

NOZZLE Program

User Guide

Version 3.111

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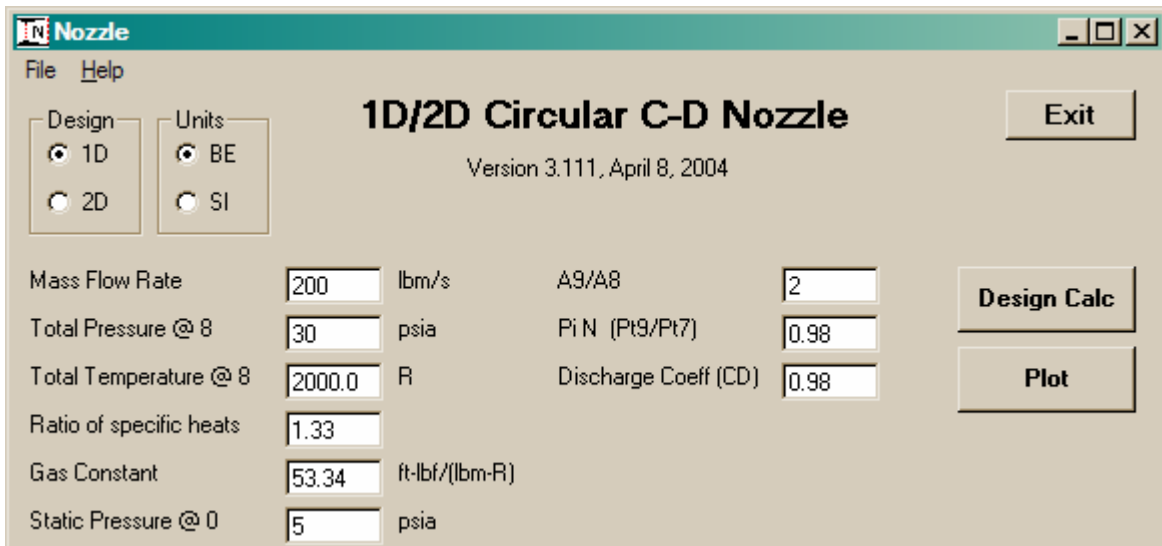
Hint for Data Editing: This program uses edit fields for user editing of each piece of data. The program waits until you enter the “tab” or “enter” key to accept your data entry in that field. Use the “tab” key to move between data edit fields.

1. MAIN Window

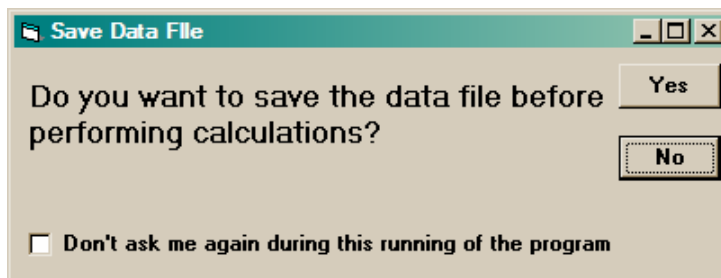
The NOZZLE conceptual design program analyzes both 1-D and 2-D circular convergent-divergent nozzles. It is based on the equations developed in Chapter 10 of *Aircraft Engine Design, Second Edition*.

This program is designed to be user-friendly and multiple windows are used for program control and data input. NOZZLE input data files may be saved on disk for later use (the file extension “NOZ” is used for these files). Also, saved input data files may be read from disk for current use. The current data file name is displayed in the upper left of the Main window and in output windows. Program output is directed to output windows and may be sent to a printer.

When the NOZZLE program is run, the Main window is displayed. The top of the Main window is shown below.



NOTE When the user presses the **Perform Calc** button, they will be asked if they want to save the input data before the calculations are performed using the following window. The user can check the box and turn off this reminder.



2. Design Calculation

Pressing the **Design Calc** button causes the program to calculate the nozzle performance using the input design data and displaying the results in the output window. The one-dimensional (1-D) analysis has only dimensions normal to the flow direction (flow areas) and does not have length dimensions. The results for a 1-D circular nozzle are shown below.

