AN EXPERIMENTAL INVESTIGATION OF IMPINGEMENT COOLING IN AN AIRFOIL LEADING-EDGE CAVITY

A thesis presented

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ABSTRACT

An experimental investigation was carried out to determine the effects of the number of unblocked cross-over holes and different flow arrangements on heat transfer coefficients in impingement cooling over a curved surface, simulating the leading-edge cooling cavity of an airfoil. A jet plate through which impingement took place divided the test section to two main parts; the supply channel through which the flow was directed into the test section and the leading-edge channel were the targeted surface was installed. Experimental results were obtained for five cases: 1) nine cross-over holes, 2) eight cross-over holes, 3) seven cross-over holes, 4) six cross-over holes and 5) five cross-over holes. The different flow arrangements tested were: 1) flow entering from one side of supply channel and leaves from the opposite side of the L.E channel (parallel), 2) flow entering from one side of the supply channel and leaves from the same side of the L.E channel (circular), 3) flow entering from one side of the supply channel and leaves from both side of L.E channel (both-end-open), 4) flow entering the test section from both side of the supply channel and leaves from both sides of L.E channel. The nine, eight and five unblocked holes were tested for parallel, circular, both-end-open and 2-inlet-2-outlet flow arrangement, while the six and seven unblocked holes were tested for parallel, circular and both-end-open flow arrangements.

Most of the data available in the open literature are for jets impinging over different geometry surfaces and for different surface texture. Therefore, the present investigation includes a new geometry to study the airfoil leading-edge cooling, which is the study of the effect of different flow arrangement and different number of cross-over-holes.

The results showed that, on the target surface, the heat transfer coefficients increased with increasing the number of blocked holes. This led to the increasing of the jet Reynolds number. Also the 2-inlet-2-outlet flow arrangement resulted in a higher transfer coefficient over the rest of the flow arrangements.

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NOMENCLATURE

A_{nose}	nose copper plate surface area
d_h	cross-over holes hydraulic diameter
A_{side}	side copper plate surface area
h	average heat transfer coefficient on the leading-edge wall, $[(\upsilon_2 i_2/A_{HT}) - q_{loss}]\ /\ (T_s - T_{jet})$
i_i	current through the i-th heater
υ_i	voltage across the i-th heater
k	air thermal conductivity at jet temperature
m	air total mass flow rate through all nine cross-over holes
q_{loss}	heat loss from the copper plates to the ambient by conduction and convection as well as the heat loss by radiation to the unheated walls
T_{jet}	air jet temperature
T_s	copper plates surface temperature
μ	air dynamic viscosity at jet temperature
ρ	air density at jet temperature and pressure
Re_{jet}	Reynolds number based on the jet diameter ($\rho U_{jet}\, d_h / \mu$)
Nu_{jet}	average Nusselt number based on the jet diameter (hd_h / k)
$\mathrm{F_{rad}}$	radiational losses between the copper plate and the unheated walls
$\mathrm{T_{amb}}$	ambient temperature
$\mathrm{T_m}$	unheated walls mean temperature
$\mathrm{T_{ven}}$	air temperature at the venturi inlet
$\mathrm{P_{atm}}$	atmospheric pressure
$\mathrm{P_{ven}}$	venturi inlet pressure
$\mathrm{A_{throat}}$	area of the venturi throat
$\varepsilon_{\mathrm{brass}}$	middle brass piece emissivity
σ	Stefan-Boltzmann constant
$\mathrm{R_{total}}$	total thermal resistance from the brass piece to the lab air

CHAPTER 1
INTRODUCTION AND LITERATURE REVIEW

A turbine is a rotary engine that extracts energy from a fluid flow and converts it into useful shaft work. There are different types of turbines such as gas turbines, steam turbines, and wind turbines. The simplest turbine has one moving part, rotor, which is a rotating shaft with different span length-blades attached to it. High energy working fluid acts on the blades and imparts energy to the rotor.

Gas turbines are used in a wide variety of applications, industry and military for power generation. They are used to drive mechanical equipments in industrial plants such as pumps and compressors, and to drive electrical generators as well. Gas Turbines are used in jet engines to power aircrafts.

1.1 Need for Turbine Blade Cooling

Gas turbines have relatively low thermal efficiency, compared to steam turbines. One major reason is the limitations in the gas turbine inlet temperature. The low efficiency of gas turbines limited its application in the industry. Increasing the gas turbine's inlet temperature will greatly enhance the performance of the gas turbine, but the turbine's blade will be exposed to high gas stream and subjected to severe environment conditions.

Therefore researches have endeavored to help increasing the turbine inlet temperature by researching and developing advanced material to withstand the harsh thermal-stress environment, and by using corrosion resistant coating in the manufacturing of turbine blades, and by researching the turbine blade cooling to reduce the surface temperature of the blade and to reduce the temperature average in the cross section of the blade which increases the material rupture capability and thus increase the life time expectancy of the blade, this thesis represents the latter.

Water is also very effective in turbine blade cooling, it has a high specific heat and let evaporative cooling takes place. The water is effective for stationary plants only, so using it in jet engines for the aircraft will be challenging and problematical, and it has other difficulties as moving the water from and to the blades.

1.2 Turbine Blade Cooling Techniques

The high-pressure and high temperature gas exits the combustion chamber to the gas turbine blade passage and causes high temperature at the blade surface, thus in most practical cases some air is bled directly after the compressor before it enters the combustion chamber as a coolant. Three techniques are used in the turbine blade cooling according the coolant passage through the blade; they are *convective cooling, film cooling, and impingement cooling.*
In the *convective cooling* technique the coolant circulates through cavities cast in the blade as shown in figure 1.1, and by allowing the coolant to flow through holes on the blade surface, it forms protective film on the blade's surface which insulates the blade from the hot gases and this referred as *film cooling* as shown in figure 1.2

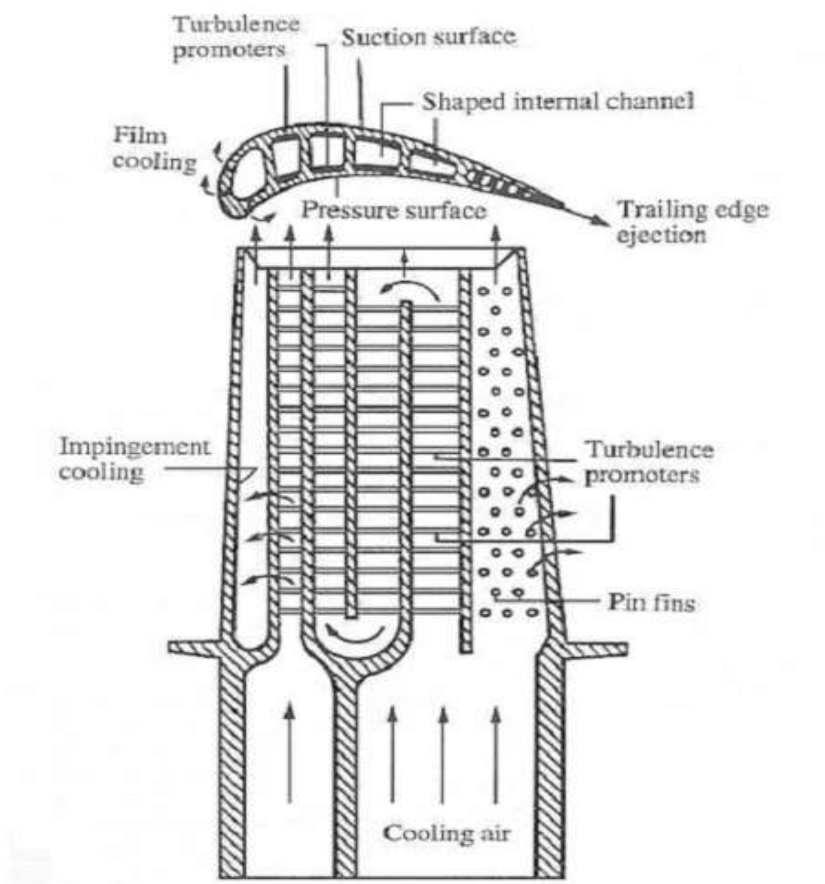


Figure 1.1 Internal forced convection cooling

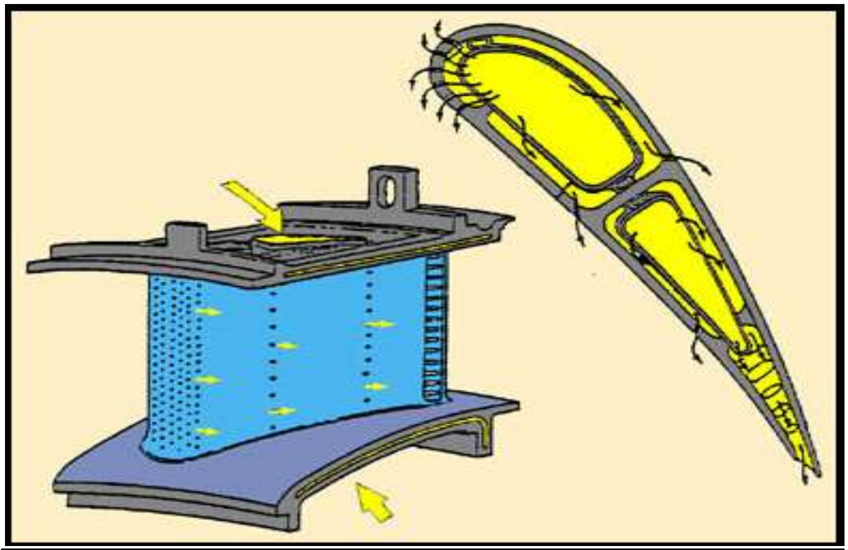


Figure 1.2 Impingement cooling

In the *impingement cooling* technique, the coolant is forced to impinge on the internal surface of the blade. Impingement cooling technique is possible to be applied with convective cooling technique, or with the film cooling technique. An airfoil may exploit impingement cooling and film cooling in the leading edge area, while the trailing edge region cooled using the convection cooling technique.

Some of the disadvantages of using the previous three techniques were: high manufacturing cost, less work extracted from the turbine as coolant passes from a stage to the other, and losses from mixing coolant with gases.

The focus of this study is on the impingement cooling technique.

1.3 Literature Review

In an investigation by Metzger et al. (1969) [1],, an experimental study of the heat transfer characteristics for single line of circular jets impinging on concave cylindrical surface was presented. According to the results obtained, circular jets impinging on concave surfaces were more efficient than on plane surfaces. In the case of impingement over concave surfaces, results showed that the highest values of heat transfer coefficients occurred at the $Z_n/b=3.5$,while in the case of impingement over plane surfaces, the maximum heat transfer coefficient occurred at $Z_n/b=8$. Where Z_n: nozzle-target spacing, b: widh of an actual or equivalent two-dimensional nozzle.

Kercher and Tabakoff (1970) [2], carried out an experimental research on heat transfer coefficients for impingement on a surface under a perforated plate of multiple square arrays and round air jets. Data collection was done over a range of jet Reynolds number from 300 to 30000, plate to surface distance of 1.0102 to 3.104, jet spacing from 3.1 to 12.5 diameter and plate-to-surface distance of 1 to 4.8 diameter. Results showed that the heat transfer coefficients increases with increasing open area and were dependent on the Reynolds number and hole spacing-to-diameter ratio. The results also showed that the heat transfer coefficient of round impinging jets on a flat plate cannot be correlated by power function expressions of dimensionless parameters.

An experiment was conducted by Akella and Han (1999) [3] to study the impingement cooling on ribbed walls in rotating two-pass rectangular channel with a sharp 180^0 turn. The purpose of this study was mainly on the effects of angled ribs in non-rotating impingement-cooled blades and the combined effects of angled ribs and rotation in rotating impingement-cooled blades, where rib pitch-to-height and rib height-to-channel hydraulic diameter were fixed at 10 and 0.124 for all tests. The overall impingement effects on the wall was lower during the rotating tests due to the Centrifugal and Coriolis forces compared with those in the non-rotating tests as a result, the heat transfer coefficients were lower in the rotating tests when compared with those in the non-rotating tests.

In an experimental study by Hwang et al. (1999) [4], heat transfer and pressure drop characteristics in triangular ducts with multiple side-entry wall jets were investigated. Transient liquid crystal technique and flow visualization via smoke injection were used in the course of this experiment.

Due to the swirl-motioned crossflow effect, the jet was deflected towards that direction. For three different duct shapes, on the bottom and the target wall, area-averaged Nusselt numbers were correlated with Reynolds numbers. The modified pressure drop coefficient Cp,the Cp defined as $2\rho\ (P-P_0\ )/U^2$ distribution, on the swirl-flow triangular duct, showed a slight decrease at the beginning and then a sharp decrease. The normalized pressure drop started with a sharp and then a slight decrease towards the downstream. This trend was in good agreement with that of the developing straight pipe flow.

In an experimental study by Strigel and Diller (1984) [5], local heat transfer rates were measured for single and multiple, plane, turbulent impinging air jests to determine the effect of entrainment temperature. In doing so, the effect of single jet, applied to an environment with a varying temperature between the jet temperature and the temperature of the heated impingement plate was first studied. Results were used to analyze the effect of recirculation region between the jets of a series of jet arrays on entrainment temperature. Correlations for the single jets were then applied to multiple jets. The entrainment effects were almost negligible in the wall jet region.

An experimental investigation was carried out by Trabold and Obot (1987) [6] to determine the effects of jet-induced crossflow on impingement heat transfer from rough surfaces with repeated square ribs. The study included the effects of open area, jet-to-plate spacing, Reynolds number and pitch-to-height ratio. The rib height was fixed at 0.813 mm and the pitch-to-height ratio was varied between 6 and 10.The standoff spacing was between 2 to 16 jet hole diameters and the jet

Reynolds numbers varied from 1300 to 21000.three nozzle plates were tested with 48, 90 and 180 square-edged holes. The first flow scheme was intermediate flow, discharge of the spent air through two opposite sides, while the second flow scheme was complete cross flow, discharge of the spent air through one side. The roughened plate heat transfer coefficients with intermediate crossflow were generally lower than the smooth surface, for small open area and narrow spacing. Results showed that in the case of impingement on a roughened surface, the best design would be the cross flowing stream. It was shown the effect of roughness on heat transfer depend on the intensity of crossflow at the impingement surface which was determined by the open area and the jet-to-surface spacing.

In an investigation by Hollworth and Cole (1987) [7], convective heat transfer measurements were reported for staggered arrays of round turbulent air jets impinging upon a heated flat surface. Spent air was arranged to form a crossflow. Three hole patterns, all having a diameter of 8.5 mm, were tested. Their X, Y coordinates were [4d, 4d], [4d, 8d] and [8d, 4d]. Standoffs had the following values Z=d, 2d and 3d and tests were run for 4, 6 and 8 row of holes. The range had a peak for each spanwise row of holes and was periodic. The peaks were shifted considerable distances to downstream by the effect of cross flow. Results were in good arrangement with the results of other experiments on similar impingement-with-crossflow systems.

An experiment was conducted by Sparrow et al. (1984) [8], to measure quasi-local heat transfer coefficients on a cylinder on which a circular jet impinged in crossflow. Flow visualization was used for examining the impingement pattern. Distance between the jets and the cylinder surface and the jet diameter varied for each test. The experimental work was performed for mass transfer and by analogy the results were also presented for heat transfer. The peak heat transfer coefficient increased as the jet-to-surface spacing decreased for a particular jet diameter and Reynolds number. Also the peak heat transfer coefficient increased as the jet diameter decreased at fixed values of Reynolds number and the jet initiation distance. The largest peak Sherwood number for a particular jet diameter and Reynolds number occurred at the smallest jet initiation distance.

In an investigation by Florschuetz et al. (1984) [9], two dimensional arrays of circular jets impinging on a heat transfer surface parallel to the jet orifice plate were considered. The impinging arrays of jets were forced to leave the test section in a single direction through a channel. An initial cross flow approached the jet arrays from the upstream of the channel, was present in addition to the crossflow which was produced by the impingement. The objective of this research was to determine the effects of the relative temperature of the initial crossflow with respect to the jet array temperature, on impingement surface heat fluxes. Most of the data collection was for a jet Reynolds number of 104.according to the results obtained, Nusselt numbers reduced significantly at the upstream region.

Florschuetz et al. (1981) [10] investigated the case of two-dimensional arrays of air jet impinging on a target surface parallel to a jet orifice. A unidirectional crossflow, made up of impinging jets was studied. Nusselt numbers were reported for one stream wise spacing, a range of jet Reynolds numbers and cross-to-jet velocity ratios. The heat transfer coefficients were measured for a uniform impingement surface temperature. Results of crossflow on streamwise resolved Nusselt numbers were comparable to that of Chance (1974), kercher and Tabakoff (1970).

Hollworth and Wilson (1984) [11] conducted experiments to characterize a heated turbulent air jet discharged from a square-edged orifice having length to diameter equal to unity. A theoretical model was developed to show the distributions of recovery temperature with the test data. The profiles of the mean axial velocity and the total temperature were similar in the main part of the jet. For the dimensionless recovery temperature, the profiles were measured on a flat plate normal to the jet axis. These profiles could be collapsed onto a universal profile for $z \geq 5$, if the radial position is normalized by dividing by the arrival value of the jet half-width.

Brahma et al. (1994) [12] investigated an experiment to study the flow characteristics of slot jet impingement on a cylinder. The effects of flow rate, distance of the cylinder from the jet exit and eccentricity of the cylinder to the jet axis on velocity profiles, width of the nozzle and pressure distribution around the c\cylinder were studied. According to the results obtained, the eccentricity caused the stagnation point to shift to a position lower than the intersection of the jet axis and the cylinder. At higher Reynolds numbers and higher nozzle widths, the jet height turned out to be higher.

Experiments were performed by Gau and Chung (2003) [13] to study surface curvature on the impingement cooling flow and the heat transfer process over concave and convex surfaces. The flow structure was viewed using Smoke-visualization technique. The Reynolds numbers ranged between 6000 and 350,000,the diameter-to-slot width ratio from 8 to 45.7 and the slot-to-plate spacing from 2 to 16.Results showed that the Nusselt number increased with the increase of the surface curvature. This showed the presence of Taylor-Gortler vortices along the surface. In the case of impingement on a concave surface, no three dimensional vortices were noticed in the stagnation point.

In an experimental investigation by Gau and Lee (1992) [14], slot-air-jet impingement cooling flow structure and heat transfer along rib-roughened walls were studied. Smoke generated by vaporizing oil coated over a heated resistance wire, was used for visualizing the flow structure. Two different ribbed walls with pitch-to-height ratios of 3 and 4 were studied. Reynolds numbers range was between 2500 and 11000. The slot-width-to-rib-height ratio was between 1.17 and 6.67 and the nozzle-to-plate spacing was between 2 and 16. Results showed that Nusselt number was affected by the mentioned parameters and was low at the stagnation point. As the slot width-to-rib height ratio increased, the wall jet separated from the rib, attached to the next rib and circulated inside the cavity. This effect significantly enhanced the heat transfer coefficient. Sakar and Florschuetz (1992) [15] carried out an experimental investigation on the heat transfer rate at the entrance region of a parallel plate channel downstream of a jet array which was located in one of the plates. Air was used as the working fluid. The jet impingement surface was isothermal whereas the opposing surface was adiabatic. The main objective of this research was do to determine how the flow rate and array geometric parameters affected the local Nusselt numbers on the entrance region of the channel at the downstream part of the array. Results showed that neither the in-line nor the staggered pattern had a significant influence on the Nusselt number at the entrance of the channel. The Nusselt number for the heated surface was 16% below that for a symmetrically heated channel.

In an experimental investigation conducted by Al-Sanea (1992) [16], a numerical model was constructed and applied for calculating the steady flow and heat transfer characteristics of a laminar slot-jet-impinging on an isothermal flat surface, using the control-volume finite-difference technique. The three cases of free-jet impingement, semi-confined jet impingement, and semi-confined jet impingement through a cross flow were tested. Results showed that the cross flow had a significant effect on reducing the nominal heat transfer rate up to 60%. The problem was changed from being a jet-impingement behavior to parallel-to-plate cross flow behavior, when the cross-flow to jet mass-flow rate ratio went up to more than two.

In an investigation by Li and Tao (1993) [17], laminar flow and heat/mass transfer of a slot-jet impinging in a rectangular cavity was studied numerically and experimentally. The equations were formed using Finite Volume technique. Effects of the jet exit velocity, jet exit-to-bottom cavity distance and Reynolds numbers were investigated. Naphthalene sublimation technique was used for local mass transfer coefficient distribution and the local Sherwood number distribution was measured. Results showed a two-dimensional heat/mass transfer and fluid flow in the central part of the bottom surface and a two-dimensional model for the local Nusselt number distribution agreed well with the experimental results. The effects of the jet-exit Reynolds number were found to be more significant on the lateral wall than on the bottom surface. The correlation between the Nusselt number and the Reynolds number was presented by power-law equations.

Results of numerical simulation of two-dimensional flow field and heat transfer impingement due to a turbulent single heated slot jet discharging normally into a confined channel using both low-Reynolds number and high-Reynolds versions of k-ε models for modeling the turbulent jet flow, were presented by Seyedein et al (1994) [18]. The range of Reynolds number and nozzle-to-impingement spacing were from 5000 to 20000 and 2.5 to 7.5 respectively. Experimental results showed that the k-ε model was not a good model for this simulation. Nusselt numbers were shown to be underestimated in this model. However, the low-Reynolds number model showed comparable results with that presented by Lam-Bremhorst and Launder-Sharma (1974).

In an investigation by Lytle and Webb (1994) [19], the local heat transfer characteristics of air jet impingement at nozzle-plate spacing less than one nozzle diameter was examined experimentally. Infra red thermal imaging technique was used during the course of this experiment. Laser Droppler velocity measurements and wall pressure measurements were used to investigate the flow structure. The Reynolds numbers ranged between 3600 and 27600. Nozzle-plate spacing was less than nozzle diameter for all experiments. The mean velocity and turbulent fluctuations showed a decreasing trend with the decrease in nozzle-plate spacing. However, stagnation point heat transfer coefficients increased significantly with the decrease of nozzle-plate spacing. The local Nusselt number showed an increasing radial trend for higher Reynolds numbers and larger nozzle-plate spacing. The data obtained in this experiment were in good agreement with an approximate extension of laminar theory of an infinite impinging jet.

An experiment was conducted by Lin et al. (1997) [20] to study heat transfer behavior of a confined slot jet impingement. The effects of jet Reynolds number and jet separation distance on heat transfer coefficients were studied. Results showed that the effects of jet separation distance were not significant on the heat transfer performance, whereas the heat transfer increased with the increase in Reynolds number notably. Two correlations for the stagnation and average Nusselt number were introduced in this experiment. The ranges of validity for using this correlation were $190 \leq R_e \leq 1537$ and $1 \leq H/W \leq 8$. Results of this experiment showed good agreement with the results presented by Chou and Hung (1994).

Chakroun et al. (1998) [21] performed an experimental investigation of heat transfer from a round air jet impinging normally from below onto heated square plate. Roughened and smoothed plates were used in the course of this experiment. Reynolds number ranges from 6500 to 19000 and were based on the jet-exit velocity and nozzle-exit diameter. The nozzle-to-plate distance ranged from 0.05 to 15 nozzle-exit diameter. The results showed that roughness caused the heat transfer to increase from 8.3% to 28% depending on the Reynolds number and the nozzle-to-plate spacing. The maximum mean velocity for the roughened case was lower than that for the smooth case. Results also showed that the turbulence intensity was affected by the roughness. The turbulence intensity and the circulation around the roughened elements were determined to be the most effective parameters influencing the heat transfer coefficients.

Parson and Han (1998) [22] studied the effect of rotation on jet impingement cooling by an in-line array of circular jets in twin channels. The impingement direction was perpendicular to a smooth heated target wall. The outflow arrangement was in a single direction and was outward in the radical direction. The rotation number varied from 0 to 0.0028 and the Reynolds number varied from 5000 to 10000. The decrease in heat transfer was up to 20% for the target walls with jet flow in rotation as opposed to the non-rotating case. A good physical explanation was the rotation-induced additional flows produced by centrfigual, coriolis and buoyancy forces.

Gillespie et al. (1998) [23] performed an experimental investigation to measure the heat transfer coefficient distribution on all surfaces of a novel impingement cooling device. Surface Temperature was measured using temperature-sensitive liquid crystals. Additional surfaces around the impingement holes played a significant role in heat transfer between the coolant and the wall in the blades. The adiabatic wall temperature distributions on the target surface were studied for investigating the flow behavior. An increase in the heat transfer was observed at the down-stream part of the impingement surface. The Nusselt number was approximately 50% of that on the impinged target surface in the downstream region, whereas on the upstream region this value was only 10% of the target surface value.

A series of experiments has been conducted by Sailor et al. (1993) [23] in which a pulsed air jet was impinged upon a heated surface for the purpose of enhancing heat transfer relative to the corresponding steady air jet. In addition to jet-to-plate spacing, Reynolds numbers and pulse frequency, an additional flow variable called the duty cycle was also considered in this experiment. The duty cycle represented the ratio of pulse cycle on time to total cycle time. Results showed that lower duty cycles with intermediate frequencies produced higher heat transfer coefficients. The highest values of heat transfer coefficients were corresponded to the highest flow rates. These results suggested possible higher values for heat transfer coefficients in the case of higher flow rates were not investigated in this study.

Experimental leading-edge impingement cooling through racetrack crossover holes was performed by Taslim and Setayeshgar (2001) [24]. Experimental results were presented for the impingement of racetrack shaped cross-over jets, with major hole (jet) axes at 0^o and 45^o angels to the cooling cavity's radial axes on smooth curved leading-edge wall, a wall roughened with conical bumps, and a wall roughened with tapered radial ribs. The overall heat transfer performance of 0^o racetrack crossover holes was shown to be superior to that 45^o racetrack crossover holes.

An experimental investigation was carried out by Taslim, Pan and Bakhtari (2002) [25] on racetrack shaped jet impingement on a roughened leading-edge wall with films holes. Experimental results were presented for four test sections representing the leading-edge cooling cavity with cross-over jets impinging on a smooth-wall, a wall roughened with big conical bumps, a wall roughened with smaller conical bumps and a wall roughened with tapered radial ribs. When the contribution of the increased area in the overall heat transfer was taken into consideration, big conical bumps foe all inflow and outflow cases as well as the two Z/d values proved to be the most effective geometry.

Hamn-Ching Chen and Je-Chin Han (2002) [26] conducted a numerical simulation of three-dimensional flow and heat transfer for non-rotating and rotating turbine blade cooling passages with and without the rib turbulators. A multi-block Reynolds-averaged Navier-Stokes method was employed in conjunction with a near-wall second-moment closure to provide detailed velocity, pressure, and temperature distributions as well as Reynolds stresses and turbulent heat fluxes in various cooling channel configurations. These numerical results were systematically evaluated to determine the effect of blade rotation, coolant-to-wall density ratio, rib shape, channel aspect ratio and channel orientation on the generation of flow turbulence and the enhancement of surface heat transfer in turbine blade cooling passages. The second-moment solutions show that the secondary flow induced by the angled ribs, centrifugal buoyancy, and Coriolis forces produced strong nonisotropic turbulent stresses and heat fluxes that significantly affected flow field and surface heat transfer coefficients.

Yoji Okita and Hector lacovides (2003) [27] carried out a computational investigation of flow and heat transfer through passages relevant to those used to internally cool gas-turbine blades, using high-Reynolds-number models of turbulence. Three types of internal flows are first examined, which between them contain all the main elements found in blade cooling passages; developing flow through a heated straight duct rotating orthogonally, repeating flow and heat transfer through a straight ribbed duct and flow and heat transfer through a round-ended U-bend of strong curvature square and of cross-section. Next, flows influenced by a combination of these elements are computed. The main objective of the study was to establish how reliably, industry-standard high-Reynolds-number models can predict flow and wall-heat transfer in blade-cooling passages. Two high-Reynolds-number models have been used, the standard version of the high-Re k-ε (EVM) model and the basic high-Re model of stress transport (DSM). In all the cases the second-moment closure (DSM) consistently produced flow and thermal predictions that are closer to available measurements than those of the EVM model. Even the high-Re DSM predictions, however, are not in complete agreement with the experimental data. Comparisons with predictions of earlier studies that use low-Re models of turbulence show that at least some of the remaining differences between the current predictions and experimental data are due to the use of the wall-function approach.

Evan A. Sewall and Danesh K. Tafti (2004) [28] studied the implementation of Large Eddy Simulation (LES) on the entrance section of a gas turbine blade internal cooling passage. The channel was fitted with in-line turbulators orthogonal to the flow, and the domain studied covers the first six ribs of the channel. The rib height-to-hydraulic diameter ratio (e/D_h) is 0.1, and the rib pitch-to-rib height ratio (P/e) is 10. A constant temperature boundary condition was imposed on the walls and the ribs, and the flow Reynolds number was fixed at 20,000. Results indicated that the mean flow is essentially fully developed by the fifth rib. Turbulent kinetic energy near the ribbed wall approaches fully developed values very quickly by the third or fourth ribs. However, turbulent intensities at the center of the duct are not fully developed by the sixth rib.

As a consequence, heat transfer augmentation on the ribbed walls reaches a fully developed state quickly after the third rib, whereas, the smooth wall heat transfer augmentation shows a slight but steady increasing trend toward the fully developed value up to the sixth rib. Both augmentation ratios are to within 10% of their fully developed values after the third rib.

R.Jia and B.sunden (2005) [29] carried out investigations on the heat transfer and fluid flow phenomena in ducts with V-shaped ribs to clarify this. Wherein a numerical approach was used and the heat and fluid flow was numerically simulated by a multi-block parallel 3D solver. For turbulence modeling, the $\overline{v^2}$ f-kε model was employed but results from previous EASM calculations were also considered in analyzing and attempting to understand the various experimental data. Large eddy simulations (LES) were also carried to evaluate the accuracy and reliability of the results of Reynolds-averaged Navier-Stokes (RANS) methods and to understand the underlying physical phenomena. It was suggested that the discrepancy between the various experiments most probably was due to the measurement methods, or the number of sampling points. With the TC (thermocouples) technique, a few sampling points might not be sufficient to represent the heat transfer behavior in V-shaped ribs, due to the uneven distribution of the heat transfer coefficients.

Taslim et al. (2005) [30] conducted a numerical and experimental study on the impingement in the leading-edge of an airfoil with and without showerhead film holes and its effects on heat transfer coefficients on the airfoil nose area as well as the pressure and suction side areas. A comparison between the experimental and numerical results was also made. The tests were run for a range of flow conditions pertinent to common practice and at an elevated range of jet Reynolds numbers (8000–48000). The major conclusions of this study were: a) the presence of showerhead film holes along the leading edge enhances the internal impingement heat transfer coefficients significantly, and b) while the numerical predictions of impingement heat transfer coefficients for the no-showerhead case were in good agreement with the measured values, the case with showerhead flow was underestimated by as much as 30% indicating a need for a more elaborate turbulence modeling.

Jose Martinez Lucci and R.s Amano (2007) [31] carried out a numerical investigation on the three-dimensional turbulent flows and heat transfer inside a sharp U-bend by using a non-linear low-Reynolds number (low-Re) k-ω model in which the cubic terms were included to represent the effects of extra strain-rates such as streamline curvature and three-dimensionality on both turbulence normal and shear stresses. The finite volume difference method incorporated with the higher-order bounded interpolation scheme has been employed in the study. For the purpose of comparison, the predictions with the linear low-Reynolds number k-ω model were also performed. The success of the present prediction indicates that the model can be applied to the flow and heat transfer through a coolant passage in an actual gas turbine blade. It is shown that the non-linear model produced satisfactory predictions of the flow development inside the sharp U-bend comparing with linear Launder-Sharma model.

Taslim et al. 2009 [32] conducted a numerical and experimental on the impingement on the leading edge of an airfoil in the presence of cross-flows beyond the cross-flow created by the upstream jets (spent air). Measurements of heat transfer coefficients on the airfoil nose area as well as the pressure and suction side areas were reported. The tests were run for a range of axial to jet mass flow rates (M_{axial}/M_{jet}) ranging from 1.14 to 6.4 and jet Reynolds numbers is ranging from 8000 to 48,000. Comparisons were also made between the experimental results of impingement with and without the presence of cross-flow and between representative numerical and measured heat transfer results. It was concluded that (a) the presence of the external cross-flow reduces the impinging jet effectiveness both on the nose and sidewalls; (b) even for an axial to jet mass flow ratio as high as 5, the convective heat transfer coefficient produced by the axial channel flow was less than that of the impinging jet without the presence of the external cross-flow; and (c) the agreement between the numerical and experimental results was reasonable with an average difference ranging from −8% to −20%.

The current study will experimentally investigate the impingement cooling behavior in an airfoil leading edge smooth cavity using air as cooling fluid, by studying the effect of varying the cross flow-impinging flow ratio, in addition, the dependency of the Nusselt number on Reynolds number will also be considered . Four different flow arrangements will be studied: 1) Parallel 2) Circular 3) Both end open 4) 2- inlet-2-outlet.Controlling the cross flow will be accomplished by manipulating the number of blocked/unblocked crossover holes, in addition jet Reynolds number will be varying from 7000 up to 33000. Detailed description of the model, flow arrangement, power supply, and test procedure will be presented in the next section.

CHAPTER 2
EXPERIMENTAL APPARATUS AND TEST PROCEDURE

In the present chapter, the experimental system which allowed the acquisition of the heat transfer data for impingement cooling is described. The detailed description of the experimental apparatus and testing procedure is presented next in this chapter.

2.1 Test Section

A longitudinal cross section of the test section is shown in figure 2.1. Figure 2.2 shows a cross section of the test section and its relevant dimensions. As shown figure 2.2, the test section consists of a main channel divided into two parts by the jet plate. The upper part is called the supply channel, and the lower part is called the leading edge channel. As shown in these figures, nine copper plates were installed in the middle part of the leading edge section. These plates are the means by which we could test and study the impingement in the test section. Three side plates, called *Front Side Plates*, another three side plates, called *Back Side Plates*, and three *Nose plates* were installed. The middle copper plates were the focus of our attention and the side plates acted like guard heater. Figure 2.3 shows a detailed description for the copper plates.

2.2 Jet Plate

A jet plate made of clear acrylic plastic was used in the present investigation. As shown in figure 2.4A and figure 2.4B, nine racetrack-shaped holes were drilled in the jet plates represent the cross-over holes which directs the flow on the leading edge channel surface and thus the copper plate target. The holes were arranged to be 2.43” apart from each other.

