Foxboro Evo™ Process Automation System

Product Specifications

Foxboro by Schneider Electric

PSS 31S-4PHYSPROP

Physical Properties Library

SATURATED STEAM PROPERTIES

TEMPERATURE (°F)	SATURATION PRESSURE (psia)	WATER ENTHALPY (BTU/lb)	STEAM ENTHALPY (BTU/lb)	HEAT OF VAPORIZATION (BTU/lb)
32.0	0.09	0.0	1075.5	1075.5
80.0	0.51	48.0	1096.4	1048.4
120.0	1.69	88.0	1113.6	1025.6
160.0	4.74	128.0	1130.2	1002.2
200.0	11.53	168.1	1146.0	977.9
240.0	24.97	208.4	1160.6	952.1
280.0	49.20	249.2	1173.8	924.6
320.0	89.64	290.4	1185.2	894.8
360.0	153.01	332.3	1194.4	862.1
400.0	247.26	375.1	1201.0	825.9
440.0	381.54	419.0	1204.4	785.4
480.0	566.15	464.5	1204.1	739.6
520.0	812.53	512.0	1199.0	687.0
560.0	1133.38	562.4	1187.7	625.3
600.0	1543.22	617.1	1167.7	550.6
640.0	2059.89	679.1	1133.7	454.6
680.0	2708.59	758.5	1068.5	310.1
704.0	3177.24	854.2	956.2	102.0

OVERVIEW

This library calculates physical properties of industrial materials for use in energy balance calculations, flow measurement compensation, and other application functions.

The Physical Properties Library contains FORTRAN and C language function subroutines for calculating physical properties of steam, water, and gases in English and metric units. An application program can call these functions to support energy balance calculations and other application functions. Each library function calculates one physical property for a specific material, based on input data passed by an application program. The library functions calculate physical properties for:

- Steam and water
- Air
- Carbon dioxide
- Carbon monoxide
- Sulfur dioxide
- Nitrogen
- Oxygen.

The Physical Properties Library includes steam property tables and chemical properties data. Steam table routines allow the calculation of volume,

enthalpy, and entropy as functions of temperature and pressure. They include the four regions of the American Society of Mechanical Engineers (ASME) Steam Table Formulations. Other steam table routines calculate saturation temperature, quality, volume, and entropy as functions of pressure and enthalpy.

The library includes a range of chemical properties applicable to many industrial processes. Subroutines for calculating thermodynamic properties of air and the heat capacity of other gases are available.

You can link the library functions to your C and FORTRAN application programs that run under the Foxboro Evo™ Control Core Services. The library consists of a set of object modules that are installed in a Foxboro Evo Application Processor (AP) or Personal Workstation (PW).

Other Foxboro Evo application packages, e.g., Optimizer and Spreadsheet, support use of the Physical Properties Library functions (see Figure 1).

You can call the library functions from an application program. For example, you can calculate boiler efficiency using the library (see Figure 2). Assume that the flows (f_1, f_2, and f_3), temperatures (t_1, t_2, and t_3), pressures (p_1, p_2, and p_3), and fuel heat energy flow (q_f) have been determined. The following C language code segment calculates the boiler efficiency:

```
/*
* Call Functions to calculate enthalpies of boiler
flows:
*/
hpt_wtr(p1, t1, &h1);
hpt_stm(p2, t2, &h2);
hpt_wtr(p3, t3, &h3);
/*
* Calculate boiler efficiency
*/
eff = (h2*f2 + h3*f3 - h1*f1) / qf;
```

