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THESIS

EXPERIMENTAL AND NUMERICAL ANALYSIS OF A
CROSSFLOW FAN

by

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December 2003

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EXPERIMENTAL AND NUMERICAL ANALYSIS OF A CROSSFLOW FAN

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Submitted in partial fulfillment of the
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ABSTRACT

An auto vehicle that can take off and land vertically is envisioned to solve current and future problems of road congestion by utilizing the enormous air space above us. Crossflow Fan has been looked into in the past to serve this purpose but not sufficient to justify its capability to provide enough vertical thrust with limited power and space. Hence more in depth study is required to further improve the thrust efficiency and thrust to power ratio to a point where this thrust producing method is viable.

A 12-inch diameter, 1.5-inch span, 30-blade Cross Flow fan test apparatus was constructed and tested using an existing Turbine Test Rig (TTR) as a power source. Instrumentation was installed and a data acquisition program was developed to measure the performance of the Crossflow Fan. Performance measurement was taken over a speed range of 1,000 to 6,000 RPM.

An experiment was conducted with the Crossflow Fan to determine among other things the stalling characteristics of the compressor. Performance and flow visualization results were then compared to predictions obtained from 2-D numerical simulation conducted using Flo++, a commercial PC-based computational fluid dynamics software package by Softflo.

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I. INTRODUCTION

A. OVERVIEW

As the world population increases, road congestion will become increasingly prevalent. It is commonly believed that there will be a demand for personal air vehicles in the near future. Hence a vehicle that can take off and land vertically is envisioned to solve this problem by utilizing the enormous air space above us. By using the air space, a new type of transportation can be created that doesn't rely on roads, which could one day make traffic jams a 20th century relic. In the past, airplanes and automobiles have changed the way we all live one way or another. The advancement of technology has made vehicles more affordable for the general population to travel in. They also allowed the population to move farther away from cities, and airplanes have cut travel time to faraway destinations considerably. Now the next milestone of the 21st century is to merge the features of an automobile and an airplane, in short what is needed is a flying automobile.

In line with this vision, NASA's General Aviation Program (GAP) aims to provide doorstep to destination travel at four times the speed of highways to 25 percent of the nation's suburban, rural, and remote communities by 2007 and more than 90 percent by 2022. To accomplish this goal NASA have invested in the revolutionary technologies necessary not only to build the next generation of vehicles for business and personal air transportation but also to train the average person to safely operate them. To bring this type of transportation capability to the average person, the vehicles must be **easier and safer to operate** and the related training simplified and reduced in cost (both in time and money). Follow-on investments are now being made to create the infrastructure, referred to as the Small Aircraft Transportation System, which are also necessary for reaching NASA's goals [Ref. 1].

One such program that supports NASA's GAP is the development of civil alternatives to private ground transport; the intent being to reduce ground traffic by replacing the private automobile with a similarly-sized and purposed vertical takeoff and landing (VTOL) vehicle. This would serve the purpose of reducing ground traffic without requiring runways. Some might argue that there are already many VTOL aircraft

flying in the form of helicopters, which obtain their vertical lift from the thrust of large rotors, and utilize the horizontal force for forward speed from the horizontal component of the rotor thrust. Due to the way a helicopter obtains its horizontal thrust, the speed is limited. It is hence desirable for a VTOL aircraft to achieve what the helicopter lags in terms of speed. Another disadvantage of helicopter is the higher risk for potential property and body damage due to close proximity operations. Likewise, jet engines could create a serious fire, noise, and foreign object debris hazard when used outside the controlled atmosphere of the conventional runway. It also has the additional drawback of being prohibitively expensive to purchase and maintain in relation to the automobile's internal combustion engine. Hence, it is desirable to have VTOL designs that do not incorporate exposed nor hazardous propulsion systems but are still able to satisfy the high lift and flight performance requirement.

The main objective of this thesis is hence targeted at evaluating one such device, the Crossflow Fan (CFF), to determine an optimal configuration that is suitable for this purpose. CFFs have been investigated in the past but not sufficient to justify its capability to provide enough vertical thrust with limited power and space. Despite an in-depth knowledge of the design parameters and airflow relationships in the crossflow fan, the existing data supports the hypothesis that with further development the thrust efficiency and thrust to weight ratio could improve to a point where this thrust producing method is viable.

Experiments were conducted using the existing Crossflow Fan Test Assembly (CFTA) which was established at the Naval Postgraduate School Turbopropulsion Laboratory [Ref. 5]. In the present study, the 30-blade, 12 inch diameter and 1.5 inch span CFF was used to determine the performance characteristics at speeds varying from 1,000 RPM to 6,000 RPM. At each of the speeds measurements taken from full open throttle to stall. Studies of different cavity configurations for the CFTA were also made.

A commercial PC-based computational fluid dynamics software package by Softflo Flo++, was used to conduct a 2-D numerical simulation on the CFF. The main aim is to represent the numerical model as close to the actual CFTA. The results obtained from the numerical runs are compared to those obtained from experiment.

B. BACKGROUND

The design of Vertical and Short Takeoff (V/STOL) aircraft encompasses a broad and diverse range of complex engineering problems. Research and development of V/STOL aircraft have produced a bewildering variety of configurations, as illustrated in Figure 1, a summary compiled in 1977 which includes only vehicles with V/STOL capabilities. The most challenging task of designing a successful V/STOL aircraft is to conceive of a configuration that can achieve optimal thrust to weight ratio and thrust to power (i.e. efficiency) [Ref. 2].

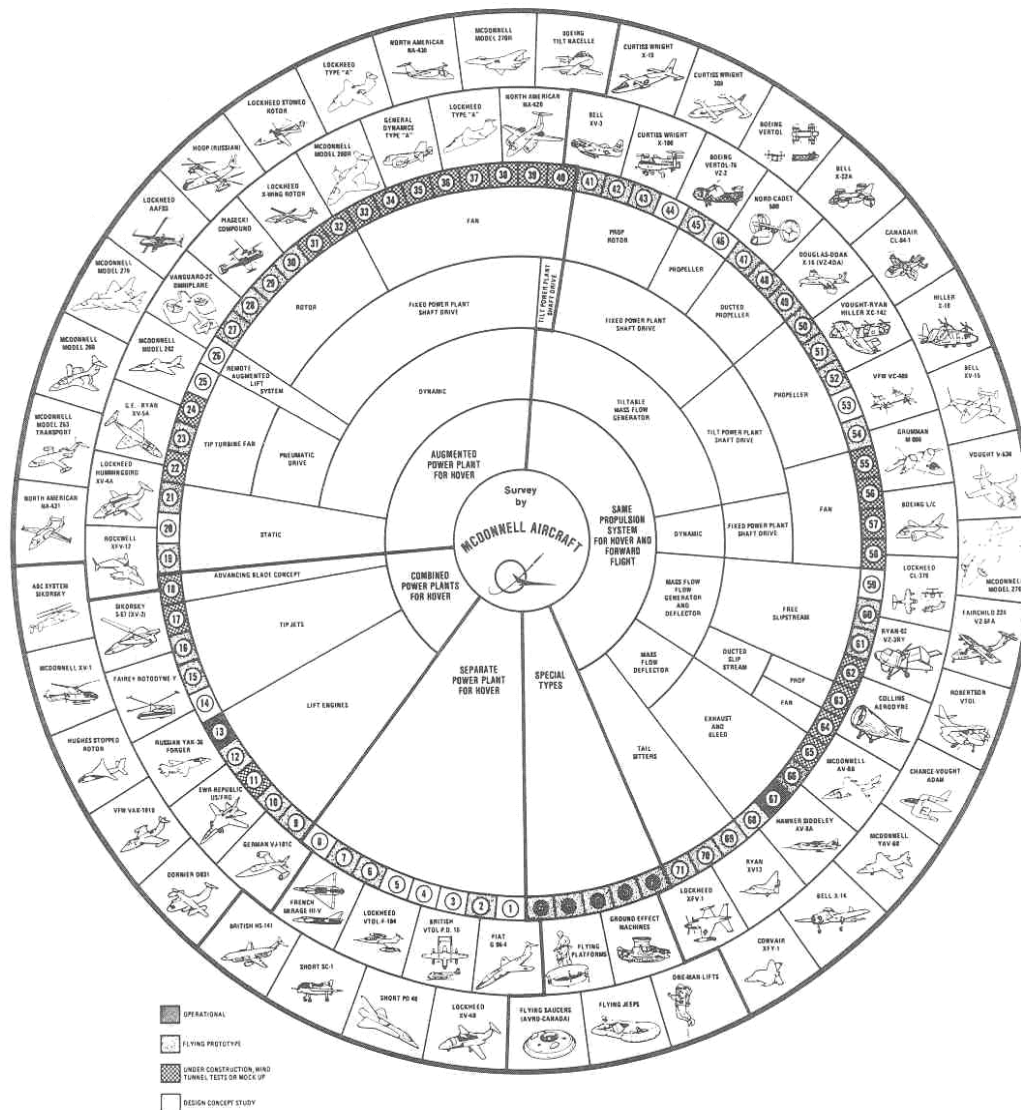


Figure 1. V/STOL Aircraft Summary (From Ref. 2)

One of the possible propulsion systems for V/STOL aircrafts is a CFF. Back in 1975, Vought Systems Division (VSD) (a division of the LTV Aerospace Corporation) was awarded a 12 month contract “Multi-Bypass Ratio Propulsion System Technology Development” by the Naval Air Systems Command [Ref. 3]. The main objectives were to verify the performance capabilities of the Multi-Bypass Ratio (MBPR) Propulsion System through additional tests of the CFF and to conduct studies of the fan structure and fan system. VSD designed, constructed and tested a CFF measuring 12 inches in diameter and both 1.5 inches and 12 inches in span between 6,000 and 13,000 RPM in order to establish baseline performance. Several configurations of a typical setup as shown in Fig. 2 [Ref. 3], which included varying the shape of the low and high cavities, different blade designs and the different area of the exhaust outlet, were used to measure the performance of the CFF. The cavities were used to influence the recirculation flow vortices while the ratio of the fan inner to outer radius also greatly affected the performance. Even though extensive tests had been conducted for several configurations, the optimal design parameters were too complex to be determined. In this project, the experimental setup of the CFF was modeled after one of the most optimal configurations determined by VSD.

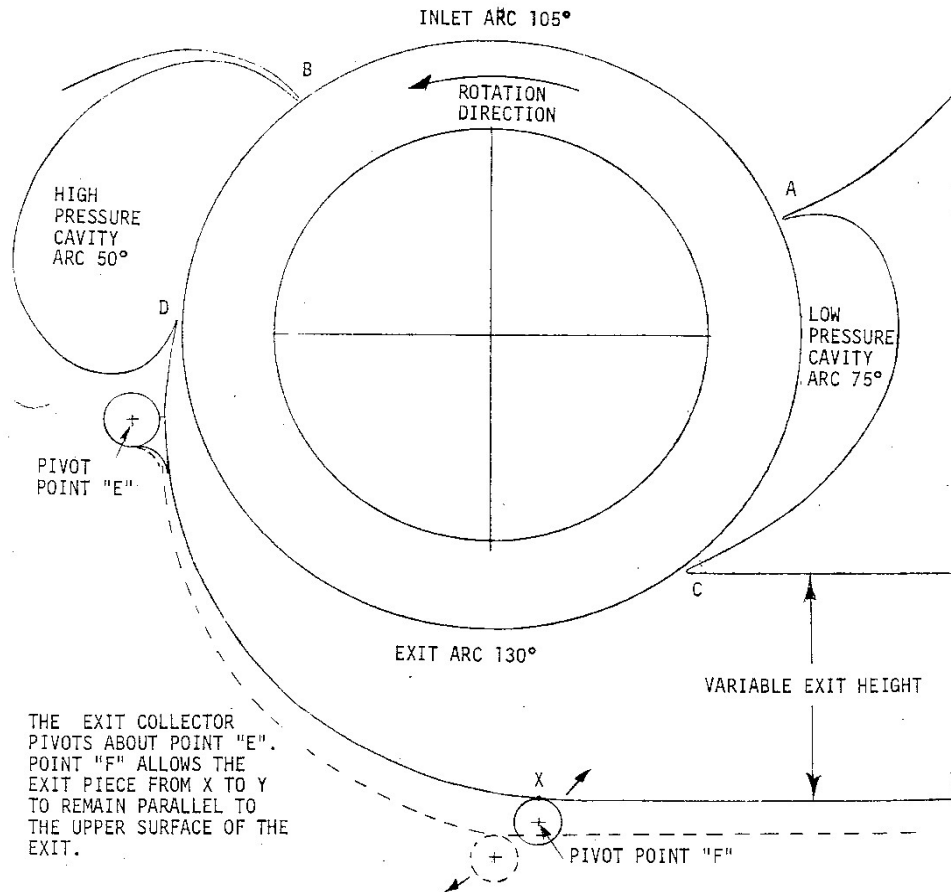


Figure 2. Typical Fan Housing Setup (From Ref. 3)

In line with NASA's interest, Naval Postgraduate School (NPS) Aeronautical Turbomachinery Laboratory was tasked to pursue the CFF in more detail. A thesis was written based on evaluating the performance of the CFF, similar to that from VSD, through experiments as well as numerical simulation [Ref. 5]. A speed range of 1,000 to 6,000 RPM was covered in the experiment. Results were comparable to those measured by VSD. The highest thrust-to-power ratio was obtained at 3,000 RPM. Flow visualization was also conducted using dye-injection methods. The results from the experiment were then compared to predictions obtained from a 2D numerical simulation by Flo++. Seaton [Ref. 5] was only able to model a 15 bladed rotor and an incompressible solution was achieved at a fan speed of 3,000 RPM in a reasonable computational time. The flow fields and performance parameters predicted were similar to those obtained from the experiments.

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II. EXPERIMENT SETUP AND RESULTS

A. CROSSFLOW FAN DESIGN AND SETUP

1. Test Rig

The Turbine Test Rig (TTR) at the Naval Postgraduate School Turbopropulsion Laboratory was used as a power source for the Crossflow Fan Test Assembly (CFTA). The TTR comprised of an air supply system and associated piping, test cell, data acquisition system, and the turbine from Space Shuttle Main Engine HP Fuel Turbopump (SSME HPFTP). The air supply system consisted of a 1,250 horsepower (HP) electric motor which drove an Allis Chalmers 12 stage axial compressor at 12,000 RPM through a gearbox. The compressor was capable of providing 10,000 cubic feet per minute of air at a maximum pressure of 30psig. A schematic of the air supply system is shown in Figure 3.

2. Crossflow Fan

The CFTA was modeled closely after VSD Multi-Bypass Ratio System test assembly #6 [Ref. 3]. The initial set of tests was conducted using the standard CFTA configuration as described in [Ref. 5] and the second set of tests was done with the addition of an inlet bellmouth and exhaust ducting with a throttle valve at the exit. The inlet bellmouth had a two-to-one elliptic section with a throat diameter of 6.25 inch and the exhaust was constructed out of a PVC pipe and throttling valve.

The fan rotor was assembled from a machined disc with 30 rotor blades and a retaining ring as shown in Figure 4. The rotor disc was then secured to the drive shaft via three countersunk screws.

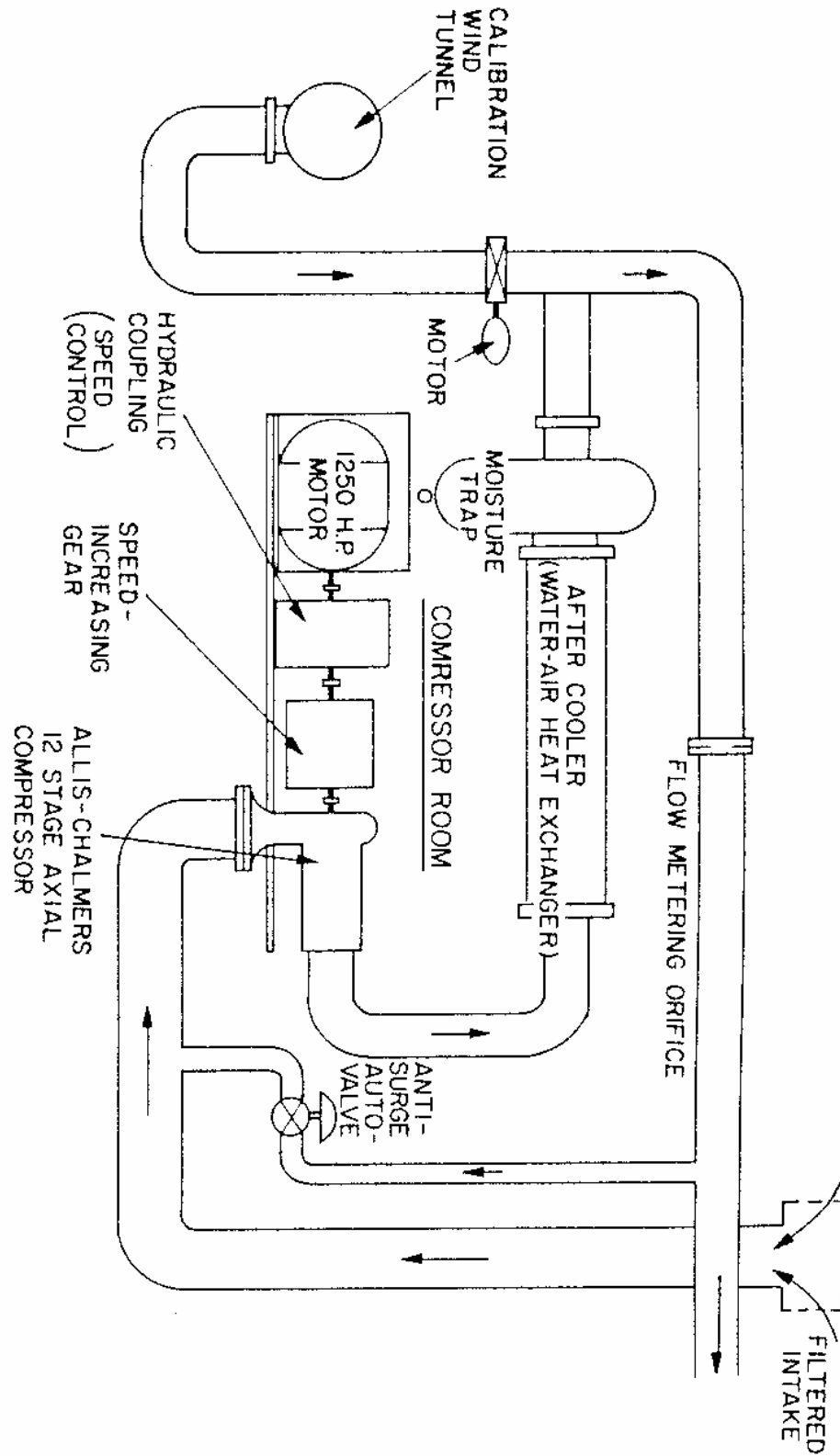


Figure 3. Schematic Layout of Air Supply System (From Ref. 5)



Figure 4. Fan Rotor (From Ref. 5)

The CFTA front plate provided for the replacement of the aluminum plate with a Plexiglas viewing window. Both the options contained inner blanks that could be rotated to provide for alternate positioning of pressure/temperature probes and/or dye injectors. The cavity components and exhaust duct wall were secured in place between the CFTA front and back plates. Figure 5 shows the partially assembled CFTA and Figure 6 shows the complete standard baseline assembly used for the initial setup of tests.



Figure 5. Partially Assembled CFTA (From Ref. 5)

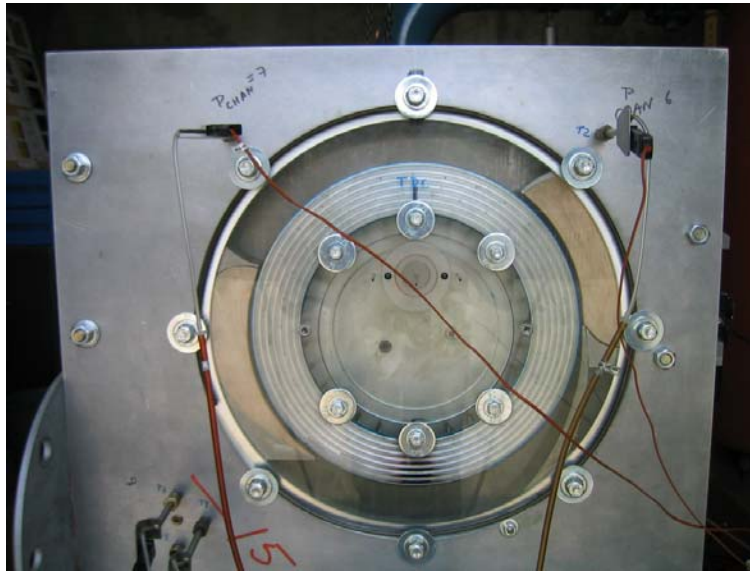


Figure 6. CFTA1 for Test Plan 1

For the second set of tests conducted, a bellmouth was bolted to a wood and aluminum plenum chamber which was constructed around the inlet of the CFF as shown in Figure 7. The purpose of the bellmouth was to meter the air mass flow rate into the system. Three static pressure taps were placed around the throat of the bellmouth in order to measure static pressure which in turn was used to calculate mass flow rate. The exhaust outlet was extended with a 6.25 inch diameter, 25 inch long PVC pipe. A throttle control, as shown in Figure 7, was installed at the end of the PVC pipe. The main purpose of this throttle was to vary the mass flow rate and hence the other performance parameters in order to obtain the characteristic curves of the CFF at different speeds.

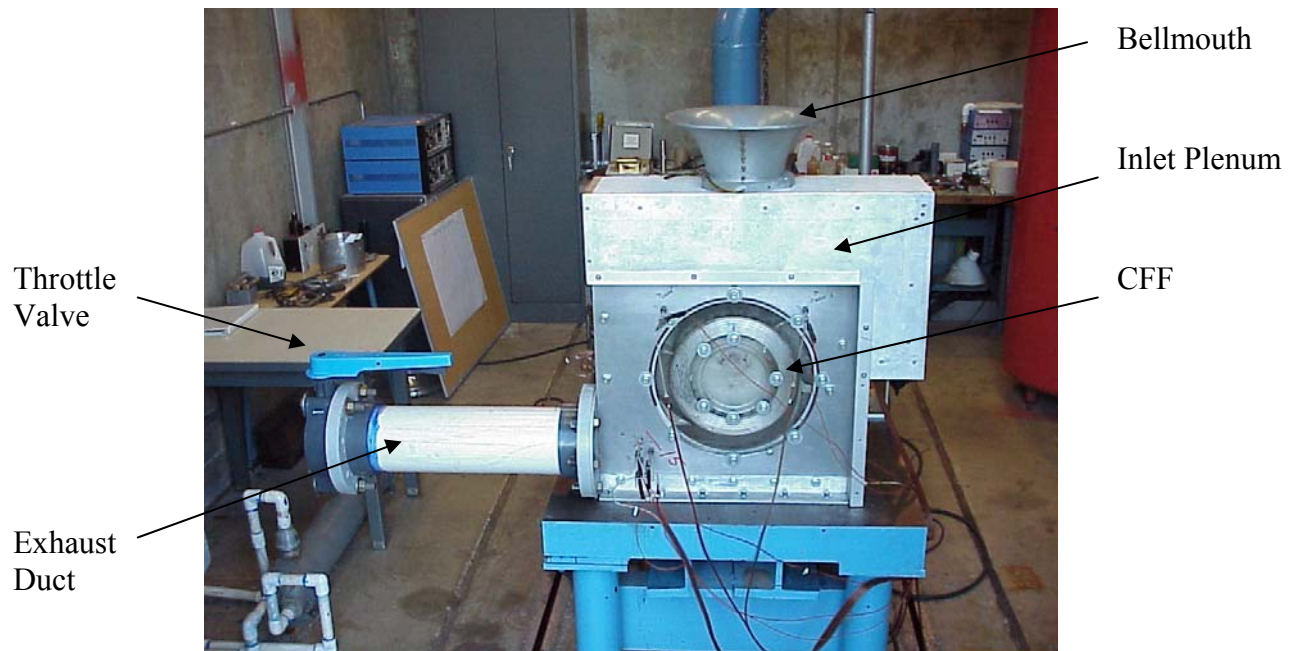


Figure 7. CFT A2 for Test Plan 2

B. CONTROLS AND INSTRUMENTATION

The TTR and CFT A were operated from the control station as shown in Figure 8. The air flow to the turbine was controlled from the operator's console by activating an electric valve in the test cell. Two thermocouples were used to measure the bearing temperatures to ensure that they don't overheat and hence causing seizure. Two accelerometers were also used to monitor the vibration levels on the TTR and CFT A.

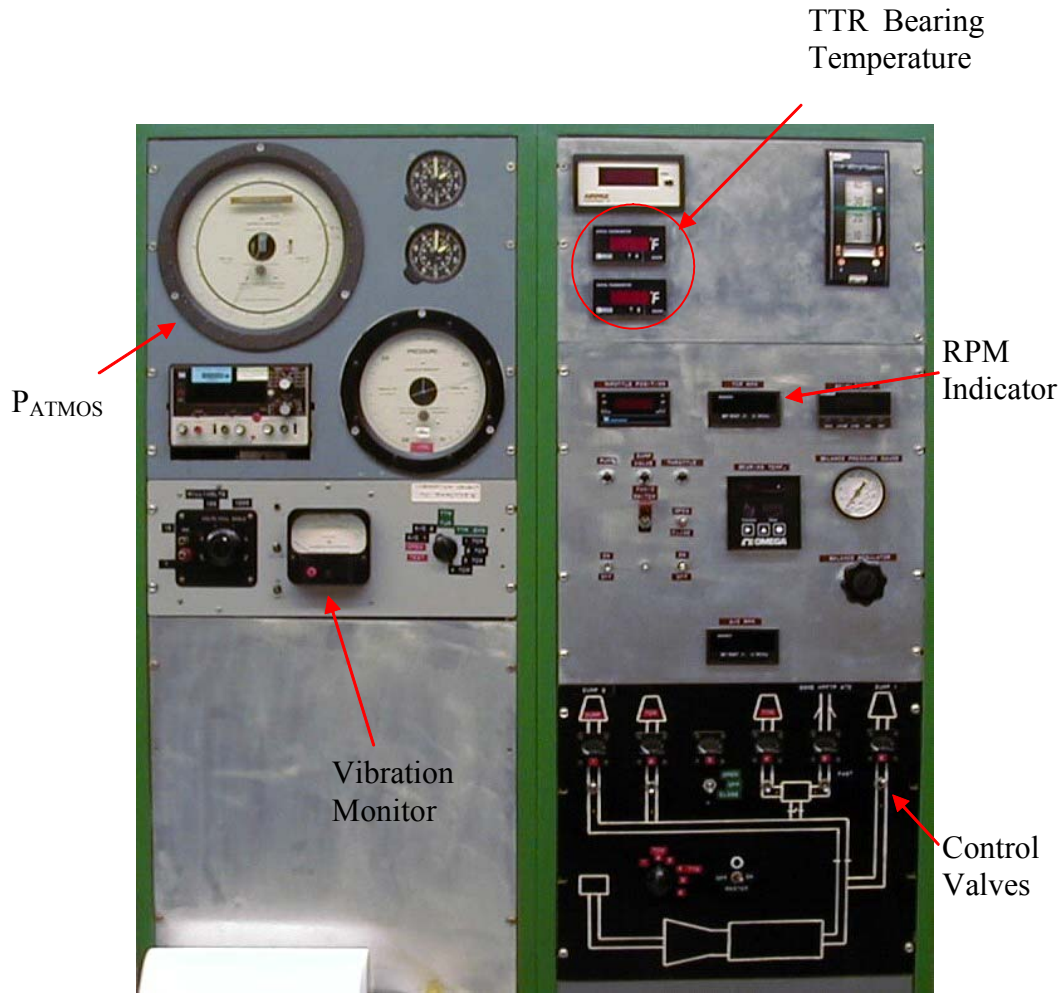


Figure 8. Control Station (From Ref. 5)

Instrumentation for data collection consisted of several combination pressure/thermocouple probes and static pressure taps to capture the information for data reduction.

Three static pressure probes were installed around the neck of the bellmouth, which was used in the final set of tests, as shown in Figure 9 and known as Pnoz1, Pnoz2 and Pnoz3. Two combination probes were placed at approximately 10 o'clock and 2 o'clock positions viewed from the front as shown in Figure 9 known as T1 and T2. Three combination probes, as shown in Figure 11 and known as T3, T4 and T5, were installed in the exhaust duct to detect the total pressure and temperature profiles along the centerline of the exit. The 12 inch diameter static pressure taps (P_A through P_L in Figure

9) were drilled normally into the cavities and exhaust duct walls.. Instrument nonmenclature is provided in Table 1.

Probe/Tap	Type	Nomenclature
T1	Combo	$P_{in} \text{ CFF} / T_{in} \text{ CFF}$ (10) o'clock)
T2	Combo	$P_{in} \text{ CFF} / T_{in} \text{ CFF}$ (2) o'clock)
T3	Combo	$P_{out} \text{ CFF} / T_{out} \text{ CFF}$ (Top)
T4	Combo	$P_{out} \text{ CFF} / T_{out} \text{ CFF}$ (Mid)
T5	Combo	$P_{out} \text{ CFF} / T_{out} \text{ CFF}$ (Bot)
T6	Combo	$P_{noz} 1 \text{ CFF}$ at neck of bellmouth
T7	Combo	$P_{noz} 2 \text{ CFF}$ at neck of bellmouth
T8	Combo	$P_{noz} 3 \text{ CFF}$ at neck of bellmouth
A	Static	P_A
B	Static	P_B
C	Static	P_C
D	Static	P_D
E	Static	P_E
F	Static	P_F
G	Static	P_G
H	Static	P_H
I	Static	P_I
J	Static	P_J
K	Static	P_K
L	Static	P_L

Table 1. Combo Probe / Pressure Tap Nonmenclature

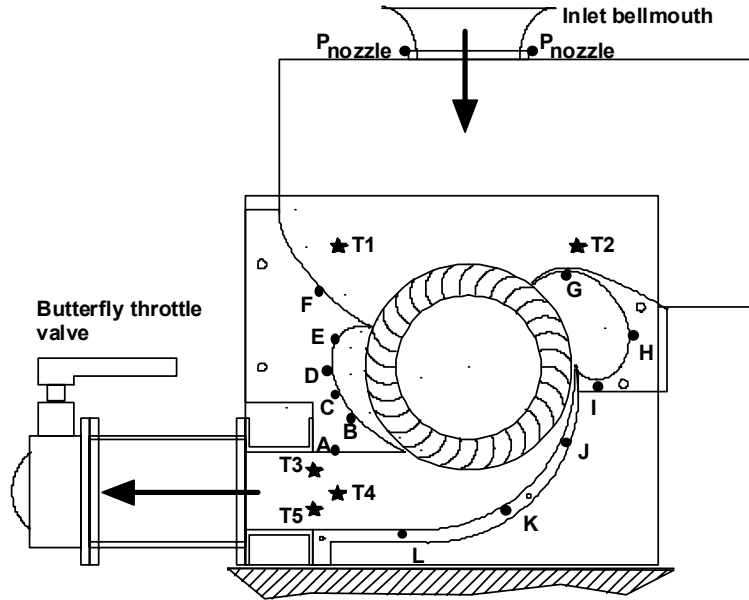


Figure 9. Combo Probes and Pressure Taps Layout

C. DATA ACQUISITION SYSTEM

1. Hardware

A full description of the data acquisition system can be found in [Ref. 5]. The system hardware layout is shown in Figure 10. Table 2 lists the Scanivalve port assignments for the pressure lines and Table 3 lists the thermocouple multiplexer channel assignments for thermocouple lines.

Port #	Type	Nomenclature
1	Static	P_{ATMOS}
2	Static	P_{CAL}
3	Total	$P_{in}TTR$ (5 o'clock)
4	Total	$P_{out}TTR$
5	Total	$P_{in}TTR$ (8 o'clock)
6	Total	$P_{in}CFF$ (2 o'clock)
7	Total	$P_{in}CFF$ (10 o'clock)
8	Total	$P_{out}CFF$ (Top)
9	Total	$P_{out}CFF$ (Mid)
10	Total	$P_{out}CFF$ (Bot)
11	Static	P_A
12	Static	P_B
13	Static	P_C
14	Static	P_D
15	Static	P_E
16	Static	P_F
17	Static	P_G
18	Static	P_H
19	Static	P_I
20	Static	P_J
21	Static	P_K
22	Static	P_L
24	Static	$P_{noz}1$
25	Static	$P_{noz}2$
26	Static	$P_{noz}3$
32	Static	P_{in}
33	Static	$P_{in}(\text{Flange})$
34	Static	$P_{out}(\text{Flange})$
35	Static	$P_{out}(\text{Vena})$

Table 2. Scanivalve Port Assignments

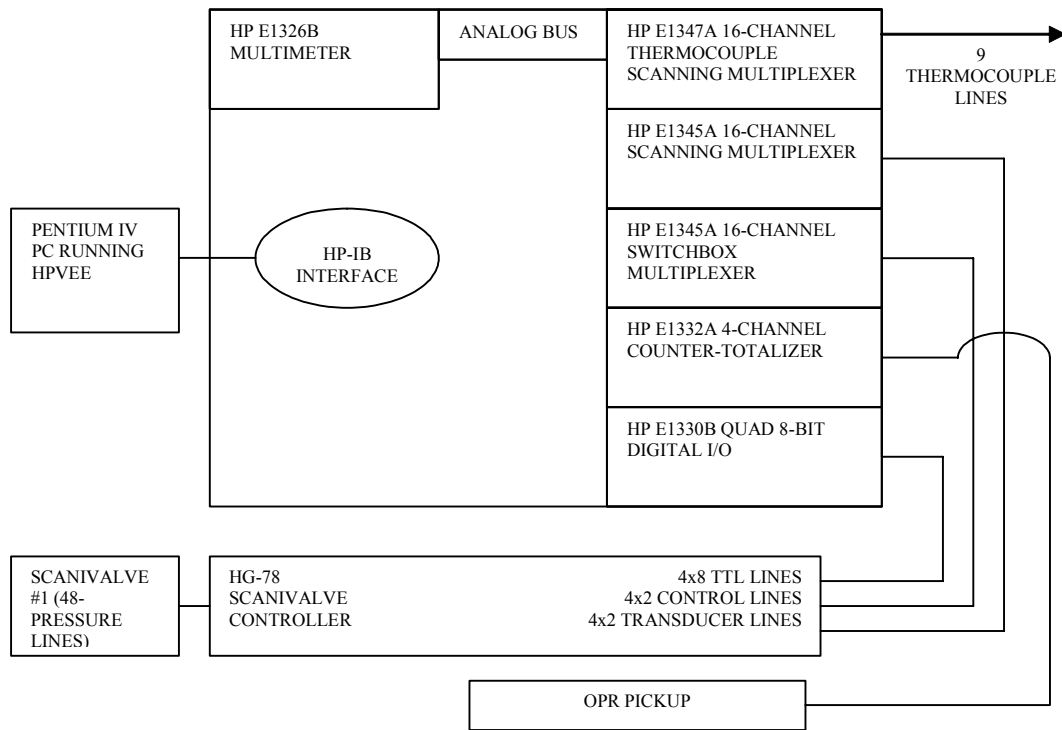


Figure 10. Data Acquisition System Layout (From Ref. 5)

Multiplexer Channel	Nomenclature
6	$T_{in}CFF$ (2 o'clock)
8	$T_{in}CFF$ (10 o'clock)
9	$T_{in}TTR$ (8 o'clock)
10	$T_{in}TTR$ (5 o'clock)
11	$T_{out}TTR$
12	$T_{in}Orifice$
13	$T_{out}CFF$ (Bot)
14	$T_{out}CFF$ (Mid)
15	$T_{out}CFF$ (Top)

Table 3. Thermocouple Scanning Multiplexer Channel Assignments (From Ref. 5)

2. Software

The data obtained from all the probes were recorded by a software program written in HPVEE. A routine was created in [Ref. 5] and used to capture, calculate and output all the parameters required to study the CFF performance. An example of the User Control Panel is shown in Figure 11.

