NASA 2-phase tables

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Fast and accurate 2-phase properties

- Tabulate data from REFPROP for target fluids
- Optimize table points to minimize number of points while meeting desired interpolation accuracy
- Faster than REFPROP calls
- REFPROP challenges near “tricky” states:
  - Near critical point, may return errors or bad values
  - Does not work below triple point temperature
  - No values below freeze/maximum density line
    - Solids not modeled, but solvers need to recover if accidentally reaching this state
  - Does not return certain properties in the vapor dome (e.g. sound speed)
  - Crashes/bad values returned for some fluids for all enthalpies in a narrow pressure band below critical point

Time for 450,000 calls STP

Fluid	Tables	REFPROP9	REFPROP xSlower
Oxygen	0.951	20.2	21.2
Para-hydrogen	0.936	27.6	29.5
RP-1	0.889	1103.9	1241.7
Nitrogen	0.952	23.4	24.6
Helium	0.936	35.4	37.8

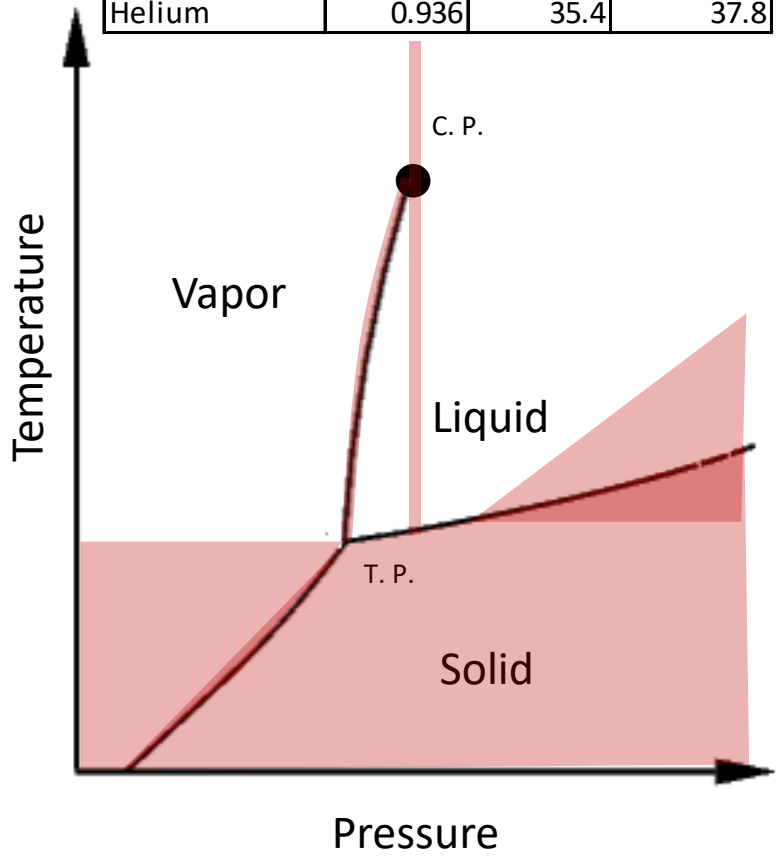
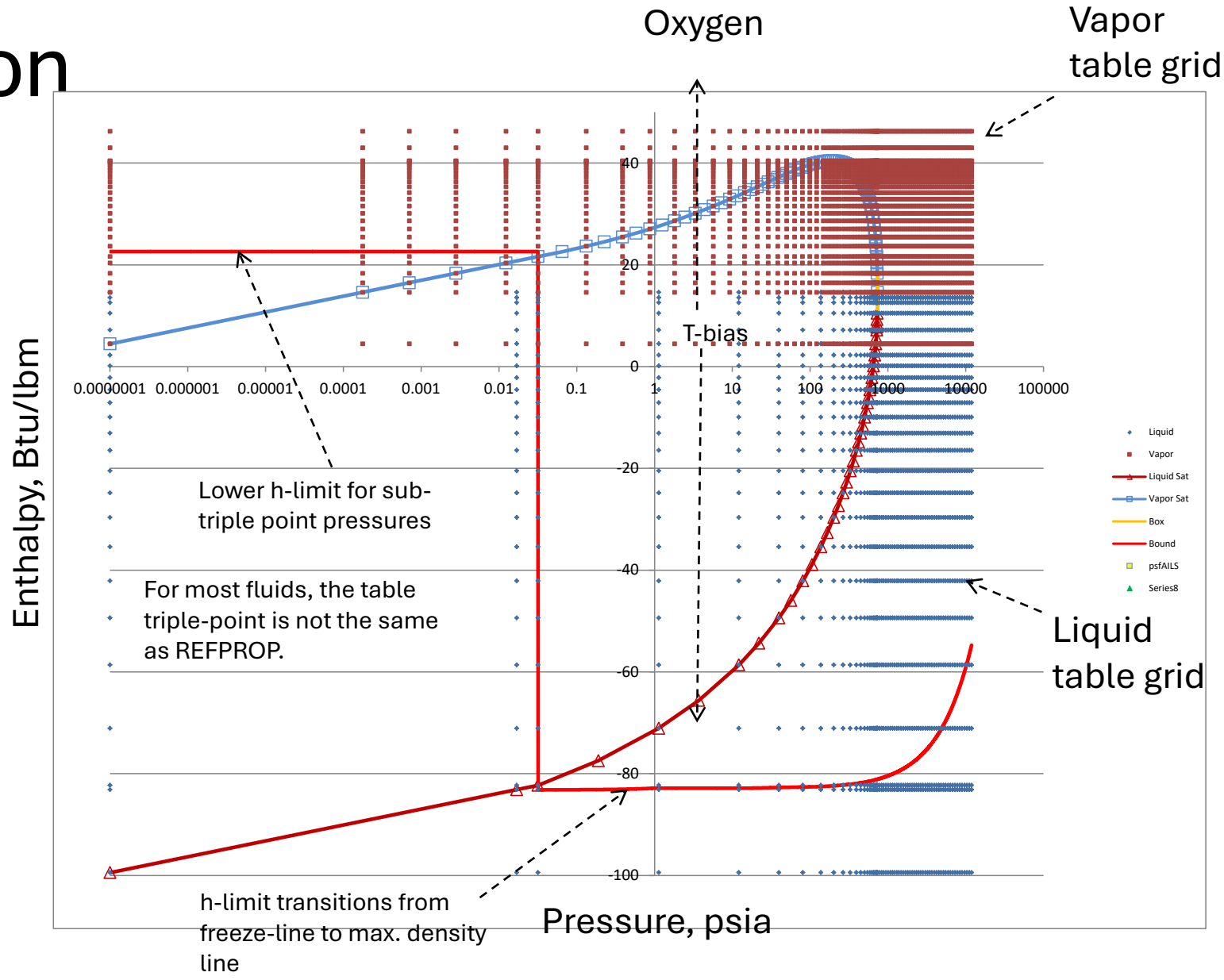


