73) Transient current	$i_t = i_o \cdot e^{-\frac{R \cdot t}{L}} + \frac{V}{R} (1 - e^{-\frac{R \cdot t}{L}})$	IT
(74) Voltage across resistor	$V_{Rt} = i_t \cdot R = i_o \cdot R \cdot e^{-\frac{R \cdot t}{L}} + V(1 - e^{-\frac{R \cdot t}{L}})$	$VRT \rightarrow$

ELECTRICITY

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>VOLTAGE DROP: (ELEC/VDRP)</u>		

Line Current:

(75) Single phase load	$I = \frac{1000 \times KW}{V \times PF}$	<i>I1φ</i>
(76) Three phase load	$I = \frac{1000 \times KW}{\sqrt{3} \times V \times PF}$	<i>I3φ</i>

Voltage drop, copper conductors:

(77) AWG size Conductors: 14 AWG - 1 AWG, 20 amps - 130 amps:		
$VD = .001 \times L \times I (.1257 e^{(-.2285 \times AWG)} \times PF + (.0552 + .00121 \times AWG) \times \sin(\arccos(PF)))$		<i>AWG</i>
(78) AUGT size Conductors: 1/0 - 4/0, 150 amps - 230 amps:		
$VD = .001 \times L \times I (.1512 e^{(-.2169 \times AUT)} \times PF + (.0565 - .0014 \times AUT) \times \sin(\arccos(PF)))$		<i>AUT</i>
(79) KCMIL size Conductors: 250 Kcmil - 1000 Kcmil, 255 amps - 545 amps:		
$VD = .001 \times L \times I (4.322 \times Kcmil^{-.8} \times PF + .0835 \times Kcmil^{-.0876} \times \sin(\arccos(PF)))$		<i>KCM</i>

ELECTRICITY

VARIABLES IDENTIFICATION

SYMBOL DESCRIPTION; UNIT

<u>ACmil</u>	Section area of wire; <u>Circular mil</u> .
<u>C</u>	Capacitance; <u>farad</u> .
<u>Ce</u>	Equivalent Capacitance; <u>farad</u> .
<u>Cval</u>	Capacitor value; <u>farad</u> .
<u>dt</u>	Temperature difference; <u>oC</u> .
<u>E</u>	Energy; <u>kwh</u> .
<u>F</u>	Force; <u>newton</u> .
<u>f</u>	Frequency; <u>cps</u> .
<u>h</u>	Head; <u>ft</u> .
<u>I</u>	Current; <u>Amp</u> .
<u>io</u>	Transient current at t=0; <u>Amp</u> .
<u>it</u>	Transient current at t=t; <u>Amp</u> .
<u>KWI</u>	Inductive load; <u>kw</u> .
<u>KWR</u>	Resistive load; <u>kw</u> .
<u>L</u>	Inductance; <u>henry</u> : Length; <u>ft</u> .
<u>Le</u>	Equivalent Inductance; <u>henry</u> .
<u>M</u>	Flow quantity; <u>lb/sec</u> .
<u>n</u>	Rotational speed; <u>rpm</u> .
<u>p</u>	Number of poles; <u>none</u> .
<u>P</u>	Effective Power; <u>watt</u> .
<u>Pa</u>	Apparent Power; <u>volt amp</u> .
<u>PF</u>	Power Factor; <u>None</u> .
<u>PFI</u>	Induction's load Power Factor; <u>None</u> .
<u>Pi</u>	Instantaneous effective Power; <u>watt</u> .
<u>Pr</u>	Reactive Power; <u>var</u> .
<u>Q</u>	Flow quantity; <u>gpm</u> .
<u>R</u>	Resistance; <u>ohm</u> .
<u>Ro</u>	Original resistance (at 20 Oc); <u>ohm</u> .
<u>S</u>	Slip; <u>decimal</u> .
<u>SG</u>	Specific Gravity; <u>None</u> .
<u>T</u>	Period of cycle; <u>spc</u> : Torque; <u>in-lbf</u> .
<u>t</u>	Temperature; <u>oC</u> : Time; <u>sec</u> .
<u>v</u>	Speed; <u>fpm</u> .

ELECTRICITY

VARIABLES IDENTIFICATION

SYMBOL DESCRIPTION; UNIT

<u>V</u>	Voltage; <u>volt</u> : Flow quantity; <u>cfs</u> .
<u>VCo</u>	Voltage across the capacitor at t=0; <u>volt</u> .
<u>VCt</u>	Voltage across the capacitor at t=t; <u>volt</u> .
<u>VLt</u>	Voltage across the inductor at t=t; <u>volt</u>
<u>VRt</u>	Voltage across the resistor at t=t; <u>volt</u>
<u>VD</u>	Voltage Drop; <u>volt</u>
<u>w</u>	Weight; <u>lbf</u> .
<u>X</u>	Reactance; <u>ohm</u> .
<u>Xc</u>	Capacitive reactance; <u>ohm</u> .
<u>XL</u>	Inductive reactance; <u>ohm</u> .
<u>Z</u>	Impedance; <u>ohm</u>
<u>α</u>	Thermal coefficient of resistance; <u>1/oC</u> .
<u>η</u>	Overall efficiency; <u>decimal</u> .
<u>η_M</u>	Motor's efficiency; <u>decimal</u> .
<u>ω</u>	Angular velocity; <u>rad. or deg./sec</u> .
<u>φ</u>	Phase angle; <u>deg</u> .
<u>ρ</u>	Resistivity; <u>ohm-CM/ft</u> .

ENGINEERING ECONOMICS

ANNUAL COST, EQUIVALENT UNIFORM: (ENEC/ANNU)

- (01) With Sinking Fund depreciation, SF $A = \frac{i(P-L)(1+i)^n}{(1+i)^n - 1} + L \cdot i + AE$ **SF**
- (02) With SF & uniform gradient, G $A = \frac{i(P-L)(1+i)^n}{(1+i)^n - 1} + L \cdot i + AE + G(A/G, i, n)$ **SF+G**
- (03) With Straight Line depreciation, SL $A = \frac{P-L}{n} + \frac{i}{2 \cdot n} (n+1)(P-L) + L \cdot i + AE$ **SL**
- (04) Equalized Annual Cost/Income (For up to five (5) years, same interest rate.)
- $$A_{eq} = \frac{i(1+i)^n}{(1+i)^n - 1} (A_1(1+i)^{-1} + A_2(1+i)^{-2} + A_3(1+i)^{-3} + A_4(1+i)^{-4} + A_5(1+i)^{-5})$$
- AEQ**
-

BONDS: (ENEC/BOND)

- (05) Present Worth $PW = BSV(1+R)^{-N} + \frac{i \cdot BSV}{2} \frac{(1+R)^N - 1}{R(1+R)^N}$ **PW**
- (06) Rate of Return (approximate) $ROR = \frac{\frac{BSV - PW}{N} + i \cdot BSV}{\frac{BSV + PW}{2}}$ **ROR**
-

CAPITALIZED COST: (ENEC/CAPIT)

- (07) With no periodical replacement $CC = P + \frac{A}{i}$ **N. REP**
- With periodical replacement/cost: (ENEC/CAPIT/W.REP)
- (08) With in-kind periodical replacement $CC = P + \frac{P-L}{(1+i)^n - 1} + \frac{A}{i}$ **KIND**
- (09) With other periodical cost $CC = P + \frac{PC}{(1+i)^n - 1} + \frac{A}{i}$ **OTHER**

ENGINEERING ECONOMICS

COMPOUND FACTORS/VALUES: (ENEC/FACTR)

(10) Future to Annual/Annual to Future	$A = \frac{f}{(1+f)^n - 1} * F$	AF
(11) Gradient to Annual/Annual to Gradient	$A = \left(\frac{1}{f} - \frac{n}{(1+f)^n - 1} \right) * G$	AG
(12) Present to Annual/Annual to Present	$A = \frac{f(1+f)^n}{(1+f)^n - 1} * P$	AP
(13) Present to Future/Future to Present	$F = (1+f)^n * P$	FP
(14) Gradient to Present/Present to Gradient	$P = \left(\frac{(1+f)^n - 1}{f^2(1+f)^n} - \frac{n}{f(1+f)^n} \right) * G$	PG

DEPRECIATION: (ENEC/DEPRI)

Double Declining Balance: (ENEC/DEPRI/DDB)

(15) For the xth year	$D_x = \frac{2P}{n} \left(1 - \frac{2}{n}\right)^{(x-1)}$	DX
(16) Book value after x year(s)	$BV_x = P \left(1 - \frac{2}{n}\right)^x$	BVX
(17) After Tax Depreciation Recovery (ATDR)	$ATDR = TAX * R \left(\frac{2P}{n \left(1 - \frac{2}{n}\right)} \frac{\left(\frac{(1+f)n}{n-2}\right)^n - 1}{\left(\frac{(1+f)n}{n-2}\right)^n \left(\frac{(1+f)n}{n-2} - 1\right)} \right)$	RECOV

Sinking Fund: (ENEC/DEPRI/SF)

(18) For the xth year	$D_x = (P-L) \frac{f}{(1+f)^n - 1} (1+f)^{(x-1)}$	DX
(19) Book value after x year(s)	$BV_x = P - (P-L) \frac{f}{(1+f)^n - 1} \frac{(1+f)^x - 1}{f}$	BVX

ENGINEERING ECONOMICS

DEPRECIATION: (ENEC/DEPRI)

Straight line: (ENEC/DEPRI/SL)

(20) For the xth year

$$D_x = \frac{P-L}{n} \quad \mathbf{DX}$$

(21) Book value after x year(s)

$$BV_x = \frac{(P-L)(n-x)}{n} + L \quad \mathbf{BVX}$$

(22) After Tax Depreciation Recovery (ATDR)

$$ATDR = TAX \cdot R \frac{P-L}{n} \frac{(1+i)^n - 1}{i(1+i)^n} \quad \mathbf{RECOV}$$

Sum Of the Years' Digits: (ENEC/DEPRI/SOYD)

(23) For the xth year

$$D_x = \frac{2(P-L)(n-x+1)}{n(n+1)} \quad \mathbf{DX}$$

(24) Book value after x year(s)

$$BV_x = P - 2(P-L) \left(n - \frac{x-1}{2} \right) \frac{x}{n(n+1)} \quad \mathbf{BVX}$$

(25) After Tax Depreciation Recovery (ATDR)

$$ATDR = TAX \cdot R \left(\frac{2n}{n(n+1)} \frac{(1+i)^n - 1}{i(1+i)^n} - \frac{2}{n(n+1)} \left(\frac{(1+i)^n - 1}{i^2(1+i)^n} - \frac{n}{i(1+i)^n} \right) \right) \quad \mathbf{RECOV}$$

INTEREST RATE, COMPOUNDED/INFLATION: (ENEC/INTER)

(26) Continuous (yield)

$$i_{CO} = e^{i \cdot y} - 1 \quad \mathbf{YIELD}$$

(27) Effective

$$i_{EF} = \left(1 + \frac{i}{m} \right)^m - 1 \quad \mathbf{EFFECT}$$

(28) Equivalent

$$i_{EQ} = e^{\left(\frac{\ln(1+i)}{m} \right)} - 1 \quad \mathbf{EQUIV}$$

(29) Interest and Inflation combined

$$i_{INF} = i + r(1+i) \quad \mathbf{INFLT}$$

ENGINEERING ECONOMICS

MORTGAGE: (ENEC/MORT)

(30) Installment (Periodical Payment)	$INSTL = \frac{I(1+I)^n}{(1+I)^n - 1} LOAN$	INSTL
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(31) Number of payments	$NP = \frac{-\ln((1 - I \cdot LV) / INSTL)}{\ln(1 + I)}$	NUMB
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(32) Balance after xth payment	$BAL_x = \frac{INSTL}{I} (1 - (1 + I)^{(x-n)})$	BALAN
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Interest Paid: (ENEC/MORT/INTER)

(33) As a part of xth payment	$I_x = INSTL (1 - (1 + I)^{x-1-n})$	XTH
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(34) Total, after xth payment	$I_t = INSTL \cdot x - LOAN + \frac{INSTL}{I} (1 - (1 + I)^{(x-n)})$	TOTAL
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Principal Paid: (ENEC/MORT/PRINC)

(35) As a part of xth payment	$P_x = INSTL (1 + I)^{(x-1-n)}$	XTH
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(36) Total, after xth payment	$P_t = LOAN - \frac{INSTL}{I} (1 - (1 + I)^{(x-n)})$	TOTAL
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PRESENT WORTH (No depreciation): (ENEC/PW)

Before Tax: (ENEC/PW/B.TAX)

(37) With Uniform Annual Expenses	$PW = -P + (AR - AE) \frac{(1+i)^n - 1}{i(1+i)^n} + \frac{L}{(1+i)^n}$	UNIF
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(38) With Uniform Gradient on Annual Expenses	$PW = -P + (AR - AE - (A/G, i, n) G) \frac{(1+i)^n - 1}{i(1+i)^n} + \frac{L}{(1+i)^n}$	GRADI
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ENGINEERING ECONOMICS

PRESENT WORTH (No depreciation): (ENEC/PW)

After Tax: (ENEC/PW/A.TAX)

(39) With Uniform Annual Expenses

$$PW = -P + (AR - AE) (1 - TAX.R) \frac{(1+i)^n - 1}{i(1+i)^n} + \frac{L}{(1+i)^n} \quad UNIF$$

(40) With Uniform Gradient on Annual Expenses

$$PW = -P + (AR - AE - (A/G, i, n) G) (1 - TAX.R) \frac{(1+i)^n - 1}{i(1+i)^n} + \frac{L}{(1+i)^n} \quad GRADI$$

Rate Of Return on Investment: (ENEC/ROR)

(41) With salvage value

$$\frac{((1+ROR)^n - 1) AAR}{ROR(1+ROR)^n} + \frac{L}{(1+ROR)^n} = P \quad SAL > 0$$

(42) Without salvage value

$$\frac{((1+ROR)^n - 1) AAR}{ROR(1+ROR)^n} = P \quad SAL = 0$$

ENGINEERING ECONOMICS

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT</u>
<u>A</u>	Annuity; <u>amount</u> .
<u>AAR</u>	Annual Average Revenue; <u>amount</u> .
<u>A1</u>	A2, A3, A4, or A5= Annual expense/income for different years; <u>amount</u> .
<u>AE</u>	Annual Uniform Expense; <u>amount</u> .
<u>Aeq</u>	Equalized Annual Cost/Income; <u>amount</u> .
<u>AI</u>	Annual Income; <u>amount</u> .
<u>APR</u>	Annual Percentage Rate; <u>decimal</u> .
<u>AR</u>	Annual Revenue; <u>amount</u> .
<u>ATDR</u>	After Tax Depreciation Recovery (Present Worth); <u>amount</u> .
<u>BFV</u>	Bond's Face Value; <u>amount</u> .
<u>BSV</u>	Bond's Sale Value; <u>amount</u> .
<u>BV_x</u>	Book value at the end of xth year; <u>amount</u> .
<u>CC</u>	Capitalized Cost; <u>amount</u> (Initial capital investment to perpetually support project from the interest earned).
<u>F</u>	Future Value; <u>amount</u> .
<u>G</u>	Uniform Gradient; <u>amount</u> .
<u>I</u>	Interest rate per period; APR/12 for monthly payment in case of mortgage; <u>decimal</u> .
<u>i=I</u>	Interest rate per period; <u>decimal</u> . ("i" is HP48 designated variable. It should not be used for programming.)
<u>INSTL</u>	Installment (Payment per period); <u>amount</u> .
<u>L</u>	Salvage Value; <u>amount</u> .
<u>LOAN</u>	Loan Value; <u>amount</u> .
<u>m</u>	Compound number; <u>None</u> .
<u>N</u>	$N = 2n$ ($R = ROR/2$); <u>none</u> . (Number of payments for bonds with semi annually interest payment. In case of annual interest payment, $R = ROR$ and $N = n$).
<u>n</u>	Number of Payments or Periods; <u>none</u> .
<u>P</u>	Present Value; <u>amount</u> .
<u>PC</u>	Periodical Uniform Costs; <u>amount</u> .
<u>PW</u>	Present Worth; <u>amount</u> .
<u>r</u>	Inflation rate per period; <u>decimal</u> .
<u>R</u>	$ROR/2$ ($N = 2n$); <u>decimal</u> (Rate for bonds with semi annually interest payment. In case of annual interest payment $R = ROR$ and $N = n$).
<u>ROR</u>	Rate of Return; <u>decimal</u> .
<u>TAX.R</u>	Tax rate; <u>decimal</u> .
<u>x</u>	Period number; <u>none</u> .
<u>y</u>	Period; <u>years</u> .