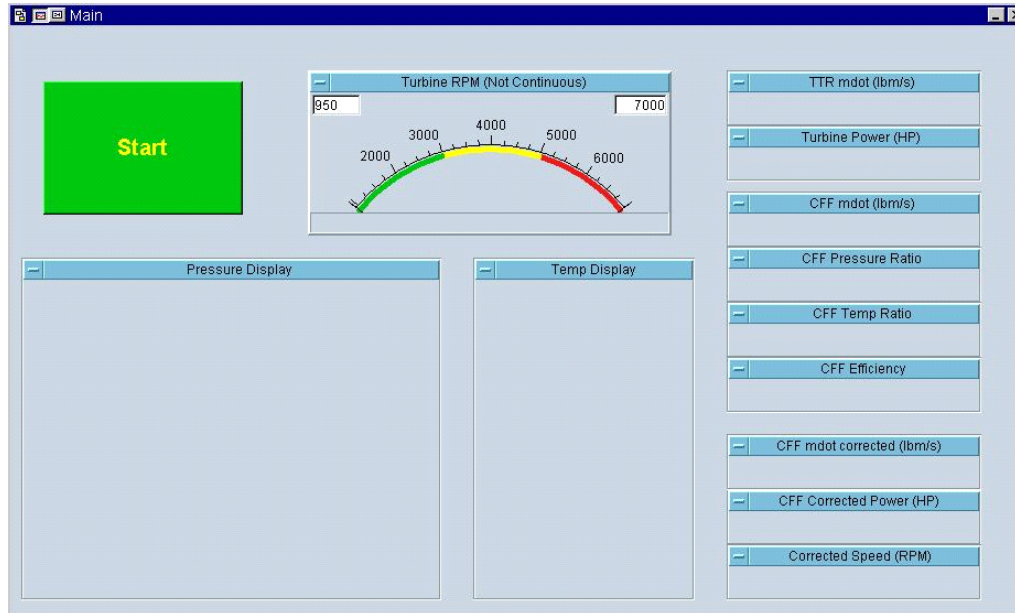


Figure 11. HPVEE User Control Panel (From Ref. 5)

D. TEST PLAN

1. Test Plan 1 – Baseline Configurations

The test assembly used for these tests was shown in Figure 6. Four configurations were chosen for evaluation, which was a similar setup used in [Ref. 5]. The four configurations tested were a permutation between opening and closing the low pressure (LP) and high pressure (HP) cavities. The main objective was to understand the difference in performance between the four configurations namely;

- Both cavities opened
- Both cavities closed
- LP cavity closed and the HP cavity opened
- HP cavity closed and the LP cavity opened

With these four configurations, the CFF was run at five speeds starting from 1,000 RPM up to 5,000 RPM in 1,000 RPM intervals. Pressure and temperature values were recorded at every speed. Primary data reduction was carried out in the HPVEE acquisition program.

A detailed discussion on the equations used to derive the performance parameters were discussed in [Ref. 5]. Some of the more important equations are as follows:

The total-to-total pressure ratio and temperature ratio for the CFF are given by

$$\pi_{CFF} = \frac{P_{out,CFF(avg)}}{P_{in,CFF(avg)}} \quad \text{and} \quad \tau_{CFF} = \frac{T_{out,CFF(avg)}}{T_{in,CFF(avg)}} \quad (1)$$

where $P_{out,CFF(avg)}$ and $T_{out,CFF(avg)}$ are the average total-to-total pressures and temperatures of the three CFF exhaust duct combination probes T3, T4 and T5. $P_{in,CFF(avg)}$ and $T_{in,CFF(avg)}$ are the average total-to-total pressures and temperatures of the two CFF inlet combination probes T1 and T2.

Compression efficiency through the CFF was calculated from the values found in (1) above, using the isentropic efficiency:

$$\eta_{CFF} = \frac{\pi_{CFF}^{\left(\frac{\gamma-1}{\gamma}\right)} - 1}{\tau_{CFF} - 1} \quad (2)$$

assuming $\gamma = 1.4$.

CFF performance values were corrected to standard atmospheric conditions, such that:

$$\dot{m}_{corr} = \dot{m} \frac{\sqrt{\theta}}{\delta}, \quad N_{corr} = \frac{N}{\sqrt{\theta}}, \quad HP_{corr} = \frac{HP}{\delta\sqrt{\theta}} \quad (3)$$

where $\dot{m}$ is the mass flow rate in lbm/sec, N is fan speed in RPM, HP is the horse power,

$\theta = \frac{T_{in,CFF(avg)}}{T_{ref}}$, and $\delta = \frac{P_{in,CFF(avg)}}{P_{ref}}$. T_{ref} and P_{ref} were standard atmospheric temperature

(518.7 °R) and pressure (29.92 inHg), respectively.

2. Test Plan 2 – Throttling Studies

The test assembly used for this test was shown in Figure 7. Two configurations were evaluated. The first configuration had both the LP and HP cavities open (baseline geometry) and the second configuration had both the cavities blanked off.

With these two configurations, the CFF was ran at five speeds starting from 2,000 RPM up to 6,000 RPM in 1,000RPM interval. At every speed, the exhaust throttle was closed slightly to simulate a back pressure on the CFF. A total of eight positions were tested for every speed line. By doing so, the compressor performance map for the CFF could be obtained. Table 4 shows the test matrix for the whole experiment.

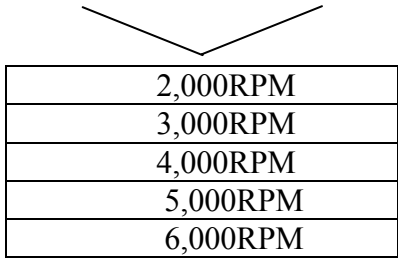
		Both Cavities Opened	Both Cavities Closed
Eight Throttling Positions	Fully opened Throttle		
	...		
	Partially opened Throttle		
	...		
	Maximum Throttle closure		
		2,000RPM	
		3,000RPM	
		4,000RPM	
		5,000RPM	
		6,000RPM	

Table 4. Experimental Test Matrix for Test Plan 2

Seaton [Ref. 5] used the three exit plane combination probes to calculate the mass flow rate through the CFF by integrating the velocity profile obtained by only three measurement points. In the present study, the inlet bellmouth was added to give a more accurate measurement of inlet flow which is one of the standard ways of obtaining mass flow rate.

E. RESULTS AND DISCUSSION

1. Test Plan 1

a. Discussion on Performance Plots

Performance data were plotted and analyzed for the four CFF configurations tested. These plots included total-to-total pressure versus corrected mass flow rate, total-to-total temperature versus corrected mass flow rate, efficiency versus speed, corrected mass average mass flow versus corrected speed, corrected mass averaged power versus speed, thrust versus corrected speed and corrected thrust versus power. The plots were illustrated from Figure 12 to Figure 18.

Figure 12 shows a plot of total-to-total pressure versus corrected mass flow rate for the four configurations tested. We observed that t-t pressure increased at an increasing rate with mass flow rate and other than the both cavities closed configuration, all the other three curves collapsed onto one curve. The highest t-t pressure of 1.17 was achieved at a mass flow rate of 1.8 lbm/s, speed of 5,000 RPM with the both cavities opened configuration. The LP cavity opened, HP cavity closed configuration follows the above mentioned curve closely.

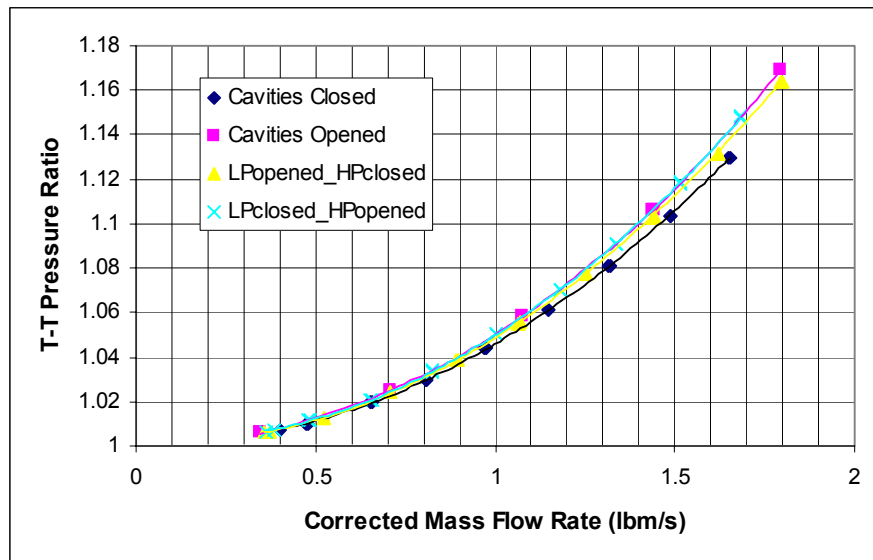


Figure 12. T-T Pressure Ratio versus Corrected Mass Flow Rate

Figure 13 shows a plot of total-to-total temperature versus corrected mass flow rate for the four configurations tested. The trends of the curves are similar to that of Figure 12. Both cavities opened configuration was slightly above the three curves and hence had larger t-t temperature values for the same mass flow rate. And this value was 1.068 achieved at a mass flow rate of 1.8 lbm/s, speed of 5,000 RPM.

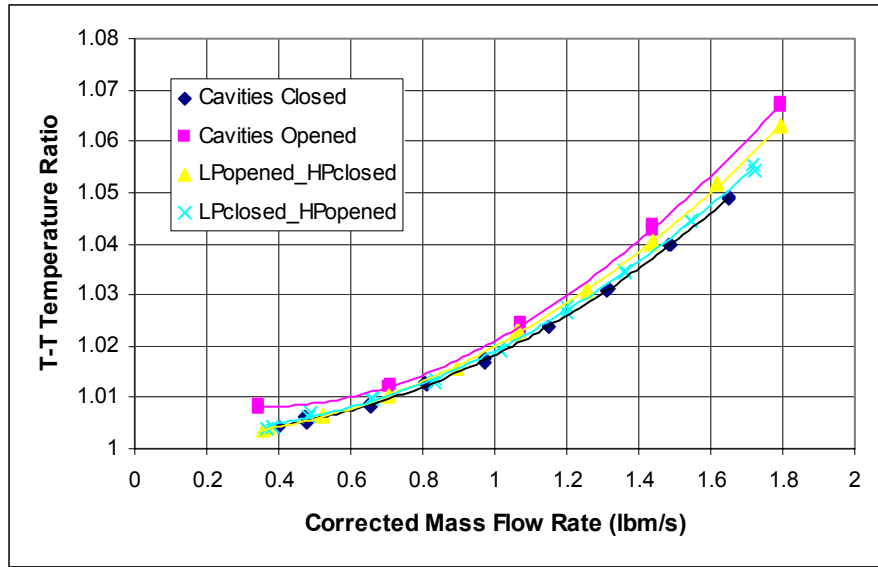


Figure 13. T-T Temperature Ratio versus Corrected Mass Flow Rate

Figure 14 shows a plot of efficiency versus corrected speed for the four configurations tested. The efficiencies were in the region of 66% to 74% for all the four configurations between speeds of 3,000 RPM and 5,000 RPM. The efficiencies dropped drastically when the speed was reduced from 3,000 RPM to 1,000 RPM. The lowest efficiency of 0.22 was seen with the both cavities opened configuration. As discussed before, the t-t temperature ratio for this configuration was higher than the rest. And since t-t temperature ratio has an inverse relation with efficiency, the efficiency for this configuration was the lowest compared to the other configurations. The highest efficiency occurred for the LP cavity closed configuration between speed of 3,000 RPM and 5,000 RPM.

Figure 15 shows a plot of corrected mass flow rate versus corrected speed for the four configurations tested. As expected, the mass flow rate was directly proportional to the speed as shown by the linear curves.

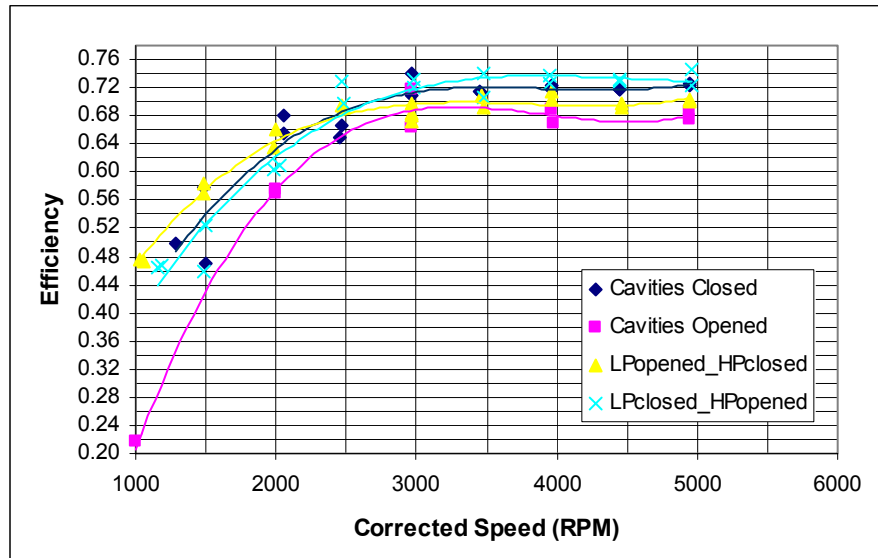


Figure 14. Efficiency versus Corrected Speed

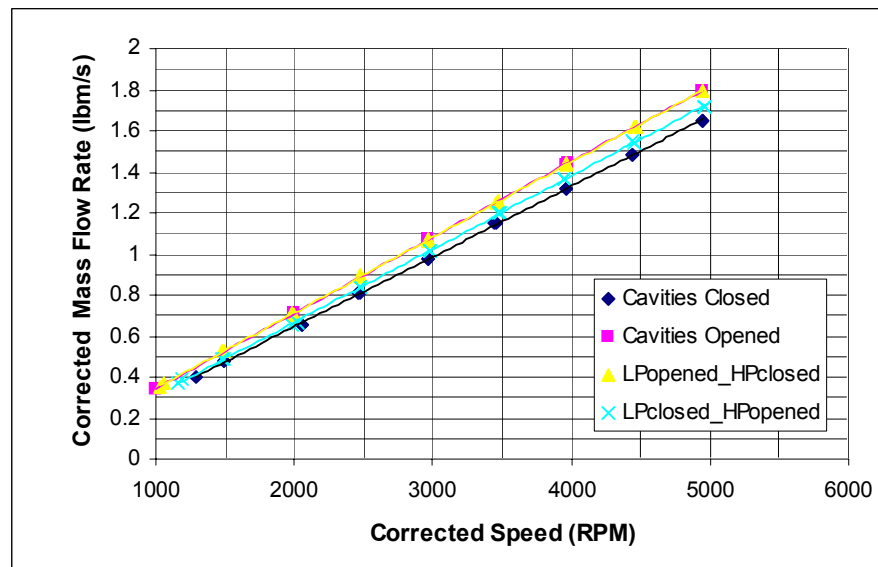


Figure 15. Corrected Mass Flow Rate versus Corrected Speed

Figure 16 shows a plot of corrected mass averaged power versus corrected speed for the four configurations tested. The mass average power increased at an increasing rate with corrected speed for all the configurations. This phenomenon indicated that as the rotor speed was increased to obtain more thrust, the unit power consumption also increased. Hence operating at high rotor speed might not be advisable.

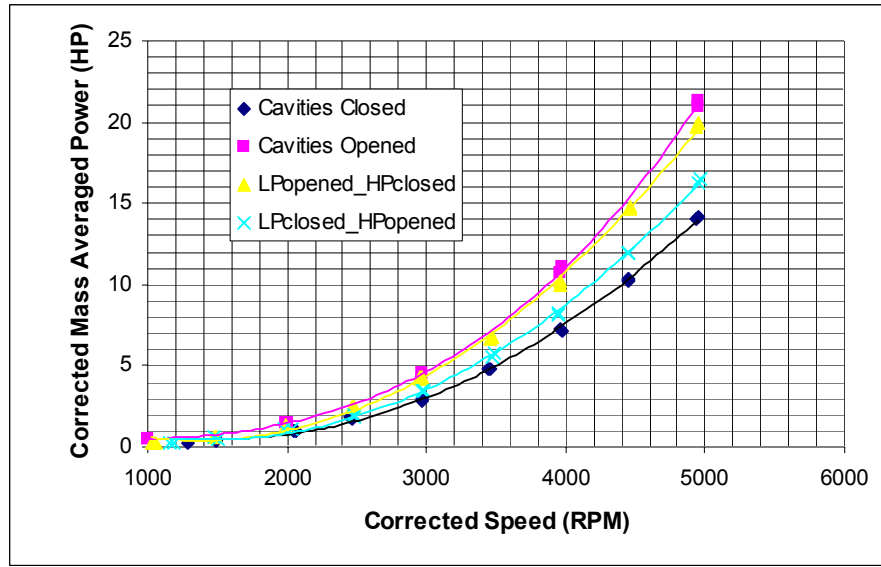


Figure 16. Corrected Mass Averaged Power versus Corrected Speed

Figure 17 shows a plot of corrected thrust per foot span versus corrected speed for the four configurations tested. The maximum thrust occurred at 5,000 RPM for the both cavities opened configuration.

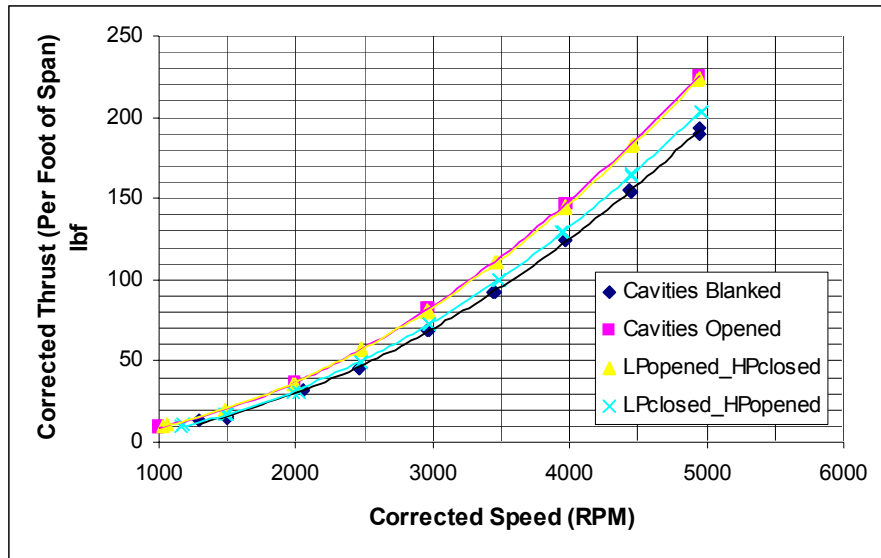


Figure 17. Corrected Thrust versus Corrected Speed

Figure 18 shows a plot of corrected thrust per foot span versus corrected power for the four configurations tested. Other than the both cavities opened configurations curve, the other three curves fall onto the same line. The curves also increased at a decreasing rate and hence suggesting that the amount of thrust obtained per unit power increased with speed. This phenomenon only occurred after 3,000 RPM.

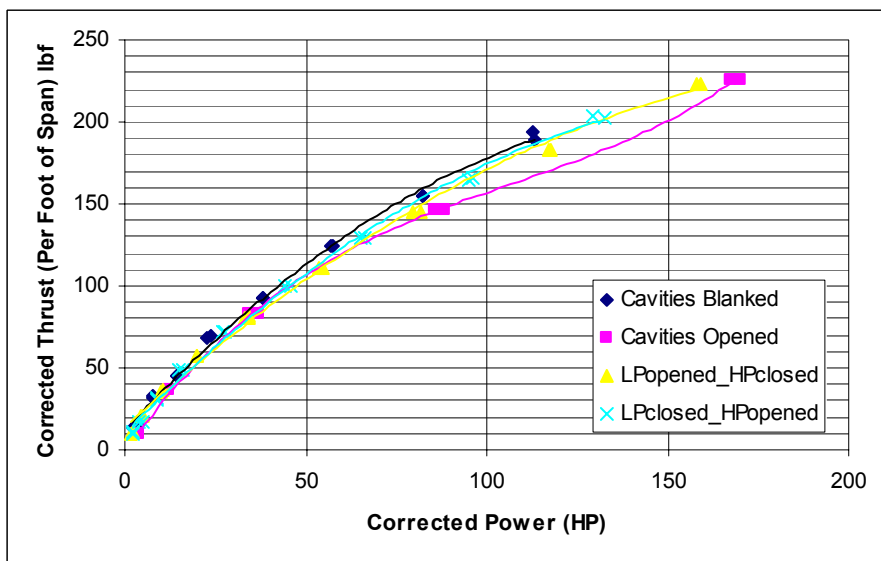


Figure 18. Corrected Thrust versus Corrected Power

b. Flow Visualization

Flow visualization was conducted with the aim of understanding the major flow features in the CFF. In Figure 19, the visualization due to three dyes injected in the left, center, and right ports of the Plexiglas inner blank for the both cavities opened configuration was shown [Ref. 5]. All flow visualization was performed at a rotational speed of 3,000 RPM. The picture shows the re-circulating streamlines inside the fan core and the centre of vortex at the LP cavity. Figure 20 shows the flow visualization for the both cavities closed configuration. The centre of vortex became smaller and its location had shifted downwards compared to that from Figure 19.

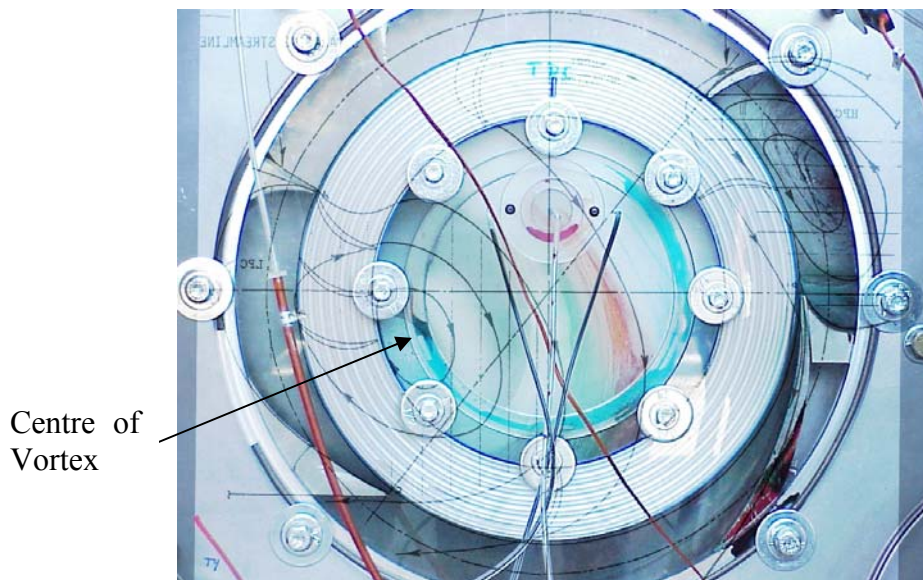


Figure 19. Flow Visualization for Both Cavities Opened Configuration

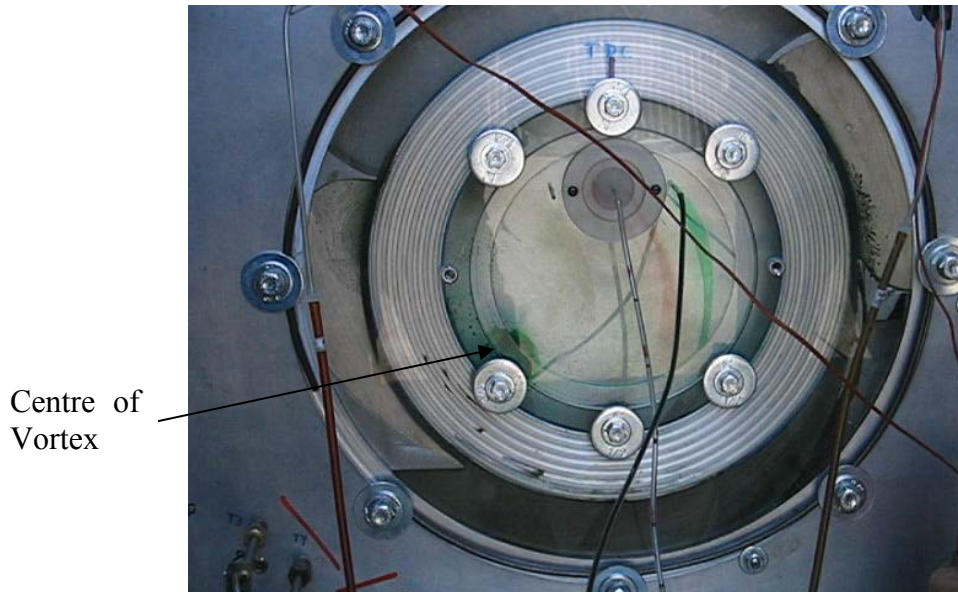


Figure 20. Flow Visualization for Both Cavities Closed Configuration

2. Test Plan 2

a. Discussion of Performance Plots

Performance data were plotted and analyzed for the two CFF configurations tested. These plots included total-to-total pressure versus corrected mass flow rate, total-to-total temperature versus corrected mass flow rate, efficiency versus corrected mass flow rate, corrected thrust per unit foot of span versus corrected mass flow rate, corrected thrust per unit foot of span versus corrected mass averaged horse power (HP) and corrected mass average HP versus corrected mass flow rate. The plots were illustrated from Figure 21 to 32.

Starting from full open on the throttle, for each speed, the total pressure dropped as the mass flow rate was decreased as shown in Figure 21. This characteristic is similar to centrifugal compressors which have forward swept vanes. For the baseline case the characteristic started out relatively flat and then increased in slope as the fan was taken into stall (the last point on the curve). In contrast, the configuration with the cavities blanked off exhibited nearly linear behavior with throttling over the whole speed range tested as shown in Figure 22. This configuration produced a slightly lower peak pressure ratio (1.23 versus 1.27) and mass flow rate (2.24 lbm/sec versus 2.38 lbm/sec) at 6,000 RPM than the baseline configuration.

Similarly, the temperature ratio for the baseline configuration as shown in Figure 23 showed a non-linear behavior when compared to the blanked off configuration Figure 24, particularly for the two highest speed lines of 5,000 and 6,000 RPM. Maximum temperature ratios of approximately 1.1 and 1.085 were achieved at mass flow rates of 2.4 lbm/s and 2.25 lbm/s respectively at the 6,000 RPM for baseline configuration and that with both cavities blanked off.

From the efficiency formula (2), which is a function of both pressure and temperature ratios, the efficiency versus corrected mass flow rate plots were obtained as shown in Figure 25 and 26. The sharp increase in temperature ratio across the baseline configuration at stall resulted in a sharp drop in efficiency at stall from a peak value around 70% to below 30% and interestingly all the speed lines tend to converge to the same point. The configuration with the cavities blanked off had a slightly higher peak efficiency in the mid 70% range which did not decrease as noticeably near stall. The drastic drop in efficiency is known to be the stall condition for the CFF. It seemed that the dropped in efficiency during stall was more drastic for the baseline configuration compared to both cavities blanked off as seen from the efficiencies values at the region of 0.6 lbm/s to 0.8 lbm/s. This meant that the baseline configuration was more sensitive to the change in mass flow rate compared to the blanked off configuration.

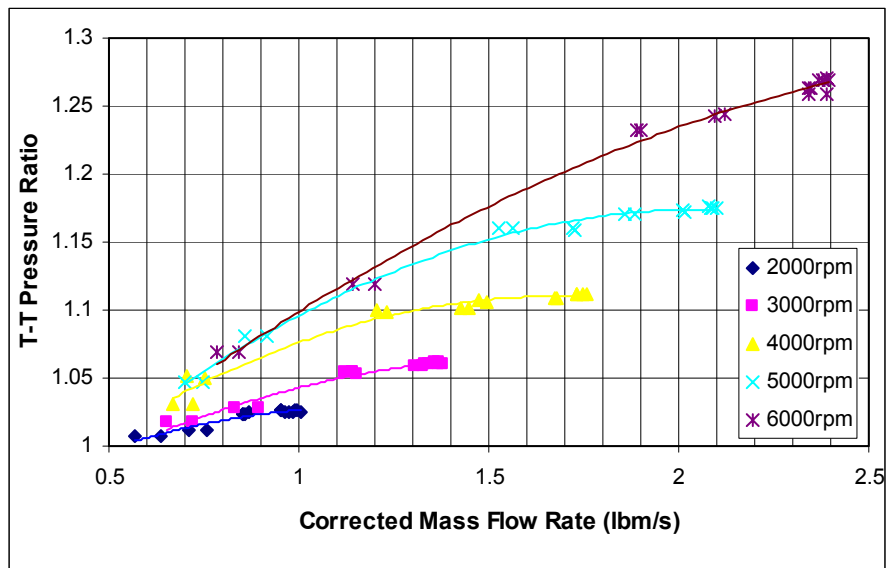


Figure 21. T-T Pressure Ratio versus Corrected Mass Flow Rate for Baseline Geometry

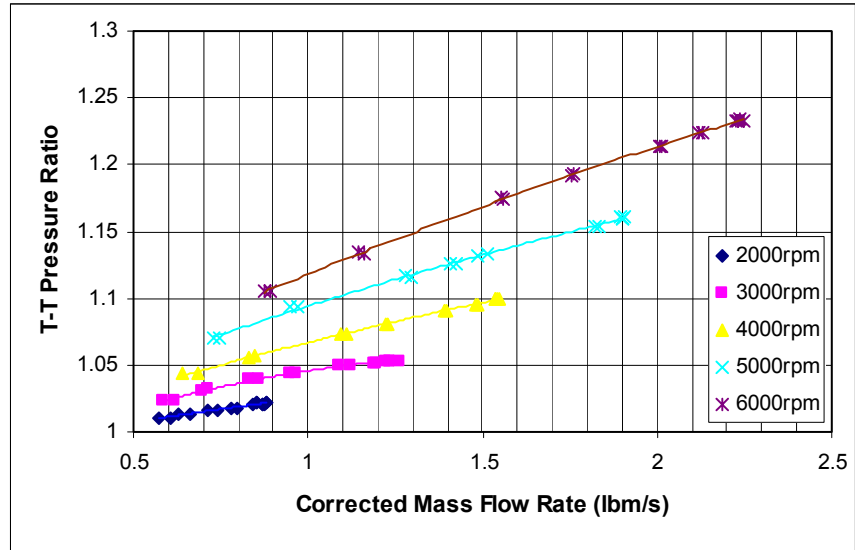


Figure 22. T-T Pressure Ratio versus Corrected Mass Flow Rate of Baseline Geometry for Both Cavities Blanked Off

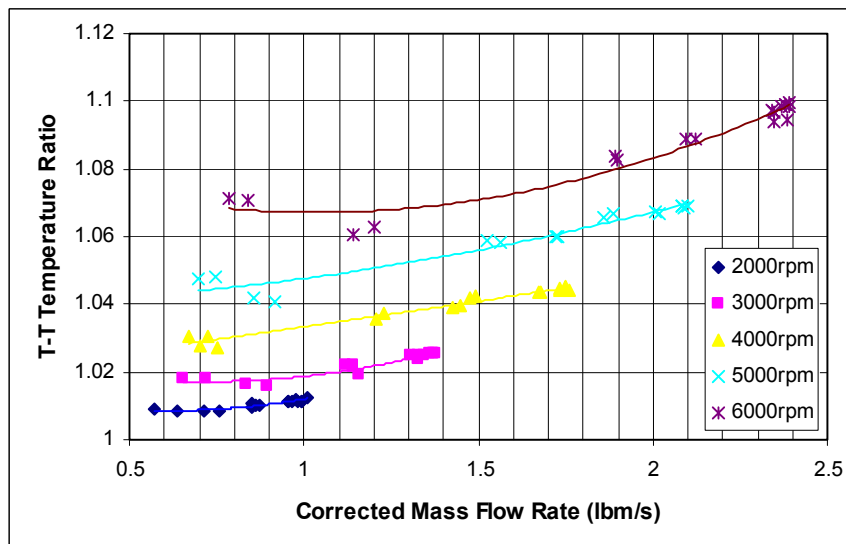


Figure 23. T-T Temperature Ratio versus Corrected Mass Flow Rate for Baseline Geometry

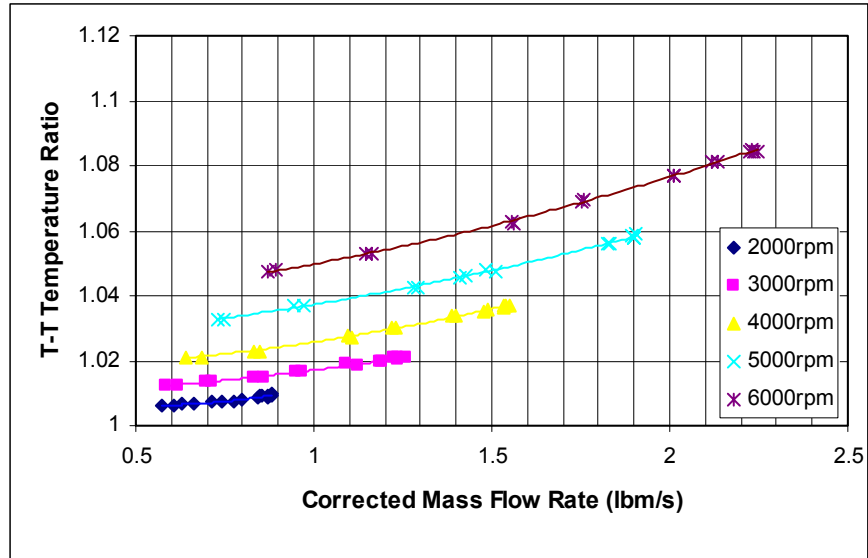


Figure 24. T-T Temperature Ratio versus Corrected Mass Flow Rate of Baseline Geometry for Both Cavities Blanked Off

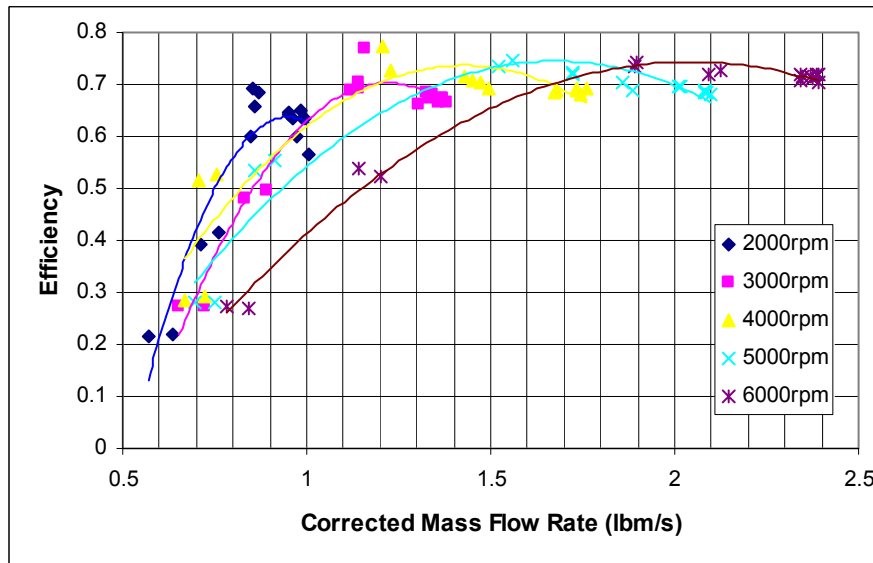


Figure 25. Efficiency versus Corrected Mass Flow Rate for Baseline Geometry

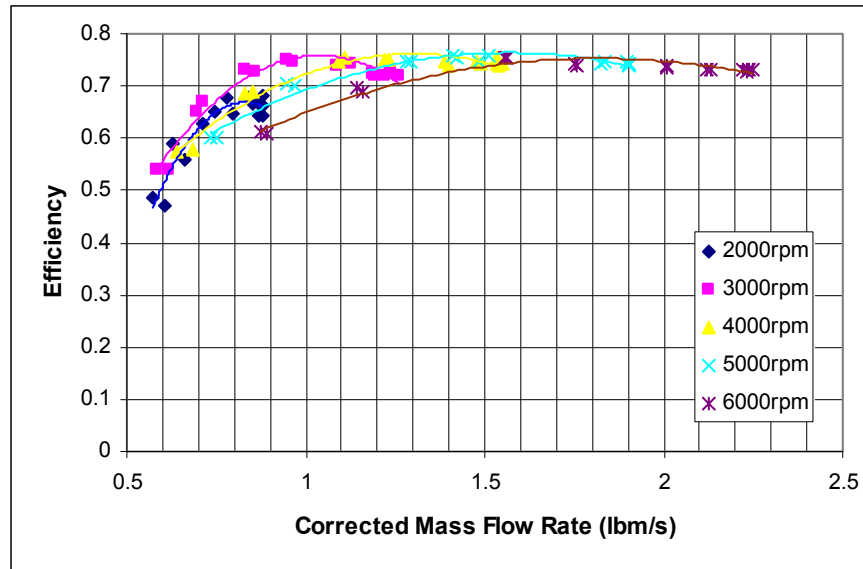


Figure 26. Efficiency versus Corrected Mass Flow Rate for Both Cavities Blanked Off

The thrust per foot span versus mass flow rate plot for the baseline configuration, as shown in Figure 27, almost collapsed onto a single curve, which surprisingly was the case for the configuration with the blanked cavities as shown in Figure 28. This indicated that the same thrust could be obtained with the fan operating at 5,000 RPM at full open throttle versus the rotor turning at 6,000 RPM at partial mass flow rate. However, the 5,000 RPM operation was at a reduced power consumption of 25HP versus 35HP at 6,000 RPM. The maximum thrust per foot span obtained for the baseline configuration was 370lbf at 2.4 lbm/s while the maximum thrust per foot span obtained for both blanked off configuration was 340 lbf at 2.25 lbm/s.

