USING A LOOK UP TABLE FOR FLUID PROPERTIES

Version 20.9 includes the option to obtain the fluid properties from a lookup table rather than from a perfect or semi-perfect gas model.

The properties are tabulated as functions of density and specific internal energy since these are the primary fluid properties calculated by the solver. The table is "rectangular" in the sense that the density varies along one axis, the "I" axis and the internal energy along the other, "J" axis, i.e. for a given value of "I" the density is the same for all "J" values and for a given value of "J" the internal energy is constant for all "I" values. The values need not be uniformly spaced and for the density in particular a geometric progression in spacing is better because it varies over such a wide range, e.g 0.02 to 200 kg/m^3, for steam. The internal energy varies over a much smaller range and its values may be evenly spaced.

The properties which must be tabulated are :

Pressure.	
Temperature.	
Entropy.	
Isentropic Index	The pressure:density relationship for a small isentropic expansion. i.e. gamma in P/rho**gamma = constant.
Dryness Fraction.	

The entropy and dryness fraction are not used at all during the calculation but are output to the plotting file so they can be visualised in the solution.

The tables must be named "props_table.dat" and must be in the same directory from which the solver is being run.

The table is searched using a bilinear interpolation in which it is first divided into coarse, typically 8x8, blocks, these are searched to find the coarse block containing the input values and this is then searched cell by cell to find the matching point. The size of the table depends on the range of properties to be covered, for typical high pressure or low pressure steam turbines 70x70 blocks are sufficient but the whole range of properties likely to occur in steam turbines may be covered by a 150x150 point table. The latter takes slightly longer to run than the smaller tables but, unless run time is at a premium, it is simpler to use the same table for all runs. Suitable tables for high pressure steam turbines, low pressure steam turbines and the whole range of steam conditions likely in steam turbines are provided. These must be copied to "props_table.dat" before being used.

The format required for the tabulated data is described below. The required tables can be generated from the COOLPROP system of fluid properties (www.coolprop.org) using the Fortran program " make-all-tables.f " which is included in this folder. This must be linked to the COOLPROP system and compiled before it can be run. The COOLPROP system is not easy to use and the author cannot give any guidance on it. The program "make-all-tables.f " is set up for steam and to cover the whole range of likely steam turbine properties with a 150x150 table. It can easily be changed to use other gases, different property ranges and different table sizes if required.

COOLPROP sometimes gives overflows near discontinuities in the fluid properties, e.g. near the saturation line for steam. To prevent this causing failure the tabulated values are searched by MULTALL, before they are used, any large changes between adjacent points are smoothed over.

DATA INPUT TO USE A LOOKUP TABLE

There is very little change to the input data compared to recent versions of MULTALL. The changes are described in "new-readin-input-data-20.9.doc" .

In CARD 2 now read in CP, GAMMA, IFGAS instead of just CP and GAMMA.
Set IFGAS =0 for a perfect gas,
Set IFGAS = 1 for a semi-perfect gas with Cp a function of temperature.
Set IFGAS = 3 to use a lookup table.
If IFGAS is not included then it defaults to zero.

In CARD 77 Read in HOIN(K) instead of TO1(K) .
HOIN(K) is the inlet stagnation enthalpy in kJ/kg .

Also the file "props_table.dat " must be available in the directory from which the program is being run.

PLOTTING THE OUTPUT WHEN USING A LOOKUP TABLE

The plotting routine "plotall" uses the gas constant and specific heat ratio to evaluate flow quantities, hence some quantities are not accurate when the fluid properties are obtained from a lookup table. The velocities and density and mass fluxes are accurate but pressure, temperature, Mach number and entropy are not. If the usual plotting program, "plotall-20.1", is used with a lookup table solution the output from MULTALL has been slightly changed so that item 9 on the menu is the true static pressure and item 33 is the true entropy. A modified version of the plotting program, " plot-steam.f" has been developed to give accurate plotted quantities when using a lookup table. If a lookup table is used the solver outputs extra data to the plotting file "flow_out", this is read in and used by "plotall-steam", hence "plotall-steam" cannot be used for solutions which do not use a lookup table. A version of "plotall-steam" compiled for LINUX is provided.

INPUT DATA FOR THE PROPERTY TABLE

Note that all the data in this file is read in to MULTALL as "Free Format". However, the tables can be much more easily understood and checked for any errors if they are written out as formatted data. This is done by program " make-all-tables.f " .

In order to be read by MULTALL this file must be named "props_table.dat" . Any queries about the data input can usually be answered by studying the tables provided for steam, e.g. "HP-steam-tables.dat".

CARD 0. COMMENT CARD

CARD 1. ITAB, JTAB

ITAB	The number of input data points in then “I” dimension
JTAB	The number of input data points in then “J” dimension

CARD 2. COMMENT CARD

CARD 3. ROAXIS(I) , I =1,ITAB

ROAXIS	The values of density along the “I” axis of the tables. They need not be uniformly spaced and are usually best spaced as a geometric progression. In kg/m^3 .

CARD 4. COMMENT CARD

CARD 5. UAXIS(J) , J =1,JTAB

UAXIS	The values of internal energy along the “J” axis of the tables. They need not be uniformly spaced but it is usually acceptable if they are. In J/kg .

CARD 6. COMMENT CARD
CARD 7. COMMENT CARD

CARDS 8. FOR I = 1 to ITAB
READ COMMENT CARD
READ COMMENT CARD
READ RO_TAB(I,J), J=1,JTAB

RO_TAB	The tabulated values of density. In kg/m^3 . These do not vary in the J direction and the value in the I direction must be the same as ROAXIS in CARD 3 .

CARD 9. COMMENT CARD
CARD 10. COMMENT CARD

CARDS 11. FOR I = 1 to ITAB
READ COMMENT CARD
READ COMMENT CARD

READ U_TAB(I,J), J=1,JTAB

U_TAB	The tabulated values of internal energy. In J/kg .These do not vary in the I direction and the value in the J direction must be the same as UAXIS in CARD 5 .

CARD 12. COMMENT CARD
CARD 13. COMMENT CARD

CARDS 14. FOR I = 1 to ITAB
READ COMMENT CARD
READ COMMENT CARD
READ P_TAB(I,J), J=1,JTAB

P_TAB The tabulated values of static pressure. In N/m^2 .

CARD 15. COMMENT CARD
CARD 16. COMMENT CARD

CARDS 17. FOR I = 1 to ITAB
READ COMMENT CARD
READ COMMENT CARD
READ T_TAB(I,J), J=1,JTAB

T_TAB The tabulated values of static temperature. In K .

CARD 18. COMMENT CARD
CARD 19. COMMENT CARD

CARDS 20. FOR I = 1 to ITAB
READ COMMENT CARD
READ COMMENT CARD
READ ENT_TAB(I,J), J=1,JTAB

ENT_TAB The tabulated values of entropy. In J/kg K .
This is not used in the calculation but is useful for the output.

CARD 21. COMMENT CARD
CARD 22 COMMENT CARD

CARDS 23. FOR I = 1 to ITAB
READ COMMENT CARD
READ COMMENT CARD
READ GA_PV_TAB(I,J), J=1,JTAB

GA_PV_TAB The tabulated values of isentropic index for a small pressure-density change i.e. gamma in
P /rho**gamma = constant along an isentropic.

CARD 24. COMMENT CARD
CARD 25. COMMENT CARD

CARDS 26. FOR I = 1 to ITAB
READ COMMENT CARD
READ COMMENT CARD
READ DRY_TAB(I,J), J=1,JTAB

DRY_TAB The tabulated values of fluid dryness fraction.
This is not used in the calculation but is useful for the output.