FANS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>ATMOSPHERIC AIR PRESSURE/TEMPERATURE AT ALTITUDES: (FANS/ALTIT)</u>		
<u>English Units: (FANS/ALTIT/ENG)</u>		
(01) Pressure (psia) at altitudes between 0 - 60,000 feet	6 equations	PRESS
(02) Temperature (oF) at altitudes between 0 - 60,000 feet	2 equations	TEMP
<u>SI Units: (FANS/ALTIT/SI)</u>		
(03) Pressure (Pa) at altitudes between 0 - 18,500 meters	6 equations	PRESS
(04) Temperature (oC) at altitudes between 0 - 18,500 meters	2 equations	TEMP

DENSITY: (FANS/DENSI)

English Units: (FANS/DENSI/ENG)

(05) Air density	$\rho = \frac{2.7 * P}{t + 460}$	ρ_{AIR}
(06) Density Factor	$K_d = \frac{t_{AC} + 460}{36.05 * P_{AC}}$	ρ_{FAC}

SI Units: (FANS/DENSI/SI)

(07) Air density	$\rho = \frac{0.003487 * P}{(t + 273.15)}$	ρ_{AIR}
(08) Density Factor	$K_d = \frac{345.74 (t_{AC} + 273.15)}{P_{AC}}$	ρ_{FAC}

EFFICIENCY: (FANS/EFFI)

Mechanical efficiency: (FANS/EFFI/ η_M)

With the given brake horsepower: (FANS/EFFI/ η_M /BHP)

(09) English Units	$\eta_M = \frac{P_t * cfm}{6356 * bhp}$	ENG
(10) SI Units	$\eta_M = \frac{P_t * lps}{746449 * bhp}$	SI
(11) With the given air and brake horsepower	$\eta_M = \frac{ahp}{bhp}$	HPS
(12) Static pressure efficiency	$\eta_s = \frac{P_s}{P_t} \eta_M$	η_S

FANS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>HORSEPOWER: (FANS/HP)</u>		
<u>English Units: (FANS/HP/ENG)</u>		
<u>Air horsepower: (FANS/HP/ENG/AIR)</u>		
(13) Standard (70 oF, 14.7 psia)	$ahp = \frac{Pt_{st} * Q_{st}}{6356}$	STAN
<u>Actual: (FANS/HP/ENG/AIR/ACTU)</u>		
(14) With the given actual data	$ahp = \frac{Pt_{ac} * Q_{ac}}{6356}$	ACT.D
(15) With the given standard data	$ahp = \frac{Pt_{st} * Q_{st} * P_{ac}}{176.3 * (t_{ac} + 460)}$	STD.D
<u>Brake horsepower: (FANS/HP/ENG/BRAK)</u>		
(16) Standard (70 oF, 14.7 psia)	$bhp = \frac{Pt_{st} * Q_{st}}{6356 * \eta_m}$	STAN
<u>Actual: (FANS/HP/ENG/BRAK/ACTU)</u>		
(17) With the given actual data	$bhp = \frac{Pt_{ac} * Q_{ac}}{6356 * \eta_m}$	ACT.D
(18) With the given standard data	$bhp = \frac{Pt_{st} * Q_{st} * P_{ac}}{176.3 * (t_{ac} + 460) * \eta_m}$	STD.D
<u>SI Units: (FANS/HP/SI)</u>		
<u>Air horsepower: (FANS/HP/SI/AIR)</u>		
(19) Standard (20 oC, 1 atm)	$ahp = \frac{Pt_{st} * Q_{st}}{746449}$	STAN
<u>Actual: (FANS/HP/SI/AIR/ACTU)</u>		
(20) With the given actual data	$ahp = \frac{Pt_{ac} * Q_{ac}}{746449}$	ACT.D
(21) With the given standard data	$ahp = \frac{Pt_{st} * Q_{st} * P_{ac}}{258077277 * (t_{ac} + 273.15)}$	STD.D
<u>Brake horsepower: (FANS/HP/SI/BRAK)</u>		
(22) Standard condition (20 oC, 1 atm)	$ahp = \frac{Pt_{st} * Q_{st}}{746449 * \eta_m}$	STAN
<u>Actual: (FANS/HP/SI/BRAK/ACTU)</u>		
(23) With actual data	$ahp = \frac{Pt_{ac} * Q_{ac}}{746449 * \eta_m}$	ACT.D
(24) With standard data	$ahp = \frac{Pt_{st} * Q_{st} * P_{ac}}{258077277 * (t_{ac} + 273.15) * \eta_m}$	STD.D

FANS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>LAWS EQUATIONS: (FANS/LAW)</u>		
<u>Change in horsepower (FANS/LAW/ ΔHP)</u>		
(25) Due to change in rpm.	$\frac{hp_1}{hp_2} = \left(\frac{n_1}{n_2} \right)^3$	RPM
(26) Due to change in diameter	$\frac{hp_1}{hp_2} = \left(\frac{D_1}{D_2} \right)^3$	DIAM
<u>Change in pressure (FANS/LAW/ ΔP)</u>		
(27) Due to change in rpm.	$\frac{P_1}{P_2} = \left(\frac{n_1}{n_2} \right)^2$	RPM
(28) Due to change in diameter	$\frac{P_1}{P_2} = \left(\frac{D_1}{D_2} \right)^2$	DIAM
<u>Change in flow quantity (FANS/LAW/ ΔQ)</u>		
(29) Due to change in rpm.	$\frac{Q_1}{Q_2} = \left(\frac{n_1}{n_2} \right)$	RPM
(30) Due to change in diameter	$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2} \right)$	DIAM

PRESSURE: (FANS/PRESS)

ENGLISH UNITS: (FANS/PRESS/ENG)

Total pressure: (FANS/PRESS/ENG/TOTAL)

(31) Standard	$Pt_{ST} = Ps_{ST} + \left(\frac{fpm}{4005} \right)^2$	STAN
(32) Actual	$Pt_{AC} = Ps_{AC} + \left(\frac{fpm}{667.72} \right)^2 \left(\frac{P_{AC}}{t_{AC} + 460} \right)$	ACTU

Velocity pressure: (FANS/PRESS/ENG/VELO)

(33) Standard conditions	$Pv_{ST} = \left(\frac{fpm}{4005} \right)^2$	STAN
(34) Actual conditions	$Pv_{AC} = \left(\frac{fpm}{667.72} \right)^2 \left(\frac{P_{AC}}{t_{AC} + 460} \right)$	ACTU

FANS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
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PRESSURE (Continued): (FANS/PRESS)

SI UNITS: (FANS/PRESS/SI)

Total pressure: (FANS/PRESS/SI/TOTAL)

(35) Standard	$Pt_{ST} = Ps_{ST} + \left(\frac{mps}{1.29} \right)^2$	STAN
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(36) Actual	$Pt_{AC} = Ps_{AC} + \left(\frac{mps}{23.982} \right)^2 \left(\frac{P_{AC}}{t_{AC} + 237.15} \right)$	ACTU
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Velocity pressure: (FANS/PRESS/SI/VELO)

(37) Standard conditions	$Pv_{ST} = \left(\frac{mps}{1.29} \right)^2$	STAN
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(38) Actual conditions	$Pv_{AC} = \left(\frac{mps}{23.982} \right)^2 \left(\frac{P_{AC}}{t_{AC} + 237.15} \right)$	ACTU
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SIMILARITY EQUATIONS: (FANS/SIMIL)

(39) Diameters	$\frac{D_A}{D_B} = \left(\frac{Q_A}{Q_B} \right)^{.5} \left(\frac{P_B}{P_A} \right)^{.25} \left(\frac{\rho_A}{\rho_B} \right)^{.25}$	DIAM
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Flow: (FANS/SIMIL/FLOW)

(40) With diameter and rpm	$\frac{Q_A}{Q_B} = \left(\frac{D_A}{D_B} \right)^3 \left(\frac{n_A}{n_B} \right)$	D. N
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(41) With diameter, pressure, and density	$\frac{Q_A}{Q_B} = \left(\frac{D_A}{D_B} \right)^2 \left(\frac{P_A}{P_B} \right)^{.5} \left(\frac{\rho_B}{\rho_A} \right)^{.5}$	D. P. ρ
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Horsepower: (FANS/SIMIL/HP)

(42) With diameter, rpm, and density	$\frac{ahp_A}{ahp_B} = \left(\frac{D_A}{D_B} \right)^5 \left(\frac{n_A}{n_B} \right)^3 \left(\frac{\rho_A}{\rho_B} \right)$	D. N. ρ
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(43) With diameter, pressure, density	$\frac{ahp_A}{ahp_B} = \left(\frac{D_A}{D_B} \right)^2 \left(\frac{P_A}{P_B} \right)^{1.5} \left(\frac{\rho_B}{\rho_A} \right)^{.5}$	D. P. ρ
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(44) With flow and pressure	$\frac{ahp_A}{ahp_B} = \left(\frac{Q_A}{Q_B} \right) \left(\frac{P_A}{P_B} \right)$	Q. P
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(45) Pressure	$\frac{P_A}{P_B} = \left(\frac{D_A}{D_B} \right)^2 \left(\frac{n_A}{n_B} \right)^2 \left(\frac{\rho_A}{\rho_B} \right)$	PRESS
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FANS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>Rotational velocity: (<i>FANS/SIMIL/RPM</i>)</u>		
(46) With diameter , pressure , and density	$\frac{n_A}{n_B} = \left(\frac{D_A}{D_B} \right) \left(\frac{P_A}{P_B} \right)^{.5} \left(\frac{\rho_B}{\rho_A} \right)^{.5}$	<i>D . N . ρ</i>
(47) With flow , pressure , and density	$\frac{n_A}{n_B} = \left(\frac{Q_B}{Q_A} \right)^{.5} \left(\frac{P_A}{P_B} \right)^{.75} \left(\frac{\rho_B}{\rho_A} \right)^{.75}$	<i>Q . P . ρ</i>
(48) Systems Characteristics (Pressure/Flow) curve	$P_2 = P_1 \left(\frac{Q_2}{Q_1} \right)^2$	<i>CURVE</i>

FANS

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT</u>
<u>ahp</u>	Air horsepower; <u>hp</u> .
<u>bhp</u>	Brake horsepower; <u>hp</u> .
<u>cfm</u>	Flow quantity in cubic foot per minute (1 cfm = 0.47195 lps)
<u>D</u>	Diameter; <u>in</u> , <u>mm</u> (1 in = 25.4 mm).
<u>fpm</u>	Velocity in foot per minute (1 fpm = 0.00508 mps)
<u>Kd</u>	Density factor; <u>None</u> .
<u>lps</u>	Flow quantity in liter per second (1 lps = 2.11887 cfm)
<u>mps</u>	Velocity in meter per second (1 mps = 196.85 fpm)
<u>n</u>	Rotational velocity; <u>rpm</u> .
<u>P</u>	Ambient pressure; <u>psi</u> , <u>Pa</u> (1 psi = 6894.76 Pa).
<u>P.AC</u>	Actual ambient pressure; <u>psi</u> , <u>Pa</u> (1 psi = 6894.76 Pa).
<u>Ps</u>	Static pressure; <u>inH2O</u> , <u>Pa</u> (1 inH2O = 248.84 Pa).
<u>Ps.AC</u>	Actual static pressure; <u>inH2O</u> , <u>Pa</u> (1 inH2O = 248.84 Pa).
<u>Ps.ST</u>	Standard condition static pressure; <u>inH2O</u> , <u>Pa</u> (1 inH2O = 248.84 Pa).
<u>Pt</u>	Total pressure; <u>inH2O</u> , <u>Pa</u> (1 inH2O = 248.84 Pa).
<u>Pt.AC</u>	Actual total pressure; <u>inH2O</u> , <u>Pa</u> (1 inH2O = 248.84 Pa).
<u>Pt.ST</u>	Standard condition total pressure; <u>inH2O</u> , <u>Pa</u> (1 inH2O = 248.84 Pa).
<u>Pv</u>	Velocity pressure; <u>inH2O</u> , <u>Pa</u> (1 inH2O = 248.84 Pa).
<u>Q</u>	Flow quantity; <u>cfm</u> , <u>lps</u> (1 cfm = 0.47195 lps).
<u>Q.AC</u>	Actual flow quantity; <u>cfm</u> , <u>lps</u> (1 cfm = 0.47195 lps).
<u>Q.ST</u>	Standard condition flow quantity; <u>cfm</u> , <u>lps</u> (1 cfm = 0.47195 lps).
<u>t</u>	Air temperature; <u>oF</u> , <u>oC</u> .
<u>t.AC</u>	Actual ambient temperature; <u>oF</u> , <u>oC</u> .
<u>v</u>	Flow velocity; <u>fpm</u> , <u>mps</u> (1 fpm = 0.00508 mps).
<u>η_s</u>	Fan's static pressure efficiency; <u>decimal</u> .
<u>η_M</u>	Fan's mechanical efficiency; <u>decimal</u> .
<u>ρ</u>	Air density; <u>lbm/ft3</u> , <u>kg/m3</u> (1 lbm/ft3 = 0.06243 kg/m3).

GEARS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>BEVEL GEARS: (GEAR/BEVEL)</u>		
(01) Load transmitted	$W_t = \frac{\sigma * Y * F * (1 - \frac{F}{L})}{P}$	LOAD
<u>Stress: (GEARS/BEVEL/STRES)</u>		
(02) Actual stress	$\sigma = \frac{W_t * P}{Y * F * (1 - \frac{F}{L})}$	ACTU
<u>Design stress: (GEARS/BEVEL/STRES/DSIGN)</u>		
(03) For cut teeth	$\sigma_D = \frac{1200}{1200 + v} \sigma_A$	CUT
(04) For generated teeth	$\sigma_D = \frac{78}{78 + v} \sigma_A$	GENE
<u>SPUR GEARS: (GEAR/SPUR)</u>		
(05) Diametral pitch	$P = \left(\frac{\sigma * Y * N * F * n}{126050 * hp} \right)^{.5}$	DIA . P
<u>Load: (GEAR/SPUR/LOAD)</u>		
(06) Dynamic load	$W_d = W_t + \frac{.5 * v * (F * C + W_t)}{.05 * v + (F * C + W_t)^{.5}}$	DYNA
<u>Load transmitted/static load: (GEAR/SPUR/LOAD/STAT)</u>		
(07) With given horsepower	$W_t = \frac{33000 * hp}{v}$	HP
(08) With Form Factor (Lewis Strength Equation)	$W_t = \frac{\sigma * F * Y}{P}$	LEWIS
(09) Wear load	$W_w = D * F * K * \left(\frac{2N_g}{N_g + N_p} \right)$	WEAR
<u>Stress: (GEAR/SPUR/STRES)</u>		
<u>Actual stress: (GEAR/SPUR/STRES/ACTU)</u>		
(10) With load (Lewis Strength Equation)	$\sigma = \frac{W_t * P}{Y * F}$	LEWIS
(11) With horsepower	$\sigma = \frac{126050 * hp * P^2}{Y * N * F * n}$	HP

GEARS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>SPUR GEARS' STRESS (continued): (GEAR/SPUR/STRES)</u>		
<u>Design stress: (GEAR/SPUR/STRES/DSIGN)</u>		
(12) $v < 2000$ fpm	$\sigma_D = \frac{600}{600 + v} \sigma_A$	
(13) $4000 = > v = > 2000$ fpm	$\sigma_D = \frac{1200}{1200 + v} \sigma_A$	DSIGN
(14) $v > 4000$ fpm	$\sigma_D = \frac{78}{78 + v} \sigma_A$	
(15) Stress fatigue factor	$K = \frac{S_{es}^2 * SIN(\phi)}{1.4} \left(\frac{1}{E_p} + \frac{1}{E_g} \right)$	K. FAC

GENERAL EQUATIONS: (GEAR/GNRL)

Horsepower: (GEAR/GNRL/HRSP)

(16) With given load	$hp = \frac{W_t * v}{33000}$	LOAD
(17) With given torque	$hp = \frac{T * n}{63025}$	TORQ
(18) Load	$W_t = \frac{2 * T}{D}$	LOAD
(19) Torque	$T = \frac{63025 * hp}{n}$	TORQ

Velocity: (GEAR/GNRL/VELO)

(20) With pitch diameter	$v = \frac{\pi * D * n}{12}$	DIAM
(21) With number of teeth	$v = \frac{\pi * D * n}{12 * P}$	TEETH

GEARS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>TABLES OF VALUES AND FACTORS: (GEAR/TABLE)</u>		
<u>Deformation Factor Value (C) (GEAR/TABLE/DEFOR)</u>		
(22) Cast iron pinion and cast iron gear ($14.5^\circ/20^\circ$)	3 equations	CI.CI
(23) Steel pinion and cast iron gear ($14.5^\circ/20^\circ$)	3 equations	ST.CI
(24) Steel pinion and steel gear ($14.5^\circ/20^\circ$)	3 equations	ST.ST
<u>Error Values: (GEAR/TABLE/EROR)</u>		
<u>Based on cutting classification: (GEAR/TABLE/EROR/CLASS)</u>		
(25) First Class gears (commercial)	2 equations	1ST
(26) Second Class gears (Carefully cut)	2 equations	2ND
(27) Third Class gears (Precision)	2 equations	3RD
(28) Based on linear velocity	3 equations	VELO
<u>Fatigue Factors (K) (GEAR/TABLE/FATIG)</u>		
(29) Steel pinion and steel gear ($14.5^\circ/20^\circ$)	4 equations	ST.ST
(30) Steel pinion and cast iron gear ($14.5^\circ/20^\circ$)	4 equations	ST.CI
(31) Steel pinion and bronze gear ($14.5^\circ/20^\circ$)	4 equations	ST.BR
(32) Cast iron pinion and cast iron gear ($14.5^\circ/20^\circ$)	4 equations	CI.CI
<u>Form Factor (Y) (GEAR/TABLE/FORM)</u>		
(33) 14.5° Full depth	3 equations	14.5°
(34) 20° Full depth/Stub	6 equations	20°
<u>Surface Endurance Limit Value (Ses) (GEAR/TABLE/ENDU)</u>		
(35) Steel pinion and steel gear	1 equation	ST.ST
(36) Steel pinion and cast iron gear	1 equation	ST.CI
(37) Steel pinion and bronze gear	1 equation	ST.BR
(38) Cast iron pinion and cast iron gear	1 equation	CI.CI

GEARS

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT</u>
<u>BHN</u>	Brinell Hardness Number; <u>None</u> . (150-400 for ST/ST, 150-250 ST/CI, 150-200 ST/BR)
<u>C</u>	Deformation factor; <u>None</u> . (Values in CHOTKEH's built-in table, GEAR/TABLE/DEFOR)
<u>D</u>	Pitch diameter; <u>in.</u> ($D=N/P$)
<u>Eg</u>	Gear's modules of elasticity; <u>psi</u> .
<u>Ep</u>	Pinion's modules of elasticity; <u>psi</u> .
<u>EROR</u>	Action error; <u>in.</u> (Values in CHOTKEH's built-in table, GEAR/TABLE/EROR)
<u>F</u>	Face width; <u>in.</u> (For spur gear, limited to 4 times the circular pitch $F=4P=4\pi/P=4\pi D/N$) (For bevel gear, $F=L/3$)
<u>f</u>	Wear factor; <u>None</u> .
<u>g</u>	Gear; <u>None</u> .
<u>K</u>	Stress fatigue factor; <u>None</u> . (Values in CHOTKEH's built-in table, GEAR/TABLE/FATIG)
<u>L</u>	Cone distance; <u>in.</u>
<u>N</u>	Number of teeth; <u>None</u> . ($N=P \cdot D$)
<u>n</u>	Rotational velocity; <u>rpm</u> .
<u>Ni</u>	Imaginary spur gear's number of teeth for bevel gear; <u>None</u> .
<u>P</u>	Diametral pitch = pitch = N/D ; <u>1/in.</u>
<u>p</u>	Circular pitch; <u>in.</u> ($P=\pi/P=\pi D/N$)
<u>p</u>	Pinion; <u>None</u> .
<u>r</u>	Pitch radius; <u>in.</u>
<u>rb</u>	Backbone distance for bevel gear; <u>in.</u>
<u>Ses</u>	Surface Endurance Limit; <u>psi</u> .
<u>T</u>	Torque; <u>in-lbf</u> .
<u>v</u>	Linear velocity; <u>fpm</u> .
<u>Vr</u>	Angular velocity ratio; <u>None</u> . ($V_r=N_g/N_p=D_g/D_p$)
<u>Wd</u>	Dynamic load; <u>lbf</u> .
<u>Wt</u>	Load transmitted; <u>lbf</u> .
<u>Ww</u>	Wear load; <u>lbf</u> .
<u>Y</u>	Lewis form factor; <u>None</u> . (Values in CHOTKEH's built-in table, GEAR/TABLE/FORM)
ϕ	Pressure angle; <u>deg</u> .
σ	Stress; <u>psi</u> .
σ_A	Allowable stress; <u>psi</u> .
σ_D	Design stress; <u>psi</u> .