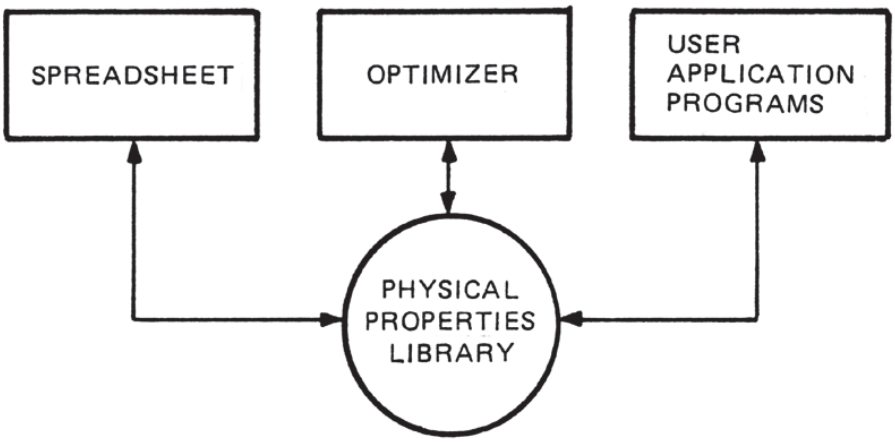

Figure 1. Physical Properties Library Application

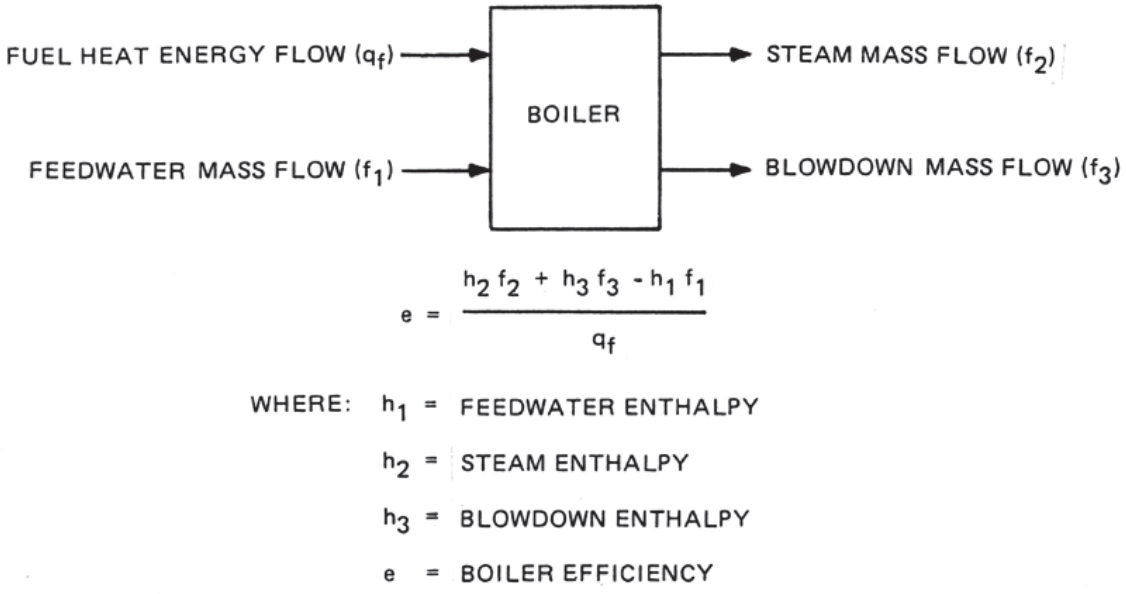

Figure 2. Boiler Efficiency Diagram

FUNCTIONS

The Physical Properties Library routines are written as functions in both the C and FORTRAN languages. The calling program passes the required input parameters to the function. Each function returns to the caller one calculated value and an input error code.

Table 1 identifies the physical property variables and their engineering units. Table 2 lists the library function calls for steam and water properties in English units. Table 3 lists the library function calls for gas properties in English units. The metric unit function calls are similar to those for English units, except that the character “m” replaces the underscore in the function name.

An error code is set whenever an input parameter is outside of its preset range for the function; e.g., if you call a water property routine for a temperature greater than 705 °F, the routine returns error code T_HI (see Figure 3).

The steam property functions cover all six regions defined by the International Formulations Committee, from 0 to 15,500 psia and from 32 to 1500 °F (see Figure 1).

For air properties, the range of the calculations include air in the gaseous state from 0 to 3000 psia and from 0 to 3200 °F.

For the other gases, the range of the calculations are from 0 to 1000 °F

Table 1.