The corrected mass averaged HP versus corrected mass flow rate plots, as shown in Figure 29 and 30, had similar curve profiles as the thrust to mass flow rate plots except that they do not collapse onto a single curve. Peak power consumption obtained for the baseline was 42HP at 2.4lbm/s and the peak power consumption obtained for the configuration with both cavities blanked off was 35HP at 2.25lbm/s.

The thrust per foot span versus corrected mass averaged power is shown in Figure 31 and 32. The maximum thrust-to-power ratio (lbf/hp) for the baseline configuration was 27.3 at 2,000 RPM and open throttle, which decreased to 9.0 at 6,000

RPM. These values were slightly up, 31.2 and 9.9 respectively, for the blanked-off configuration. The conclusion here being that if vertical lift thrust is required for minimum power consumption, then slow rotor operation is required.

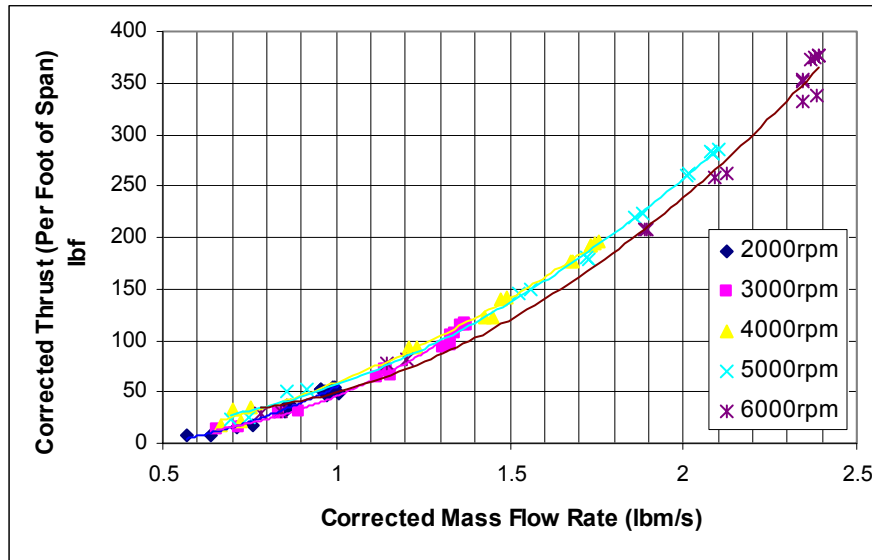


Figure 27. Corrected Thrust versus Corrected Mass Flow Rate for Baseline Geometry

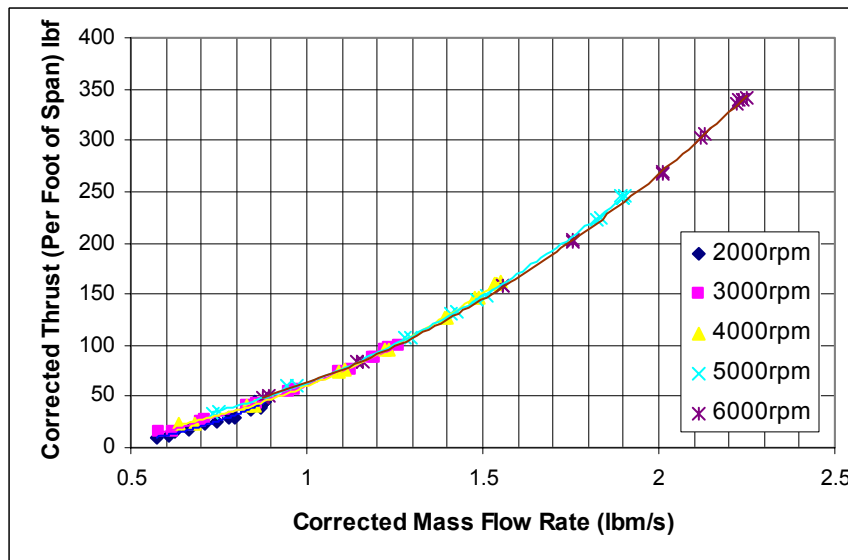


Figure 28. Corrected Thrust versus Corrected Mass Flow Rate for Both Cavities Blanked Off

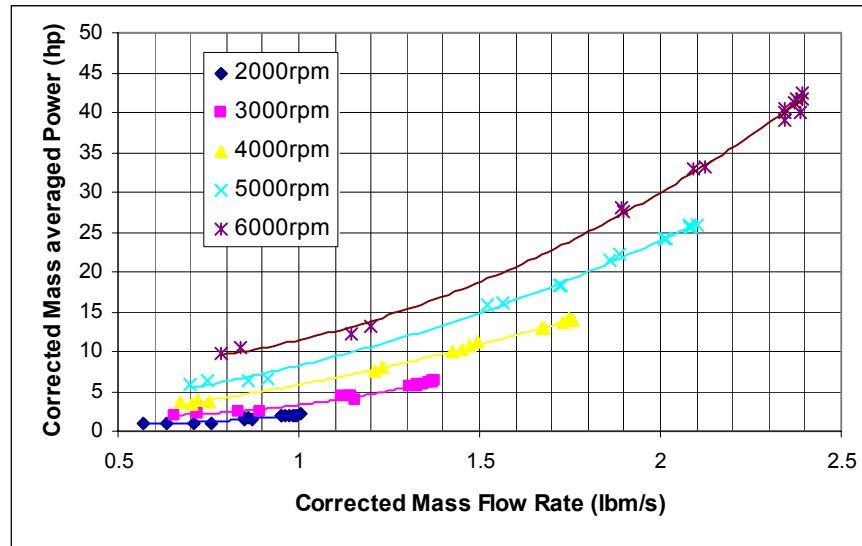


Figure 29. Corrected Mass Average Power versus Corrected Mass Flow Rate for Baseline Geometry

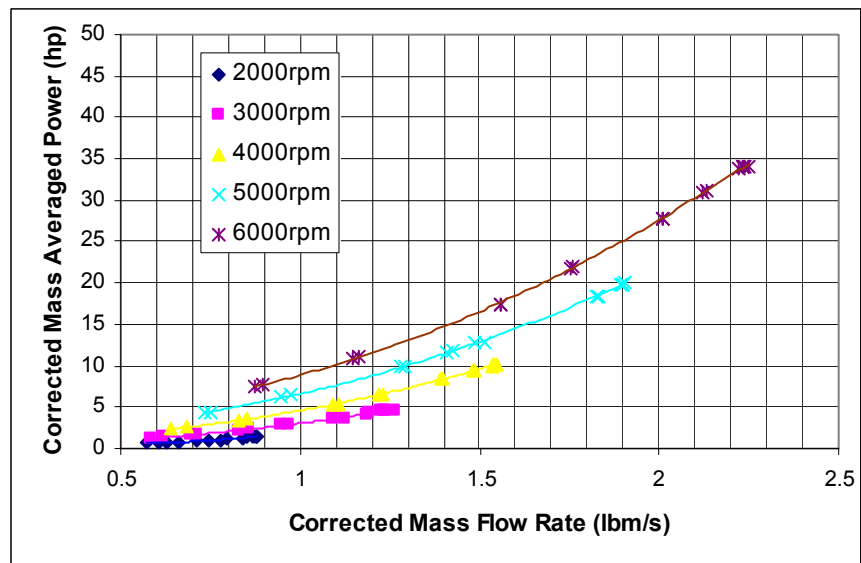


Figure 30. Corrected Mass Average Power versus Corrected Mass Flow Rate for Both Cavities Blanked Off

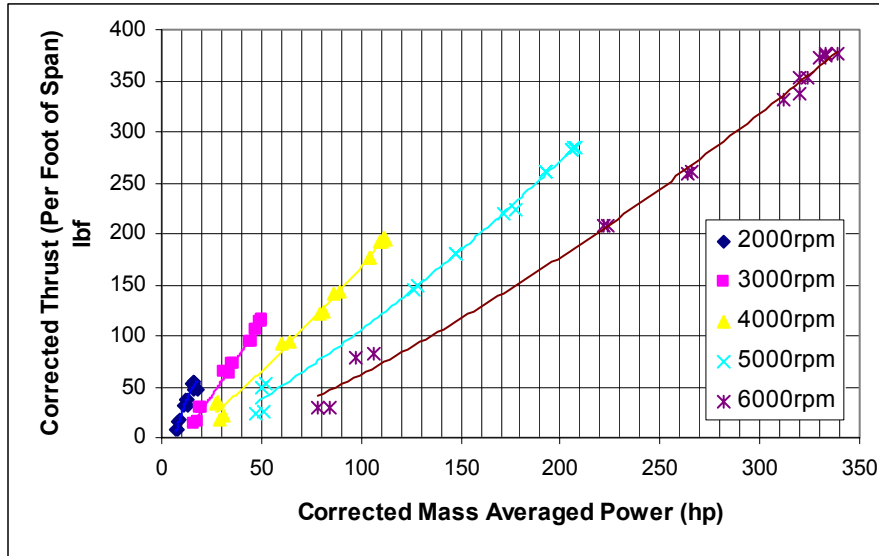


Figure 31. Corrected Thrust versus Corrected Mass Average Power for Baseline Geometry

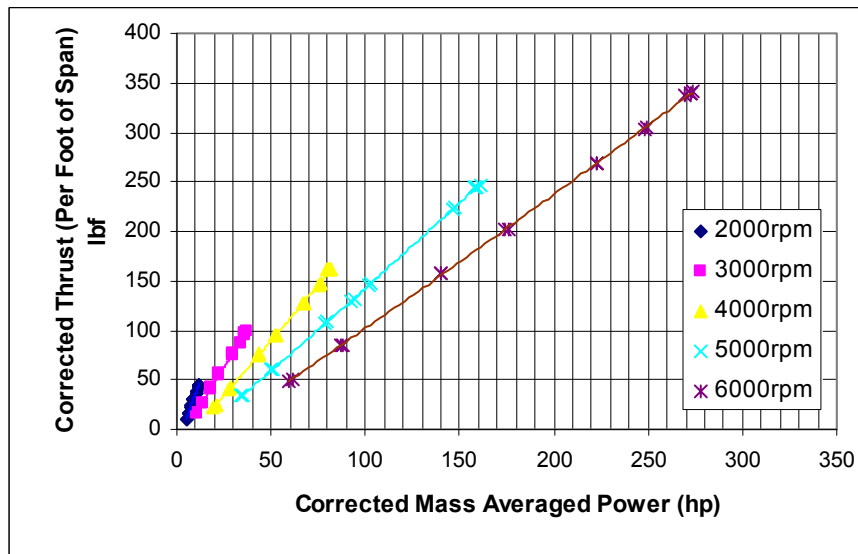


Figure 32. Corrected Thrust versus Corrected Mass Average Power of Baseline Geometry for Both Cavities Blanked Off

b. Flow Visualization for Both Cavities Blanked Off Configuration

It was of interest to understand the changes in flow patterns within the rotor with changes in mass flow. As the flow through the fan was throttled, in this case at 3,000 RPM, the following changes were observed, shown in Figures 33 and 34. At peak efficiency as shown in Figure 33, the streamline through the centre of the rotor were well

behaved i.e. curved towards the exit. There was a small vortex located in the lower left hand portion of the rotor outside the LP cavity. At stall as shown in Figure 34, the extent of the vortex had grown to encompass most of the centre of the rotor. The streamline patterns were also very irregular indicating that the flow was more unsteady.

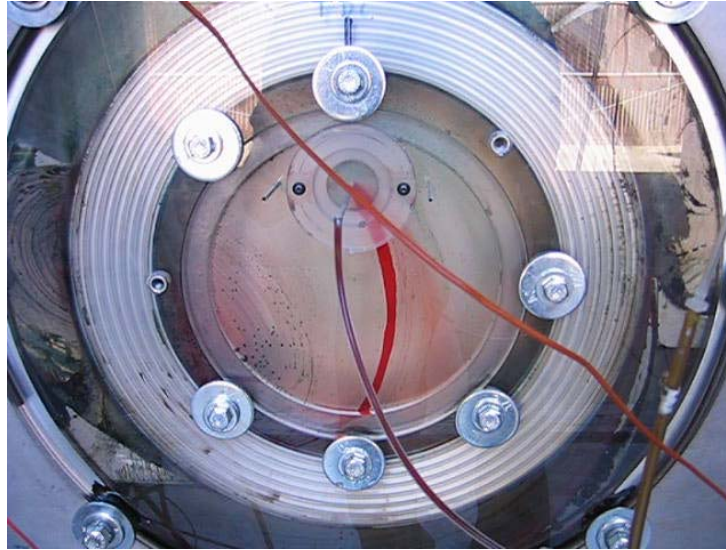


Figure 33. Flow Visualization at Peak Efficiency at 3,000 RPM

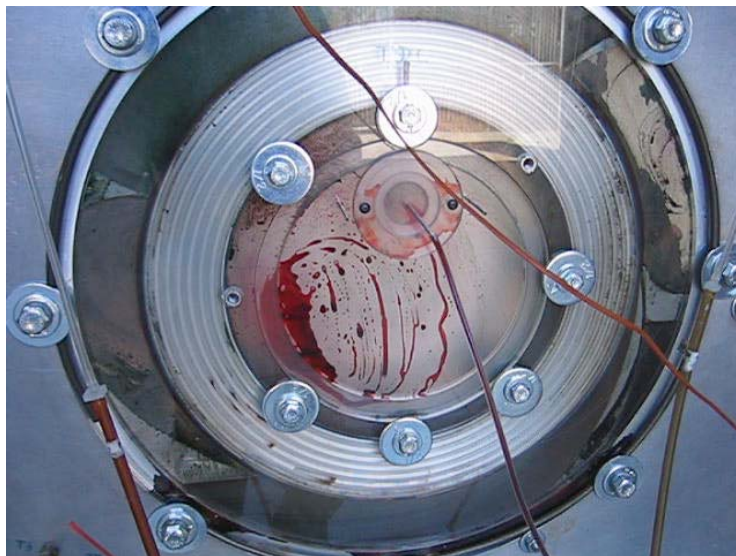


Figure 34. Flow Visualization at Stall at 3,000 RPM

III. NUMERICAL SIMULATION

A. CROSSFLOW FAN DESIGN AND SETUP

1. Overview

A commercial PC-based computational fluid dynamics software package Flo++ developed by Softflo, was used to conduct a 2-D numerical simulation on the CFF. The 0.305 m (12 inch) diameter and 30 bladed CFF, similar to that used during the experimental program, was modeled and ran at a speed of 3000 RPM. Incompressible and turbulent flow using a time marching upwind differencing modified PISO algorithm was used to solve the unsteady flow through the CFF. For turbulent flow calculations the high Reynolds number k- ϵ model was incorporated. Sliding meshes were used to model moving or rotating boundaries.

2. Grid Generation and Boundary Conditions

Grid generation for the CFF model was initiated with a Matlab code to generate the coordinates of the blade profile as shown in Figure 35. After which the coordinates text file was read into the Flo++ preprocessor and used to create the complete rotor of the CFF. A more detail discussion of the grid can be found in [Ref. 5]. Although Seaton generated a 15 bladed configuration versus a 30 blade configuration in this report, the setup procedure was almost similar.

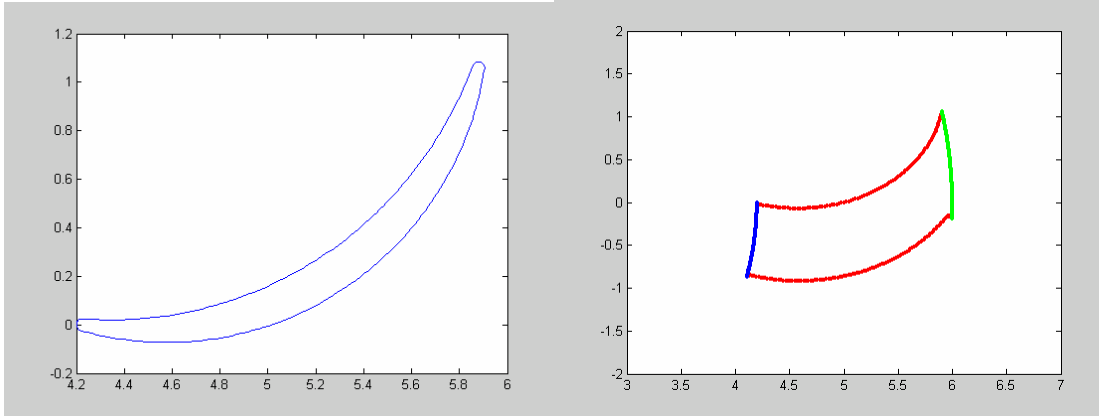


Figure 35. Matlab Generated Blade and Blade Passage Vertices

Figures 36 and 37 show the 2-D computational grid and boundary groups for the CFF respectively. The boundaries used included inlet (purple), outlet(yellow), walls

(white), and attached (orange and blue). The boundaries of type attached were used for sliding meshes where two group of grids slid against each other. The inlet and outlet boundary conditions were set to (0.97 bar and 300K) and (1bar and 300K) respectively. The reason for creating a pressure gradient was to bring the flow into the fan on the onset of the solution and thus assisting the solver computation in the initial stage. A total of 58,600 vertices and 27,130 cells were used.

The time step was set at ‘Adjustable’ such that the program would automatically adjust the time step in order to meet the criteria of the specified Courant number $Courant$ i.e. 1.0 in our case. If the newly calculated time step was bigger than the Courant criteria, a time step adjustment was made to specified Courant number. When stable, the previous time step was increased with the ratio of 1.5. This method ensured that the solution was always running at an optimal time step i.e. smaller time step used at the start up and bigger time step used when the solution was more stable. As the time step was varying, predicting the time for the solution to turn one revolution could only be done by observing the real run time. It also depended on the speed of the computer running the simulation. By running on a Pentium4 2.4 GHz, the estimated time taken, based on the configuration as described above, to run one revolution was 2 days.

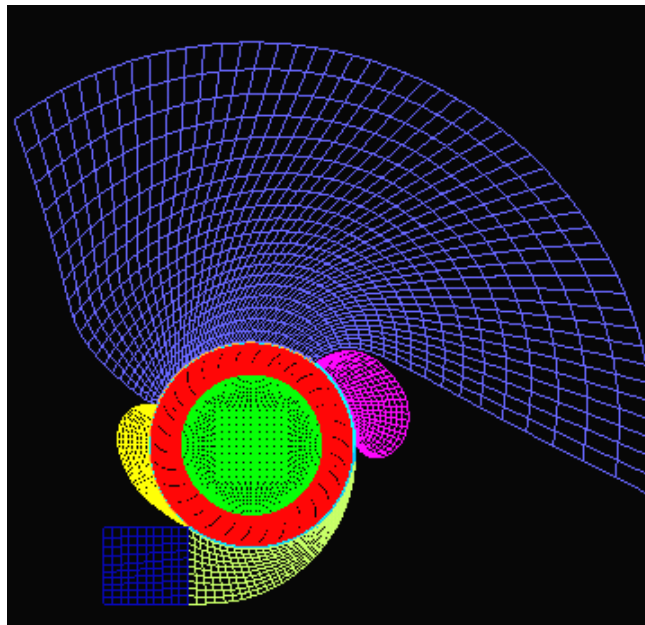


Figure 36. Complete CFF Baseline Assembly Computational Grid

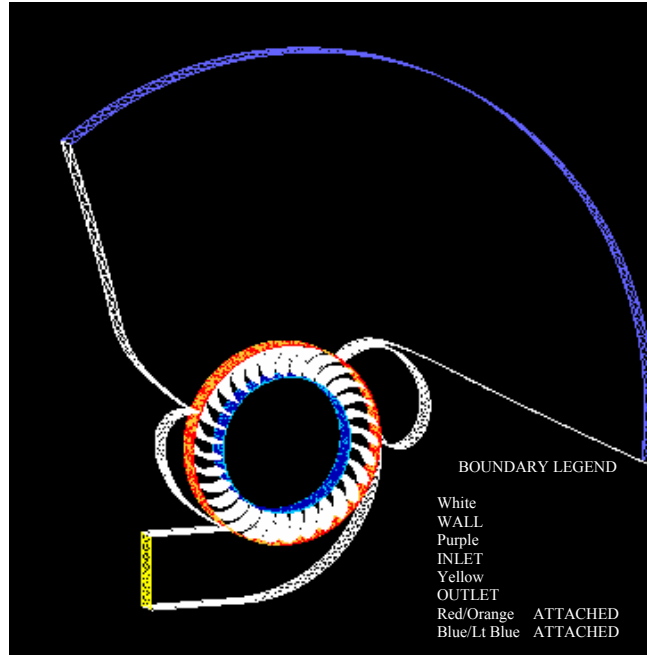


Figure 37. Boundary Groups

B. RESULTS AND DISCUSSION

1. Baseline Configuration

The main objective of studying the baseline configuration was to compare the computational results with the experiment. Figure 38 shows the contour plot of the total pressure for the model. The figure illustrates the solution after eight revolutions which were assumed to be stable based on the convergent behavior of the total-to-total pressure ratio versus no. of revolutions plots as shown in Figure 39. This showed that the solution only converged from the fourth revolution onwards and any information before that was not useful. Eight revolutions corresponded to 138,900 iterations at an average time step of approximately 1.1×10^{-6} sec. The re-circulation of flow vortices in both cavities were observed to be similar to those obtained from experiment. The lowest pressure occurred at locations just outside the left cavity, which justifies its name as the Low Pressure Cavity. The predicted total pressure ratio for this case was 1.033 versus the measured value of 1.061. Figure 40 shows the behavior of the mass flow rate with no. of revolutions. The trend of the curve follows that of Figure 39 closely. The predicted mass flow rate was 1.0 lbm/sec versus the measured value of 1.08 lbm/sec. Grid resolution and turbulence model and the difficulty of computing the flow details between rotor and housing are likely reasons for the lack of agreement with experiment.

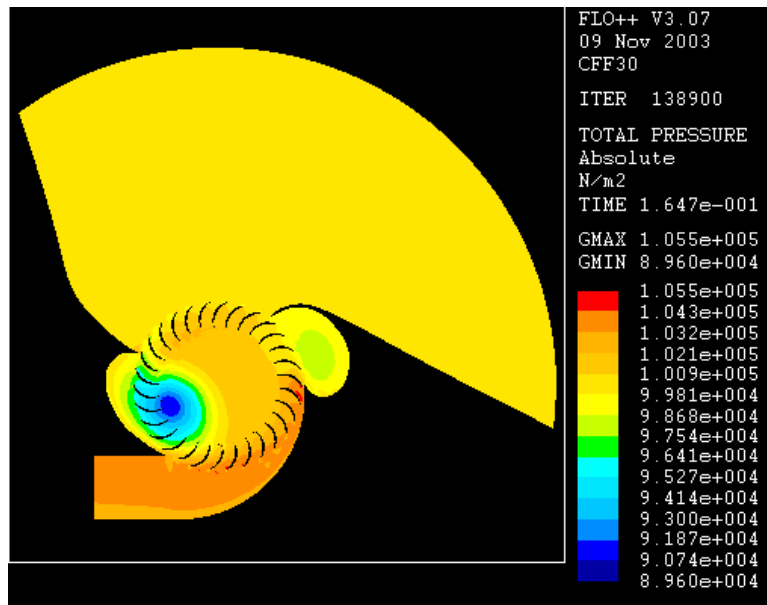


Figure 38. Contour Plot of Total Pressure at Eighth Revolution

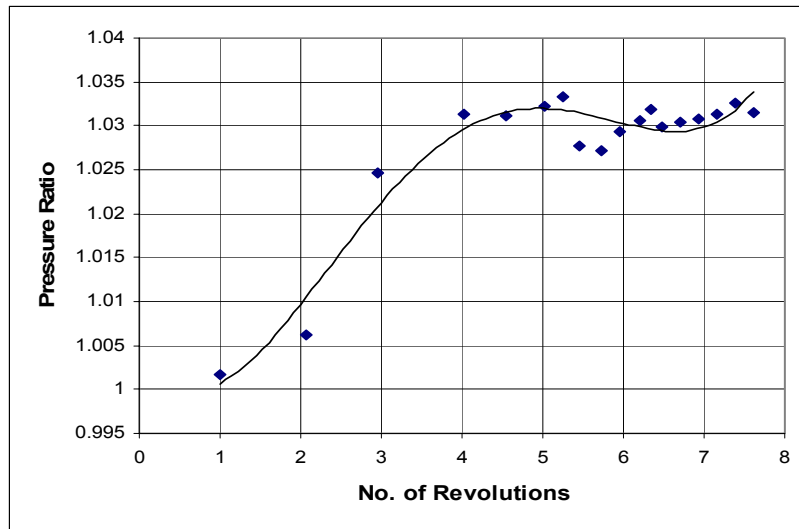


Figure 39. Total Pressure Variation with Number of Revolutions during the Computational Simulation

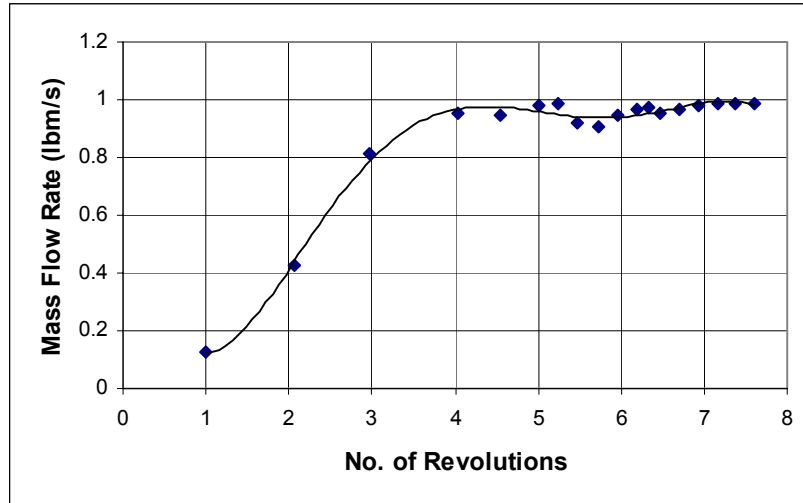


Figure 40. Mass Flow Rate with Number of Revolutions during the Computational Simulation

Figure 41 shows a contour plot of velocity magnitude for the eighth revolution solution, which also showed the two re-circulating flow vortices. The velocity was observed to be higher in the LP cavity compared to that with the HP cavity. The predicted exit velocity was about 84 m/s which was supported by an experimental value of 94 m/s.

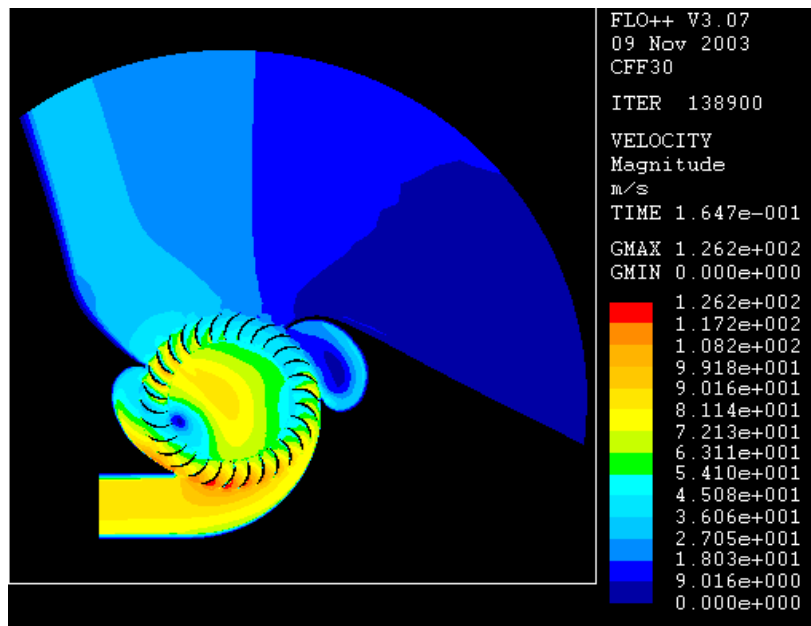


Figure 41. Contour Plot of Velocity

The vortical flow features of the two cavities are displayed in more detail in Figures 42 and 43, which are very similar to those observed during the flow visualization experiments.