Table construction

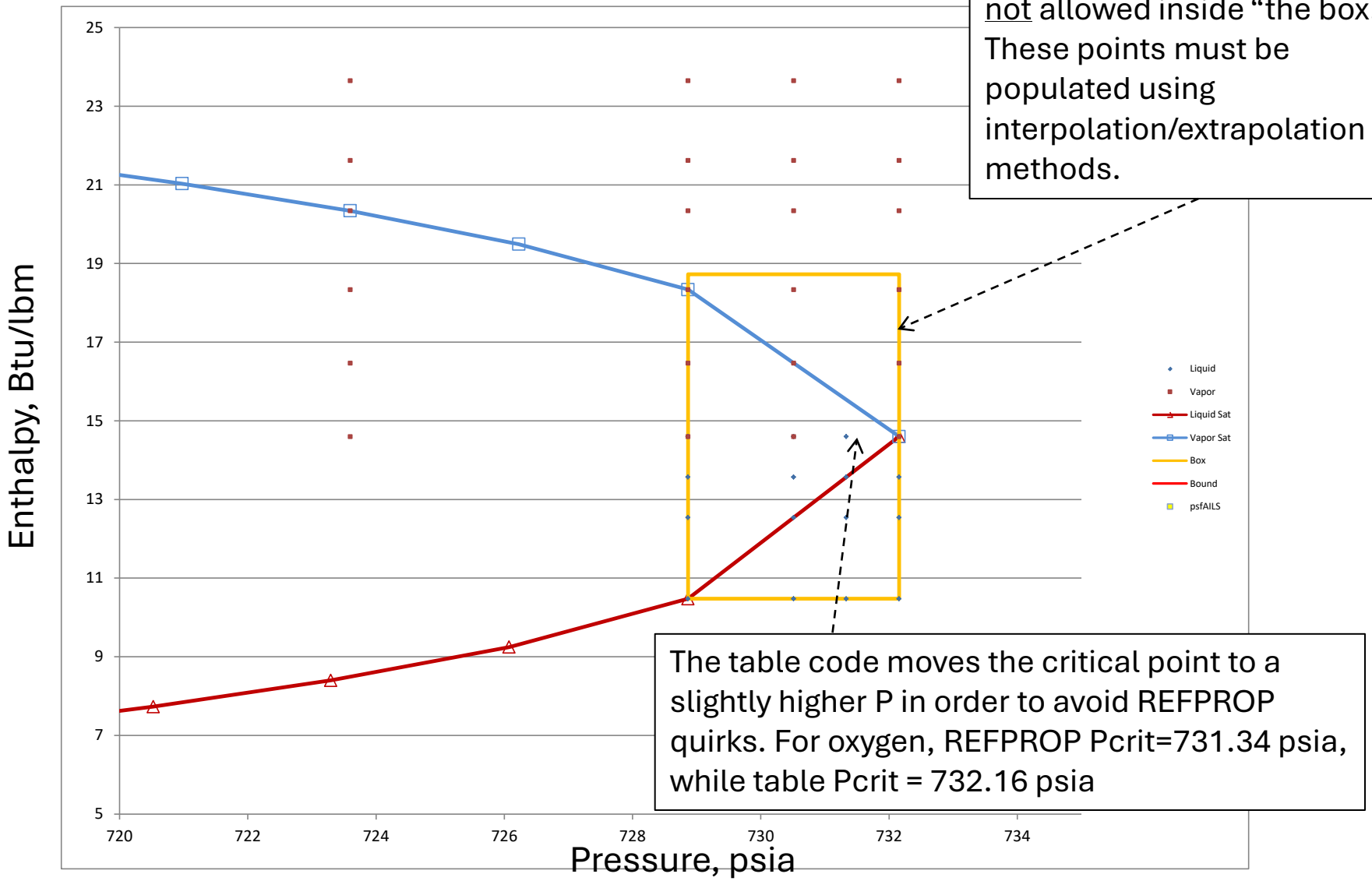
- Many fluids available
- Points clustered around critical point to minimize interpolation error
- Populate points with REFPROP calls
- Interpolate/Extrapolate to fill gaps
- Apply constraints

e.g. S should always increase in the h-direction $\frac{ds}{dh} = \frac{1}{T} > 0$