HEAT TRANSFER

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>COEFFICIENT OF HEAT TRANSFER: (HIT.TR/UCOEF)</u>		
(01) Slab	$U = \frac{1}{\Sigma (L:K) + \Sigma (1:h)}$	SLAB
<u>Pipe: (HIT.TR/UCOEF/PIPE)</u>		
(02) Inside (If using inside surface area)	$U_i = \frac{1}{\frac{1}{h_i} + \frac{r_i}{K} \ln(r_o/r_i) + \frac{r_i}{r_o h_o}}$	IN
(03) Outside (If using outside surface area)	$U_o = \frac{1}{\frac{1}{h_o} + \frac{r_o}{K} \ln(r_o/r_i) + \frac{r_o}{r_i h_i}}$	OUT
<u>FILM COEFFICIENT: (HIT.TR/FILMC)</u>		
(04) Inside of pipe, turbulence flow	$h_i = \frac{.0225 * K * N_{Re}^{.8} * N_{Pr}^{.4}}{D_i}$	IN
<u>Outside of pipe, condensing vapor (HIT.TR/FILMC/OUT):</u>		
(05) English Units	$h_o = 5.6158 \left(\frac{\rho_1 (\rho_1 - \rho_v) * h_{fg} * K^3}{D_o * \mu_1 (t_{sv} - t_s)} \right)^{.25}$	ENG
(06) SI Units	$h_o = .4098 \left(\frac{\rho_1 (\rho_1 - \rho_v) * g * h_{fg} * K^3}{D_o * \mu_1 (t_{sv} - t_s)} \right)^{.25}$	SI
<u>HEAT EXCHANGER: (HIT.TR/HIT.EX)</u>		
<u>Heat Balance Equations: (HIT.TR/HIT.EX/HIT.BA)</u>		
(07) With the given Δt	$m_1 * cp_1 * \Delta t_1 = m_2 * cp_2 * \Delta t_2$	ΔT
(08) With the given Δh	$m_1 * \Delta h_1 = m_2 * cp_2 * \Delta t_2$	ΔH
<u>Heat Flow: (HIT.TR/HIT.EX/FLOW)</u>		
(09) Multiple pass	$Q = F_c * U * A * LMTD$	MULTI
<u>Single pass: (HIT.TR/HIT.EX/FLOW/SINGL)</u>		
(10) With $LMTD$	$Q = U * A * LMTD$	LMTD
(11) With Δt	$Q = m * cp * \Delta t$	ΔT
(12) With Δh	$Q = m * \Delta h$	ΔH

HEAT TRANSFER

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>HEAT EXCHANGER (continued): (HIT.TR/HIT.EX)</u>		
(13) Heat requirement	$q = m \cdot c_p \cdot \Delta t$	HIT.RE
<u>Logarithmic Mean Temperature Difference: (HIT.TR/HIT.EX/LMTD)</u>		
<u>Counter flow: (HIT.TR/HIT.EX/LMTD/COUNT)</u>		
(14) English Units	$LMTD = \frac{(T_1 - t_o) - (T_o - t_1)}{\ln \frac{T_1 - t_o}{T_o - t_1}}$	ENG
(15) SI Units	$LMTD = \frac{(T_1 - t_o) - (T_o - t_1)}{\ln \frac{T_1 - t_o}{T_o - t_1}} - 17.78$	SI
<u>General Equation: (HIT.TR/HIT.EX/LMTD/GNRL)</u>		
(16) English Units	$LMTD = \frac{\Delta T_1 - \Delta T_o}{\ln (\Delta T_1 / \Delta T_o)}$	ENG
(17) SI Units	$LMTD = \frac{\Delta T_1 - \Delta T_o}{\ln (\Delta T_1 / \Delta T_o)} - 17.78$	SI
<u>Parallel flow: (HIT.TR/HIT.EX/LMTD/PARAL)</u>		
(18) English Units	$LMTD = \frac{(T_o - t_o) - (T_1 - t_1)}{\ln \frac{T_o - t_o}{T_1 - t_1}}$	ENG
(19) SI Units	$LMTD = \frac{(T_o - t_o) - (T_1 - t_1)}{\ln \frac{T_o - t_o}{T_1 - t_1}} - 17.78$	SI
<u>Tube, heat exchanger: (HIT.TR/HIT.EX/TUBE)</u>		
<u>Length: (HIT.TR/HIT.EX/TUBE/LNTH)</u>		
(20) English Units	$l = \frac{900 \rho \cdot D_i^2 \cdot c_p (t_o - t_1) \cdot v}{U_o \cdot D_o \cdot LMTD}$	ENG
(21) SI Units	$l = \frac{.45 \rho \cdot D_i^2 \cdot c_p (t_o - t_1) \cdot v}{U_o \cdot D_o \cdot (1.8 \cdot LMTD + 32)}$	SI
(22) Surface area	$A = \frac{q}{U \cdot LMTD}$	AREA
<u>HEAT FLOW THROUGH: (HIT.TR/HIT.FL)</u>		
<u>Film: (HIT.TR/HIT.FL/FILM)</u>		
(23) Slab	$q = h \cdot A \cdot \Delta t$	SLAB
(24) Cylinder	$q = 2\pi \cdot r \cdot l \cdot h \cdot \Delta t$	CYLIN

HEAT TRANSFER

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>HEAT FLOW THROUGH: (HIT.TR/HIT.FL)</u>		
<u>Pipe: (HIT.TR/HIT.FL/PIPE)</u>		
<u>Bare pipe: (HIT.TR/HIT.FL/PIPE/BARE)</u>		
(25) Conduction only (1K)	$q = \frac{2\pi * K * l * \Delta t}{\ln \frac{r_o}{r_i}}$	1K
(26) Convection only (1H)	$q = 2\pi * r * l * h * \Delta t$	1H
(27) Composite (1K+1H)	$q = \frac{2\pi * l * \Delta t}{\frac{\ln(r_o/r_i)}{K} + \frac{1}{r_o h_o}}$	1K1H
(28) Composite (1K+2H)	$q = \frac{2\pi * l * \Delta t}{\frac{1}{r_i h_i} + \frac{\ln(r_o/r_i)}{K} + \frac{1}{r_o h_o}}$	1K2H
<u>Insulated pipe: (HIT.TR/HIT.FL/PIPE/INSUL)</u>		
(29) Conduction only (2K)	$q = \frac{2\pi * l * \Delta t}{\frac{\ln(\frac{r_o}{r_i})}{K_p} + \frac{\ln(\frac{r_t}{r_o})}{K_{ins}}}$	2K
(30) Composite (2K+1H)	$q = \frac{2\pi * l * \Delta t}{\frac{\ln(\frac{r_o}{r_i})}{K_p} + \frac{\ln(\frac{r_t}{r_o})}{K_{ins}} + \frac{1}{r_t h_o}}$	2K1H
(31) Composite (2K+2H)	$q = \frac{2\pi * l * \Delta t}{\frac{1}{r_i h_i} + \frac{\ln(\frac{r_o}{r_i})}{K_p} + \frac{\ln(\frac{r_t}{r_o})}{K_{ins}} + \frac{1}{r_t h_o}}$	2K2H
<u>Slab: (HIT.TR/HIT.FL/SLAB)</u>		
<u>Single: (HIT.TR/HIT.FL/SLAB/SINGL)</u>		
(32) With the given K and L	$q = \frac{K * A * \Delta t}{L}$	K+L
(33) With the given U	$q = U * A * \Delta t$	U
(34) Composite (2K)	$q = \frac{A * \Delta t}{\frac{L_1}{K_1} + \frac{L_2}{K_2}}$	2K

HEAT TRANSFER

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>Slab (Continued): (HIT.TR/HIT.FL/SLAB)</u>		
(35) Composite (3K)	$q = \frac{A \cdot \Delta t}{\frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3}}$	3K
(36) Composite (1K+1h)	$q = \frac{A \cdot \Delta t}{\frac{L}{K} + \frac{1}{h}}$	1K1H
(37) Composite (1K+2h)	$q = \frac{A \cdot \Delta t}{\frac{1}{h_1} + \frac{L}{K} + \frac{1}{h_2}}$	1K2H
(38) Composite (2K+1h)	$q = \frac{A \cdot \Delta t}{\frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{1}{h}}$	2K1H
(39) Composite (2K+2h)	$q = \frac{A \cdot \Delta t}{\frac{1}{h_1} + \frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{1}{h_2}}$	2K2H
(40) Composite (3K+2h)	$q = \frac{A \cdot \Delta t}{\frac{1}{h_1} + \frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3} + \frac{1}{h_2}}$	3K2H
(41) Ideal gas equation	$p \cdot V = m \cdot R \cdot T$	IDEAL
(42) Interpolation	$A_n = A_1 + \frac{(A_2 - A_1)(B_n - B_1)}{B_2 - B_1}$	INTRP

RADIANT HEAT FLOW: (HIT.TR/RADIA)

Radiation: (HIT.TR/RADIA/RADIA)

(43) English Units	$q_r = .1713EE-8 \cdot A \cdot F_{\bullet} \cdot F_{\bullet} (T_1^4 - T_2^4)$	ENG
(44) SI Units	$q_r = 5.6724EE-8 \cdot A \cdot F_{\bullet} \cdot F_{\bullet} (T_1^4 - T_2^4)$	SI

Thermocouple Actual Temperature: (HIT.TR/RADIA/COUPL)

TP > TW: (HIT.TR/RADIA/COUPL/TP > TW)

(45) English Units	$T_g = T_p + \frac{.1713EE-8 \cdot F_{\bullet} (T_p^4 - T_w^4)}{h}$	ENG
(46) SI Units	$T_g = T_p + \frac{5.6724EE-8 \cdot F_{\bullet} (T_p^4 - T_w^4)}{h}$	SI

HEAT TRANSFER

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>TW > TP: (HIT.TR/RADIA/COUPL/TW > TP)</u>		
(47) English Units	$T_g = T_p + \frac{.1713EE-8 * F_o (T_v^4 - T_p^4)}{h}$	ENG
(48) SI Units	$T_g = T_p + \frac{5.6724EE-8 * F_o (T_v^4 - T_p^4)}{h}$	SI
<u>REYNOLDS NUMBER: (HIT.TR/REYN)</u>		
(49) With Absolute Viscosity	$N_{Re} = \frac{D * v * \rho}{\mu * g}$	ABSOL
(50) With Kinetic Viscosity	$N_{Re} = \frac{D * v}{\nu}$	KINET
<u>STEAM: (THER/STIM)</u>		
(51) Enthalpy	$h = h_f + X * (h_g - h_f)$	ENTH
(52) Entropy	$s = s_f + X * (s_g - s_f)$	ENTR
(53) Specific volume	$v = v_f + X * (v_g - v_f)$	SPCV
<u>Steam Rate: (THER/STIM/RATE)</u>		
(54) English Units	$M = \frac{q}{3600 (h_1 - h_2)}$	ENG
(55) SI Units	$M = \frac{q}{h_1 - h_2}$	SI
<u>TRANSIENT HEAT FLOW (English Units): (HIT.TR/TRNS/ENG)</u>		
(56) Heat flow at time "t"	$q_t = h * A_s (T_o - T_\infty) e^{\frac{-t}{R_s * C_o}}$	HTFLO
(57) Biot Number	$N_{Bi} = \frac{h * L}{k}$	BIOT
(58) Fourier Number	$N_{Fo} = \frac{k * t}{\rho * c_p * L^2}$	FORI→
(59) Fourier Number	$N_{Fo} = \frac{\alpha * t}{L^2}$	

HEAT TRANSFER

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>Temperature at time t: (HIT.TR/TRNS/ENG/TEMP)</u>		
(60) With r & t	$T_t = T_{\infty} + (T_o - T_{\infty}) e^{-r \cdot t}$	R+T
(61) With Re & Ce	$T_t = T_{\infty} + (T_o - T_{\infty}) e^{\frac{-t}{R_{\infty} \cdot C_{\infty}}}$	RECE
(62) NBi < =0.1	$T_t = T_{\infty} + (T_o - T_{\infty}) e^{-NB_i \cdot N_{\infty}}$	NB ≤ . 1
(63) Thermal Capacitance	$C_{\infty} = c p \cdot \rho \cdot V$	CAPAC
(64) Thermal Resistance	$R_{\infty} = \frac{1}{h \cdot A_{\infty}}$	RESIS
(65) Time to reach to "Tt"	$t = -\frac{1}{r} \cdot \ln \left(\frac{T_t - T_{\infty}}{T_o - T_{\infty}} \right)$	TIME

HEAT TRANSFER VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT (ENG, SI)</u>
<u>A</u>	Area; <u>ft²</u> , <u>m²</u> (1 ft ² = .0929 m ²).
<u>a</u>	Thermal diffusivity; <u>ft²/hr</u> , <u>m²/hr</u> (1 ft ² /hr = .0929 m ² /hr).
<u>As</u>	Surface area; <u>ft²</u> , <u>m²</u> (1 ft ² = .0929 m ²).
<u>Ce</u>	Thermal capacitance; <u>btu/oR</u> .
<u>cp</u>	Specific heat at constant pressure; <u>btu/lbm-oR</u> , <u>J/kg.K</u> (1 btu/lbm-oR = 4186.8 J/kg.K).
<u>Di</u>	Inside diameter; <u>ft</u> , <u>m</u> (1 ft = 0.3048 m).
<u>Do</u>	Outside diameter; <u>ft</u> , <u>m</u> (1 ft = 0.3048 m).
<u>Fa</u>	Shape factor; <u>None</u> .
<u>Fc</u>	Correction factor; <u>None</u> .
<u>Fe</u>	Emissivity factor; <u>None</u> .
<u>g</u>	Gravitational acceleration; <u>ft/sec²</u> , <u>m/s²</u> (1 ft/sec ² = 0.3048 m/s ²).
<u>h</u>	Film coefficient; <u>btu/hr-ft²-oR</u> , <u>W/m².K</u> (1 btu/hr-ft ² -oR = 5.68 W/m ² .K).
<u>h</u>	Enthalpy; <u>btu/lbm</u> , <u>J/kg</u> (1 btu/lbm = 2236 J/kg =, 1 btu = 1055 J).
<u>hf</u>	Enthalpy of Saturated Liquid; <u>btu/lbm</u> , <u>J/kg</u> (1 btu/lbm = 2236 J/kg =, 1 btu = 1055 J).
<u>hfg</u>	Enthalpy of vaporization; <u>btu/lbm</u> , <u>J/kg</u> (1 btu/lbm = 2236 J/kg =, 1 btu = 1055 J).
<u>hg</u>	Enthalpy of saturated vapor; <u>btu/lbm</u> , <u>J/kg</u> (1 btu/lbm = 2236 J/kg =, 1 btu = 1055 J).
<u>hi</u>	Inside film coefficient; <u>btu/hr-ft²-oR</u> , <u>W/m².K</u> (1 btu/hr-ft ² -oR = 5.68 W/m ² .K).
<u>ho</u>	Outside film coefficient; <u>btu/hr-sf-oR</u> , <u>W/m².K</u> (1 btu/hr-ft ² -oR = 5.68 W/m ² .K).
<u>K</u>	Thermal conductivity; <u>btu/hr-ft-oR</u> , <u>W/m.K</u> (1 btu/hr-ft-oR = 1.731 W/m.K).
<u>k</u>	Ratio of Specific Heat; <u>None</u> .
<u>L</u>	Thickness; <u>ft</u> , <u>m</u> (1 ft = 0.3048 m).
<u>L</u>	Characteristic length (V/As); <u>ft</u> , <u>m</u> (1 ft = 0.3048 m).
<u>l</u>	Length; <u>ft</u> , <u>m</u> (1 ft = 0.3048 m).
<u>LMTD</u>	Logarithmic Mean Temperature Difference; <u>oF</u> , <u>oC</u> .
<u>M</u>	Mass; <u>lbm</u> , <u>kg</u> (1 lbm = 0.4536 kg).
<u>n</u>	Coefficient (turbulent heat flow in pipe); <u>None</u> (n = .3 if t(bulk) > t(wall), n = .4 if t(bulk) < t(wall))
<u>NBi</u>	Biot number; <u>None</u> .
<u>NFo</u>	Fourier number; <u>None</u> .
<u>NPr</u>	Prandtl number; <u>None</u> .
<u>NRe</u>	Reynold number; <u>None</u> (NRe <= 2000: laminar flow, NRe > 2000 turbulent flow).
<u>q</u>	Heat flow; <u>btu/h</u> , <u>W (J/s)</u> (1 btu/h = .2931 W (J/s) = .252 kcal/h).
<u>τ</u>	Transient heat flow time constant; <u>None</u>
<u>r</u>	Radius; <u>ft</u> , <u>m</u> (1 ft = 0.3048 m).
<u>R</u>	Specific Heat Constant; <u>ft-lbf/lbm-oR</u> , <u>J/kg.K</u> (1 ft-lbf/lbm-oR = 5.3803 J/kg.K).
<u>Re</u>	Thermal resistance; <u>hr-oR/btu</u> .
<u>ri</u>	Pipe's inside radius; <u>ft</u> , <u>m</u> (1 ft = 0.3048 m).

HEAT TRANSFER

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT (ENG, SI)</u>
<u>ro</u>	Pipe's outside radius; <u>ft.</u> , <u>m</u> (1 ft=0.3048 m).
<u>rt</u>	Insulated pipe's total radius; <u>ft.</u> , <u>m</u> (1 ft=0.3048 m).
<u>s</u>	Entropy; <u>btu/lbm-oF</u> , <u>J/kg-oC</u> (1 btu/lbm-oF=4186.8 J/kg-oC).
<u>sf</u>	Entropy of Saturated Liquid; <u>btu/lbm-oF</u> , <u>J/kg-oC</u> (1 btu/lbm-oF=4186.8 J/kg-oC).
<u>sfg</u>	Entropy of vaporization; <u>btu/lbm-oF</u> , <u>J/kg-oC</u> (1 btu/lbm-oF=4186.8 J/kg-oC).
<u>sg</u>	Entropy of Saturated Vapor; <u>btu/lbm-oF</u> , <u>J/kg-oC</u> (1 btu/lbm-oF=4186.8 J/kg-oC).
<u>t</u>	Time; <u>hour</u> .
<u>T</u>	Temperature; <u>oR</u> , <u>oK</u> .
<u>Tg</u>	Gas temperature; <u>oR</u> , <u>oK</u> .
<u>Ti</u>	Hot fluid inlet temperature; <u>oF</u> , <u>oC</u> .
<u>ti</u>	Cold fluid inlet temperature; <u>oF</u> , <u>oC</u> .
<u>To</u>	Initial temperature; <u>oF</u> , <u>oC</u> : Hot fluid outlet temperature; <u>oF</u> , <u>oC</u> .
<u>to</u>	Cold fluid outlet temperature; <u>oF</u> , <u>oC</u> .
<u>Tp</u>	Thermocouple probe temperature; <u>oR</u> , <u>oK</u> .
<u>ts</u>	Surface temperature; <u>oF</u> , <u>oC</u> .
<u>tsv</u>	Saturated vapor temperature; <u>oF</u> , <u>oC</u> .
<u>Tt</u>	Temperature at time t; <u>oF</u> , <u>oC</u> .
<u>Tw</u>	Wall temperature; <u>oR</u> , <u>oK</u> .
<u>T</u>	Environment or surrounding temperature; <u>oF</u> , <u>oC</u> .
<u>U</u>	Overall heat transfer coefficient; <u>btu/hr-ft2-oR</u> , <u>W/m2.K</u> (1 btu/hr-ft2-oR=5.68 W/m2.K).
<u>Ui</u>	Pipe's inside heat transfer coefficient; <u>btu/hr-ft2-oR</u> , <u>W/m2.K</u> (1 btu/hr-ft2-oR=5.68 W/m2.K).
<u>Uo</u>	Pipe's outside heat transfer coefficient; <u>btu/hr-ft2-oR</u> , <u>W/m2.K</u> (1 btu/hr-ft2-oR=5.68 W/m2.K).
<u>V</u>	Body's volume; <u>ft3</u> , <u>m3</u> (1 ft3=.0283 m3).
<u>v</u>	Specific volume; <u>ft3/lb</u> , <u>m3/kg</u> (1 ft3/lb=.06243 m3/kg).
<u>vf</u>	Specific volume of Saturated Liquid; <u>ft3/lb</u> , <u>m3/kg</u> (1 ft3/lb=.06243 m3/kg).
<u>vfg</u>	Specific volume of vaporization; <u>ft3/lb</u> , <u>m3/kg</u> (1 ft3/lb=.06243 m3/kg).
<u>vg</u>	Specific volume of Saturated Vapor; <u>ft3/lb</u> , <u>m3/kg</u> (1 ft3/lb=.06243 m3/kg).
<u>ρ</u>	Body's density; <u>lbm/ft3</u> , <u>kg/m3</u> (1 lbm/ft3=16.0185 kg/m3).
<u>ρl</u>	Liquid density; <u>lbm/ft3</u> , <u>kg/m3</u> (1 lbm/ft3=16.0185 kg/m3).
<u>ρv</u>	Vapor density; <u>lbm/ft3</u> , <u>kg/m3</u> (1 lbm/ft3=16.0185 kg/m3).
<u>μ</u>	Absolute viscosity; <u>lbf-sec/ft2</u> , <u>kg.s/m2</u> (1 lbf-sec/ft2=4.882 kg.s/m2).
<u>ν</u>	Kinetic viscosity; <u>ft2/sec</u> , <u>m2/s</u> (1 ft2/sec=0.0929 m2/s).