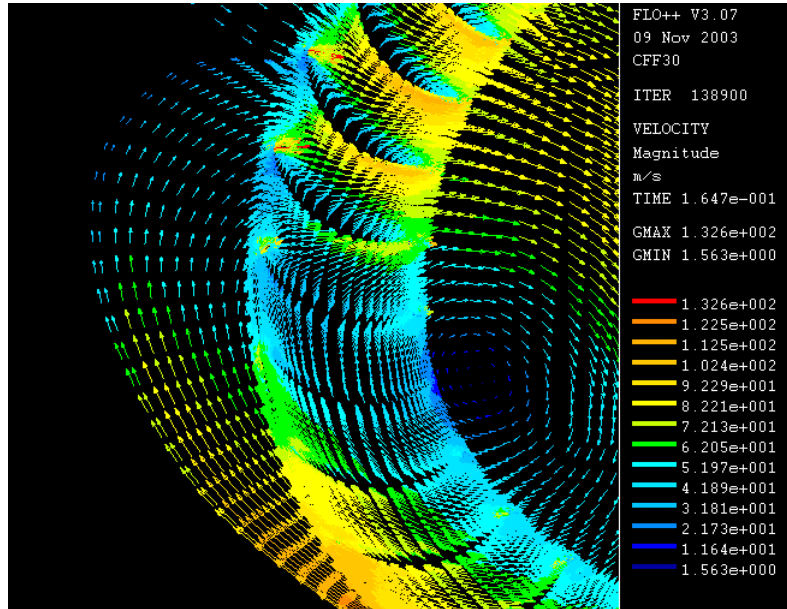


Figure 42. Vector Plot of Velocity in the LP Cavity

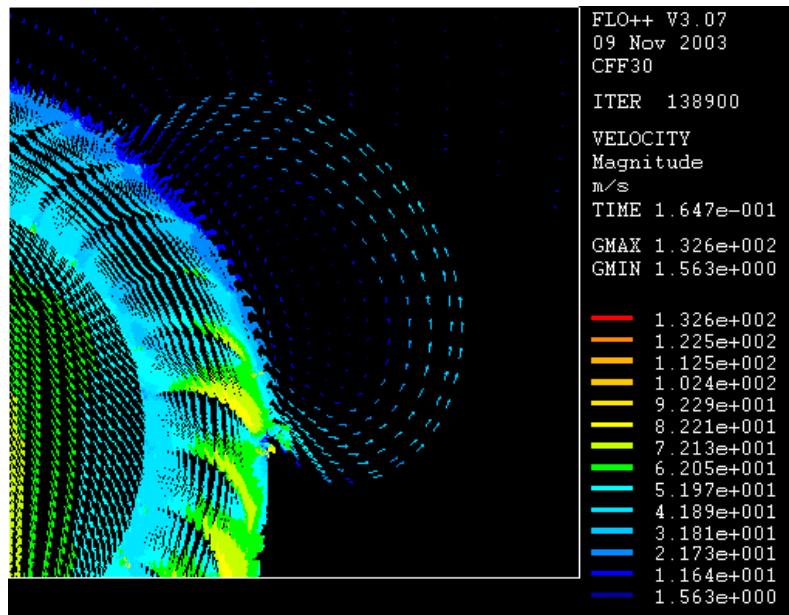


Figure 43. Vector Plot of Velocity in the HP Cavity

2. Throttling Configuration

The main objective of studying the CFF configurations with varying exhaust outlet area was to attempt to derive the compressor characteristics for 3,000 RPM. In other words, the stalling characteristics of the CFF was obtained at a speed that was found to be most efficient. It was also to understand the off-design characteristics of the CFF that were more difficult to predict and normally measured experimentally. The preprocessing files were modified from the baseline configuration to include varying exhaust outlet area.

The baseline configuration, with the original exhaust, was defined as the E100% configuration and subsequent reductions of exhaust area were defined as E**% i.e. E90% meant a CFF with 90% exhaust area. A total of 6 CFF configurations, ranging from E50% to E100% were computed.

The results for the 6 configurations of different exhaust area were computed for the 4th, 4.5th and 5th revolution. The total-to-total pressure ratio versus mass flow rate was plotted as shown in Figure 44. The pressure ratio was observed to rise to a peak value of about 1.037 at between E70% and E80% with a mass flow rate of 0.62 lbm/s and 0.7 lbm/s respectively before it fell at stall. The slight difference in the shape of the three curves was due to the fact that the solution was still fluctuating and had not reached a steady state yet as shown in Figure 39 and 40.

Next let us take a look at the pressure flow field for E100% E80% (peak efficiency) and E60% (stall) configuration at 4.5 revolutions as shown in Figure 45, 46 and 47 respectively. We observed that the vortex built up (grew bigger) on the low pressure (LP) side as the exhaust area was reduced. This was due to the back pressure from the smaller exhaust outlet and also an indication of stall.

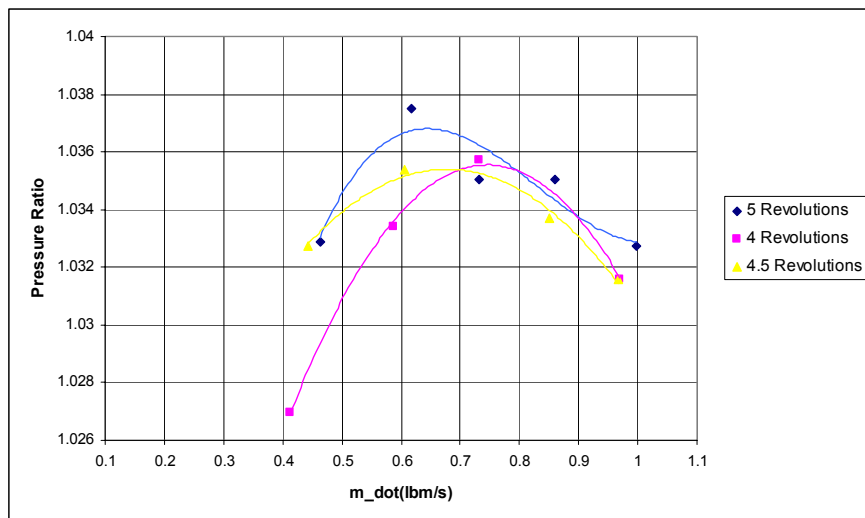


Figure 44. Pressure Plot for CFF at 3,000 RPM

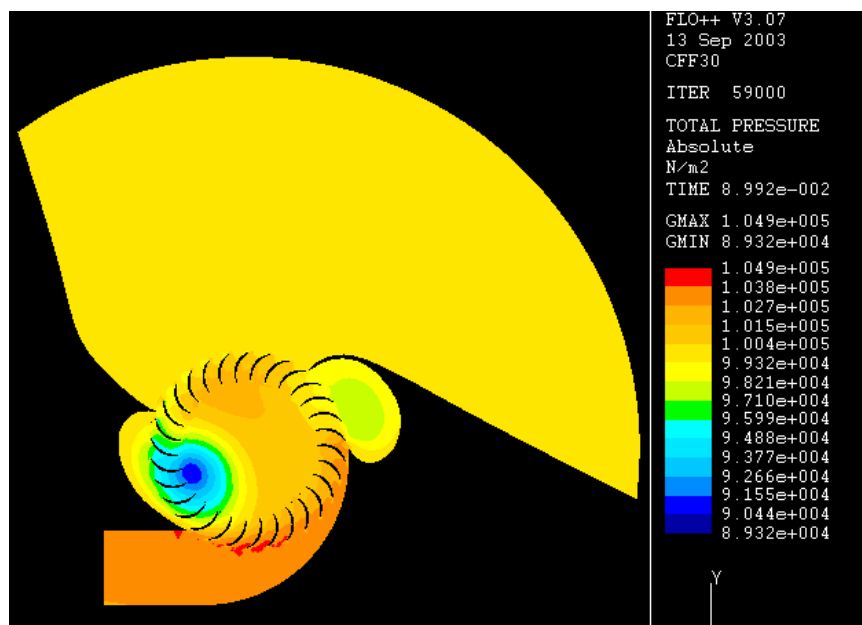


Figure 45. Contour Plot of Total Pressure for Baseline Configuration at 4.5 Revolution

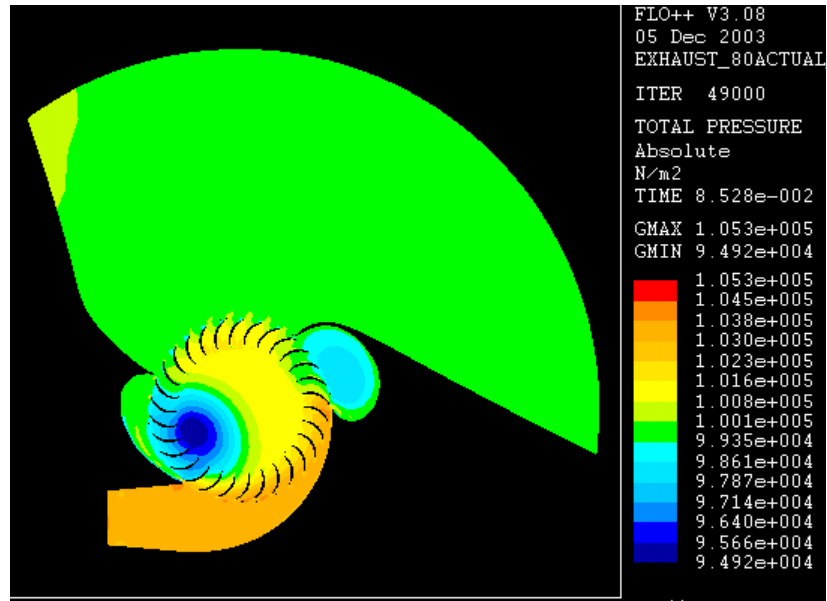


Figure 46. Contour Plot of Total Pressure for E80% (Peak Efficiency) at 4.5 Revolution

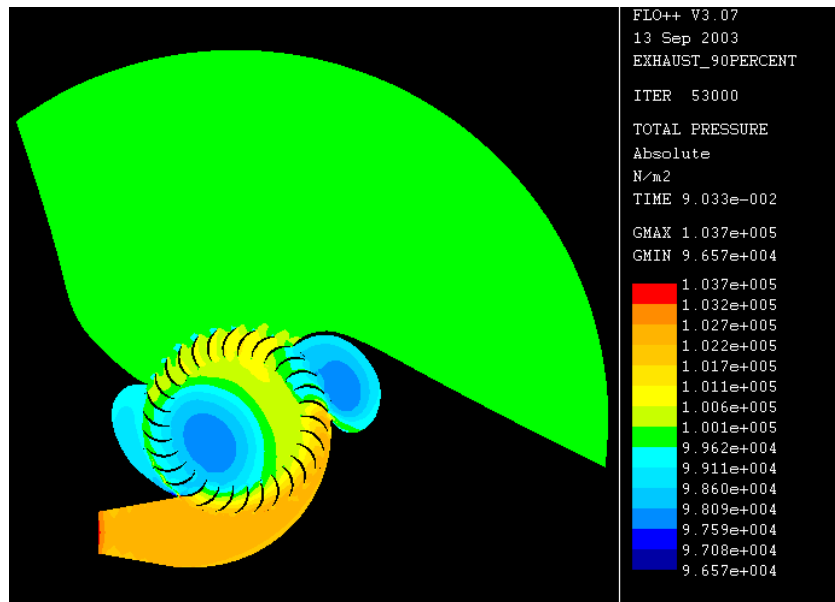


Figure 47. Contour Plot of Total Pressure for E60% Configuration at 4.5 Revolution

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IV. CONCLUSION

The Crossflow Fan Test Assembly (CFTA), which was constructed to validate the experimental tests conducted by Vought Systems Division and Seaton [Ref 5.], was used as the baseline configuration in this thesis. Improvements such as including a bellmouth to the air intake were made to the CFTA in order to achieve more accurate mass flow rate readings.

Two main test programs were conducted. The first set of tests investigated the performance of four configurations which included the baseline configuration and three others with permutations of the LP and HP Cavities opened and blanked off. The tests were conducted from 1,000 RPM to 5,000 RPM. The measured maximum efficiencies for the four configurations ranged from 66% to 74%, with the highest occurring from the LP closed & HP opened configuration. The other performance plots also showed similar trends and relatively small variance between the four configurations. It also indicated that efficiency in excess of 70% could be achieved at speeds lower than 5,000 RPM. The second set of tests investigated the stalling characteristics of two CFF configurations by means of a throttle system installed downstream of the CFTA. The two configurations were the baseline configuration and one with both cavities blanked off, with a throttling device attached to the exhaust. The tests were conducted from 2,000 RPM to 6,000 RPM. A complete compressor map was obtained by throttling the exhaust to vary the mass flow rate, t-t pressure ratio and other performance parameters. The measured maximum efficiencies for the two configurations were all in the vicinity of 75% except those running at 2,000 RPM. The stalling points for both configurations were observed to be at the same throttle setting. The efficiencies at various speeds were observed to drop drastically to about 30% after stall. But for the two cavities blanked off configuration, the efficiencies for the various speeds only dropped to 50% after stall at the same throttle setting.

Flow Visualization was conducted during all tests and the flow patterns were shown to be similar to those from VSD tests. All these results are encouraging because at these relatively low rotational speeds the use of CFFs for aircraft propulsion purposes is

likely to be advantageous from a performance and noise point of view. These data as well as the associated flow visualization and probe measurements will also make a valued data set for numerical predictions.

A 30 blade Crossflow Fan, similar to that used in the experiment, was modeled using a numerical simulation program Flo++. An incompressible, unsteady flow solution was obtained at a speed of 3,000 RPM. Based on the resolution of the grid and Courant number used, it took about 10 days to run 4 revolutions (relatively stable state). The results obtained validated that it is possible to reproduce the measured flow patterns from experiments. The throttling of the exhaust was simulated by reducing the area of the exhaust outlet. The results showed similar characteristics to a typical stalling compressor but more work is required in order to achieve a more accurate compressor map.

Future test will include variations in the blade as well as cavity configurations. Also, most importantly tests of lower diameter CFFs will be performed in view of their easier installation in aircraft wing sections.

V. RECOMMENDATIONS

The current CFF configuration, which made up of a 12-inch diameter, 1.5-inch span and 30 blade rotor, was based on VSD's studies some 18 years back. Now that we have validated the performance of VSD's CFF, we can now take one step further by modifying the existing CFF in search for a better configuration. Since the rotor and both cavities are modular to the main assembly, modifications will be much easier and will not cost as much.

In line with the potential of installing CFF inside an aircraft's wing section as a lift / propulsion device, the diameter of the rotor should be reduced to suit the space limitation. The optimum number of blades, together with the blade profile, should also be looked into. As there are too many configurations, it is not feasible to build all the rotors to be tested. Instead, CFD can be utilized in this case to run the simulation on different configurations and finding the efficiency and power generated by the force. After which, we just need to build a few of the better configurations for testing and validation purposes. Similarly for both the cavities, we should explore different cavities design which includes the slope on top of that module that brings air into the CFF. But we understand that the current runs on the CFD software takes up a lot of time as well as effort in order to run one configuration. The difficulty in the coding makes the whole process slower. Several efforts had been put in to define a compressible flow but the solution always got unstable. Hence we can conclude that Flo++ might not be suitable for computing compressible for our CFF model. Instead, a more user friendly and established CFD softwares such as ACE and OVERFLOW should be explored to solve the compressible CFF model. Comparisons can then be made between different software and the experimental results. After which, the software which is easier to use and have shorter solution run time to steady state should be used for running the different configurations CFF as mentioned above.

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APPENDIX A. DATA LISTING

A1. TEST 1

Both Cavities Blanked	Run #	RPM	Patm	Pcal	Pin TTR (5 o/c)	Pout TTR	Pin TTR (8 o/c)	Pin CFF (2 o/c)	Pin CFF (10 o/c)	Pout CFF (Top)	Pout CFF (Mid)	Pout CFF (Bot)	PA	PB	PC	PD	PE	PF	PG	PH	PI	PJ
	1	1306.7398	29.99	39.99	29.7903	30.0700	30.5992	29.9881	29.9837	30.1864	30.2147	30.2283	29.9970	29.9982	29.9934	29.9953	29.9940	29.9857	29.9854	29.9851	29.9967	30.0014
	2	2078.1238	29.99	39.99	29.8038	30.1310	31.1224	29.9875	29.9803	30.5410	30.5909	30.5944	30.0093	30.0094	29.9971	30.0044	30.0053	29.9857	29.9834	29.9832	29.9978	30.0210
	3	2084.2019	29.99	39.99	29.8264	30.1311	31.1224	29.9868	29.9786	30.5410	30.5917	30.5865	30.0096	30.0088	29.9932	30.0015	30.0039	29.9840	29.9819	29.9808	29.9939	30.0185
	4	3000.0601	29.99	39.99	29.8497	30.2682	32.1052	29.9847	29.9704	31.2439	31.3407	31.2754	30.0270	30.0272	29.9842	29.9938	30.0243	29.9820	29.9779	29.9771	29.9906	30.0455
	5	3009.2387	29.99	39.99	29.8648	30.2688	32.0949	29.9828	29.9670	31.2421	31.3384	31.2863	30.0265	30.0267	29.9829	29.9895	30.0247	29.9809	29.9757	29.9743	29.9857	30.0463
	6	4015.9303	29.99	39.99	29.9130	30.5175	33.6266	29.9844	29.9648	32.3384	32.4877	32.3436	30.0568	30.0507	29.9884	29.9881	30.0609	29.9922	29.9790	29.9780	29.9868	30.0676
	7	4012.1708	29.99	39.99	29.9220	30.5200	33.6236	29.9828	29.9599	32.3487	32.5017	32.3560	30.0495	30.0425	29.9975	29.9837	30.0586	29.9820	29.9779	29.9771	29.9871	30.0949
	8	4999.4176	29.99	39.99	29.9695	30.8167	35.8525	29.9828	29.9492	33.8193	34.1149	33.6358	30.0735	29.9988	30.0441	30.0087	30.0221	29.9718	29.9772	29.9761	29.9901	30.1338
	9	5007.0939	29.85	39.85	29.8450	30.5693	35.4829	29.9418	29.8020	33.6473	33.9599	33.4890	29.9192	29.8712	29.8989	29.8990	29.8928	29.8324	29.8360	29.8347	29.8502	29.9862
	11	4487.5156	29.90	39.90	29.9059	30.5599	34.4321	29.8918	29.8602	32.9107	33.1519	32.8509	29.9493	29.9266	29.8810	29.9180	29.9535	29.8812	29.8895	29.8852	29.8898	30.0261
	12	4501.8350	29.90	39.90	29.9159	30.5618	34.4302	29.8920	29.8609	32.9132	33.1271	32.8472	29.9455	29.9247	29.8803	29.9213	29.9512	29.8794	29.8862	29.8852	29.8897	30.0220
	13	3483.6741	29.90	39.90	29.9212	30.3025	32.6516	29.8941	29.8808	31.6489	31.7943	31.6700	29.9296	29.9146	29.8852	29.9015	29.8820	29.8858	29.8843	29.8833	29.8792	
	14	3503.5682	29.90	39.90	29.9253	30.3060	32.6489	29.8933	29.8731	31.6438	31.7914	31.6784	29.9325	29.9165	29.8857	29.9040	29.9344	29.8827	29.8861	29.8859	29.8846	29.8823
	15	2502.2000	29.90	39.90	29.9081	30.1102	31.3661	29.8932	29.8861	30.7339	30.8066	30.7927	29.8120	29.8062	29.8857	29.8907	29.8122	29.8827	29.8851	29.8838	29.8801	29.9353
	16	2491.4566	29.90	39.90	29.9098	30.1080	31.3563	29.8932	29.8845	30.7284	30.8113	30.7780	29.9125	29.9042	29.8860	29.8925	29.9149	29.8833	29.8856	29.8847	29.8832	29.9356
	17	1511.4150	29.90	39.90	29.8890	29.9908	30.5695	29.8966	29.8902	30.1757	30.2075	30.2179	29.9017	29.9018	29.8921	29.8941	29.9032	29.8869	29.8870	29.8867	29.8817	29.9079
	18	1512.9624	29.90	39.90	29.8863	29.9885	30.5649	29.8955	29.8913	30.1746	30.2035	30.2106	29.9015	29.9018	29.8908	29.8925	29.9022	29.8862	29.8868	29.8878	29.8834	29.9090
Both Cavities Opened	Run #	RPM	Patm	Pcal	Pin TTR (5 o/c)	Pout TTR	Pin TTR (8 o/c)	Pin CFF (2 o/c)	Pin CFF (10 o/c)	Pout CFF (Top)	Pout CFF (Mid)	Pout CFF (Bot)	PA	PB	PC	PD	PE	PF	PG	PH	PI	PJ
	1	1006.9852	29.95	39.95	29.9540	30.0265	30.4445	29.9512	29.9229	30.1022	30.1117	30.1238	29.9598	29.8238	29.8694	29.9195	29.9494	29.9390	29.9077	29.9015	29.9311	29.9806
	2	1006.9564	29.95	39.95	29.9588	30.0258	30.4486	29.9499	29.9222	30.1028	30.1110	30.1233	29.9571	29.8229	29.8678	29.9184	29.9475	29.9381	29.9068	29.9007	29.9280	29.9797
	3	2016.9018	29.95	39.95	29.6127	30.1809	31.3540	29.9492	29.8335	30.6238	30.6276	30.6439	29.9813	29.3501	29.5002	29.8316	29.9521	29.8886	29.7378	29.7099	29.8052	30.0519
	4	2011.4520	29.95	39.95	29.6357	30.1634	31.3632	29.9485	29.8303	30.6278	30.6329	30.6547	29.9788	29.3411	29.5563	29.8311	29.9602	29.8849	29.7357	29.7065	29.8027	30.0499
	5	2984.6099	29.95	39.95	29.6854	30.3963	32.8962	29.9479	29.6806	31.5558	31.6788	31.5222	30.0226	28.5373	28.0193	28.6450	30.0119	29.8324	29.4450	29.3848	29.4992	30.1506
	6	2999.6852	29.95	39.95	29.7378	30.4347	32.8918	29.9460	29.6796	31.5514	31.5745	31.5086	30.0211	28.5436	29.0187	29.6451	30.0113	29.8318	29.4421	29.3841	29.4967	30.1504
	7	4005.0737	29.95	39.95	29.7719	30.8183	35.1107	29.9432	29.4555	32.9332	32.8585	32.7508	30.0845	27.3532	28.1699	29.2951	29.9842	29.7412	29.0184	29.9105	29.0974	30.2891
	8	4015.0873	29.95	39.95	29.7952	30.8282	35.1352	29.9428	29.4574	32.9513	32.8888	32.7426	30.0844	27.3363	28.1557	29.2895	29.9822	29.7409	29.0195	29.9584	29.0871	30.2908
	9	4995.6711	29.95	39.95	29.8375	31.2945	37.8884	29.9410	28.1895	34.6292	34.6044	34.4146	30.1734	25.8555	27.0172	28.7404	29.8387	29.6313	28.4877	28.3223	28.5585	30.4470
	10	4987.4907	29.95	39.95	29.8513	31.2972	37.9746	29.9390	28.1824	34.6321	34.6023	34.4221	30.1736	25.8379	27.0045	28.7320	29.8312	29.6325	28.4619	28.3186	28.5630	30.4400

LP Cav opened HP Cav closed	Run #	RPM	Patm	Pcal	Pin TTR (5 o/c)	Pout TTR	Pin TTR (8 o/c)	Pin CFF (2 o/c)	Pin CFF (10 o/c)	Pout CFF (Top)	Pout CFF (Mid)	Pout CFF (Bot)	PA	PB	PC	PD	PE	PF	PG	PH	PI	PJ
	1	1042.852	29.96	39.96	29.6042	30.0379	30.5268	29.9593	29.8336	30.1165	30.1201	30.1330	29.9599	29.9638	29.9584	29.9567	29.9628	29.9596	29.9605	29.9599	29.9659	29.9820
	2	1063.8977	29.96	39.96	29.6360	30.0383	30.6336	29.9592	29.9289	30.1336	30.1363	30.1503	29.9597	29.9642	29.9590	29.9572	29.9637	29.9587	29.9594	29.9594	29.9642	29.9836
	3	1492.4448	29.96	39.96	29.7061	30.0823	30.8424	29.9598	29.9017	30.3158	30.3152	30.3280	29.9616	29.9689	29.9579	29.9533	29.9705	29.9575	29.9591	29.9586	29.9608	30.0000
	4	1502.9345	29.96	39.96	29.7201	30.0809	30.8369	29.9586	29.9005	30.3149	30.3143	30.3239	29.9605	29.9679	29.9572	29.9529	29.9691	29.9576	29.9591	29.9588	29.9613	30.0005
	5	2008.6776	29.96	39.96	29.7396	30.1530	31.3325	29.9578	29.8525	30.6317	30.6279	30.6148	29.9671	29.9755	29.9550	29.9537	29.9769	29.9538	29.9557	29.9567	29.9579	30.0245
	6	2016.3596	29.96	39.96	29.7472	30.1524	31.3380	29.9557	29.8491	30.6279	30.6222	30.6061	29.9657	29.9744	29.9527	29.9512	29.9767	29.9517	29.9538	29.9536	29.9522	30.0228
	7	2499.2816	29.96	39.96	29.7633	30.2413	31.9767	29.9555	29.7825	31.1040	31.0299	30.9625	29.9762	29.9826	29.9507	29.9551	29.9870	29.9498	29.9521	29.9518	29.9545	30.0521
	8	2509.5469	29.96	39.96	29.7823	30.2404	31.9774	29.9557	29.7866	31.0967	31.0259	30.9522	29.9769	29.9808	29.9482	29.9546	29.9869	29.9492	29.9518	29.9513	29.9524	30.0532
	9	3003.2288	29.96	39.96	29.8017	30.3631	32.7586	29.9539	29.7140	31.5336	31.5028	31.4130	29.9873	29.9921	29.9378	29.9528	29.9951	29.9445	29.9485	29.9475	29.9474	30.0839
	10	2994.8191	29.96	39.96	29.8150	30.3653	32.7663	29.9531	29.7092	31.5423	31.4940	31.4101	29.9854	29.9956	29.9369	29.9539	29.9909	29.9433	29.9480	29.9473	29.9473	30.0826
	11	3502.8274	29.96	39.96	29.8867	30.5565	33.7166	29.9544	29.8144	32.1834	32.1253	31.9881	29.9998	30.0170	29.9890	29.9590	30.0070	29.9434	29.9526	29.9522	29.9491	30.1301
	12	3512.8603	29.96	39.96	29.8634	30.5599	33.7270	29.9548	29.8133	32.1893	32.1141	31.9779	29.9986	30.0156	29.9912	29.9572	30.0097	29.9425	29.9513	29.9509	29.9477	30.1317
	13	4007.9899	29.96	39.96	29.8744	30.7528	34.8455	29.9521	29.5095	32.9305	32.8012	32.9693	30.0137	30.0281	30.0190	29.9621	30.0212	29.9342	29.9505	29.9498	29.9551	30.1768
	14	4006.9728	29.96	39.96	29.8771	30.7494	34.8556	29.9514	29.5096	32.9416	32.8146	32.9248	30.0138	30.0279	30.0204	29.9628	30.0214	29.9322	29.9500	29.9493	29.9549	30.1748
	15	4514.6394	29.96	39.96	29.9017	30.9609	36.1496	29.9518	29.3860	33.7980	33.5896	33.3211	30.0272	30.0454	30.0442	29.9640	30.0379	29.9225	29.9488	29.9481	29.9516	30.2234
	16	4505.6213	29.96	39.96	29.9099	30.9624	36.1539	29.9500	29.3815	33.7999	33.5956	33.3021	30.0226	30.0444	30.0451	29.9638	30.0340	29.9241	29.9485	29.9470	29.9544	30.2292
	17	4986.2469	29.96	39.96	29.9254	31.1992	37.6628	29.9492	29.2437	34.6447	34.5483	34.1030	30.0496	30.0593	30.0661	29.9495	30.0516	29.9269	29.9473	29.9458	29.9476	30.2717
	18	5021.0645	29.96	39.96	29.9203	31.1921	37.6901	29.9508	29.2406	34.6543	34.5496	34.1329	30.0417	30.0592	30.0617	29.9499	30.0592	29.9270	29.9470	29.9456	29.9454	30.2729
	19	5009.8918	29.96	39.96	29.9503	30.4145	32.8951	29.9673	29.7103	31.5423	31.5104	31.4490	29.9888	29.9978	29.9997	29.9633	29.9948	29.9549	29.9543	29.9505	29.9561	30.2729
	20	2997.6321	29.96	39.96	29.8458	30.4098	32.8769	29.9590	29.7139	31.5302	31.5006	31.4132	29.9870	29.9959	29.9973	29.9612	29.9991	29.9548	29.9524	29.9520	29.9477	30.0889
LP Cav closed HP Cav opened	Run #	RPM	Patm	Pcal	Pin TTR (5 o/c)	Pout TTR	Pin TTR (8 o/c)	Pin CFF (2 o/c)	Pin CFF (10 o/c)	Pout CFF (Top)	Pout CFF (Mid)	Pout CFF (Bot)	PA	PB	PC	PD	PE	PF	PG	PH	PI	PJ
	1	1166.875	29.94	39.935	29.3996	30.0175	30.5231	29.93538	29.9089	30.0845	30.1223	30.1392	29.9413	29.9453	29.9441	29.93428	29.9443	29.9372	29.9647	29.9572	29.9182	29.965
	2	1189.754	29.94	39.935	29.4494	30.0175	30.5256	29.93455	29.9055	30.1078	30.1388	30.1594	29.9399	29.9451	29.9437	29.93318	29.9445	29.9358	29.9582	29.9494	29.9039	29.964
	3	1492.24	29.94	39.935	29.4653	30.0498	30.7127	29.93407	29.8968	30.2298	30.2564	30.2814	29.9425	29.9462	29.9446	29.92998	29.9446	29.9338	29.9106	29.7945	29.8778	29.976
	4	1507.433	29.94	39.935	29.4772	30.0418	30.7139	29.93364	29.8978	30.2174	30.25	30.2777	29.9418	29.9454	29.9446	29.93012	29.9447	29.9334	29.9096	29.7932	29.8767	29.976
	5	1994.834	29.94	39.935	29.5181	30.0842	31.0913	29.93148	29.8458	30.4994	30.5399	30.5452	29.9448	29.9509	29.9494	29.92047	29.9487	29.9333	29.8991	29.7709	29.7492	30
	6	2045.889	29.94	39.935	29.5347	30.0848	31.0915	29.93159	29.8458	30.4994	30.5394	30.5354	29.9442	29.9509	29.9494	29.92248	29.951	29.9343	29.8991	29.8862	29.7499	30.001
	7	2498.418	29.94	39.935	29.5957	30.1528	31.9998	29.9316	29.793	30.8148	30.9009	30.8955	29.9517	29.9578	29.9536	29.91894	29.9599	29.9378	29.9548	29.9137	29.8961	30.03
	8	2501.647	29.94	39.935	29.5748	30.1541	31.8002	29.92985	29.7928	30.8192	30.8902	30.8977	29.952	29.9581	29.954	29.91866	29.9548	29.9396	29.9549	29.9135	29.8954	30.029
	9	3003.349	29.94	39.935	29.6022	30.2449	32.2607	29.93039	29.7283	31.2323	31.3996	31.3355	29.9561	29.9677	29.9677	29.91367	29.9624	29.9405	29.9307	29.9238	29.4553	30.069
	10	3004.627	29.94	39.935	29.6147	30.2449	32.2549	29.92937	29.7281	31.2369	31.4009	31.3406	29.9529	29.9659	29.9617	29.9141	29.9634	29.9392	29.9391	29.9243	29.4546	30.063
	11	3510.908	29.94	39.935	29.6862	30.4045	33.0403	29.93008	29.6508	31.8035	31.8485	31.8742	29.957	29.9799	29.9814	29.91414	29.9715	29.9448	29.9198	29.9228	29.2625	30.108
	12	3517.886	29.94	39.935	29.6919	30.4065	33.0404	29.9272	29.644	31.8055	31.8469	31.8638	29.9532	29.9795	29.9786	29.91275	29.9711	29.9476	29.91801	29.9105	29.267	30.11
	13	3993.239	29.94	39.935	29.7187	30.5391	33.9111	29.92884	29.5545	32.354	32.6736	32.444	29.9598	29.9824	29.9829	29.91112	29.9829	29.9503	29.9538	28.8505	29.0223	30.154
	14	3988.646	29.94	39.935	29.737	30.5374	33.8994	29.92828	29.5547	32.3544	32.6685	32.4453	29.9602	29.9906	29.9914	29.91176	29.9791	29.9471	29.9573	28.8558	29.0274	30.153
	15	4490.985	29.94	39.935	29.7543	30.7015	34.9704	29.92537	29.4444	33.0629	33.3692	33.1362	29.9878	30.0065	29.9963	29.90668	29.9963	29.9657	28.6742	28.5456	28.7912	30.203
	16	4495.224	29.94	39.935	29.7614	30.7079	34.9819	29.9249	29.4383	33.0786	33.3996	33.1498	29.9856	30.006	29.9981	29.90992	29.9912	29.9692	28.6648	28.5408	28.7971	30.2
	17	5009.101	29.94	39.94	29.7952	30.8968	36.161	29.93106	29.3243	33.8571	34.241	33.9541	29.9779	30.0261	30.0199	29.90483	30.009	30.0087	28.3834	28.2425	28.5254	30.254
	19	5009.729	29.94	39.935	29.8236	30.891	36.1528	29.92564	29.322	33.8325	34.2107	33.9476	29.9755	30.0232	30.012	29.8979	30.0001	30.0056	28.382	28.2368	28.5068	30.246