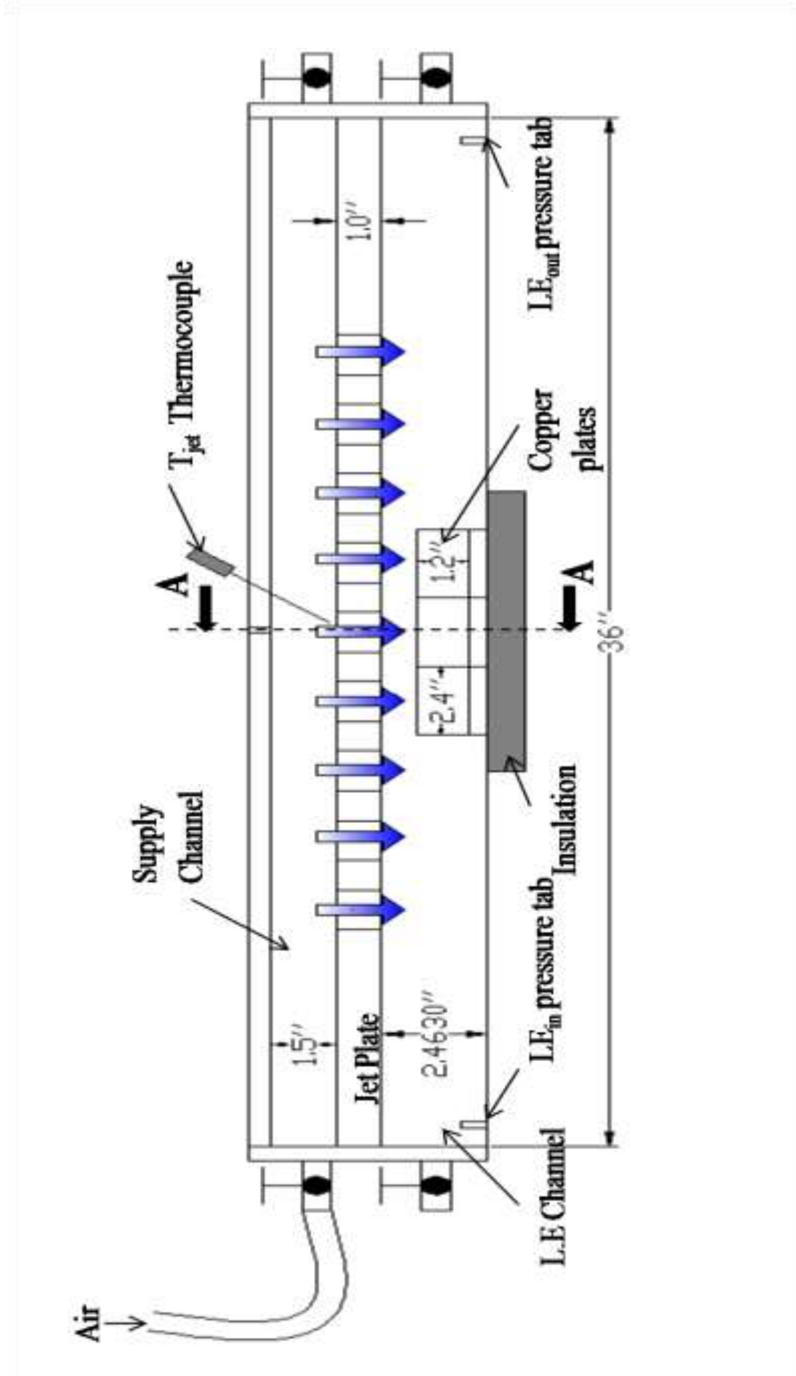


Figure 2.1 Longitudinal cross-section of the test section

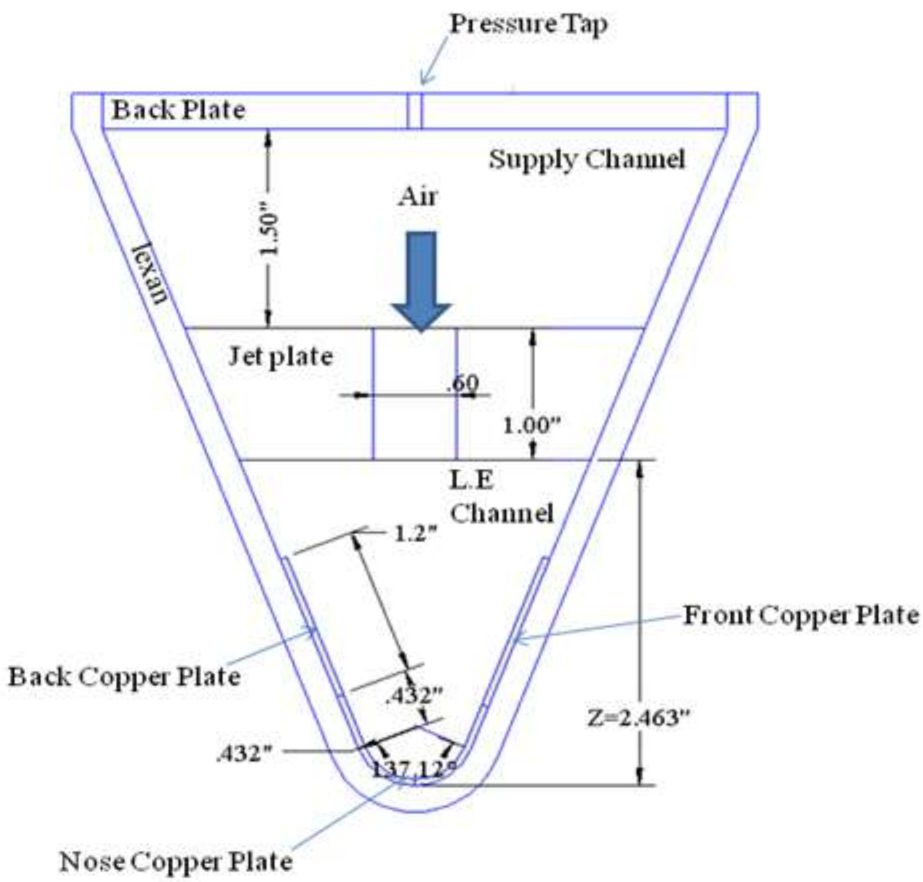


Figure 2.2 Cross-section A-A

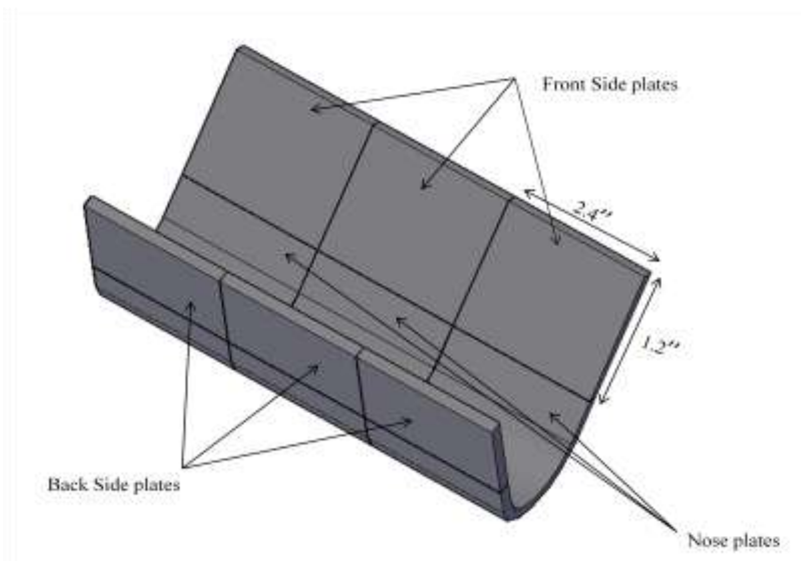
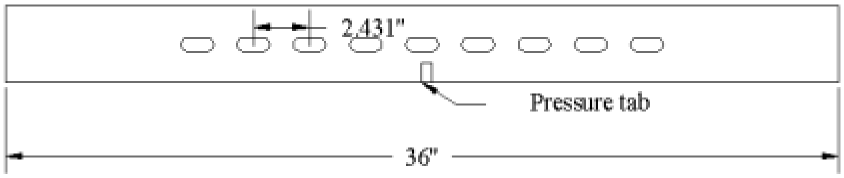


Figure 2.3 Copper plates



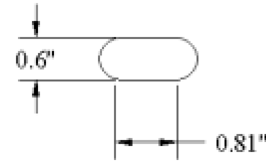


Figure 2.4A Jet plate **Figure 2.4B Cross-Over Hole**

2.2 Air Flow System

A schematic figure of the air flow system is shown in figure 2.5. A compressor delivers the compressed air to a storage tank. The compressor was rated of a maximum pressure of 110 psig. The unit was placed in a utility room outside the laboratory as not to influence the experimental environment Air pressure in the storage tank was maintained at 110 psig. The tank was used as a calming section to muffle any oscillation in the delivery of the compressed air. A Balston 62A-3/4-DX air filter was installed downstream from the storage tank. Air was then directed into a single-pass baffled counter flow water cooler. A Balston 915A-1/2-BX air filter was used at the second filtration stage downstream from the water cooler. Cooling the air to approximately 60^0F resulted in higher surface to-air temperature differences and thereby reducing the uncertainty in heat transfer coefficient calculations. Air mass flow was measured using a critical venture with 0.32'' throat diameter. The critical venturi was manufactured by Fox Valve Development Corp. A calibration chart and a correlating formula were provided by the manufacturer to correlate static pressure readings to actual mass flow rates in lb_m/sec as shown $m^o = 0.5215\frac{A_{th}(P_{ven}+P_{atm})}{\sqrt{(T_{ven}+460)}}$. Air temperatures were monitored at several locations as shown in figures 2.2 and 2.5. The first was at the inlet of the critical venturi, called $T_{ven,}$ and used for air mass flow rate calculations. The second was at the fifth cross-over-hole to measure the jet temperature impinging on the target surface, called T_{jet} and was used for the calculation of heat transfer coefficient. The last was the laboratory ambient temperature was also measured to assess the amount of heat loss to the environment.

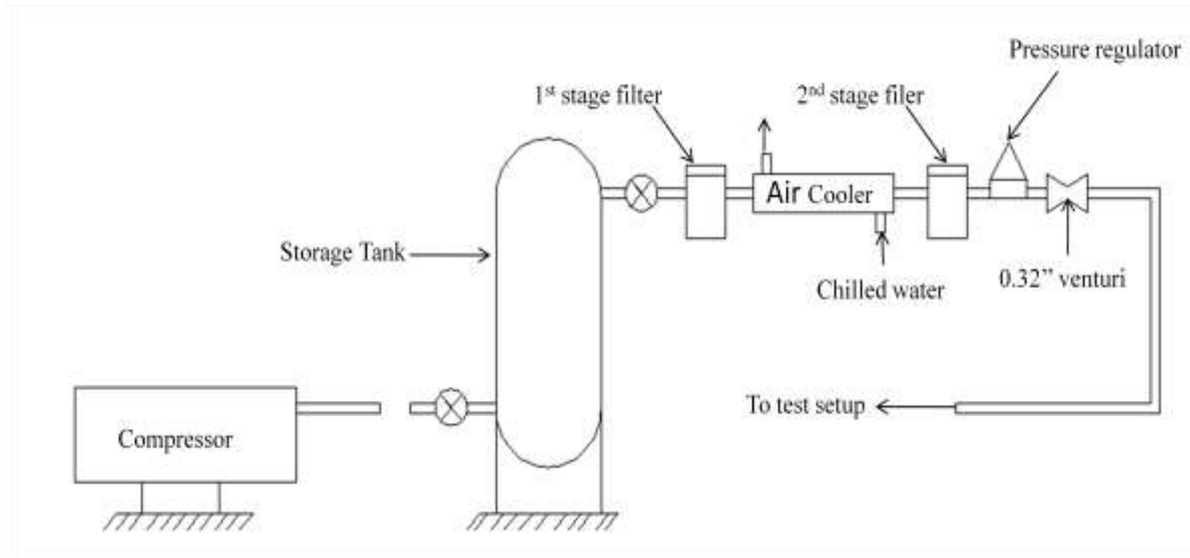


Figure 2.5 Air flow system.

2.3 Heaters and Power Supply

The nine copper plates were connected to eighteen heaters named as shown schematically in figure 2.6. Each side plate of the six existed side plates was connected to one heater, and each nose plate of the three existed nose plates was connected to four heaters. Figure 2.7 shows a table for the resistance value of each heater. In order to achieve constant heat flux on the copper plates, and since the power panel used to deliver the power to the heaters has eight rheostats only, the heaters were connected as follow.

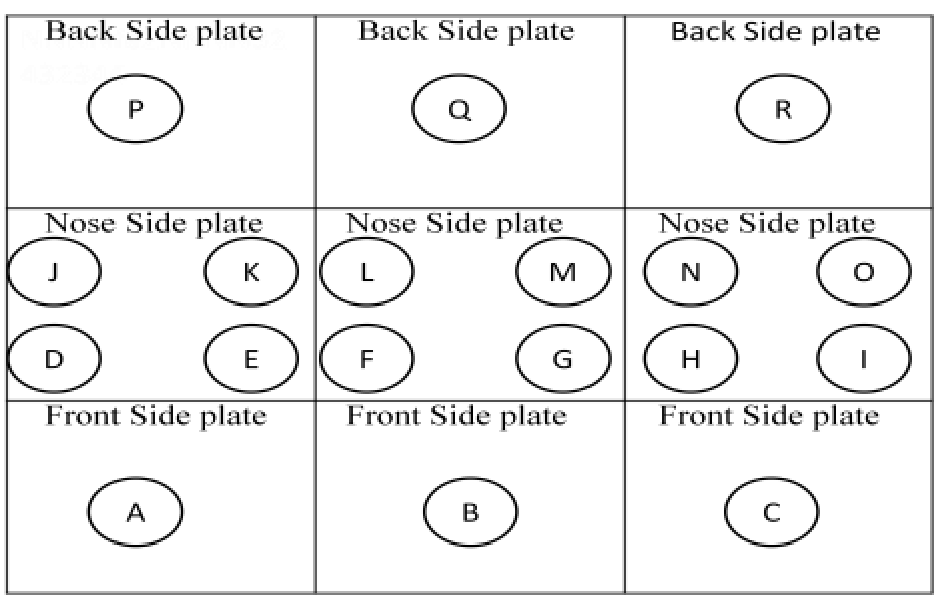


Figure 2.6 A schematic of the heaters mounted on the copper plate

Heater	A	B	C	D	E	F	G	H	I
Resistance	31.57	31.59	31.62	14.88	14.79	17.24	14.86	14.89	14.67
Heater	J	K	L	M	N	O	P	Q	R
Resistance	14.82	14.92	14.79	14.95	15.07	17.25	31.71	31.71	31.65

Figure 2.7 Resistance values of the heaters

Heaters A and P were connected in parallel, and the resultant was connected in series to the resultant of C and R which were connected in parallel. The overall resultant of this connection was plugged in the power distribution unite in Panel 1. Heaters B and Q were connected directly in the power distribution unite in Panel 3 and 5 respectively. Heaters J and K were connected in parallel and the resultant was connected in series to the resultant of D and E which were connected in parallel, the overall resultant of this connection was connected in Panel 2. Heaters F and G were connected in parallel and the resultant was connected in series to the resultant of L and M which were connected in parallel, the overall resultant of this connection was connected in Panel 4. Heaters H and I were connected in parallel and the resultant was connected in series to the resultant of N and O which were connected in parallel, the overall resultant of this connection was connected in Panel 6. Figure 2.6 shows a schematic description for the previous discussed connections. The values of the overall resistances were calculated using the equations $\frac{1}{R_t} = \sum \frac{1}{R_n}$ for parallel connection and $R_t = \sum R_n$ for series connection; the values of these resistances are shown in table 2.2 below.

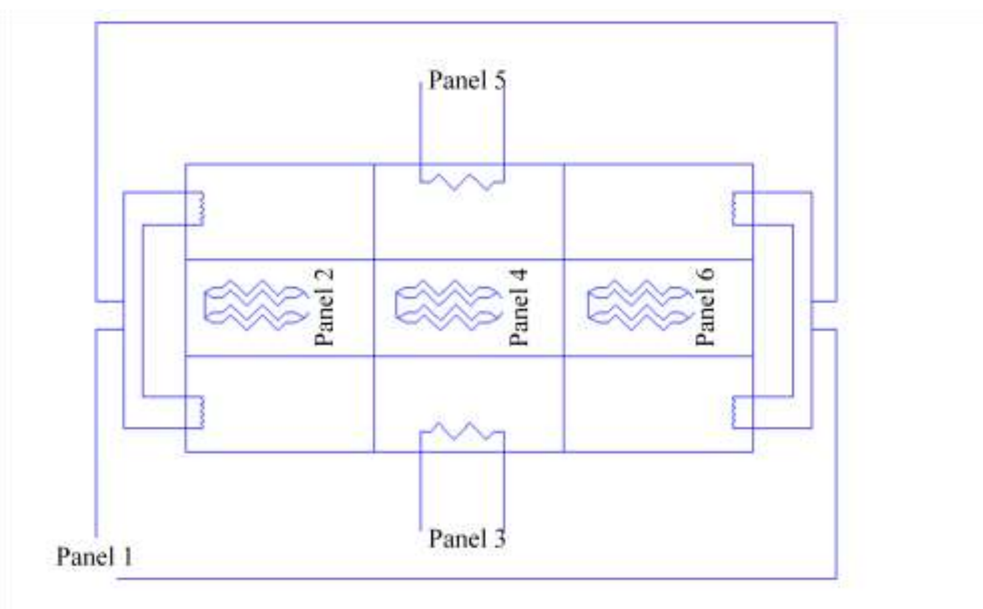


Figure 2.8 A schematic of the heaters circuits.

Panel No.	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Panel 6
Resistance	31.64	14.85	31.49	15.44	31.71	15.43

Figure 2.9 Overall resistances of the panels.

Figure 2.10 Power distribution unit used to run the experiment.

Figure 2.6 shows the home-made power distribution unit used in the test. The unit contains eight rheostats. Each rheostat controlled the voltage across a panel, since six panels were used during the experiment, only six rheostats were used. The heaters connected to the panel as mentioned before have different resistance. Therefore to have a uniform heat flux on the heated copper plates, the rheostat were set differently to control the voltage across each panel using the following equations, $q_1 = V_1 * I_1 \,/\, A_s = \frac{V_1^2}{R_1 \mathrm{A}_{s1}}$, and for constant q we get.

$$\mathrm{q}_1 = \mathrm{q}_2$$

$$V_1 = V_2 \sqrt{\frac{R_1 A_{s1}}{R_2 A_{s2}}}$$

Six of the small rheostats were set to a percentage that gives constant heat fluxes over the copper plates. While the one big rheostat was used to increase and decrease the voltage with the same amount for all the panels and thus increasing or decreasing the heat flux over the copper plates with the same amount. An eight –way switch connects the volt-and amp-meters to one heater at a time, and therefore the voltage and current for each heater was able to be recorded. Eight 2-amp fuses prevented any malfunction of the rheostat.

2.4 Temperature and Pressure Measurements

Three manometers were used, depending on the level of pressure. A micro-manometer as shown in figure 2.11 was used for lowest pressure, orange oil manometer for medium pressure levels, and a red oil manometer for the highest pressure levels. The micro-manometer 1430 Microtector Portable Electronic Point Gage with an accuracy of ±0.00015 inches of water column powered by an AA battery, used a fluid type of A-126 fluoresce in green color concentrate with a specific gravity of 1.0. The maximum pressure measured by the micro-manometer is 2 inches of water column. The micro-manometer needed to be primed every time it was used. First the instrument had to be leveled, and then while both ends of the tubes were opened to ambient air, the needle had to be adjusted by turning it up or down until the tip make contact with the liquid surface. This position was set to zero. Any other pressure was measured with respect to the zero reference. The micro-manometer was used for measuring small pressure with respect to the zero reference, in most cases ΔP_{jet}. Whenever the pressure exceeded the maximum scale of the micro-manometer the orange oil manometer was used. The specific gravity of the orange colored oil was 0.827. This manometer was used for measuring pressures for most cases. Whenever the pressure exceeded the maximum scale the red oil manometer was used. The red colored oil has a specific gravity of 2.95 and was used for certain flow arrangement at very high pressures.

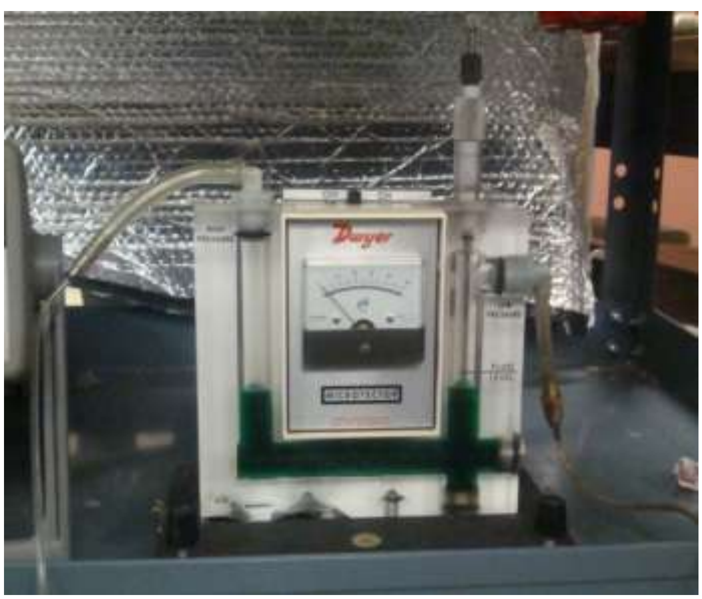


Figure 2.11 A picture of the Micro-manometer.

Figure 2.12 Agilent Data Acquisition Unit

Thermocouples were connected to an Agilent 34970A Data Acquisition Unit to record the temperatures. The data acquisition unit is shown in figure 2.12. The data acquisition unit was connected to regular CPU unit Windows Xp operated, and by using Agilent Data management software the temperatures was monitored. The temperature monitored was for 45 different channels. Channels 113, 114 and 115 were designated to monitor the T_{ven} ,T_{jet} and T_{amb} respectively, while the rest of all channels were designated to monitor the copper plates temperatures. The first terminal was designated to monitor channels 101-115, the second terminal was designated for channel 201-218, and the third for 301-312. Figure 2.13 is a schematic figure that shows the locations and the numbering of the thermocouples connected to the copper plates.

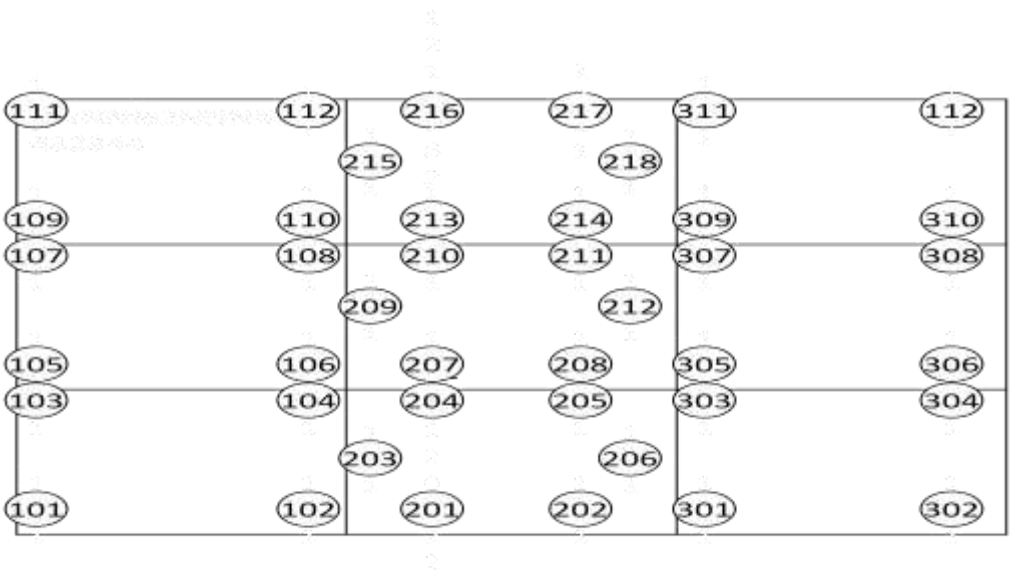


Figure 2.13 A schematic of the locations of thermocouples connected to the copper plates

2.5 Flow Arrangement.

Four flow arrangement were used: parallel flow, circular flow, Both-Ends-Open flow, and 2-inlet-2-outlet flow. The following section describes each of the flow arrangement.

2.5.1 Parallel Flow

In the parallel flow arrangement, flow was directed into the test section from the inlet side of the supply channel and left the test section from the opposite side in the L.E section. Figure 2.14 shows a schematic description for the parallel flow arrangement.

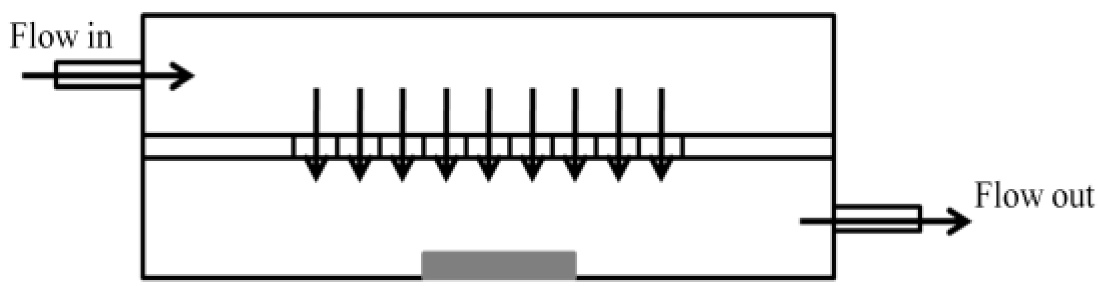


Figure 2.14 A schematic of the Parallel Flow Arrangement.

2.5.2 Circular Flow

In the circular flow arrangement, flow was directed into the test section from the inlet side of the supply channel and left the test section from the same side of the L.E channel as shown in figure 2.15.

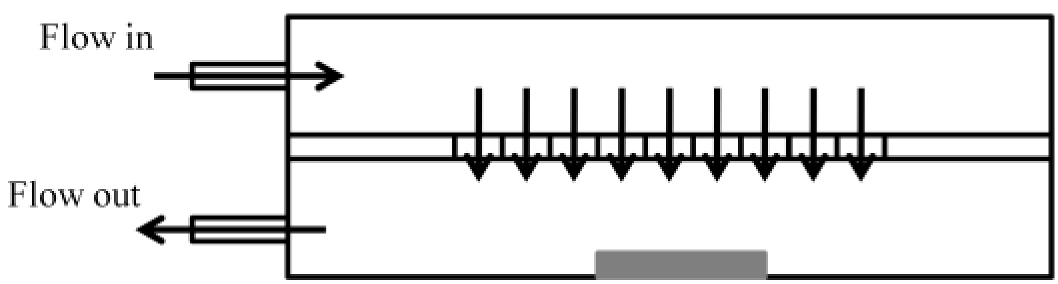


Figure 2.15 A schematic of the Circular Flow Arrangement.

2.5.3 Both-Ends-Open Flow

In the case of BEO flow, the flow was directed to the test section through the inlet side of supply channel and left from both sides of the L.E channel as shown in figure 2.16.

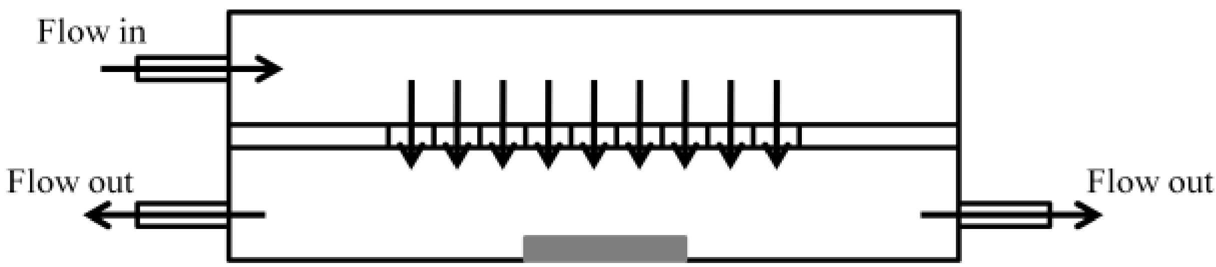


Figure 2.16 A Schematic of the B.E.O Flow Arrangement.

2.5.4 2-Inlets-2-Outlets Flow

The 2-inlet-2outlet flow was a special flow arrangement used for three tests which will be discussed in chapter 3. In this flow arrangement, the flow was directed to the test section from both sides of the supply channel, and left from both sides of the L.E channel as shown in figure 2.17.

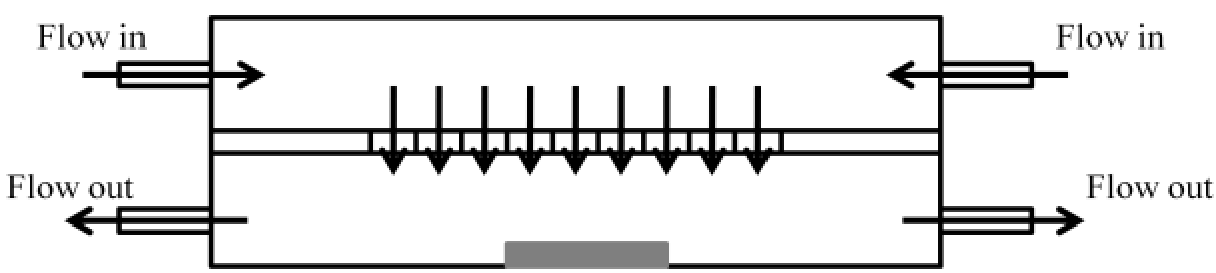


Figure 2.17 A Schematic of the 2-inlets-2-outlets Flow Arrangement.

2.6 Test Procedure.

The experimental investigation was divided into two parts; one was the heat transfer test and the other was the cold test. Several flow arrangements were studied combined with studying different geometries based on the number of cross-over holes. Figures 2.18 through 2.22 show the flow charts for the planned testing procedure. The heat transfer test was run for seven different venturi inlet pressures of 19, 30, 41, 52, 63.5, 74.5 and 90 psig corresponding to seven Jet Reynolds numbers, while the cold test was run for twelve venturi inlet pressures of 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80 and 90 psig. The cold tests were used to accurately measure the pressure variation along the test section. Before turning the compressor on, the water from the condensation in the storage tank and the pipes was drained, in order to minimize the amount of water going into the test section and thus more accurate pressure readings were recorded. Then the compressor was turned on to supply the coolant air to the storage tank located in the laboratory where the investigation was performed. The venturi gauge pressure was set to a pre-determined level and the electrical power unit, volt-meter, amp-meter, data acquisition switch unit, micro-manometer and the CPU was turned on. The voltage was set in the electrical power unit to a certain amount that brings the target copper plate to a certain temperature. This temperature was monitored for the nose-copper plate connected to channel 207 with a value of 110 ^{0}F , after the system reached equilibrium the pressure from all pressure tabs were recorded, and the temperatures from all thermocouples were monitored using the data acquisition software installed on the CPU unit, then with increasing venturi pressure to move to the next pressure, the equilibrium of the system came to an end, therefore the amount of voltage was increased to maintain channel 207 temperature at 110 ^{0}F. After the system reached equilibrium the new readings for the corresponding venturi pressure were recorded.

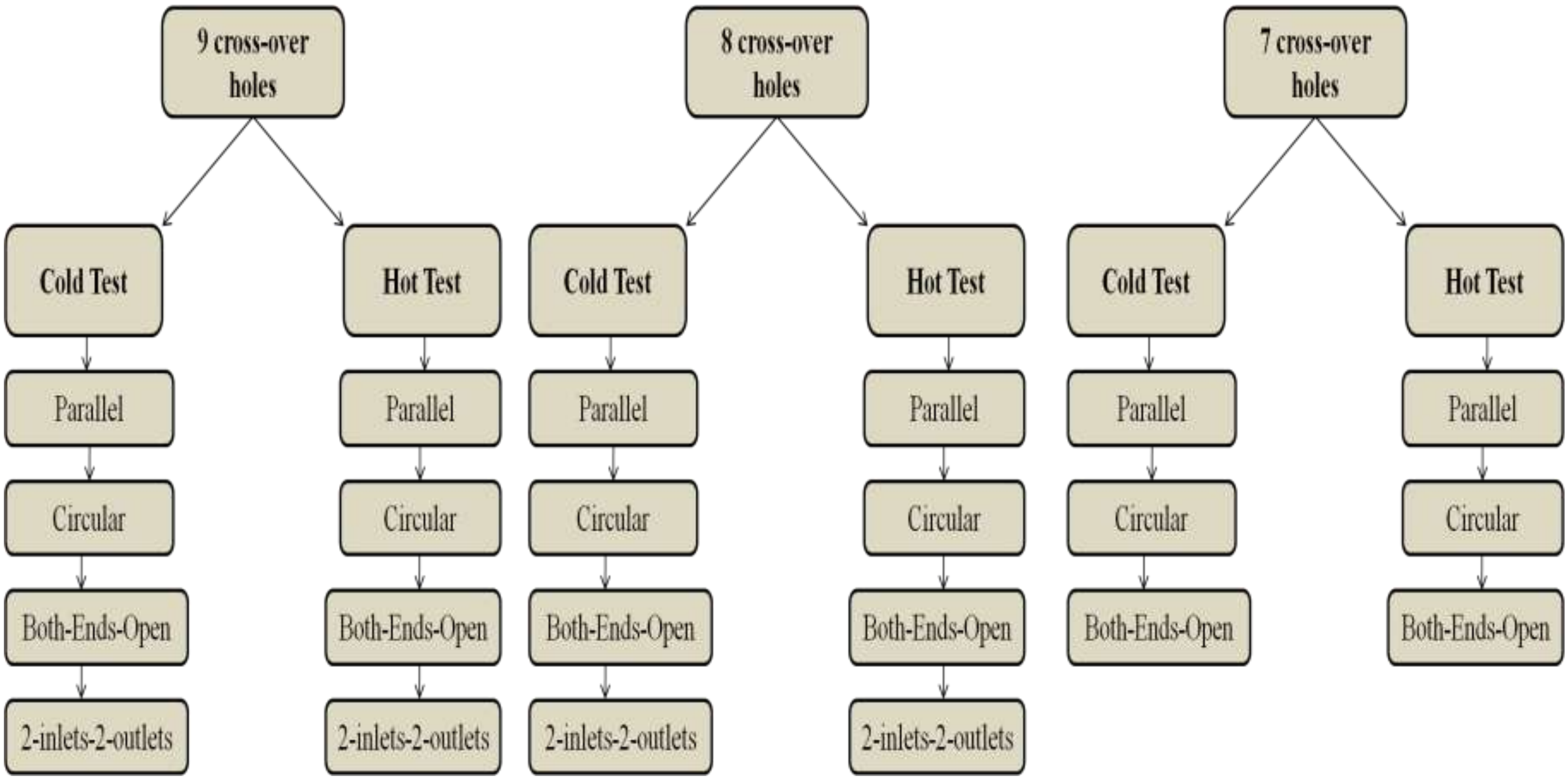


Figure 2.18 A Flow chart for the conducted tests for the 9, 8 and 7 cross-over holes geometries.

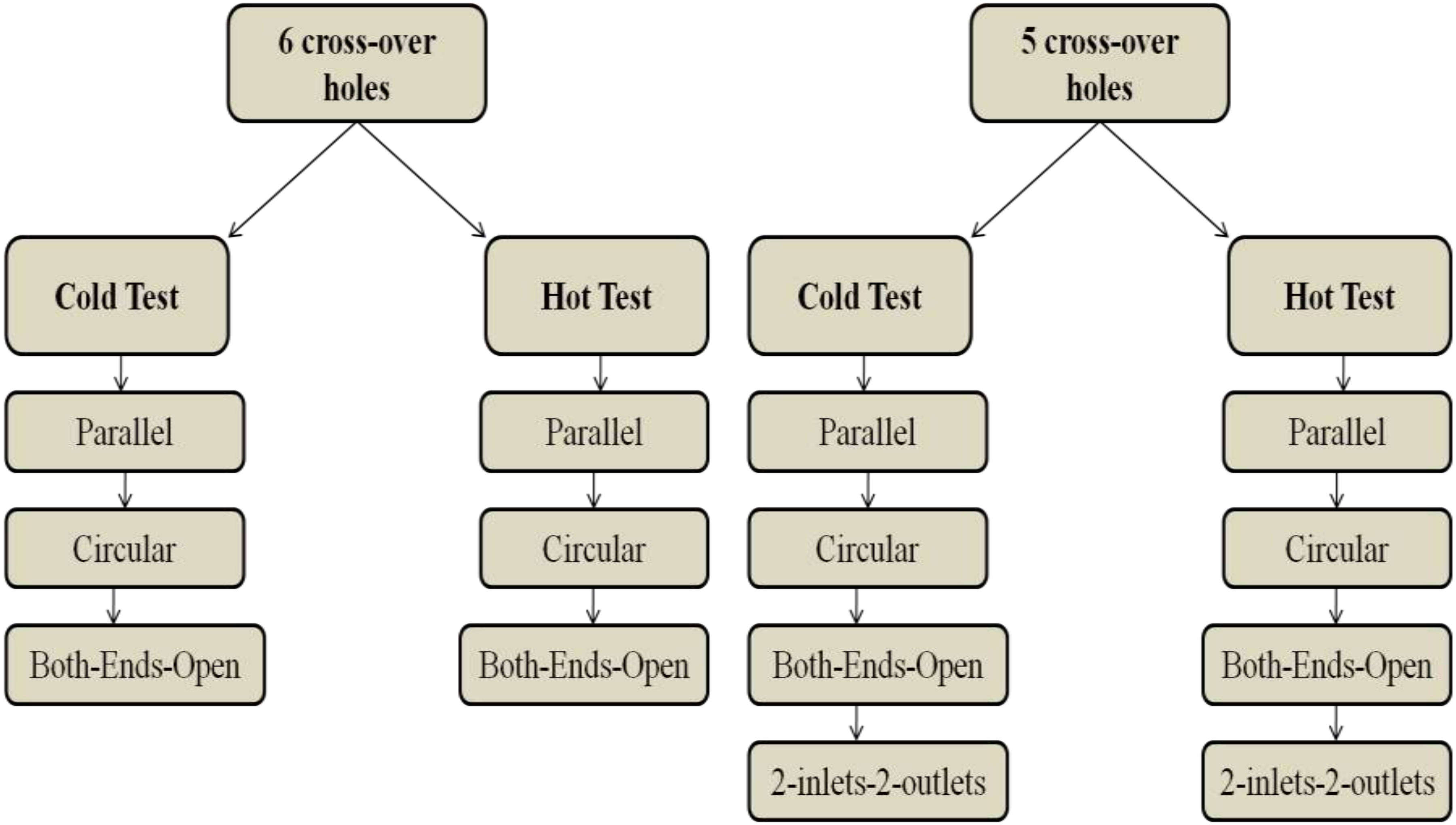


Figure 2.19 A Flow chart for the conducted tests for the 6 and 5 cross-over holes geometries.

CHAPTER 3
RESULTS AND DISCUSSION

3.1 Data Reduction

The solution algorithm for the reduction of raw data and calculation of the average heat transfer coefficient which was followed in the data reduction code can be summarized as follows: the first step in the data reduction process was to read the raw data files acquired during each test, and then calculate the corresponding average heat transfer coefficients. An air mass flow rate was measured using a custom-made critical venturi for which the following correlation was provided.

$$m^o = \frac{0.5215A_{throat}\,(P_{ven} + P_{atm})}{\sqrt{T_{ven} + 460}}$$

Air properties are subject to change with temperature and are calculated using a linear interpolation for 1^o F increment in subroutine AIRPROP. Jet Reynolds number and Nusselt numbers are calculated as follows:

$$Re_{jet} = 4\,m^o/P_j * \mu_j$$

$$N_u = hD_h/k$$

Where the m^o refers to the mass flow rate entering the 5^{th} cross-over hole and h is the heat transfer coefficient calculated in subroutine COEFFICIENT as follows:

h_{nose}= (Flux- F_{loss}- F_{rad}) / (T_{snose}-T_{jet}) where, $h = (Flux) / (Ts - Tjet)$

T_{snose}= (T_{206} + T_{207}+ T_{208} + T_{209} + T_{210} + T_{211}+T_{212})/6 and

Flux = I*V / A_{snose} , F_{loss}=(T_{snose}-T_{amb})/R_{backN}

R_{nose} is the thermal resistance between the nose copper plate and the lab air which consists of the following thermal resistances: RbackN = 0.5*Rcopper + Radh2 + Rkap + Radh1 + Rinc + Radh1 + Rkap+ Radh2 + Rrubber + Radh2 + Rlexan + Ralum + Rsty + Rconv.

F_{rad} is the radiative heat transfer between the heated copper plates and the unheated surrounding walls. It is determined in subroutine RAD as follows:

$F_{rad}=\varepsilon_{brass}\,\sigma(T_1^4-T_2^4)$

3.2 Results

Results are presented in section 3.2 for various cases, and for different flow arrangement. Different cases refer to the number of cross-over holes (9, 8, 7, 6 and 5 holes). The first case wherein all 9 cross-over holes were open was tested for 4 types of flow arrangements (Parallel, Circular, Both-Ends-Open, and 2 inlets-2outlets) which were defined in chapter 2. As well as the cases of 8 and 5 cross-over holes were tested for the same 4 types of flow arrangements. The cases of 6 and 7 cross-over holes were tested for only 3 types of flow arrangements (Parallel, Circular and Both-Ends-Open). Each test was conducted using 7 different mass flow rates entering the test section, the corresponding Reynolds numbers calculated based on the average mass flow rate through the cross-over holes varied between 7000 to 33000. All the results obtained were for the middle copper plates; nose, front side and back side.

3.2.1 Nine Holes

The first case tested was the 9-hole case, wherein all 9 cross-over holes were open. 4 different flow arrangements were tested for this case, parallel, circular, Both-Ends-Open and 2-inlets-2-outlets flow arrangements as shown in Figure 3.1.