The screenshot shows the 'Nozzle' software interface. The title bar reads 'Nozzle'. The main window title is '1D/2D Circular C-D Nozzle' with the version 'Version 3.11, December 8, 2003'. The interface includes a 'File' menu, 'Design' and 'Units' selection buttons (1D, 2D, BE, SI), and an 'Exit' button. Input fields are provided for Mass Flow Rate (200 lbm/s), Total Pressure @ 8 (30 psia), Total Temperature @ 8 (2000 R), Ratio of specific heats (1.33), Gas Constant (53.34 ft-lbf/(lbm-R)), and Static Pressure @ 0 (5 psia). Additional input fields include A9/A8 (2), Pi N (Pt9/Pt7) (0.98), and Discharge Coeff (CD) (0.98). Action buttons for 'Design Calc', 'Plot', and 'Print' are present. A text area at the bottom displays the following calculated results:

m dot	=	200.0	lbm/sec	Pi N	=	0.9800
Mach 8	=	1.000		Area 8	=	4.044 ft ²
Mach 9	=	2.146		Area 9	=	8.088 ft ²
P 9	=	3.011	psia	V 9	=	3456.7 ft/sec
Mach 9i	=	2.125		V 9i	=	3437.1 ft/sec
P 9i	=	3.180	psia			
V s	=	3151.1	ft/sec			
Fg a	=	19170	lbf	Fg i	=	19988 lbf
CV	=	1.0057		CD	=	0.9800
Cfg	=	0.9591		P9/P0	=	0.6021

The two-dimensional (2-D) analysis has both dimensions normal to the flow direction (flow areas) and length dimensions. The results for an example 2-D circular convergent-divergent nozzle are shown below. Note that the nozzle can be sketched for the 2-D analysis.

The screenshot shows the 'Nozzle' software interface. The title bar reads 'Nozzle'. The main window title is '1D/2D Circular C-D Nozzle' with the version 'Version 3.11, December 8, 2003'. There are 'Exit', 'Design Calc', 'Contour Plot', 'Sketch', and 'Print' buttons on the right side.

Design and Units:

- Design: 1D, 2D
- Units: BE, SI

Input Parameters:

- Mass Flow Rate: 200 lbm/s
- Total Pressure @ 8: 30 psia
- Total Temperature @ 8: 2000 R
- Ratio of specific heats: 1.33
- Gas Constant: 53.34 ft-lbf/(lbm-R)
- Static Pressure @ 0: 5 psia
- A9/A8: 2
- Convergent Angle: 15
- Divergent Angle: 10
- Diameter @ 7: 36 in

Calculated Results:

\dot{m}	= 200.0 lbm/sec	Area 7	= 7.069 ft ²
Mach 7	= 0.351	Area 8	= 4.099 ft ²
Mach 8	= 1.000	Area 9	= 8.198 ft ²
Mach 9	= 2.169	V 9	= 3477.2 ft/sec
P 9	= 2.902 psia	V 9i	= 3488.4 ft/sec
Mach 9i	= 2.182	Fg i	= 19588 lbf
P 9i	= 2.902 psia	Cfgpeak	= 0.9879
V s	= 3151.1 ft/sec	CA	= 0.9911
Fg a	= 18947 lbf	P9/P0	= 0.5804
CD	= 0.9669		
CV	= 0.9968		
Pi N	= 0.9880		
Cfg	= 0.9673		

3. Gross Thrust Coefficient Contours

The variation of the gross thrust coefficient (C_{fg}) with design variable(s) can be calculated and presented using the **Contours/Plot** button. The following data window is displayed for the 1-D circular nozzle. The **Plot** and **Plot+** buttons become active after the **Calc Cfg's** button has been pressed and the performance calculated. Similar to the INLET program, the **Plot** button displays a plot where the mouse arrow becomes a cross-hair when the user moves the mouse across the plot. This feature allows the user to capture and display at the bottom of the screen the coordinates and total pressure value by pressing the left mouse button. Pressing the **Plot+** button produces an Oletra Chart plot of the gross thrust coefficient versus nozzle area ratio.

