FOXBORO®

PSS 21S-4C1 B3

# I/A Series® Software
# 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 |

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 I/A Series System Software. The library consists of a set of object modules that are installed in an I/A Series Application Processor (AP) or Personal Workstation (PW).

Other I/A Series 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;
```

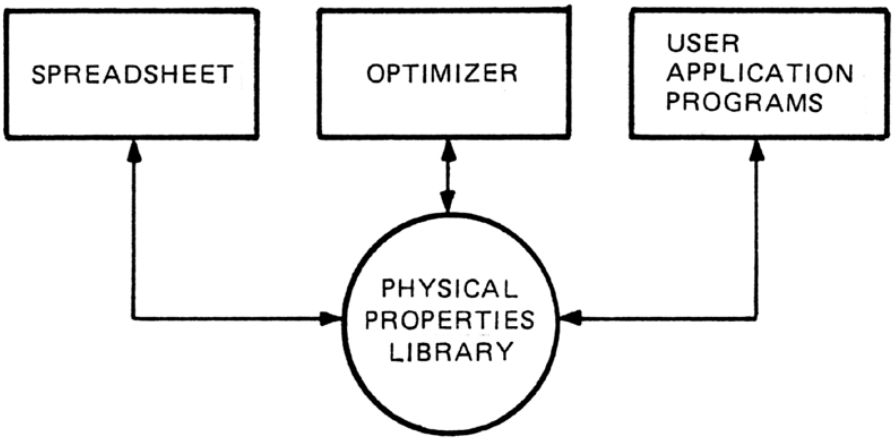


Figure 1. Physical Properties Library Application

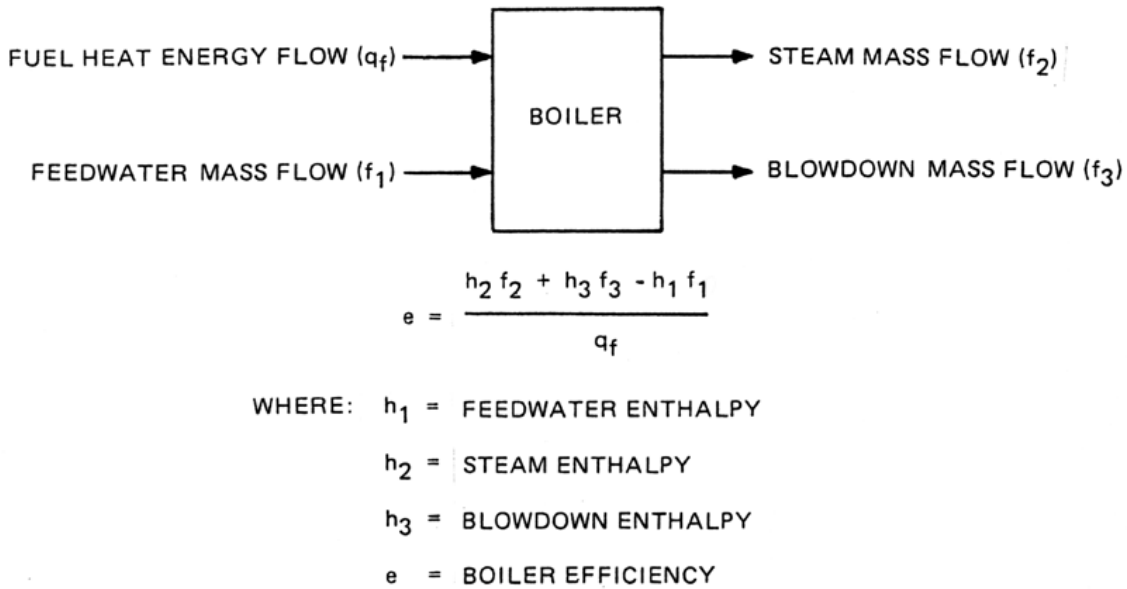


Figure 2. Boiler Efficiency Diagram

## 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 |

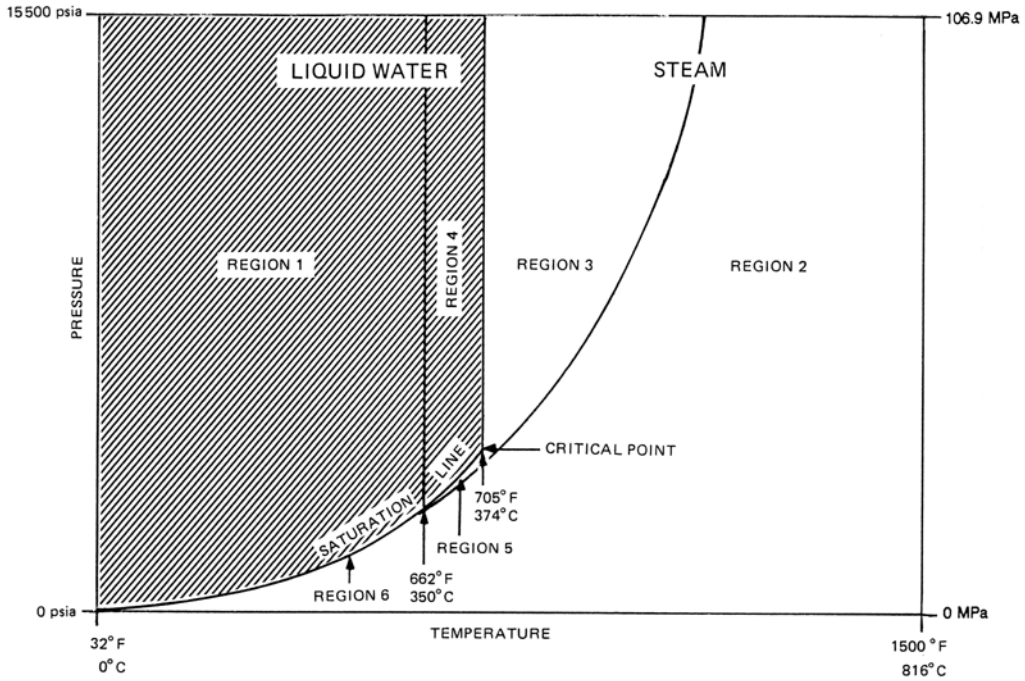


Figure 3. Subregions of the Temperature-Pressure Diagram

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