LP Cav opened HP Cav closed	Run #	RPM	PK	PL	Pin	Pin (Flange)	Pout (Flange)	Pout (Vena)	Tin CFF (2 o/c)	Tin CFF (11 o/c)	Tin TTR (8 o/c)	Tin TTR (5 o/c)	Tout TTR	Tin Orifice	Tout CFF (Bot)	Tout CFF (Mid)	Tout CFF (Top)	TTR Mass Flow (lbm/s)	Turbine Power (HP)	CFF Mass Flow (lbm/s)	Pi CFF	Tau CFF	CFF Efficiency	CFF Corrected Mass Flow
	1	1042.3852	29.9608	29.9608	33.2731	29.9821	33.2992	33.2456	529.0363	531.8958	535.5468	535.4677	533.8223	536.8286	532.0844	532.6358	532.3054	1.0495	-0.4244	0.9418	1.0059	1.0035	0.4755	0.9507
	2	1063.8977	29.9598	29.9599	33.2601	29.9603	33.2263	33.2340	528.3714	531.8149	535.8579	535.8315	534.1300	536.9624	531.8061	532.4354	532.2983	1.0217	-0.4205	0.8395	1.0065	1.0039	0.4739	0.8472
	3	1482.4446	29.9588	29.9588	33.1820	29.9585	33.1265	33.1284	527.7930	532.1788	536.9038	536.8300	534.3585	536.1327	532.8552	533.7538	533.8863	1.1856	-0.8892	0.8435	1.0130	1.0055	0.5895	0.8515
	4	1502.9345	29.9588	29.9591	33.1461	29.9595	33.1054	33.1277	531.3139	533.1087	536.9811	536.9020	534.3671	536.1643	535.4677	535.9440	535.3200	0.8623	-0.5266	0.8516	1.0130	1.0063	0.5832	0.8594
	5	2008.8776	29.9550	29.9546	34.8513	29.9544	34.8059	34.8329	530.8341	532.4829	537.2202	537.1768	533.4338	536.8558	536.8950	537.7089	537.4768	0.8836	-0.7988	0.8436	1.0241	1.0107	0.8356	0.9608
	6	2016.3596	29.9531	29.9527	34.8666	29.9520	34.8168	34.8552	531.0503	532.0171	537.2378	537.2132	533.4391	536.8550	536.0770	537.3714	536.9688	0.7006	-0.6366	0.8484	1.0240	1.0103	0.5992	0.4805
	7	2499.2816	29.9503	29.9498	34.8871	29.9489	34.8227	34.8189	531.2753	532.7430	537.8848	537.8558	532.3247	540.7903	539.4930	540.9118	540.8360	1.6768	-2.2319	1.1065	1.0389	1.0158	0.6947	1.1215
	8	2509.5489	29.9502	29.9498	34.8960	29.9490	34.8492	34.8487	532.0927	532.9545	537.9743	537.9251	532.4688	540.6567	540.0810	541.4389	541.2438	1.3993	-1.8406	0.9138	1.0386	1.0158	0.5907	0.9285
	9	3003.2288	29.9457	29.9454	35.7565	29.9440	35.6730	35.6639	537.1182	532.5415	538.2382	538.2028	530.7919	540.2577	543.2583	545.0161	544.7964	1.9750	-3.5207	1.2147	1.0553	1.0227	0.6827	1.2328
	10	2994.8191	29.9453	29.9446	35.7020	29.9440	35.6112	35.6334	531.5389	532.5514	538.3505	538.2802	530.8979	540.0956	542.5469	544.4272	544.5889	1.7022	-3.0304	1.0692	1.0553	1.0222	0.6892	1.0650
	11	3502.8274	29.9507	29.9506	37.5513	29.9490	37.4902	37.4830	531.5407	532.3300	538.6177	538.6054	528.8897	539.8638	546.3134	548.8763	549.1874	1.6102	-3.7536	0.9860	1.0775	1.0304	0.7081	0.9818
	12	3512.8603	29.9494	29.9498	37.8040	29.9488	37.5273	37.5174	531.5249	532.0048	538.5968	538.5930	528.8248	539.8139	546.6157	549.0543	549.2542	1.9597	-4.5950	1.1571	1.0775	1.0311	0.8028	1.1758
	13	4007.9899	29.9480	29.9481	39.5877	29.9483	39.5853	39.5965	532.1647	531.9837	538.7407	538.7706	526.3692	539.8815	550.8907	554.0776	554.5188	2.0641	-6.1359	1.2124	1.1025	1.0396	0.7132	1.2346
	14	4006.9728	29.9479	29.9476	39.7181	29.9484	39.5845	39.5893	531.8725	531.4038	538.7794	538.7618	528.4237	539.8995	550.9645	553.7685	554.3079	2.4584	-7.2648	1.4134	1.1031	1.0404	0.7038	1.4386
	15	4514.6364	29.9461	29.9458	39.6241	29.9434	39.4895	39.4458	531.7481	531.0485	538.8497	538.8444	523.4535	539.9905	556.0804	559.7852	560.6044	2.8722	-10.8043	1.6115	1.1315	1.0516	0.6962	1.6833
	16	4505.6213	29.9455	29.9453	39.8006	29.9437	39.4497	39.4610	531.4546	531.0520	539.9112	538.8989	523.5216	539.9940	555.9743	559.7975	560.6114	2.5451	-9.3966	1.4216	1.1314	1.0518	0.6927	1.4496
	17	4886.2469	29.9429	29.9430	41.8832	29.9408	41.4976	41.5125	529.8550	529.2769	539.0729	539.0975	520.5270	540.2471	559.0751	564.3049	565.1132	2.8833	-12.8463	1.6091	1.1634	1.0628	0.7034	1.6420
	18	5001.0844	29.9428	29.9428	41.8991	29.9405	41.5304	41.5304	530.5458	529.8282	539.2294	539.2294	520.0088	540.3790	560.1368	565.0411	565.8388	2.7976	-12.5031	1.5543	1.1633	1.0632	0.7008	1.5898
	19	5005.8918	29.9529	29.9529	36.9022	29.9520	36.8500	36.8460	533.7626	534.4747	538.3384	538.2645	531.9925	540.3755	545.1831	547.0747	548.9901	1.5867	-2.7483	0.9304	1.0559	1.0230	0.6793	0.9489
	20	2997.6321	29.9514	29.9507	36.9158	29.9499	36.8476	36.8348	533.0981	533.5604	539.1854	539.1538	531.9643	540.1364	544.4729	546.1727	546.1552	1.8761	-3.2443	1.1016	1.0552	1.0230	0.6727	1.1191

LP Cav closed HP Cav opened	Run #	RPM	PK	PL	Pin	Pin (Flange)	Pout (Flange)	Pout (Vena)	Tin CFF (2 o/c)	Tin CFF (11 o/c)	Tin TTR (8 o/c)	Tin TTR (5 o/c)	Tout TTR	Tin Orifice	Tout CFF (Bot)	Tout CFF (Mid)	Tout CFF (Top)	TTR Mass Flow (lbm/s)	Turbine Power (HP)	CFF Mass Flow (lbm/s)	Pi CFF	Tau CFF	CFF Efficiency	CFF Corrected Mass Flow
	1	1165.8748	29.938	29.9387	33.3451	29.952	33.304	33.338	528.138	529.99	534.884	534.786	532.982	540.047	531.4405	531.978	530.5845	0.5671	-0.2477	0.483	1.007	1.004	0.464	0.487
	2	1181.7539	29.937	29.9373	33.3263	29.946	33.318	33.316	524.942	526.878	535.434	534.58	536.732	528.969	530.105	530.1098	0.5884	-0.2699	0.483	1.007	1.004	0.466	0.487	
	3	1480.2403	29.934	29.934	33.2462	29.945	33.245	33.233	524.645	525.553	535.997	535.955	533.487	540.221	530.4528	531.259	530.8007	1.004	-0.5998	0.668	1.011	1.007	0.455	0.673
	4	1507.4355	29.934	29.9338	33.2802	29.95	33.211	33.226	525.45	530.161	536.299	536.229	533.715	540.813	530.3173	531.541	531.2641	0.8891	-0.4277	0.56	1.011	1.008	0.523	0.554
	5	1994.8335	29.929	29.9295	34.7826	29.929	34.754	34.758	527.617	531.11	536.612	536.508	533.045	539.395	534.2848	535.174	534.3339	1.0057	-0.8484	0.675	1.021	1.01	0.603	0.682
	6	2045.8894	29.93	29.9301	34.9381	29.93	34.883	34.884	527.157	530.047	538.726	538.652	533.081	540.038	533.3829	534.255	533.7802	1.5037	-1.3024	1.043	1.021	1.01	0.809	1.053
	7	2498.4778	29.927	29.9267	36.7642	29.926	36.763	36.757	528.871	531.21	537.37	537.305	532.381	541.448	536.4608	537.581	536.8493	1.6885	-1.298	0.76	1.034	1.013	0.73	0.789
	8	2501.6472	29.927	29.9262	36.8065	29.926	36.75	36.751	528.968	531.506	537.436	537.366	532.489	540.994	536.9987	538.222	537.2635	1.5553	-1.8411	1.057	1.034	1.014	0.696	1.07
	9	3003.349	29.925	29.9243	36.8762	29.924	36.818	36.811	527.58	529.793	537.523	537.407	530.794	536.876	538.3083	539.743	538.978	1.6794	-2.6887	1.085	1.05	1.02	0.72	1.088
	10	3004.6273	29.923	29.9224	36.8964	29.921	36.826	36.824	529.713	531.527	537.588	537.505	530.882	540.01	540.2823	541.72	540.5179	1.7728	-2.8353	1.156	1.05	1.019	0.732	1.172
	11	3510.9077	29.924	29.9238	36.7799	29.923	36.711	36.725	527.802	531.187	538.28	538.234	529.512	540.495	542.1333	544.666	543.6204	1.5807	-3.3428	0.996	1.07	1.026	0.739	1.01
	12	3517.886	29.924	29.9234	36.7823	29.922	36.726	36.735	528.5	531.989	538.549	538.47	528.72	541.376	544.6821	546.617	544.9054	1.4712	-3.1036	0.882	1.097	1.028	0.707	0.866
	13	3993.2387	29.922	29.9223	38.5937	29.92	38.495	38.495	531.175	531.895	538.748	538.693	527.732	541.188	548.103	551.028	548.7798	2.1119	-5.9899	1.275	1.091	1.034	0.738	1.297
	14	3988.6463	29.922	29.922	38.5751	29.92	38.485	38.485	531.885	532.174	538.648	538.618	527.884	540.511	550.3001	551.974	548.4228	2.0013	-5.2588	1.182	1.091	1.035	0.725	1.263
	15	4480.985	29.919	29.919	40.5907	29.916	40.48	40.475	528.648	530.125	538.662	538.653	525	540.488	551.7186	554.796	552.4796	2.3421	-7.6767	1.361	1.118	1.044	0.73	1.384
	16	4485.2245	29.918	29.9178	40.617	29.915	40.507	40.433	531.941	531.47	538.915	538.887	528.228	541.325	555.0288	557.194	553.9581	2.9509	-9.683	1.703	1.119	1.045	0.732	1.737
	17	5006.1008	29.92	29.9197	40.171	29.917	39.998	39.994	530.303	530.24	539.359	539.293	522.557	541.613	558.0714	561.362	558.3333	2.8786	-11.585	1.683	1.148	1.054	0.745	1.717
	18	5009.7283	29.914	29.9137	40.1033	29.912	39.969	39.988	529.147	529.767	539.402	539.374	522.625	541.581	567.1977	561.084	558.1979	2.3254	-8.3552	1.327	1.148	1.055	0.723	1.383

LP Cav opened HP Cav closed	Run #	RPM	Corrected Power (HP)	Corrected Speed (RPM)	X1	mdot1	X2	mdot2	X3	mdot3	Computed MA Mdot	Computed MA HP	Corrected Computed MA Mdot(lbm/s)	Corrected Computed MA HP	Pt_bar	Tt_bar	Mach Exit	Temp Exit	Velocity Exit	Corrected Thrust
	1	1042.3852	0.5833	1031.7516	0.0386	0.1334	0.0390	0.0771	0.0405	0.1403	0.3507	0.2174	0.3544	0.2148	30.1239	532.2636	0.0985	530.2339	33.9256	8.8018
	2	1083.8977	0.5880	1053.4166	0.0406	0.1406	0.0410	0.0809	0.0425	0.1472	0.3588	0.2552	0.3725	0.2523	30.1409	532.1319	0.1028	529.9028	35.2950	10.7181
	3	1482.4446	0.9742	1477.8910	0.0579	0.2003	0.0578	0.1144	0.0589	0.2039	0.5198	0.5950	0.5240	0.5884	30.3205	533.3652	0.1378	530.3399	47.4502	30.2824
	4	1502.8345	0.7353	1485.1639	0.0579	0.2001	0.0579	0.1142	0.0586	0.2026	0.5168	0.5798	0.5234	0.5722	30.3183	535.5157	0.1376	531.4918	47.4188	30.2224
	5	2038.6776	1.1167	1985.9587	0.0790	0.2734	0.0788	0.1557	0.0780	0.2700	0.6991	1.3399	0.7082	1.3241	30.6243	537.3038	0.1826	530.2307	62.8860	35.2476
	6	2016.3596	0.8904	1963.7879	0.0789	0.2730	0.0786	0.1553	0.0776	0.2686	0.6969	1.2805	0.7058	1.2656	30.6182	536.9461	0.1818	529.9373	62.5817	35.9612
	7	2498.2816	3.1236	2470.1963	0.1025	0.3549	0.0991	0.1960	0.0960	0.3323	0.8632	2.5002	0.8960	2.4730	31.0343	540.3475	0.2292	529.2313	78.8140	67.4262
	8	2509.5469	2.5746	2479.1352	0.1021	0.3535	0.0989	0.1955	0.0954	0.3303	0.8792	2.4841	0.8923	2.4556	31.0266	540.8567	0.2284	529.7981	78.5883	67.0309
	9	3003.2288	4.9319	2967.5275	0.1194	0.4139	0.1183	0.2341	0.1148	0.3980	1.0460	4.2544	1.0627	4.2119	31.4808	544.2803	0.2705	528.7828	92.9984	80.2704
	10	2984.8191	4.2464	2959.8704	0.1198	0.4154	0.1180	0.2337	0.1148	0.3981	1.0472	4.1710	1.0637	4.1308	31.4812	543.7776	0.2705	528.3101	92.9884	80.3169
	11	3502.6274	5.2685	3462.1102	0.1410	0.4886	0.1392	0.2761	0.1341	0.4682	1.2319	6.7310	1.2532	6.6770	32.0889	548.0300	0.3178	526.7529	109.0389	110.8044
	12	3512.8603	6.4507	3472.7813	0.1411	0.4900	0.1389	0.2754	0.1345	0.4673	1.2327	6.8831	1.2539	6.8290	32.0911	548.2115	0.3179	526.9068	109.1096	110.9383
	13	4007.9899	8.6274	3961.1097	0.1617	0.5628	0.1583	0.3145	0.1528	0.5314	1.4087	10.0323	1.4359	9.9691	32.7751	553.0517	0.3632	525.3320	124.4571	144.6444
	14	4006.9728	10.2479	3962.1012	0.1620	0.5639	0.1588	0.3154	0.1535	0.5344	1.4137	10.2635	1.4403	10.2039	32.7934	552.9234	0.3643	525.0471	124.8081	144.6444
	15	4514.6394	14.9498	4464.6697	0.1823	0.6399	0.1775	0.3535	0.1712	0.5971	1.5865	14.7109	1.6194	14.6571	33.5721	558.7117	0.4090	523.6754	139.6216	183.0234
	16	4505.6213	13.2503	4456.3596	0.1824	0.6361	0.1778	0.3540	0.1708	0.5958	1.5859	14.7707	1.6187	14.7203	33.5661	558.6877	0.4087	523.7048	139.8149	182.7927
	17	4986.2469	18.1862	4930.5817	0.1998	0.6963	0.1979	0.3957	0.1886	0.6608	1.7959	19.7264	1.7935	19.7364	34.4191	562.6584	0.4519	520.749	154.0761	222.6889
	18	5001.8442	17.6921	4951.8442	0.2002	0.7004	0.1977	0.3951	0.1893	0.6625	1.7987	19.9005	1.7967	19.9013	34.4362	563.4309	0.4527	520.465	154.4401	223.5777
	19	5009.8918	3.8433	2965.1251	0.1197	0.4140	0.1185	0.2341	0.1182	0.4021	1.0503	4.3954	1.0688	4.3046	31.4894	548.3038	0.2721	530.9915	93.7013	87.3441
	20	2997.8321	4.5400	2959.0818	0.1195	0.4136	0.1182	0.2337	0.1148	0.3977	1.0448	4.3242	1.0626	4.2767	31.4809	545.5189	0.2705	530.0050	93.1077	80.3621
LP Cav closed HP Cav opened																				
	1	1165.8749	0.3470	1155.5114	0.0382	0.1321	0.0415	0.0820	0.0434	0.1500	0.3642	0.2592	0.3878	0.2567	30.1192	531.1608	0.0974	529.1524	33.5003	10.0384
	2	1188.7539	0.3774	1181.0258	0.0400	0.1384	0.0435	0.0861	0.0456	0.1580	0.3825	0.2893	0.3857	0.2869	30.1357	529.6373	0.1014	527.4699	34.8012	10.9340
	3	1485.2403	0.8421	1478.7514	0.0514	0.1779	0.0547	0.1083	0.0567	0.1965	0.4828	0.6004	0.4888	0.5958	30.2538	530.7620	0.1260	527.4128	43.2607	17.1488
	4	1507.4355	0.6001	1495.8161	0.0511	0.1771	0.0541	0.1070	0.0564	0.1956	0.4797	0.5116	0.4841	0.5074	30.2493	530.9470	0.1251	527.6420	42.9748	16.9399
	5	1994.8335	1.1895	1976.5416	0.0701	0.2426	0.0747	0.1478	0.0751	0.2603	0.6507	1.1358	0.6580	1.1254	30.5144	534.5051	0.1679	528.5472	57.8991	30.8956
	6	2045.8894	1.8274	2028.5899	0.0704	0.2438	0.0749	0.1482	0.0757	0.2626	0.6547	1.1394	0.6616	1.1299	30.5189	533.7282	0.1685	527.7344	57.8753	31.1598
	7	2498.4178	1.8175	2473.9273	0.0899	0.3116	0.0942	0.1866	0.0939	0.3259	0.8240	1.9081	0.8346	1.8912	30.8662	536.8612	0.2114	527.4354	72.5748	49.2441
	8	2501.6472	2.5816	2476.6425	0.0901	0.3122	0.0937	0.1854	0.0940	0.3261	0.8236	1.9949	0.8343	1.9770	30.8663	537.3820	0.2114	527.9468	72.6168	49.2519
	9	3003.3490	3.7798	2977.7134	0.1089	0.3780	0.1156	0.2295	0.1130	0.3931	1.0006	3.4860	1.0132	3.4435	31.3113	538.8902	0.2556	525.1620	87.5858	72.0716
	10	3004.6273	3.9788	2973.5505	0.1092	0.3785	0.1157	0.2294	0.1134	0.3936	1.0015	3.4276	1.0161	3.3994	31.3152	540.7007	0.2560	526.8888	87.8522	72.4903
	11	3510.9077	4.7019	3478.2836	0.1302	0.4524	0.1350	0.2862	0.1325	0.4815	1.1821	5.5309	1.1985	5.4980	31.8640	543.2770	0.3012	524.2485	103.1194	130.3177
	12	3517.8880	4.3610	3481.0912	0.1304	0.4525	0.1351	0.2878	0.1323	0.4897	1.1890	5.7937	1.1992	5.7534	31.8603	545.2070	0.3010	526.1451	103.2998	130.3475
	13	3983.2387	7.8328	3948.9029	0.1474	0.5124	0.1537	0.3052	0.1500	0.5217	1.3393	8.1763	1.3638	8.1282	32.4391	549.4179	0.3418	524.8897	117.0734	139.2813
	14	3988.8462	7.3912	3942.1518	0.1474	0.5121	0.1535	0.3046	0.1500	0.5212	1.3379	8.3187	1.3632	8.2031	32.4386	550.3454	0.3418	525.7810	117.1588	139.1883
	15	4480.9850	10.8361	4449.2799	0.1664	0.5802	0.1739	0.3467	0.1682	0.5874	1.5143	11.9408	1.5421	11.9122	33.1615	552.7154	0.3862	521.6016	131.8595	164.3314
	16	4485.2245	13.5412	4444.1835	0.1669	0.5811	0.1747	0.3476	0.1686	0.5871	1.5157	12.0457	1.5469	11.9930	33.1798	555.1148	0.3872	523.7054	132.4816	165.6117
	17	5009.1008	16.3683	4997.5176	0.1848	0.6456	0.1931	0.3855	0.1870	0.6538	1.6849	16.2188	1.7209	16.1946	33.9628	558.9247	0.4304	520.3683	146.7823	203.7548
	19	5009.7263	13.2331	4963.3541	0.1844	0.6439	0.1925	0.3844	0.1869	0.6539	1.6822	16.5680	1.7185	16.5628	33.9637	558.4687	0.4294	520.1035	146.4177	202.8990

A2. TEST 2: TWO CAVITIES OPENED

Run #	RPM	Patm	Pcal	Pin TTR (5 o/c)	Pout TTR	Pin TTR (8 o/c)	Pin CFF (2 o/c)	Pin CFF (10 o/c)	Pout CFF (Top)	Pout CFF (Mid)	Pout CFF (Bot)	PA	PB	PC	PD	PE	PF	PG	PH	PI	PJ	PK	PL
1	2029.3788	29.90	39.90	30.1101	30.1427	31.5586	29.8566	29.8297	30.5909	30.6524	30.6294	29.7676	29.0600	29.3215	29.6497	29.8573	29.7837	29.5992	29.5701	29.6572	29.9546	29.8911	29.8868
2	2031.1444	29.90	39.90	30.1357	30.1471	31.5559	29.8592	29.8295	30.5997	30.6573	30.6330	29.7671	29.0631	29.3170	29.6486	29.8585	29.7830	29.6000	29.5693	29.6606	29.9549	29.8912	29.8869
3	2024.6127	29.90	39.90	30.1514	30.1392	31.5212	29.8584	29.8304	30.5791	30.6354	30.6278	29.7926	29.1075	29.3319	29.6544	29.8574	29.7824	29.6054	29.5732	29.6836	29.9516	29.8867	29.8820
4	2023.8887	29.90	39.90	30.1554	30.1586	31.5159	29.8587	29.8306	30.5899	30.6435	30.6179	29.7924	29.0996	29.3264	29.6516	29.8580	29.7814	29.6016	29.5738	29.6832	29.9543	29.8872	29.8829
5	2017.2069	29.90	39.90	30.1622	30.1356	31.4286	29.8599	29.8335	30.5786	30.6381	30.6287	29.8650	29.1968	29.4114	29.7044	29.8821	29.7881	29.6446	29.6181	29.7218	29.9817	29.8638	29.8796
6	2029.0412	29.90	39.90	30.1722	30.1356	31.4275	29.8608	29.8360	30.5757	30.6427	30.6282	29.8668	29.1994	29.4146	29.7042	29.8852	29.7908	29.6436	29.6190	29.7281	29.9857	29.8863	29.8823
7	2039.0132	29.90	39.90	30.1946	30.0986	31.1386	29.8546	29.8560	30.6328	30.6722	30.0982	29.5356	29.6818	29.8342	29.9209	29.8238	29.7951	29.7669	29.8639	30.0682	29.8844	29.8812	
8	2050.2728	29.90	39.90	30.2014	30.0816	31.1401	29.8724	29.8546	30.6649	30.6270	30.5955	30.0986	29.5377	29.6807	29.8342	29.9219	29.8208	29.7943	29.7670	29.8618	30.0676	29.8837	29.8803
9	2022.0812	29.90	39.90	30.2008	29.9751	30.6070	29.8606	29.8881	30.0949	30.5915	30.6968	30.0430	29.3907	29.4980	29.8778	29.5018	29.4791	29.5706	29.6788	29.8611	29.8769		
10	2039.4846	29.90	39.90	30.2039	29.9785	30.6062	29.8628	29.8910	30.0923	30.5989	30.6920	30.0497	29.4586	29.3465	29.3967	29.4953	29.8606	29.5037	29.4743	29.5637	29.7991	29.8665	29.8633
11	2025.8842	30.00	39.97	30.0802	30.2057	31.3467	29.9430	29.9534	30.6489	30.7101	30.6992	30.0677	29.4450	29.8572	29.9170	30.0743	29.8678	29.8144	29.7851	29.9420	30.1164	29.9731	29.9661
12	2040.0390	30.00	39.97	30.0834	30.2072	31.3480	29.9438	29.9228	30.6610	30.7241	30.6954	30.0691	29.4394	29.8594	29.9162	30.0760	29.8606	29.8169	29.8440	30.1191	29.9783	29.9706	
13	2042.9378	30.00	39.97	30.0872	30.1376	31.0997	29.9548	29.9412	30.6008	30.6926	30.6221	30.2630	29.7560	29.8721	29.8809	30.0518	29.8233	29.8874	29.8604	30.0963	30.1700	29.9813	29.9724
14	2018.0821	30.00	39.97	30.0904	30.1399	31.0683	29.9542	29.9400	30.6025	30.6962	30.6249	30.2648	29.7531	29.8703	29.8691	30.0532	29.8216	29.8892	29.8692	30.1076	29.9813	29.9734	
15	2035.8841	30.00	39.97	30.0445	30.0628	30.7049	29.9638	29.9622	30.3048	30.3493	30.3170	30.1775	29.8637	29.5872	29.6035	29.6349	29.6000	29.6440	29.6191	29.7235	29.8625	29.8713	29.8646
16	2034.8228	30.00	39.97	30.0493	30.0624	30.7038	29.9634	29.9627	30.2990	30.3389	30.3118	30.1756	29.8629	29.6006	29.6056	29.6388	29.6027	29.6471	29.6122	29.7229	29.8649	29.8751	29.8728
1	3033.7813	29.90	39.90	30.2586	30.5488	33.3624	29.8149	29.7518	31.5697	31.6077	31.5942	29.6581	28.0120	28.5480	29.3034	29.7788	29.6444	29.2164	29.1557	29.2684	30.0148	29.8922	29.8839
2	3036.3914	29.90	39.90	30.2683	30.5426	33.3573	29.8142	29.7487	31.5644	31.6014	31.6011	29.6570	27.9985	28.5427	29.3006	29.7762	29.6437	29.2101	29.1525	29.2657	30.0174	29.8905	29.8827
3	3021.0875	29.90	39.90	30.2793	30.5308	33.3017	29.8150	29.7514	31.5408	31.6578	31.5576	29.6545	28.0566	28.5779	29.3202	29.7883	29.6460	29.2269	29.1689	29.2845	30.0193	29.8676	29.8792
4	3018.5339	29.90	39.90	30.2880	30.5331	33.3013	29.8156	29.7508	31.5538	31.6571	31.5707	29.6756	28.0591	28.5815	29.3233	29.7883	29.6490	29.2298	29.1730	29.1818	30.0189	29.8885	29.8809
5	3018.8884	29.90	39.90	30.3016	30.4738	33.2877	29.8214	29.7644	31.5108	31.6472	31.6809	29.6449	28.0697	28.5934	29.3344	29.8444	29.6655	29.3267	29.2699	29.3032	30.0668	29.8849	29.8769
6	3012.2148	29.90	39.90	30.3107	30.4755	33.0625	29.8220	29.7632	31.5105	31.6378	31.5851	29.6447	28.0692	28.7738	29.4365	29.6477	29.6666	29.3311	29.2689	29.3014	30.0660	29.8864	29.8760
11	3022.7007	30.00	39.97	30.1345	30.4737	32.8591	29.8664	31.5589	31.6788	31.5788	30.1929	28.0884	28.2105	28.6347	30.1678	29.7843	29.6787	29.5058	29.3074	30.0210	29.8623	29.8600	
12	3063.6633	30.00	39.97	30.1262	30.4796	32.8776	29.9102	29.8624	31.5581	31.7378	31.5788	30.1945	28.7051	29.2135	29.6394	30.2066	29.7875	29.5832	29.3213	29.7736	30.0752	29.8636	29.8642
17	2995.3872	29.90	39.90	30.3350	30.2913	32.3805	29.8455	29.8066	31.3672	31.6087	31.3882	30.3493	29.0567	29.3849	29.7517	29.9487	29.7369	29.6572	29.6923	30.0263	29.8850	29.8850	29.8850
18	3003.2888	29.90	39.90	30.3416	30.2927	32.3829	29.8471	29.8056	31.3678	31.5957	31.4048	30.3489	29.0644	29.3878	29.7550	29.9495	29.7371	29.6558	29.5982	29.7946	30.0729	29.8851	29.8788
19	3019.8997	29.90	39.97	30.3193	30.3135	32.1746	29.8999	29.8999	31.4521	31.6410	31.4509	30.6149	29.4211	29.7043	30.0060	30.1599	29.8481	29.9608	29.8927	30.1947	30.0400	29.9753	29.9598
14	3020.1141	30.00	39.97	30.1185	30.3199	32.2021	29.9329	29.8990	31.4786	31.6333	31.4569	30.6278	29.4157	29.7053	30.0150	30.1768	29.8517	29.9646	29.8967	30.0205	30.0419	29.9626	29.9656
15	3012.3599	30.00	39.97	30.0949	30.3261	32.1321	29.9557	29.9551	30.7474	30.8317	30.7557	30.4563	29.2452	29.6810	29.1046	29.1883	29.9441	29.1834	29.9990	29.1488	29.9206	29.9639	29.9628
16	3024.3620	30.00	39.97	30.0998	30.3273	32.1304	29.9573	29.9534	30.7504	30.8363	30.7642	30.4515	29.2454	29.6780	29.0921	29.1890	29.9494	29.1679	29.1230	29.1428	29.9247	29.9711	29.9692
9	3011.6294	29.90	39.90	30.3367	30.2727	32.1291	29.8684	29.8695	30.4903	30.4982	30.3844	30.2709	29.0968	29.7926	28.8716	29.0466	29.8766	29.0248	29.0244	29.9764	29.8770	29.8770	29.8770
10	3012.1845	29.90	39.90	30.3356	30.0286	31.1222	29.8880	29.8847	30.4014	30.4160	30.3882	30.2767	29.0004	28.7892	28.8701	29.0464	29.8752	29.0953	29.0932	29.2122	29.7137	29.8630	29.8605
1	4022.8504	29.80	39.90	30.3482	30.9930	35.8372	29.7561	29.6421	32.9367	33.1907	32.9592	29.5176	28.8596	27.4998	28.7768	29.6153	29.4750	28.6988	28.8959	28.7492	30.1131	29.8982	29.8776
2	4029.7130	29.80	39.90	30.3613	30.9986	35.8360	29.7569	29.6418	32.9338	33.1847	32.9044	29.5197	28.8602	27.4876	28.7761	29.6233	29.4756	28.7030	28.8920	28.7707	30.1208	29.8914	29.8814
3	4015.7859	29.80	39.90	30.3744	30.9928	35.7835	29.7574	29.6450	32.9300	33.1881	32.9154	29.5432	28.8472	27.5051	28.7690	29.6337	29.4762	28.7168	28.6103	29.7875	30.1226	29.8903	29.8807
4	4014.2771	29.80	39.90	30.3838	30.9941	35.7897	29.7566	29.6530	32.9291	33.1883	32.9317	29.5457	28.8406	27.5021	28.7683	29.6375	29.4781	28.7272	28.6197	29.7894	30.1269	29.8926	29.8827
5	4016.2107	29.80	39.90	30.3968	30.9989	35.4530	29.7577	29.6673	32.8848	33.1952	32.8867	29.5170	27.5118	27.8168	28.6820	29.7388	29.6092	29.6890	28.6029	29.8869	30.1269	29.8869	29.8781
6	4017.1889	29.80	39.90	30.4086	30.9993	35.4592	29.7678	29.6665	32.8715	33.0993	32.8907	29.5224	27.5115	27.8188	28.6903	29.7418	29.5139	28.6780	28.7716	29.8534	30.1246	29.8907	29.8809
7	4013.7813	29.80	39.90	30.4287	30.9920	32.7773	29.8065	29.7310	32.7133	33.0077	32.9619	29.7188	28.5920	28.8864	29.5638	29.6367	29.6133	29.4863	29.6259	30.0510	29.8623	29.8776	
8	4005.6616	29.80	39.90	30.4393	30.9951	32.7914	29.8083	29.7352	32.7305	33.0002	32.9586	29.7230	28.5900	28.8900	29.5569	29.6340	29.6195	29.4460	29.3443	29.6283	30.0594	29.8909	29.8815
9	4006.0352	29.80	39.90	30.4352	30.6063	31.8303	29.8939	29.8777	30.8280	30.8339	30.8014	30.6010	29.2958	27.9795	28.1006	28.4061	29.6804	29.4819	29.3003	29.6305	29.9793	29.8798	29.8786
10	4017.3823	29.80	39.90	30.4304	30.0902	31.8203	29.8859	29.8800	30.8093	30.8289	30.7926	30.6074	28.1132	27.9965	28.1062	28.4297	29.6849	29.5000	29.3874	28.6221	29.9560	29.8939	29.8928
11	4044.7300	29.87	39.97	30.1456	30.6517	35.0549	29.8652	29.7782	32.9547	33.1968	32.8266	29.3879	27.7185	27.9990	29.								