HEAT TRANSFER
PROPERTIES OF WATER, ENGLISH UNITS

TEMP oF	ρ lbm/ft ³	c_p btu/lbm-oF	μ lbf-sec/ft ²	ν ft ² /sec	K btu/hr-ft-oF	N_{Pr} -
32	62.4	1.010	3.727 EE-5	1.93 EE-5	0.319	13.70
40	62.4	1.000	3.230 EE-5	1.67 EE-5	0.325	11.60
50	62.4	1.000	2.733 EE-5	1.40 EE-5	0.332	9.55
60	62.3	0.999	2.360 EE-5	1.22 EE-5	0.340	8.03
70	62.3	0.998	2.043 EE-5	1.06 EE-5	0.347	6.82
80	62.2	0.998	1.795 EE-5	0.93 EE-5	0.353	5.89
90	62.1	0.997	1.596 EE-5	0.825 EE-5	0.359	5.13
100	62.0	0.998	1.422 EE-5	0.740 EE-5	0.364	4.52
150	61.2	1.000	0.907 EE-5	0.477 EE-5	0.384	2.74
200	60.1	1.000	0.637 EE-5	0.341 EE-5	0.394	1.88
250	58.8	1.010	0.491 EE-5	0.269 EE-5	0.396	1.45
300	57.3	1.030	0.391 EE-5	0.220 EE-5	0.395	1.18
350	55.6	1.050	0.326 EE-5	0.189 EE-5	0.391	1.02
400	53.6	1.080	0.283 EE-5	0.170 EE-5	0.381	0.927
450	51.6	1.120	0.248 EE-5	0.155 EE-5	0.367	0.876
500	49.0	1.190	0.221 EE-5	0.145 EE-5	0.349	0.870
550	45.9	1.310	0.199 EE-5	0.139 EE-5	0.325	0.930
600	42.4	1.510	0.180 EE-5	0.137 EE-5	0.292	1.090

HEAT TRANSFER
PROPERTIES OF WATER, SI UNITS

TEMP oC	ρ kg/m ³	C_p J/kg.K	μ kg.s/m ²	ν m ² /s	K W/m.K	N_{Pr} -
0	999.3	4186.8	1.820 EE-4	1.793 EE-6	0.552	13.700
5	999.3	4186.8	1.552 EE-4	1.526 EE-6	0.564	11.395
10	999.3	4186.8	1.334 EE-4	1.301 EE-6	0.575	9.55
15	997.9	4186.8	1.171 EE-4	1.150 EE-6	0.587	8.182
20	997.9	4179.3	1.029 EE-4	1.015 EE-6	0.598	7.062
25	996.6	4178.4	9.128 EE-5	0.900 EE-6	0.608	6.169
30	995.2	4175.9	8.182 EE-5	0.805 EE-6	0.617	5.434
40	992.3	4180.1	6.605 EE-5	0.656 EE-6	0.633	4.276
60	982.7	4185.1	4.931 EE-5	0.492 EE-6	0.658	3.096
90	964.6	4186.8	3.267 EE-5	0.332 EE-6	0.680	1.983
120	942.5	4227.0	2.424 EE-5	0.253 EE-6	0.685	1.467
150	916.7	4315.8	1.891 EE-5	0.203 EE-6	0.684	1.169
180	887.2	4406.2	1.554 EE-5	0.172 EE-6	0.676	1.001
210	852.0	4546.9	1.337 EE-5	0.154 EE-6	0.656	0.908
240	817.4	4736.1	1.166 EE-5	0.140 EE-6	0.628	0.862
270	769.7	5238.5	1.027 EE-5	0.131 EE-6	0.593	0.868
300	710.4	5853.1	0.930 EE-5	0.128 EE-6	0.537	1.000

HVAC

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>AIR: (HVAC/AIR)</u>		
<u>Atmospheric Air: (HVAC/AIR/ATMO)</u>		
<u>Pressure: (HVAC/AIR/ATMO/PRESS)</u>		
<u>Air pressure: (HVAC/AIR/ATMO/PRESS/AIR)</u>		
(01) Dry air	$P_{da} = P_{at} - P_{vv}$	DRY
(02) Atmospheric air	$P_{at} = P_{da} + P_{vv}$	ATMO
<u>Vapor pressure: (HVAC/AIR/ATMO/PRESS/VAPOR)</u>		
(03) With given Specific Humidity	$P_{vv} = \frac{H_s * P_{at}}{.621 + H_s}$	SPC.H
(04) With given Relative Humidity	$P_{vv} = .01 * RH\% * P_{sww}$	REL.H
(05) With given number of moles	$P_{vv} = \left(\frac{n_{vv}}{n_{vv} + n_{da}} \right) P_{tot}$	MOLE
<u>Relative Humidity: (HVAC/AIR/ATMO/REL.H)</u>		
(06) With given pressures	$RH\% = \frac{100 P_{vv}}{P_{sww}}$	PRESS
(07) With given Specific Humidity	$RH\% = \frac{161 * H_s * P_{da}}{P_{sww}}$	SPC.H
<u>Specific Humidity: (HVAC/AIR/ATMO/SPC.H)</u>		
(08) With given dry air pressure	$H_s = \frac{.621 * P_{vv}}{P_{da}}$	DRY.P
(09) With given atmospheric pressure	$H_s = \frac{.621 * P_{vv}}{P_{at} - P_{vv}}$	ATM.P
<u>Air Flow Rate: (HVAC/AIR/FLOW)</u>		
<u>English System: (HVAC/AIR/FLOW/ENG)</u>		
(10) Through the A/C Supply Fan (total)	$cfm_f = \frac{q_s}{1.08 (t_x - t_s)}$	FAN
<u>Through the coil: (HVAC/AIR/FLOW/ENG/COIL)</u>		
(11) With given fan flow (cfmF)	$cfm_c = \frac{t_x - t_s}{t_x - t_{sp}} cfm_f$	CFMF
(12) With given sensible cooling load (qs)	$cfm_c = \frac{q_s}{1.08 (t_x - t_{sp})}$	QS

HVAC

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>SI System: (HVAC/AIR/FLOW/SI)</u>		
(13) Through the A/C Supply Fan (total)	$lps_f = \frac{q_s}{1.207(t_x - t_s)}$	FAN
<u>Through the coil: (HVAC/AIR/FLOW/SI/COIL)</u>		
(14) With given fan flow (lpsF)	$lps_c = \frac{t_x - t_s}{t_x - t_{ap}} lps_f$	LPSF
(15) With given sensible cooling load (qs)	$lps_c = \frac{q_s}{1.207(t_x - t_{ap})}$	QS
 <u>Air Mixture Properties: (HVAC/AIR/MIXTR)</u>		
<u>With given volumetric flow: (HVAC/AIR/MIXTR/VOLM)</u>		
(16) Temperature of mixture	$t_{mix} = \frac{Q_1 v_2 t_1 + Q_2 v_1 t_2}{Q_1 v_2 + Q_2 v_1}$	TEMP
(17) Enthalpy of mixture	$h_{mix} = \frac{Q_1 v_2 h_1 + Q_2 v_1 h_2}{Q_1 v_2 + Q_2 v_1}$	ENTH
(18) Specific Humidity of mixture	$HS_{mix} = \frac{Q_1 v_2 HS_1 + Q_2 v_1 HS_2}{Q_1 v_2 + Q_2 v_1}$	SPC. H
(19) Specific Volume of mixture	$v_{mix} = \frac{Q_1 + Q_2}{Q_1/v_1 + Q_2/v_2}$	SPC. V
(20) Mass of mixture	$m_{mix} = \frac{Q_1}{v_1} + \frac{Q_2}{v_2}$	MASS
 <u>With given mass flow: (HVAC/AIR/MIXTR/MASS)</u>		
(21) Temperature of mixture	$t_{mix} = \frac{m_1 t_1 + m_2 t_2}{m_1 + m_2}$	TEMP
(22) Enthalpy of mixture	$h_{mix} = \frac{m_1 h_1 + m_2 h_2}{m_1 + m_2}$	ENTH
(23) Specific Humidity of mixture	$HS_{mix} = \frac{m_1 HS_1 + m_2 HS_2}{m_1 + m_2}$	SPC. H
(24) Specific Volume of mixture	$v_{mix} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$	SPC. V
(25) Volume of mixture	$Q_{mix} = m_1 * v_1 + m_2 * v_2$	VOLM

HVAC

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
(26) Bypass Factor	$BF = \frac{t_{oc} - t_{ap}}{t_{ic} - t_{ap}}$	BYPAS
<u>CHILLER: (HVAC/CHILR)</u>		
<u>English System: (HVAC/CHILR/ENG)</u>		
(27) Chilled water flow quantity	$gpm = \frac{q}{500.5 (t_o - t_i)}$	GPM
(28) Circulating pump power	$hp = \frac{h_a * gpm}{246858 * v_{lw} * \eta}$	HP
<u>SI System: (HVAC/CHILR/SI)</u>		
(29) Chilled water flow quantity	$lps = \frac{q}{4186 (t_o - t_i)}$	LPS
(30) Circulating pump power	$hp = \frac{h_a * lps}{75000 * v_{lw} * \eta}$	HP
(31) Coefficient of Heat Transfer	$U = \frac{1}{\Sigma \left(\frac{1}{h} \right) + \Sigma \left(\frac{L}{K} \right) + \Sigma R}$	UCOEF
<u>COIL: (HVAC/COIL)</u>		
(32) Temp. of entering mixed air	$t_{mix} = \frac{Q_v * v_r * t_o + (Q_r - Q_v) * v_o * t_r}{Q_v * v_r + (Q_r - Q_v) * v_o}$	TMIX
(33) Weight of condensate water	$m_w = m_a (HS_1 - HS_o)$	WATR
(34) Sensible Heat Ratio	$SHR = 1 - \left(\frac{HS_1 - HS_2}{h_1 - h_2} \right) h_{fg}$	SHR
<u>ENERGY EFFICIENCY RATIO (English System only): (HVAC/EER/ENG)</u>		
(35) With refrigeration tonnage	$EER = \frac{12000 \text{ ton}_R}{745.7 \text{ hp}}$	TONR
(36) With input power in watts	$EER = \frac{q}{\text{watt}}$	WATT

<u>DESCRIPTION</u>	<u>HVAC</u>	<u>FORMULA</u>	<u>NAME</u>
<u>EXCHANGERS (AIR WASHER/ COOLING TOWER/SPRAYER): (HVAC/EXCH)</u>			

(37) Efficiency		$\eta = \frac{t_i - t_o}{t_i - t_v}$	EFFI
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Heat Balance Equations: (HVAC/EXCH/HTBAL)

(38) With given mass flow		$m_a \cdot (h_{i_a} - h_{o_a}) = m_v \cdot (h_{o_v} - h_{i_v})$	MASS
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With volumetric flow: (HVAC/EXCH/HTBAL/VOLM)

(39) English System		$\frac{cfm_a}{v_{i_a}} (h_{i_a} - h_{o_a}) = .13368 \cdot \frac{gpm_v}{v_{i_v}} (h_{o_v} - h_{i_v})$	ENG
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(40) SI System		$\frac{lps_a}{v_{i_a}} (h_{i_a} - h_{o_a}) = \frac{lps_v}{v_{i_v}} (h_{o_v} - h_{i_v})$	SI
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Water added/removed: (HVAC/EXCH/WATR)

Volumetric flow of water: (HVAC/EXCH/WATR/VOLM)

English System: (HVAC/EXCH/WATR/VOLM/ENG)

(41) With volumetric flow of air		$gpm_v = \frac{v_{i_v} \cdot cfm_a (Hs_i - Hs_o)}{.13368 \cdot v_{i_a}}$	VOLM
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(42) With mass flow of air		$gpm_v = \frac{v_{i_v} \cdot m_a (Hs_i - Hs_o)}{8.0208}$	MASS
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SI System: (HVAC/EXCH/WATR/VOLM/SI)

(43) With volumetric flow of air		$lps_v = \frac{v_{i_v} \cdot lps_a (Hs_i - Hs_o)}{v_{i_a}}$	VOLM
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(44) With mass flow of air		$lps_v = 1000 v_{i_v} \cdot m_a (Hs_i - Hs_o)$	MASS
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Mass flow of water: (HVAC/EXCH/WATR/MASS)

With volumetric flow of air (HVAC/EXCH/WATR/MASS/VOLM)

(45) English System		$m_v = \frac{cfm_a (Hs_i - Hs_o)}{v_{i_a}}$	ENG
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(46) SI System		$m_v = \frac{lps_a (Hs_i - Hs_o)}{1000 v_{i_a}}$	SI
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(47) With mass flow of air, mass		$m_v = m_a (Hs_i - Hs_o)$	MASS
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FUEL CONSUMPTION (English System only): (HVAC/FUEL/ENG)

(48) Based on degree days		$FC = \frac{24 \cdot q_d \cdot (DAYS \cdot (t_{i_a} - 65) + DEGD)}{(t_{i_d} - t_{o_d}) \cdot HV \cdot \eta}$	DEGD
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(49) Based on heat loss		$FC = \frac{hr_{pik} \cdot q_{pik} + hr_{off} \cdot q_{off}}{HV \cdot \eta}$	HEAT
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HVAC

HEAT ADDED/GAINED/LOST: (HVAC/HEAT)

Heat added: (HVAC/HEAT/ADD)

By lighting: (HVAC/HEAT/ADD/LIGHT)

(50) English System $q_s = 3.41 * watt * CL$ **ENG**

(51) SI System $q_s = watt * CL$ **SI**

By equipment (motor in the area): (HVAC/HEAT/ADD/EQMT)

(52) English System $q_s = \frac{2545 * hp}{\eta}$ **ENG**

(53) SI System $q_s = \frac{745.7 * hp}{\eta}$ **SI**

By occupants: (HVAC/HEAT/ADD/OCCUP)

(54) Sensible $q_s = SEN. H * NP$ **SENS**

(55) Latent $q_l = LAT. H * NP$ **LATN**

By ventilation: (HVAC/HEAT/ADD/VENT)

English System: (HVAC/HEAT/ADD/VENT/ENG)

(56) Sensible $q_s = 1.08 * cfm_v (t_o - t_i)$ **SENS**

(57) Latent $q_l = 4840 * cfm_v (Hs_o - Hs_i)$ **LATN**

(58) Total $q = 4.5 * cfm_v (h_o - h_i)$ **TOTAL**

SI System: (HVAC/HEAT/ADD/VENT/SI)

(59) Sensible $q_s = 1.207 * lps_v (t_o - t_i)$ **SENS**

(60) Latent $q_l = 3006 * lps_v (Hs_o - Hs_i)$ **LATN**

(61) Total $q = .0012 * lps_v (h_o - h_i)$ **TOTAL**

Heat Gained: (HVAC/HEAT/GAIN)

Through windows: (HVAC/HEAT/GAIN/WIND)

(62) Instantaneous $q_s = U * A (t_o - t_i)$ **INSTN**

(63) Solar radiation $q_s = A * C_s * F_{shg}$ **SOLAR**

(64) Total $q_s = A (C_s * F_{shg} + U (t_o - t_i))$ **TOTAL**

(65) Through the wall/roof (Instantaneous) $q_s = U * A * CLTD$ **WALL**

(66) Through the partitions $q_s = U * A (t_{sj} - t_i)$ **PARTI**

HVAC

Heat Loss: (HVAC/HEAT/LOSS)

(64) Through the surface	$Q_{sur} = U \cdot A (t_i - t_o)$	SURF
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By ventilation: (HVAC/HEAT/LOSS/VENT)

English System: (HVAC/HEAT/LOSS/VENT/ENG)

(65) Sensible	$Q_s = 1.08 \cdot cfm_v (t_i - t_o)$	SENS
(66) Latent	$Q_l = 4840 \cdot cfm_v (HS_i - HS_o)$	LATN
(67) Total	$Q = 4.5 \cdot cfm_v (h_i - h_o)$	TOTAL

SI System: (HVAC/HEAT/LOSS/VENT/SI)

(68) Sensible	$Q_s = 1.207 \cdot lps_v (t_i - t_o)$	SENS
(69) Latent	$Q_l = 3006 \cdot lps_v (HS_i - HS_o)$	LATN
(70) Total	$Q = .0012 \cdot lps_v (h_i - h_o)$	TOTAL

HUMIDIFIER (HVAC/HUMID)

(71) English system	$lbph = 60 cfm_v \left(\frac{HS_i}{v_i} - \frac{HS_o}{v_o} \right) - \frac{NP \cdot LAT \cdot H}{hfg_i}$	ENG
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(72) SI system	$kgph = 3.6 lps_v \left(\frac{HS_i}{v_i} - \frac{HS_o}{v_o} \right) - \frac{3600 NP \cdot LAT \cdot H}{hfg_i}$	SI
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(73) Ideal gas equation	$p \cdot V = m \cdot R \cdot T$	IDEAL
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(74) Interpolation	$A_m = A_1 + (A_2 - A_1) \frac{B_m - B_1}{B_2 - B_1}$	INTRP
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(75) Room Sensible Heat Ratio	$RSHR = \frac{Q_s}{Q_s + Q_l}$	RSHR
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(76) Steam and Water mixture	$m_{st} (h_{st} - h_{mix}) = m_v (h_{mix} - h_v)$	STIM
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TONS OF REFRIGERATION: (HVAC/TONR)

English System: (HVAC/TONR/ENG)

(77) With the volumetric flow, cfm	$tonR = \frac{cfm \cdot (h_i - h_o)}{200 \cdot v_i}$	CFM
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(78) With the mass flow, lbph	$tonR = \frac{lbph \cdot (h_i - h_o)}{12000}$	LBPH
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SI System: (HVAC/TONR/SI)

(79) With the volumetric flow, lps	$tonR = \frac{lps \cdot (h_i - h_o)}{3.5522E6 \cdot v_i}$	LPS
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(80) With the mass flow, kgph	$tonR = \frac{kgph \cdot (h_i - h_o)}{1.2661E7}$	KGPH
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HVAC