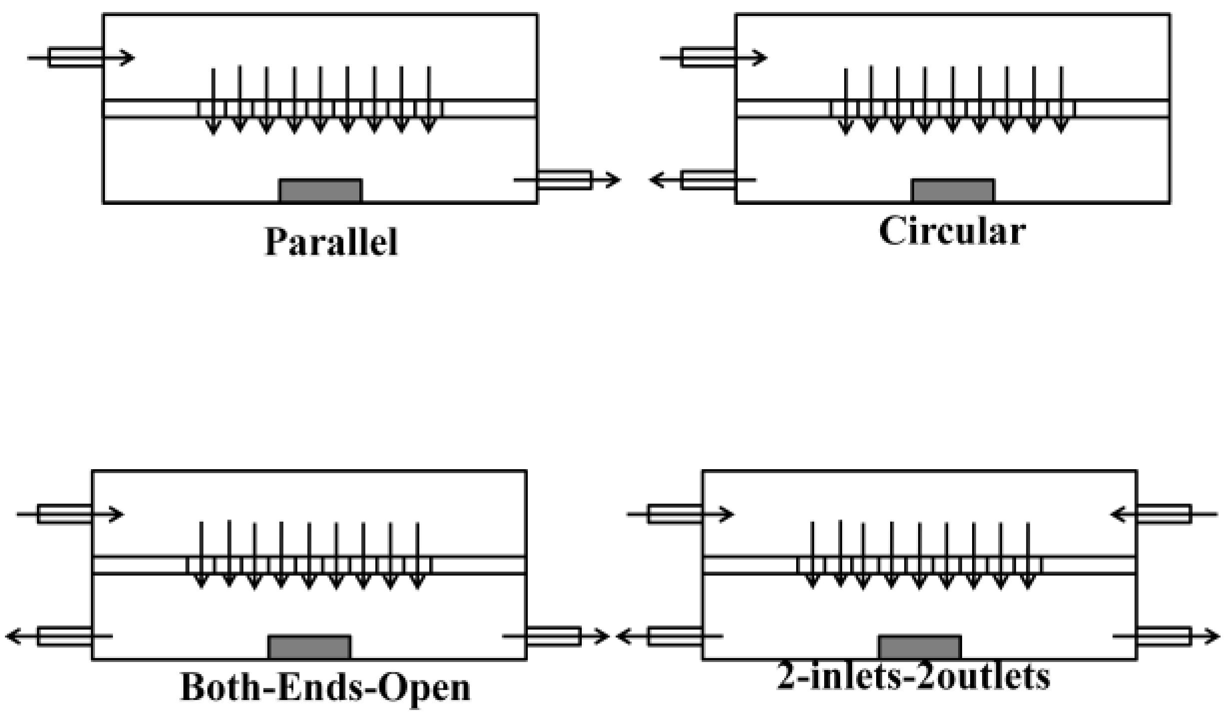


Figure 3.1 A Schematic of the 9 cross-over-hole geometry and the flow arrangements tested.

Figure 3.3 shows the variation of Nusselt number with Reynolds number for the nose and the variation of the Average Nusselt Number for both sides (front side and back side) where $Nu_{side}=(Nu_{front}+Nu_{back})/2$ with Reynolds number.

As illustrated in figures 3.3, 3.4, 3.5 and 3.6 monotonic behavior can be observed between Nusselt and Reynolds numbers for all flow arrangements, in addition the sides Nusselt is higher than the nose as a result of a higher heat transfer rate at the sides. The reason can be summarized as follows:

1. Since all nine cross over holes were open, at the location of the fifth jet an axial flow was formed in the L.E test section by the four upstream jets. This axial flow caused the jet to deflect to some extent. As a result, impingement on the target surface was somewhat reduced.
2. Since the jets turn into an axial flow after impingement. They may not cover the entire nose surface. Less interaction with the target wall will result in less heat transfer. The cross flow will cause radial cooling on the sides plates causing more cooling for the sides over the nose.

Figures 3.7 and 3.8 show a comparison between the side and nose Nusselt number respectively for different flow arrangements. The Both-Ends-Open provided the highest Nusselt on both the nose and the side. Since both sides of the L.E channel were unblocked in the Both-Ends-Open flow arrangement, jets upstream the 5^{th} cross-over-hole, after impinging on the L.E surface, exit the L.E channel from the $L.E_{in}$ side, while the jets downstream the 5^{th} cross-over-hole, after impinging, exit the L.E channel from the $L.E_{out}$ side, this will weaken the axial flow and therefore better impinging takes place at the 5^{th} jet location. For the Parallel and Circular flow arrangements since on side of the L.E channel was blocked, axial flow was generated along the L.E channel. Figure 3.6 shows the pathlines provided from the CFD simulation conducted by Kariem Elebiary (2010) [33].

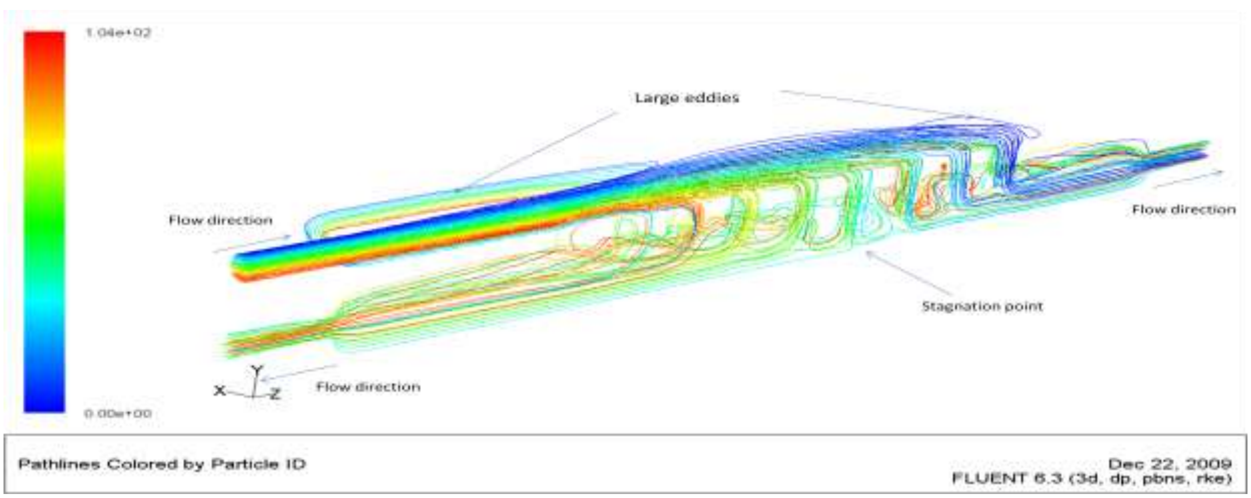


Figure 3.2 PathLines for the case of 9 cross-over holes and both-ends-open flow arrangement.

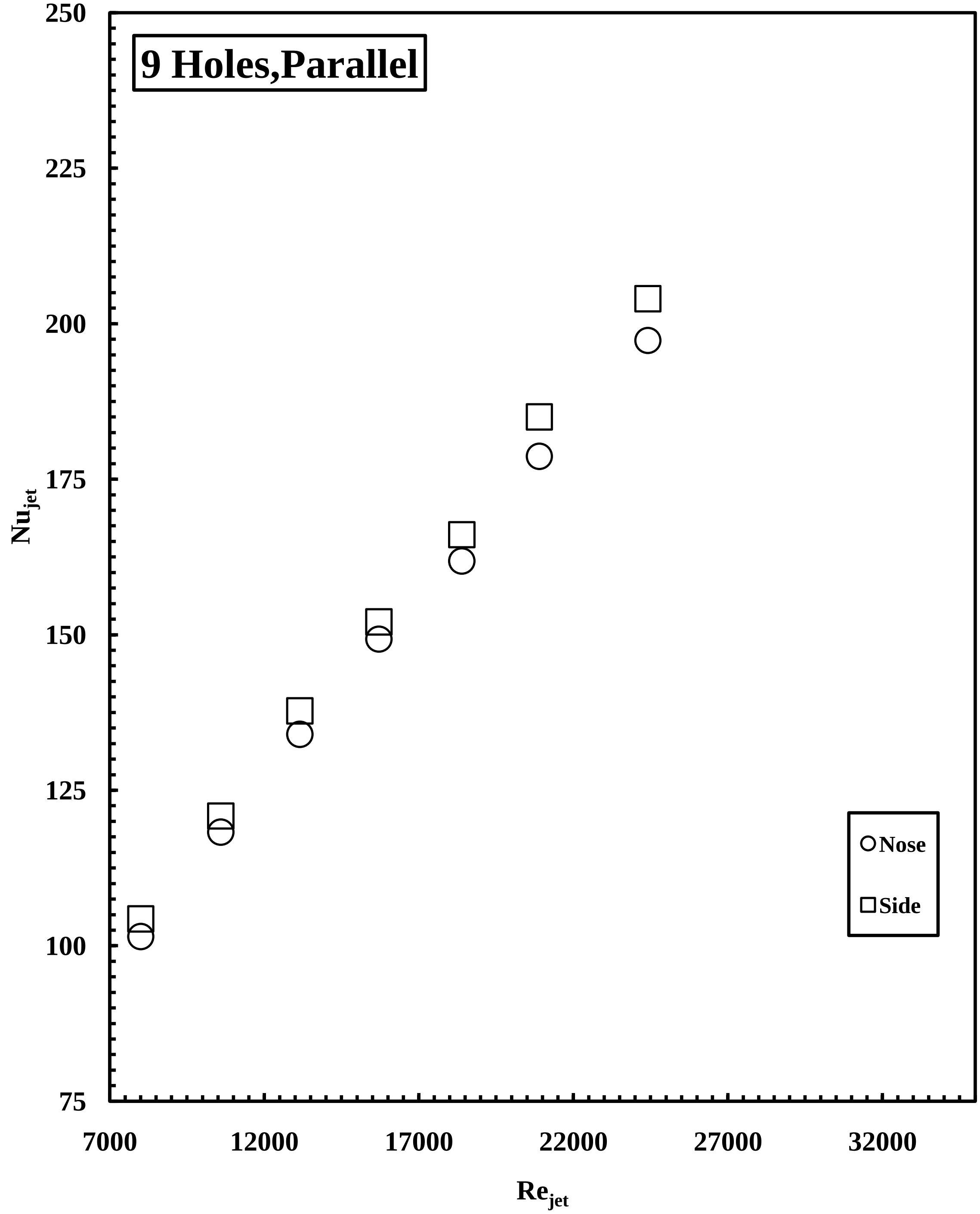


Figure 3.3 Comparison of the side and nose Nusselt numbers for the case of 9 cross-over holes and parallel flow arrangement.

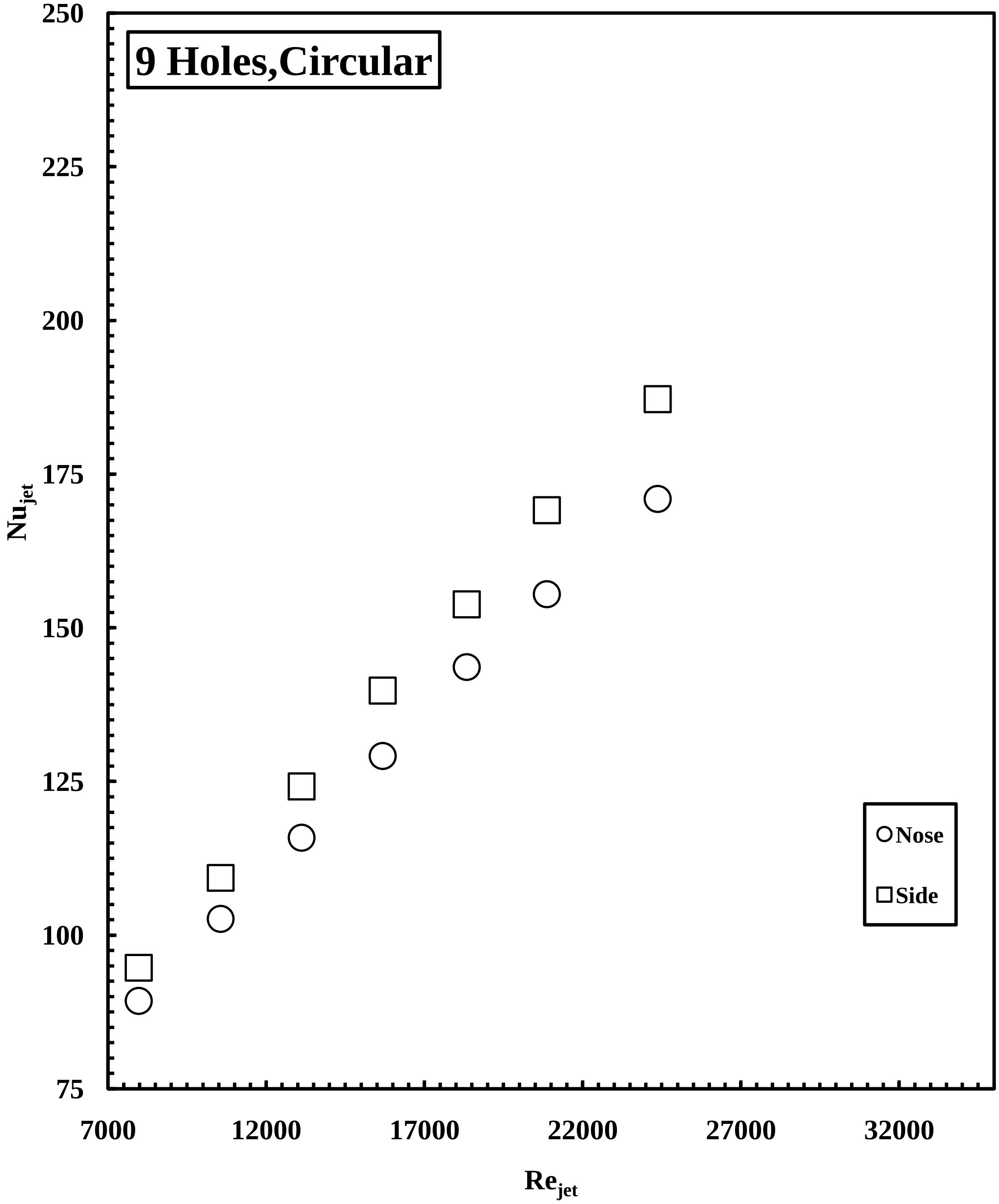


Figure 3.4 Comparison of the side and nose Nusselt numbers for the case of 9 cross-over holes and circular flow arrangement.

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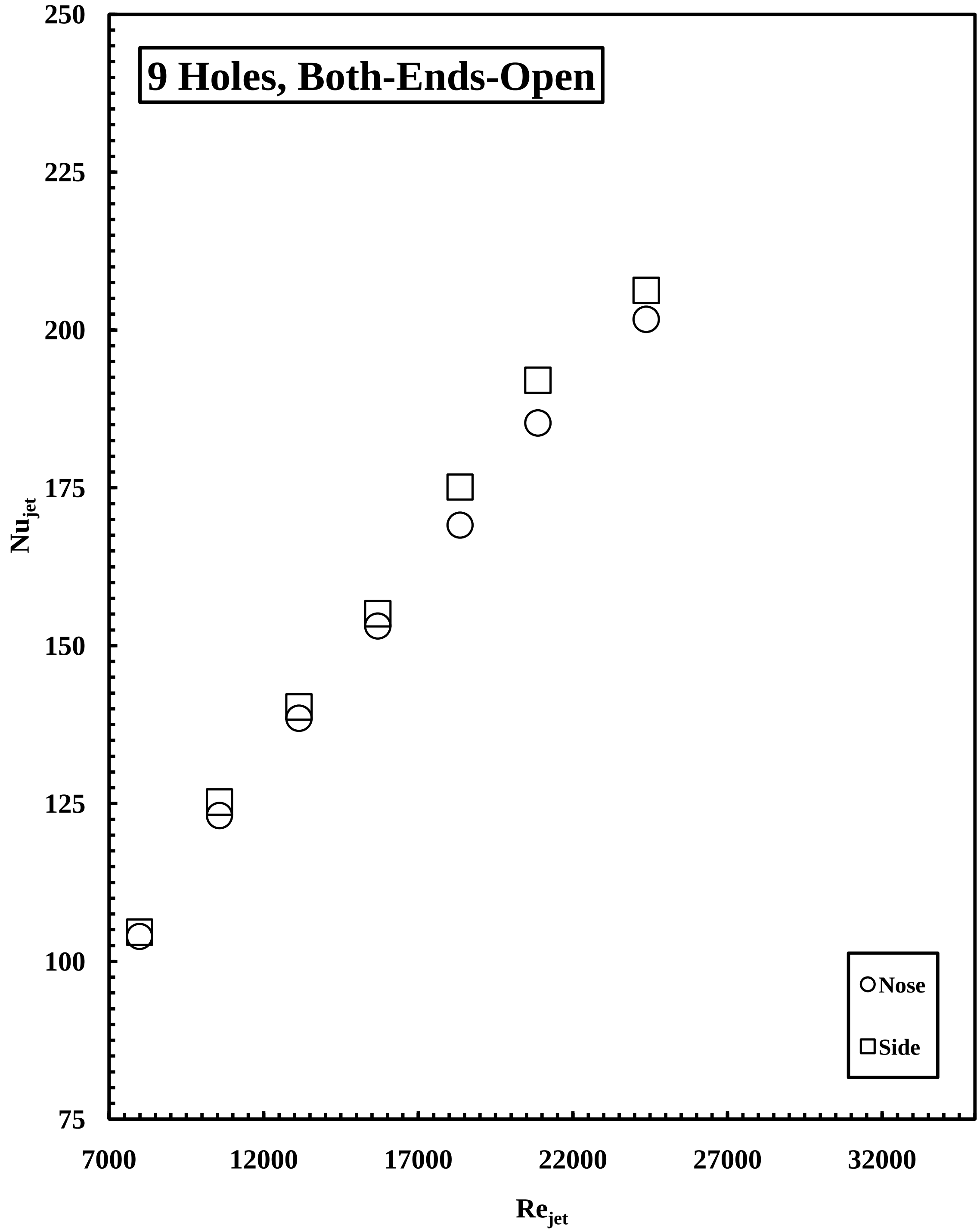

Figure 3.5 Comparison of the side and nose Nusselt numbers for the case of 9 cross-over holes and both-ends-open flow arrangement.

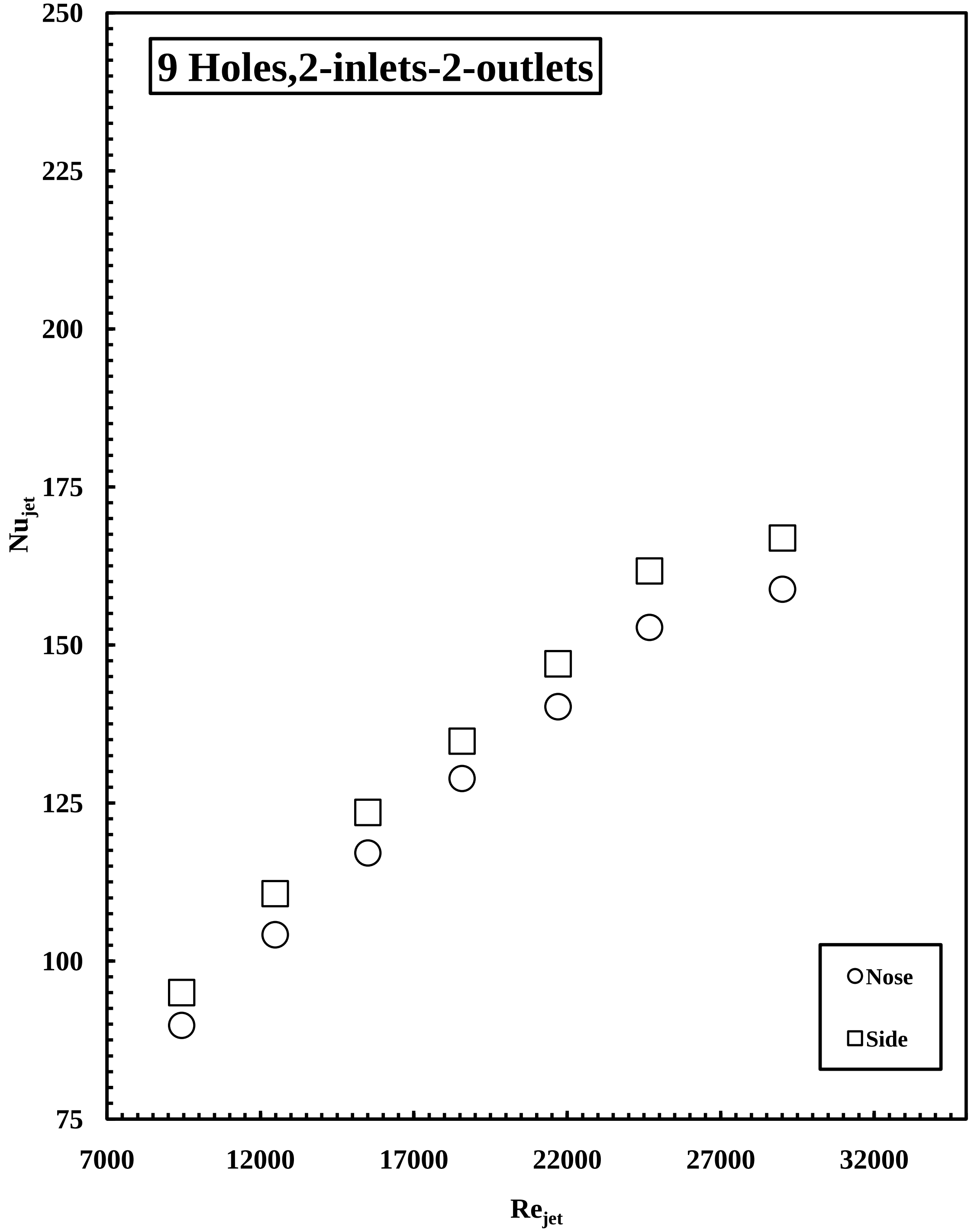

Figure 3.6 Comparison of the side and nose Nusselt numbers for the case of 9 cross-over holes and both-ends-open flow arrangement.

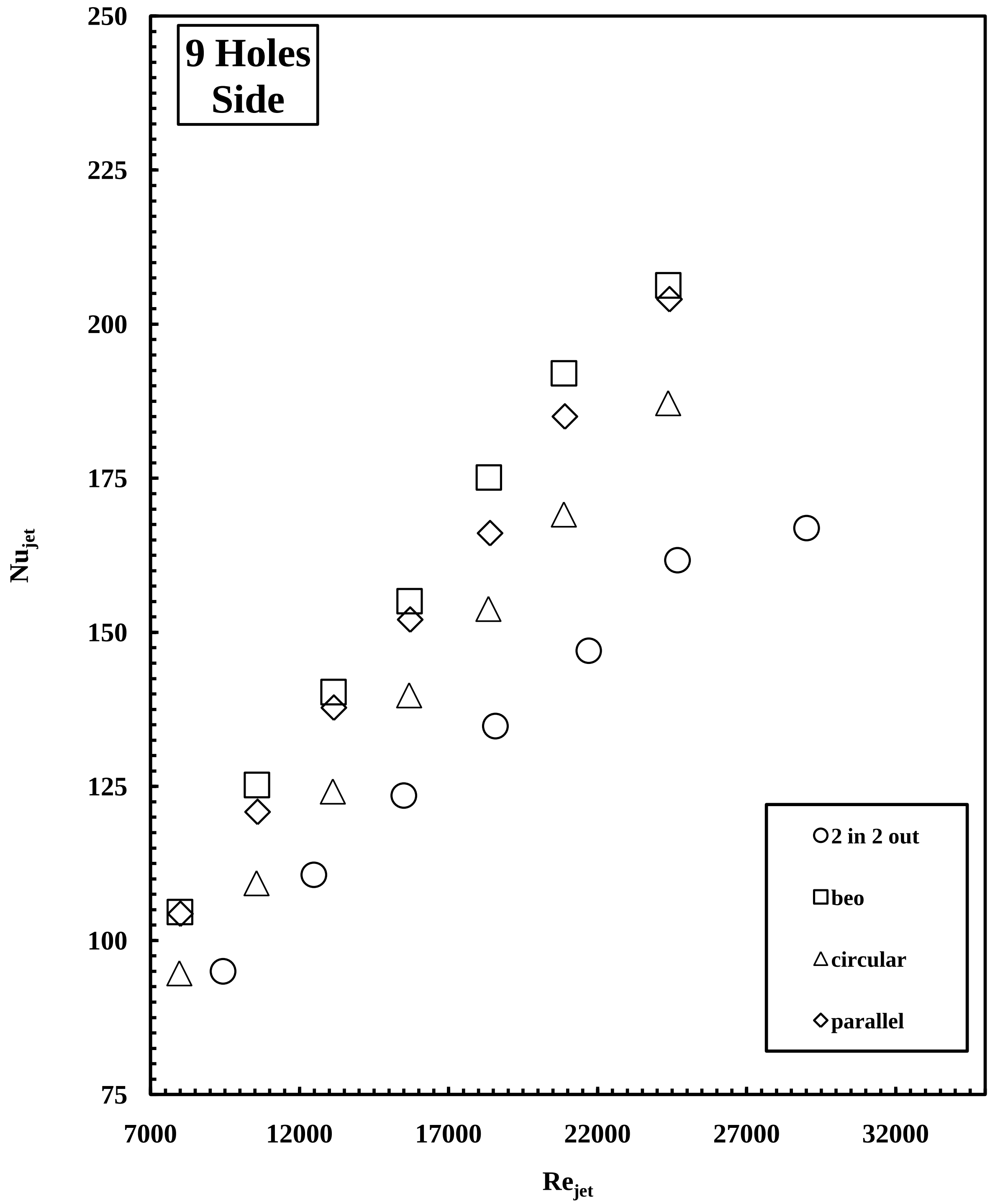

Figure 3.7 Comparison of the side Nusselt number for the case of 9 cross-over holes and all flow arrangements.

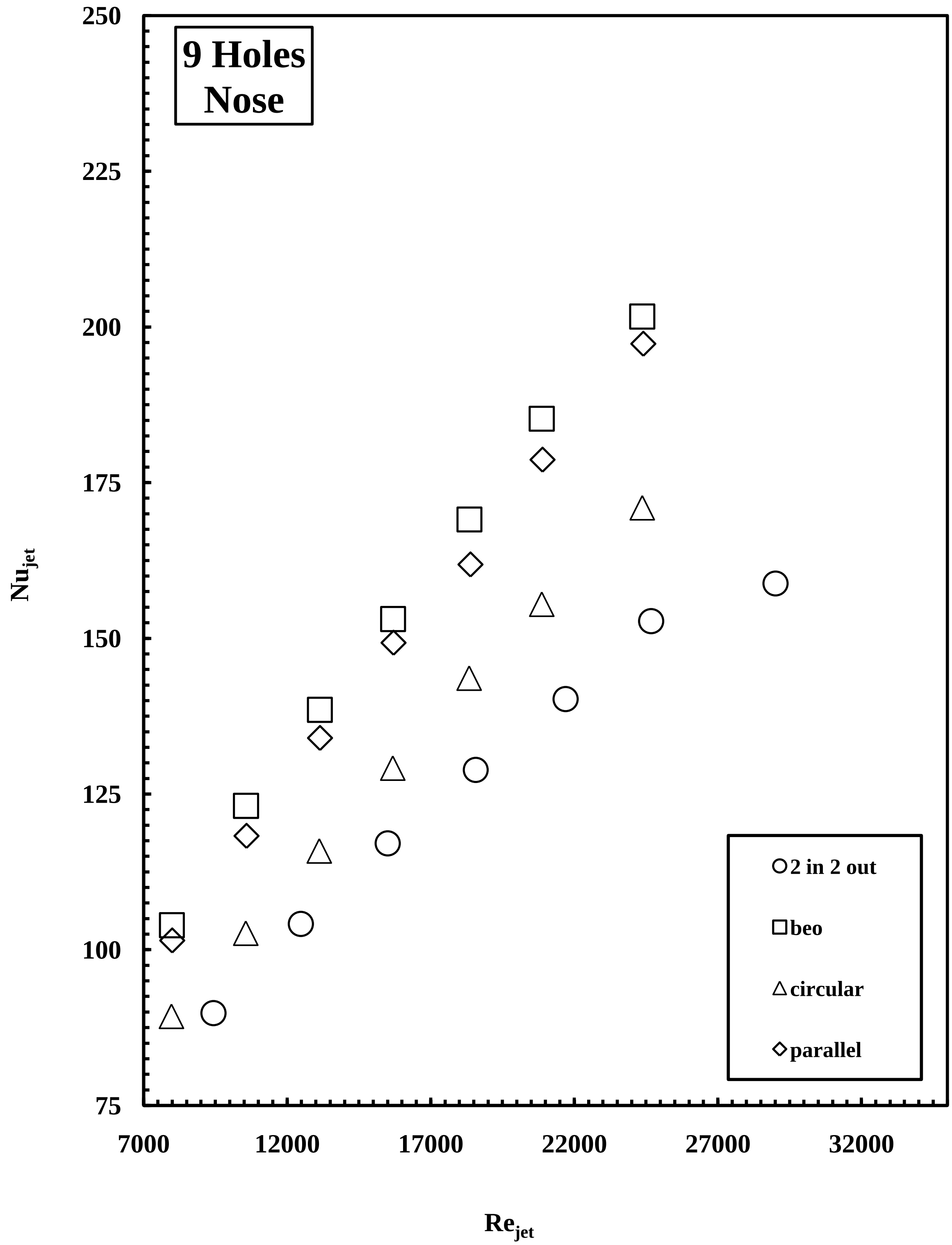

Figure 3.8 Comparison of the nose Nusselt number for the case of 9 cross-over holes and all flow arrangements.

3.2.2 Eight Holes

Figure 3.9 shows the 8 cross-over-hole case where the first cross-over hole was blocked and the flow entered the L.E channel through 8 cross-over holes. All four flow arrangements were tested for this case, parallel, circular, both-end-open and 2inlet-2outet.

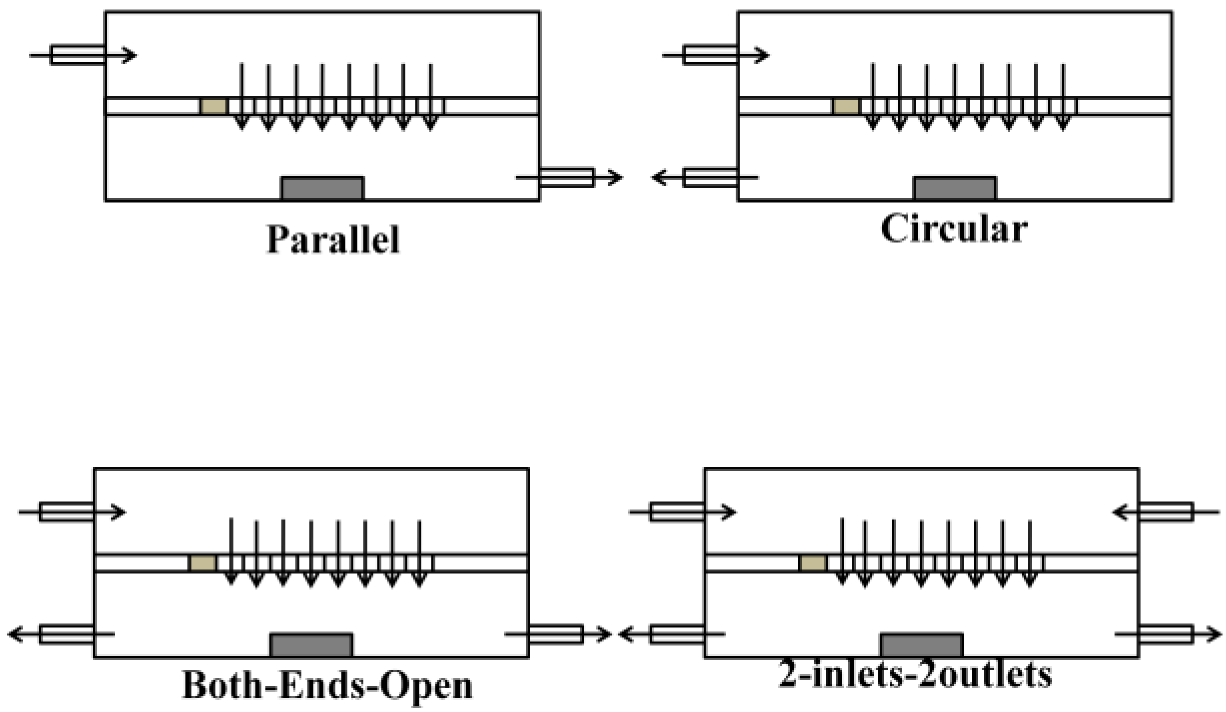

Figure 3.9 A Schematic of the 8 cross-over-hole geometry and the flow arrangements tested.

As illustrated in figures 3.11, 3.12, 3.13 and 3.14, it can be noticed the monotonic increase of the Nusselt with Reynolds number for all flow arrangements. The side Nusselt is higher than the nose as a result of more effective interaction between the cooling air and the side walls than at the nose area. The reason can be explained as follows: Since Eight cross-over-holes were open, at the location of the fifth jet, an axial flow generated in the L.E test section by the three upstream jets. This axial flow caused the jet to deflect to some extent. As a result, impingement on the targeted surface was somewhat reduced. Since the jets turn into an axial flow after impingement, they may not cover the entire nose surface. Less interaction with the target wall will result in less heat transfer. The cross flow will cause radial cooling on the sides plates causing more cooling for the sides over the nose.

Figures 3.15 and 3.16 show a comparison between the side and nose Nusselt numbers respectively for different flow arrangements. The Both-Ends-Open provided the highest Nusselt number on both the nose and the side. Since both sides of the L.E channel were unblocked in the

Both-Ends-Open flow arrangement, jets upstream the 5th cross-over-hole, after impinging on the L.E surface, exit the L.E channel from the $L.E_{in}$ side, while the jets downstream the 5th cross-over-hole, after impinging, exit the L.E channel from the $L.E_{out}$ side, this will weaken the axial flow and therefore better impinging takes place at the 5th jet location. For the Parallel and Circular flow arrangements since on side of the L.E channel was blocked, axial flow was generated along the L.E channel. Figures 3.10 shows the pathlines for the circular flow arrangement where it can be noticed that the stagnation point where pure impingement takes place was shifted away from the targeted surface. At Re_{jet}=26000, the highest Nusselt number was obtained for the both-ends-open flow arrangement with a value of 191 for the nose and 199 for the side.

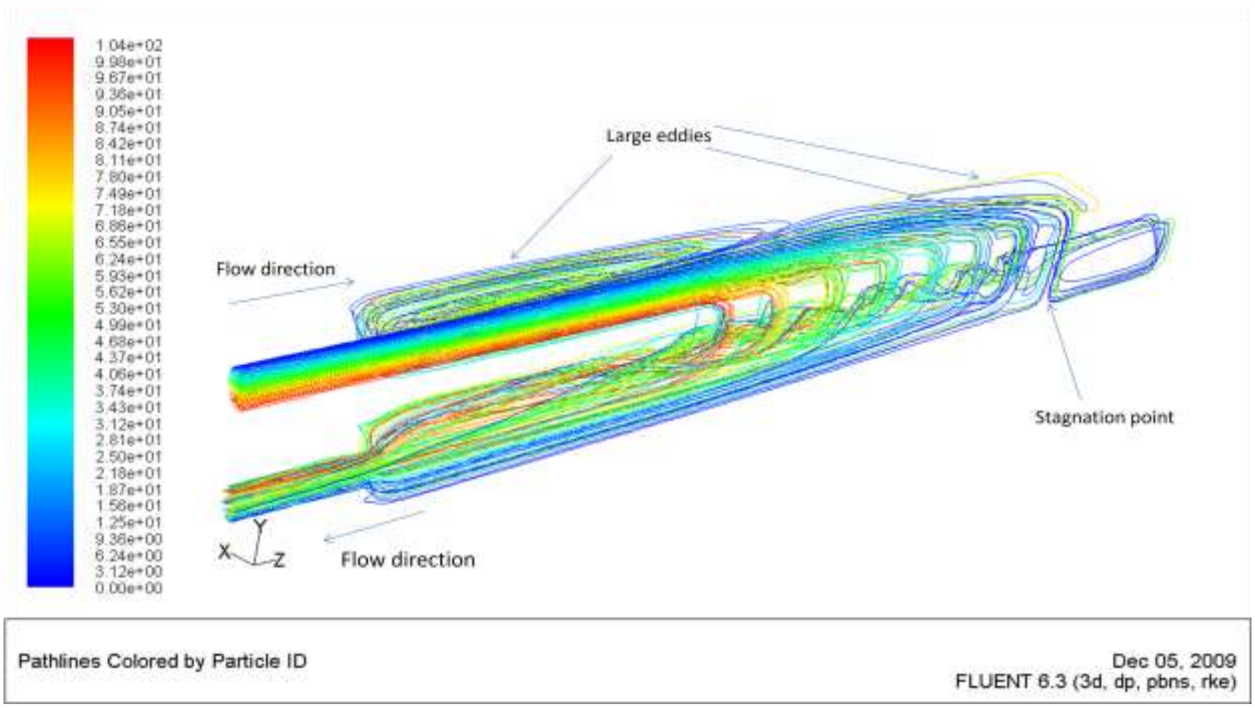

Figure 3.10 PathLines for the case of 8 cross-over holes and circular flow arrangement.

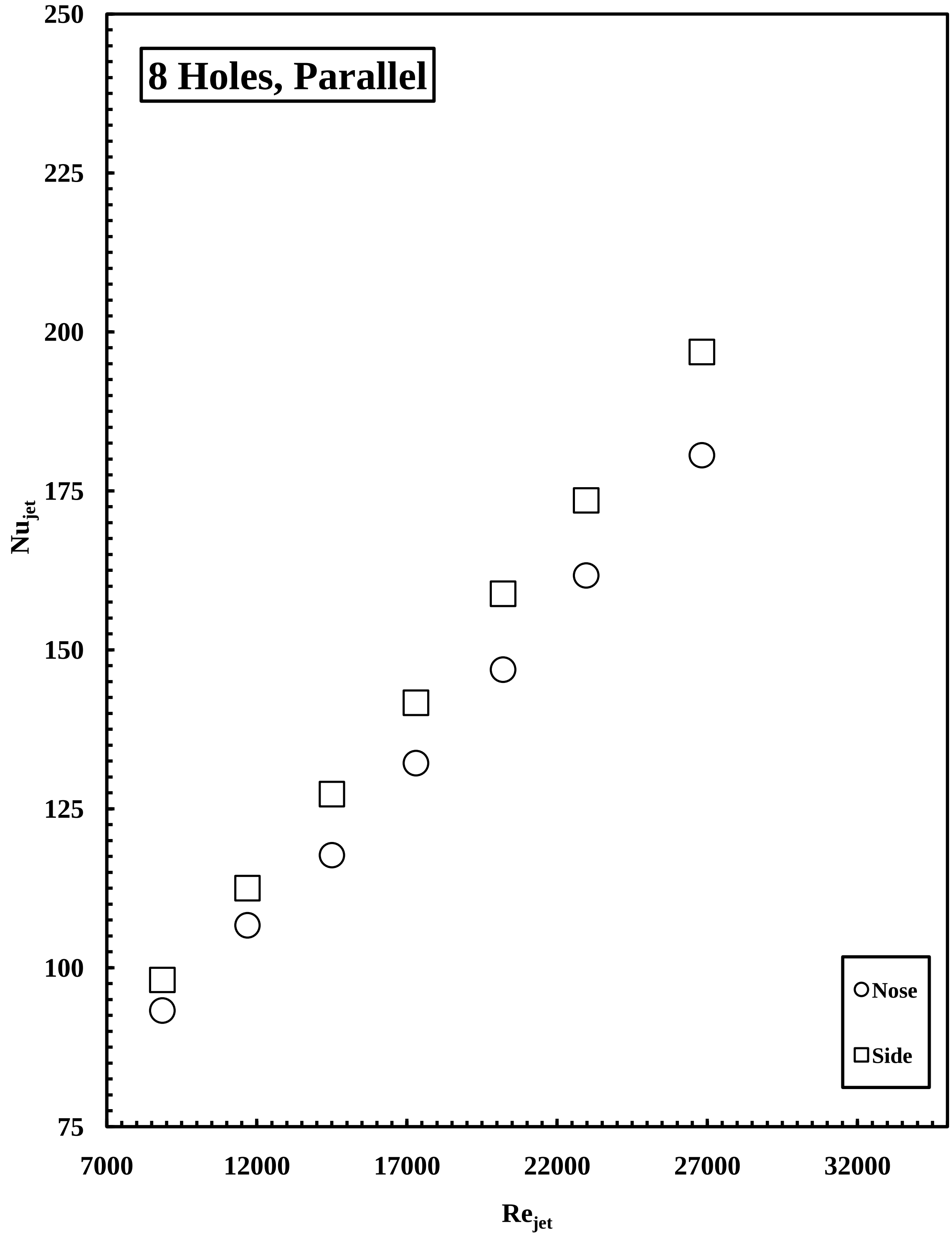

Figure 3.11 Comparison of the side and nose Nusselt numbers for the case of 8 cross-over holes and parallel flow arrangement.