Run #	RPM	Pnoz1	Pnoz2	Pnoz3	Pin	Pin (Flange)	Pout (Flange)	Pout (Vena)	Tin CFF (2 o/c)	Tin CFF (11 o/c)	Tin TTR (8 o/c)	Tin TTR (5 o/c)	Tout TTR	Tin Orifice	Tout CFF (Bot)	Tout CFF (Mid)	Tout CFF (Top)	TTR Mass Flow (lbm/s)	Turbine Power (HP)	CFF Mass Flow (lbm/s)	PI CFF	Tau CFF	CFF Efficiency
1	2023.3789	29.8438	29.8508	29.8371	35.3611	29.8878	35.3151	35.3178	532.1659	532.8710	535.8891	535.5432	531.1891	540.1610	538.2345	539.2030	538.1387	1.5505	-1.4315	0.9713	1.0281	1.0115	0.8419
2	2031.1441	29.8432	29.8513	29.8378	35.3407	29.8878	35.3002	35.2841	532.5978	532.8749	535.5070	535.8283	531.4885	538.0800	538.4886	538.4176	538.3735	1.4008	-1.4737	0.9867	1.0283	1.0116	0.8446
3	2034.6127	29.8385	29.8463	29.8337	35.2289	29.8816	35.1612	35.1836	533.2887	533.2184	538.8739	538.7496	532.4583	540.2788	538.8408	538.6671	538.8231	1.3475	-1.4072	0.9577	1.0258	1.0115	0.8330
4	2031.8887	29.8395	29.8465	29.8332	35.2045	29.8810	35.1700	35.1675	533.3354	533.2721	538.8651	538.7649	532.4917	538.4737	538.0051	538.7339	538.8055	1.2503	-1.2974	0.8797	1.0259	1.0115	0.8330
5	2017.2088	29.8423	29.8477	29.8343	34.9247	29.8797	34.8659	34.8883	533.4761	533.4708	537.4680	537.3766	533.1855	541.3782	539.0588	538.8077	538.5264	1.2144	-1.2337	0.8880	1.0257	1.0112	0.8485
6	2028.5412	29.8428	29.8494	29.8363	34.9436	29.8816	34.9108	34.8965	533.5358	533.5300	537.5630	537.4655	533.2511	541.0751	539.3087	540.0626	538.7866	1.3970	-1.4268	0.8694	1.0257	1.0115	0.8331
7	2036.0732	29.8546	29.8586	29.8503	33.9577	29.8806	33.9206	33.9262	533.6290	533.7028	537.7335	537.6421	534.0421	540.8145	538.7287	539.6600	538.9604	1.0219	-0.8841	0.6673	1.0242	1.0105	0.8683
8	2050.2728	29.8541	29.8574	29.8485	33.8776	29.8799	33.8241	33.8286	533.6732	533.4022	537.9444	537.8337	534.1968	541.5128	538.8053	539.2804	538.6386	1.3906	-1.2324	0.9506	1.0244	1.0101	0.8625
9	2022.0812	29.8760	29.8753	29.8740	33.1054	29.8764	33.0827	33.0998	534.0880	534.1809	537.9190	537.8354	535.0168	541.1841	538.1046	538.0641	538.1835	0.9964	-0.3378	0.3026	1.0067	1.0087	0.2205
10	2039.4848	29.8812	29.8802	29.8788	33.1148	29.8813	33.0841	33.1163	534.0104	534.1177	537.9719	537.9128	535.8854	541.4636	538.1485	538.1204	538.2679	0.1880	-0.1068	0.0931	1.0067	1.0090	0.2149
11	2025.8842	29.9357	29.9425	29.9307	33.3488	29.9680	33.3093	33.2881	534.9964	535.1511	538.3624	538.2850	532.3001	540.6128	531.4721	532.1384	531.3948	1.5708	-1.5189	0.9584	1.0250	1.0126	0.5646
12	2040.0363	29.9404	29.9453	29.9352	33.3090	29.9723	33.2789	33.2638	534.2689	534.5639	538.2182	538.0979	538.5300	530.3275	531.1804	530.5721	1.5431	-1.3395	0.8890	1.0253	1.0120	0.5662	
13	2022.9376	29.9549	29.9583	29.9502	33.4775	29.9594	33.4509	33.4363	534.1579	534.8208	538.1075	538.0372	532.8024	541.2544	530.1960	530.7286	529.7214	1.2817	-1.0674	0.7767	1.0231	1.0109	0.5664
14	2018.0821	29.9548	29.9579	29.9500	33.4710	29.9590	33.4333	33.4760	534.0502	534.9335	538.6632	538.5837	532.4319	540.1698	538.4013	529.1132	528.8544	0.4802	-0.3829	0.3204	1.0233	1.0093	0.6930
15	2005.8841	29.9630	29.9648	29.9630	33.8717	29.9701	33.8713	33.8764	532.7657	532.9837	538.6100	538.5397	532.9487	540.3139	527.0618	527.4825	526.9458	0.4470	-0.2817	0.2715	1.0120	1.0086	0.4812
16	2034.8228	29.9678	29.9687	29.9676	33.7611	29.9740	33.7433	33.7670	532.8993	532.9210	538.6103	538.5731	532.9476	540.8976	527.5417	527.9091	527.1813	1.1730	-0.7433	0.6607	1.0118	1.0086	0.3716
1	2033.7813	29.7857	29.8047	29.7703	39.3099	29.8846	39.2394	39.2105	533.9882	533.7520	538.9112	538.8743	530.2982	541.1102	548.2079	548.2482	548.3190	2.0315	-4.1914	1.2719	1.0613	1.0057	0.6671
2	2036.3914	29.7838	29.8022	29.7697	39.3071	29.8856	39.2502	39.2438	534.1071	533.9331	538.9341	538.8600	530.2382	540.8251	548.4048	548.2856	548.4421	1.7143	-3.5644	1.0848	1.0617	1.0056	0.6729
3	2021.0875	29.7822	29.7994	29.7669	39.3110	29.8796	39.0851	39.0883	534.3110	534.0598	538.7231	538.6887	530.2979	538.7381	548.5471	548.3454	548.4192	1.7042	-4.4392	1.0546	1.0605	1.0054	0.6658
4	2018.5339	29.7829	29.8017	29.7711	39.1761	29.8819	39.0805	39.0799	534.1704	533.8223	538.9112	538.8444	530.3685	540.8486	548.0550	548.1292	548.2888	2.1784	-4.4499	1.3746	1.0608	1.0053	0.6732
5	2018.8864	29.7884	29.8046	29.7601	38.9391	29.8784	38.9270	38.9391	534.2970	533.9419	538.2268	538.2206	531.0766	541.7009	548.1383	547.9675	547.8725	1.6800	-3.2836	1.0391	1.0600	1.0047	0.6793
6	2012.2148	29.7893	29.8067	29.7799	38.9574	29.8791	38.9331	38.9505	534.5114	534.2003	538.1797	538.1397	531.0593	541.1948	548.5438	548.2839	548.1309	1.8826	-3.8880	1.1857	1.0599	1.0049	0.6737
11	2022.7070	29.8889	29.9071	29.8750	33.5559	29.9599	33.5559	33.5524	534.1614	534.1614	537.2554	537.1799	529.4014	541.5163	534.5800	537.1675	537.2747	1.4487	-2.7138	0.9017	1.0595	1.0039	0.6680
12	2031.6633	29.8931	29.9098	29.8761	33.5174	29.9635	33.5648	33.6456	534.0766	534.3524	537.0002	538.9565	528.9986	538.8688	537.3854	540.1188	538.4948	1.0900	-2.0506	0.6580	1.0592	1.0047	0.6590
17	2095.3072	29.8193	29.8307	29.8107	36.7030	29.8642	36.6656	36.6442	534.7614	534.1721	538.9271	538.7319	531.5485	538.6108	545.6980	546.9801	548.8897	1.2716	-2.0912	0.7372	1.0562	1.0021	0.6639
18	2011.2885	29.8208	29.8297	29.8110	36.7058	29.8618	36.6544	36.6700	534.5345	534.1915	538.0483	538.1622	532.0962	540.8021	545.4432	546.9321	545.7087	2.2548	-2.1096	0.7653	1.0561	1.0021	0.7036
13	2010.8997	29.9158	29.9251	29.9081	35.6548	29.9602	35.4008	35.4254	534.3145	534.3145	538.7772	538.7772	530.1802	540.5613	538.8471	538.2182	538.8085	2.5572	-1.9600	0.7117	1.0535	1.0044	0.7711
14	2020.1141	29.9210	29.9302	29.9127	33.4271	29.9656	33.4164	33.4034	534.0398	534.5328	537.0625	538.6186	530.3454	541.5288	538.5488	538.9794	538.8598	1.4550	-2.3386	0.8426	1.0542	1.0020	0.6881
15	2012.3509	29.9493	29.9512	29.9487	33.2855	29.9609	33.2461	33.2343	533.4485	534.4864	536.3030	536.2633	537.8764	538.6500	532.2596	532.9674	531.9802	1.4372	-1.5292	0.7735	1.0275	1.0157	0.4992
16	2034.3620	29.9554	29.9586	29.9544	33.2761	29.9688	33.2820	33.2761	531.8759	532.0388	536.2688	536.2622	537.8852	542.2955	530.5792	531.4389	530.5687	0.9127	-0.0668	0.5792	1.0277	1.0163	0.7490
9	2011.6704	29.8991	29.8990	29.8960	33.2239	29.8704	33.1542	33.1771	534.9403	534.6985	538.9745	538.9323	535.1091	541.3264	544.7981	544.7911	543.8327	1.3995	-1.2543	0.5451	1.0172	1.0179	0.2720
10	2012.1845	29.8745	29.8750	29.8717	33.2152	29.8761	33.2043	33.1670	535.0686	534.9122	538.8708	538.8005	535.0071	540.8923	544.9194	544.9563	543.7364	1.3786	-1.2867	0.5929	1.0172	1.0178	0.2742
1	4022.8504	29.7089	29.7399	29.6867	42.8081	29.8777	42.4606	42.4955	534.1405	533.5283	538.1221	539.1643	525.0403	540.4897	555.1112	558.4511	558.9011	2.3721	-8.0289	1.1442	1.1113	1.0443	0.6970
2	4025.7130	29.7109	29.7424	29.6901	42.8828	29.8828	42.4885	42.5091	534.2705	533.7415	538.6354	539.5774	525.3796	541.8977	555.8073	558.8817	559.9536	2.5884	-8.8739	1.5287	1.1116	1.0451	0.6604
3	4015.7959	29.7129	29.7405	29.6923	42.5396	29.8807	42.3829	42.3761	534.3487	533.7892	538.6354	539.8182	525.7329	542.0718	555.4487	558.6479	559.3792	2.7401	-9.2769	1.6271	1.1111	1.0445	0.6629
4	4006.2771	29.7140	29.7402	29.6919	42.3656	29.8825	42.3645	42.3582	534.3971	533.7643	538.7673	539.7708	525.8854	541.5288	555.3169	558.6620	559.0083	2.5208	-8.5375	1.5085	1.1112	1.0442	0.6620
5	4014.2107	29.7244	29.7438	29.7074	41.7156	29.8800	41.6849	41.7156	534.4486	533.9768	538.8485	538.4885	526.1005	540.6462	555.3626	558.6497	558.5161	2.2875	-7.3642	1.3199	1.1087	1.0435	0.6874
6	4007.1889	29.7253	29.7502	29.7085	41.8574	29.8837	41.7010	41.6884	534.4486	534.0087	538.3208	538.2716	525.9122	540.2955	555.5577	558.7185	558.6163	2.8660	-9.2062	1.6426	1.1089	1.0437	0.6869
7	4013.7813	29.7695	29.7910	29.7548	39.9037	29.8840	39.3850	39.4078	534.5331	534.2161	538.5047	538.2618	541.8569	545.4955	556.9798	555.2782	542.1009	1.9352	-1.7422	1.1042	1.1009	1.0394	0.7003
8	4005.8618	29.7744	29.7927	29.7603	39.9073	29.8801	39.4014	39.4019	535.0071	534.3550	538.9077	538.7938	528.1378	542.2827	554.6411	556.9411	555.1516	2.2074	-8.1787	1.2319	1.1016	1.0391	0.7171
9	4006.0632	29.7884	29.8064	29.7681	35.8771	29.8851	35.8851	35.8847	535.1555	535.2005	538.6688	538.5405	533.8325	541.1278	552.2882	552.4288	550.5233	0.7354	-1.0556	0.2887	1.0315	1.0308	0.2698
10	4017.3823	29.8729	29.8738	29.8707	35.8184	29.8786	35.8500	35.8449	536.8944	536.3341	538.5300	538.456											

Run #	RPM	CFF Corrected Mass Flow (lbm/s)	Corrected Power (HP)	Corrected Speed (RPM)	X1	mdot1	X2	mdot2	X3	mdot3	Computed MA Mdot	Computed MA Power (hp)	Corrected Computed MA Mdot(kg/s)	Corrected Computed MA HP	Tbar Out	Ptbar Out	Pt_bar	Tt_bar	Mach Exit	Temp Exit	Velocity Exit (m/s)	Corrected Thrust (lbf/12inch span)	M_dot_Inlet	Corrected Computed MA Mdot(lbm/s)
1	2025.3788	0.9859	2.0038	2004.4287	0.0670	0.2991	0.0902	0.1773	0.0891	0.3065	0.7829	1.9625	0.7954	1.9414	538.7997	30.6199	30.6199	538.7997	0.1988	530.4144	68.4517	53.0300	0.9385	0.9535
2	2031.1444	1.0119	2.0624	2005.7623	0.0875	0.3008	0.0905	0.1779	0.0893	0.3071	0.7858	1.9705	0.7885	1.9488	539.0420	30.6258	30.6258	539.0420	0.1996	530.5897	68.7246	53.2462	0.9383	0.9535
3	2024.6127	0.9726	1.9688	1998.7157	0.0861	0.2959	0.0891	0.1750	0.0887	0.3051	0.7780	2.0354	0.7688	2.0125	539.3255	30.6110	30.6110	539.3255	0.1971	531.0699	67.9203	54.6880	0.9745	0.9606
4	2023.8889	0.8834	1.8150	1997.9088	0.0897	0.2880	0.0895	0.1769	0.0882	0.3033	0.7771	2.0489	0.7600	2.0258	539.4066	30.6130	30.6130	539.4066	0.1974	531.1220	68.0152	54.8732	0.9768	0.9629
5	2017.2089	0.8715	1.7255	1990.9951	0.0819	0.2818	0.0853	0.1678	0.0848	0.2921	0.7417	1.9712	0.7541	1.9485	539.4060	30.6110	30.6110	539.4060	0.1881	531.8805	64.8472	51.7314	0.9667	0.9817
6	2028.0412	0.9846	1.9953	2001.4786	0.0817	0.2813	0.0854	0.1681	0.0847	0.2918	0.7409	1.9832	0.7533	1.9600	539.6603	30.6116	30.6116	539.6603	0.1879	532.1438	64.8088	50.8022	0.9488	0.9648
7	2039.0132	0.9775	1.2495	2012.1561	0.0659	0.2283	0.0708	0.1401	0.0687	0.2311	0.5995	1.8075	0.6092	1.5877	539.1876	30.5820	30.5820	539.1876	0.1511	534.3079	52.2184	36.5190	0.8454	0.8601
8	2050.2728	0.9650	1.7227	2023.5674	0.0662	0.2293	0.0704	0.1394	0.0676	0.2343	0.6029	1.5755	0.6126	1.5564	538.8533	30.5872	30.5872	538.8533	0.1518	533.9291	52.4961	37.1374	0.8570	0.8708
9	2022.0812	0.5071	0.4715	1984.5736	0.0220	0.0758	0.0215	0.0422	0.0204	0.0702	0.1882	0.9851	0.1812	0.9747	538.7246	30.5907	30.5907	538.7246	0.0476	538.0384	16.5170	8.5484	0.8280	0.8359
10	2038.4486	0.0544	0.1491	2017.8705	0.0201	0.0682	0.0218	0.0425	0.0195	0.0673	0.1750	0.9115	0.1818	0.8955	538.8012	30.5930	30.5930	538.8012	0.0453	538.3590	15.1784	7.2751	0.5607	0.5687
11	2025.8862	0.9629	2.1323	2015.4809	0.0730	0.2576	0.0778	0.1546	0.0763	0.2883	0.8785	2.2225	0.8824	2.2080	531.5943	30.6787	30.6787	531.5943	0.1998	525.3359	58.1957	47.1491	0.9071	1.0070
12	2040.0393	0.8927	1.6842	2030.8469	0.0745	0.2601	0.0783	0.1563	0.0760	0.2856	0.8820	2.0450	0.8854	2.0329	530.6164	30.6851	30.6851	530.6164	0.1705	524.5207	58.3657	46.3461	0.9895	0.9744
13	2022.9378	0.7795	1.5005	1993.7721	0.0511	0.2302	0.0641	0.1285	0.0588	0.2652	0.5349	1.6282	0.5374	1.6177	530.7463	30.6310	30.6310	530.7463	0.1333	525.4039	45.7299	31.7074	0.8485	0.8504
14	2018.0821	0.3213	0.5387	2010.2777	0.0511	0.2004	0.0644	0.1292	0.0593	0.2682	0.5378	1.4715	0.5399	1.4054	528.6666	30.6361	30.6361	528.6666	0.1339	524.9038	45.8339	31.8008	0.8706	0.8766
15	2005.8841	0.2740	0.3965	1999.7853	0.0347	0.1213	0.0402	0.0805	0.0303	0.1270	0.3288	1.0625	0.3296	1.0866	527.1244	30.3204	30.3204	527.1244	0.0822	525.7049	28.1639	17.4506	0.7576	0.7596
16	2034.8228	0.6919	1.0458	2028.2764	0.0541	0.1194	0.0393	0.0785	0.0359	0.1254	0.3233	1.0654	0.3242	1.0624	527.4977	30.3136	30.3136	527.4977	0.0808	526.1244	27.7022	16.7495	0.7094	0.7113
1	3033.7813	1.2950	5.8726	2993.2768	0.1330	0.4580	0.1362	0.2671	0.1338	0.4598	1.1829	8.2693	1.2055	8.2080	547.4818	31.8014	31.8014	547.4818	0.3025	528.1528	103.9274	114.5945	1.3343	1.3598
2	3036.3914	1.0148	4.9938	2995.4033	0.1329	0.4554	0.1370	0.2688	0.1341	0.4608	1.1848	8.3048	1.2077	8.2428	547.8145	31.8075	31.8075	547.8145	0.3030	528.2130	104.1223	115.8820	1.3442	1.3703
3	3024.6127	0.9726	4.8173	2979.8450	0.1314	0.4507	0.1353	0.2654	0.1320	0.4534	1.1895	8.2948	1.1923	8.2314	547.6787	31.8738	31.8738	547.6787	0.2990	528.6333	102.8400	116.3522	1.3788	1.3788
4	3018.5330	1.3598	6.2341	2977.8531	0.1318	0.4521	0.1353	0.2654	0.1324	0.4551	1.1725	8.2651	1.1952	8.1430	547.3784	31.8837	31.8837	547.3784	0.2997	528.9309	102.9975	114.1488	1.3441	1.3700
5	3018.8886	1.0576	4.8121	2977.8596	0.1311	0.4273	0.1285	0.2539	0.1285	0.4376	1.1188	8.2057	1.4001	8.8912	547.2182	31.8715	31.8715	547.2182	0.2846	530.0448	97.5553	106.8890	1.3176	1.3426
6	3012.2148	1.1789	5.1634	2970.6194	0.1281	0.4272	0.1285	0.2532	0.1287	0.4372	1.1176	8.5937	1.1392	8.8712	547.5448	31.8685	31.8685	547.5448	0.2844	530.3883	97.9123	105.9955	1.3041	1.3293
7	3022.7007	0.9063	3.8257	3010.8740	0.1121	0.3851	0.1196	0.2405	0.1129	0.3970	1.0306	5.5780	1.0369	5.5574	536.2117	31.6132	31.6132	536.2117	0.2571	522.3992	87.8539	94.9120	1.3198	1.3270
8	3063.6633	0.9844	3.6445	3045.2175	0.1120	0.3820	0.1189	0.2381	0.1128	0.3959	1.0280	5.6866	1.0344	5.6234	536.8257	31.6092	31.6092	536.8257	0.2565	525.0091	87.8671	93.2707	1.2940	1.3046
9	2995.3872	0.7499	2.9245	2955.9732	0.0968	0.3377	0.1075	0.2144	0.0978	0.3412	0.8933	4.5279	0.9096	4.4751	546.0813	31.4332	31.4332	546.0813	0.2245	535.2633	77.6419	72.5693	1.1223	1.1427
10	3003.2888	0.7984	2.9444	2961.6584	0.0969	0.3379	0.1069	0.2133	0.0986	0.3441	0.8953	4.4304	0.9116	4.3784	545.8952	31.4363	31.4363	545.8952	0.2248	535.0062	77.7497	71.9593	1.1193	1.1397
11	3010.8997	0.8182	2.7984	2954.6888	0.0876	0.3106	0.0968	0.1963	0.0876	0.3108	0.8175	3.9576	0.8229	3.9332	535.4649	31.4970	31.4970	535.4649	0.2018	528.8783	89.2688	85.1647	1.1476	1.1551
12	3020.1141	0.8467	3.2510	3006.0712	0.0883	0.3131	0.0972	0.1971	0.0877	0.3110	0.8213	4.3365	0.8260	4.3128	536.0705	31.5185	31.5185	536.0705	0.2028	529.0687	89.6161	86.4770	1.1130	1.1164
13	3012.3509	0.7160	2.1499	2986.4735	0.0521	0.1834	0.0591	0.1189	0.0528	0.1880	0.4883	2.4687	0.4903	2.4508	532.3319	30.7711	30.7711	532.3319	0.1213	528.2174	41.7173	30.3856	0.8885	0.8931
14	3024.3620	0.5221	1.5024	3016.8243	0.0528	0.1851	0.0581	0.1210	0.0540	0.1904	0.4974	2.3823	0.4988	2.3711	530.8330	30.7773	30.7773	530.8330	0.1234	527.8183	42.3700	28.7699	0.8707	0.8727
15	3011.8704	0.5537	1.7500	2968.7937	0.0390	0.1208	0.0360	0.0711	0.0328	0.1131	0.3050	2.3227	0.3101	2.2902	544.3348	30.3962	30.3962	544.3348	0.0770	543.0467	26.8284	14.7136	0.7095	0.7213
16	3012.8616	0.5816	1.7688	2968.8273	0.0392	0.1184	0.0362	0.0714	0.0328	0.1116	0.3017	2.3594	0.3067	2.3305	544.4639	30.4000	30.4000	544.4639	0.0762	543.2025	26.4886	14.1748	0.6428	0.6535
1	4022.8504	1.4440	11.3817	3989.2420	0.1788	0.6014	0.1808	0.3543	0.1754	0.6028	1.5588	13.9902	1.5939	13.8930	597.3323	32.9624	32.9624	597.3323	0.4013	523.9955	137.3014	195.2728	1.7210	1.7588
2	4029.7130	1.5611	12.4162	3975.3695	0.1788	0.6024	0.1813	0.3558	0.1747	0.6001	1.5583	14.1704	1.5929	14.0696	597.9729	32.9675	32.9675	597.9729	0.4015	524.1712	137.4341	194.1254	1.7080	1.7469
3	4015.7959	1.5605	13.0312	3961.4076	0.1747	0.5986	0.1801	0.3535	0.1744	0.5995	1.5517	10.8641	1.5861	13.7636	597.6941	32.9763	32.9763	597.6941	0.3994	524.2393	136.7290	191.6811	1.6962	1.7328
4	4006.2711	1.6412	11.9605	3957.9722	0.1746	0.5986	0.1803	0.3539	0.1747	0.5998	1.5533	13.7364	1.5875	13.6344	597.5016	32.9646	32.9646	597.5016	0.3997	524.0087	136.5059	191.7319	1.6956	1.7329
5	4014.2107	1.3474	10.3371	3959.1240	0.1656	0.5712	0.1717	0.3391	0.1656	0.5730	1.4833	13.1078	1.5157	13.0034	597.3284	32.9214	32.9214	597.3284	0.3788	527.0725	130.0290	176.6334	1.6432	1.6790
6	4007.1869	1.6769	12.3229	3952.1411	0.1656	0.5713	0.1713	0.3383	0.1661	0.5747	1.4844	13.1254	1.5168	13.0211	597.4549	32.9308	32.9308	597.4549	0.3790	527.1604	130.0260	176.1276	1.6374	1.6732
7	4013.7813	1.1969	8.3148	3957.7305	0.1335	0.4710	0.1426	0.2878	0.1295	0.4568	1.2156	10.2381	1.2403	10.1367	595.3884	32.7373	32.7373	595.3884	0.3029	535.7276	104.8149	123.1621	1.4210	1.4468
8	4005.9818	1.2257	8.8538	3945.1466	0.1339	0.4726	0.1422	0.2871	0.1315	0.4843	1.2240	9.9953	1.2489	9.8938	595.3800	32.7685	32.7685	595.3800	0.3047	535.4937	105.4149	121.9051	1.3983	1.4287
9	4007.3882	0.9331	1.4720	3940.9440	0.0458	0.1593	0.0464	0.0920	0.0431	0.1484	0.4007	3.9926	0.4076	3.9154	561.8190	30.8194	30.8194	561.8190	0.1006	549.3935	36.2943	20.7331	0.7104	0.7227
10	4016.0323	0.6468	3.4810	3997.6192	0.0458	0.1593	0.0464	0.0920	0.0431	0.1484	0.400													

A3. TEST 2: TWO CAVITIES BLANKED

Run #	RPM	Patm	Pcal	Pin TTR (5 o/c)	Pout TTR	Pin TTR (8 o/c)	Pin CFF (2 o/c)	Pin CFF (10 o/c)	Pout CFF (Top)	Pout CFF (Mid)	Pout CFF (Bot)	PA	PB	PC	PD	PE	PF	PG	PH	PI	PJ	PK	PL
1	2037.5868	29.80	39.80	30.1766	29.8698	31.0637	29.7965	29.7461	30.3880	30.4189	30.4568	29.7164	29.4059	29.4001	29.4036	29.4373	29.7151	29.7787	29.8470	29.9327	29.8031	29.7979	29.7893
2	2035.0298	29.80	39.80	30.1896	29.8703	31.0695	29.7939	29.7466	30.4020	30.4316	30.4606	29.7151	29.4053	29.3986	29.4020	29.4356	29.7146	29.7795	29.8497	29.9417	29.8061	29.7991	29.7900
3	2016.5357	29.80	39.80	30.2049	29.9652	31.0448	29.7896	29.7496	30.3871	30.4160	30.4562	29.7218	29.4065	29.4023	29.4038	29.4372	29.7127	29.7776	29.8405	29.9512	29.8042	29.7954	29.7864
4	2027.5409	29.80	39.80	30.2154	29.9659	31.0445	29.7903	29.7454	30.3909	30.4214	30.4620	29.7209	29.4132	29.4048	29.4038	29.4372	29.7139	29.7789	29.8478	29.9515	29.8046	29.7959	29.7869
5	2025.4448	29.80	39.80	30.2265	29.9606	30.9639	29.7891	29.7505	30.3567	30.3866	30.4304	29.7287	29.4604	29.4566	29.4602	29.4947	29.7247	29.7877	29.8483	29.9561	29.8103	29.7921	29.7831
6	2027.7386	29.80	39.80	30.2365	29.9507	30.9619	29.7908	29.7516	30.3581	30.3959	30.4431	29.7799	29.4581	29.4558	29.4572	29.4900	29.7221	29.7894	29.8494	29.9611	29.8200	29.7931	29.7839
7	2038.9747	29.80	39.80	30.2505	29.9386	30.8756	29.7913	29.7570	30.3269	30.3635	30.3942	29.8484	29.5197	29.5215	29.5247	29.5672	29.7323	29.8006	29.8555	29.9724	29.8381	29.7883	29.7799
8	2030.9244	29.80	39.80	30.2598	29.9371	30.8766	29.7934	29.7590	30.3354	30.3655	30.4101	29.8497	29.5206	29.5228	29.5284	29.5693	29.7349	29.8027	29.8582	29.9717	29.8370	29.7812	29.7821
9	2059.5485	29.80	39.80	30.2730	29.9183	30.7388	29.7956	29.7698	30.2990	30.3320	30.3705	29.9363	29.5978	29.6106	29.6171	29.6588	29.7500	29.8115	29.8600	29.9740	29.8512	29.7879	29.7800
10	2021.0460	29.80	39.80	30.2793	29.9179	30.7390	29.7969	29.7698	30.2903	30.3260	30.3637	29.9362	29.5971	29.6110	29.6185	29.6594	29.7512	29.8115	29.8591	29.9723	29.8520	29.7895	29.7812
11	2039.8937	29.80	39.80	30.2910	29.8993	30.6344	29.7878	29.7448	30.2394	30.3092	30.3728	29.9785	29.6327	29.6480	29.6517	29.6789	29.7626	29.8234	29.8909	29.9608	29.8471	29.7870	29.7796
12	2046.7967	29.80	39.80	30.2967	29.8889	30.6327	29.8000	29.7767	30.2279	30.2991	30.3626	29.9754	29.6362	29.6536	29.6568	29.6840	29.7651	29.8251	29.8522	29.9581	29.8482	29.7897	29.7834
13	2049.6075	29.80	39.80	30.3028	29.8785	30.6176	29.7994	29.7540	30.1443	30.2088	30.2632	30.0146	29.6703	29.6974	29.7012	29.7190	29.7752	29.8244	29.8447	29.9420	29.8343	29.7872	29.7813
14	2033.5913	29.80	39.80	30.3111	29.8775	30.6229	29.8016	29.7548	30.1543	30.2200	30.2780	30.0239	29.6875	29.6998	29.7008	29.7190	29.7772	29.8200	29.8497	29.9480	29.8375	29.7803	29.7839
15	2078.2173	29.80	39.80	30.3148	29.8672	30.4536	29.8009	29.7687	30.0697	30.1261	30.1741	30.0172	29.6636	29.7168	29.7290	29.7435	29.7619	29.7870	29.8236	29.9028	29.8066	29.7664	29.7622
16	2058.0516	29.80	39.80	30.3201	29.8674	30.4536	29.8023	29.7601	30.0692	30.1264	30.1686	30.0165	29.6663	29.7194	29.7315	29.7470	29.7642	29.7893	29.8248	29.9015	29.8067	29.7687	29.7649
1	3059.6200	29.80	39.80	30.3434	30.1436	32.3678	29.7290	29.6790	31.2285	31.2936	31.3294	29.6160	28.9169	28.8767	28.8695	28.9316	29.6078	29.7610	29.9480	30.1369	29.8033	29.8004	29.7816
2	3086.4974	29.80	39.80	30.3552	30.1469	32.3729	29.7307	29.6817	31.2266	31.3079	31.3360	29.6176	29.9186	28.8763	28.8734	28.9348	29.6083	29.7658	29.9533	30.1414	29.8068	29.8043	29.7856
3	3054.0727	29.80	39.80	30.3686	30.1586	32.3489	29.7308	29.6826	31.2227	31.3159	31.3205	29.6312	29.9319	28.8914	28.8932	28.9487	29.6106	29.7686	29.9489	30.1399	29.8115	29.8067	29.7844
4	3051.4630	29.80	39.80	30.3773	30.1589	32.3576	29.7323	29.6843	31.2260	31.2940	31.3359	29.6322	29.9357	28.8936	28.8872	28.9523	29.6114	29.7710	29.9516	30.1421	29.8121	29.8060	29.7865
5	3059.3629	29.80	39.80	30.3864	30.1559	32.1634	29.7373	29.6846	31.1672	31.2544	31.2920	29.7646	29.9307	29.0000	29.9973	29.0571	29.6311	29.7912	29.9742	30.1517	29.8533	29.8015	29.7832
6	3059.7105	29.80	39.80	30.3941	30.1635	32.2062	29.7368	29.6937	31.1656	31.2549	31.2900	29.7649	29.9276	29.9954	29.9955	29.0556	29.6307	29.8029	29.9757	30.1730	29.8530	29.8034	29.7841
7	3051.6027	29.80	39.80	30.4102	30.1290	32.0043	29.7432	29.7005	31.1174	31.2228	31.2618	29.9112	29.1601	29.1442	29.1363	29.2051	29.6549	29.8319	29.9851	30.1950	29.9019	29.8001	29.7832
8	3086.4504	29.80	39.80	30.4192	30.1310	32.0107	29.7453	29.7093	31.1304	31.2341	31.2349	29.9127	29.1622	29.1451	29.1374	29.2020	29.6587	29.8372	29.9916	30.2025	29.9060	29.8053	29.7877
9	3086.2310	29.80	39.80	30.4278	30.0475	30.0475	29.7592	29.7346	30.9598	31.1389	31.2043	29.9387	29.3788	29.4574	29.7024	29.7024	29.6735	30.0041	30.2134	29.9510	29.8013	29.7858	29.7832
10	3082.1466	29.80	39.80	30.4339	30.0470	31.6421	29.7611	29.7350	30.9750	31.1478	31.0403	30.1326	29.3724	29.3696	29.3784	29.4565	29.7041	29.8731	30.0056	30.2141	29.9528	29.8036	29.7863
11	3086.4504	29.80	39.80	30.4401	29.9853	31.3846	29.7688	29.7535	30.8295	31.0337	30.8863	30.2427	29.4605	29.4797	29.4883	29.5455	29.7386	29.8577	29.9823	30.1701	29.9431	29.7989	29.7856
12	3059.5234	29.80	39.80	30.4450	29.9863	31.3797	29.7697	29.7540	30.8325	31.0333	30.8844	30.2446	29.4621	29.4821	29.4888	29.5470	29.7383	29.8589	29.9830	30.1827	29.9488	29.8010	29.7877
13	3063.0845	29.80	39.80	30.4480	29.9352	31.0835	29.7810	29.7736	30.6293	30.7762	30.7499	30.3286	29.5809	29.5925	29.6343	29.7652	29.8528	29.9504	30.1430	30.4011	29.8539	29.7999	29.7805
14	3053.4358	29.80	39.80	30.4492	29.9331	31.0841	29.7814	29.7744	30.6207	30.7706	30.7444	30.3279	29.5799	29.5829	29.6332	29.7644	29.8550	29.9548	30.1386	30.9105	29.7894	29.7862	29.7842
15	3055.1624	29.80	39.80	30.4536	29.9030	30.8732	29.7879	29.7651	30.6254	30.7454	30.7454	30.2965	29.5607	29.5624	29.6080	29.6928	29.7778	29.7944	29.8842	30.2445	29.8336	29.7847	29.7855
16	3059.3988	29.80	39.80	30.4537	29.9034	30.8746	29.7893	29.7694	30.4760	30.5301	30.4721	30.3049	29.5042	29.5024	29.6006	29.6949	29.7816	29.7997	29.8905	30.0307	29.8384	29.7874	29.7875
1	4075.7552	29.75	39.75	30.4436	30.4708	34.2423	29.6332	29.5455	32.4558	32.5840	32.5740	29.4554	28.9169	28.1105	28.0529	28.1388	29.4228	29.7010	30.0421	30.3422	29.7714	29.7760	29.7453
2	4077.1958	29.75	39.75	30.4459	30.4699	34.2530	29.6330	29.5464	32.4471	32.5384	32.5343	29.4555	28.9169	28.1090	28.0968	28.1423	29.4252	29.7018	30.0441	30.3428	29.7700	29.7761	29.7471
3	4054.9882	29.75	39.75	30.4628	30.4638	34.2098	29.6329	29.5471	32.4244	32.5693	32.5688	29.4772	29.2844	28.1357	28.0794	28.1653	29.4250	29.7072	30.0484	30.3451	29.7737	29.7732	29.7433
4	4074.4621	29.75	39.75	30.4721	30.4671	34.2383	29.6336	29.5445	32.4321	32.5981	32.5981	29.4789	29.2827	28.1440	28.0838	28.1684	29.4258	29.7088	30.0500	30.3422	29.7729	29.7728	29.7430
5	4086.7903	29.75	39.75	30.4862	30.4687	33.9315	29.6453	29.5651	32.3504	32.4946	32.4338	29.7047	29.2471	28.1353	28.0948	28.1684	29.4594	29.7754	30.0977	30.3963	29.8529	29.7702	29.7403
6	4061.3815	29.75	39.75	30.4970	30.4031	33.9110	29.6436	29.5654	32.3317	32.5010	32.4575	29.7056	28.4444	28.1395	28.0955	28.1684	29.4613	29.7740	30.1005	30.4011	29.8539	29.7699	29.7406
7	4087.0825	29.75	39.75	30.5096	30.3270	33.9428	29.6575	29.5637	32.3123	32.4051	32.3111	29.7057	28.4444	28.1395	28.0955	28.1684	29.4613	29.7740	30.1005	30.4011	29.8539	29.7699	29.7406
8	4073.4310	29.75	39.75	30.5175	30.3279	33.9444	29.6583	29.5616	32.2079	32.4146	32.3144	29.7048	28.4444	28.1395	28.0955	28.1684	29.4613	29.7740	30.1005	30.4011	29.8539	29.7699	29.7406
9	4067.9075	29.75	39.75	30.5265	30.3273	32.9073	29.6796	29.6326	31.9377	32.2522	31.9943	30.3620	29.6049	28.0962	28.0958	28.1629	29.4777	29.7712	30.1177	30.1884	29.8644	29.7619	29.7389
10	4060.6394	29.75	39.75	30.5253	30.3267	32.8999	29.6812	29.6363	31.9331	32.2712	31.9739	30.3606	29.6071	28.0974	28.0950	28.1629	29.4774	29.7711	30.1176	30.1883	29.8641	29.7619	29.7389
11	4066.8873	29.75	39.75	30.5253	30.3267	32.5313	29.6940	29.6607	31.7401	32.1268</													