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT (ENG, SI)</u>
<u>A</u>	Area; <u>ft²</u> , <u>m²</u> (1 ft ² = 0.0929 m ²).
<u>CL</u>	Light correction factor; <u>None</u> .
<u>cfm</u>	Cubic feet per minute (1 cfm = 0.47195 L/s).
<u>cfmC</u>	Flow rate, through the coil (conditioned air); <u>cfm</u> , <u>L/s</u> (1 cfm = 0.47195 L/s)
<u>cfmF</u>	Flow rate, Fan; <u>cfm</u> , <u>L/s</u> (1 cfm = 0.47195 L/s)
<u>cfmV</u>	Flow rate, Ventilation; <u>cfm</u> , <u>L/s</u> (1 cfm = 0.47195 L/s)
<u>CLF</u>	Cooling Load Factor; <u>None</u> .
<u>CLTD</u>	Cooling Load Temperature Difference; <u>oF</u> , <u>oC</u> .
<u>Cs</u>	Shading factor; <u>None</u> .
<u>EER</u>	Energy Efficiency Ratio; <u>BTU/hr/watt</u> .
<u>F</u>	Factor; <u>None</u> .
<u>FC</u>	Fuel Consumption; <u>gal</u> .
<u>Fshg</u>	Solar Heat Gain Factor; <u>BTU/hr-ft²</u> , <u>W/m²</u> (1 BTU/hr-ft ² = 3.155 W/m ²).
<u>gpm</u>	Gallon per minute (1 gpm = 0.00228 cfs = 6.309EE-5 m ³ /s = 0.06309 L/s).
<u>h</u>	Enthalpy; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm = 2326 J/kg, subscript <u>a</u> for air; <u>i</u> , inside; <u>mix</u> , mixture; <u>o</u> , outside; <u>st</u> , steam; and <u>w</u> , water)
<u>h</u>	Film Coefficient; <u>BTU/hr-ft²-oF</u> , <u>W/m².oC</u> (1 BTU/hr-ft ² -oF = 5.68 W/m ² .oC).
<u>hfg</u>	Enthalpy of evaporation; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm = 2326 J/kg).
<u>Hsi</u>	Inside air Specific Humidity; <u>lbw/lbda</u> , <u>kgw/kgda</u> .
<u>Hso</u>	Outside air Specific Humidity; <u>lbm/lbda</u> , <u>kgw/kgda</u> .
<u>HV</u>	Heat Value; <u>BTU/gal</u> .
<u>kgph</u>	Kilogram per hour (1 kg/h = 2.205 lb/h)
<u>LAT.H</u>	People/occupants rate of latent heat; <u>BTU/person/hr</u> , <u>W/person</u> (1 BTU/hr = 0.2931 W).
<u>lbph</u>	Pound per hour (1 lb/hr = 0.4536 kg/hr)
<u>lbpm</u>	Pound per minute (1 lb/min = 0.4536 kg/min)
<u>lps</u>	Liter per second (1 L/s = 2.1189 cfm = 15.85 gpm).
<u>m</u>	Mass; <u>lbm</u> , <u>kg</u> (1 lbm = 0.4536 kg).
<u>ma</u>	Mass flow rate of air; <u>lb/min</u> , <u>kg/s</u> (1 lb/min = 0.00761 kg/s).
<u>mw</u>	Mass flow rate of water; <u>lb/min</u> , <u>kg/s</u> (1 lb/min = 0.00761 kg/s).
<u>nda</u>	Number of moles of dry air; <u>moles</u> .
<u>nwv</u>	Number of moles of water vapor; <u>moles</u> .
<u>NP</u>	Number of people/occupants; <u>None</u> .
<u>P</u>	Pressure; <u>psi</u> , <u>Pa</u> (1 psi = 6894.76 Pa).
<u>p</u>	Pressure; <u>psf</u> , <u>Pa</u> (1 psf = 47.88 Pa).

HVAC

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT</u>
<u>Pat</u>	Atmospheric pressure; <u>psia</u> , <u>Pa</u> (1 psi = 6894.76 Pa).
<u>Pda</u>	Dry air pressure; <u>psia</u> , <u>Pa</u> (1 psi = 6894.76 Pa).
<u>Pswv</u>	Saturated water vapor pressure; <u>psia</u> , <u>Pa</u> (1 psi = 6894.76 Pa).
<u>Ptot</u>	Total pressure; <u>psia</u> , <u>Pa</u> (1 psi = 6894.76 Pa).
<u>Pwv</u>	Water vapor pressure; <u>psia</u> , <u>Pa</u> (1 psi = 6894.76 Pa).
<u>Q</u>	Flow quantity; <u>cfm</u> , <u>gpm</u> , <u>L/s</u> (1 cfm = 7.48052 gpm = 0.47195 L/s).
<u>q</u>	Heat gain/loss; <u>BTU/hr</u> , <u>W (J/s)</u> (1 BTU/hr = 0.2931 W = 0.252 kcal/hr).
<u>ql</u>	Heat gain/loss, latent; <u>BTU/hr</u> , <u>W (J/s)</u> (1 BTU/hr = 0.2931 W = 0.252 kcal/hr).
<u>q</u>	Design heat loss; <u>BTU/hr</u> , <u>W (J/s)</u> (1 BTU/hr = 0.2931 W = 0.252 kcal/hr).
<u>qs</u>	Heat gain/loss, sensible; <u>BTU/hr</u> , <u>W (J/s)</u> (1 BTU/hr = 0.29307 W = 0.252 kcal/hr).
<u>R</u>	Specific heat constant; <u>ft-lbf/lbm-oR</u> , <u>J/kg.K</u> (1 ft-lbf/lbm-oR = 5.3803 J/kg.K).
<u>R</u>	Thermal Resistivity Factor; <u>hr-oF-ft2/BTU</u> , <u>K.m2/W</u> .
<u>RH%</u>	Relative Humidity; <u>percent</u> .
<u>SEN.H</u>	People/occupants rate of sensible heat; <u>BTU/hr/person</u> , <u>W/person</u> (1 BTU/hr = 0.2931 W).
<u>T</u>	Temperature; <u>oR</u> , <u>K</u> .
<u>t1</u>	Air dry bulb temperature before cooling coil; <u>oF</u> , <u>oC</u> .
<u>t2</u>	Air dry bulb temperature after cooling coil; <u>oF</u> , <u>oC</u> .
<u>tap</u>	Apparatus dew point; <u>oF</u> , <u>oC</u> .
<u>tc</u>	Cooling coil temperature; <u>oF</u> , <u>oC</u> .
<u>ti</u>	Inside or in-going temperature; <u>oF</u> , <u>oC</u> .
<u>to</u>	Outside or outgoing temperature; <u>oF</u> , <u>oC</u> .
<u>tonR</u>	Ton of Refrigeration; <u>ton</u> . (tonR = 12000 BTU/hr = 3517 W = 3024 kcal/hr).
<u>tr</u>	Room design temperature; <u>oF</u> , <u>oC</u> .
<u>ts</u>	Room supply air temperature; <u>oF</u> , <u>oC</u> .
<u>tst</u>	Steam temperature; <u>oF</u> , <u>oC</u> .
<u>tw</u>	Water temperature; <u>oF</u> , <u>oC</u> .
<u>U</u>	Overall heat transfer coefficient; <u>BTU/hr-ft2-oR</u> , <u>W/m2.K</u> (1 BTU/hr-ft2-oR = 5.68 W/m2.K).
<u>v</u>	Specific volume, subscripts similar to t; <u>ft3/lbm</u> , <u>m3/kg</u> (1 ft3/lbm = 0.06243 m3/kg).
<u>viw</u>	Specific volume of water; <u>ft3/lbm</u> , <u>m3/kg</u> (1 ft3/lbm = 0.06243 m3/kg).
<u>V</u>	Volume; <u>ft3</u> , <u>m3</u> (1 ft3 = 0.0283 m3).
<u>watt</u>	Input power; <u>watts</u> .
<u>η</u>	Efficiency; <u>decimal</u> .

HYDRAULIC MACHINES

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
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AFFINITY: (HYDM/AFFIN)

Changing the pump's speed: (HYDM/AFFIN/RPM)

(01) Change in Flow quantity	$\frac{Q_1}{Q_2} = \frac{n_1}{n_2}$	FLOW
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(02) Change in Head	$\frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2$	HEAD
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(03) Change in Brake Horsepower	$\frac{bhp_1}{bhp_2} = \left(\frac{n_1}{n_2}\right)^3$	BHP
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Changing the pump's impeller diameter: (HYDM/AFFIN/DIAM)

(04) Change in Flow quantity	$\frac{Q_1}{Q_2} = \frac{D_1}{D_2}$	FLOW
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(05) Change in Head	$\frac{H_1}{H_2} = \left(\frac{D_1}{D_2}\right)^2$	HEAD
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(06) Change in Brake Horsepower	$\frac{bhp_1}{bhp_2} = \left(\frac{D_1}{D_2}\right)^3$	BHP
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BERNOULLI EQUATIONS: (HYDM/BERN)

English System: (HYDM/BERN/ENG)

(07) No friction loss	$\frac{P_1}{\rho} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{v_2^2}{2g} + z_2$	NO. HF
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(08) With friction loss	$\frac{P_1}{\rho} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{v_2^2}{2g} + z_2 + hf$	W. HF
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(09) Friction & minor loss	$\frac{P_1}{\rho} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho} + \frac{v_2^2}{2g} + z_2 + h_f + h_{frr}$	HF+
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SI System: (HYDM/BERN/SI)

(10) No friction loss	$\frac{P_1}{\rho \times g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho \times g} + \frac{v_2^2}{2g} + z_2$	NO. HF
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(11) With friction loss	$\frac{P_1}{\rho \times g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho \times g} + \frac{v_2^2}{2g} + z_2 + hf$	W. HF
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(12) Friction & minor loss	$\frac{P_1}{\rho \times g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho \times g} + \frac{v_2^2}{2g} + z_2 + h_f + h_{frr}$	HF+
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HYDRAULIC MACHINES

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>FRICITION FACTOR (MOODY CHART): (HYDM/FRIC.F)</u>		
(13) Laminar flow, $NRe < 2000$	$f = \frac{64}{NRe}$	LAMT
(14) Turbulent flow, $NRe > 4000$	$\frac{1}{\sqrt{f}} = -2 \log \left(\frac{\epsilon/D}{3.7} + \frac{2.51}{NRe \sqrt{f}} \right)$	TURBU
<u>FRICITION HEAD/LOSS IN PIPE: (HYDM/FRIC.H)</u>		
<u>Darcy Equations: (HYDM/FRIC.H/DARCY)</u>		
(15) General, with the given velocity, in fps or mps	$h_f = \frac{f * L_e * v^2}{2 * g * D}$	GENER
<u>English System: (HYDM/FRIC.H/DARCY/ENG)</u>		
(16) With the given flow, in gpm	$h_f = \frac{f * L_e * gpm^2}{248528 * g * D^5}$	GPM
(17) With the given flow, in cfs	$h_f = \frac{f * L_e * cfs^2}{1.2337 * g * D^5}$	CFS
<u>SI System: (HYDM/FRIC.H/DARCY/SI)</u>		
(18) With the given flow, in lps	$h_f = \frac{f * L_e * lps^2}{1233700 * g * D^5}$	LPS
(19) With the given flow, in m3ps	$h_f = \frac{f * L_e * m3ps^2}{1.2337 * g * D^5}$	M3PS
<u>Hazen-Williams equation (HYDM/FRIC.H/HAZN)</u>		
(20) English System	$h_f = \frac{3.012 * v^{1.85} * L_e}{C_{HW}^{1.85} * D^{1.165}}$	ENG
(21) Si System	$h_f = \frac{6.797 * v^{1.85} * L_e}{C_{HW}^{1.85} * D^{1.165}}$	SI
(22) Fittings, Valves, Entrances	$h_f = \frac{K * v^2}{2 * g}$	FITIN
(23) Nozzle, Orifice, Ventury	$h_f = \left(\frac{1}{C_v^2} - 1 \right) \frac{v^2}{2 * g}$	NOZL
(24) Sudden Contraction	$h_f = \frac{K_c * v_2^2}{2 * g}$	CONT
<u>Enlargement: (HYDM/FRIC.H/NLRG)</u>		
(25) Gradual	$h_f = \frac{K_e (v_1 - v_2)^2}{2 * g}$	GRAD
(26) Sudden	$h_f = \left(1 - \left(\frac{D_1}{D_2} \right)^2 \right)^2 \frac{v_1^2}{2 * g}$	SUDD
(27) Scaled pipe	$h_f = h_{f_{new}} \left(\frac{D_{new}}{D_{scal}} \right)^5$	SCALE

HYDRAULIC MACHINES

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>HEAD: (HYDM/HEAD)</u>		
<u>Added by Pump: (HYDM/HEAD/PUMP)</u>		
(28) English system	$h_A = \frac{P_d - P_i}{\rho} + \frac{v_d^2 - v_i^2}{2g} + Z_d - Z_i + h_f$	ENG
(29) SI system	$h_A = \frac{P_d - P_i}{g \times \rho} + \frac{v_d^2 - v_i^2}{2g} + Z_d - Z_i + h_f$	SI
(30) Atmospheric	$h_a = \frac{P_a}{\rho}$	ATMO
<u>Dynamic: (HYDM/HEAD/DYNA)</u>		
(31) Discharge	$H_d = h_{sd} + \frac{v_d^2}{2g} + h_{fd}$	DISCH
(32) Suction	$H_s = h_{ss} - h_{fs}$	SUCTN
(33) Total	$H = h_{sd} - h_{ss} + \frac{v_d^2}{2g} + h_{fs} + h_{fd}$	TOTAL
(34) Vapor pressure	$h_{vp} = \frac{P_{vp}}{\rho}$	VAP. P
(35) Velocity	$h_v = \frac{v^2}{2g}$	VELO

PIPE: (HYDM/PIPE)

Area of flow: (HYDM/PIPE/AREA)

(36) Full	$A = \frac{\pi * D^2}{4}$	FULL
(37) Semi full	$A = .5 r^2 \left(\frac{\pi * \text{ACOS}(\frac{r-h}{r})}{90} - \text{SIN}(2 \text{ACOS}(\frac{r-h}{r})) \right)$	SEMI

Flow quantity: (HYDM/PIPE/FLOW)

English System: (HYDM/PIPE/FLOW/ENG)

(38) Flow in gpm	$gpm = \frac{v * \pi * D^2}{.00891}$	GPM
(39) Flow in cfs	$cfs = \frac{v * \pi * D^2}{4}$	CFS

SI System: (HYDM/PIPE/FLOW/SI)

(40) Flow in lps	$lps = 785.4 * v * D^2$	LPS
(41) Flow in m3ps	$m3ps = \frac{v * \pi * D^2}{4}$	M3PS

HYDRAULIC MACHINES

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>Velocity: (HYDM/PIPE/VELO)</u>		
<u>English System: (HYDM/PIPE/VELO/ENG)</u>		
(42) Flow in gpm	$v = \frac{.00891 * gpm}{\pi * D^2}$	GPM
(43) Flow in cfs	$v = \frac{4 * cfs}{\pi * D^2}$	CFS
<u>SI System: (HYDM/PIPE/VELO/SI)</u>		
(44) Flow in lps	$v = \frac{lps}{785.4 * D^2}$	LPS
(45) Flow in m3ps	$v = \frac{4 * m3ps}{\pi * D^2}$	M3PS
<u>Hydraulic Radius: (HYDM/PIPE/HYD.R)</u>		
(46) General	$HR = \frac{\text{Flow Area (FA)}}{\text{Wet Perimeter (WP)}}$	GENER
(47) Given central angle	$HR = \frac{r (.5 * \pi * \Omega - 90 * \sin \Omega)}{\pi * \Omega}$	ANGL
(48) Given height of the liquid	$HR = .5 * r - \frac{90 (r - h) * \sin(\arccos(\frac{r-h}{r}))}{\pi * \arccos(\frac{r-h}{r})}$	HIGHT

PUMP: (HYDM/PUMP)

Head added by: (HYDM/PUMP/HEAD)

English System: (HYDM/PUMP/HEAD/ENG)

(49) Flow in gpm	$hA = \frac{246858 * hp * \eta}{gpm * \rho}$	GPM
(50) Flow in cfs	$hA = \frac{550 * hp * \eta}{cfs * \rho}$	CFS

SI System: (HYDM/PUMP/HEAD/SI)

(51) Flow in lps	$hA = \frac{76150 * hp * \eta}{lps * \rho}$	LPS
(52) Flow in m3ps	$hA = \frac{76.15 * hp * \eta}{m3ps * \rho}$	M3PS

Horsepower: (HYDM/PUMP/HP)

English System: (HYDM/PUMP/HP/ENG)

(53) Flow in gpm	$hp = \frac{hA * gpm * \rho}{246858 * \eta}$	GPM
(54) Flow in cfs	$hp = \frac{hA * cfs * \rho}{550 * \eta}$	CFS

HYDRAULIC MACHINES

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>SI System: (HYDM/PUMP/HP/SI)</u>		
(55) Flow in lps	$hp = \frac{hA \times lps \times \rho}{76150 \times \eta}$	LPS
(56) Flow in m3ps	$hp = \frac{hA \times m3ps \times \rho}{76.15 \times \eta}$	M3PS
<u>Net Positive Suction Head, available: (HYDM/PUMP/NPSH)</u>		
(57) English System	$NPSHA = \frac{1.44 (P - P_{vp})}{\rho} + h_{ss} - h_{fs}$	ENG
(58) SI System	$NPSHA = \frac{P - P_{vp}}{g \times \rho} + h_{ss} - h_{fs}$	SI
(59) Resistant Head	$REH_2 = REH_1 \left(\frac{Q_2}{Q_1} \right)^2$	RES. H
<u>Specific Speed: (HYDM/PUMP/SPC.S)</u>		
(60) English System	$N_s = n \frac{gpm^{.5}}{h_A^{.75}}$	ENG
(61) SI System	$N_s = 1.633 n \frac{lps^{.5}}{h_A^{.75}}$	SI
<u>REYNOLDS NUMBER: (HYDM/REYN)</u>		
<u>With Absolute Viscosity: (HYDM/REYN/ABSO)</u>		
(62) English System	$NR_e = \frac{D \times v \times \rho}{\mu \times g}$	ENG
(63) SI System	$NR_e = \frac{D \times v \times \rho}{\mu}$	SI
(64) With Kinematic Viscosity	$NR_e = \frac{D \times v}{\nu}$	KINET
<u>TURBINE HORSEPOWER: (HYDM/TURB/HP)</u>		
<u>English System: (HYDM/TURB/HP/ENG)</u>		
(65) Flow in gpm	$hp = \frac{gpm \times \rho \times h \times \eta}{246858}$	GPM
(66) Flow in cfs	$hp = \frac{cfs \times \rho \times h \times \eta}{550}$	CFS
<u>SI System: (HYDM/TURB/HP/SI)</u>		
(67) Flow in lps	$hp = \frac{h \times lps \times \rho \times \eta}{76150}$	LPS
(68) Flow in m3ps	$hp = \frac{h \times m3ps \times \rho \times \eta}{76.15}$	M3PS