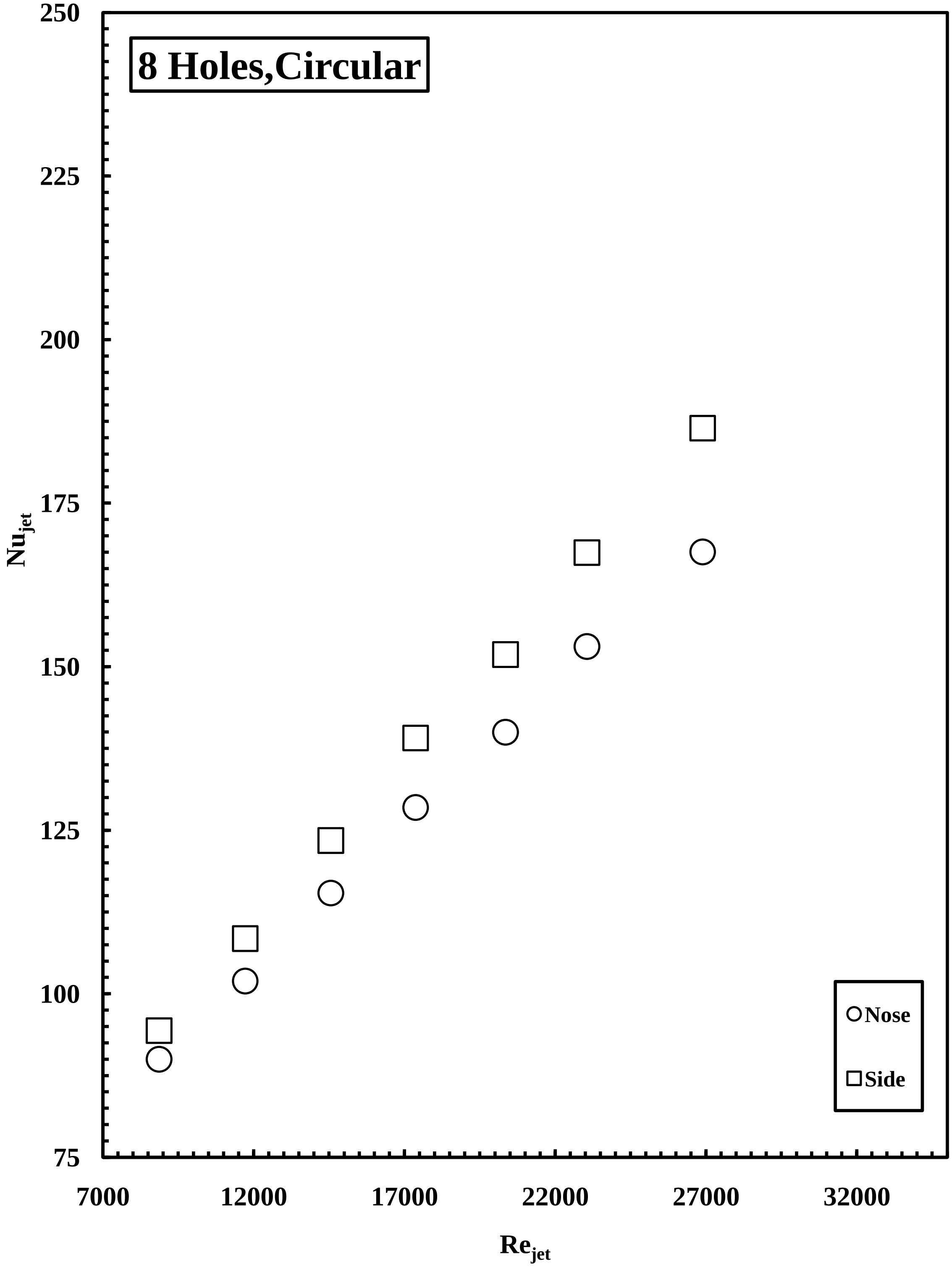

Figure 3.12 Comparison of the side and nose Nusselt numbers for the case of 8 cross-over holes and circular flow arrangement.

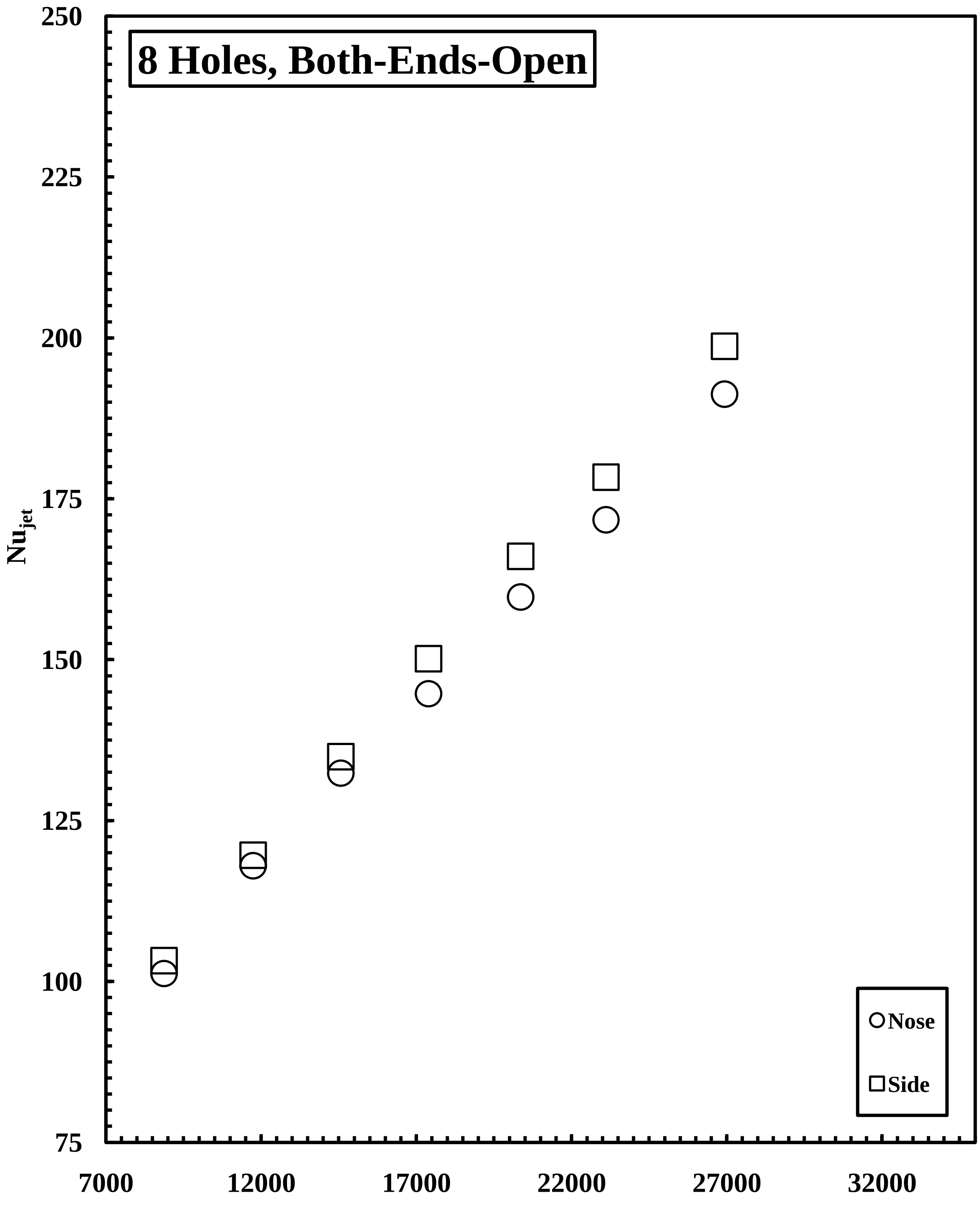

Figure 3.13 Comparison of the side and nose Nusselt numbers for the case of 8 cross-over holes and both-ends-open flow arrangement.

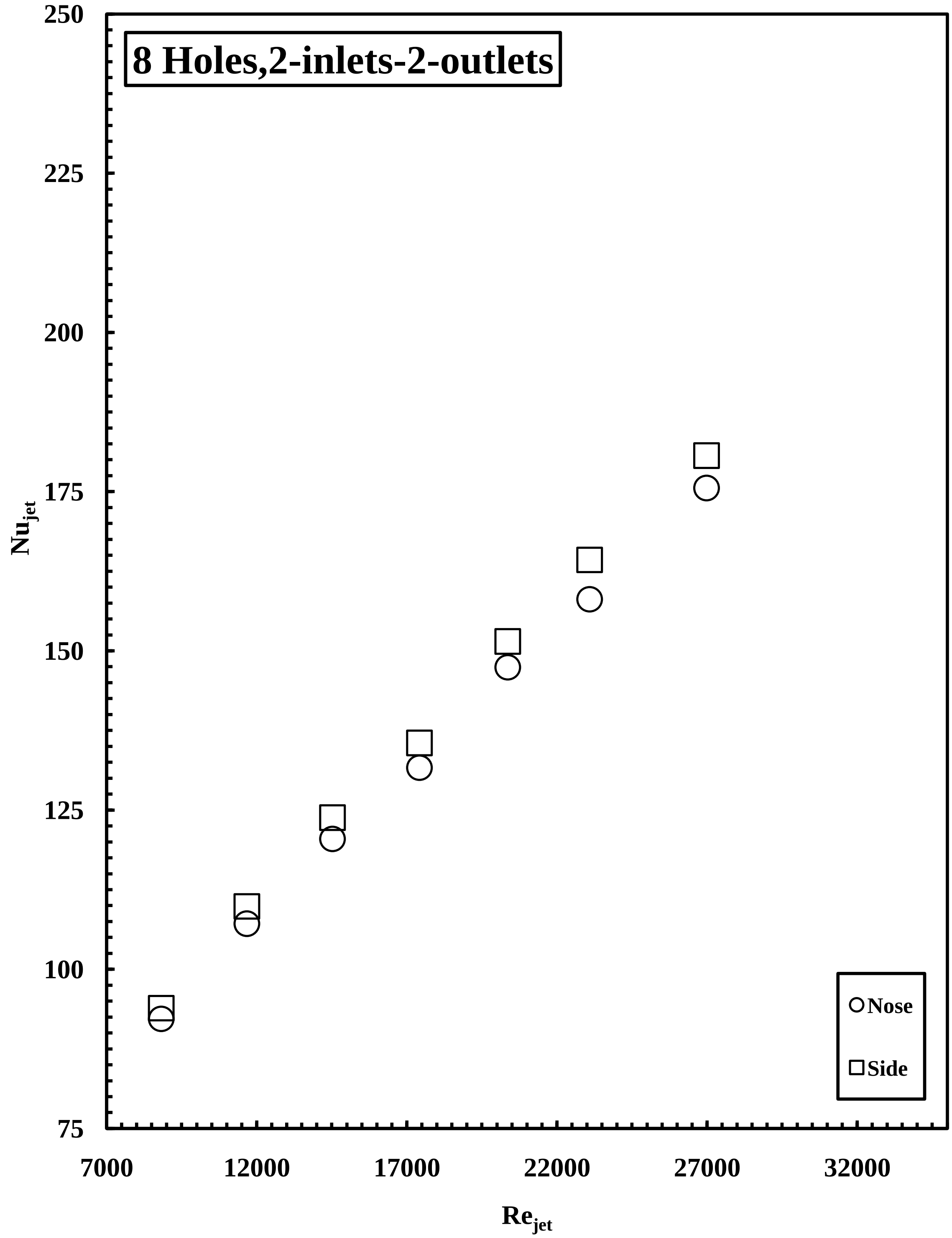

Figure 3.14 Comparison of the side and nose Nusselt numbers for the case of 8 cross-over holes and 2-inlets-2-outlets flow arrangement.

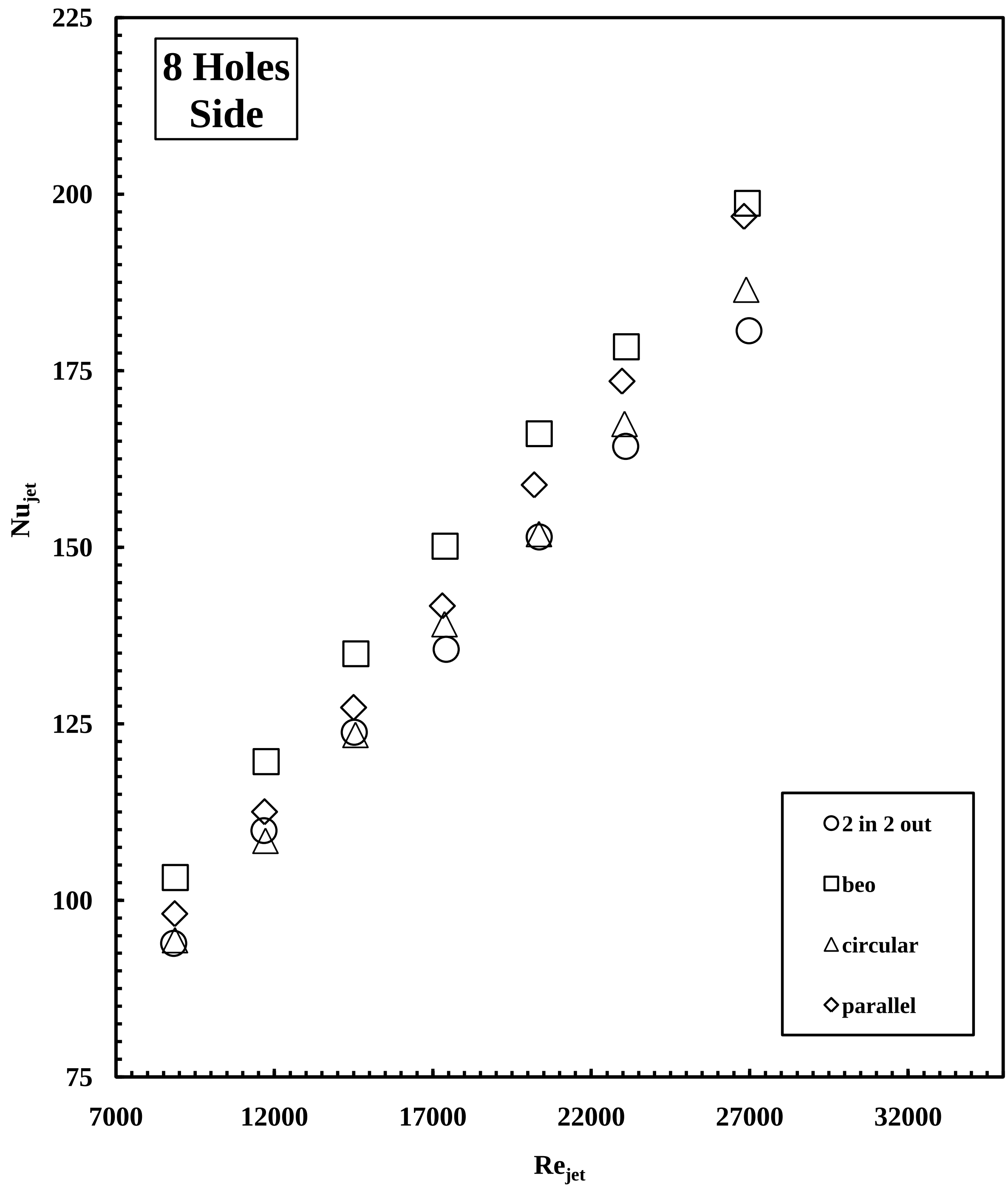

Figure 3.15 Comparison of the side Nusselt number for the case of 8 cross-over holes and all flow arrangements.

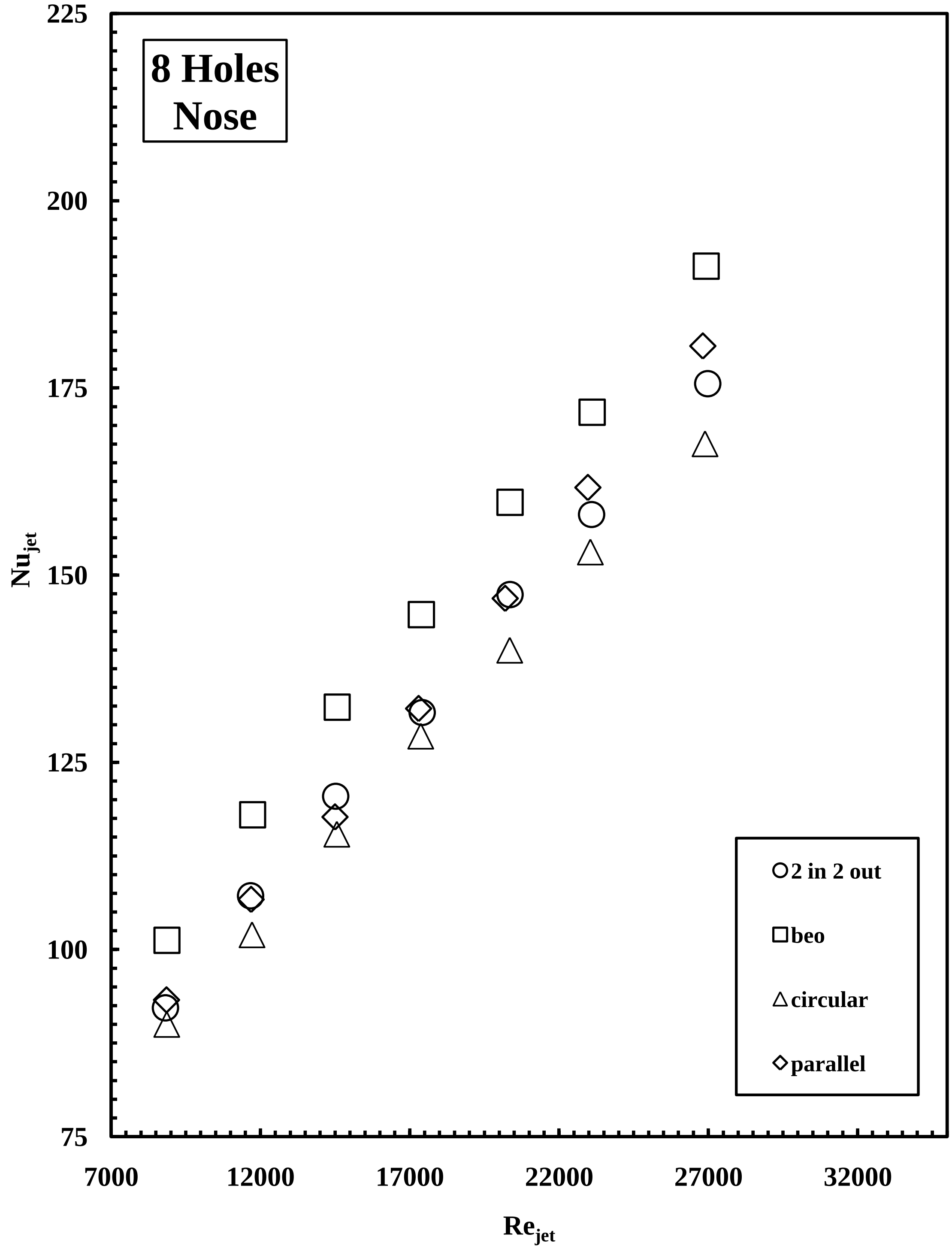

Figure 3.16 Comparison of the nose Nusselt number for the case of 8 cross-over holes and all flow arrangements.

3.2.3 Seven Holes

Figure 3.17 shows the 7 cross-over-hole case where the first 2 cross-over-holes were blocked and the flow entered the L.E channel through 7 cross-over holes. Three flow arrangements were tested for this case, parallel, circular and both-ends-open.

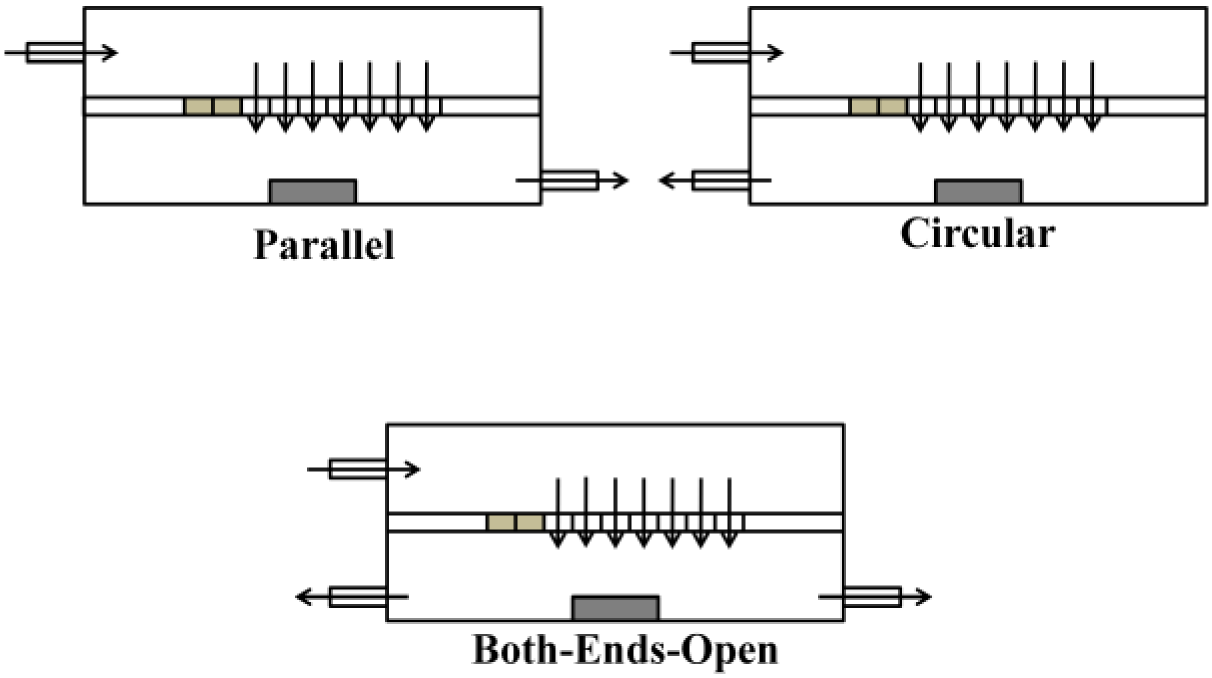

Figure 3.17 A Schematic of the 7 cross-over-hole geometry and the flow arrangements tested.

As illustrated in figures 3.19, 3.20, 3.21 and 3.22, it can be noticed the monotonic increase of the Nusselt with Reynolds number for all flow arrangements. The side Nusselt is higher than the nose as a result of more effective interaction between the cooling air and the side walls than at the nose area. The reason can be explained as follows: Since seven cross-over-holes were open, at the location of the fifth jet, an axial flow was formed in the L.E test section by the two upstream jets. This axial flow caused the jet to deflect to some extent. As a result impingement on the targeted surface was somewhat reduced. Since the jets turns into an axial flow after impingement, they may not cover the entire nose surface. Less interaction with the target wall will result in less heat transfer. The axial flow will cause radial cooling on the side plates causing more cooling for the sides over the nose.

Figures 3.23 and 3.24 show a comparison between the side and nose Nusselt numbers respectively for different flow arrangements. The Both-Ends-Open provided the highest Nu on both the nose and the side. Since both sides of the L.E channel were unblocked in the Both-Ends-Open flow arrangement, jets upstream the 5^{th} cross-over-hole, after impinging on the L.E surface, exit the L.E channel from the $L.E_{in}$ side, while the jets downstream the 5^{th} cross-over-hole, after impinging exit the L.E channel from the L.E_{out} side, this will weaken the axial flow and therefore better impinging takes place at the 5^{th} jet location. For the Parallel and Circular flow arrangements since on side of the L.E channel was blocked, axial flow was generated along the L.E channel. Figures 3.18 shows the pathlines for the circular flow arrangement where it can be noticed that the stagnation point where pure impingement takes place was shifted away from the targeted surface. At Re_{jet}=26400 the highest Nusselt number were obtained for the both-ends-open flow arrangement with a value of 198 for the nose and 203 for the side.

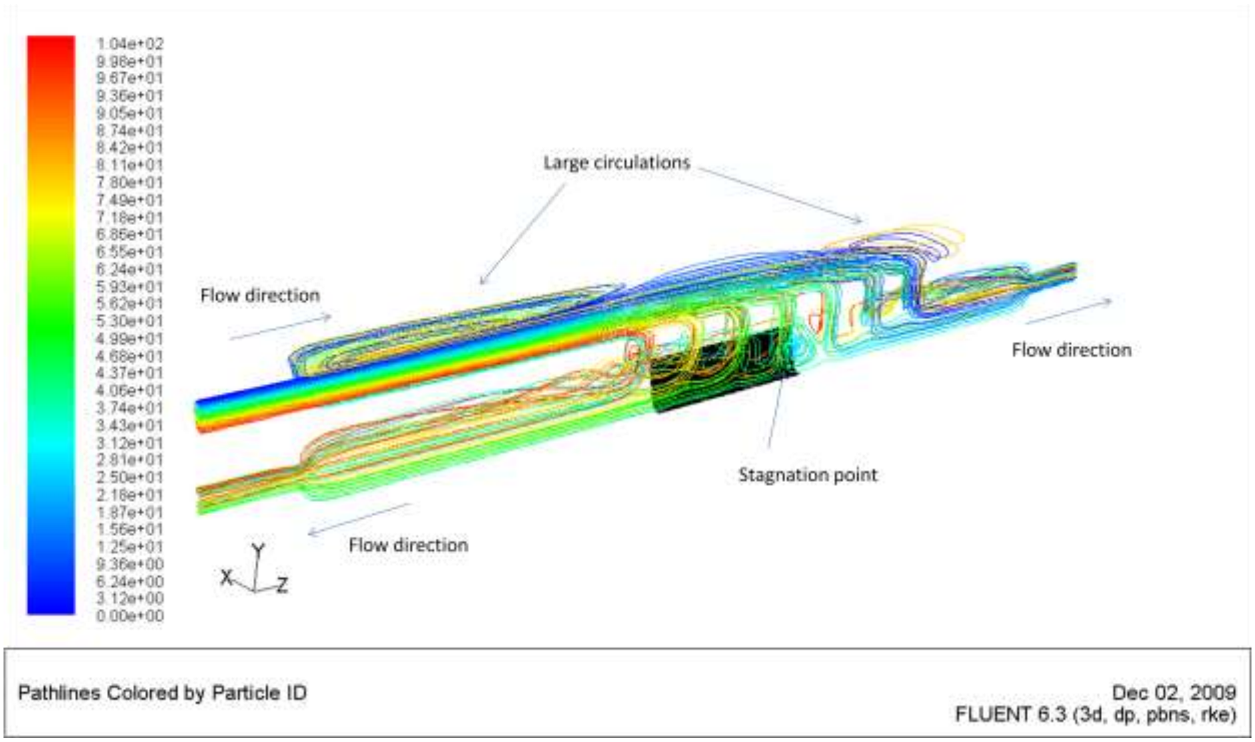

Figure 3.18 PathLines for the case of 7 cross-over holes and both-ends-open flow arrangement.

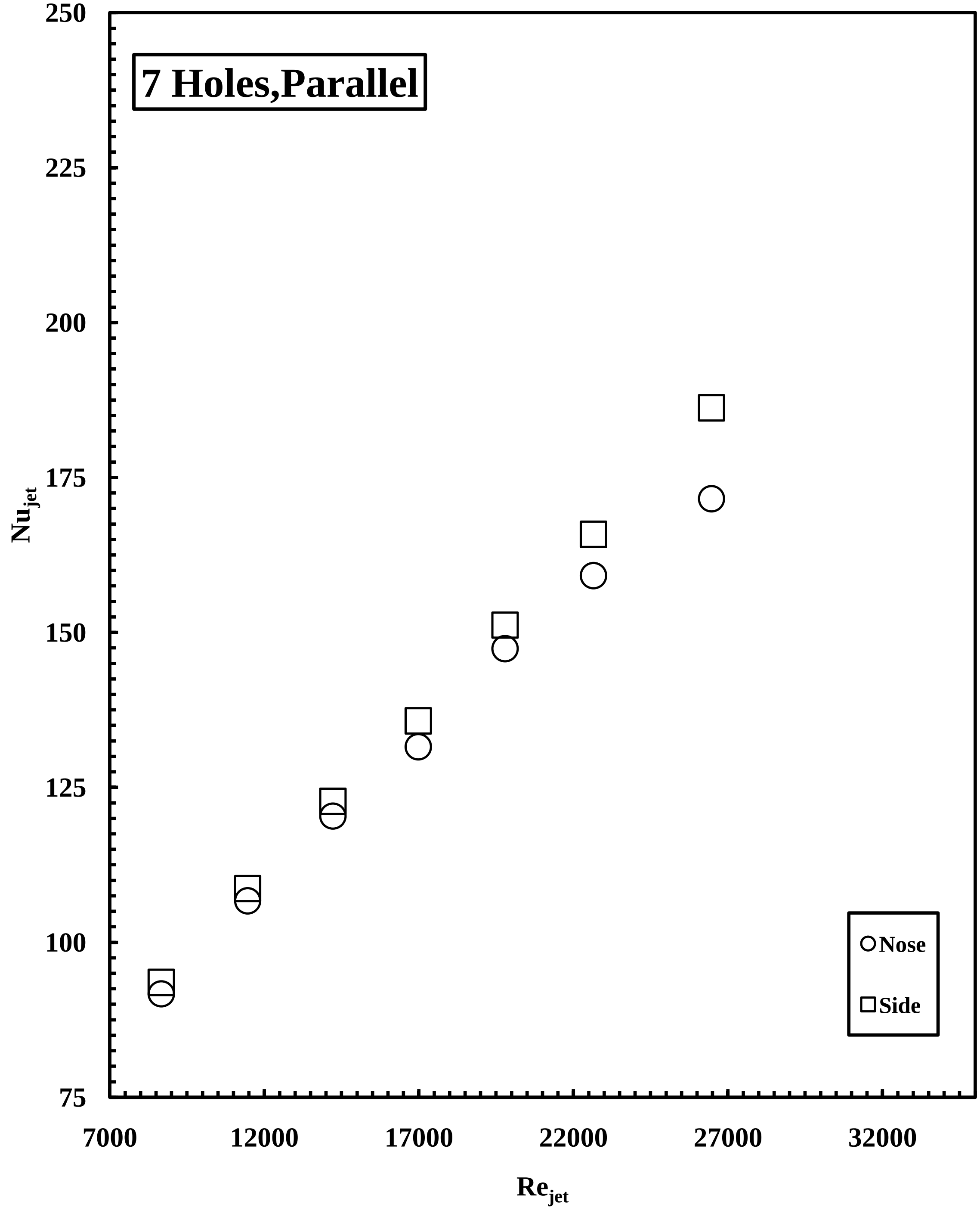

Figure 3.19 Comparison of the side and nose Nusselt numbers for the case of 7 cross-over holes and parallel flow arrangement.

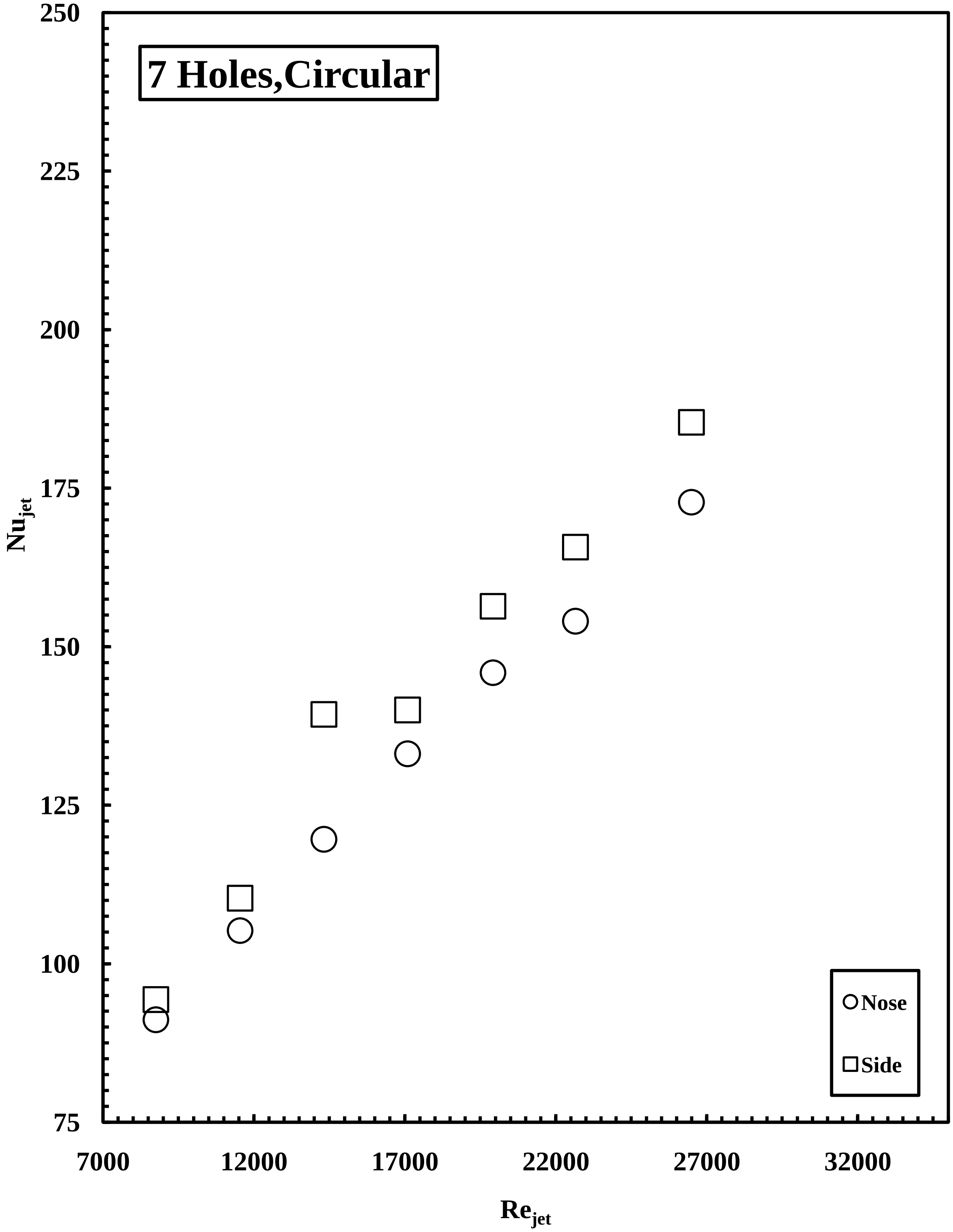

Figure 3.20 Comparison of the side and nose Nusselt numbers for the case of 7 cross-over holes and circular flow arrangement.

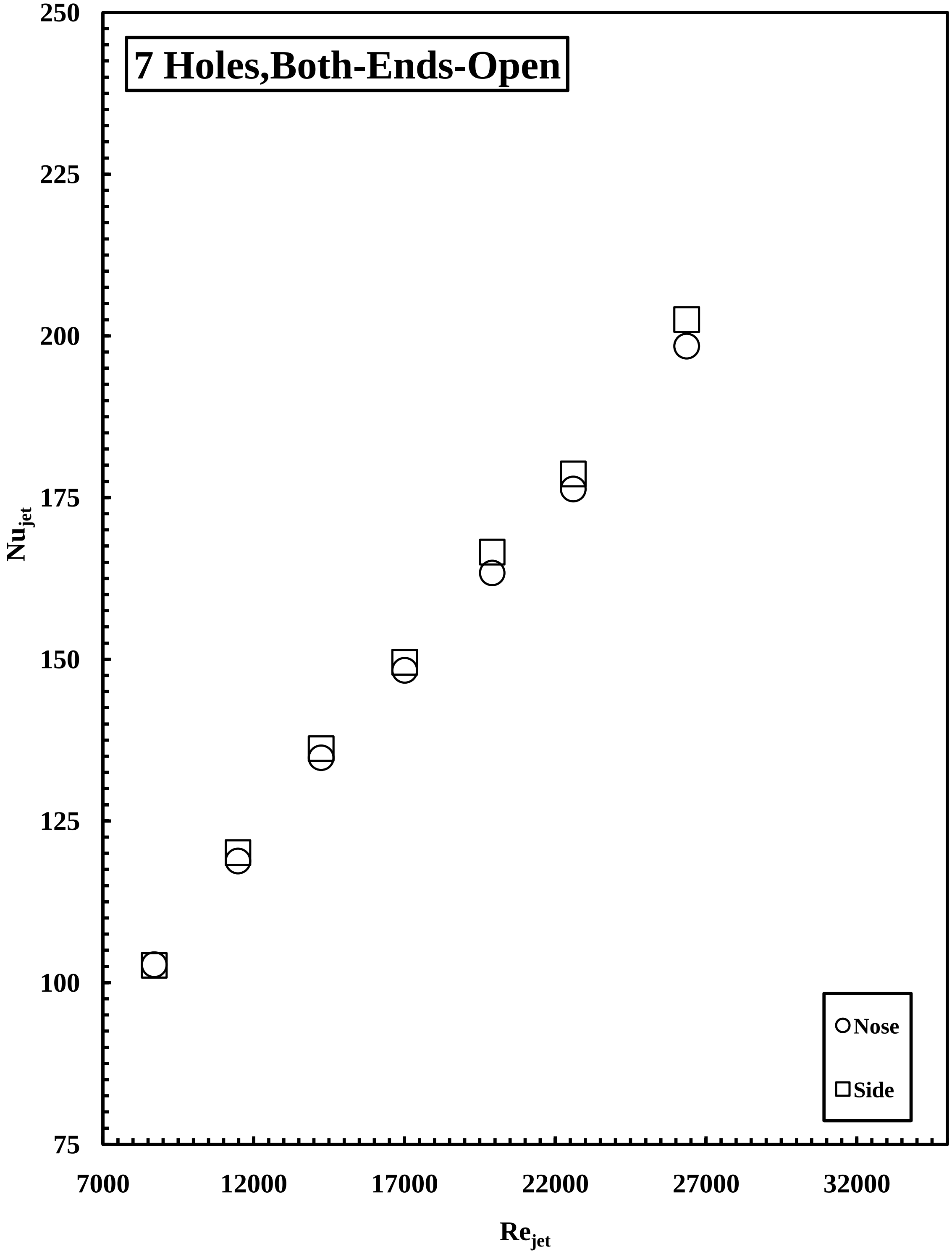

Figure 3.21 Comparison of the side and nose Nusselt numbers for the case of 8 cross-over holes and both-ends-open flow arrangement.