Contour Data

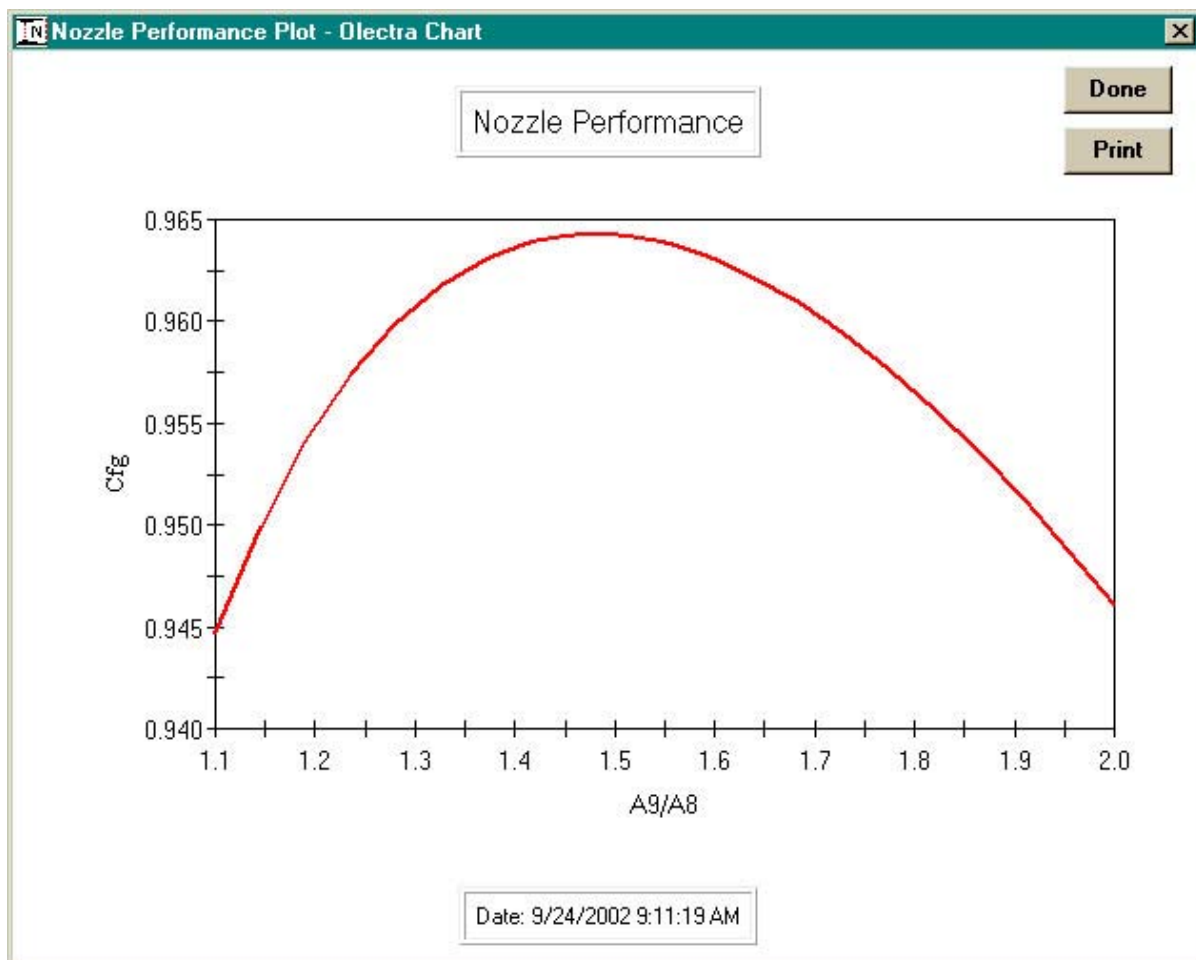
A9/A8

Variable Minimum

Variable Maximum

Number of Calcs (max = 100)

The plot generated by the **Plot+** button for the 1-D circular convergent-divergent nozzle is shown below.