HYDRAULIC MACHINES

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT (ENG, SI)</u>
<u>A</u>	Area; <u>ft²</u> , <u>m²</u> (1 ft ² = .0929 m ² .)
<u>bhp</u>	Break horsepower; <u>hp</u> .
<u>cfs=ft³/s</u>	Cubic foot per second (1 cfs = 448.83 gpm = 0.028317 m ³ /s = 28.317 L/s.)
<u>C.HW</u>	Hazen Williams Coefficient; <u>None</u> (Assumed same value for ENG and SI.)
<u>Cv</u>	Velocity Coefficient; <u>None</u> .
<u>D</u>	Diameter; <u>ft</u> , <u>m</u> (1 ft = .3048 m.)
<u>f</u>	Friction Factor; <u>None</u> .
<u>FA</u>	Flow area; <u>ft²</u> , <u>m²</u> (1 ft ² = .0929 m ² .)
<u>g</u>	Gravity acceleration; <u>ft/s²</u> , <u>m/s²</u> (g=32.2 ft/s ² , g=9.8067 (9.81) m/s ² .)
<u>gpm</u>	Gallon per minute (1 gpm = 0.002228 cfs = 6.309EE-5 m ³ /s = 0.06309 L/s.)
<u>H</u>	Total Head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>h</u>	Height, head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>hA</u>	Added head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>Hd</u>	Total dynamic discharge head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>hf</u>	Friction head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>hfd</u>	Discharge friction head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>hFIT</u>	Fittings friction head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>hfs</u>	Suction friction head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>hp</u>	Horsepower.
<u>HR</u>	Hydraulic Radius; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>Hs</u>	Total Suction Head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>hsd</u>	Discharge static head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>hss</u>	Suction static head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>hv</u>	Velocity head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>hvp</u>	Vapor pressure head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>hv</u>	Velocity head; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>K</u>	Coefficient; <u>None</u> .
<u>Kc</u>	Contraction Coefficient; <u>None</u> .
<u>k</u>	Specific Heat Ratio; <u>None</u> .
<u>L</u>	Length; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>Le</u>	Equivalent length; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>lps=L/s</u>	Liter per second (1 L/s = 15.85 gpm = 0.035315 cfs = 1 EE-3 m ³ /s.)
<u>m³ps=m³/s</u>	Cubic meter per second (1 m ³ /s = 15850 gpm = 35.315 cfs = 1000 L/s.)
<u>n</u>	Pump's rotational speed; <u>rpm</u> .
<u>NPSHA</u>	Net Positive Suction Head Available; <u>ft</u> , <u>m</u> (1 ft = .3048 m).
<u>NRe</u>	Reynold's number; <u>None</u> .
<u>Ns</u>	Pump's specific rotational speed; <u>rpm</u> .
<u>P</u>	Pressure; <u>lbf/in²</u> , <u>Pa</u> (1 lbf/in ² = 6894.8 Pa.)

HYDRAULIC MACHINES

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT (ENG, SI)</u>
<u>p</u>	Pressure; <u>lbf/ft²</u> , <u>Pa</u> (1 lbf/ft ² = 47.88 Pa.)
<u>pA</u>	Added pressure by pump; <u>lbf/ft²</u> , <u>Pa</u> (1 lbf/ft ² = 47.88 Pa.)
<u>Pa</u>	Atmospheric pressure; <u>lbf/in²</u> , <u>Pa</u> (1 lbf/in ² = 6894.8 Pa.)
<u>pa</u>	Atmospheric pressure; <u>lbf/ft²</u> , <u>Pa</u> (1 lbf/ft ² = 47.88 Pa.)
<u>pd</u>	Discharge pressure; <u>lbf/ft²</u> , <u>Pa</u> (1 lbf/ft ² = 47.88 Pa.)
<u>pi</u>	Inlet pressure; <u>lbf/ft²</u> , <u>Pa</u> (1 lbf/ft ² = 47.88 Pa.)
<u>Pvp</u>	Vapor pressure; <u>lbf/in²</u> , <u>Pa</u> (1 lbf/in ² = 6894.8 Pa.)
<u>Q</u>	Flow quantity; <u>gpm</u> , <u>L/s</u> .
<u>r</u>	Radius of pipe; <u>ft</u> , <u>m</u> (1 ft = .3048 m.)
<u>RH</u>	System resistance head; <u>ft</u> , <u>m</u> (1 ft = .3048 m.)
<u>SG</u>	Specific Gravity; <u>None</u> : subscript 1 = heavier, 2 = lighter.
<u>T</u>	Absolute temperature; <u>oR</u> , <u>K</u> .
<u>v</u>	Velocity; <u>ft/s</u> , <u>m/s</u> (1 ft/s = .3048 m/s.)
<u>vd</u>	Discharge velocity; <u>ft/s</u> , <u>m/s</u> (1 ft/s = .3048 m/s.)
<u>vi</u>	Inlet velocity; <u>ft/s</u> , <u>m/s</u> (1 ft/s = .3048 m/s.)
<u>WP</u>	Wet perimeter; <u>ft</u> , <u>m</u> (1 ft = .3048 m.)
<u>z</u>	Heights above datum; <u>ft</u> , <u>m</u> (1 ft = .3048 m.)
<u>zd</u>	Discharge height above datum; <u>ft</u> , <u>m</u> (1 ft = .3048 m.)
<u>zi</u>	Inlet height above datum; <u>ft</u> , <u>m</u> (1 ft = .3048 m.)
<u>ε</u>	Specific roughness; <u>ft</u> , <u>m</u> (1 ft = .3048 m). (If not given, assume the design values as; copper/plastic: 0.000005, 0.0000015; cast iron: 0.0008, 0.00024; steel: 0.0002, 0.00006; concrete: 0.004, 0.0012)
<u>η</u>	Efficiency; <u>decimal</u> .
<u>μ</u>	Absolute viscosity; <u>lbf-sec/ft²</u> , <u>N.s/m²</u> (1 lbf-sec/ft ² = 47.88 N.s/m ² = 47.88 Pa.s).
<u>ν</u>	Kinematic viscosity, <u>ft²/sec</u> , <u>m²/s</u> (1 ft ² /sec = 0.0929 m ² /s).
<u>Ω</u>	Central angle; <u>deg</u> .
<u>ρ</u>	Density; <u>lb/ft³</u> , <u>kg/m³</u> (If not given for water, assume: 62.4 lb/ft ³ , 1000 kg/m ³ .)
<u>η</u>	Efficiency; <u>decimal</u> .

POWER CYCLE

INTRODUCTION:

When using this section's equations, take the following into consideration:

1. The outlet characteristics of gas and steam, i.e. h_{2C}, h_{2G}, h_{2S} are the actual values and the isentropic efficiency is taken into consideration.
2. The compressor is directly powered by the gas turbine.
3. If not mentioned, the mechanical efficiency of the plant equipment assumed to be 100%. Apply the efficiency if specified.
4. The following subscript symbols are used for the distinction of the equipment:

B: Boiler/Exchanger	BL: Bleeding point	C: Compressor
CO: Combustor	CON: Condenser	DR: Drain
EV: Evaporator	G: Gas turbine	P: Feed pump
PH: Pre-heater	S: Steam turbine	

DESCRIPTION

FORMULA

NAME

COMPRESSOR: (PCYCL/COMP)

Displacement: (PCYCL/COMP/DISP)

Piston displacement: (PCYCL/COMP/DISP/PISTN)

English System: (PCYCL/COMP/DISP/PISTN/ENG)

(01) With Bore and Stroke	$disp = \frac{\pi * bore^2 * strk}{4}$	B&S
(02) With mass flow	$disp = \frac{103680 * M_g * v_g}{\eta_v * RPM}$	MASS
(03) With volumetric flow	$disp = \frac{1728 * cfm_g}{\eta_v * RPM}$	VOLM

SI System: (PCYCL/COMP/DISP/PISTN/SI)

(04) With Bore and Stroke	$disp = \frac{\pi * bore^2 * strk}{4 * EE3}$	B&S
(05) With mass flow	$disp = \frac{6 * EE4 * M_g * v_g}{\eta_v * RPM}$	MASS
(06) With volumetric flow	$disp = \frac{60 * lps_g}{\eta_v * RPM}$	VOLM

POWER CYCLE

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>Gas displacement: (PCYCL/COMP/DISP/GAS)</u>		
<u>English System: (PCYCL/COMP/DISP/GAS/ENG)</u>		
<u>Mass flow: (PCYCL/COMP/DISP/GAS/ENG/MASS)</u>		
(07) With Bore and Stroke	$M_g = \frac{\pi * bore^2 * strk * RPM * \eta_v}{414720 * v_g}$	B&S
(08) With volume	$M_g = \frac{cfm_g}{60 v_g}$	VOLM
<u>Volume: (PCYCL/COMP/DISP/GAS/ENG/VOLM)</u>		
(09) With Bore and Stroke	$cfm_g = \frac{\pi * bore^2 * strk * RPM * \eta_v}{6912}$	B&S
(10) With mass flow	$cfm_g = 60 * M_g * v_g$	MASS
<u>SI System: (PCYCL/COMP/DISP/GAS/SI)</u>		
<u>Mass flow: (PCYCL/COMP/DISP/GAS/SI/MASS)</u>		
(11) With Bore and Stroke	$M_g = \frac{\pi * bore^2 * strk * RPM * \eta_v}{2.4EE8 * v_g}$	B&S
(12) With volume	$M_g = \frac{1ps_g}{1000 v_g}$	VOLM
<u>Volume: (PCYCL/COMP/DISP/GAS/SI/VOLM)</u>		
(13) With Bore and Stroke	$1ps_g = \frac{\pi * bore^2 * strk * RPM * \eta_v}{2.4EE5}$	B&S
(14) With mass flow	$1ps_g = 1000 * M_g * v_g$	MASS
(15) Enthalpy at the exit	$h2_c = h1_c + (h2_{cx} - h1_c) / \eta_c$	ENTH
(16) Relative pressure at the exit	$Pr2_c = Pr1_c \frac{P2_c}{P1_c}$	PR
<u>Power: (PCYCL/COMP/POWR)</u>		
<u>English System: (PCYCL/COMP/POWR/ENG)</u>		
(17) Power in hp	$hp_c = 1.415 * M_g * (h2_c - h1_c)$	HP
(18) Power in kW	$kW_c = 1.0548 * M_g * (h2_c - h1_c)$	KW
<u>SI System: (PCYCL/COMP/POWR/SI)</u>		
(19) Power in hp	$hp_c = .001341 * M_g * (h2_c - h1_c)$	HP
(20) Power in kW	$kW_c = .001 * M_g * (h2_c - h1_c)$	KW
(21) Work	$W_c = h2_c - h1_c$	WORK

POWER CYCLE

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>EFFICIENCY: (PCYCL/EFFI)</u>		
(22) Carnot	$\eta_{CAR} = \frac{T_H - T_L}{T_H}$	CARNO
<u>Compressor: (PCYCL/EFFI/COMP)</u>		
(23) Thermal efficiency	$\eta_c = \frac{h2_{cI} - h1_c}{h2_c - h1_c}$	THRM
(24) Volumetric efficiency	$\eta_v = 1 - .01 \text{ c1r\%} \left(\left(\frac{P2}{P1} \right)^{\frac{1}{n}} - 1 \right)$	VOLM
(25) Gas turbine	$\eta_g = \frac{h1_g - h2_g}{h1_g - h2_{gI}}$	G. TURB
<u>Internal Combustion Engines: (PCYCL/EFFI/ENGN)</u>		
<u>Thermal efficiency (PCYCL/EFFI/ENGN/THRM)</u>		
<u>English System: (PCYCL/EFFI/ENGN/THRM/ENG)</u>		
(26) With input energy	$\eta_{th} = \frac{W_{out}}{Q_{in}}$	QIN
(27) With Fuel Consumption	$\eta_{th} = \frac{2545 \text{ hp}}{FC * HV}$	FC
(28) With Specific Fuel Consumption	$\eta_{th} = \frac{2545}{SFC * HV}$	SFC
<u>SI System: (PCYCL/EFFI/ENGN/THRM/SI)</u>		
(29) With input energy	$\eta_{th} = \frac{W_{out}}{Q_{in}}$	QIN
(30) With Fuel Consumption	$\eta_{th} = \frac{2684520 \text{ hp}}{FC * HV}$	FC
(31) With Specific Fuel Consumption	$\eta_{th} = \frac{2684520}{SFC * HV}$	SFC
<u>Volumetric efficiency: (PCYCL/EFFI/ENGN/THRM/VOLM)</u>		
(32) English System	$\eta_v = \frac{6912 * cfmG}{\pi * RPM * bore^2 * strk}$	ENG
(33) SI System	$\eta_v = \frac{2.4EE5 * lpsG}{\pi * RPM * bore^2 * strk}$	SI
(34) Steam turbine	$\eta_s = \frac{h1_s - h2_s}{h1_s - h2_{sI}}$	S. TURB

POWER CYCLE

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
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System's Efficiency: (PCYCL/EFFI/SYST)

English System: (PCYCL/EFFI/SYST/ENG)

(35) With output heat	$\eta_{sys} = \frac{3415 (kW - kW_{in})}{3415 * kW + Q_{out}}$	QOUT
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(36) With input heat	$\eta_{sys} = \frac{3415 (kW - kW_{in})}{Q_{in}}$	QIN
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SI System: (PCYCL/EFFI/SYST/SI)

(37) With output heat	$\eta_{sys} = \frac{kW - kW_{in}}{kW + .001 Q_{out}}$	QOUT
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(38) With input heat	$\eta_{sys} = \frac{kW - kW_{in}}{.001 Q_{in}}$	QIN
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GAS EQUATIONS: (PCYCL/GAS)

(39) Ideal gas	$P * V = m * R * T$	IDEAL
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(40) Real gas	$P * V = m * R * T * Z$	REAL
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Isentropic Process: (PCYCL/GAS/ISENT)

(41) Pressure/Temperature change	$P_2 = P_1 \left(\frac{T_2}{T_1} \right)^{\frac{k}{k-1}}$	$\delta P / \delta T$
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(42) Pressure/Volume change	$P_2 = P_1 \left(\frac{V_1}{V_2} \right)^k$	$\delta P / \delta V$
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(43) Temperature/Volume change	$T_2 = T_1 \left(\frac{V_1}{V_2} \right)^{k-1}$	$\delta T / \delta V$
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Polytropic Process: (PCYCL/GAS/POLYT)

(44) Pressure/Temperature change	$P_2 = P_1 \left(\frac{T_2}{T_1} \right)^{\frac{n}{n-1}}$	$\delta P / \delta T$
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(45) Pressure/Volume change	$P_2 = P_1 \left(\frac{V_1}{V_2} \right)^n$	$\delta P / \delta V$
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(46) Temperature/Volume change	$T_2 = T_1 \left(\frac{V_1}{V_2} \right)^{n-1}$	$\delta T / \delta V$
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GAS TURBINE: (PCYCL/G.TURB)

Combustors: (PCYCL/G.TURB/CMBS)

(47) Heat balance	$M_g (h2_{co} - h1_{co}) = M_{FV} * HV * \eta_{co}$	HTBAL
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(48) Actual enthalpy at the exit	$h2_g = h1_g - (h1_g - h2_{gI}) \eta_g$	ENTH
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POWER CYCLE

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>GAS TURBINE (continued): (PCYCL/G.TURB)</u>		
<u>Power: (PCYCL/G.TURB/POWER)</u>		
<u>English System: (PCYCL/G.TURB/POWER/ENG)</u>		
<u>Turbine's Power in hp: (PCYCL/G.TURB/POWER/ENG/HP)</u>		
(49) Flow in lbm/sec	$hp_g = 1.4145 * M_g (h1_g - h2_g)$	LBPS
(50) Flow in cfm	$hp_g = .023576 \frac{p1_g * cfm (h1_g - h2_g)}{R * T1_g}$	CFM
<u>Generator's Power in kw: (PCYCL/G.TURB/POWER/ENG/KW)</u>		
(51) Flow in lbm/sec	$kW_g = 1.0548 * M_g (h1_g - h2_g - h2_c + h1_c) \eta_{GEN}$	LBPS
(52) Flow in cfm	$kW_g = .01758 \frac{p1_g * cfm (h1_g - h2_g - h2_c + h1_c)}{R * T1_g} \eta_{GEN}$	CFM
<u>SI System: (PCYCL/G.TURB/POWER/SI)</u>		
<u>Turbine's Power in hp: (PCYCL/G.TURB/POWER/SI/HP)</u>		
(53) Flow in kg/s	$hp_g = .001341 * M_g (h1_g - h2_g)$	KGPS
(54) Flow in lps	$hp_g = 1.341EE-6 \frac{p1_g * lps (h1_g - h2_g)}{R * T1_g}$	LPS
<u>Generator's Power in kW: (PCYCL/G.TURB/POWER/SI/KW)</u>		
(55) Flow in kg/s	$kW_g = .001 * M_g (h1_g - h2_g - h2_c + h1_c) \eta_{GEN}$	KGPS
(56) Flow in lps	$kW_g = \frac{p1_g * lps (h1_g - h2_g - h2_c + h1_c)}{1EE5 * R * T1_g} \eta_{GEN}$	LPS
(57) Relevant pressure	$Pr2_g = Pr1_g \frac{P2_g}{P1_g}$	PR
(58) Work	$W_g = h1_g - h2_g$	WORK
(59) Interpolation	$A_x = \frac{(A_1 - A_2) (B_x - B_1)}{B_1 - B_2} + A_1$	INTRP
<u>INTERNAL COMBUSTION ENGINES: (PCYCL/ENGN)</u>		
<u>Car: (PCYCL/ENGN/CAR)</u>		
<u>English System: (PCYCL/ENGN/CAR/ENG)</u>		
(60) Engine rpm	$RPM = \frac{1056 * mph * TR}{\pi * WIL_d}$	RPM
(61) Mile per gallon	$MPG = \frac{8.342 * SG_f * mph}{SFC * hp}$	MPG

POWER CYCLE

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>SI System: (PCYCL/ENGN/CAR/SI)</u>		
(62) Engine rpm	$RPM = \frac{1666.7 * kph * TR}{\pi * \pi L_d}$	RPM
(63) Kilometer per liter	$KMPL = \frac{SG_f * kph}{SFC * hp}$	KMPL
<u>Engine displacement: (PCYCL/ENGN/DISP)</u>		
<u>English System: (PCYCL/ENGN/DISP/ENG)</u>		
(64) With Bore & Stroke	$disp = \frac{\pi * bore^2 * strk * NCYL}{4}$	B&S
(65) With Engine's gas volume displacement	$disp = \frac{3456 * cfm_g}{RPM * \eta_v}$	VOLM
<u>SI System: (PCYCL/ENGN/DISP/SI)</u>		
(66) With Bore & Stroke	$disp = \frac{\pi * bore^2 * strk * NCYL}{4EE3}$	B&S
(67) With Engine's gas volume displacement	$disp = \frac{120 * lps_g}{RPM * \eta_v}$	VOLM
<u>Fuel Consumption: (PCYCL/ENGN/FC)</u>		
(68) English System	$FC = \frac{2545hp}{HV * \eta_{th}}$	ENG
(69) SI System	$FC = \frac{2684520 * hp}{HV * \eta_{th}}$	SI
<u>Indicated horsepower: (PCYCL/ENGN/IHP)</u>		
<u>English System: (PCYCL/ENGN/IHP/ENG)</u>		
(70) With Mean Effective Pressure	$ihp = \frac{\pi * P_m * bore^2 * strk * RPM * NCYL}{79200 * NSTR}$	PM
(71) With Mean Effective Work	$ihp = \frac{W_m * RPM * NCYL}{16500 * NSTR}$	WM
(72) With displacement	$ihp = \frac{P_m * disp * RPM}{198000 * NSTR}$	DISP
<u>SI System: (PCYCL/ENGN/IHP/SI)</u>		
(73) With Mean Effective Pressure	$ihp = \frac{\pi * P_m * bore^2 * strk * RPM * NCYL}{8.9484EE10 * NSTR}$	PM
(74) With Mean Effective Work	$ihp = \frac{W_m * RPM * NCYL}{22371 * NSTR}$	WM
(75) With displacement	$ihp = \frac{P_m * disp * RPM}{2.2371EE7 * NSTR}$	DISP