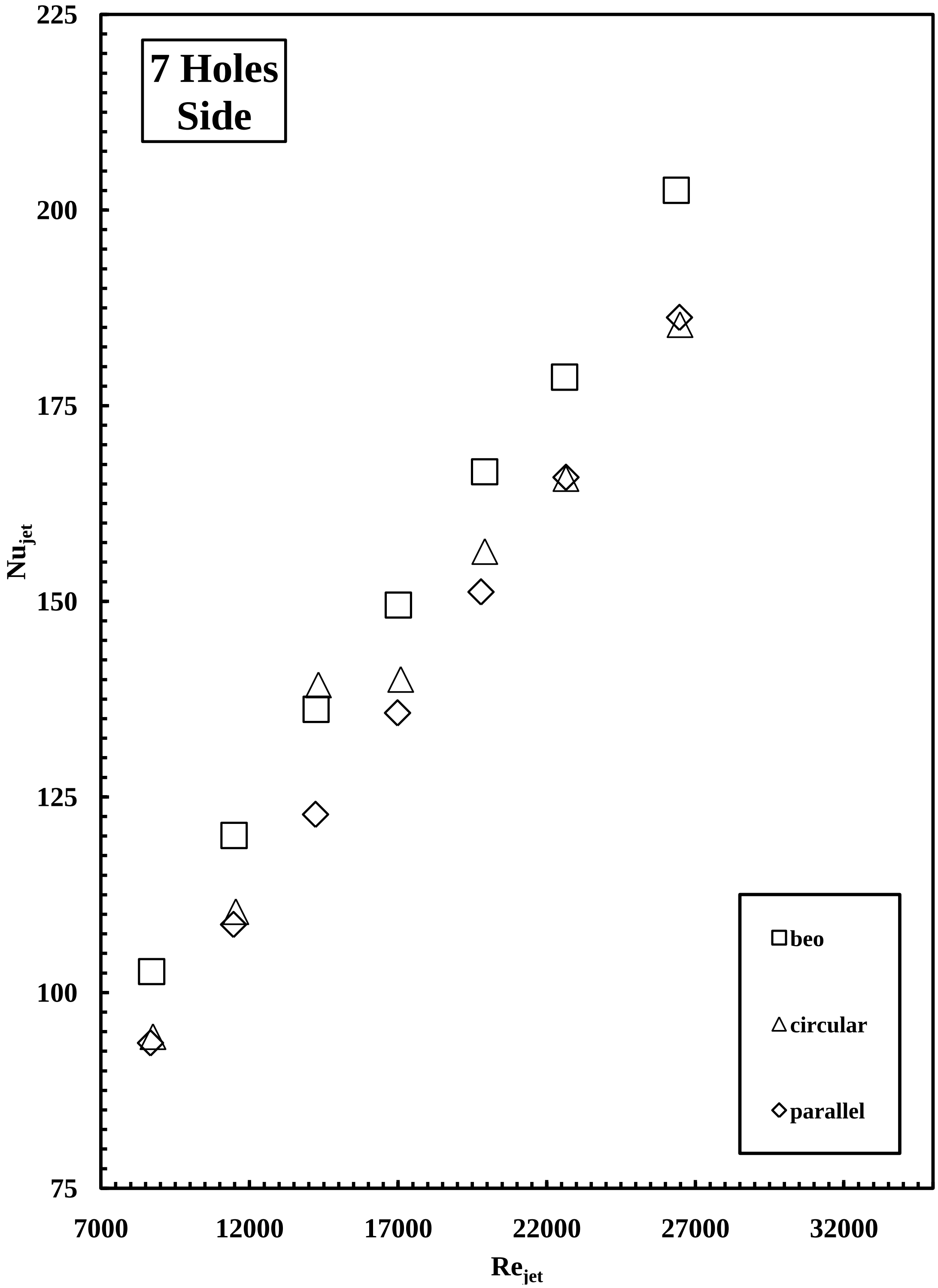

Figure 3.22 Comparison of the side Nusselt number for the case of 7 cross-over holes and all flow arrangements.

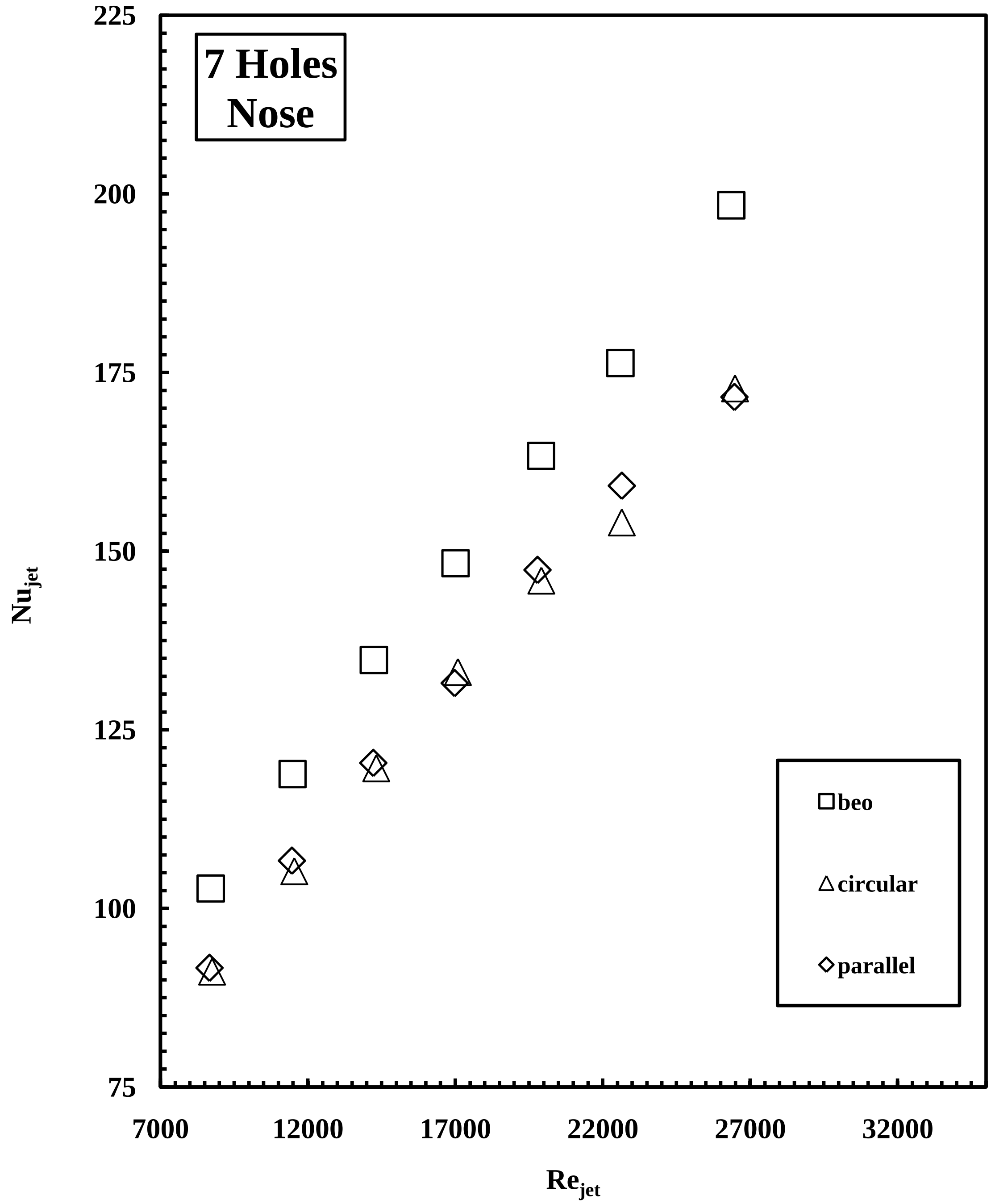

Figure 3.23 Comparison of the nose Nusselt number for the case of 7 cross-over holes and all flow arrangements.

3.2.4 Six Holes

Figure 3.24 shows the 6-hole case where the first 3 cross-over-holes were blocked and the flow entered the L.E channel through 6 cross-over holes. Three flow arrangements were tested for this case, parallel, circular and both-ends-open.

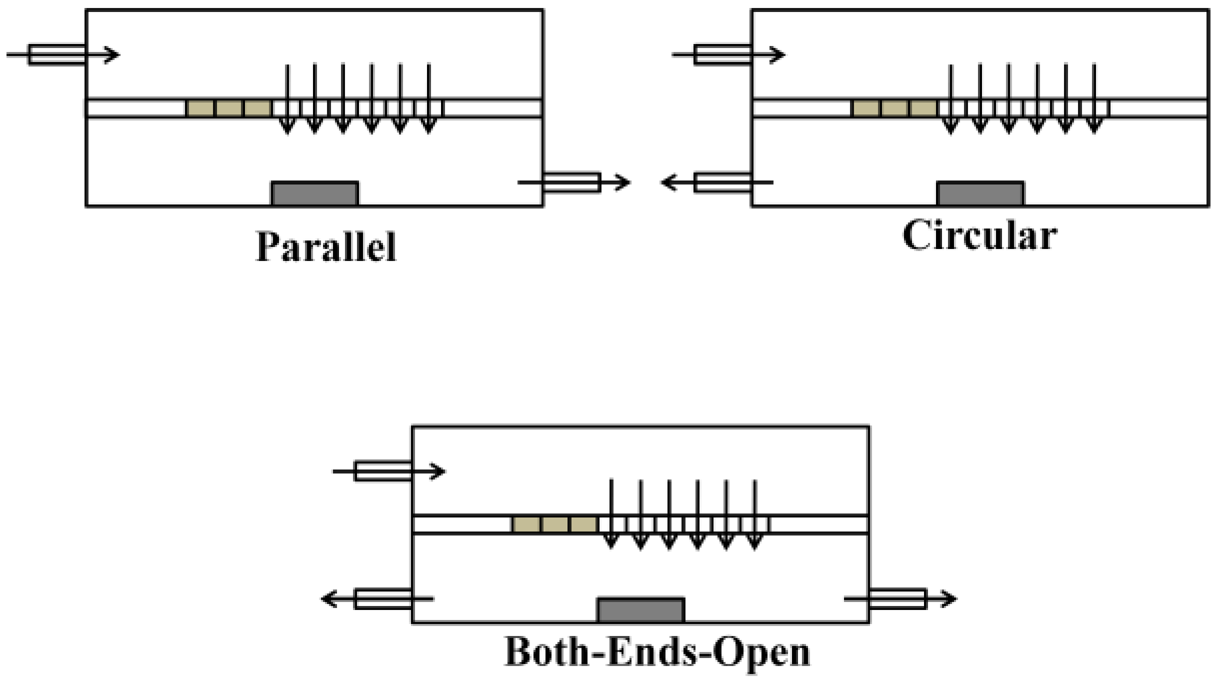

Figure 3.24 A Schematic of the 6 cross-over-hole geometry and the flow arrangements tested.

As illustrated in figures 3.26, 3.27, 3.28 and 3.29, it can be noticed the monotonic increase of the Nusselt with Reynolds number for all flow arrangements. The side Nusselt is higher than the nose as a result of more effective interaction between the cooling air and the side walls than at the nose area. The reason can be explained as follows: Since six cross-over-holes were open, at the location of the fifth jet, an axial flow was formed in the L.E test section by the upstream jets. This axial flow caused the jet to deflect to some extent. As a result impingement on the targeted surface was somewhat reduced. Since the jets turn into an axial flow after impingement, they may not cover the entire nose surface. Less interaction with the target wall will result in less heat transfer. The cross flow will cause radial cooling on the sides plates causing more cooling for the sides over the nose.

Figures 3.30 and 3.31 show comparison between the side and the nose Nusselt number respectively for different flow arrangements. The Both-Ends-Open provided the highest Nusselt on both the nose and the side. Since both sides of the L.E channel were unblocked in the Both-Ends-Open flow arrangement, jets upstream the 5th cross-over-hole, after impinging on the L.E surface, exit the L.E channel from the L.E$_{in}$ side, while the jets downstream the 5th cross-over-hole, after impinging, exit the L.E channel from the L.E_{out} side, this will weaken the axial flow and therefore better impinging takes place at the 5^{th} jet location. For the Parallel and Circular flow arrangements, since on side of the L.E channel was blocked, axial flow was generated along the L.E channel. Figures 3.25 shows the pathlines for the Both-Ends-Open flow arrangement where it can be noticed that two stagnation points where impingement takes place. Both stagnation points were shifted away from the target. At Re_{jet}=27500 the highest Nusselt number were obtained for the both-ends-open flow arrangement with a value of 213 for the nose and 218 for the side.

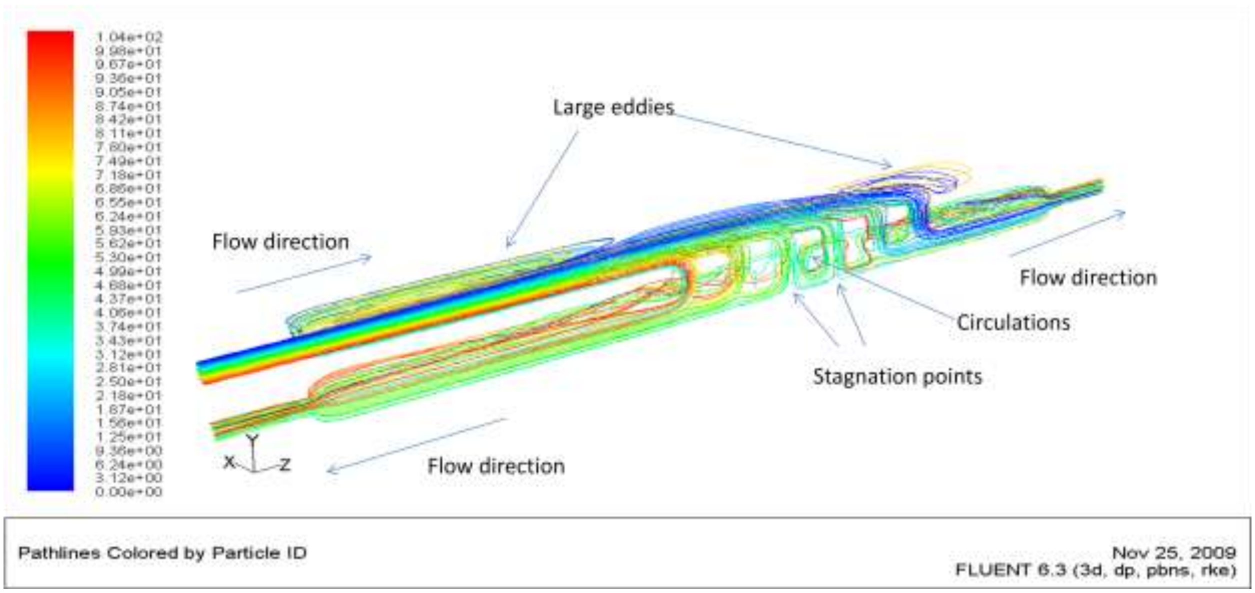

Figure 3.25 PathLines for the case of 6 cross-over holes and both-ends-open flow arrangement.

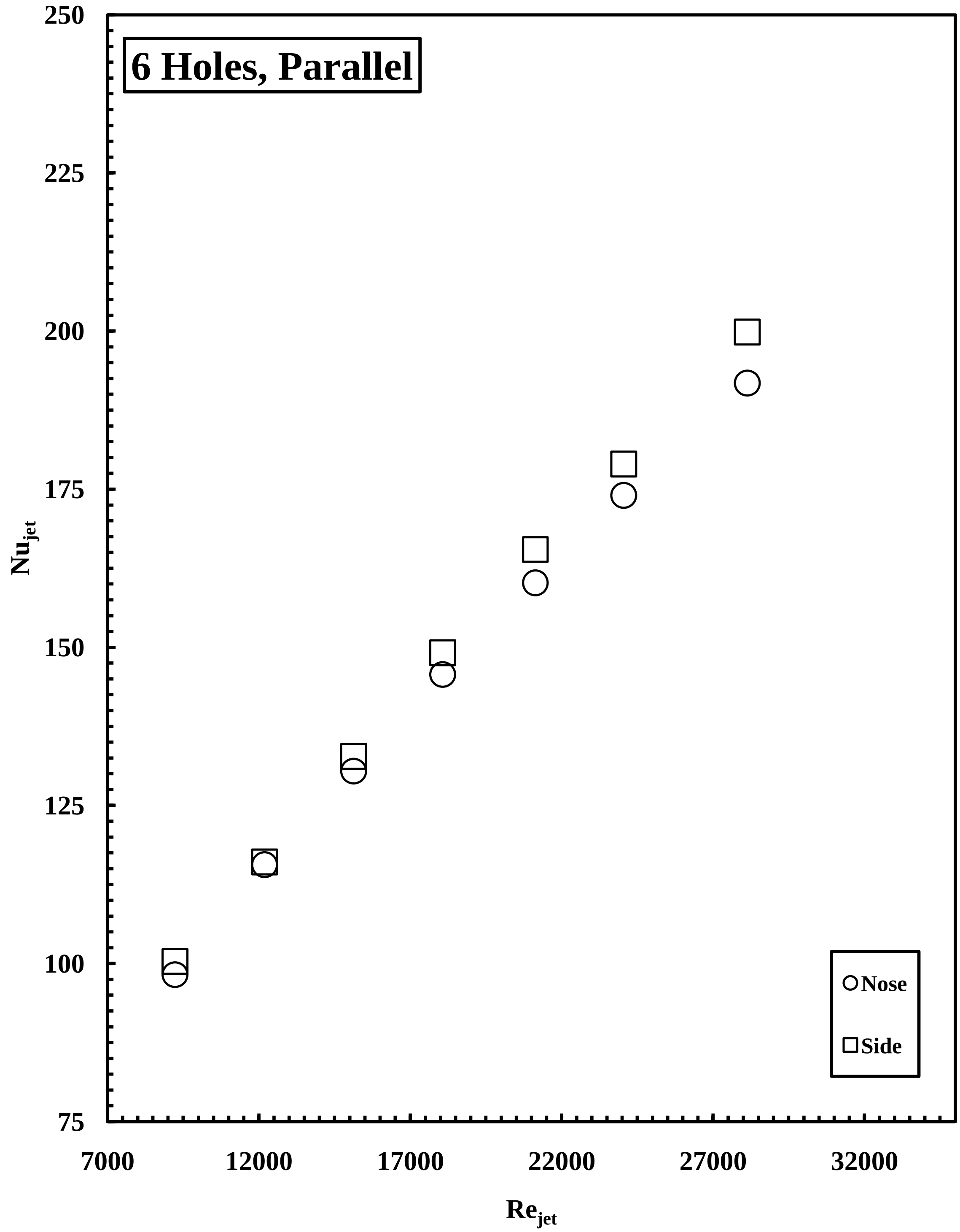

Figure 3.26 Comparison of the side and nose Nusselt numbers for the case of 6 cross-over holes and parallel flow arrangement.

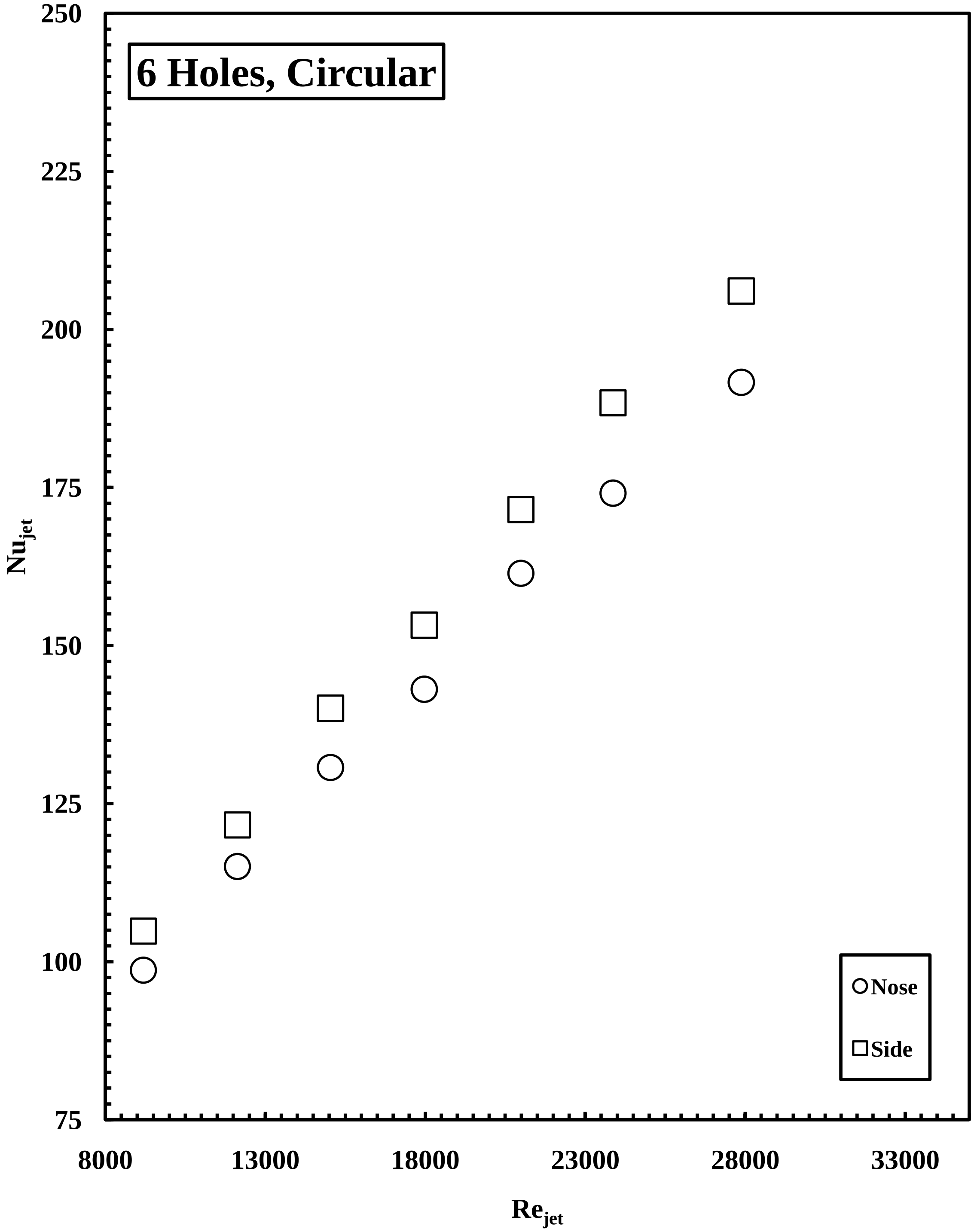

Figure 3.27 Comparison of the side and nose Nusselt numbers for the case of 6 cross-over holes and circular flow arrangement.

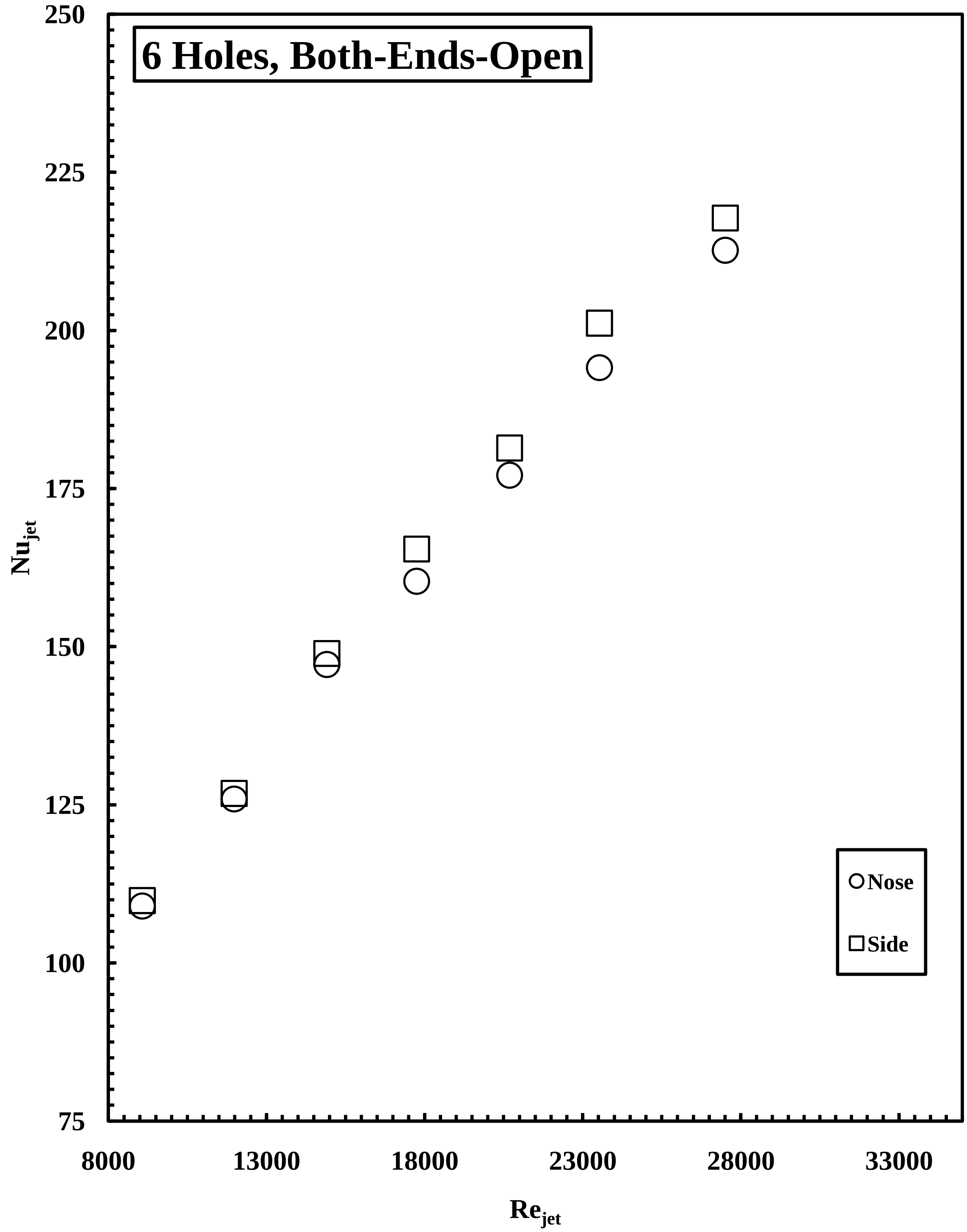

Figure 3.28 Comparison of the side and nose Nusselt numbers for the case of 6 cross-over holes and both-ends-open flow arrangement.

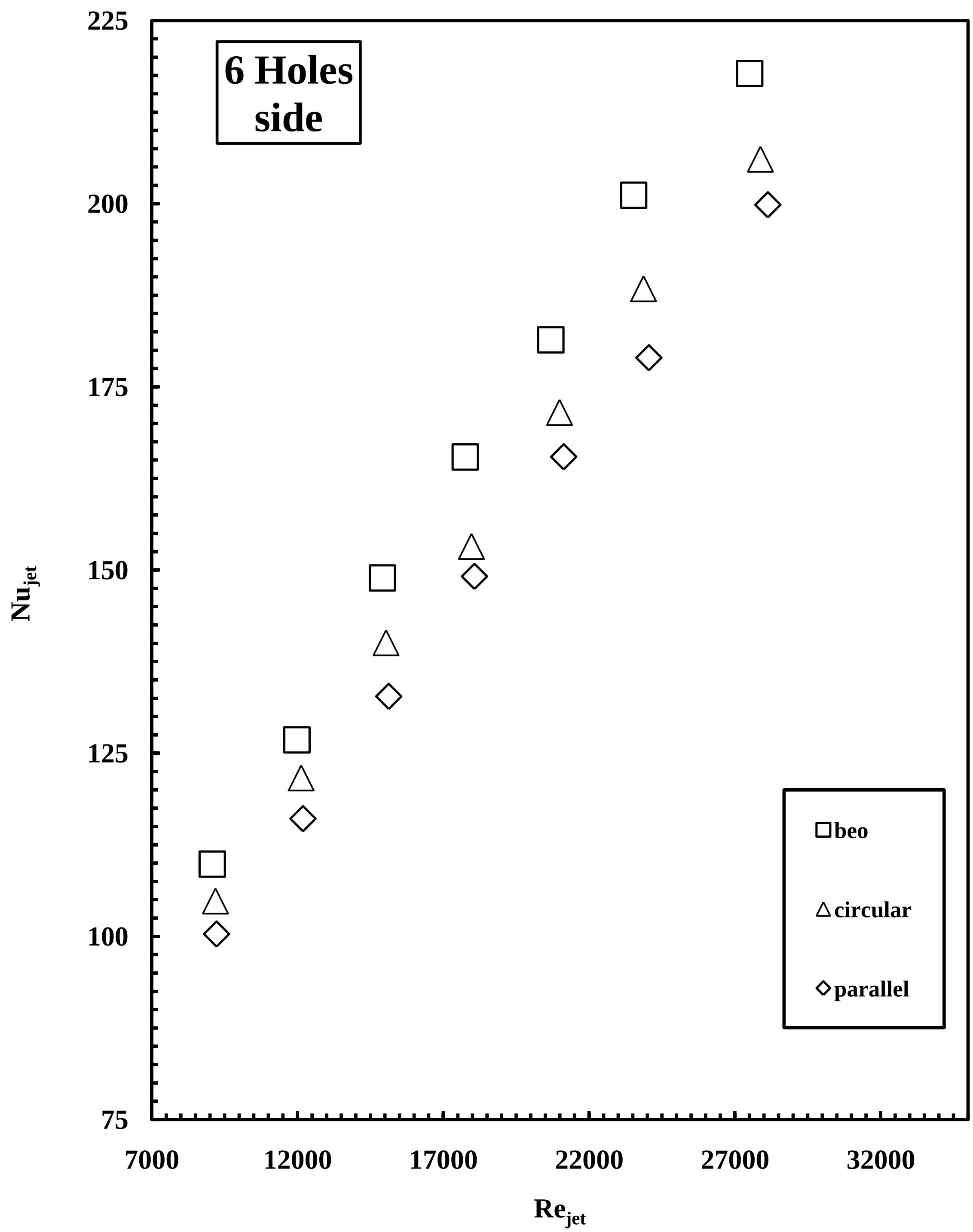

Figure 3.29 Comparison of the side Nusselt number for the case of 6 cross-over holes and all flow arrangements.

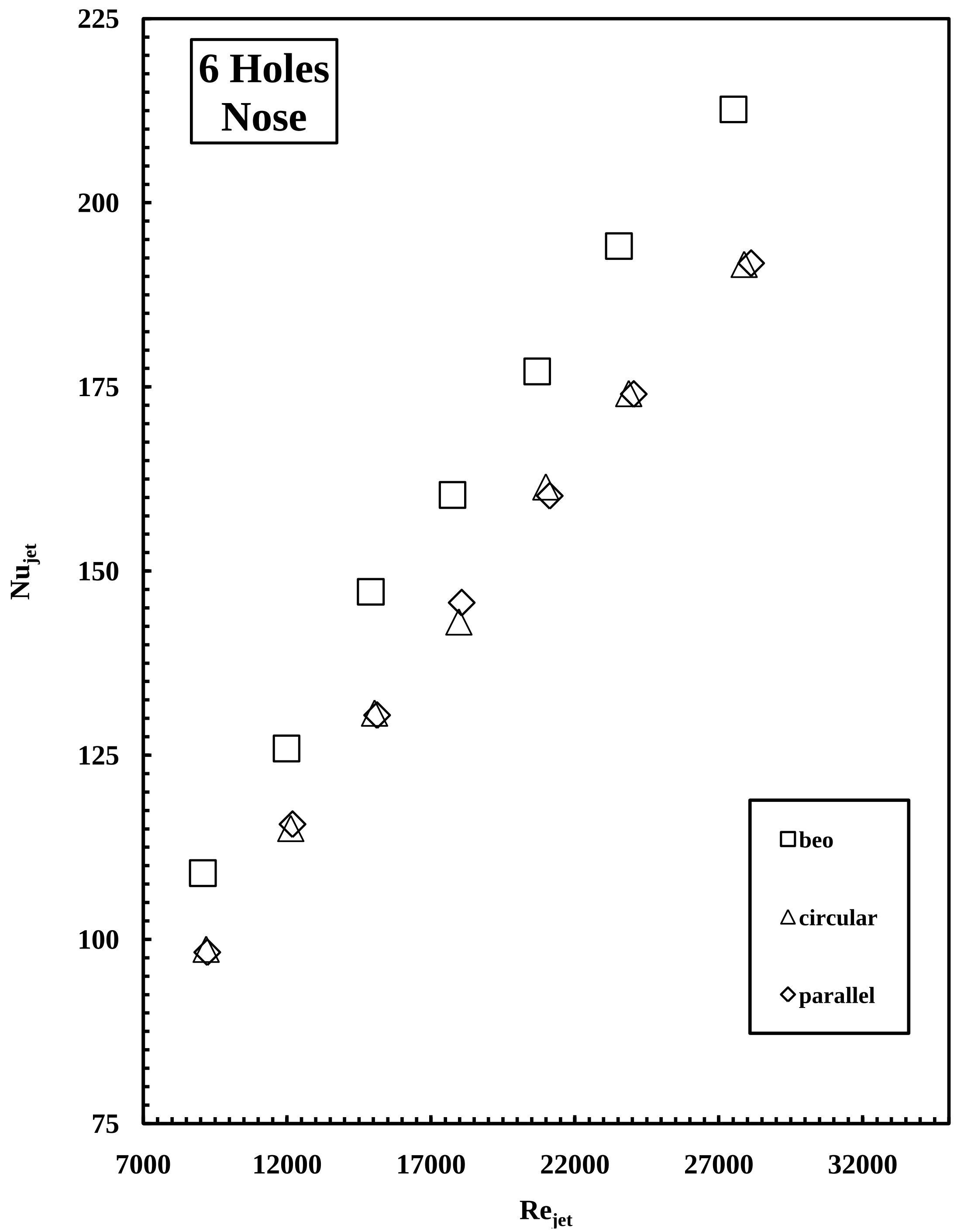

Figure 3.30 Comparison of the nose Nusselt number for the case of 6 cross-over holes and all flow arrangements.

3.2.5 Five Holes

Figure 3.31 shows the 5-hole case where 5 cross-over-holes were open and the flow entered the L.E channel through 5 cross-over holes. Four flow arrangements were tested for this case, parallel, circular, both-ends-open and 2-inlets-2-outlets.

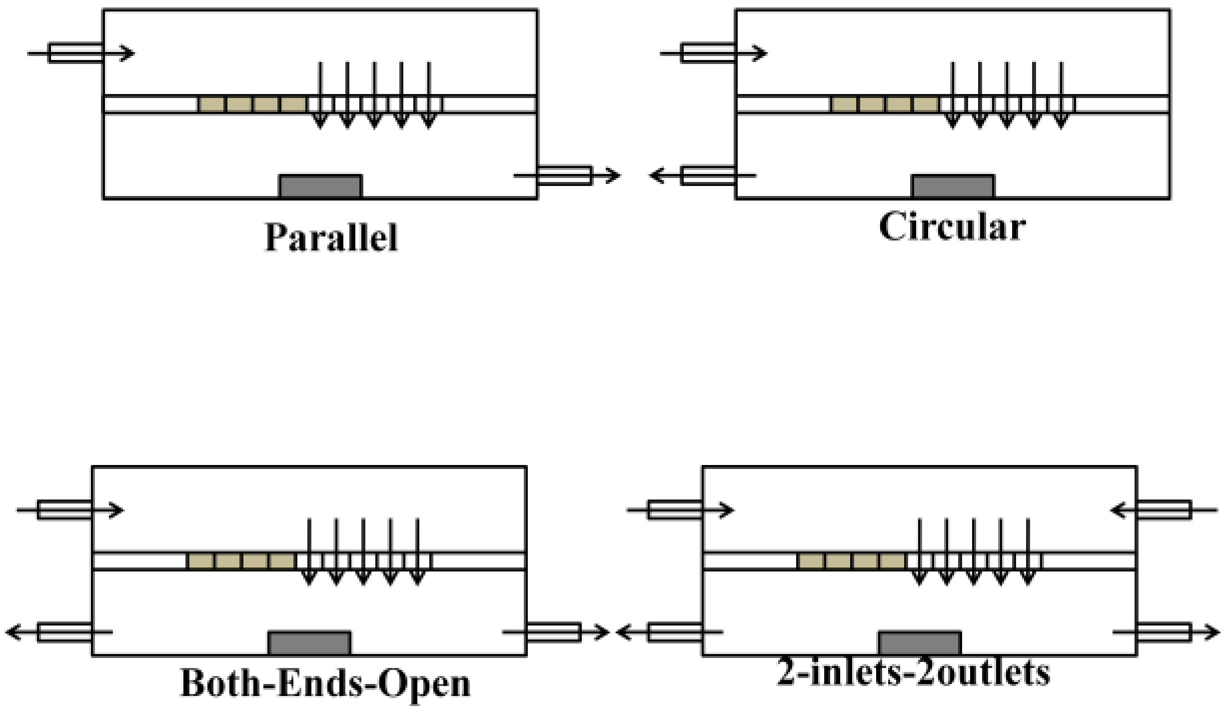

Figure 3.31 A Schematic of the 5 cross-over-hole geometry and the flow arrangements tested.