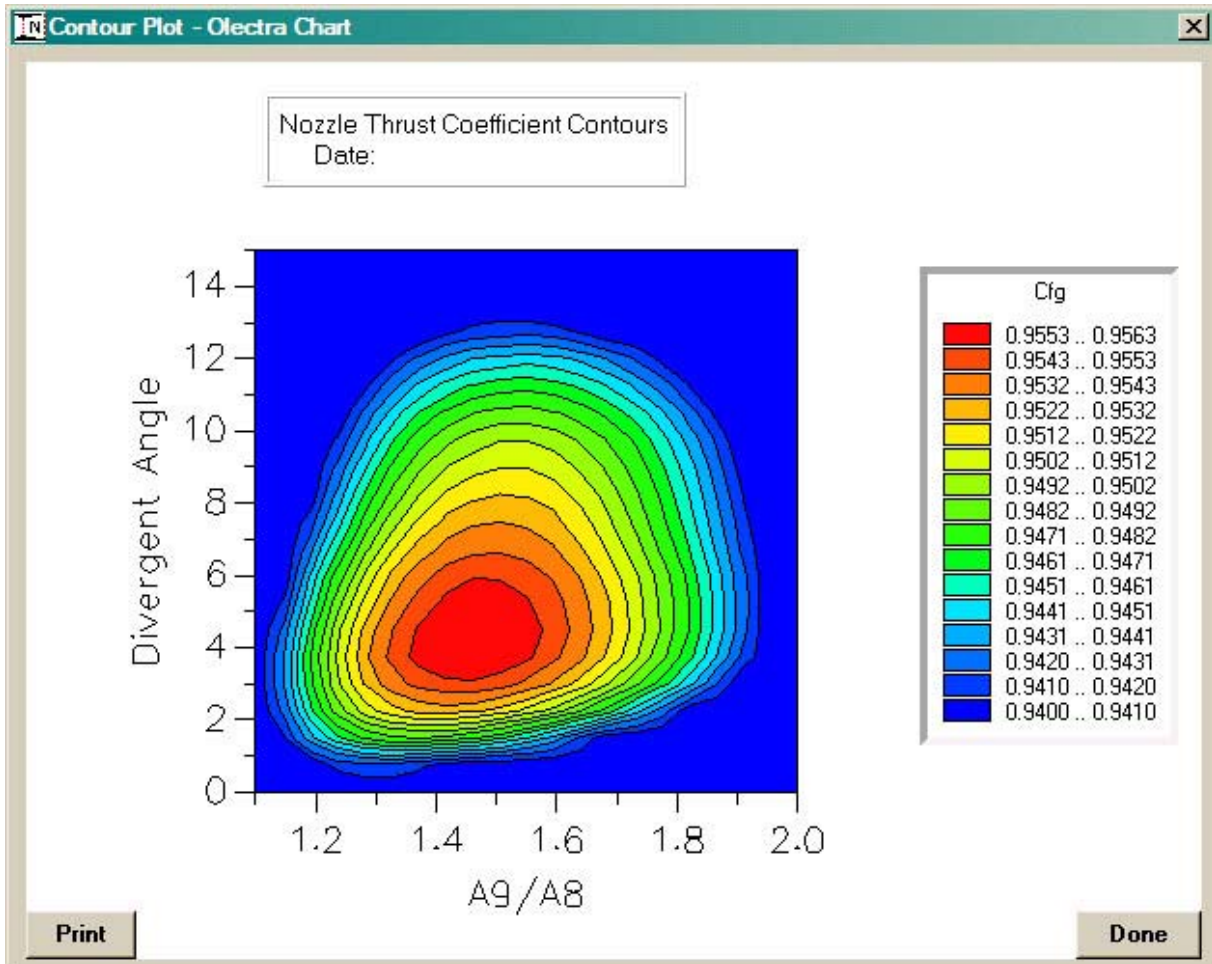


The following data window is displayed for the 2-D circular nozzle when the **Contours/Plot** button is pressed.

	A9/A8	Divergent Angle
Variable Minimum	1.10	0.00
Variable Maximum	2.00	15.00
Number of Calcs (max = 100)	20	

Plot Contour Data	
Data Minimum	0.89002
Data Maximum	0.95640
Contour Min	0.94000
Contour Max	0.95630
Increment	0.00100

After the **Calc Cfg's** button is pressed, values of the gross thrust coefficient are calculated over the input ranges of the area ratio and divergent angle. The **Plot** and **Plot+** buttons also become active. Similar to the INLET program, the **Plot** button displays a contour plot where the mouse arrow becomes a cross-hair when the user moves the mouse across the contour plot. This feature allows the user to capture and display at the bottom of the screen the coordinates and gross thrust coefficient value by pressing the left mouse button. Pressing the **Plot+** button produces an Olectra Chart contour plot of the gross thrust coefficient versus nozzle area ratio and divergent flap angle as shown on the next page.



4. SKETCH Window

After design calculations have been performed for a 2-D circular convergent-divergent nozzle, pressing the **Sketch** button on the Main window opens the Sketch window and displays the outline of the nozzle at the design point as shown below. The ramps are shown in black, the oblique shocks are shown in blue, and the terminal normal shock is shown in red. The lengths and radii of the nozzle are given on the left of the sketch. The bit map image on the Sketch Pad can be copied to the Windows clip board by pressing the “Alt” and “PrtSc” keys simultaneously. From the Window’s clip board, the image can be pasted into the Paint program and saved to a file for later use.