POWER CYCLE

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>Specific Fuel Consumption: (PCYCL/ENG/SFC)</u>		
(76) English System	$SFC = \frac{2545}{HV * \eta_{th}}$	ENG
(77) SI System	$SFC = \frac{2684520}{HV * \eta_{th}}$	SI
(78) Volume Clearance	$VC = \frac{disp}{(CR-1) * NCYL}$	VCLR

REFRIGERATION (English System Only): (PCYCL/REFRI/ENG)

Cooling Capacity: (PCYCL/REFRI/ENG/CAPAC)

Capacity in BTU/hr: (PCYCL/REFRI/ENG/CAPAC/BTU.H)

(79) Flow in cfm	$q = \frac{60 * p * cfm * cp (t_1 - t_2)}{R * T}$	CFM
(80) Flow in lbm/sec	$q = 3600 * lbps * cp (t_1 - t_2)$	LBPS

Capacity in tons of refrigeration: (PCYCL/REFRI/ENG/CAPAC/TON.R)

(81) Flow in cfm	$tonR = \frac{p * cfm * cp (t_1 - t_2)}{200 * R * T}$	CFM
(82) Flow in lbm/sec	$tonR = .3 * lbps * cp (t_1 - t_2)$	LBPS

Coefficient Of Performance: (PCYCL/REFRI/ENG/COP)

(83) With input heat (thru evaporator)	$COP = \frac{3.9293EE-4 * q_{1n}}{hp}$	QIN
(84) With high and low temperature	$COP = \frac{T_L}{T_H - T_L}$	TEMP
(85) With tonR	$COP = 4.715 \frac{tonR}{hp}$	TONR

Condenser: (PCYCL/REFRI/ENG/COND)

(86) Heat balance	$q_{out} = 3600 M_g (h1_{con} - h2_{con})$	HTBAL
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Energy Efficiency Ratio: (PCYCL/REFRI/ENG/EER)

(87) Power in hp	$EER = \frac{16.09 * tonR}{hp}$	HP
(88) Power in watts	$EER = \frac{12000 * tonR}{watt}$	WATT

Evaporator, heat balance: (PCYCL/REFRI/ENG/EVAP/HTBAL)

(89) With BTUh absorbed	$q_{1n} = 3600 M_g (h2_{ev} - h1_{ev})$	BTUH
(90) With ton of refrigeration	$tonR = .3 * M_g (h2_{ev} - h1_{ev})$	TONR

POWER CYCLE

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>STEAM TURBINE: (PCYCL/S.TURB)</u>		
<u>Boilers/Heat Exchangers Heat Balance: (PCYCL/S.TURB/BOILR)</u>		
<u>With Burners: (PCYCL/S.TURB/BOILR/BURN)</u>		
(91) English system	$Q_{12} = 3600 M_s (h_{2s} - h_{1s} + \frac{DR}{1-DR} (h_{DR} - h_{1s}))$	ENG
(91a) SI system	$Q_{12} = M_s (h_{2s} - h_{1s} + \frac{DR}{1-DR} (h_{DR} - h_{1s}))$	SI
(92) Heat exchanger/waste heat	$M_G (h_{1G} - h_{2G}) \eta_B = M_s (h_{2s} - h_{1s})$	HTEXC
<u>Enthalpy: (PCYCL/S.TURB/ENTH)</u>		
(93) Actual enthalpy at the final exit	$h_{2s} = h_{1s} - (h_{1s} - h_{2sT}) \eta_s$	EXIT
(94) Actual enthalpy at bleeding point	$h_{BL} = h_{1s} - (h_{1s} - h_{BLT}) \eta_s$	BLID
<u>Mixture of steam and water: (PCYCL/S.TURB/MIXT)</u>		
(95) Heat balance	$M_s * H_s + M_w * H_w = M_{MIX} * H_{MIX}$	HTBAL
<u>Power: (PCYCL/S.TURB/POWR)</u>		
<u>English System : (PCYCL/S.TURB/POWR/ENG)</u>		
<u>Turbine's power in hp: (PCYCL/S.TURB/POWR/ENG/HP)</u>		
(96) Single path	$hp_s = 1.4145 * M_s (h_{1s} - h_{2s})$	SINGL
(97) With bleed	$hp_s = 1.4145 (M_s (h_{1s} - h_{BL}) + (M_s - M_{BL}) * (h_{BL} - h_{2s}))$	BLID
<u>Generators's power in kW: (PCYCL/S.TURB/POWR/ENG/KW)</u>		
(98) Single path	$kW_s = 1.0548 * M_s (h_{1s} - h_{2s}) \eta_{GEN}$	SINGL
(99) With bleed	$kW_s = 1.0548 (M_s (h_{1s} - h_{BL}) + (M_s - M_{BL}) * (h_{BL} - h_{2s})) \eta_{GEN}$	BLID
<u>SI System: (PCYCL/S.TURB/POWR/SI)</u>		
<u>Turbine's power in hp (PCYCL/S.TURB/POWR/SI/HP)</u>		
(100) Single path	$hp_s = .001341 * M_s (h_{1s} - h_{2s})$	SINGL
(101) With bleed	$hp_s = .001341 (M_s (h_{1s} - h_{BL}) + (M_s - M_{BL}) * (h_{BL} - h_{2s}))$	BLID
<u>Generators's power in kW: (PCYCL/S.TURB/POWR/SI/KW)</u>		
(102) Single path	$kW_s = .001 * M_s (h_{1s} - h_{2s}) \eta_{GEN}$	SINGL
(103) With bleed	$kW_s = .001 (M_s (h_{1s} - h_{BL}) + (M_s - M_{BL}) * (h_{BL} - h_{2s})) \eta_{GEN}$	BLID
<u>Pre-Heater, to use bled steam: (PCYCL/S.TURB/PREHT)</u>		
(104) Heat balance	$h_{2PH} = h_{BL} * BLD + (1 - BLD) h_{1PH}$	HTBAL

POWER CYCLE

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>Pump, Feeder: (PCYCL/S.TURB/PUMP)</u>		
<u>English System: (PCYCL/S.TURB/PUMP/ENG)</u>		
(105) Enthalpy at the exit	$h_{2_P} = h_{1_P} + \frac{vf_{1_P}(p_{2_P} - p_{1_P})}{778 * \eta_P}$	ENTH
(106) Power	$hp_P = M_P \frac{vf_{1_P}(p_{2_P} - p_{1_P})}{550 * \eta_P}$	POWR
(107) Work	$W_P = \frac{vf_{1_P}(p_{2_P} - p_{1_P})}{778 * \eta_P}$	WORK
<u>SI System: (PCYCL/S.TURB/PUMP/SI)</u>		
(108) Enthalpy at the exit	$h_{2_P} = h_{1_P} + \frac{vf_{1_P}(p_{2_P} - p_{1_P})}{\eta_P}$	ENTH
(109) Power	$hp_P = M_P \frac{vf_{1_P}(p_{2_P} - p_{1_P})}{745.7 * \eta_P}$	POWR
(110) Work	$W_P = \frac{vf_{1_P}(p_{2_P} - p_{1_P})}{\eta_P}$	WORK
<u>Rate of Heat and Steam: (PCYCL/S.TURB/RATE)</u>		
<u>English System: (PCYCL/S.TURB/RATE/ENG)</u>		
<u>Heat Rate: (PCYCL/S.TURB/RATE/ENG/HEAT)</u>		
(111) Turbine's Heat Rate	$RATE = \frac{Q_{12}}{kW}$	TURB
(112) Plant's Heat Rate	$RATE = \frac{Q_{12}}{(kW - kW_{12}) \eta_B}$	PLNT
(113) Steam Rate	$RATE = \frac{3415}{h_{1_s} - h_{2_s}}$	STIM
<u>SI System: (PCYCL/S.TURB/RATE/SI)</u>		
<u>Heat Rate: (PCYCL/S.TURB/RATE/SI/HEAT)</u>		
(114) Turbine's Heat Rate	$RATE = 3600 \frac{Q_{12}}{kW}$	TURB
(115) Plant's Heat Rate	$RATE = \frac{3600 Q_{12}}{(kW - kW_{12}) \eta_B}$	PLNT
(116) Steam Rate	$RATE = \frac{3.6EE6}{h_{1_s} - h_{2_s}}$	STIM
<u>Work: (PCYCL/S.TURB/WORK)</u>		
(117) Single path	$W_s = h_{1_s} - h_{2_s}$	SINGL
(118) With bleed	$W_s = h_{1_s} - h_{BL} + (1 - BLD) (h_{BL} - h_{2_s})$	BLID

POWER CYCLE

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT (ENG, SI)</u>
<u>BLD</u>	Bleeding rate; <u>decimal</u> .
<u>bore</u>	Piston's bore; <u>in</u> , <u>cm</u> (1 in = 2.54 cm).
<u>cfm</u>	Cubic feet per minute.
<u>cfmG</u>	Gas displacement; <u>cfm</u> , <u>lps</u> (1 cfm = .47195 lps).
<u>clr%</u>	Volumetric clearance; <u>%</u> .
<u>COP</u>	Coefficient of Performance; <u>none</u> .
<u>cp</u>	Specific heat, constant pressure; <u>BTU/lbm-oF</u> , <u>J/kg.oC</u> (1 BTU/lbm-oF = 4186.8 J/kg.oC).
<u>CR</u>	Compression ratio; <u>none</u> .
<u>disp</u>	Displacement of piston; <u>ci/cycle</u> , <u>liter(L)/cycle</u> (1 ci = .016387 L).
<u>DR</u>	Boiler's drainage rate; <u>decimal</u> .
<u>g</u>	Gravitational acceleration; <u>ft/sec²</u> , <u>m/sec²</u> (1 ft/sec ² = .3048 m/sec ²).
<u>h</u>	Enthalpy; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm = 2326 J/kg)
<u>h1C</u>	Enthalpy at the compressor's inlet; <u>BTU/lbm</u> , <u>J/kg</u> (B: Boiler, CO: Combustor, CON: Condenser, DR: Drain, EV: Evaporator, G: Gas turbine, P: Pump, PH, Pre-heater, S: Steam turbine)
<u>h2C</u>	Actual enthalpy at the compressor's exit; <u>BTU/lbm</u> , <u>J/kg</u> (B: Boiler, CO: Combustor, CON: Condenser, DR: Drain, EV: Evaporator, G: Gas turbine, P: Pump, PH, Pre-heater, S: Steam turbine)
<u>h2CI</u>	Ideal enthalpy at the compressor's exit; <u>BTU/lbm</u> , <u>J/kg</u> (G: Gas turbine, S: Steam turbine)
<u>hp</u>	Horse power; <u>hp</u> .
<u>HV</u>	Heat value; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm = 2326 J/kg)
<u>ihp</u>	Indicate horsepower; <u>hp</u> .
<u>k</u>	Specific Heat Ratio; <u>none</u> .
<u>KMPL</u>	Kilometers per liter.
<u>kph</u>	Kilometers per hour (1 kph = .62137 mph)
<u>kW</u>	kilowatt; <u>kW</u> .
<u>kWin</u>	Power input to the system; <u>kW</u> .
<u>lbs</u>	Pound per second.
<u>m</u>	Mass; <u>lbm</u> , <u>kg</u> (1 lbm = .4536 kg).
<u>MFU</u>	Mass flow of fuel; <u>lbm/sec</u> , <u>kg/s</u> (1 lbm/sec = .4536 kg/s)
<u>MG</u>	Mass flow of gas; <u>lbm/sec</u> , <u>kg/s</u> . (S: Steam, P: Pump)
<u>mph</u>	Miles per hour (1 mph = 1.609 kph).
<u>MPG</u>	Miles per gallon.
<u>n</u>	Polytropic Exponent; <u>None</u>
<u>NCYL</u>	Number of cylinders.
<u>NSTR</u>	Number of strokes per cycle.
<u>p</u>	Pressure; <u>psf</u> , <u>Pa</u> (1 psf = 47.88 Pa)
<u>P1</u>	Inlet pressure; <u>psia</u> , <u>Pa</u> (1 psia = 6894.76 Pa)
<u>P2</u>	Exit pressure; <u>psia</u> , <u>Pa</u> (1 psi = 6894.76 Pa)
<u>Pm</u>	Mean Effective Pressure; <u>Psi</u> , <u>Pa</u> (1 psi = 6894.76 Pa)
<u>Pr</u>	Relative pressure; <u>psia</u> . (Subscript 1 for inlet, 2 for exit)

POWER CYCLE

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT (ENG, SI)</u>
<u>q_{in}</u>	Heat input to the system; <u>BTU/hr</u> , <u>W (J/s)</u> (1 BTU/hr = .2931 J/s).
<u>q_{out}</u>	Heat output from the system; <u>BTU/hr</u> , <u>W (J/s)</u> (1 BTU/hr = .2931 J/s).
<u>R</u>	Specific Heat Constant; <u>ft-lbf/lbm-oR</u> , <u>J/kg.K</u> (1 ft-lbf/lbm-oR = 5.38 J/kg.K).
<u>RATE</u>	Steam rate; <u>lbm/kW-hr</u> , <u>kg/kW-hr</u> .
<u>RPM</u>	Revolution per minute; <u>rpm</u> .
<u>s</u>	Entropy; <u>BTU/lbm-oF</u> , <u>J/kg.oC</u> (1 BTU/lbm-oF = 4186.8 J/kg.oC).
<u>SGF</u>	Specific Gravity of Fuel; <u>None</u> .
<u>strk</u>	Piston's stroke; <u>in</u> , <u>cm</u> (1 in = 2.54 cm).
<u>t</u>	Temperature; <u>oF</u> , <u>oC</u> .
<u>T</u>	Temperature; <u>oR</u> , <u>K</u> .
<u>TH</u>	High temperature; <u>oR</u> , <u>K</u> .
<u>TL</u>	Low temperature; <u>oR</u> , <u>K</u> .
<u>tonR</u>	Ton of refrigeration; <u>tonR</u> .
<u>TR</u>	Transmission (Engine/Wheel rpm) ratio; <u>none</u> .
<u>u</u>	Internal energy; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm = 2326 J/kg).
<u>V</u>	Volume; <u>ft3</u> , <u>m3</u> (1 ft3 = .028317 m3).
<u>VC</u>	Volume Clearance; <u>ci</u> , <u>L</u> (1 ci = .016387 L)..
<u>vf</u>	Specific volume of liquid; <u>ft3/lbm</u> , <u>m3/kg</u> .
<u>vG</u>	Specific volume of gas; <u>ft3/lbm</u> , <u>m3/kg</u> (1 ft3/lbm = .062428 m3/kg).
<u>W</u>	Work; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm = 2326 J/kg).
<u>WIL.d</u>	Wheel diameter; <u>in</u> , <u>cm</u> (1 in = 2.5 cm).
<u>Wm</u>	Mean Effective Work; <u>ft-lbf/cycle/cylinder</u> , <u>J/cycle/cylinder</u> (1 ft-lbf = 1.3558 J (N.m)).
<u>Wout</u>	Output work; <u>BTU/lbm</u> , <u>J/kg</u> (1 BTU/lbm = 2326 J/kg).
<u>Z</u>	Factor of compressibility; <u>decimal</u> .
<u>η^{GEN}</u>	Generator's efficiency; <u>decimal</u> .
<u>η^C</u>	Compressor's thermal efficiency; <u>decimal</u> . (B: Boiler, CO: Combustor, CON: Condenser, EV: Evaporator, G: Gas turbine, S: Steam turbine).
<u>η^{CAR}</u>	Carnot efficiency; <u>decimal</u> .
<u>ηth</u>	Thermal efficiency; <u>decimal</u> .
<u>η^V</u>	Volumetric efficiency; <u>decimal</u> .

SCREWS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>ACME SCREWS: (SCRW/ACME)</u>		
(01) Overhauling Condition	$OC = \frac{L - f \cdot \pi \cdot d_m}{\cos \alpha}$	AOC
(02) Torque, lowering load	$T = \frac{W \cdot d_m}{2} \cdot \frac{L - \frac{\pi \cdot d_m \cdot f}{\cos \alpha}}{\pi \cdot d_m + \frac{L \cdot f}{\cos \alpha}}$	ATL
(03) Torque, raising load	$T = \frac{W \cdot d_m}{2} \cdot \frac{L + \frac{\pi \cdot d_m \cdot f}{\cos \alpha}}{\pi \cdot d_m - \frac{L \cdot f}{\cos \alpha}}$	ATR
<u>SQUARE SCREWS: (SCRW/SQUR)</u>		
(04) Efficiency	$\eta = \frac{W \cdot L}{2 \pi \cdot T}$	SCE
(05) Overhauling Condition	$OC = L - f \cdot \pi \cdot d_m$	SOC
(06) Torque, lowering load	$T = \frac{W \cdot d_m}{2} \cdot \frac{L - \pi \cdot d_m \cdot f}{\pi \cdot d_m + L \cdot f}$	STL
(07) Torque, raising load	$T = \frac{W \cdot d_m}{2} \cdot \frac{L + \pi \cdot d_m \cdot f}{\pi \cdot d_m - L \cdot f}$	STR
<u>MISCELLANEOUS: (SCRW/MSCL)</u>		
(08) Bearing pressure	$P_b = \frac{W}{\pi \cdot N \cdot d_m \cdot h}$	PB
(09) Number of threads carrying load	$N = \frac{NL}{P}$	NT
(10) Stress on thread, bending	$\sigma_b = \frac{3W \cdot H}{2 \pi \cdot r_m \cdot N \cdot b^2}$	SB
(11) Stress on thread, shear	$\tau_m = \frac{W}{\pi \cdot d_m \cdot N \cdot b}$	SSH

SCREWS

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT</u>
<u>b</u>	Thread's thickness, at root; <u>in</u> .
<u>dc</u>	Mean collar diameter; <u>in</u> .
<u>dm</u>	Mean diameter; <u>in</u> .
<u>f</u>	Friction coefficient; <u>None</u> .
<u>E</u>	Modules of Elasticity; <u>psi</u> .
<u>fc</u>	Collar friction factor; <u>None</u> .
<u>H</u>	Thread's depth; <u>in</u> .
<u>L</u>	Lead (Nut's displacement per rotation); <u>in</u> .
<u>N</u>	Number of threads carrying load; <u>None</u> .
<u>NL</u>	Nut's length; <u>in</u> .
<u>OC</u>	Overhauling Condition; <u>None</u> .
<u>P</u>	Pitch; <u>in</u> .
<u>Pb</u>	Bearing pressure; <u>psi</u> .
<u>rm</u>	Mean radius; <u>in</u> .
<u>T</u>	Torque; <u>in-lbf</u> .
<u>W</u>	Load; <u>lbf</u> .
<u>α</u>	Half thread angle; <u>deg</u> .
<u>η</u>	Screw's efficiency; <u>decimal</u> .
<u>σ_b</u>	Bending stress at thread's root; <u>psi</u> .
<u>τ_m</u>	Thread's mean shear stress; <u>psi</u> .