As illustrated in figures 3.34, 3.35, 3.36 and 3.37, it can be noticed the monotonic increase of the Nusselt with Reynolds number for all flow arrangements. The side Nusselt is higher than the nose as a result of more effective interaction between the cooling air and the side walls than at the nose area. For the parallel flow arrangement a higher Nusselt for the nose over the side was noticed. The reason can be explained as follows: Since the four cross-over-holes upstream the 5^{th} cross-over-hole were blocked, the axial flow generated in the L.E channel was somewhat reduced. As a result more effective impingement took place on the nose surface. Figures 3.38 and 3.39 show comparison between the side and nose Nusselt numbers respectively for different flow arrangements. The 2-inlets-2-outlets provided the highest Nusselt number on both the nose and the side. Figures 3.32 and 3.33 show the pathlines for the 2-inlets-2-outlets and the parallel flow arrangements respectively. It can be noticed that two stagnation points where impingement took place for the 2-inlets-2-outlets flow arrangement were shifted away from the targeted surface, while for the parallel flow the stagnation point lies on the nose surface.

At Re_{jet}=31900 the highest Nusselt number were obtained for the 2-inlets-2-outlets flow arrangement with a value of 245 for the Nose and 253 for the side.

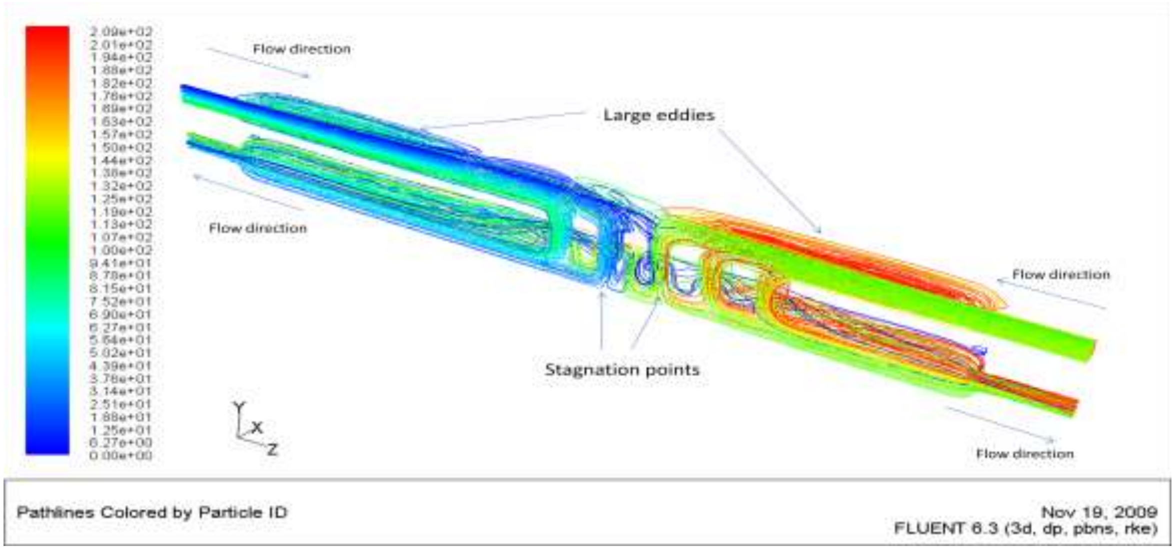

Figure 3.32 PathLines for the case of 5 cross-over holes and 2-inlets-2-outlets flow arrangement.

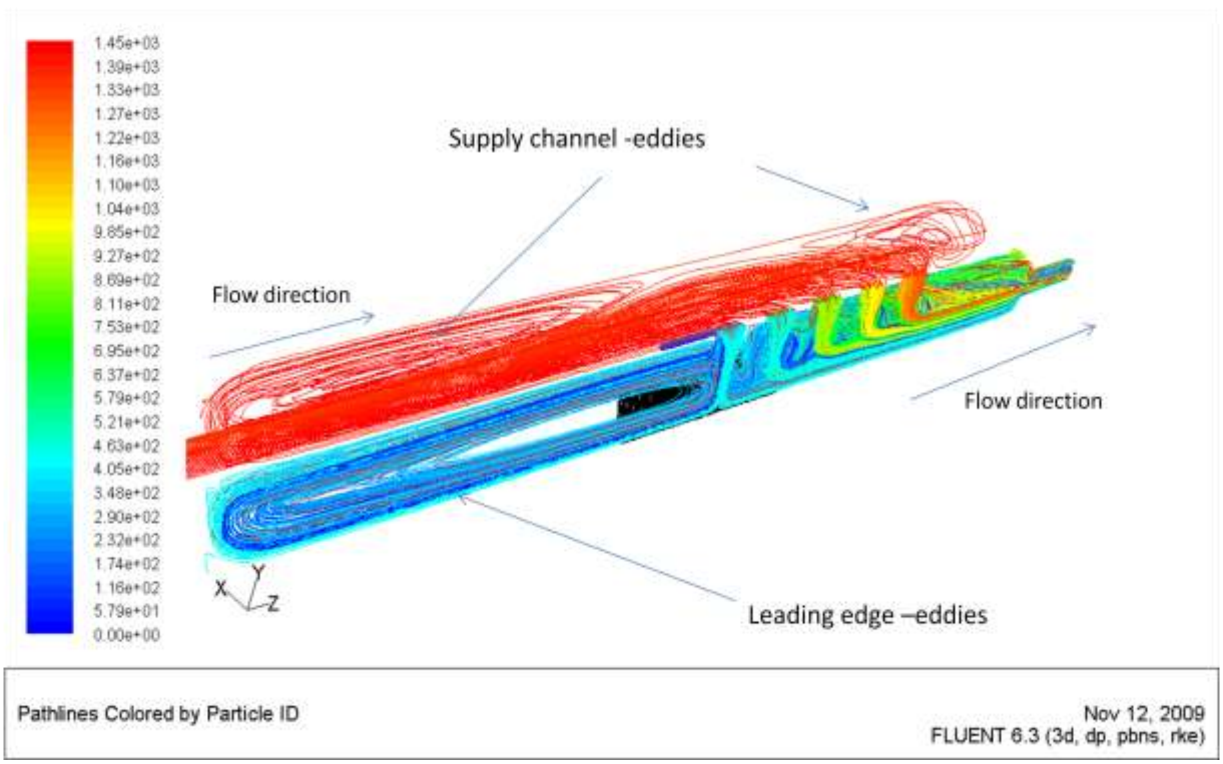

Figure 3.33 PathLines for the case of 5 cross-over holes and parallel flow arrangement.

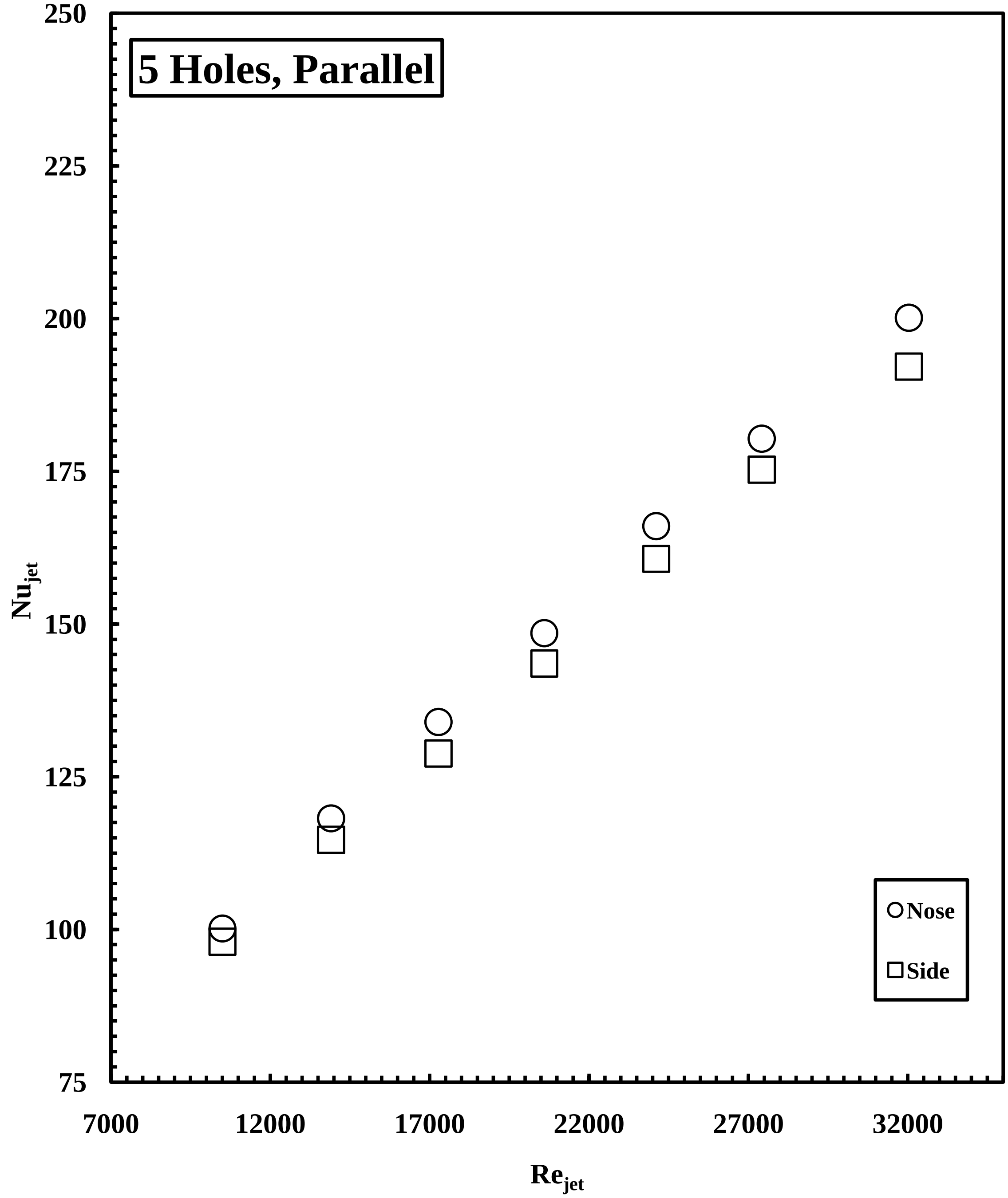

Figure 3.34 Comparison of the side and nose Nusselt numbers for the case of 5 cross-over holes and parallel flow arrangement.

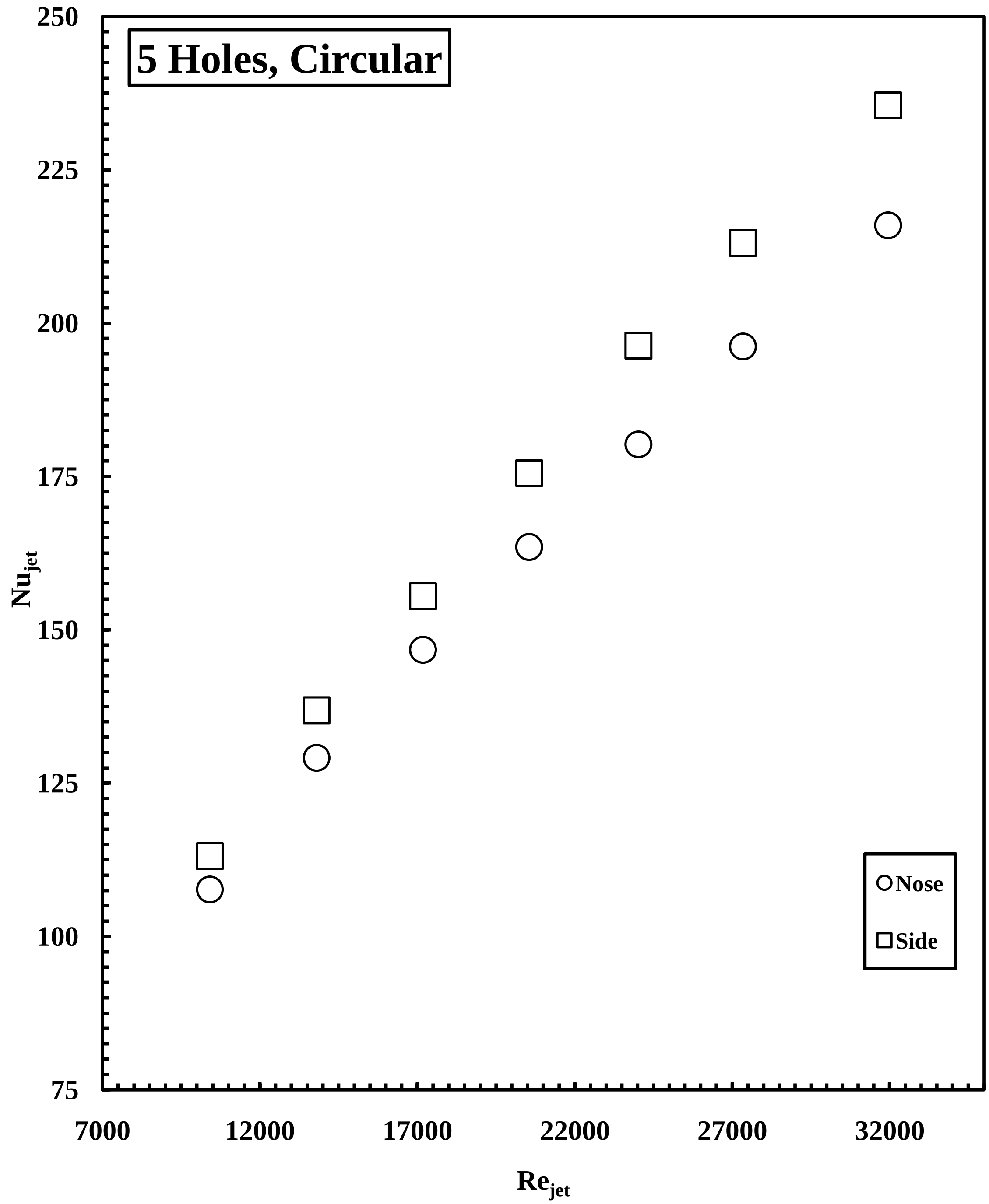

Figure 3.35 Comparison of the side and nose Nusselt numbers for the case of 5 cross-over holes and circular flow arrangement.

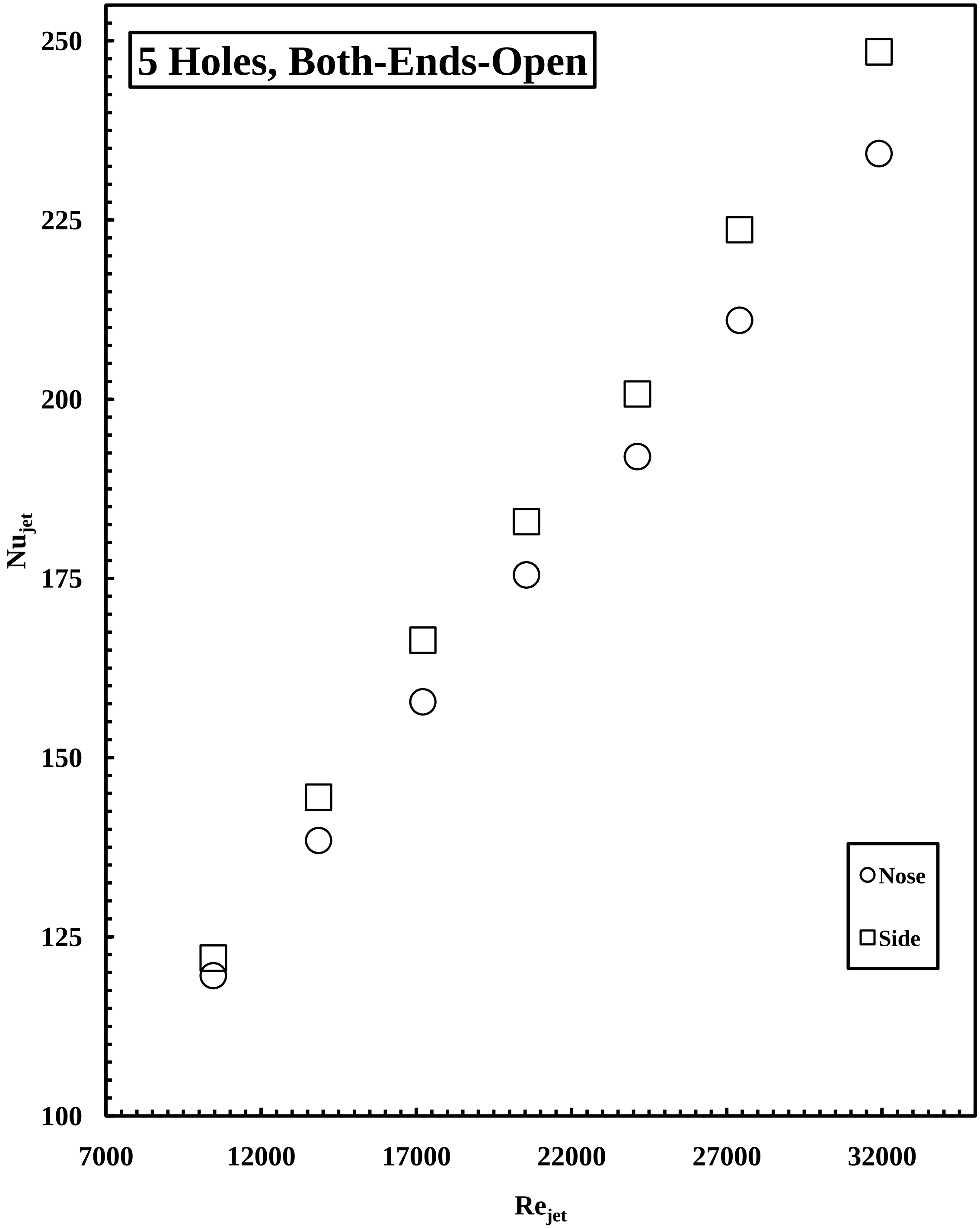

Figure 3.36 Comparison of the side and nose Nusselt numbers for the case of 5 cross-over holes and both-ends-open flow arrangement.

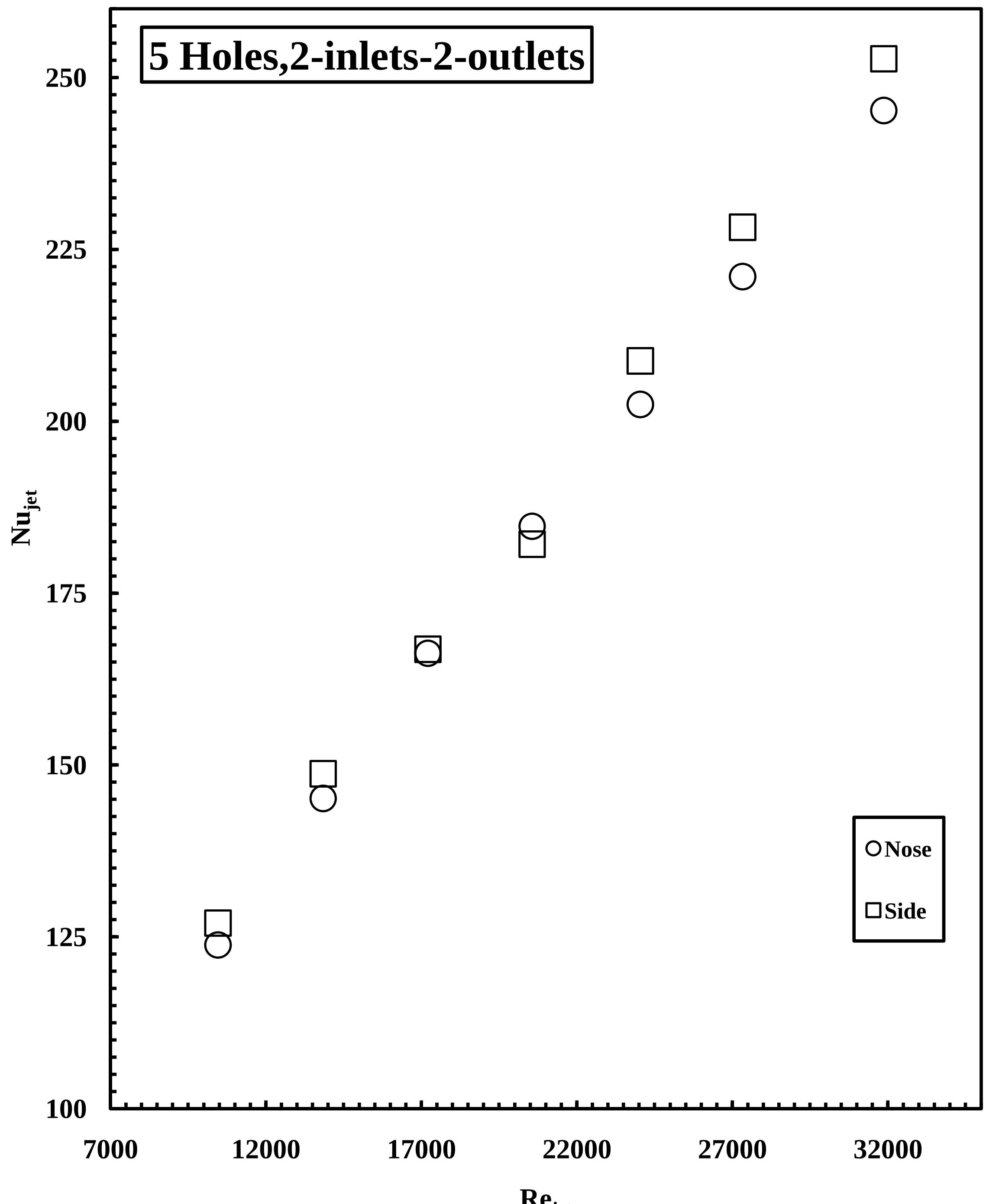

Figure 3.37 Comparison of the side and nose Nusselt numbers for the case of 5 cross-over holes and 2-inlets-2-outlets flow arrangement.

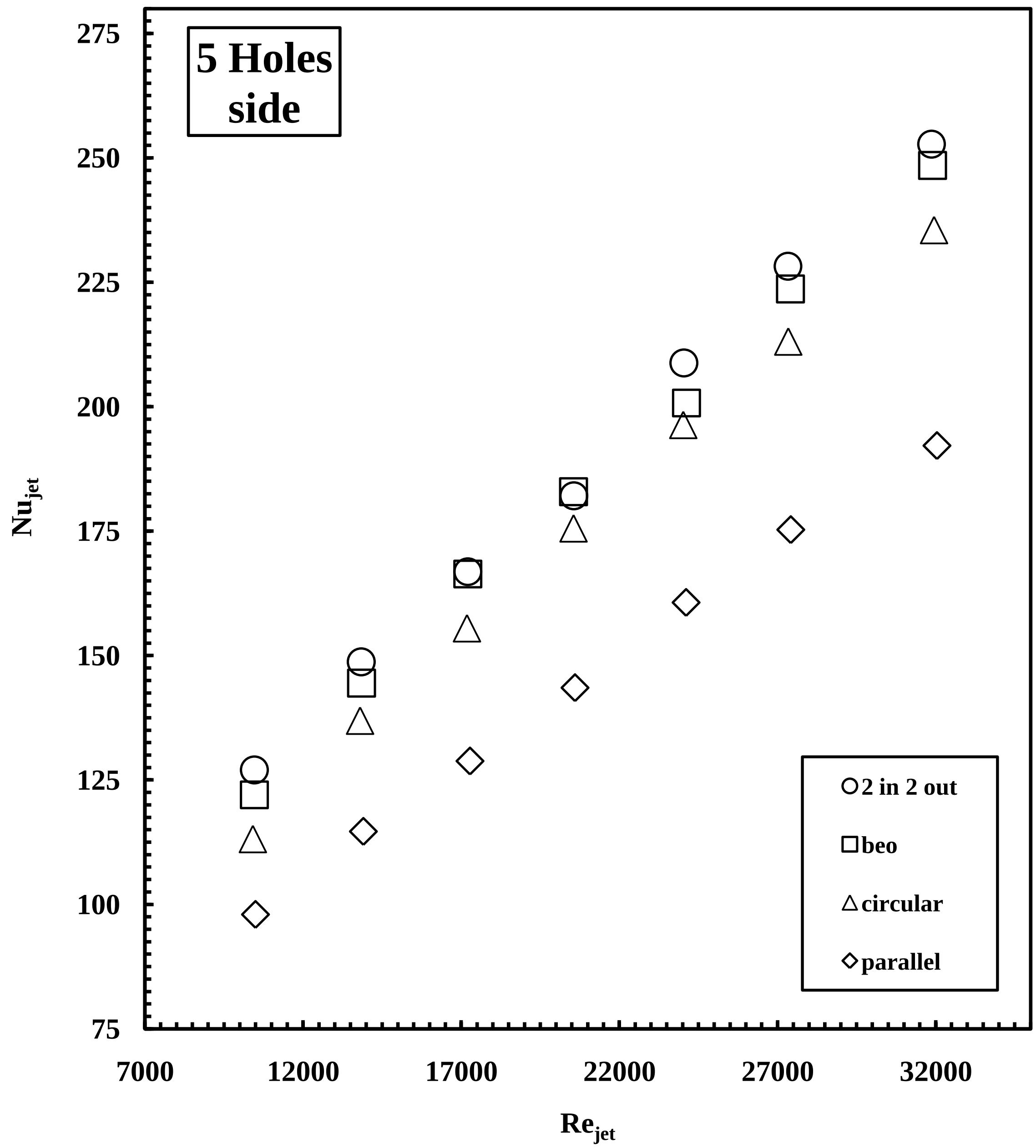

Figure 3.38 Comparison of the side Nusselt number for the case of 5 cross-over holes and all flow arrangements.

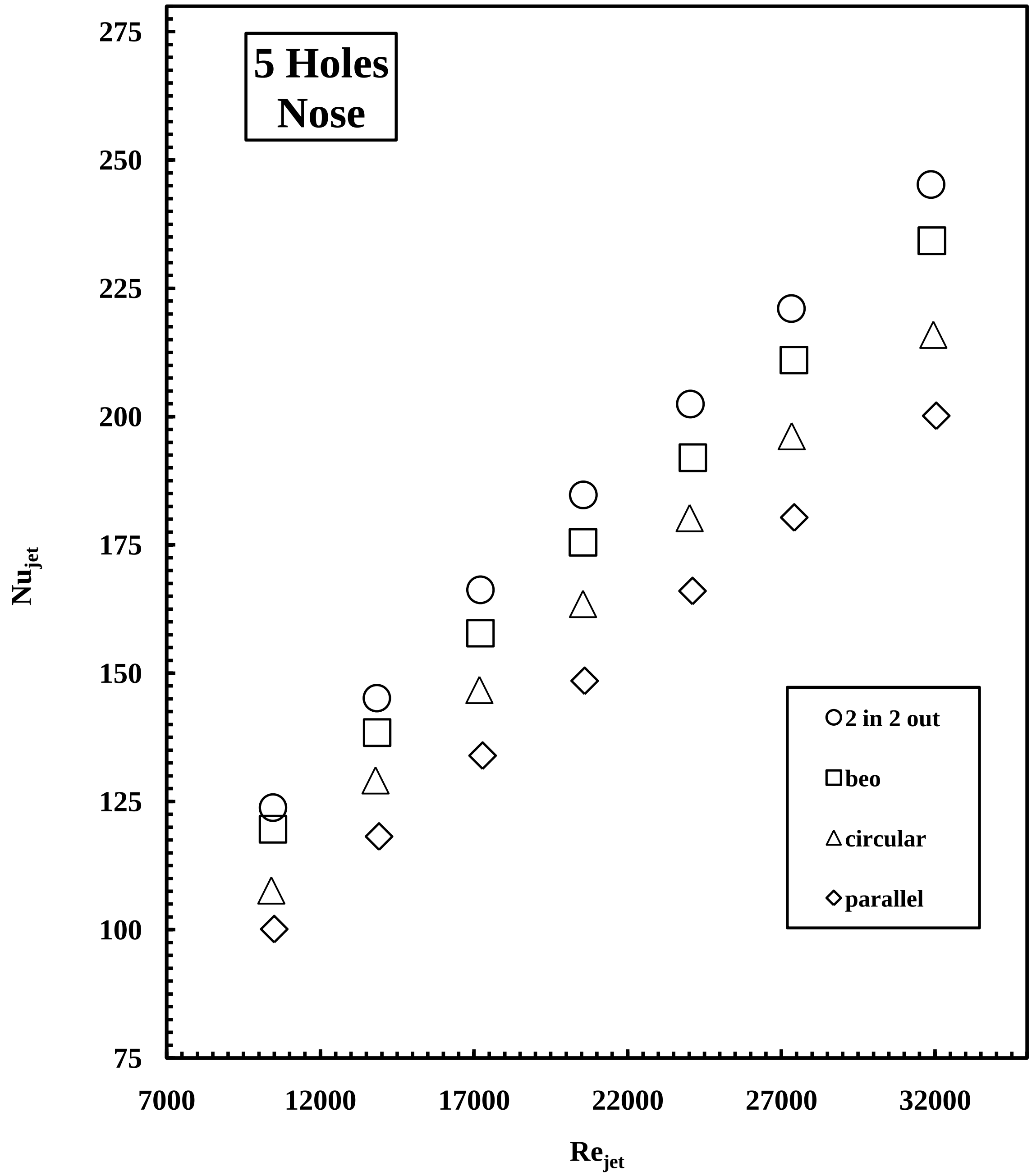

Figure 3.39 Comparison of the side Nusselt number for the case of 5 cross-over holes and all flow arrangements.

3.3 Comparisons Across The Geometries

In this section, a comparison will be made between five different geometries to identify the best geometry which provides the highest Nusselt number on the side and the nose surfaces individually. This comparison will be conducted for all four different flow arrangements.

3.3.1 Parallel Flow Arrangement

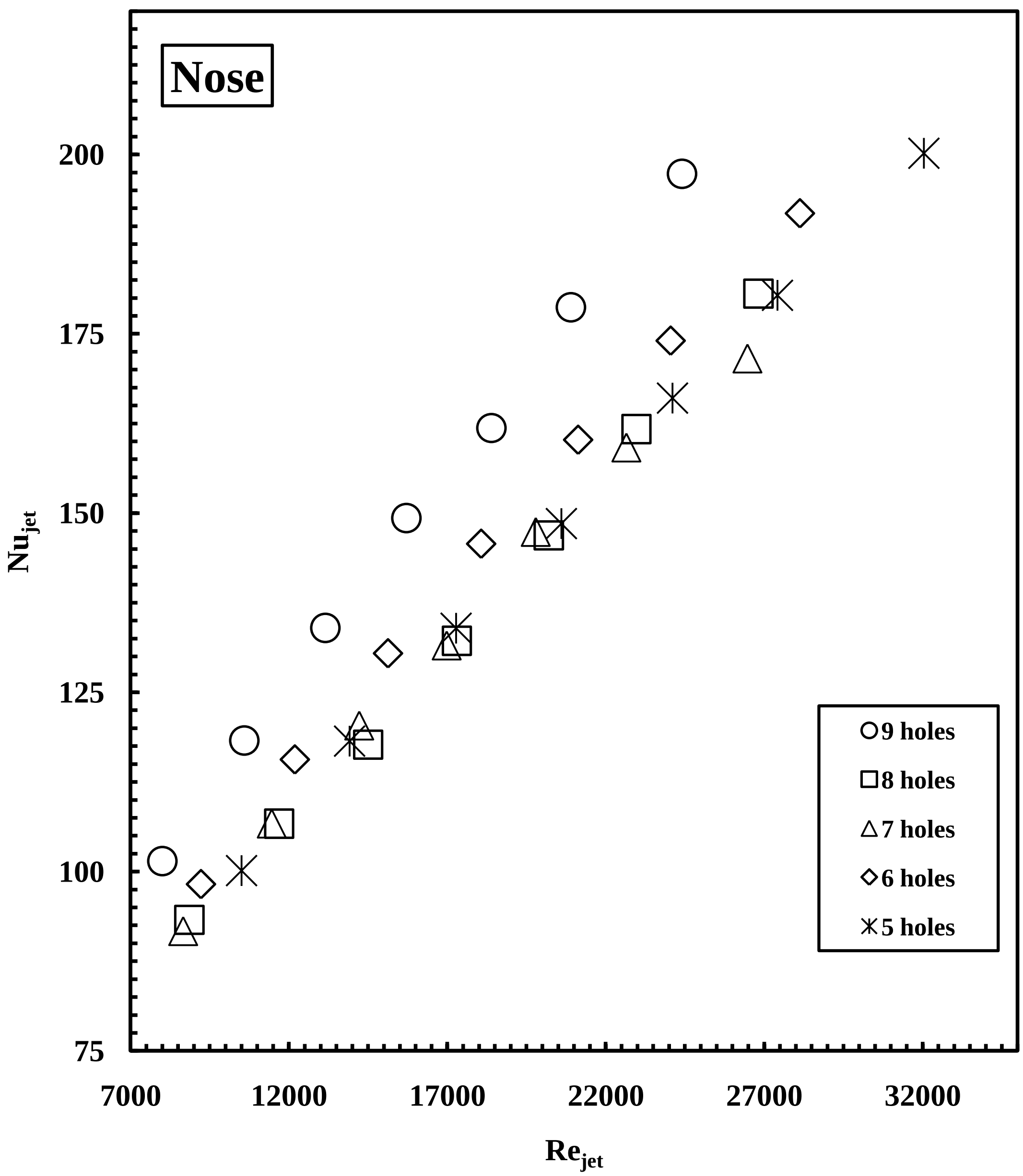

Figure 3.40 A comparison between the nose Nusselt number of all geometries for parallel flow arrangement.

The case of 5 cross-over holes provided the highest Nusselt numbers on the nose area followed by six- and nine-hole geometries. Proximity between the behaviors of the eight- and seven-hole geometries can be observed as shown in figure 3.40. Nine-hole geometry provided the highest Nusselt number on the side wall followed by six-, seven- and eight-hole with a slight difference. 5-hole geometry provided the lowest Nusselt number as shown in figure 3.41.

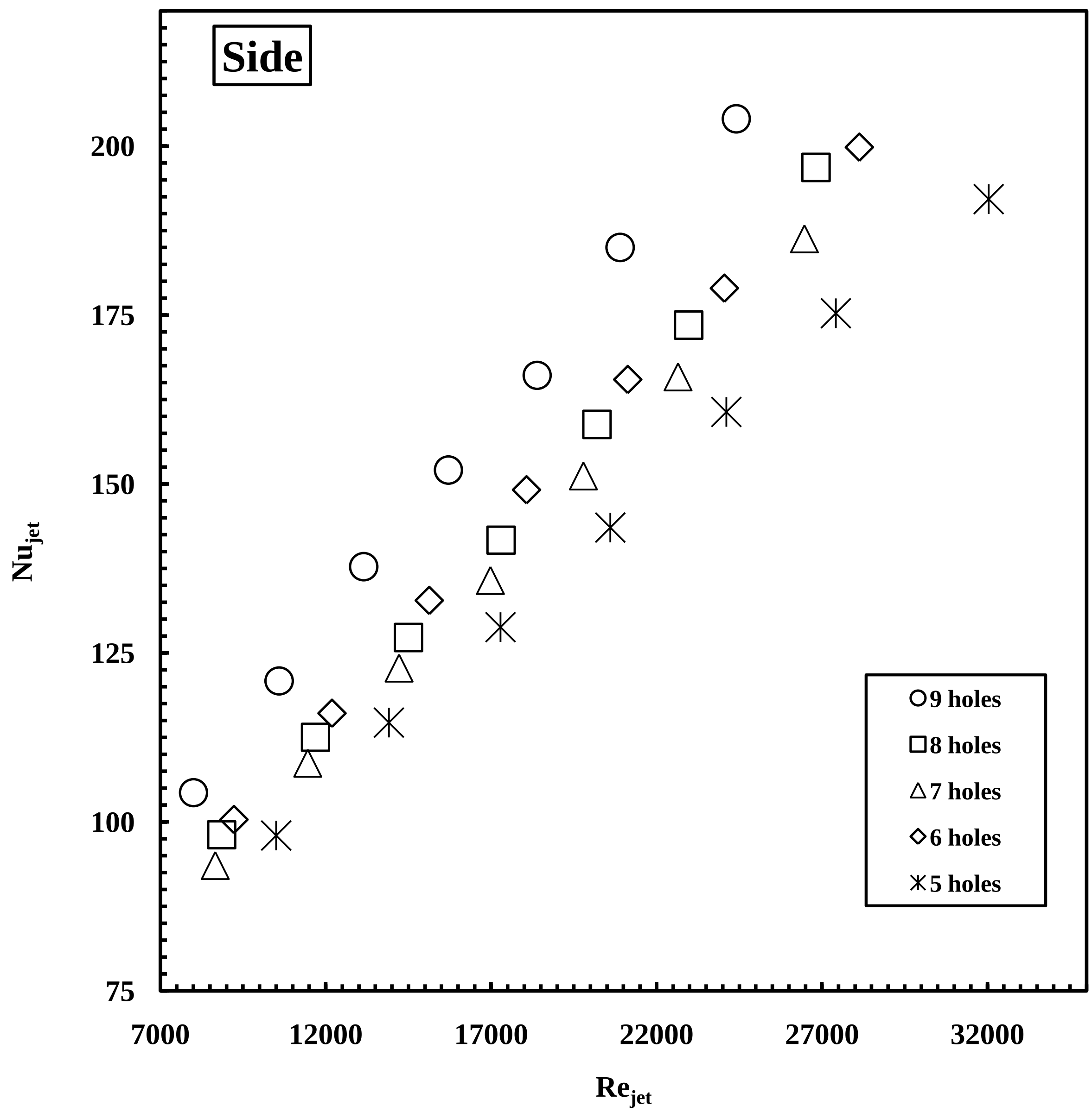

Figure 3.41 A comparison between the side Nusselt number of all geometries for parallel flow arrangement.

3.3.2 Circular Flow Arrangement

All geometries have the same rate of change of Nusselt number with respect to Reynolds number in addition to direct relation of Nusselt number with Reynolds number. 5-holes geometry provided the highest Nusselt number followed by the six-, seven-, eight- and nine-hole geometries as shown in figure 3.42.