Run #	RPM	Pho21	Pho22	Pho23	Pin	Pin (Flange)	Pout (Flange)	Pout (Vena)	Tin CFF (2 o/c)	Tin CFF (11 o/c)	Tin TTR (8 o/c)	Tin TTR (5 o/c)	Tout TTR	Tin Office	Tout CFF (Bot)	Tout CFF (Mid)	Tout CFF (Top)	TTR Mass Flow (lbm/s)	Turbine Power (HP)	CFF Mass Flow (lbm/s)	Pi CFF	Tau CFF	CFF Efficiency
1	2037.5988	29.7547	29.7636	29.7491	35.5971	29.7941	35.5959	35.5969	335.1723	334.9913	337.6913	337.8368	334.1651	340.4440	339.8461	340.5055	339.7936	1.0589	0.8892	0.7459	1.0219	1.0093	0.8673
2	2035.8298	29.7560	29.7602	29.7513	35.6379	29.7928	35.5798	35.5823	335.0423	334.7434	338.0099	337.9479	334.4059	341.5288	339.8636	340.3333	339.8425	1.0245	1.3066	0.9817	1.0223	1.0093	0.8763
3	2016.8387	29.7524	29.7570	29.7492	35.4072	29.7879	35.3864	35.3725	335.4044	335.3218	338.1712	338.1901	334.6274	340.7334	340.4071	340.9397	340.2173	1.5151	1.2847	1.0377	1.0219	1.0090	0.8434
4	2027.8409	29.7528	29.7572	29.7483	35.4235	29.7893	35.3543	35.3981	335.5134	335.2967	338.1958	338.1468	334.7241	340.3825	340.0555	340.7798	340.1073	1.2580	1.0408	0.8801	1.0231	1.0092	0.8798
5	2025.6448	29.7532	29.7573	29.7469	35.4551	29.7848	35.4047	35.4277	335.5503	335.3024	338.2872	338.2995	334.9790	340.4036	340.0925	340.5934	340.0098	1.0795	0.8897	0.7445	1.0210	1.0090	0.8638
6	2027.7396	29.7534	29.7595	29.7485	35.4294	29.7851	35.4207	35.4197	335.6628	335.5134	338.5403	338.5315	335.1882	341.3880	340.2753	340.7798	340.1768	0.6505	0.5226	0.4515	1.0211	1.0090	0.6642
7	2038.8747	29.7543	29.7570	29.7505	35.2668	29.7808	35.2518	35.2456	336.1866	336.0794	338.7794	338.7593	335.5679	341.3054	340.8712	341.1841	340.5231	0.9484	0.7286	0.6423	1.0200	1.0088	0.6420
8	2030.9244	29.7570	29.7619	29.7517	35.2577	29.7831	35.2236	35.2354	336.1180	335.8625	338.7548	338.7460	335.5591	340.9503	340.3843	340.8923	340.2929	0.9722	0.7446	0.6890	1.0202	1.0084	0.6783
9	2029.5485	29.7616	29.7649	29.7574	35.0078	29.7802	34.9664	34.9626	336.3747	336.2024	338.7811	338.7565	335.9036	340.8149	340.4546	340.8641	340.1997	1.3710	0.9428	0.9314	1.0180	1.0079	0.6485
10	2021.0460	29.7634	29.7664	29.7598	34.9305	29.7819	34.8707	34.8682	336.4573	336.2042	338.9903	338.9534	336.1884	341.7026	340.3878	340.7147	340.1434	1.3246	0.8849	0.9026	1.0182	1.0076	0.6789
11	2039.8937	29.7669	29.7685	29.7638	33.8921	29.7795	33.8417	33.8796	336.7966	336.5452	339.1873	339.1538	336.6032	341.3352	340.4932	340.8395	340.1610	1.7202	0.4412	0.4803	1.0184	1.0071	0.6515
12	2046.7967	29.7693	29.7716	29.7666	33.8552	29.7821	33.8646	33.8566	336.8352	336.6612	339.1903	339.1257	336.5417	341.1261	340.6128	340.9397	340.3034	1.0458	0.6517	0.7016	1.0189	1.0072	0.6280
13	2049.6075	29.7740	29.7745	29.7715	33.5204	29.7797	33.4941	33.5254	337.0567	336.8036	339.3208	339.2751	337.0233	341.6815	340.7024	340.8343	340.0507	0.4581	0.2501	0.2894	1.0132	1.0076	0.5585
14	2033.5813	29.7766	29.7771	29.7746	33.5465	29.7824	33.5118	33.5050	337.2272	336.9719	339.4315	339.4227	337.1569	342.1421	340.8237	340.8817	340.1452	1.2856	0.6505	0.6890	1.0137	1.0066	0.5895
15	2078.2173	29.7780	29.7781	29.7768	33.3257	29.7787	33.2848	33.3117	337.3889	337.1745	339.4443	339.4526	337.3382	341.4231	340.8360	340.8993	340.2946	0.7523	0.3850	0.4725	1.0105	1.0063	0.4714
16	2068.0510	29.7807	29.7807	29.7791	33.3064	29.7818	33.2993	33.2729	337.4505	337.1446	339.4673	339.4704	337.3854	341.1542	340.7499	340.8237	340.2243	1.1532	0.5656	0.6137	1.0105	1.0061	0.4855
1	3059.8200	29.7018	29.7141	29.6954	34.3587	29.7907	34.3251	34.3096	337.1024	336.4819	340.0995	340.1276	333.0682	341.9629	347.2925	348.6911	347.7794	1.4151	0.3928	0.8961	1.0532	1.0207	0.7193
2	3008.4974	29.7082	29.7180	29.6989	34.3085	29.7948	34.3268	34.3115	337.0482	336.4889	340.1680	340.1470	333.0454	341.3548	347.0745	348.7497	347.7354	1.5226	0.3989	0.9780	1.0533	1.0207	0.7240
3	3054.0727	29.7080	29.7183	29.6986	34.3150	29.7943	34.2456	34.2570	338.9776	338.3923	340.1083	340.1030	333.0984	340.6409	346.9110	348.4333	347.5034	1.8262	0.5842	0.9658	1.0532	1.0204	0.7322
4	3051.4030	29.7070	29.7125	29.7019	34.3255	29.7953	34.2705	34.2586	337.0620	336.4749	340.0942	339.9430	332.9540	340.7786	347.2879	348.6952	347.6563	1.6386	0.7414	1.0286	1.0531	1.0207	0.7195
5	3059.3829	29.7121	29.7298	29.7084	34.0516	29.7918	34.0127	33.9809	337.0444	336.4768	340.9237	340.0896	333.3477	341.0874	347.0875	348.2540	347.2327	1.6857	0.7244	0.9652	1.0532	1.0199	0.7205
6	3059.1055	29.7132	29.7242	29.7066	34.0717	29.7918	34.0014	34.0031	337.0057	336.5048	340.3388	340.3245	333.5042	341.8206	346.9391	348.2733	347.1483	1.6599	0.7198	0.9592	1.0514	1.0199	0.7239
7	3051.6027	29.7219	29.7313	29.7175	33.6699	29.7920	33.5962	33.5979	337.0919	336.5278	340.0682	340.0595	333.8962	340.5759	346.5155	347.4768	346.4944	1.6572	0.4634	0.2295	1.0492	1.0188	0.7440
8	3066.4204	29.7282	29.7394	29.7189	33.6829	29.7994	33.6090	33.6137	337.0708	336.4954	340.2361	340.1357	333.9798	341.6341	346.6099	347.6696	346.6499	1.6563	0.5186	0.9368	1.0495	1.0189	0.7377
9	3068.2310	29.7428	29.7606	29.7369	33.1301	29.7915	33.0962	33.1098	337.2009	336.5038	340.4247	340.3790	334.9561	341.3969	345.5223	348.5999	345.6296	0.9073	1.1858	0.5746	1.0437	1.0185	0.4489
10	3062.1486	29.7449	29.7617	29.7399	33.1173	29.7944	33.1178	33.1038	337.1808	336.5388	340.2735	340.2524	334.8542	340.8800	345.5346	348.5348	345.5557	0.8440	1.0957	0.5183	1.0439	1.0185	0.4489
11	3068.4094	29.7552	29.7693	29.7518	32.8990	29.7897	32.8919	32.8992	337.6346	337.2940	340.1683	340.1628	334.4009	340.4409	345.4784	348.2399	344.9581	0.8602	1.0962	0.5212	1.0388	1.0181	0.7260
12	3059.5234	29.7574	29.7619	29.7549	32.9462	29.7896	32.8965	32.8959	337.7317	337.4284	340.0837	340.0661	335.3710	340.7042	345.5610	348.2011	344.9897	1.4034	1.5844	0.8214	1.0388	1.0149	0.7315
13	3063.0945	29.7662	29.7726	29.7671	32.8808	29.7825	32.8268	32.8076	337.7124	337.3450	340.4159	340.4001	335.4879	342.0243	344.8350	345.2235	344.0405	1.6835	1.5920	0.9250	1.0316	1.0133	0.6993
14	3053.4355	29.7704	29.7726	29.7685	32.8262	29.7838	32.8188	32.8037	337.8561	337.2568	340.3350	340.3630	335.5030	341.6692	344.9845	345.2953	344.0757	1.6404	0.8817	0.5027	1.0314	1.0136	0.6516
15	3055.1524	29.7773	29.7774	29.7756	32.8605	29.7813	32.8026	32.8336	337.9813	337.5596	340.2929	340.2984	335.9565	340.9061	344.6452	344.9018	343.9175	1.0374	0.8311	0.5193	1.0235	1.0124	0.5379
16	3059.3988	29.7800	29.7801	29.7782	32.8711	29.7836	32.8192	32.8397	338.0165	337.8020	340.2946	340.2964	335.9563	340.7378	344.7050	344.9739	344.0593	1.1136	0.8887	0.5585	1.0237	1.0124	0.5412
1	4075.7552	29.6035	29.6295	29.5935	35.0702	29.7597	34.9763	34.9709	337.3061	336.5751	340.7587	340.7059	338.8829	341.7132	354.8212	358.3438	358.3680	2.0218	5.7496	1.2242	1.0996	1.0364	0.7548
2	4077.1958	29.6066	29.6293	29.5982	35.0863	29.7653	34.9727	34.9675	337.1710	336.4808	340.6778	340.6145	338.7721	341.2192	355.0497	358.2735	358.4507	2.2058	6.2975	1.3279	1.0993	1.0368	0.7439
3	4054.9082	29.6015	29.6247	29.5914	35.0148	29.7586	34.9050	34.9054	337.0444	336.2007	340.4423	340.4054	338.6983	340.6163	355.1507	357.8411	358.2450	2.1294	5.9726	1.2574	1.0992	1.0369	0.7425
4	4074.4821	29.6036	29.6260	29.5925	35.0248	29.7590	34.9095	34.9198	337.0251	336.2516	340.3712	340.3473	338.6122	340.3966	355.2782	358.0309	358.4509	2.0791	5.8632	1.2246	1.0994	1.0372	0.7381
5	4068.7053	29.6153	29.6377	29.6017	34.8406	29.7557	34.6326	34.6476	337.3011	336.5487	340.7815	340.7253	338.9399	341.5145	355.0971	357.4368	358.5190	1.8545	5.3268	1.1204	1.0953	1.0356	0.7400
6	4061.1815	29.6145	29.6349	29.6066	34.9171	29.7559	34.6288	34.6121	337.4417	336.7772	340.6354	340.6216	338.4155	341.2280	355.1921	357.4948	358.5313	2.0746	5.8334	1.2298	1.0994	1.0353	0.7474
7	4077.0825	29.6305	29.6487	29.6203	34.4174	29.7519	34.3607	34.3500	337.4241	336.6950	340.6376	340.5864	338.1784	340.7270	354.5610	356.6897	358.3001	1.6555	4.4540	0.9489	1.0906	1.0339	0.7404
8	4073.4130	29.6317	29.6479	29.6228	34.4227	29.7531	34.3160	34.3442	337.4891	336.8020	340.5354	340.4809	338.1221	340.6231	354.4784	356.5458	358.7016	1.8164	4.5327	1.0465	1.0907	1.0336	0.7477
9	4077.8075	29.6573	29.6883	29.6500	33.8089	29.7457	33.6084	33.6104	337.0607	336.3473	340.3473	340.3263	337.4774	340.1329	353.0001	354.6298	352.6942	1.8081	3.4191	0.8404	1.0812	1.0300	0.7521
10	4060.8394	29.6584	29.6705	29.6517	33.8004	29.7478	33.5845	33.5937	337.0880	337.0813	340.												

Run #	RPM	CFF Corrected Mass Flow	Corrected Power (HP)	Corrected Speed (RPM)	X1	mdot1	X2	mdot2	X3	mdot3	Computed MA Mdot	Computed MA Power (HP)	Corrected Computed MA	Corrected Computed MA	HP	Tbar Out	Pbar Out	Pt_bar	Tt_bar	Mach Exit	Temp Exit	Velocity Exit (m/s)	Corrected Thrust (lbf)	M_dot_Inlet	Corrected Computed MA Mdot(lbm/s)
1	2037.5988	0.7926	1.2450	2008.0983	0.0758	0.2731	0.0816	0.1595	0.0838	0.2870	0.7196	1.4158	0.7345	1.4009	539.9731	30.4231	30.4231	30.4231	30.4231	0.1535	532.7943	63.3364	43.7031	0.8340	0.8513
2	2035.0298	1.1131	1.8297	2005.8206	0.0807	0.2782	0.0824	0.1611	0.0845	0.2884	0.7287	1.4212	0.7417	1.4085	539.8940	30.4356	30.4356	30.4356	30.4356	0.1553	532.4688	63.3305	44.1009	0.8339	0.8511
3	2016.5357	1.0986	1.7384	1988.8190	0.0794	0.2717	0.0811	0.1585	0.0833	0.2852	0.7154	1.5319	0.7305	1.5057	540.4530	30.4207	30.4207	30.4207	30.4207	0.1525	533.3480	63.0787	44.3768	0.8613	0.8794
4	2027.5409	0.8979	1.4569	1987.8200	0.0797	0.2727	0.0814	0.1582	0.0837	0.2869	0.7187	1.4516	0.7339	1.4381	540.2333	30.4200	30.4200	30.4200	30.4200	0.1533	533.0671	63.3808	45.1631	0.8624	0.8808
5	2025.6448	0.7585	1.2019	1985.6749	0.0740	0.2536	0.0788	0.1500	0.0785	0.2692	0.6728	1.4156	0.6870	1.4004	540.1730	30.3955	30.3955	30.3955	30.3955	0.1714	533.8995	59.2681	42.0530	0.8590	0.8778
6	2027.7396	0.4807	0.7314	1987.4370	0.0740	0.2536	0.0784	0.1485	0.0792	0.2715	0.6748	1.4101	0.6889	1.3948	540.3501	30.4507	30.4507	30.4507	30.4507	0.1719	534.0352	59.4030	41.9335	0.8528	0.8709
7	2038.8747	0.6586	1.0190	2007.3648	0.0673	0.2309	0.0712	0.1394	0.0719	0.2485	0.6188	1.3840	0.6302	1.3680	540.8116	30.3666	30.3666	30.3666	30.3666	0.1570	535.3316	54.3181	38.3099	0.8516	0.8701
8	2030.9244	0.7000	1.0415	1999.8048	0.0678	0.2327	0.0712	0.1396	0.0728	0.2499	0.6222	1.2771	0.6355	1.2624	540.4940	30.3767	30.3767	30.3767	30.3767	0.1583	535.0994	54.7512	37.3496	0.8238	0.8415
9	2009.5485	0.9505	1.3180	2007.4452	0.0562	0.1829	0.0627	0.1231	0.0611	0.2099	0.5280	1.1299	0.5473	1.1164	540.4570	30.3130	30.3130	30.3130	30.3130	0.1338	536.6155	46.3313	29.9509	0.7805	0.7673
10	2021.0460	0.9212	1.2370	1989.4646	0.0569	0.1856	0.0631	0.1239	0.0614	0.2111	0.5306	1.0690	0.5421	1.0561	540.3740	30.3211	30.3211	30.3211	30.3211	0.1349	536.4707	46.7027	29.4473	0.7612	0.7776
11	2039.8837	0.4903	0.6164	2007.3814	0.0498	0.1706	0.0559	0.1099	0.0528	0.1815	0.4821	0.9555	0.4721	0.9436	540.4529	30.2888	30.2888	30.2888	30.2888	0.1174	537.4886	40.8922	24.5200	0.7272	0.7431
12	2046.7967	0.7613	0.9105	2014.0292	0.0489	0.1681	0.0554	0.1087	0.0522	0.1793	0.4561	0.9282	0.4461	0.9145	540.5761	30.2585	30.2585	30.2585	30.2585	0.1180	537.6551	40.1971	23.9555	0.6964	0.7115
13	2049.6075	0.2844	0.3493	2016.4533	0.0351	0.1208	0.0429	0.0842	0.0423	0.1454	0.3502	0.8087	0.3579	0.7983	540.5234	30.1842	30.1842	30.1842	30.1842	0.0897	538.7877	31.1436	16.7216	0.6479	0.6620
14	2033.5813	0.4047	0.6782	2000.4211	0.0352	0.1210	0.0431	0.0847	0.0440	0.1513	0.3570	0.7531	0.3648	0.7433	540.6075	30.2011	30.2011	30.2011	30.2011	0.0917	538.7938	31.8351	16.1809	0.6132	0.6286
15	2078.2173	0.4824	0.5375	2043.9312	0.0262	0.0902	0.0321	0.0631	0.0287	0.0987	0.2320	0.6965	0.2575	0.6872	540.6581	30.1045	30.1045	30.1045	30.1045	0.0644	539.7629	22.3659	11.0075	0.5936	0.6067
16	2058.0510	0.7287	0.7895	2044.0878	0.0303	0.0903	0.0423	0.0634	0.0298	0.1023	0.2560	0.6363	0.2817	0.6308	540.5827	30.1087	30.1087	30.1087	30.1087	0.0635	539.6514	22.7387	10.5805	0.5601	0.5724
1	3059.8200	0.9174	3.3524	3010.7115	0.1225	0.4186	0.1250	0.2439	0.1263	0.4319	1.0944	4.7148	1.1214	4.6884	547.7882	31.2821	31.2821	31.2821	31.2821	0.2807	531.0462	96.7143	98.0351	1.2307	1.2611
2	3008.4974	0.9999	3.6409	3017.3009	0.1225	0.4184	0.1254	0.2448	0.1264	0.4326	1.0958	4.5913	1.1228	4.5458	547.7011	31.2879	31.2879	31.2879	31.2879	0.2811	530.9247	96.8223	96.7147	1.2054	1.2351
3	3054.0727	1.0826	3.6206	3005.3597	0.1218	0.4183	0.1252	0.2445	0.1264	0.4292	1.0900	4.5330	1.1167	4.4884	547.4788	31.2823	31.2823	31.2823	31.2823	0.2794	530.9616	96.2470	96.1501	1.2057	1.2352
4	3051.4300	1.0528	3.8403	3002.5050	0.1219	0.4186	0.1244	0.2428	0.1258	0.4308	1.0902	4.5993	1.1069	4.5138	547.7342	31.2846	31.2846	31.2846	31.2846	0.2795	531.1363	96.3087	95.2582	1.1936	1.2229
5	3059.3829	1.0849	3.8153	3010.2297	0.1143	0.3919	0.1177	0.2306	0.1191	0.4090	1.0315	4.2947	1.0565	4.2867	547.3895	31.2362	31.2362	31.2362	31.2362	0.2635	532.0062	90.9072	87.7886	1.1651	1.2034
6	3059.1055	1.0838	3.8088	3010.7074	0.1142	0.3917	0.1177	0.2306	0.1188	0.4112	1.0335	4.2827	1.0586	4.2193	547.3161	31.2428	31.2428	31.2428	31.2428	0.2640	532.4705	91.8082	87.4766	1.1591	1.1732
7	3051.0227	1.0333	3.4487	3002.4069	0.1060	0.3647	0.1104	0.2171	0.1104	0.3801	0.9516	3.7776	0.9849	3.7278	546.7249	31.1825	31.1825	31.1825	31.1825	0.2446	533.9484	84.4919	78.0103	1.0773	1.1233
8	3066.4204	1.0926	3.5256	3017.0503	0.1065	0.3663	0.1108	0.2178	0.1108	0.3817	0.9509	3.7933	0.9890	3.6647	546.8684	31.1951	31.1951	31.1951	31.1951	0.2456	533.9829	84.8545	74.7860	1.0635	1.0990
9	3066.2130	0.9999	3.5996	3016.3899	0.0975	0.3035	0.0968	0.1914	0.0923	0.3184	0.8143	2.8771	0.8444	2.8440	546.8158	31.0343	31.0343	31.0343	31.0343	0.2061	533.9685	71.3761	55.3919	0.9435	0.9596
10	3062.1496	0.9269	3.5324	3012.3721	0.0886	0.3063	0.0907	0.1919	0.0919	0.3179	0.8161	2.8338	0.8352	2.7913	546.7778	31.0411	31.0411	31.0411	31.0411	0.2064	533.8305	71.4942	54.8989	0.9263	0.9480
11	3068.0404	0.9395	2.2307	3015.3525	0.0740	0.2583	0.0857	0.1688	0.0774	0.2883	0.6944	2.3349	0.7106	2.3089	546.4725	30.9074	30.9074	30.9074	30.9074	0.1757	530.7928	60.3795	48.3742	0.8374	0.8710
12	3059.5234	0.8399	2.2138	3008.2115	0.0741	0.2585	0.0858	0.1686	0.0772	0.2875	0.6936	2.2474	0.7098	2.2193	545.5306	30.9016	30.9016	30.9016	30.9016	0.1755	538.8928	60.3038	41.0310	0.8124	0.8315
13	3063.0845	0.9453	2.2234	3011.8562	0.0531	0.1840	0.0646	0.1281	0.0627	0.2176	0.5296	1.7225	0.5417	1.7001	544.6530	30.7144	30.7144	30.7144	30.7144	0.1345	540.7402	48.7596	36.9566	0.6952	0.7115
14	3053.4355	0.9137	1.2515	3002.5178	0.0515	0.1815	0.0643	0.1274	0.0624	0.2165	0.5252	1.7228	0.5371	1.7003	544.7445	30.7080	30.7080	30.7080	30.7080	0.1335	540.8987	46.4226	26.2329	0.6815	0.6870
15	3055.1524	0.5307	1.1600	3003.2830	0.0401	0.1388	0.0460	0.0910	0.0396	0.1370	0.3668	1.3906	0.3752	1.3717	544.4334	30.4827	30.4827	30.4827	30.4827	0.0929	542.9623	32.3353	16.2176	0.6047	0.6185
16	3059.3988	0.5074	1.2403	3007.1695	0.0403	0.1395	0.0460	0.0909	0.0396	0.1370	0.3674	1.3067	0.3758	1.2908	544.5252	30.4887	30.4887	30.4887	30.4887	0.0930	542.9541	32.3783	15.2772	0.5988	0.5818
1	4075.7552	1.2583	8.0858	4009.7838	0.1653	0.5844	0.1688	0.3287	0.1684	0.5761	1.4892	10.0437	1.5115	9.9819	556.2038	32.5308	32.5308	32.5308	32.5308	0.3793	525.9303	130.0632	160.6871	1.4907	1.5338
2	4077.1958	1.3636	8.8568	4011.6702	0.1651	0.5835	0.1674	0.3263	0.1689	0.5779	1.4677	10.1770	1.5098	10.1155	556.3044	32.5254	32.5254	32.5254	32.5254	0.3790	526.0757	129.9676	161.1711	1.4931	1.5359
3	4054.9862	1.2919	8.8414	3990.5355	0.1639	0.5597	0.1660	0.3278	0.1676	0.5735	1.4610	10.2895	1.5026	10.2380	556.1767	32.5160	32.5160	32.5160	32.5160	0.3770	526.2544	129.3073	161.3622	1.5062	1.5490
4	4074.4821	1.2583	8.2475	4009.6834	0.1641	0.5603	0.1676	0.3270	0.1681	0.5754	1.4628	10.3255	1.5055	10.2650	556.3447	32.5241	32.5241	32.5241	32.5241	0.3775	526.3375	129.4914	160.7682	1.4984	1.5411
5	4068.7603	1.1941	7.4867	4002.9036	0.1512	0.5329	0.1591	0.3121	0.1575	0.5414	1.3864	9.5431	1.4245	9.4794	555.7860	32.4154	32.4154	32.4154	32.4154	0.3554	529.0302	122.2332	146.6021	1.4473	1.4881
6	4061.3815	1.2605	7.8464	3995.0181	0.1546	0.5309	0.1593	0.3124	0.1581	0.5436	1.3869	9.4711	1.4263	9.3529	555.8408	32.4191	32.4191	32.4191	32.4191	0.3556	529.0796	122.2861	145.7423	1.4378	1.4787
7	4077.0525	0.9743	8.6206	4020.7116	0.1462	0.4919	0.1481	0.2925	0.1454	0.5028	1.2872	8.5485	1.3293	8.4838	555.1475	32.2847	32.2847	32.2847	32.2847	0.3297	535.1475	112.9398	127.9237	1.3600	1.3978
8	4073.4310	1.0746	8.3650	4006.5495	0.1412	0.4911	0.1483	0.2929	0.1453	0.5028	1.2868	8.4261	1.3226	8.3622	555.0341	32.2966	32.2966	32.2966	32.2966	0.3293	532.2311	112.8810	126.4872	1.3517	1.3883
9	4077																								

APPENDIX B. CROSSFLOW FAN GRID GENERATION CODE

B1. GRID GENERATION FLO++ INPUT CODE

```
// MESHDEMO
// Pre processing
// Demonstrating different meshing techniques

reset

// *** crossflowfan : Flo++ input file
// *** Insert your Flo++ code here
reset
csys 0
#def span 1.5
#def spnblk 1
#def chordblk 30
#def cbr 1.2
#def cscblk 20
#def cscr 1.2
#def clnc 6.13
// *** Mesh generation *****
// *** (Template for flow between parallel plates)

////Build fan passage splines//////////
//vread c:\vread15mod.txt 0 ALL
wall yes
vread d:\nps\thesis\vread15mod_cheng.txt 0 ALL
vp
vset news vlist 338 339
vmerge vset 0.0001
vset news vlist 111 112
vmerge vset 0.0001
vset news vlist 211 212

vmax

spline 1 vran vmax - 436 vmax - 325 1
#def bp1 vmax - 378
splmodify 1 modify bp1 -bp1
spline 2 vran vmax - 325 vmax - 225 1
#def bp2 vmax - 277
splmodify 2 modify bp2 -bp2
spline 3 vran vmax - 225 vmax - 99 1
#def bp3 vmax - 162
splmodify 3 modify bp3 -bp3
spline 4 vlist vmax - 99 vmax - 89 vmax - 79 vmax - 69 vmax - 59 vmax - 49 vmax - 39 vmax - 29 vmax - 19 vmax - 9
vmax - 436
#def bp4 vmax - 49
splmodify 4 modify bp4 -bp4
sp

vset all
vcopy 2 vmax vset span 0 0
vp

spline 5 vran vmax - 436 vmax - 325 1
#def bp5 vmax - 378
splmodify 5 modify bp5 -bp5
spline 6 vran vmax - 325 vmax - 225
```

```
#def bp6 vmax - 277
splmodify 6 modify bp6 -bp6
spline 7 vran vmax - 225 vmax - 99 1
#def bp7 vmax - 162
splmodify 7 modify bp7 -bp7
spline 8 vlist vmax - 99 vmax - 89 vmax - 79 vmax - 69 vmax - 59 vmax - 49 vmax - 39 vmax - 29 vmax - 19 vmax - 9
vmax - 436
#def bp8 vmax - 49
splmodify 8 modify bp8 -bp8
sp
```

vmax

/////Build fan passage block//////////

```
cgro 1
block 1 vmax - 873 vmax - 762 vmax - 662 vmax - 536 vmax - 436 vmax - 325 vmax - 225 vmax - 99
blplot
blfactors 1 chordblk cscblk spnblk 1
bled 1 1 chordblk / 2 cbr chordblk / 2 1 / cbr
bled 1 2 chordblk / 2 cbr chordblk / 2 1 / cbr
bled 1 3 chordblk / 2 cbr chordblk / 2 1 / cbr
bled 1 4 chordblk / 2 cbr chordblk / 2 1 / cbr
bled 1 5 cscblk / 2 cscr cscblk / 2 1 / cscr
bled 1 6 cscblk / 2 cscr cscblk / 2 1 / cscr
bled 1 7 cscblk / 2 cscr cscblk / 2 1 / cscr
bled 1 8 cscblk / 2 cscr cscblk / 2 1 / cscr
```

```
blex 1
view 1 0 0
cp
```

```
local 2 cyli 0 0 0 0 90 0 0
csys 2
mcrea 4.15 4.2 2 77.97949 84.18 10 0 span spnblk 1 cscr 1
mcrea 4.15 4.2 2 84.18 90 10 0 span spnblk 1 1 / cscr 1
```

```
cp
mcrea 6 6.1 3 88.2039 94.1432 10 0 span spnblk 1.5 cscr 1
mcrea 6 6.1 3 94.1432 100.2038 10 0 span spnblk 1.5 1 / cscr 1
cp
save 12
```

resu 12

```
spldelete all
bldelete all
cset news cgro 1
vset news cset
vset unsel
vdel vset
vset all
cp
vcdist all
// VCDIST tell us that we should not merge closer than aprox 0.002181
vmerge all 0.002
vcomp all
vcdist all
cp
```

/////Copy fan passage and build complete fan/////

```
cset news cgro 1
local 2 cyli 0 0 0 0 90 0 0
```

```

csys 2
cgro 2
// Louis: Copy in 1 action
mcopy 30 vmax 0 12 0 active
vcdist all
vmerge all 0.0015
vcomp all
vcdist all

cset all
cgro 0
cgmodify all

save 13

resu 13

/////Build fan clearance layer/////
csys 2
cgro 2
mcrea 6.1 clnc 3 0 360 360 0 span spnblk 1 1 1

/////Build Intake/////
/////Intake First Block/////

csys 3

spldelete all
v vmax + 1 0 4.8676 3.726
v vmax + 1 0 4.8852 3.7369
v vmax + 1 0 4.9001 3.7228
v vmax + 1 0 4.9211 3.7142
v vmax + 1 0 4.9415 3.7136
v vmax + 1 0 4.9571 3.7183

csys 2

v vmax + 1 6.1967 125 0
v vmax + 1 6.1967 120 0
v vmax + 1 6.1967 115 0
v vmax + 1 6.1967 110 0
v vmax + 1 6.1967 105 0
v vmax + 1 6.1967 100 0
v vmax + 1 6.1967 95 0
v vmax + 1 6.1967 90 0
v vmax + 1 6.1967 85 0
v vmax + 1 6.1967 80 0
v vmax + 1 6.1967 75 0
v vmax + 1 6.1967 70 0
v vmax + 1 6.1967 65 0
v vmax + 1 6.1967 60 0
v vmax + 1 6.1967 55 0
v vmax + 1 6.1967 50 0
v vmax + 1 6.1967 45 0
v vmax + 1 6.1967 40 0
v vmax + 1 6.1967 35 0
v vmax + 1 6.1967 30 0
v vmax + 1 6.1967 25 0

csys 3

```

```

v vmax + 1 0 2.4157 -5.6827
v vmax + 1 0 2.4057 -5.6731
v vmax + 1 0 2.3921 -5.6666
v vmax + 1 0 2.3789 -5.6648
v vmax + 1 0 2.3645 -5.6673
v vmax + 1 0 2.3603 -5.6574

```

csys 2

```

v vmax + 1 clnc 25 0
v vmax + 1 clnc 30 0
v vmax + 1 clnc 35 0
v vmax + 1 clnc 40 0
v vmax + 1 clnc 45 0
v vmax + 1 clnc 50 0
v vmax + 1 clnc 55 0
v vmax + 1 clnc 60 0
v vmax + 1 clnc 65 0
v vmax + 1 clnc 70 0
v vmax + 1 clnc 75 0
v vmax + 1 clnc 80 0
v vmax + 1 clnc 85 0
v vmax + 1 clnc 90 0
v vmax + 1 clnc 95 0
v vmax + 1 clnc 100 0
v vmax + 1 clnc 105 0
v vmax + 1 clnc 110 0
v vmax + 1 clnc 115 0
v vmax + 1 clnc 120 0
v vmax + 1 clnc 125 0

```

vmax

vp

spldelete all

#def bp1 vmax - 52

spline 1 vlist vmax - 53 -bp1 vmax - 51 vmax - 50 vmax - 49 vmax - 48

spline 2 vran vmax - 48 vmax - 26 1

#def bp3 vmax - 22

spline 3 vlist vmax - 26 vmax - 25 vmax - 24 vmax - 23 -bp3 vmax - 21

```

    spline 4 vlist vmax - 21 vmax - 20 vmax - 19 vmax - 18 vmax - 17 vmax - 16 vmax - 15 vmax - 14 vmax - 13
    vmax - 12 vmax - 11 vmax - 10 vmax - 9 vmax - 8 vmax - 7 vmax - 6 vmax - 5 vmax - 4 vmax - 3 vmax - 2
    vmax - 1 vmax vmax - 53

```

sp

csys 3

vcopy 2 54 vran vmax - 53 vmax 1 span 0 0

vp

#def bp5 vmax - 52

spline 5 vlist vmax - 53 -bp5 vmax - 51 vmax - 50 vmax - 49 vmax - 48

spline 6 vran vmax - 48 vmax - 26 1

#def bp7 vmax - 22

spline 7 vlist vmax - 26 vmax - 25 vmax - 24 vmax - 23 -bp7 vmax - 21

```

    spline 8 vlist vmax - 21 vmax - 20 vmax - 19 vmax - 18 vmax - 17 vmax - 16 vmax - 15 vmax - 14 vmax - 13
    vmax - 12 vmax - 11 vmax - 10 vmax - 9 vmax - 8 vmax - 7 vmax - 6 vmax - 5 vmax - 4 vmax - 3 vmax - 2
    vmax - 1 vmax vmax - 53