SPRINGS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>COIL SPRING: (SPRIN/COIL)</u>		
<u>Critical Load/Frequency: (SPRIN/COIL/CRTIC)</u>		
(01) Critical load (buckling)	$F_{cr} = k * L_f * KL$	LOAD
(02) Critical frequency	$f_{cr} = \frac{m}{2} \left(\frac{386.4 * k}{W} \right)^{.5}$	FREQ
(03) Deflection (static)	$y = \frac{8 * F * N * D_m^3}{G * d^4}$	DFLEC
(04) Diameter, mean	$D_m = \left(\frac{y * d^4 * G}{8 * F * N} \right)^{\frac{1}{3}}$	DIAM
<u>Length: (SPRIN/COIL/LNTH)</u>		
(05) Free	$L_f = \frac{F}{k} + N_t * d$	FREE
(06) Solid	$L_s = N_t * d$	SOLID
(07) Load (Force)	$F = \frac{y * d^4 * G}{8 * D_m^3 * N}$	LOAD
<u>Number of active load: (SPRIN/COIL/NUMB)</u>		
(08) With given deflection	$N = \frac{y * d^4 * G}{8 * D_m^3 * F}$	DFLEC
(09) With given rate	$N = \frac{d^4 * G}{8 * D_m^3 * k}$	RATE
(10) Wire diameter	$d = \left(\frac{8 * F * N * D_m^3}{y * G} \right)^{.25}$	WIRE

CONSTANT/RATE: (SPRIN/CONS)

Equivalent Constant: (SPRIN/CONS/EQUIV)

(11) Two or Three in Parallel	$k_e = k_1 + k_2 + k_3$	PARAL
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SPRINGS

<u>DESCRIPTION</u>	<u>FORMULA</u>	<u>NAME</u>
<u>CONSTANT/RATE (continued): (SPRIN/CONS)</u>		
<u>Series: (SPRIN/CONS/EQUIV/SERIS)</u>		
(12) Two in series	$k_o = \frac{k_1 * k_2}{k_1 + k_2}$	TWO
(13) Three in series	$k_o = \frac{k_1 * k_2 * k_3}{k_1 * k_2 + k_1 * k_3 + k_2 * k_3}$	THREE
(14) Spring Constant (rate)	$k = \frac{d^4 * G}{8 * D_n^3 * N}$	RATE
<u>SHEAR STRESS: (SPRIN/SHEAR)</u>		
<u>Corrected Shear: (SPRIN/SHEAR/COREC)</u>		
(15) With diameter	$\tau = \left(\frac{D_n - .25d}{D_n - d} + \frac{.615d}{D_n} \right) \frac{8F * D_n}{\pi d^3}$	DIAM
(16) With Wahl Factor	$\tau = \frac{8 * KW * F * D_n}{\pi d^3}$	WHAL
(17) Direct shear	$\tau_d = \frac{F}{A}$	DIRCT
<u>Factor: (SPRIN/SHEAR/FCTR)</u>		
(18) Static	$K_s = 1 + \frac{.5d}{D_n}$	STAT
(19) Correction, Wahl	$KW = \frac{D_n - .25d}{D_n - d} + \frac{.615 * d}{D_n}$	WHAL
<u>Static: (SPRIN/SHEAR/STAT)</u>		
(20) With diameter	$\tau_s = \frac{8 * F * D_n}{\pi d^3} \left(1 + \frac{.5d}{D_n} \right)$	DIAM
(21) With Static Factor	$\tau_s = \frac{8 * K_s * F * D_n}{\pi d^3}$	STAT
(22) Work done by spring	$work = .5 * k (y_2^2 - y_1^2)$	WORK

SPRINGS

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT</u>
<u>A</u>	Coil's wire section area; <u>sq.</u>
<u>C</u>	Spring index (D_m/d); <u>None</u> .
<u>d</u>	Coil's wire diameter; <u>in.</u>
<u>D_m</u>	Coil's mean diameter; <u>in.</u>
<u>F</u>	Static load; <u>lbf.</u>
<u>F_{cr}</u>	Critical buckling load; <u>lbf.</u>
<u>f_{cr}</u>	Critical frequency; <u>cps.</u>
<u>G</u>	Shear modules; <u>psi.</u>
<u>h</u>	Height; <u>ft.</u>
<u>k</u>	Spring constant; <u>lbf/in.</u>
<u>KL</u>	Buckling constant; <u>None</u> .
<u>K_s</u>	Static shear stress factor; <u>None</u> .
<u>KW</u>	Wahl correction factor; <u>None</u> .
<u>L_f</u>	Spring's free length; <u>in.</u>
<u>L_s</u>	Spring's solid length; <u>in.</u>
<u>m</u>	Harmonic number (for fundamental frequency, $m=1$); <u>None</u> .
<u>N</u>	Number of active coils; <u>None</u> . (Plain ends $N=N_t-.5$, Plain and grounded ends $N=N_t-1$ Squared ends $N=N_t-1.5$, Squared and grounded ends $N=N_t-2$)
<u>N_t</u>	Number of total coils; <u>None</u> .
<u>W</u>	Weight; <u>lbf.</u>
<u>y</u>	Spring deflection; <u>in.</u>

WELDING

DESCRIPTION

FORMULA

NAME

LOAD PER LINEAR INCH: (WELD/LOAD)

(01) Bending	$f = \frac{M}{Z_w}$	WLB
(02) Shear	$f = \frac{P}{L_w}$	WLS
(03) Twisting shear	$f = \frac{T \cdot C}{J_w}$	WLT

STRESS: (WELD/STRS)

(04) Bending	$\sigma_b = \frac{M}{Z_w \cdot W}$	WSB
(05) Shear, parallel load	$\tau_p = \frac{F}{.707 \cdot n \cdot W \cdot L}$	SSP
(06) Shear, traverse load	$\tau_t = \frac{.924 F}{.765 \cdot n \cdot W \cdot L}$	SST
(07) Tension, compression	$\sigma = \frac{P}{A}$	STC
(08) Twisting shear	$\tau = \frac{T \cdot C}{J}$	WST
(09) Vertical shear	$\tau = \frac{V}{A}$	WSV

WELDING

VARIABLES IDENTIFICATION

<u>SYMBOL</u>	<u>DESCRIPTION; UNIT</u>
<u>A</u>	Throat area; <u>sq.</u>
<u>C</u>	Distance from neutral axis to extreme fiber; <u>in.</u>
<u>F</u>	Compression, tension force; <u>lbf.</u>
<u>f</u>	Load per linear inch of weld; <u>lbf/in.</u>
<u>J</u>	Polar moment of inertia; <u>in⁴.</u>
<u>J_w</u>	Weld line polar moment of inertia; <u>in⁴.</u>
<u>L</u>	Length of weld; <u>in.</u>
<u>M</u>	Bending moment; <u>in-lbf.</u>
<u>n</u>	Number of fillets; <u>None.</u>
<u>T</u>	Torque; <u>in_lbf.</u>
<u>V</u>	Vertical force; <u>lbf.</u>
<u>W</u>	Leg size, weld size; <u>in.</u>
<u>Z_w</u>	Section modules; <u>in³.</u>
<u>σ_b</u>	Bending stress; <u>psi.</u>
<u>τ</u>	Shear stress; <u>psi.</u>
<u>τ_p</u>	Parallel load shear stress; <u>psi.</u>
<u>τ_t</u>	Traverse load shear stress; <u>psi.</u>

AIR AND STEAM TABLES

The Air and Steam Tables are combination of over 400 equations, all extracted from the subjects tables. The calculated properties, by this software, have the accuracy of over 99%, compared with the properties in published tables. It also have the unique advantages of (a) no interpolation requirement and (b) elimination of interpolation estimation error. It is applicable for both **ENG** and **SI** systems.

Tables in page 14-5 and 14-6 display the covered subjects, properties, ranges, directories, sub-directories, and equations' name.

The following steps will direct the user to an easy and fast calculation.

Step 1 At **LIBRARY** press **↩** **PREV**. The list of Air and Steam tables directories will appear on the screen menu.

Step 2 From the following listed directories, select the subject directory and press the associated soft key:

AIR For Air Table.

SAT.T For Saturated Steam Table, based on Temperature.

SAT.P For Saturated Steam Table, based on Pressure.

SUPHT For Super-heated Steam Table.

Step 3 From the following listed sub-directories, select the subject sub-directory and press the associated soft key:

ABS.P For Absolute Pressure Table.

SPC.V For Specific Volume Table.

ENTH For Enthalpy Table.

ENTR For Entropy Table.

ENRG For Internal Energy Table.

PR For Pressure Ratio.

VR For Volume Ratio.

Step 4 Select the system, the subject property from the menu and press the respective soft key. Examples of properties are: **vf**, **vg**, **hf**, **hfg**, **hg**, **x**, **sf**, **sg**, **uf**, **ug**, **Pr**, **Vr**, etc.

Step 5 From the screen menu, select the temperature or pressure range, in which the given temperature or pressure will fit. press the soft key associated with selected **≤T≤** , **≤PSI≤** ,or **≤MPA≤** .

Step 6 Enter the known value(s), and solve for the subject property.

AIR AND STEAM TABLES

EXAMPLES:

1. Determine (a) the enthalpy and (b) the entropy of air at 354 oF.

Solution:

Reminder: Temperature in Air Table is in Rankin (oR) scale. Therefore, $T = 460 + 354 = 814$ oR

- a. At LIBRARY press ↩ PREV AIR ENG ENTH 550R<T≤850R
For T=814 oR

$h = 195.2 \text{ BTU/lbm, Answer for (a)}$

- b. At LIBRARY press ↩ PREV AIR ENG ENTR 550R<T≤850R
For T=814 oR

$\phi = .69978 \text{ BTU/lbm-oR, Answer for (b)}$

* * * * *

2. Determine (a) the enthalpy and (b) the specific volume of 950 oF super-heated steam at 100 psig pressure. Assume atmospheric pressure equals to 14.6 psia.

Solution:

Reminder: Pressure in tables is in absolute pressure. Therefore, $P = 14.6 + 100 = 114.6$ psia.

- a. At LIBRARY press ↩ PREV SUPHT ENTH ENG NXT 67<PSI<135 750F<T<1200F
For T=950 oF and P=114.6 psia

$h = 1506.4 \text{ BTU/lbm, Answer for (a)}$

- b. At LIBRARY press ↩ PREV SUPHT SPC.V NXT 67<P≤135 750F<T≤1200F
For T=950 oF and P=114.6 psia

$v = 7.282 \text{ cf/lbm, Answer for (b)}$

* * * * *

3. Determine the quality of 130 oC steam if its enthalpy equals to 2450 kJ/kg.

Solution:

To find the quality of steam, the enthalpy of saturated liquid (hf) and saturated steam (hg) must be calculated first.

AIR AND STEAM TABLES

Step 1 Find hf:

At LIBRARY press $\leftarrow$ PREV SAT.T ENTH SI HF 100 C < T $\leq$ 150 C
For T = 130 oC hf = 546.5 kJ/kg.

Step 2 Find hg:

At LIBRARY press $\leftarrow$ PREV SAT.T ENTH SI HG 100 C < T $\leq$ 150 C
For T = 130 oC hg = 2720 kJ/kg.

Step 3 Find the quality, x:

At LIBRARY press $\leftarrow$ PREV SAT.T ENTH SI X
For h = 2450 kJ/kg and the stored calculated values for hf and hg (you may check by pressing $\rightarrow$ and the associated soft key for hf and hg.)

$x = .876 = 87.6\%, \text{Answer}$

* * * * *

4. Determine the entropy of 120 psia steam if its quality is equal to 0.89.

Solution:

To find the entropy of steam, the entropy of saturated liquid (sf) and saturated steam (sg) must be calculated first.

Step 1 Find sf:

At LIBRARY press $\leftarrow$ PREV SAT.P ENTR ENG SF NXT 115 < PSI < 250
For P = 120 psia sf = .4924 BTU/lbm-oR.

Step 2 Find sg:

At LIBRARY press $\leftarrow$ PREV SAT.P ENTR ENG SG NXT 115 < PSI < 250
For P = 120 psia sg = 1.5894 BTU/lbm-oR.

Step 3 Find the quality, x:

At LIBRARY press $\leftarrow$ PREV SAT.P ENTR ENG X
For x = .89 and the stored calculated values for sf and sg (you may check by pressing $\rightarrow$ and the associated soft key for hf and hg.)

$s = 1.4688 \text{ BTU/lbm-oR, Answer}$

AIR AND STEAM TABLES

IMPORTANT NOTE:

In order to achieve this high accuracy of more than 99% (in major cases over 99.7 %), the base parameters of the tables, pressure and temperature, had to be broken into ranges. Therefore solving the equations for temperature or pressure may not be one shot calculation. However, to get the accurate result, the user should be able to reach the answer in two (2) steps.

Following is the procedure:

Follow Step 1 through Step 4, as described in page 14-1

Step 5 Guess the range for the temperature or the pressure. If no idea, select a range close to the middle range.

Step 6 Solve the equation for temperature or pressure. If the result is within the selected range, the calculated figure is the answer. Otherwise go to step 7.

Step 7 Select the new range based on the calculated figure (prev. MENU key) and continue solving for temperature or pressure. The final answer must be generated. Check the range.

EXAMPLE:

Determine the temperature of air (in oF) if its Pressure Ratio (Pr) equals to 26.

SOLUTION:

At LIBRARY press $\leftarrow$ PREV AIR ENG PR. Since the temperature is not known, select the middle range, i.e. NXT 850R < T ≤ 1150R

For Pr=26

$$T = 1228.87 \text{ oR}$$

Since the calculated temperature (1228.87 oR) is out of the selected range (850R - 1150R), press prev. MENU key and select the proper range (1150 - 1450)

For Pr=26

$T = 1225.79 \text{ oR} = 765.79 \text{ oF, Answer}$
--

AIR AND STEAM TABLES

SUBJECT	RANGE ENG & SI	DIRECTORY	SUB DIRECTORY	NAME
<u>AIR TABLE:</u>	360 - 2500 oR	AIR		
Enthalpy	200 - 1400 K		ENTH	-
Entropy			ENTR	-
Internal Energy			ENRG	-
Pressure Ratio			PR	-
Volume Ratio			VR	-
<u>SATURATED STEAM, TEMP:</u>	32 - 500 oF	SAT.T		
Absolute pressure	0 - 260 oC		ABS.P	-
Specific volume:			SPC.V	
- Saturated liquid				VF
- Saturated vapor				VG
Enthalpy:			ENTH	
- Saturated liquid				HF
- Vaporization				HFG
- Saturated vapor				HG
- Quality of steam				X
Entropy:			ENTR	
- Saturated liquid				SF
- Saturated vapor				SG
- Quality of steam				X

AIR AND STEAM TABLES

SUBJECT	RANGE	DIRECTORY	SUB DIRECTORY	NAME
<u>SATURATED STEAM, PRESS:</u> Temperature Specific volume: - Saturated liquid - Saturated vapor Enthalpy: - Saturated liquid - Vaporization - Saturated vapor - Quality of steam Entropy: - Saturated liquid - Saturated vapor - Quality of steam Internal Energy: - Saturated liquid - Saturated vapor	1 - 750 psia .0007 - 5.2 MPa	SAT.P	TEMP SPC.V ENTH ENTR ENRG	- VF VG HF HFG HG X SF SG X UF UG
<u>SUPER HEATED STEAM:</u> Specific volume Enthalpy Entropy	250 - 1500 oF 1-2200 psia 95 - 815 oC .001 - 15 MPa	SUPHT	SPC.V ENTH ENTR	- - -

PSYCHOMETRIC CHART

The chart is a combination of programmed equations, which calculates the properties of atmospheric air, at the standard condition, within the range of 30 oF and 105 oF dry bulb temperature in English system (ENG) and 0 oC and 50 oC in International System (SI). Calculated values have 100% accuracy. The measured properties, needed for calculation of other properties, are either **dry bulb & wet bulb temperature (DB.WB)** or **dry bulb temperature & relative humidity (DB.RH)**.

Table in page 15-2 displays the covered subjects, properties, ranges, directory, and equations' name.

The following steps will direct the user to an easy and fast calculation.

Step 1 At LIBRARY press $\leftarrow$ PREV. The PSYCH directory appears on the screen menu.

Step 2 Press PSYCH

Step 3 Select **ENG** (for English System) or **SI** (for International System)

Step 4 Select **DB.WB** (for the given dry bulb and wet bulb temperature) or **DB.RH** (for the given dry bulb temperature and relative humidity).

Step 4 From the following listed names, select the subject name and press the associated soft key:

WET.B For wet bulb temperature (**twb**, oF or oC).

REL.H For relative humidity (**RH**, %).

ENTH For Enthalpy (**h**, BTU/lbda or kJ/kgda).

SPC.H For Specific Humidity (**Hs**, lbw/lbda or kgw/kgda).

SPC.V For Specific Volume (**v**, ft³/lbda or m³/kgda).

DEW.P For Dew Point temperature (**tdp**, oF or oC).

Step 5 Enter the known values, and solve for the subject property.

EXAMPLES:

1. Determine (a) the enthalpy and (b) the Specific Humidity of 70 oF tdb and 45% RH air.

Solution:

a. At LIBRARY press $\leftarrow$ PREV PSYCH ENG DB.RH ENTH
For **tdb=70** oF and **RH%=45**

$h = 24.47 \text{ BTU/lbda}$, Answer for (a)

b. press MENU SPC.H
For the same data.

$Hs = .007 \text{ lbw/lbda}$, Answer for (b)

PSYCHOMETRIC CHART

2. Determine (a) the Dew Point temperature and (b) the Specific Volume of 30 oC tdb and 24 oC twb air.

Solution:

- a. At LIBRARY press $\leftarrow$ PREV PSYCH SI DB.WB DEW.P
For twb=24 oC and tdb=30 oC

tdp = 21.71 oC, Answer for (a)

- b. press MENU SPC.V
For the same data

v = .88 m3/kgda, Answer for (b)

PSYCHOMETRIC CHART'S TABLE OF CONTENT

SUBJECT	RANGE	DIRECTORY	NAME
<u>PSYCHOMETRIC CHART:</u>			
Wet bulb temperature (twb)			WET.B
Relative Humidity (RH)			REL.H
Enthalpy (h)			ENTH
Specific Humidity (Hs)			SPC.H
Specific Volume (v)			SPC.V
Dew Point (tdp)			DEW.P
	30 - 105 oF tdb 0 - 50 oC tdb	PSYCH	