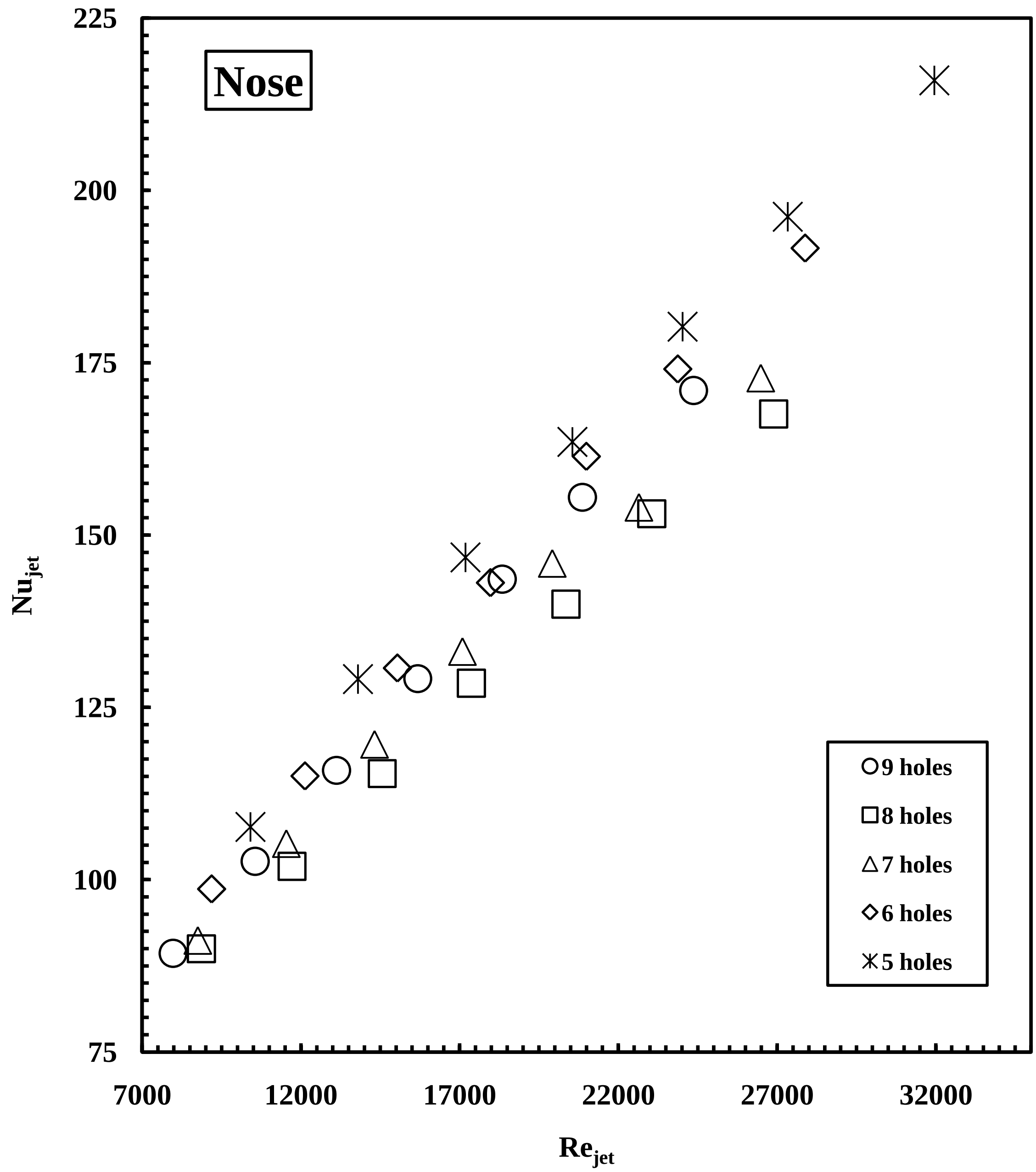

Figure 3.42 A comparison between the nose Nusselt number of all geometries for circular flow arrangement.

Same behavior was observed on the side wall as well with the five-hole geometry providing the highest Nusselt numbers as shown in figure 3.43.

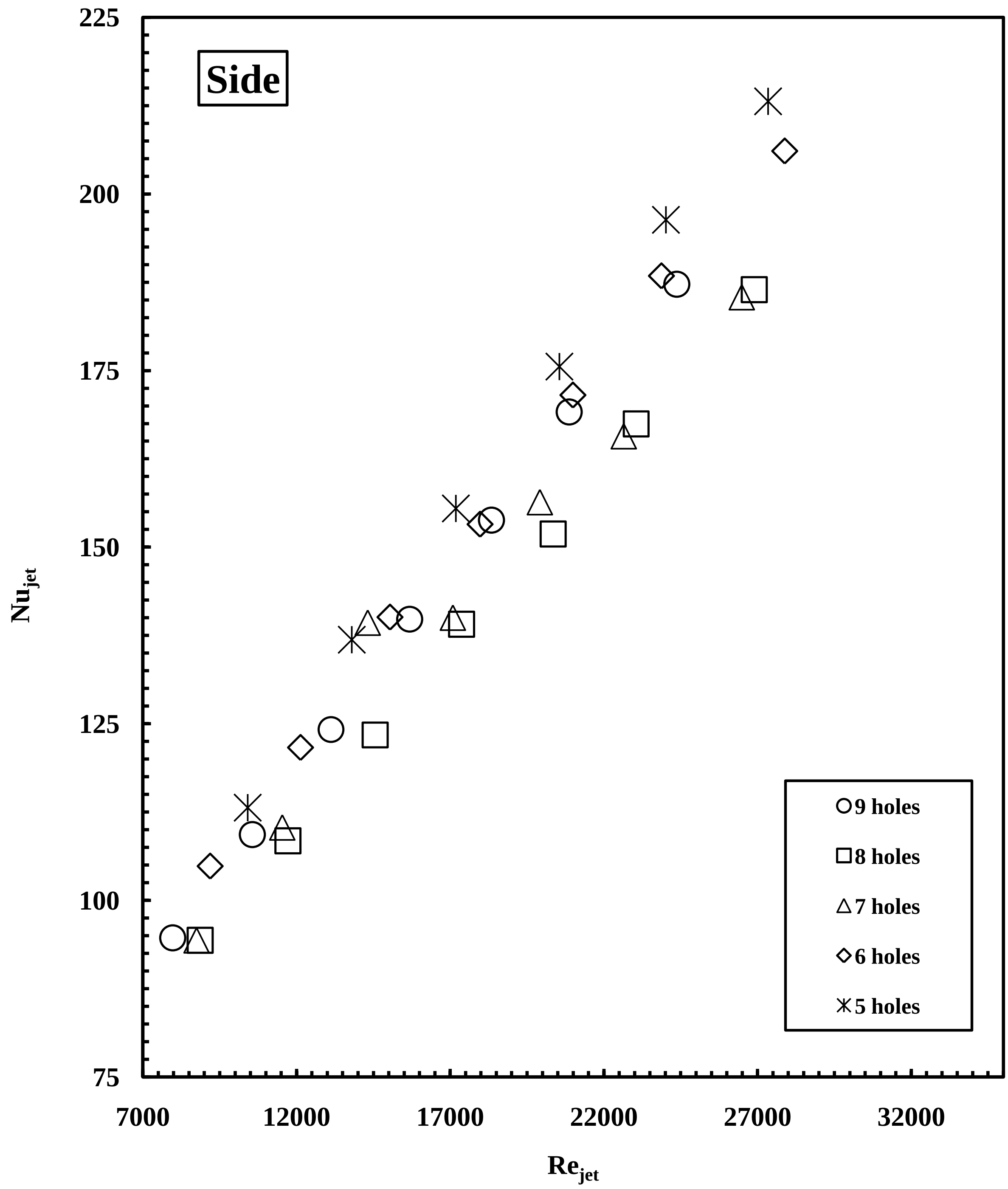

Figure 3.43 A comparison between the side Nusselt number of all geometries for circular flow arrangement.

3.3. 3 Both-Ends-Open Flow Arrangement

As the five-hole geometry provided the highest Reynolds number in addition to the direct relation between the Reynolds number and the Nusselt number, five-hole geometry provided the highest Nusselt number while the nine-hole geometry provided the lowest as shown in figure 3.44.

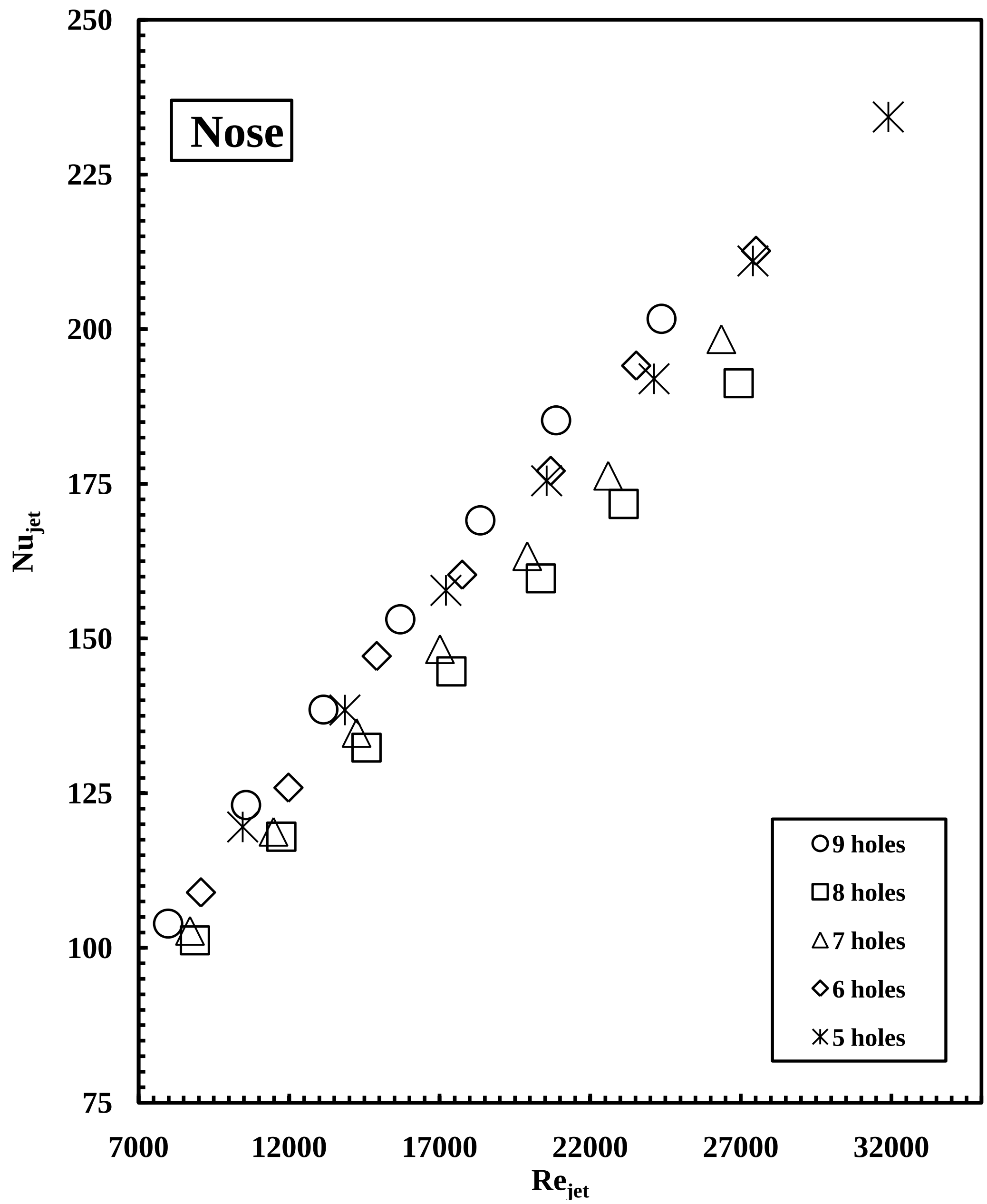

Figure 3.44 A comparison between the nose Nusselt number of all flow geometries for both-ends-open flow arrangement.

Similar behavior can be observed on the side plate as shown in figure 3.44

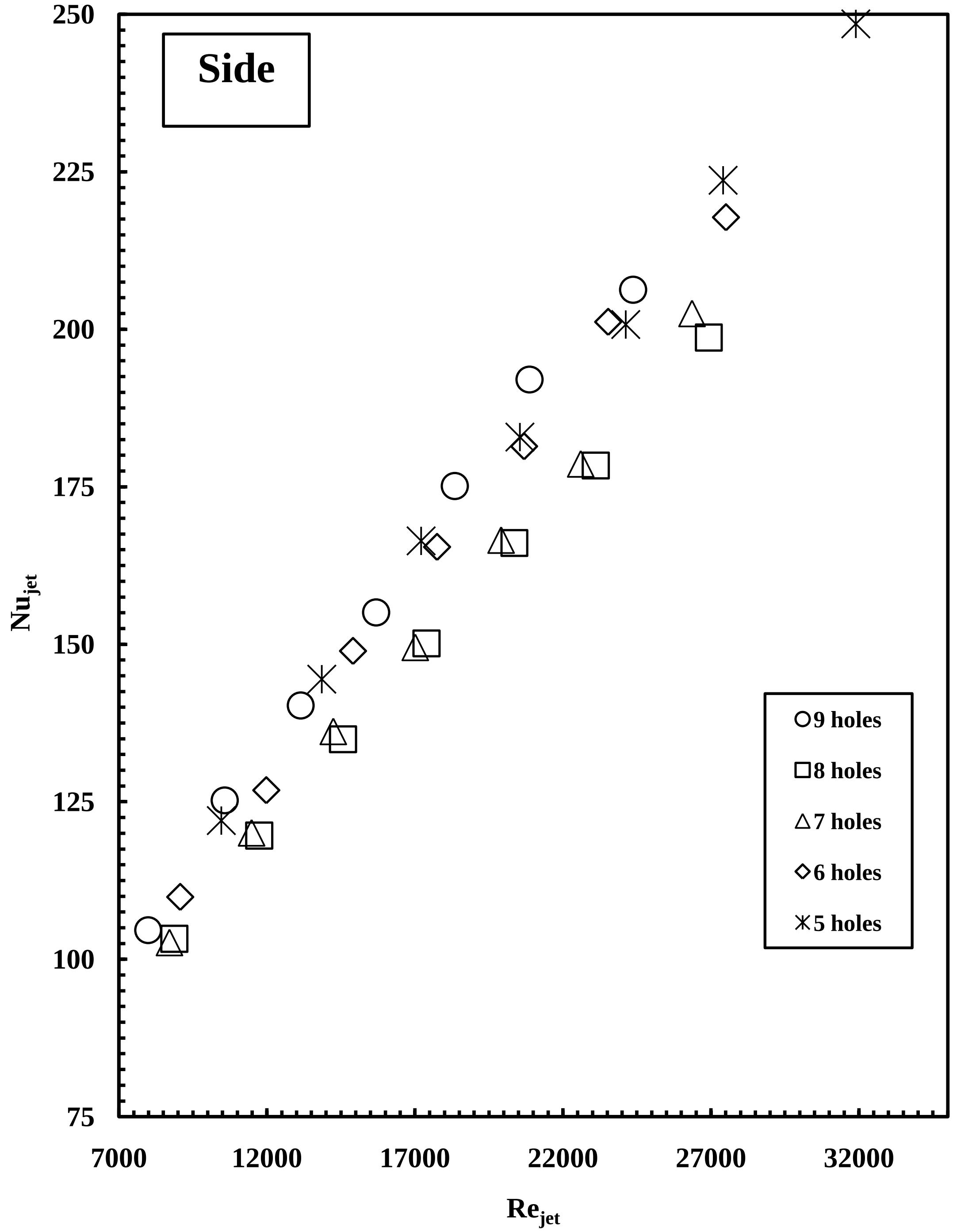

Figure 3.45 A comparison between the side Nusselt number of all flow geometries for both-ends-open flow arrangement.

3.3.4 2-Inlets-2-Outlets Flow Arrangement

Five-hole geometry inherently provided the highest Nusselt number on the side wall, due to a more effective interaction between the cooling air and the side wall as shown in figure 3.45.

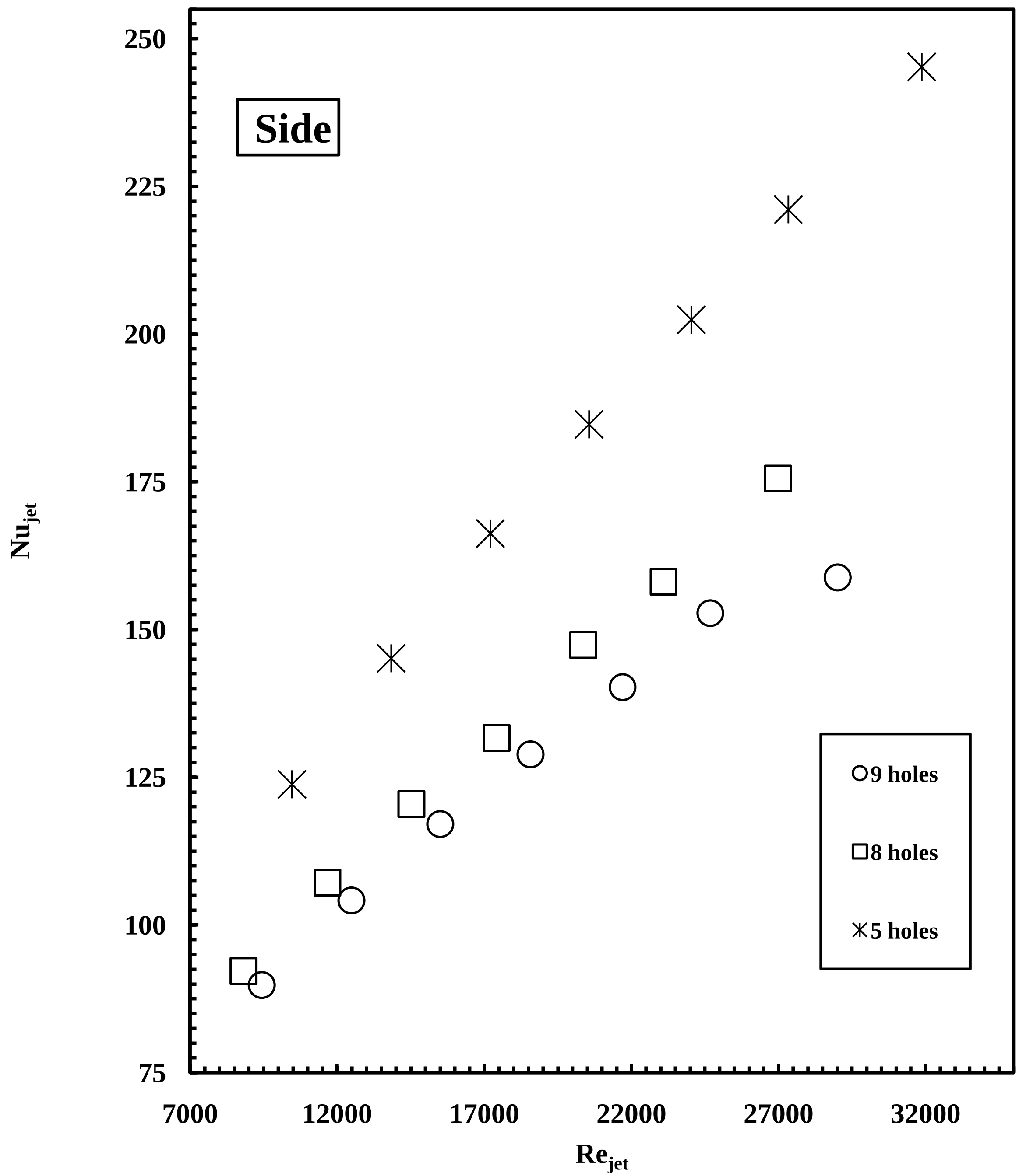

Figure 3.46 A comparison between the side Nusselt number of all geometries for 2-inlets-2-outlets flow arrangement.

Similar behavior can be observed on the nose surface as shown in figure 3.46

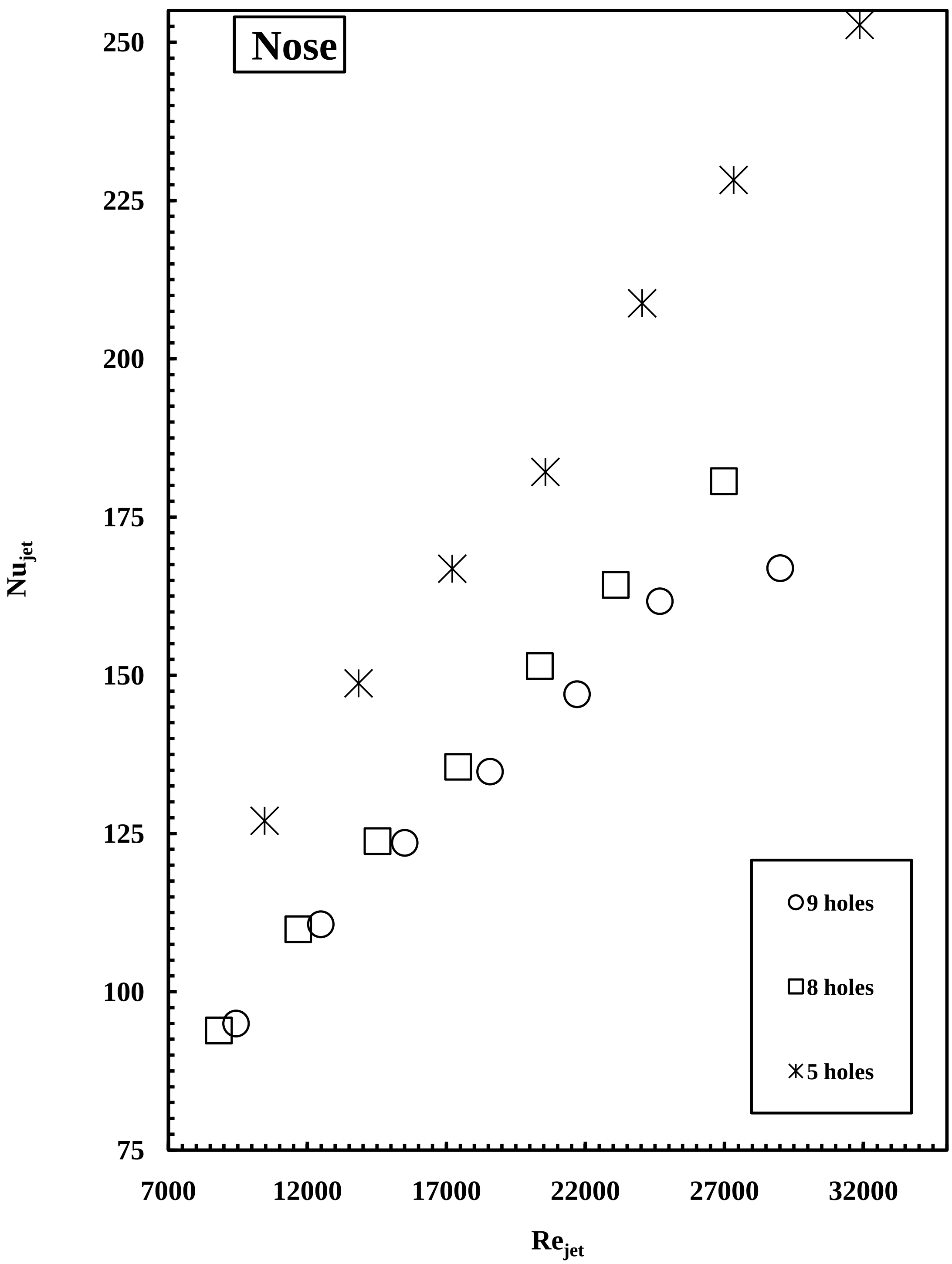

Figure 3.47 A comparison between the nose Nusselt number of all geometries for 2-inlets-2-outlets flow arrangement.

3.4 Conclusion

The major conclusions of this study were:

a) In general, for those cases that there were upstream jets, the heat transfer coefficients on the sidewalls were higher than those on the nose area. This behavior is attributed to the cross-flow created by the upstream jets and the shape of the leading-edge. The cross-over jets diffused into the relatively narrow shape leading-edge channel and interacted with the sidewall, thus producing a high heat transfer coefficient on the those walls.

b) The cross-flow produced by the upstream jets caused a slight reduction in impingement heat transfer coefficients by deflecting the jets.

c) Depending on the location of the cross-over holes with respect to the incoming jet into the supply channel and the number of cross-over holes, there could be a significant variation in mass flow rate through the cross-over holes.

d) Case of 5 cross-over holes and 2-inlet-2-outlet flow arrangement provided the highest heat transfer coefficient.

e) The heat transfer coefficient on the nose area and sidewalls for the case of 5 cross-over holes decreased in the following order: 2-inlet-2outlet, Both-Ends-Open, Circular and Parallel.

f) Case of 9 cross-over holes and 2-inlet-2-outlet flow arrangement, although representing a symmetric flow, did not result in the highest value for the heat transfer coefficient.

g) Case of 9 cross-over holes and 2-inlet-2-outlet flow arrangement provided the lowest heat transfer coefficient.

