

# README

The attached folders contain the 3D MULTALL based design system.

The system has been developed over many years, it has been run on a very large number of data sets and gives realistic results in almost all cases. However, due to the limitations of turbulence and transition modeling, CFD is not an exact science, and the author will accept no responsibility for the accuracy of the results obtained.

**The most important component of a CFD system is the user, who must understand the physics of the flow they are trying to achieve.**

The system consists of three linked programs. These are written in FORTRAN77 and should run on any computer with a FORTRAN compiler. The only exception is that STAGEN contains calls to the plotting package HGRAPH, which is no longer available. These calls can be removed by deleting lines 1447 to 1537 of STAGEN, the program will then run but will not plot out the blade profiles. Executable versions of STAGEN, which include the plotting, are supplied for LINUX and WINDOWS systems but they are not guaranteed to work on all systems.

MULTALL contains calls to the timing routine MCLOCK used by the gfortran and g77 compilers, these may produce an error on other compilers but they can either be commented out, removed, or replaced with similar calls for the compiler being used.

The system is described with examples of its use in the attached powerpoint presentation, multall-design.pptx .

**See the Updates file in this folder for changes since the original release.**

## MEANGEN

is a meanline program that accepts input from either the screen or from a file called **meangen.in** . Given the required basic design parameters it performs a 1D design to obtain the velocity triangles on a specified stream surface. The required flow area is calculated and used to obtain the annulus boundaries. This is done for as many stages as required. An initial guess of blade numbers and blade profiles is generated and the blades are twisted to produce a free vortex flow. The program then writes an input file called **stagen.dat** for the program STAGEN. It also writes out a file **meangen.out**, which is a copy of the input data, this can be copied to **meangen.in**, edited if required, and used as input for further runs if there are only minor changes to the design.

A new version MEANGEN-17.4.F was added on 3/10/2017.

## STAGEN

is a blade geometry generation and manipulation program. It takes the initial guess of blade geometry produced by MEANGEN from the file **stagen.dat**, and allows the blade sections to be refined, stacked and combined into multiple stages. The input file **stagen.dat** can also be generated manually, but this takes some time and it is usually easier to start with an initial data set from MEANGEN, even if it requires significant changes. Once a data set **stagen.dat** has been set up changes to the geometry can usually be made in a few seconds.

The number of grid points to be used and the grid spacings are set in STAGEN as are most of the control parameters for MULTALL. STAGEN can plot out the blade sections generated but this requires the use of the graphics package HGRAPH, which is no longer available, however, it should be easy to implement a different graphics program. Delete the relevant section of the code if a plotting package is not available.

STAGEN writes out two input files for MULTALL, **stage\_new.dat** is in the “new” format which uses all unformatted data, **stage\_old.dat** is in the same format as used in previous versions of MULTALL and uses mainly formatted data. Either data set can be used in MULTALL depending on the setting of the file **intype**.

## MULTALL

Is a three-dimensional Navier-Stokes solver written specifically for turbomachinery. It has been continuously developed over many years and contains options to model the most common flow features found in turbomachines. It solves for the main blade path, assuming axisymmetric annulus boundaries, and so cannot deal with split blade paths or with hub and casing cavities. Although written in cylindrical coordinates, the program can be run with effectively Cartesian grids, for cascades, or for applications other than turbomachinery, by making the radial extent of the calculated region small relative to the radius. It can also be run as a quasi-3D blade-to-blade solver or as an axisymmetric throughflow solver by using only a single cell in the spanwise or pitchwise directions.

MULTALL reads in the data sets **stage\_new.dat** or **stage\_old.dat** depending on the value of the variable ANSIN, which is read from file **intype**. It solves for steady flow through multiple stages using a mixing plane model to transfer the flow between blade rows. The grids are automatically made contiguous at the mixing planes. It can predict the flow through axial, mixed or radial flow machines and predicts the machine efficiency, mass flow, pressure ratio, etc, as well as the detailed flow field. A great deal of user experience ensures that the realistic results are usually obtained.

MULTALL is very fast relative to most CFD codes and its speed benefits greatly from using the highest possible level of compiler optimisation.

Output files **flow\_out** and **grid\_out** can be used for plotting the results but these need to be interfaced to the user’s plotting system. Alternatively the supplied executable plotting programs may work. The same files can be used as restart files if starting a new calculation with no change to the grid point numbers.

A program to convert these files to a TECPLOT input file was added on 3/10/2017, see below.

## CONVERTING OLD DATA SETS

For users of earlier versions of MULTALL, it is possible to convert old data sets for MULTALL-15 or MULTALL-14 to MULTALL\_OPEN data sets using a program CONVERT. This reads in a file which must be named **old\_readin.dat** and writes out a file called **new\_readin.dat** for input to the latest version of MULTALL.

## PLOTTING THE RESULTS

The plotting programs used by the author are all based on the HGRAPH graphics system, which is no longer available. Users should interface the output to their own plotting system. However, executable versions of the author’s plotting programs for LINUX and for WINDOWS systems are provided. They should work on

most 64 bit systems but some calls are system dependent and so they may not work on all. **The author cannot help with sorting out problems with running the plotting programs.**

A fortran program called CONVERT-TO-TECPLOT.F which converts the MULTALL output plotting files “flow\_out” and “grid\_out” to a file named “tecplot-input.dat”, which should be readable by the commercial plotting program TECPLOT, was added on 3/10/2017. To run this, simply compile it, type the name of the executable and answer the questions on the screen.

## **STARTING OFF**

Learning to use a new CFD system can be a frustrating experience until the user becomes familiar with the many options available. There is no substitute for actually running the programs and studying the results if one wants to understand a code.

It is suggested that new users should first run one of the sample MULTALL data sets provided to ensure that MULTALL is working properly, all the data sets should converge. Then try running MEANGEN to design a single stage axial turbine or compressor, using screen input, the option FLO\_TYP = AXI is the easiest to use. Run STAGEN on the resulting data set, **stagen.dat**, accepting the simplified blade profiles with no changes. Then run the resulting data set, **stage\_new.dat**, on MULTALL, remember to set file **intype** to contain the single character “N” if using the “new” input format.

Next try editing **stagen.dat** to change the blade profiles, for example, change the blade thickness, camber line angles or restagger the blades, and re-run STAGEN then MULTALL. Next re-run MEANGEN to design a two-stage machine, or try FLO\_TYP= MIX for a machine with significant radius changes, and again run the design through STAGEN and MULTALL. You will soon become an expert. Good Luck.

More details of the programs can be obtained from the user manuals and from ASME paper GT2017-63993 .

John Denton. February 2017.