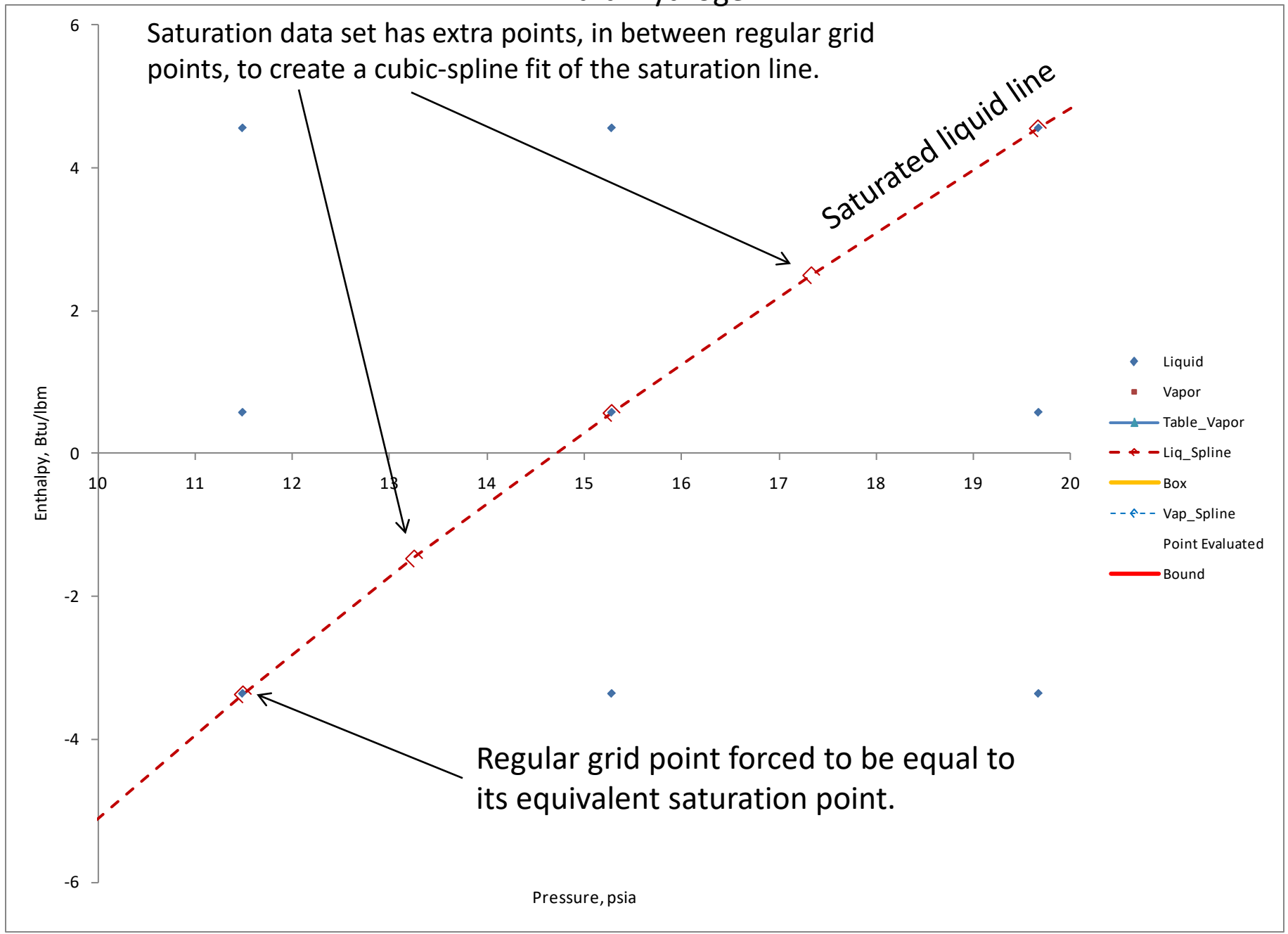
Handling “tricky” states

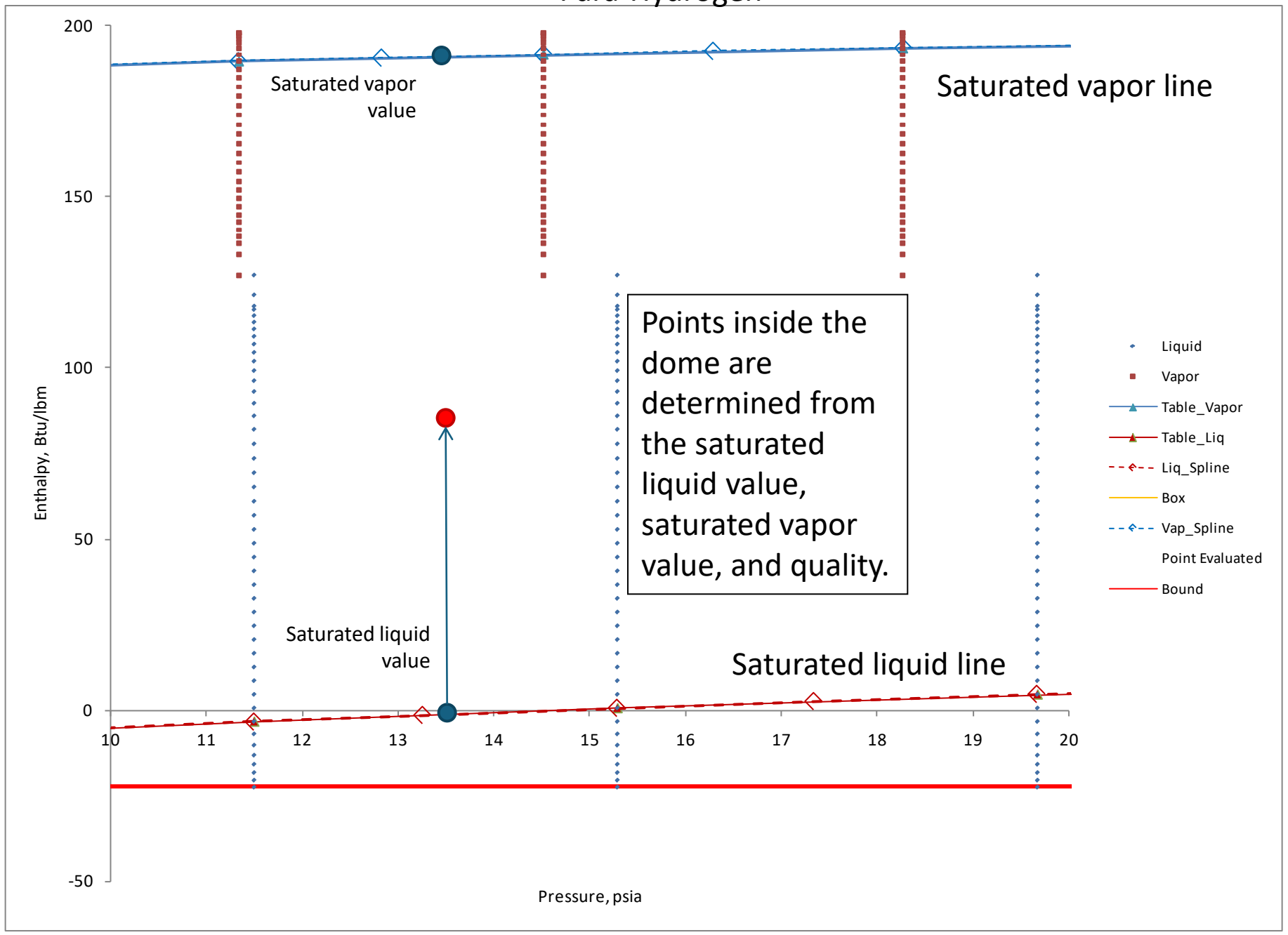
REFPROP calls are allowed on the edges of “the box,” but <u>not</u> allowed inside “the box.” These points must be populated using interpolation/extrapolation methods.



The table code moves the critical point to a slightly higher P in order to avoid REFPROP quirks. For oxygen, REFPROP Pcrit=731.34 psia, while table Pcrit = 732.16 psia

Para-Hydrogen





Speed of sound in the dome by two approaches:

- Homogenous: smooth, continuous curve inside dome
- Equilibrium: discontinuous at saturation lines

Current state & next steps

- Need to port from Fortran77 to modern C++ in NPSS
  - Table reader is complete
  - Table generator is in progress
- Planned improvements
  - Dynamic on-demand table generation -> Require less user input
  - Serialize tables -> Even faster property lookup, improved memory efficiency
  - Interface with other property sources (e.g. CoolProp)
  - Goal deadline end-of-government fiscal year (Sept. 30)

Benefits over REFPROP

- Can get sound speed in the vapor dome
- Stable in other “tricky” spots
- Speedup using a table-lookup approach