```

sp

vmax

bldelete all

block 9 vmax - 48 vmax - 26 vmax - 21 vmax - 53 vmax - 102 vmax - 80 vmax - 75 vmax - 107

blfactors 9 50 5 spnblk 3

blex 9

/////Intake Second Block////////////////////////////////////
vset none

csys 3

v vmax + 1 0 4.9571 3.7183
v vmax + 1 0 5.0204 3.7809
v vmax + 1 0 5.0811 3.8448
v vmax + 1 0 5.1426 3.9136
v vmax + 1 0 5.2094 3.9943
v vmax + 1 0 5.4164 4.2939
v vmax + 1 0 5.6144 4.6854
v vmax + 1 0 5.7769 5.1999
v vmax + 1 0 5.8362 5.7068
v vmax + 1 0 5.7902 6.2869
v vmax + 1 0 5.6351 6.9151
v vmax + 1 0 5.2369 7.9234
v vmax + 1 0 3.35 11.56
v vmax + 1 0 -3.007 23.8109////
//v vmax + 1 0 9.16 6.56 //Adjusted point from z=11.56
//v vmax + 1 0 11.16 2 //Added to adjust grid
//v vmax + 1 0 11.16 -6.56 //Added for smoothness

csys 2

v vmax + 1 24 180 0
v vmax + 1 24 170 0
v vmax + 1 24 160 0
v vmax + 1 24 150 0
v vmax + 1 24 140 0
v vmax + 1 24 130 0
v vmax + 1 24 120 0
v vmax + 1 24 110 0
v vmax + 1 24 100 0
v vmax + 1 24 90 0
v vmax + 1 24 80 0
v vmax + 1 24 70 0
v vmax + 1 24 60 0

csys 3

v vmax + 1 0 19.3968 -14.1337////
v vmax + 1 0 9.16 -11.05
v vmax + 1 0 7.07 -10.42
v vmax + 1 0 4.26 -8.21
v vmax + 1 0 2.78 -6.41
v vmax + 1 0 2.53 -6.00 //added for continuity
v vmax + 1 0 2.4157 -5.6827

csys 2

v vmax + 1 6.1967 125 0
v vmax + 1 6.1967 120 0
v vmax + 1 6.1967 115 0
v vmax + 1 6.1967 110 0
v vmax + 1 6.1967 105 0
v vmax + 1 6.1967 100 0
v vmax + 1 6.1967 95 0
v vmax + 1 6.1967 90 0
v vmax + 1 6.1967 85 0
v vmax + 1 6.1967 80 0

```

v vmax + 1 6.1967 75 0
v vmax + 1 6.1967 70 0
v vmax + 1 6.1967 65 0
v vmax + 1 6.1967 60 0
v vmax + 1 6.1967 55 0
v vmax + 1 6.1967 50 0
v vmax + 1 6.1967 45 0
v vmax + 1 6.1967 40 0
v vmax + 1 6.1967 35 0
v vmax + 1 6.1967 30 0
v vmax + 1 6.1967 25 0
vp
vmax

```

```

spldelete all
spline 1 vran vmax - 54 vmax - 41 1
spline 2 vran vmax - 41 vmax - 27 1
spline 3 vran vmax - 27 vmax - 21 1
spline 4 vlist vmax - 21 vmax vmax - 1 vmax - 2 vmax - 3 vmax - 4 vmax - 5 vmax - 6 vmax - 7 vmax - 8 vmax - 9
vmax - 10
spline 4 vlist vmax - 11 vmax - 12 vmax - 13 vmax - 14 vmax - 15 vmax - 16 vmax - 17 vmax - 18 vmax - 19 vmax -
20 vmax - 54
sp
csys 3
vcopy 2 55 vran vmax - 54 vmax 1 span 0 0
vp

```

```

spline 5 vran vmax - 54 vmax - 41 1
spline 6 vran vmax - 41 vmax - 27 1
spline 7 vran vmax - 27 vmax - 21 1
spline 8 vlist vmax - 21 vmax vmax - 1 vmax - 2 vmax - 3 vmax - 4 vmax - 5 vmax - 6 vmax - 7 vmax - 8 vmax - 9
vmax - 10
spline 8 vlist vmax - 11 vmax - 12 vmax - 13 vmax - 14 vmax - 15 vmax - 16 vmax - 17 vmax - 18 vmax - 19 vmax -
20 vmax - 54
sp
vmax
bldelete all
block 10 vmax - 54 vmax - 41 vmax - 27 vmax - 21 vmax - 109 vmax - 96 vmax - 82 vmax - 76
blfactors 10 20 50 spnblk 4
blcd 10 1 20 1.1
blcd 10 4 20 1.1
blcd 10 2 20 1 / 1.1
blcd 10 3 20 1 / 1.1
blex 10

```

```

cset news cgro 4
cp
cset cgro 3

```

```

#def cm1 12310
/////Build inner fan mesh/////
#def vm1 vmax
cgro 1
csys 2
v vmax + 1 3 135 0
v vmax + 1 4.15 135 0
v vmax + 1 4.15 125 0
v vmax + 1 4.15 115 0
v vmax + 1 4.15 105 0
v vmax + 1 4.15 95 0

```

```

v vmax + 1 4.15 85 0
v vmax + 1 4.15 75 0
v vmax + 1 4.15 65 0
v vmax + 1 4.15 55 0
v vmax + 1 4.15 45 0
v vmax + 1 3 45 0
vp
spline 9 vlist vmax - 11 vmax - 10
spline 10 vran vmax - 10 vmax - 1 1
spline 11 vlist vmax - 1 vmax
spline 12 vlist vmax vmax - 11
sp
vset none
vset news vran vmax - 11 vmax 1
vcopy 2 12 vset 0 0 span
vp

spline 13 vlist vmax - 11 vmax - 10
spline 14 vran vmax - 10 vmax - 1 1
spline 15 vlist vmax - 1 vmax
spline 16 vlist vmax vmax - 11
sp
block 2 vmax - 23 vmax - 22 vmax - 10 vmax - 11 vmax - 12 vmax - 13 vmax - 1 vmax
blplot
blfactors 2 10 spnblk 30 1
blcd 2 1 10 1 / 1.4
blcd 2 2 10 1 / 1.4
blcd 2 3 10 1.4
blcd 2 4 10 1.4

blex 2

cset cgro 1

view 1 0 0

vset news cset
vp
cset news cgro 1

#def vm2 vmax - vm1

mcopy 4 vm2 0 90 0 active
cset news cgro 1
cp

/////Build inner fan mesh center block/////
vmax
csys 0
cgro 1
mcrea 0 span spnblk -2.12132 2.12132 30 -2.12132 2.12132 30 1 1 1
cset cgro 1
cp

vset news cset
vp
vmerge vset
csys 0
/////Build LP cavity/////
/////LP First Block/////

```

```

vset none
vset news
csys 3
v vmax + 1 0 2.3603 -5.6574
v vmax + 1 0 2.3645 -5.6673
v vmax + 1 0 2.3516 -5.6744
v vmax + 1 0 2.3407 -5.6866
v vmax + 1 0 2.3344 -5.7035
v vmax + 1 0 2.3351 -5.7205
vp
csys 2
v vmax + 1 6.1787 20 0
v vmax + 1 6.1787 15 0
v vmax + 1 6.1787 10 0
v vmax + 1 6.1787 5 0
v vmax + 1 6.1787 0 0
v vmax + 1 6.1787 -5 0
v vmax + 1 6.1787 -10 0
v vmax + 1 6.1787 -15 0
v vmax + 1 6.1787 -20 0
v vmax + 1 6.1787 -25 0
v vmax + 1 6.1787 -30 0
v vmax + 1 6.1787 -35 0
v vmax + 1 6.1787 -40 0
v vmax + 1 6.1787 -45 0
v vmax + 1 6.1787 -50 0
vp
csys 3
v vmax + 1 0 -4.8676 -3.8054
v vmax + 1 0 -4.8818 -3.7668
v vmax + 1 0 -4.8459 -3.7542
vp
csys 2
v vmax + 1 clnc -50 0
v vmax + 1 clnc -45 0
v vmax + 1 clnc -40 0
v vmax + 1 clnc -35 0
v vmax + 1 clnc -30 0
v vmax + 1 clnc -25 0
v vmax + 1 clnc -20 0
v vmax + 1 clnc -15 0
v vmax + 1 clnc -10 0
v vmax + 1 clnc -5 0
v vmax + 1 clnc 0 0
v vmax + 1 clnc 5 0
v vmax + 1 clnc 10 0
v vmax + 1 clnc 15 0
v vmax + 1 clnc 20 0
vp

vmax
spldelete all
#def bp1 vmax - 37
spline 1 vlist vmax - 38 -bp1 vmax - 36 vmax - 35 vmax - 34 vmax - 33
spline 2 vran vmax - 33 vmax - 17 1
#def bp3 vmax - 16
spline 3 vlist vmax - 17 -bp3 vmax - 15
spline 4 vlist vmax - 15 vmax - 14 vmax - 13 vmax - 12 vmax - 11 vmax - 10 vmax - 9 vmax - 8 vmax - 7 vmax - 6
vmax - 5 vmax - 4 vmax - 3 vmax - 2 vmax - 1 vmax vmax - 38
sp

vcopy 2 39 vset 0 0 span

```

```

vp
#def bp5 vmax - 37
spline 5 vlist vmax - 38 -bp5 vmax - 36 vmax - 35 vmax - 34 vmax - 33
spline 6 vran vmax - 33 vmax - 17 1
#def bp7 vmax - 16
spline 7 vlist vmax - 17 -bp7 vmax - 15
spline 8 vlist vmax - 15 vmax - 14 vmax - 13 vmax - 12 vmax - 11 vmax - 10 vmax - 9 vmax - 8 vmax - 7 vmax - 6
vmax - 5 vmax - 4 vmax - 3 vmax - 2 vmax - 1 vmax vmax - 38
sp

```

```

vmax
bdelete all
block 11 vmax - 38 vmax - 33 vmax - 17 vmax - 15 vmax - 77 vmax - 72 vmax - 56 vmax - 54
bplot
bfactors 11 5 30 spnblk 5
blex 11

```

////LP Second Block////////////////////////////////////

```
vset news none
```

```

csys 3
v vmax + 1 0 2.3351 -5.7205
v vmax + 1 0 2.3576 -5.8582
v vmax + 1 0 2.3791 -6.0989
v vmax + 1 0 2.3753 -6.3741
v vmax + 1 0 2.3418 -6.649
v vmax + 1 0 2.2034 -7.0359
v vmax + 1 0 1.8774 -7.4162
v vmax + 1 0 1.4134 -7.7727
v vmax + 1 0 .4909 -7.9588
v vmax + 1 0 -.2726 -7.9034
v vmax + 1 0 -1.2811 -7.5651
v vmax + 1 0 -2.0786 -7.1576
v vmax + 1 0 -2.8812 -6.5783
v vmax + 1 0 -3.5716 -5.8094
v vmax + 1 0 -4.21 -4.9431
v vmax + 1 0 -4.6805 -4.188
v vmax + 1 0 -4.8676 -3.8054
v vmax + 1 0 -4.8676 -3.8054

```

```
csys 2
```

```

v vmax + 1 6.1787 20 0
v vmax + 1 6.1787 15 0
v vmax + 1 6.1787 10 0
v vmax + 1 6.1787 5 0
v vmax + 1 6.1787 0 0
v vmax + 1 6.1787 -5 0
v vmax + 1 6.1787 -10 0
v vmax + 1 6.1787 -15 0
v vmax + 1 6.1787 -20 0
v vmax + 1 6.1787 -25 0
v vmax + 1 6.1787 -30 0
v vmax + 1 6.1787 -35 0
v vmax + 1 6.1787 -40 0
v vmax + 1 6.1787 -45 0
v vmax + 1 6.1787 -50 0

```

```

csys 3
v vmax + 1 0 2.3351 -5.7205

```

```

vmax
vp
spldelete all
spline 1 vran vmax - 33 vmax - 17 1
spline 2 vlist vmax - 16 vmax - 1 vmax - 2 vmax - 3 vmax - 4 vmax - 5 vmax - 6 vmax - 7 vmax - 8 vmax - 9 vmax - 10
vmax - 11 vmax - 12 vmax - 13 vmax - 14 vmax - 15 vmax
sp

csys 2

vcopy 2 34 vset 0 0 span
vp
vmax
spline 3 vran vmax - 33 vmax - 17 1
spline 4 vlist vmax - 16 vmax - 1 vmax - 2 vmax - 3 vmax - 4 vmax - 5 vmax - 6 vmax - 7 vmax - 8 vmax - 9 vmax - 10
vmax - 11 vmax - 12 vmax - 13 vmax - 14 vmax - 15 vmax
sp

bldelete all
block 12 vmax - 33 vmax - 17 vmax - 16 vmax vmax - 67 vmax - 51 vmax - 50 vmax - 34
blfactors 12 30 10 spnblk 6
blcd 12 1 30 1 / 1.01
blcd 12 4 30 1 / 1.01
blex 12
cset news cgro 6
cp
/////Build Exhaust Wall////////////////////////////////////
/////First Block////////////////////////////////
save 22

resu 22
vset none

cset news
cgro 4
vset none
#def vmo vmax

csys 3
v vmax + 1 0 -4.8459 -3.7542
v vmax + 1 0 -4.8818 -3.7668
v vmax + 1 0 -4.8863 -3.7626
v vmax + 1 0 -4.9088 -3.7547
v vmax + 1 0 -4.9347 -3.7653
v vmax + 1 0 -4.9454 -3.7909
vp
csys 2
v vmax + 1 6.2312 305 0
v vmax + 1 6.2312 300 0
v vmax + 1 6.2312 295 0
v vmax + 1 6.2312 290 0
v vmax + 1 6.2312 285 0
v vmax + 1 6.2312 280 0
v vmax + 1 6.2312 275 0
v vmax + 1 6.2312 270 0
v vmax + 1 6.2312 265 0
v vmax + 1 6.2312 260 0
v vmax + 1 6.2312 255 0
v vmax + 1 6.2312 250 0
v vmax + 1 6.2312 245 0
v vmax + 1 6.2312 240 0
v vmax + 1 6.2312 235 0

```

```

v vmax + 1 6.2312 230 0
v vmax + 1 6.2312 225 0
v vmax + 1 6.2312 220 0
v vmax + 1 6.2312 215 0
v vmax + 1 6.2312 210 0
v vmax + 1 6.2312 205 0
v vmax + 1 6.2312 200 0
v vmax + 1 6.2312 195 0
v vmax + 1 6.2312 190 0

```

```

csys 3
v vmax + 1 0 -1.0097 6.1489
v vmax + 1 0 0.0089 6.1376
v vmax + 1 0 0.0089 6.13

```

```

csys 2
v vmax + 1 6.13 305 0
v vmax + 1 6.13 300 0
v vmax + 1 6.13 295 0
v vmax + 1 6.13 290 0
v vmax + 1 6.13 285 0
v vmax + 1 6.13 280 0
v vmax + 1 6.13 275 0
v vmax + 1 6.13 270 0
v vmax + 1 6.13 265 0
v vmax + 1 6.13 260 0
v vmax + 1 6.13 255 0
v vmax + 1 6.13 250 0
v vmax + 1 6.13 245 0
v vmax + 1 6.13 240 0
v vmax + 1 6.13 235 0
v vmax + 1 6.13 230 0
v vmax + 1 6.13 225 0
v vmax + 1 6.13 220 0
v vmax + 1 6.13 215 0
v vmax + 1 6.13 210 0
v vmax + 1 6.13 205 0
v vmax + 1 6.13 200 0
v vmax + 1 6.13 195 0
v vmax + 1 6.13 190 0

```

```

v vmax + 1 6.13 187 0
v vmax + 1 6.13 185 0
v vmax + 1 6.13 183 0
v vmax + 1 6.13 181.5 0
#def dvm vmax - vmo
save 18

```

```

resu 18
vp

```

```

spldelete all
#def bp1 vmax - 59
spline 1 vlist vmax - 60 -bp1 vmax - 58 vmax - 57 vmax - 56 vmax - 55
#def bp2 vmax - 30
spline 2 vran vmax - 55 vmax - 29
splm 2 modi vmax - 30 vmax - 30 * -1
spline 3 vlist vmax - 29 vmax - 28
save 19

```

```

resu 19
sp

```

```

spline 4 vlist vmax - 28 vmax * -1 vmax - 1 vmax - 2 vmax - 3 vmax - 4 vmax - 5 vmax - 6 vmax - 7 vmax - 8
spline 4 vlist vmax - 9 vmax - 10 vmax - 11 vmax - 12 vmax - 13 vmax - 14 vmax - 15 vmax - 16 vmax - 17
spline 4 vlist vmax - 18 vmax - 19 vmax - 20 vmax - 21 vmax - 22 vmax - 23 vmax - 24 vmax - 25 vmax - 26 vmax -
27 vmax - 60
sp

```

```
vcopy 2 dvm vset 0 0 span
```

```

#def bp5 vmax - 59
spline 5 vlist vmax - 60 -bp5 vmax - 58 vmax - 57 vmax - 56 vmax - 55
#def bp6 vmax - 30
spline 6 vlist vmax - 55 vmax - 54 vmax - 53 vmax - 52 vmax - 51 vmax - 50 vmax - 49 vmax - 48 vmax - 47
spline 6 vlist vmax - 46 vmax - 45 vmax - 44 vmax - 43 vmax - 42 vmax - 41 vmax - 40 vmax - 39 vmax - 38 vmax -
37 vmax - 36 vmax - 35 vmax - 34 vmax - 33 vmax - 32 vmax - 31 -bp6 vmax - 29
spline 7 vlist vmax - 29 vmax - 28
spline 8 vlist vmax - 28 vmax * -1 vmax - 1 vmax - 2 vmax - 3 vmax - 4 vmax - 5 vmax - 6 vmax - 7 vmax - 8
spline 8 vlist vmax - 9 vmax - 10 vmax - 11 vmax - 12 vmax - 13 vmax - 14 vmax - 15 vmax - 16 vmax - 17 vmax - 18
vmax - 19 vmax - 20 vmax - 21 vmax - 22 vmax - 23 vmax - 24 vmax - 25 vmax - 26 vmax - 27 vmax - 60
sp

```

```

bdelete all
block 13 vmax - 29 vmax - 28 vmax - 60 vmax - 55 vmax - 90 vmax - 89 vmax - 121 vmax - 116

```

```

blfactors 13 5 70 spnblk 7
blex 13
cset news cglist 7 2
VIEW 1.0000e+000 0.0000e+000 0.0000e+000
VUP 0.0000e+000 1.0000e+000 0.0000e+000
FOCAL COORD 2.5000e-001 -6.5494e-001 6.0758e+000
SCALE VALUE 4.0470e-001
cp
save 23

```

```

resu 23
autosc on
focal center
/////Exhaust Duct Second Block/////
vset none
csys 3
v vmax + 1 0 -4.9454 -3.7909
v vmax + 1 0 -7.2027 -3.7909//bp?
v vmax + 1 0 -9.46 -3.7909
vp
csys 0
local 4 cyli 0 -0.57 -2.72 0 90 0 0 0
csys 4
v vmax + 1 8.89 -90 0
v vmax + 1 8.89 -95 0
v vmax + 1 8.89 -100 0
v vmax + 1 8.89 -105 0
v vmax + 1 8.89 -110 0
v vmax + 1 8.89 -115 0
v vmax + 1 8.89 -120 0
v vmax + 1 8.89 -125 0
v vmax + 1 8.89 -130 0
v vmax + 1 8.89 -135 0
v vmax + 1 8.89 -140 0
v vmax + 1 8.89 -145 0
v vmax + 1 8.89 -150 0
v vmax + 1 8.89 -155 0
v vmax + 1 8.89 -160 0

```

v vmax + 1 8.89 -165 0
v vmax + 1 8.89 -170 0

csys 3
v vmax + 1 0 -1.0097 6.1489
v vmax + 1 0 -1.0097 6.1489

vp

csys 2
v vmax + 1 6.2312 305 0
v vmax + 1 6.2312 300 0
v vmax + 1 6.2312 295 0
v vmax + 1 6.2312 290 0
v vmax + 1 6.2312 285 0
v vmax + 1 6.2312 280 0
v vmax + 1 6.2312 275 0
v vmax + 1 6.2312 270 0
v vmax + 1 6.2312 265 0
v vmax + 1 6.2312 260 0
v vmax + 1 6.2312 255 0
v vmax + 1 6.2312 250 0
v vmax + 1 6.2312 245 0
v vmax + 1 6.2312 240 0
v vmax + 1 6.2312 235 0
v vmax + 1 6.2312 230 0
v vmax + 1 6.2312 225 0
v vmax + 1 6.2312 220 0
v vmax + 1 6.2312 215 0
v vmax + 1 6.2312 210 0
v vmax + 1 6.2312 205 0
v vmax + 1 6.2312 200 0
v vmax + 1 6.2312 195 0
v vmax + 1 6.2312 190 0

vp
vmax

spldelete all
spline 1 vran vmax - 45 vmax - 43 1
spline 2 vran vmax - 43 vmax - 25 1
spline 3 vlist vmax - 24 vmax vmax - 1 vmax - 2 vmax - 3 vmax - 4 vmax - 5 vmax - 6 vmax - 7 vmax - 8
spline 3 vlist vmax - 9 vmax - 10 vmax - 11 vmax - 12 vmax - 13 vmax - 14 vmax - 15 vmax - 16 vmax - 17 vmax - 18
vmax - 19 vmax - 20 vmax - 21 vmax - 22 vmax - 23 vmax - 45
sp
vmax

save 44

resu 44
vcopy 2 46 vset 0 0 span
vp
vmax

spline 4 vran vmax - 45 vmax - 43 1
spline 5 vran vmax - 43 vmax - 25 1
spline 6 vlist vmax - 24 vmax vmax - 1 vmax - 2 vmax - 3 vmax - 4 vmax - 5 vmax - 6 vmax - 7 vmax - 8
spline 6 vlist vmax - 9 vmax - 10 vmax - 11 vmax - 12 vmax - 13 vmax - 14 vmax - 15 vmax - 16 vmax - 17 vmax - 18
vmax - 19 vmax - 20 vmax - 21 vmax - 22 vmax - 23 vmax - 45
sp

bldelete all

block 14 vmax - 25 vmax - 24 vmax - 45 vmax - 43 vmax - 71 vmax - 70 vmax - 91 vmax - 89

blfactors 14 10 30 spnblk 8
blcd 14 5 30 1 / 1.01025
blcd 14 6 30 1 / 1.01025
blcd 14 7 30 1
blcd 14 8 30 1
blex 14

cset news cgro 8
cp

vmax

/////Build Exhaust Wall Extension////////////////////////////////////

csys 3
vset none
v vmax + 1 0 -4.9454 -3.7909
v vmax + 1 0 -7.2027 -3.7909
v vmax + 1 0 -9.46 -3.7909
v vmax + 1 0 -4.9454 -8.825
v vmax + 1 0 -7.2027 -8.825
v vmax + 1 0 -9.46 -8.825
vp

spldelete all
#def bp1 vmax - 4
spline 1 vlist vmax - 3 -bp1 vmax - 5
spline 2 vlist vmax - 5 vmax - 2
#def bp3 vmax - 1
spline 3 vlist vmax - 2 -bp3 vmax
spline 4 vlist vmax vmax - 3
sp

vcopy 2 6 vset span 0 0
vp
#def bp5 vmax - 4
spline 5 vlist vmax - 3 -bp5 vmax - 5
spline 6 vlist vmax - 5 vmax - 2
#def bp7 vmax - 1
spline 7 vlist vmax - 2 -bp7 vmax
spline 8 vlist vmax vmax - 3
sp

vmax

bldelete all
block 6 vmax - 3 vmax - 5 vmax - 2 vmax vmax - 9 vmax - 11 vmax - 8 vmax - 6
blfactors 6 10 10 spnblk 9
blex 6

/////Build HP Cavity////////////////////////////////////

/////HPC First Block////////////////////////////////////

csys 0
csys 3
vset none
vset news

v vmax + 1 0 4.8676 3.726

```

v vmax + 1 0 4.8852 3.7369
v vmax + 1 0 4.8757 3.7578
v vmax + 1 0 4.8741 3.7775
v vmax + 1 0 4.8790 3.7954
v vmax + 1 0 4.8871 3.8086
v vmax + 1 0 4.9406 3.8754

```

csys 2

```

v vmax + 1 6.2792 175 0
v vmax + 1 6.2792 170 0
v vmax + 1 6.2792 165 0
v vmax + 1 6.2792 160 0
v vmax + 1 6.2792 155 0
v vmax + 1 6.2792 150 0//breakpoint
v vmax + 1 6.2792 145 0
v vmax + 1 6.2792 140 0
v vmax + 1 6.2792 135 0
v vmax + 1 6.2792 130 0

```

csys 3

```

v vmax + 1 0 -.0605 6.2789
v vmax + 1 0 .0075 6.2675
v vmax + 1 0 .0329 6.262
v vmax + 1 0 .053 6.249
v vmax + 1 0 .0655 6.2324
v vmax + 1 0 .0729 6.2016
v vmax + 1 0 .0676 6.1767
v vmax + 1 0 .0516 6.1543
v vmax + 1 0 .0324 6.1423
v vmax + 1 0 .0089 6.1376
v vmax + 1 0 .0089 6.13

```

csys 2

```

v vmax + 1 clnc 175 0
v vmax + 1 clnc 170 0
v vmax + 1 clnc 165 0
v vmax + 1 clnc 160 0
v vmax + 1 clnc 155 0
v vmax + 1 clnc 150 0//breakpoint
v vmax + 1 clnc 145 0
v vmax + 1 clnc 140 0
v vmax + 1 clnc 135 0
v vmax + 1 clnc 130 0
v vmax + 1 clnc 127.5 0
vp

```

vmax

spldelete all

#def bp1 vmax - 37

spline 1 vlist vmax - 38 -bp1 vmax - 36 vmax - 35 vmax - 34 vmax - 33 vmax - 32

spline 2 vlist vmax - 32 vmax - 22 vmax - 23 vmax - 24 vmax - 25 vmax - 26 vmax - 27 vmax - 28 vmax - 29 vmax - 30 vmax - 31 vmax - 21

#def bp3 vmax - 12

spline 3 vlist vmax - 21 vmax - 20 vmax - 19 vmax - 18 vmax - 17 vmax - 16 vmax - 15 vmax - 14 vmax - 13 -bp3 vmax - 11

spline 4 vlist vmax - 11 vmax - 10 vmax - 9 vmax - 8 vmax - 7 vmax - 6 vmax - 5 vmax - 4 vmax - 3 vmax - 2 vmax - 1 vmax vmax - 38

sp

```

csys 3
vcopy 2 39 vset span 0 0
vp

#def bp5 vmax - 37
spline 5 vlist vmax - 38 -bp5 vmax - 36 vmax - 35 vmax - 34 vmax - 33 vmax - 32
spline 6 vlist vmax - 32 vmax - 22 vmax - 23 vmax - 24 vmax - 25 vmax - 26 vmax - 27 vmax - 28 vmax - 29 vmax -
30 vmax - 31 vmax - 21
#def bp7 vmax - 12
spline 7 vlist vmax - 21 vmax - 20 vmax - 19 vmax - 18 vmax - 17 vmax - 16 vmax - 15 vmax - 14 vmax - 13 -bp7
vmax - 11
spline 8 vlist vmax - 11 vmax - 10 vmax - 9 vmax - 8 vmax - 7 vmax - 6 vmax - 5 vmax - 4 vmax - 3 vmax - 2 vmax - 1
vmax vmax - 38
sp

vmax

bldelete all
block 7 vmax - 21 vmax - 32 vmax - 38 vmax - 11 vmax - 60 vmax - 71 vmax - 77 vmax - 50
blfactors 7 20 10 spnblk 10
blex 7
cset news cgro 10
cp

/////HPC Second Block////////////////////////////////////
vset none
csys 3

v vmax + 1 0 4.9406 3.8754
v vmax + 1 0 5.29 4.5
v vmax + 1 0 5.59 5.68
v vmax + 1 0 5.29 6.99
v vmax + 1 0 5.05 7.4156
v vmax + 1 0 4.2003 8.3185
v vmax + 1 0 3.3509 8.9136//breakpoint ?????
v vmax + 1 0 2.9006 9.1322
v vmax + 1 0 2.502 9.2577
v vmax + 1 0 1.77 9.35
v vmax + 1 0 .8759 9.221
v vmax + 1 0 0 8.84
v vmax + 1 0 -.58 8.16
v vmax + 1 0 -.79 7.39
v vmax + 1 0 -.6908 7.0132
v vmax + 1 0 -.5907 6.7994
v vmax + 1 0 -.3601 6.4987
v vmax + 1 0 -.2105 6.3704
v vmax + 1 0 -.0605 6.2789
v vmax + 1 0 -.0605 6.2789
vp

csys 2

v vmax + 1 6.2792 175 0
v vmax + 1 6.2792 170 0
v vmax + 1 6.2792 165 0
v vmax + 1 6.2792 160 0
v vmax + 1 6.2792 155 0
v vmax + 1 6.2792 150 0//breakpoint
v vmax + 1 6.2792 145 0
v vmax + 1 6.2792 140 0
v vmax + 1 6.2792 135 0
v vmax + 1 6.2792 130 0

```

```

csys 3

v vmax + 1 0 4.9406 3.8754
vp
vmax

spldelete all
spline 1 vran vmax - 30 vmax - 12 1
spline 2 vran vmax - 11 vmax 1
sp

vcopy 2 31 vset span 0 0
vp

spline 3 vran vmax - 30 vmax - 12 1
spline 4 vran vmax - 11 vmax 1
sp

bldelete all
block 8 vmax - 12 vmax - 30 vmax vmax - 11 vmax - 43 vmax - 61 vmax - 31 vmax - 42
blfactors 8 30 10 spnblk 11
blex 8
cset news cgro 11
cset all
cp

view -1 0 0
cp
////////////////////////////////////
////////////////////////////////////COMPLETE WITH STRUCTURE////////////////////////////////////
////////////////////////////////////
save 33

resu 33
/////Merge vertices in non-sliding cell groups/////
cset none
cset news cgro 2
cset cgro 3
cset cgro 4
cset cgro 5
cset cgro 6
cset cgro 7
cset cgro 8
cset cgro 9
cset cgro 10
cset cgro 11
cp

vset news cset
vmerge vset 0.0005

cset news cgro 3
cset cgro 10
cp
vset news cset
vmerge vset 0.0001

cset news cgro 8
cset cgro 9
cp
vset news cset

```

```

vmerge vset 0.0001

save 66

resu 66
/////Find embedded cell sets/////
cset news cgro 3
vcdis cset
cset cgro 2
cp
esfind 2 3 0.01 10 11 12

cset news cgro 2
csys 2
cset gxyzrange 5 6.13 6.135 0 22 0 span
cset gxyzrange 5 6.13 6.135 300 360 0 span
cp

cp
esfind 2 5 0.02 30 11 12

cset news cgro 5
cset cgro 6
cp
esfind 5 6 0.01 30 11 12

cset news cgro 3
cset cgro 4
cp
esfind 3 4 0.005 30 11 12

cset news cglist 2 7
csys 2
cp
esfind 2 7 0.02 30 11 12

cset news cgro 2
cset cgro 10
cp
esfind 2 10 0.05 30 11 12

cset news cgro 7
cset cgro 8
cp
esfind 8 7 0.02 10 11 12

cset news cgro 7
cset cgro 10
cp
esfind 10 7 0.0001 10 11 12

cset news cgro 7
cset cgro 5
cp
esfind 5 7 0.0001 10 11 12

cset news cgro 10
cset cgro 11
cp
esfind 10 11 0.005 30 11 12

```

/////Compress all vertex and cell numbers/////

save 1
resu 1

// Boundaries
// Inlet
cset none
cset cgro 4
view 1 0 0
cp
bface 1 east
bset news bgro 1
bp

// Outlet
cset none
cset cgro 9
view 0 0 -1
cp
bface 2 north
bset bgro 2
bp

// Symmetry
// Merge vertices first otherwise
// boundaries will be created on axis
csys 3
cset all
view 1 0 0
pltype hsurf
cp
bview 3 10
view -1 0 0
pltype hsurf
cp
bview 3 10

// Attached boundary 1
csys 2
cset news cgro 0
cset news gxyzrange 0 6 6.2 0 360 0 span
view 1 1 1
cp
bface 4 east
bset news bgro 4
bp

// Attached boundary 2
cset news cgro 2
view 1 1 1
cp
bface 5 west
bset bgro 5
bp

//Attached Boundary 3
csys 2
cset news cgro 0
cset news gxyzrange 0 4.15 4.2 0 360 0 span

```

view 1 1 1
cp
bface 6 west
bset news bgro 6
bp

//Attached Boundary 4

cset news cgro 1
cset news gxyzrange 1 4.0 4.15 0 360 0 span
view 1 1 1
cp
bface 7 east
bset news bgro 7
bp
bset bgro 6
bp

save 2

resu 2
movi on stand //yes
#def step 1.5e-6 0
// Note 1
// NB Watch out for this:
// #def speed 5000 //in RPM
// rather use this:
#def speed 3000 0 //in RPM

unst on step fixed 10 1 //1 1.05
unst on step adjust 10 1.2 10

#def dpt speed * 360 / 60 * step 0
slide on

ssdef 1 2 0 0 speed / 2 0 arbitr 4 5 0.000001 20 const 0 0 2
ssdef 2 2 0 0 speed / 2 0 arbitr 6 7 0.000001 20 const 0 0 1

ssdef 1 2 0 0 speed / 2 0 arbitr 4 5 0.0001 10 const 0 0 2
ssdef 2 2 0 0 speed / 2 0 arbitr 6 7 0.0003 10 const 0 0 1

bgdef 4 attach
2 0
bgdef 5 attach
2 0
bgdef 6 attach
2 0
bgdef 7 attach
2 0

//energy on
bgdef 3 symm

bgdef 1 pres
-3000 300 0.05 0.001
//bgdef 1 inlet const
//2 -12.62 0 0 1.2 0.05 0.001 0.001
bgdef 2 pres
0 300 0.05 0.001

```

```

mdef 0 fluid

cgdef 0 0
cgdef 1 0
cgdef 2 0
cgdef 3 0
cgdef 4 0
cgdef 5 0
cgdef 6 0
cgdef 7 0
cgdef 8 0
cgdef 9 0
cgdef 10 0
cgdef 11 0

save 5

resu 5

cset all
vset news cset
vset unsel
vdel vset

vcomp all
ccomp all
wmesh .0254

mate 0
turb on
dens const 1.204

//density ideal yes 28.7
visc const 0.000018
pgrad zero
pref 100000 cm1

rest init
iter 60000 100 1000
//restart previous 496
unst on 1e-6 adjust 1 1.5 50
unst on 1e-6 adjust 0.9 1.2 50
conv 0.001
switch 21 on
wdef

save

plty wire
view 1 2 3
bset news bgro 1

bset bgro 0
bset bgro 1
bset bgro 2
bset bgro 4
bset bgro 5
bset bgro 6
bset bgro 7
bp

```

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