Name	Identification	English Units	Metric Units
p	Pressure	psi(abs)	MPa
t	Temperature	°F	°C
v	Volume	ft. ^{3}/lb	m ^{3}/kg
h	Enthalpy	BTU/lb	kJ/kg
s	Entropy	BUT/lb/ °F	kJ/kg/ °C
c	Heat capacity	BTU/lb/ °F	kJ/kg/ °C
q	Steam quality	NA	NA
g	Specific gravity	NA	NA
d	Density	lb/ft. ^{3}	kg/m ^{3}

Table 2.

Call	Function
vpt_stm(p, t, v)	Volume – steam
hpt_stm(p, t, h)	Enthalpy – steam (pressure/temperature)
spt_stm(p, t, s)	Entropy – steam
hps_stm(p, s, h)	Enthalpy – steam (pressure/entropy)
dpt_stm(p, t, d)	Density – steam
gpt_stm(p, t, g)	Specific gravity – steam
tph_stm(p, h, t)	Temperature – steam
pt_sw(t, p)	Saturation pressure – steam/water
tp_sw(p, t)	Saturation temperature – steam/water
qph_sw(p, h, q)	Quality – steam/water
vpt_wtr(p, t, v)	Volume – water
hpt_wtr(p, t, h)	Enthalpy – water
spt_wtr(p, t, s)	Entropy – water
dpt_wtr(p, t, d)	Density – water
gpt_wtr(p, t, g)	Specific gravity – water

Table 3.

Call	Function
vpt_air(p, t, v)	Volume – air
hpt_air(p, t, h)	Enthalpy – air
dpt_air(p, t, d)	Density – air
gpt_air(p, t, g)	Specific gravity – air
ct_air(t, c)	Heat capacity – air
ct_o2(t, c)	Heat capacity – oxygen
ct_n2(t, c)	Heat capacity – nitrogen
ct_co(t, c)	Heat capacity – carbon monoxide
ct_co2(t, c)	Heat capacity – carbon dioxide
ct_so2(t, c)	Heat capacity – sulfur dioxide

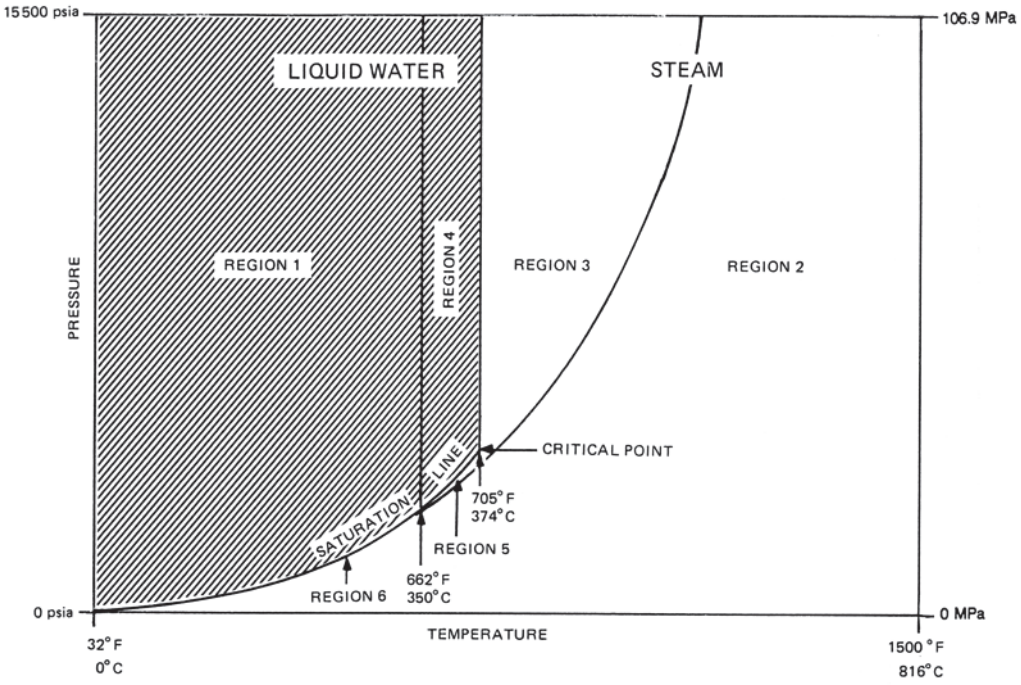

Figure 3. Subregions of the Temperature-Pressure Diagram

Foxboro®

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