APPENDIX A
DATA REDUCTION MAIN FORTRAN CODE

```
 C     TWO FALGS FOR PRESSURES ARE READ (flagsup and flag)

C    D A T A   R E D U C T I O N   P R O G R A M   F O R

C                I M P I N G E M E N T   T E S T S

C             W I T H  N O  S H O W E R H E A D

C                JANUARY         2 0 0 9  (M. TASLIM)

C     HEATERS ARRANGEMENT:

C     FRONT SIDE: V3 A3  C201 C202 C203 C204 C205 C206   (C stands for T/C
channel)
C     NOSE      : V4 A4  C207 C208 C209 C210 C211 C212
C     BACK  SIDE: V5 A5  C213 C214 C215 C216 C217 C218

      IMPLICIT REAL*8(A-H,O-Z)
      CHARACTER*80 TITLE
      REAL*8 Mv,NuSidef,NuSideb,NuNose,Jetdis,LEArea,LEperim,lod,
     &jetplth,Mach
      COMMON Rnose,flat,Dh,SArea,AreaNose,CopperL,CopperT,P,Rgas,
     &Mv,Tjet,Tamb,Pamb,TSidef,TSideb,TNose

      F(A,P,T)=0.5215*A*P/SQRT(T)   ! Correlation for the critical venturi
                                    ! provided by the manufacturer (Fox
Valves)
      PI=4.*ATAN(1.E00)

      con=3.2808             ! 1 m= 3.2808 ft.
      con2=2.2046            ! 1 Kg=2.2046 lbs
      con3=6894.76           ! 1 psi=6894.76 Pa
      con4=(con**3)/con2     ! 1 lmb/cu.ft. = 16.019 Kg/cu.m.
      con5=1.73028721        ! 1 BTU/hr.ft.R = 1.73028721 W/m.K
      con6=41.3388E-5        ! 1 lbm/hr.ft =41.3388E-5  Kg/m.s
      con7=4202.0979         ! 1 BTU/lbm.R =4202.0979  J/Kg.K

        !  F L O W   A R R A N G E M E N T S :

C     1 : FLOW ENTERING THE SUPPLY CHANNEL FROM ONE SIDE AND
C         LEAVING THE LE CHANNEL FROM THE OTHER SIDE (PARALLEL)

C     2 : FLOW ENTERING THE SUPPLY CHANNEL FROM ONE SIDE AND
C         LEAVING THE LE CHANNEL FROM THE THE SAME SIDE (CIRCULAR)


C         S M O O T H  S U R F A C E   G E O M E T R Y
```

```
C           C O N V E R S I O N   F A C T O R S

      Hgtopsi= 0.49083935            ! converts inches of Hg  to psi
      H2Otopsi=Hgtopsi/13.6          ! converts inches of H2O to psi
      Oiltopsi=0.826*Hgtopsi/13.6    ! converts inches of Orange Oil
(sg=0.826) to psi
      RedOiltopsi=2.95*Hgtopsi/13.6  ! converts inches of Red Oil
(sg=2.95) to psi
      FAC1=3.413                     ! converts Watts to BTU/hr
      PFAC=248.8*1.4504E-04*144      ! converts inches of H2O to psf

      Rgas=53.34                     ! gas constant for air
      gc=32.17                       ! lbm.ft/lbf.s2

C**********************************************
C     I N P U T / O U T P U T   F I L E S

      OPEN(UNIT=1, FILE='input.dat',STATUS='old')
      OPEN(UNIT=2, FILE='pressures.out',STATUS='old')
      OPEN(UNIT=5, FILE='uncertain.out',STATUS='old')
      OPEN(UNIT=7, FILE='output.dat',STATUS='old')
      OPEN(UNIT=8, FILE='summary.out',STATUS='old')
      OPEN(UNIT=10,FILE='nu-plt-nose.dat',STATUS='old')
      OPEN(UNIT=11,FILE='nu-plt-front.dat',STATUS='old')
      OPEN(UNIT=12,FILE='nu-plt-back.dat',STATUS='old')
      OPEN(UNIT=3,FILE='for-cfd.dat',STATUS='old')
      OPEN(UNIT=4,FILE='axial-flow.dat',STATUS='old')

C**********************************************
C     T E S T   S E C T I O N   G E O M E T R Y

      Rnose=0.432              ! inches
      Rnose=Rnose/12.          ! feet
      Angle=137.12             ! degrees
      flat=0.432               ! inches
      flat=flat/12.            ! inches
      CopperL=2.4              ! inches
      CopperL=CopperL/12.      ! feet
      CopperT=0.167            ! inches
      CopperT=CopperT/12.      ! feet
C**********************************************
C     JET HOLES

      XL=0.81                   ! inches, center to center
      XL=XL/12.                 ! feet, center to center
      d=0.6                     ! inches, diameter
      d=d/12.                   ! feet, diameter
      Areaj=(PI*(d**2)/4.)+XL*d
      Perimj=PI*d + 2.*XL
      Dhj=4.*Areaj/Perimj
      jetplth=1.0               ! Jet Plate Thickness
      jetplth=jetplth/12.       ! Jet Plate Thickness
      Space=2.431               ! Center-to-Center Distance for Jet Holes
      Space=Space/12.           ! Center-to-Center Distance for Jet Holes
```

```
      sod=Space/Dhj             ! S/Dh for Jet Holes
      lod=jetplth/Dhj           ! L/Dh for Jet Holes
      Jetdis=2.463              ! Jet Hole Distance to the Leading-Edge
      Jetdis=Jetdis/12.         ! Jet Hole Distance to the Leading-Edge
      zod=Jetdis/Dhj            ! Z/Dh
C***********************************************
C     NO GILL HOLES
C***********************************************
C     SIDE COPPER PIECE HEAT TRANSFER AREA
C***********************************************
      SLength=2.4              ! inches
      SLength=SLength/12.      ! feet
      SHeight=1.2              ! inches
      SHeight=SHeight/12.      ! inches
      SArea=SLength*SHeight    ! area
C*********************************************************
C     SHOWERHEAD HOLES   *** FIILED WITH SILICONE ***
C*********************************************************
      nshower=61               ! Number of Sowehead Holes
      Dshower=0.234            ! inches (Drill size was 0.234" according to
United Ind.)
      Dshower=Dshower/12.      ! feet
      Ashower=pi*(Dshower**2)/4. ! Square feet
      xshower=0.167            ! inches
      xshower=xshower/12.      ! feet
      Aheatsh=pi*Dshower*xshower ! Square feet
C***********************************************
C     NOSE COPPER PIECE HEAT TRANSFER AREA
C***********************************************
      AreaNoseC=CopperL*((2.*pi*Rnose*Angle/360.)+2.*flat)
      AreaNoseC=AreaNoseC-7*Ashower
      AreaNose=4.2480672616616       ! Measured by UG
      AreaNose=AreaNose/144.         ! Square feet
C***********************************************
C     LE Channel Geometry (See Sketches)
C***********************************************
      LEArea=3.8140554751282    ! Measured
      LEArea=LEArea/144.        ! square feet
      LEperim=8.273341559273    ! Measured
      LEperim=LEperim/12.       ! feet
      Dh=4.*LEArea/LEperim
C***********************************************

      Write(7,101)12.*Rnose,Angle,12.*flat,12.*CopperL,
     &12.*CopperT,144.*AreaNoseC,144.*AreaNose,144.*SArea,144.*Areaj,
     &12.*Perimj,12.*Dhj,12.*jetplth,lod,
     &12.*Space,sod,12.*Jetdis,zod,144.*LEArea,12.*LEperim,12.*Dh,
     &12.*Dshower,144.*Ashower


  101 format(/,
     &2x,'Nose Radius=',f8.3,' inches',/,
     &2x,'Nose Angle=',f8.3,' degrees',/,
     &2x,'Flat part of nose copper piece=',f8.3,' inches',/,
     &2x,'Copper piece length=',f8.3,' inches',/,
```

```
     &2x,'Copper piece thickness=',f8.3,' inches',/,
     &2x,'Calculated Nose Copper piece heat transfer area=',
     &f8.4,' Sq.in',/,
     &2x,'Measured Nose Copper piece heat transfer area=',
     &f8.4,' Sq.in',/,
     &2x,'Side Copper piece heat transfer area=',f8.3,' Sq.in',/,
     &2x,'Each Jet Hole Area=',f8.5,' Sq.in',/,
     &2x,'Jet Hole Perimeter=',f8.5,' inches',/,
     &2x,'Jet Hole Hydraulic Diameter=',f8.5,' inches',/,
     &2x,'Jet Plate Thickness=',f8.5,' inches',/,
     &2x,'Jet Hole L/Dh=',f8.5,/,
     &2x,'Jet Hole Spacing=',f8.5,' inches',/,
     &2x,'Jet Hole S/Dh=',f8.5,/,
     &2x,'Jet Hole Distance to LE, Z=',f8.5,' inches',/,
     &2x,'Jet Hole Z/Dh=',f8.5,/,
     &2x,'L.E. Channel Cross-Sectional Area=',f9.4,' sq.in.',/,
     &2x,'L.E. Channel Perimeter=',f8.4,' inches',/,
     &2x,'L.E. Channel Hydraulic Diameter=',f9.4,' inches',/,
     &2x,'L.E. Showerhead Hole Diameter (filled with silicone='
     &,f9.4,' inches',/,
     &2x,'Each L.E. Showerhead Hole Area=',f9.4,' sq. in.',/)


C      V E N T U R I   T H R O A T   G E O M E T R Y  (SNELL LAB,50 SN)

      Dthroat=0.32
      Athroat=PI*(Dthroat**2)/4.      ! square inches

      WRITE(7,*)'  '
      WRITE(7,2033)Dthroat
      WRITE(7,*)'  '
 2033 FORMAT(10x,'Venturi Throat Diameter=',f8.3)

      !     R E A D   I N   D A T A

      read(1,*)ntests,nj,FLOW,percentage

      WRITE(7,402)nj,ntests,percentage
      WRITE(8,402)nj,ntests,percentage
      WRITE(2,402)nj,ntests,percentage
      WRITE(3,402)nj,ntests,percentage
      WRITE(4,402)nj,ntests,percentage

  402 FORMAT(10x,'*******************',/,
     &10x,'NUMBER OF CROSS-OVER HOLES : ',I5,/,
     &10x,'NUMBER OF TESTS : ',I5,/,
     &10x,'*** PERCENTAGE OF FLOW THROUGH HOLE 5 *** : ',f6.3,/,
     &10x,'*******************',/)


      if(flow.eq.1)then
      write(7,121)
  121 format(' Flow entering the supply channel from one side and',/,
     &' leaving the LE channel from the other side',//)
      endif
```

```
      if(flow.eq.2)then
      write(7,122)
  122 format('Flow entering the supply channel from one side and  ',/,
     &' leaving the LE channel from the same side ',//)
      endif

      if(flow.eq.3)then
      write(7,123)
  123 format('Flow entering the supply channel from one side and  ',/,
     &' leaving the LE channel from BOTH sides ',//)
      endif

      if(flow.eq.4)then
      write(7,124)
  124 format('Flow entering the supply channel from BOTH sides and ',/,
     &' leaving the LE channel from BOTH sides ',//)
      endif

      DO 333 I=1,7
      READ(1,10)TITLE
      WRITE(7,10)TITLE
      WRITE(2,10)TITLE
      WRITE(3,10)TITLE
      WRITE(4,10)TITLE
  333 WRITE(8,10)TITLE

   10 FORMAT(A80,//)
   11 FORMAT(A50)

      WRITE(8,450)
  450 FORMAT(' Rej,5th Hole Nu_Side_Front   Nu_Side_back   Nu_Nose',
     &'  UncerSf UncerSb UncerN',/)

C  NOTE:
C
C   flag=1    inches of H2O
C   flag=2    inches of orange Oil (sg=0.826)
C   flag=3    inches of red Oil    (sg=2.95)
C   flag=4    psi
C

      DO I=1,ntests
      READ(1,11)TITLE
      READ(1,*)Pven,Psup,Pjet,PLEin,PLEout,flagsup,flag,
     &DPjet,V1,A1,V2,A2,V3,A3,V4,A4,V5,A5,V6,A6,Pamb
      READ(1,11)TITLE
      READ(1,*)C101,C102,C103,C104,C105,C106,C107,C108,C109,C110,C111,
     &C112,Tven,Tjet,Tamb
      READ(1,11)TITLE
      READ(1,*)C201,C202,C203,C204,C205,C206,C207,C208,C209,C210,C211,
     &C212,C213,C214,C215,C216,C217,C218
      READ(1,11)TITLE
      READ(1,*)C301,C302,C303,C304,C305,C306,C307,C308,C309,C310,C311,
     &C312
```

```
C23456789012345678901234567890123456789012345678901234567890123456789012

      WRITE(7,*)' '
      WRITE(7,*)' '
      WRITE(7,100)i
      WRITE(2,100)i
      WRITE(7,*)' '
      WRITE(7,*)'  Collected Data:'
      WRITE(7,*)'  Pven,Psup,Pjet,PLEin,PLEout,DPjet,Pamb'
      WRITE(7,*)'  V1,A1,V2,A2,V3,A3,V4,A4,V5,A5,V6,A6'
      WRITE(7,*)'  C101,C102,C103,C104,C105,C106,C107,C108,C109,C110,',
     &'C111,C112'
      WRITE(7,*)'  C201,C202,C203,C204,C205,C206,C207,C208,C209,C210,',
     &'C211,C212'
      WRITE(7,*)'  C213,C214,C215,C216,C217,C218 '
      WRITE(7,*)'  C301,C302,C303,C304,C305,C306,C307,C308,C309,C310,',
     &'C311'
      WRITE(7,*)'  Tven,Tjet,Tamb'
      WRITE(7,*)' '

      WRITE(7,200)Pven,Psup,Pjet,PLEin,PLEout,DPjet,Pamb
  200 FORMAT(5X,F5.1,7(' ',F6.2))
      WRITE(7,201)V1,A1,V2,A2,V3,A3,V4,A4,V5,A5,V6,A6
  201 FORMAT(5X,6(' ',F5.2,' ',F6.4))
      WRITE(7,202)C101,C102,C103,C104,C105,C106,C107,C108,C109,C110,C111
     &,C112
      WRITE(7,202)C201,C202,C203,C204,C205,C206,C207,C208,C209,C210,C211
     &,C112
      WRITE(7,202)C213,C214,C215,C216,C217,C218
      WRITE(7,202)C301,C302,C303,C304,C305,C306,C307,C308,C309,C310,C311
  202 FORMAT(5X,12(' ',F5.1))

C23456789012345678901234567890123456789012345678901234567890123456789012

      WRITE(7,203)Tven,Tjet,Tamb
  203 FORMAT(5X,3(' ',F5.1))

      Pamb=Pamb*Hgtopsi              ! psi

      TSidef=(C201+C202+C203+C204+C205+C206)/6.
      TNose =(C207+C208+C209+C210+C211+C212)/6.
      TSideb=(C213+C214+C215+C216+C217+C218)/6.
      Tsave=(TSidef+TSideb+TNose)/3
      write(7,3021)C201,C202,C203,C204,C205,C206
      write(7,3022)C207,C208,C209,C210,C211,C212
      write(7,3023)C213,C214,C215,C216,C217,C218

C   AIR MASS FLOW RATE FROM THE CRITICAL VENTURI

      Mv=F(Athroat,Pven+Pamb,Tven+460)

C   HEAT FLUX FROM THE COPPER PIECES, BTU/(sqft.hr)

      FluxSf=V3*A3*FAC1/(SArea)
```

```
      FluxN =V4*A4*FAC1/(AreaNose)
      FluxSb=V5*A5*FAC1/(SArea)

      ! TOTAL HEAT GENERATED BY ALL HEATERS , BTU/hr

      Q=(A1*V1+A2*V2+A3*V3+A4*V4+A5*V5+A6*V6)*FAC1

C     HEAT TRANSFER COEFFICIENT ON THE FRONT SIDE COPPER PIECE

      Tcopper=TSidef
      CALL COEFFICIENT(1,Q,FluxSf,Tcopper,Tm,hSidef,FlosSf,FradSf)

C     HEAT TRANSFER COEFFICIENT ON THE BACK SIDE COPPER PIECE

      Tcopper=TSideb
      CALL COEFFICIENT(2,Q,FluxSb,Tcopper,Tm,hSideb,FlosSb,FradSb)

C     HEAT TRANSFER COEFFICIENT ON THE NOSE AREA

      Tcopper=TNose
      CALL COEFFICIENT(3,Q,FluxN,Tcopper,Tm,hNose,FlossN,FradN)

      TjR=Tjet+460.

      CALL AIRPROP(TjR,gamj,CONj,VISj,PRj,CPj)
      VISj=VISj/3600.

      ! JET  REYNOLDS NUMBER, BASED ON THE FIFTH HOLE MASS FLOW RATE

      Rej=4.*Mv*percentage/(100*Perimj*VISj)

      !     NUSSELT NUMBER

      NuSidef=hSidef*Dhj/CONj
      NuSideb=hSideb*Dhj/CONj
      NuNose=hNose*Dhj/CONj

      !  NUSSELT NUMBER UNCERTAINTY ANALYSIS

      CALL UNCERTAIN(A3,V3,SArea,TSidef,Tjet,FlosSf,FradSf,UncerSf)
      CALL UNCERTAIN(A4,V4,AreaNose,TNose,Tjet,FlossN,FradN,UncerN)
      CALL UNCERTAIN(A5,V5,SArea,TSideb,Tjet,FlosSb,FradSb,UncerSb)

      WRITE(7,300)Tjet,TSidef,TSideb,TNose,Tm,Mv,Rej
      WRITE(7,4011)144.*SArea,NuSidef,UncerSf
      WRITE(7,4012)144.*SArea,NuSideb,UncerSb
      WRITE(7,4013)144.*AreaNose,NuNose,UncerN
      WRITE(8,403)Rej,NuSidef,NuSideb,NuNose,UncerSf,UncerSb,UncerN
      WRITE(10,407)Rej,NuNose
      WRITE(11,407)Rej,NuSidef
      WRITE(12,407)Rej,NuSideb

C    **********************************************************
C     STATIC PRESSURES AT DEFFERENT POINTS
```

```
      IF(flagsup.eq.1) then
      Psup=Psup*H2Otopsi+Pamb
      endif
      IF(flagsup.eq.2) then
      Psup=Psup*Oiltopsi+Pamb
      endif
      IF(flagsup.eq.3) then
      Psup=Psup*RedOiltopsi+Pamb
      endif
      IF(flagsup.eq.4) then
      Psup=Psup+Pamb
      endif

      IF(flag.eq.1) then
      Pjet=Pjet*H2Otopsi+Pamb
      endif
      IF(flag.eq.2) then
      Pjet=Pjet*Oiltopsi+Pamb
      endif
      IF(flag.eq.3) then
      Pjet=Pjet*RedOiltopsi+Pamb
      endif
      IF(flag.eq.4) then
      Pjet=Pjet+Pamb
      endif

C  L.E. CHANNLE PRESSURE ON THE INLET SIDE

      IF(flag.eq.1) then
      PLEin=PLEin*H2Otopsi+Pamb
      endif
      IF(flag.eq.2) then
      PLEin=PLEin*Oiltopsi+Pamb
      endif
      IF(flag.eq.3) then
      PLEin=PLEin*RedOiltopsi+Pamb
      endif
      IF(flag.eq.4) then
      PLEin=PLEin+Pamb
      endif

C  L.E. CHANNLE PRESSURE OPPOSITE THE INLET SIDE

      IF(flag.eq.1) then
      PLEout=PLEout*H2Otopsi+Pamb
      endif
      IF(flag.eq.2) then
      PLEout=PLEout*Oiltopsi+Pamb
      endif
      IF(flag.eq.3) then
      PLEout=PLEout*RedOiltopsi+Pamb
      endif
      IF(flag.eq.4) then
      PLEout=PLEout+Pamb
      endif
```

```fortran
      Psratio=Psup/Pjet

      write(7,303)Pamb,Psup,Pjet,PLEin,PLEout,Psratio
      write(2,303)Pamb,Psup,Pjet,PLEin,PLEout,Psratio

  303 format(/,
     &5x,'Ambient Pressure=',f9.4,'psia',/,
     &5x,'Supply Channel Pressure=',f9.4,'psia',/,
     &5x,'Pressure at jet exit plane=',f9.4,'psia',/,
     &5x,'LE Channel Pressure at  inlet side=',f9.4,' psia',/,
     &5x,'LE Channel Pressure at outlet side=',f9.4,' psia',/,
     &5x,'Psup/PLE=',f13.7,/)

      rhoj=(Psup*144)/(Rgas*TjR)
      Vjet=Mv*percentage/(100*Areaj*rhoj)

C****************************************************
C     CROSSFLOW CALCULATIONS FOR NINE-HOLE CASE ONLY

      IF(FLOW.EQ.1) THEN
      write(4,*)' '
      write(4,*)'   SPENT CROSSFLOW CALCULATIONS IN LE CHANNEL'
      write(4,*)' '

      !   PROPERTIES AT MEAN TEMPERATURE

      TmR=Tm+460.
      CALL AIRPROP(TmR,gamm,CONm,VISm,PRm,CPm)
      VISm=VISm/3600.
      rhom=(Pjet*144)/(Rgas*TmR)
      Vaxial=(nj-1)*Mv/(LEArea*rhom*2*nj)
      sound=sqrt(gc*gamm*Rgas*TmR)
      Mach=Vaxial/sound
      ReC=4.*(nj-1)*Mv/(LEperim*VISm*2*nj)

      WRITE(4,311)Tm,Vjet,Vaxial,Vaxial/Vjet,Rec,ReC/Rej,rhom,Sound,Mach
      ENDIF
  311 FORMAT(/,
     &' Tmean = ',F6.2,/,
     &' Jet Velocity = ',f9.3,' ft/s',/,
     &' Axial Velocity before the Middle Jet= ',f9.3,' ft/s',/,
     &' V_Axial/V_Jet= ',f9.3,/,
     &' Axial Flow Reynolds number before the Middle Jet=',F8.2,/,
     &' Re_axial/Re_jet = ',f6.3,/,
     &' Axial Flw Density=',E12.7,' lbm/cu.ft',/,
     &' Speed of Sound=',f9.2,/,
     &' Axial Flw Mach number =',f6.3,/)

C   ***********************************************************

C     FOR CFD

      write(3,150)Pven,Rej,NuNose,NuSidef,NuSideb,Mv,Mv/CON2,Mv/nj,
     &Mv/(con2*nj),Mv*(nj-1)/(2*nj),(Mv/con2)*(nj-1)/(2*nj),
```

```
     &Mv*(nj+1)/(2*nj),(Mv/con2)*(nj+1)/(2*nj),Pamb,Pamb*con3,Tamb,
     &(Tamb+460.)/1.8,Psup,Psup*con3,RHOj,RHOj*con4,Vjet,Vjet/con,
     &Tjet,(Tjet+460.)/1.8,CONj,CONj*con5,
     &VISj,VISj*3600*con6,CPj,CPj*con7,Dhj/CONj,(Dhj/con)/(CONj*con5),
     &TSidef,TSidef,TNose,Tsave,(Tsave+460)/1.8
  150 format(10x,/,' THIS IS FOR VENTURI PRESSURE OF:  ', f8.1 ,' psi',
//)
     &1x,'Rej,5th Hole=',F10.1,2x,' Nu_Nose=',F8.3,' Nu_Side_Front=',
     &F8.3,' Nu_Side_Back=',F8.3,/,
     &1x,'Total air mass flow rate entering the rig ',E13.7,' pps',/,
     &1x,'Total air mass flow rate entering the rig ',E13.7,' Kg/s',/,
     &1x,'Air mass flow rate through the middle hole ',E13.7,' pps',/,
     &1x,'Air mass flow rate through the middle hole ',E13.7,' Kg/s',/,
     &1x,'Spent cross-flow approaching the middle jet ',E13.7,' pps',/,
     &1x,'Spent cross-flow approaching the middle jet ',E13.7,' Kg/s',/,
     &1x,'Spent cross-flow departing the middle jet ',E13.7,' pps',/,
     &1x,'Spent cross-flow departing the middle jet ',E13.7,' Kg/s',/,
     &1x,'Lab pressure',F8.3,' psi',/,
     &1x,'Lab pressure',F13.1,' Pa',/,
     &1x,'Lab Temperature',F9.2,' F',/,
     &1x,'Lab Temperature',F9.2,' K',/,
     &1x,'Air pressure in supply channel ',E13.7,' psi',/,
     &1x,'Air pressure in supply channel ',E13.7,' Pa',/,
     &1x,'Air density at the inlet ',E13.7,' lbm/cu.ft',/,
     &1x,'Air density at the inlet ',E13.7,' Kg/m3',/,
     &1x,'Jet Velocity at inlet ',E13.7,' ft/s',/,
     &1x,'Jet Velocity at inlet ',E13.7,' m/s',/,
     &1x,'Jet air temperature at inlet ',F9.2,' F',/,
     &1x,'Jet air temperature at inlet ',F9.2,' K',/,
     &1x,'Air conductivity at inlet ',E13.7,
     &' BTU/hr.ft.R', /,
     &1x,'Air conductivity at inlet ',E13.7,
     &' W/m.K',/,
     &1x,'Air viscosity at inlet ',E13.7,
     &' lbm/s.ft',/,
     &1x,'Air viscosity at inlet ',E13.7,
     &' Kg/s.m'/,
     &1x,'Air specific heat at inlet ',E13.7,
     &' BTU/lbm.R',/,
     &1x,'Air specific heat at inlet ',E13.7,
     &' J/Kg.K',/,
     &1x,'Dj/K=',E13.7,'  hr.sq.ft.F/BTU',/,
     &1x,'Dj/K=',E13.7,'  sq.m.K/W',/,
     &1x,'Tside, front=',F7.2,'  F',/,
     &1x,'Tside, back=',F7.2,'  F',/,
     &1x,'Tnose=',F7.2,'  F',/,
     &1x,'Tsurface, Ave=',F7.2,'  F',/,
     &1x,'Tsurface, Ave=',F7.2,'  K',/,
     &' ***************************************'/)

      ENDDO

  100 FORMAT(30X,'TEST # ',i2)
  407 FORMAT(1X,E11.5,1X,E11.5)
```

```
  403 FORMAT(1X,E10.4,3(1X,E11.5),3(1X,E9.3))

  405 FORMAT(5X,E12.5,5X,E12.5,5X,E12.5,5X,E12.5)
  406 FORMAT(2X,'Pamb= ',f6.3,' psi',2x,
     &'Friction Factor= ',E10.4,5x,'% Uncerf=',f7.3)

  409 FORMAT(5X,E12.5,5X,E12.5,5X,E12.5)

 4011 FORMAT(/,1X,'FRONT SIDE COPPER PIECE H.T. AREA :'
     &,F11.6,' sq.in.',/,
     &5X,'Nu_Side_Front=',F8.3,2X,'% Uncer (in h) =',F8.3)

 4012 FORMAT(/,1X,'BACK SIDE COPPER PIECE H.T. AREA :'
     &,F11.6,' sq.in.',/,
     &5X,'Nu_Side_Back=',F8.3,2X,'% Uncer (in h) =',F8.3)

 4013 FORMAT(/,1X,'NOSE COPPER PIECE H.T. AREA :'
     &,F11.6,' sq.in.',/,
     &5X,'Nu_Nose=',F8.3,2X,'% Uncer (in h) =',F8.3)

  300 FORMAT(/,1X,'Tj=',F6.2,1X,'T_Side_Front=',F6.2,
     &1X,'T_Side_Back=',F6.2,1X,'T_Nose=',F6.2,1X,'Tm=',F6.2,
     &' Mv=',E9.3,' lbs/sec',1X,'Rej,5th Hole=',F8.2)

  301 FORMAT(/,1X,'Tfilm=',F6.2,1X,'ReC=',F8.2,
     &' ReC/Rej,5th Hole=',f6.3)
 3021 FORMAT(/,5X,'T/Cs IN FRONT COPPER PIECE :',/,2x,6f8.1)
 3022 FORMAT(/,5X,'T/Cs IN  NOSE COPPER PIECE :',/,2x,6f8.1)
 3023 FORMAT(/,5X,'T/Cs IN  BACK COPPER PIECE :',/,2x,6f8.1)

      STOP
      END

      SUBROUTINE COEFFICIENT(ID,Q,Flux,Tsurf,Tm,hcopper,Floss,Frad)
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 kcopper,kadh,klexan,kins,Mv,krubber,kinc,kkap,kwood,kalum
      COMMON Rnose,flat,Dh,SArea,AreaNose,CopperL,CopperT,P,Rgas,Mv,
     &Tjet,Tamb,Pamb,TSidef,TSideb,TNose

C                  B A C K   W A L L

C     FROM THE T/C INSIDE THE COPPER PIECE TO THE AMBIENT AIR

C     1/2 Copper thickness + double-stick tape + Kapton + ADHESIVE +
Inconel Heater +
C     ADHESIVE + Kapton +  double-stick tape + Rubber Gasket + double-
stick tape +
C     Lexan + Al Plate + Insulation Blanket + AMBIENT

C     Heat transfer coefficient on the outer surface

      De=10./12.             ! ft, test section side with insulation

      TambR=Tamb+460.
      CALL AIRPROP(TambR,gam,CONamb,VIS,PR,CPamb)
```

```
      VIS=VIS/3600.

C      WRITE(6,*)' TambR=',TambR,' VIS=',VIS,' CONamb=',CONamb
C      WRITE(6,*)' gam=',gam,' CPamb=',CPamb,' Pr=',PR

      ho=0.36*CONamb/De                      ! Ozisik, Page 443

C     THICKNESSES

      tinc = 0.50e-03/12.                      ! MINCO's fact sheet

      tkap = 2.0e-03/12.                       ! MINCO's fact sheet

      tcopper = CopperT

      tadh1 = 0.5e-03/12.                      ! MINCO's fact sheet

      tadh2 = 2.e-03/12.                       ! double-stck tape

      trubber = 0.032/12.                      ! Rubber

      tlexan =(1./12.)                         ! Lexan Thickness

      tins = 0.5/12.                           ! Glass Wool Insulation

      twood = 0.5/12.                          ! Wooden stand thickness
on the top

      talum= 0.5/12.                           ! Aluminum plate thickness

C     THERMAL CONDUCTIVITIES

      kkap = 0.0942          ! BTU/hr.ft.F  MINCO (0.163 W/m.K) agrees
with

      kadh = 0.1272          ! BTU/hr.ft.F  MINCO  (0.220 W/m.K)

      kinc = 9.0152          ! BTU/hr.ft.F  MINCO (inconel 600  K=15.6
W/m.K)

      kins = 0.022           ! BTU/hr.ft.F  Holman (Glass Wool)

      kwood = 0.087          ! BTU/hr.ft.F  pine wood (McAdams)

      klexan = 0.11          ! BTU/hr.ft.F

      kadh = 0.1272          ! BTU/hr.ft.F

      kcopper = 67.0         ! BTU/hr.ft.F

      krubber = 0.0069348    ! BTU/hr.ft.F

      kalum =35.6            ! BTU/hr.ft.F

C      WRITE(6,*)' tcopper=',12.*tcopper,' kcopper=',kcopper
```

```
C      WRITE(6,*)' tlexan=' ,12.*tlexan ,' klexan=' ,klexan

C     THERMAL  RESISTANCES

      Rcopper = tcopper/kcopper

      Radh1   = tadh1/kadh

      Radh2   = tadh2/kadh

      Rinc    = tinc/kinc

      Rkap    = tkap/kkap

      Rlexan  = tlexan/klexan

      Ralum   = talum/kalum

      Rwood    = twood/kwood

      Rrubber = trubber/krubber

      Rins    = tins/kins

      Rconv = 1./ho

C      write(6,*)' Radh1=',Radh1,' Radh2=',Radh2,' Rkap=',Rkap
C      write(6,*)' Rinc=',Rinc,' Rins=',Rins
C      write(6,*)' Rrubber=',Rrubber,' Rcopper=',Rcopper,' Rconv=',Rconv

      RbackS = 0.5*Rcopper + Radh2 + Rkap + Radh1 + Rinc + Radh1 + Rkap
     &+ Radh2 + Rrubber + Radh2 + 0.5*Rlexan + Rconv

      RbackN = 0.5*Rcopper + Radh2 + Rkap + Radh1 + Rinc + Radh1 + Rkap
     &+ Radh2 + Rrubber + Radh2 + Rlexan + Ralum + Rwood + Rconv

      IF(ID.EQ.1.OR.ID.EQ.2)Rback=RbackS
      IF(ID.EQ.3)Rback=RbackN

      Rfront =0.5*Rcopper

      Floss = (Tsurf-Tamb)/Rback        ! loss from the back side
      ffront=flux-Floss
      perloss=100.*(Floss/flux)

      !     AIR INLET ENTHALPY

      TinR=Tjet+460.

      CALL AIRPROP(TinR,gamin,CONin,VISin,PRin,CPin)

C      write(6,*)' TinR=',TinR,' gamin=',gamin,' CONin=',CONin,
C     &' VISin=',VISin,' PRin=',PRin,' CPin=',CPin

      FlosSf=(TSidef-Tjet)/RbackS
```

```
      FlosSb=(TSideb-Tjet)/RbackS
      FlosN=(TNose-Tamb)/RbackN

      Tm=Tjet+(Q-(SArea*FlosSf+SArea+FlosSb+AreaNose*FlosN))/
     &(3600.*Mv*CPin)                          ! Energy balance

      WRITE(7,*)' '
      IF(ID.EQ.1) WRITE(7,*)'      FRONT SIDE COPPER PIECE'
      IF(ID.EQ.2) WRITE(7,*)'      BACK  SIDE COPPER PIECE'
      IF(ID.EQ.3) WRITE(7,*)'      NOSE COPPER PIECE'
      WRITE(7,*)' '

      WRITE(7,101)flux, Floss, ffront,
     & perloss,Tsurf,Tamb,ho
  101 FORMAT(/,5X,'TOTAL HEAT FLUX = ',F8.3,'  BTU/hr.sqft',/,
     &5X,'HEAT FLUX TO THE BACK = ',F8.3,'  BTU/hr.sqft',/,
     &5X,'HEAT FLUX TO THE FRONT = ',F8.3,'  BTU/hr.sqft',/,
     &5X,'% OF HEAT LOST FROM THE BACK SIDE = ',E16.6,/,
     &5X,'COPPER BLOCK TEMPERATURE = ',F8.3,'  F',/,
     &5X,'AMBIENT TEMPERATURE = ',F8.3,'  F',/,
     &5X,'Outer heat transfer coefficient= ',F8.3,
     &'  BTU/hr.sqft.F')

      IF(ID.eq.1)WRITE(3,133)ffront,3.281*3.281*ffront/3.413
  133 FORMAT(/,
     &5X,'HEAT FLUX TO THE FRONT SIDE COPPER = ',F10.3,'  BTU/hr.sqft',/,
     &5X,'HEAT FLUX TO THE FRONT SIDE COPPER = ',F10.3,'  W/m2',/)

      IF(ID.eq.2)WRITE(3,134)ffront,3.281*3.281*ffront/3.413
  134 FORMAT(/,
     &5X,'HEAT FLUX TO THE BACK SIDE COPPER = ',F10.3,'  BTU/hr.sqft',/,
     &5X,'HEAT FLUX TO THE BACK SIDE COPPER = ',F10.3,'  W/m2',/)

      IF(ID.eq.3)WRITE(3,135)ffront,3.281*3.281*ffront/3.413
  135 FORMAT(/,
     &5X,'HEAT FLUX TO THE NOSE = ',F10.3,'  BTU/hr.sqft',/,
     &5X,'HEAT FLUX TO THE NOSE = ',F10.3,'  W/m2',/)

C     RADIATIONAL LOSSES

      call rad (Tsurf,Tm,Frad)


C     HEAT TRANSFER COEFFICIENT FROM THE NEWTON LAW OF COOLING

      hcopper=(Flux-Floss-Frad)/(Tsurf-Tjet)

       write(7,120)hcopper
  120 FORMAT(5x,'hcopper=',F10.3,'   BTU/hr.sqft.F')
      write(7,150)Frad
  150 FORMAT(5X,'Radiative Fluxes from Copper Surface'
     &,10x,4F10.3,'   BTU/sqft.hr')
      RETURN
      END
```

```
      SUBROUTINE RAD (Tsurf,Tm,qrad)
      IMPLICIT REAL*8(A-H,O-Z)

      SIGMA=0.1712E-08   ! Stephen-Boltzmann constant

      T1=Tsurf + 460.
      T2=Tm    + 460.

      ! Emissivity

      Ecopper=0.3     ! CLEANED COPPER Ozisik, Page 756
      qrad=Ecopper*SIGMA*(T1**4.-T2**4.)

      RETURN
      END

      SUBROUTINE UNCERTAIN(I,V,area,Tsurf,Tjet,Floss,Frad,Uncer)
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 I
      PI=4.*ATAN(1.)
      dv=.1
      di=.01
      da=1./(32.*32.)
      dTs=0.5
      dTjet=1.
      Ts=Tsurf
      FAC=491.3744            ! (3600 s/hr)(144 sqin/sqft)/(1055 J/BTU)
      Floss=Floss/FAC
      DFloss=0.1*Floss
      Frad=Frad/FAC
      DFrad=0.1*Frad

      A=144*Area

      H=(V*I/A-Floss-Frad)/(TS-Tjet)

      WRITE(5,*)'     heat transfer coeff., h, =',H*FAC,' BUT/hr.sqft.F'
      H2=H*H

C
C                iv
C               ----- - Floss - Frad
C                 a
C     h= --------------------------------------------------
C
C                         Ts-Tjet
C

      DHDI=(v/a)/(Ts-Tjet)      ! Derivative w.r.t. i
      ZI=(DI*DHDI)**2

      DHDV=(i/a)/(Ts-Tjet)      ! Derivative w.r.t. v
      ZV=(DV*DHDV)**2

      DHDA=(-(i*v)/(a**2))/(Ts-Tjet)      ! Derivative w.r.t. a
```

```
      ZA=(DA*DHDA)**2

      DHDTS=-(i*v/a-Floss-Frad)/((Ts-Tjet)**2)     ! Derivative w.r.t. Ts
      ZTS=(DTS*DHDTS)**2

      DHDTjet=(i*v/a-Floss-Frad)/((Ts-Tjet)**2)    ! Derivative w.r.t.
Tjet
      ZTjet=(DTjet*DHDTjet)**2

      DHDFLOSS=-1./(Ts-Tjet)                  ! Derivative w.r.t. Floss
      ZFLOSS=(DFLOSS*DHDFLOSS)**2

      DHDFRAD=-1./(Ts-Tjet)                   ! Derivative w.r.t. Frad
      ZFRAD=(DFRAD*DHDFRAD)**2

      UNCER=100*SQRT((ZI+ZV+ZA+ZTS+ZTjet+ZFLOSS+ZFRAD)/(H2))

      WRITE(5,*)'  '
      WRITE(5,*)'             UNCERTAINTY IN HEAT TRANSFER',
     &' COEFFICIENT'
      WRITE(5,*)'  '

      WRITE(5,*)' TOTAL UNCERTAINTY %    ',UNCER

      WRITE(5,*)' % Uncertainty assoc. with I',100.*sqrt(ZI)/H
      WRITE(5,*)' % Uncertainty assoc. with V',100.*sqrt(ZV)/H
      WRITE(5,*)' % Uncertainty assoc. with A',100.*sqrt(ZA)/H
      WRITE(5,*)' % Uncertainty assoc. with Ts',100.*sqrt(ZTS)/H
      WRITE(5,*)' % Uncertainty assoc. with Tjet',100.*sqrt(ZTjet)/H
      WRITE(5,*)' % Uncertainty assoc. with Floss',100.*sqrt(ZFLOSS)/H
      WRITE(5,*)' % Uncertainty assoc. with Frad',100.*sqrt(ZFRAD)/H
      RETURN
      END

      subroutine AIRPROP(t,gamx,kx,mux,prx,cpx)
      IMPLICIT REAL*8(A-H,O-Z)

c  physical properties of dry air at one atmosphere
c       ref: ge heat transfer handbook
c
c  temperature range:  160 to 3960 deg. rankine
c                     -300 to 3500 deg. fahreinheit
c
c        t     - temperature, R
c        gamx  - ratios of specific heats
c        kx    - thermal conductivity, BTU/hr.ft.R
c        mux   - viscosity, lbm/hr.ft
c        prx   - prandtl no.
c        cpx   - specific heat, BTU/lbm.R
c
c
      dimension tab(34),gam(34),pr(34),cp(34)
      real*8 k(34),mu(34),kx,mux
      data nent/34/
      data tab/     160.,  260.,
```

```
     &     360.,  460.,  560.,  660.,  760.,  860.,  960., 1060.,
     &    1160., 1260., 1360., 1460., 1560., 1660., 1760., 1860.,
     &    1960., 2060., 2160., 2260., 2360., 2460., 2560., 2660.,
     &    2760., 2860., 2960., 3160., 3360., 3560., 3760., 3960./
      data gam/    1.417, 1.411,
     &    1.406, 1.403, 1.401, 1.398, 1.395, 1.390, 1.385, 1.378,
     &    1.372, 1.366, 1.360, 1.355, 1.350, 1.345, 1.340, 1.336,
     &    1.332, 1.328, 1.325, 1.321, 1.318, 1.315, 1.312, 1.309,
     &    1.306, 1.303, 1.299, 1.293, 1.287, 1.281, 1.275, 1.269/
      data k/   0.0063,0.0086,
     &   0.0108,0.0130,0.0154,0.0176,0.0198,0.0220,0.0243,0.0265,
     &   0.0282,0.0301,0.0320,0.0338,0.0355,0.0370,0.0386,0.0405,
     &   0.0422,0.0439,0.0455,0.0473,0.0490,0.0507,0.0525,0.0542,
     &   0.0560,0.0578,0.0595,0.0632,0.0666,0.0702,0.0740,0.0780/
      data mu/   0.0130,0.0240,
     &   0.0326,0.0394,0.0461,0.0519,0.0576,0.0627,0.0679,0.0721,
     &   0.0766,0.0807,0.0847,0.0882,0.0920,0.0950,0.0980,0.1015,
     &   0.1045,0.1075,0.1101,0.1110,0.1170,0.1200,0.1230,0.1265,
     &   0.1300,0.1330,0.1360,0.1420,0.1480,0.1535,0.1595,0.1655/
      data pr/   0.7710,0.7590,
     &   0.7390,0.7180,0.7030,0.6940,0.6860,0.6820,0.6790,0.6788,
     &   0.6793,0.6811,0.6865,0.6880,0.6882,0.6885,0.6887,0.6890,
     &   0.6891,0.6893,0.6895,0.6897,0.6899,0.6900,0.6902,0.6905,
     &   0.6907,0.6909,0.6910,0.6913,0.6917,0.6921,0.6925,0.6929/
      data cp/    0.247, 0.242,
     &    0.241, 0.240, 0.241, 0.242, 0.244, 0.246, 0.248, 0.251,
     &    0.254, 0.257, 0.260, 0.264, 0.267, 0.270, 0.272, 0.275,
     &    0.277, 0.279, 0.282, 0.284, 0.286, 0.288, 0.291, 0.293,
     &    0.296, 0.298, 0.300, 0.305, 0.311, 0.318, 0.326, 0.338/
c
c
      if(t.lt.tab(1)) print 510,t,tab(1)
  510 format(" in airprop ---  temp=",f8.1," is less than min temp",
     &" of ",f8.1)
      if(t.gt.tab(nent)) print 520, t,tab(nent)
  520 format(" in airprop ---  temp=",f8.1," is greater than max",
     &" temp of ",f8.1)
      if(t-tab(1))120,120,100
  100 if(tab(nent)-t)130,130,110
  110 m=2
      go to 140
  120 j=1
      go to 180
  130 j=nent
      go to 180
  140 if(t-tab(m))160,170,150
  150 m=m+1
      go to 140
c
c -- Linear Interpolation ---
c
  160 slp=(t-tab(m-1))/(tab(m)-tab(m-1))
      mux= mu(m-1)+(mu(m)-mu(m-1))*slp
      prx= pr(m-1)+(pr(m)-pr(m-1))*slp
      cpx=cp(m-1)+(cp(m)-cp(m-1))*slp
```

```
      kx=k(m-1)+(k(m)-k(m-1))*slp
      gamx=gam(m-1)+(gam(m)-gam(m-1))*slp
      go to 190
 170  j=m
      go to 180
180   mux=mu(j)
      prx=pr(j)
      cpx=cp(j)
      kx=k(j)
      gamx=gam(j)
190   return
      end
```

APPENDIX B
CHECK.F FORTRAN CODE

```
c       This program is used for Leading Edge Impingement Cooling Tests
C23456789012345678901234567890123456789012345678901234567890123456789012

       character*25 filename
       character*80 title
       write(6,*)'enter the name of the data file that u',
      &' want to check'
       read(5,12)filename
       open(unit=1,file=filename,status='old')
       open(unit=2,file='output.dat',status='old')

       read(1,*)ntests
       do i=1,7
       read(1,10)title
       enddo

    10 FORMAT(A80,//)
    11 FORMAT(A50)
    12 FORMAT(A25)

       DO I=1,ntests
       READ(1,11)TITLE
       READ(1,*)Pven,Psup,Pjet,PLEin,PLEout,flagsup,flag,
      &DPjet,V1,A1,V2,A2,V3,A3,V4,A4,V5,A5,V6,A6,Pamb
       READ(1,11)TITLE
       READ(1,*)C101,C102,C103,C104,C105,C106,C107,C108,C109,C110,C111,
      &C112,Tven,Tjet,Tamb
       READ(1,11)TITLE
       READ(1,*)C201,C202,C203,C204,C205,C206,C207,C208,C209,C210,C211,
      &C212,C213,C214,C215,C216,C217,C218
       READ(1,11)TITLE
       READ(1,*)C301,C302,C303,C304,C305,C306,C307,C308,C309,C310,C311,
      &C312

C23456789012345678901234567890123456789012345678901234567890123456789012

       if(Pven.lt.10.or.Pven.gt.95)write(6,*)' ** CHECK Pven IN TEST ',i
       if(Pamb.lt.28.or.Pamb.gt.31)write(6,*)
      &' ** CHECK Pamb IN TEST ',i


       if(old1.eq.0)goto 31
       err1=abs((v1/a1)-old1)/old1
       err2=abs((v2/a2)-old2)/old2
       err3=abs((v3/a3)-old3)/old3
       err4=abs((v4/a4)-old4)/old4
       err5=abs((v5/a5)-old5)/old5
       err6=abs((v6/a6)-old6)/old6

       if(err1.gt..0125)write(6,*)'error in heater 1 entry, test #'
```

```
     &,i
        if(err2.gt..0125)write(6,*)'error in heater 2 entry, test #'
     &,i
        if(err3.gt..0125)write(6,*)'error in heater 3 entry, test #'
     &,i
        if(err4.gt..0125)write(6,*)'error in heater 4 entry, test #'
     &,i
        if(err5.gt..0125)write(6,*)'error in heater 5 entry, test #'
     &,i
        if(err6.gt..0125)write(6,*)'error in heater 6 entry, test #'
     &,i

   31 write(6,35)i,v1/a1,v2/a2,v3/a3,v4/a4,v5/a5,v6/a6
      write(2,35)i,v1/a1,v2/a2,v3/a3,v4/a4,v5/a5,v6/a6

      if(flag.eq.1)goto 32
      old1=v1/a1
      old2=v2/a2
      old3=v3/a3
      old4=v4/a4
      old5=v5/a5
      old6=v6/a6

      flag=1.
   32 continue
   35 format(2x,i2,1x,6(1x,f10.6))

C      Tfront=(C201+C202+C203+C204+C205+C206)/6.
      Tfront=(C202+C203+C204+C205+C206)/5.
      TNose =(C207+C208+C209+C210+C211+C212)/6.
      Tback=(C213+C214+C215+C216+C217+C218)/6.

      if(TNose.lt.80.or.TNose.gt.120)write(6,*)
     &' ** CHECK Tfront IN TEST ',i
      if(Tfront.lt.80.or.Tfront.gt.120)write(6,*)
     &' ** CHECK Tfront IN TEST ',i
      if(Tback.lt.80.or.Tback.gt.120)write(6,*)
     &' ** CHECK Tback IN TEST ',i
      if(Tjet.lt.50.or.Tjet.gt.90)write(6,*)
     &' ** CHECK Tjet IN TEST ',i
      if(Tven.lt.50.or.Tven.gt.90)write(6,*)
     &' ** CHECK Tven IN TEST ',i
      if(Tamb.lt.40.or.Tamb.gt.90)write(6,*)
     &' ** CHECK Tamb IN TEST ',i

      enddo

      write(6,*)'  '
      write(6,*)'  '
      write(6,*)'      Resistances are in file : output.dat'
      stop
      end
```

APPENDIX C
Raw Data Test#1 Through Test#18

Test # 1 9 Holes Parallel

Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	5.40	5.00	5.05	4.75	Orange Oil	0.152	13.00	0.4119	10.99	0.7369	13.12	0.4148	11.07	0.7258	13.13	0.4190	11.12	0.7269	30.01
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	92.763	92.75	92.88	93.242	98.752	99.139	98.944	99.031	92.356	92.529	92.205	92.277	64.22	65.33	69.34				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.606	107.393	109.881	109.777	109.98	110.281	110.405	110.857	110.659	110.502	110.736	110.268	109.708	109.417	109.413	110.072	109.829	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	92.691	92.378	92.561	93.438	101.948	102.136	102.224	101.837	94.176	93.182	93.222	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	9.65	9.00	9.10	8.55	Orange Oil	0.255	13.86	0.4385	11.63	0.7832	13.94	0.4425	11.86	0.7769	14.01	0.4473	11.85	0.7743	30.01
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.895	91.726	91.841	92.315	98.582	98.982	98.784	98.914	91.501	91.654	91.312	91.384	65.81	65.88	69.74				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.361	107.957	109.584	109.463	109.588	110.115	110.216	110.938	110.56	110.302	110.574	109.903	109.37	109.026	109.024	109.728	109.492	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	91.813	91.525	91.679	92.549	101.86	102.127	102.204	101.743	93.258	92.241	92.243	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	15.00	14.10	14.20	13.44	Orange Oil	0.395	14.54	0.4606	12.19	0.8200	14.61	0.4641	12.46	0.8153	14.75	0.4698	12.42	0.8105	30.01
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.35	91.127	91.305	91.809	98.6	99.023	98.852	98.977	91.008	91.231	90.848	90.893	67.6	66.97	69.36				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.096	106.542	109.382	109.228	109.337	109.976	110.097	110.837	110.43	110.162	110.502	109.733	109.055	108.758	108.801	109.541	109.355	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	91.028	90.74	90.925	91.836	101.887	102.182	102.208	101.765	92.767	91.678	91.703	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	21.65	20.35	19.70	19.40	Orange Oil	0.547	15.16	0.4810	12.80	0.8576	15.30	0.4854	13.04	0.8535	15.45	0.4924	12.99	0.8472	30.01
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.968	90.758	90.911	91.481	98.86	99.247	99.092	99.268	90.801	90.878	90.536	90.635	68.2	67.7	69.72				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.995	111.244	109.323	109.098	109.285	109.967	110.056	110.765	110.522	110.212	110.524	109.813	109.129	108.751	108.812	109.579	109.424	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	90.479	90.167	90.306	91.292	102.107	102.425	102.474	101.979	92.369	91.274	91.265	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	30.45	28.65	27.90	27.35	Orange Oil	0.745	15.75	0.4986	13.22	0.8875	15.85	0.5030	13.53	0.8847	15.93	0.5100	13.45	0.8764	30
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.743	90.434	90.574	91.188	99.04	99.403	99.259	99.405	90.482	90.61	90.266	90.331	69.7	67.9	69.84				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.805	107.793	109.112	108.868	109.062	109.777	109.955	110.887	110.329	110.032	110.344	109.489	108.769	108.401	108.434	109.294	109.075	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	89.726	89.363	89.548	90.522	102.119	102.49	102.481	101.981	91.926	90.722	90.783	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	11.00	10.40	10.20	9.80	Red Oil	2.350	16.41	0.5199	13.70	0.9208	16.53	0.5246	14.09	0.9217	16.67	0.5312	14.02	0.9126	30
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.275	89.982	90.072	90.776	99.173	99.513	99.407	99.599	90.144	90.313	89.953	90.023	72.2	68.7	69.9				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.81	106.702	109.159	108.889	109.096	109.886	110.012	110.864	110.417	110.045	110.425	109.436	108.695	108.257	108.365	109.197	109.053	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	89.143	88.726	88.906	89.962	102.344	102.704	102.769	102.172	91.494	90.295	90.391	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	15.10	14.20	14.10	13.60	Red Oil	3.250	16.99	0.5378	14.28	0.9556	17.13	0.5430	14.60	0.9557	17.29	0.5505	14.50	0.9442	30
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.871	90.193	90.293	91.039	99.837	100.116	100.021	100.247	90.473	90.578	90.241	90.333	75.2	70	69.8				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.859	108.178	109.215	108.927	109.199	109.953	110.097	111.154	110.558	110.122	110.531	109.514	108.639	108.319	108.385	109.309	109.102	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	89.077	88.729	88.871	89.905	102.881	103.252	103.27	102.631	91.526	90.263	90.346	7.9E+28							

Test # 2 9 Holes Circular

Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	6.20	5.95	5.10	6.00	Orange Oil	0.105	11.96	0.3789	10.04	0.6739	12.07	0.3821	10.17	0.6663	12.12	0.3868	10.23	0.6683	29.99
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	93.375	93.391	93.697	93.946	101.342	101.943	101.84	101.781	93.868	94.198	93.726	93.625	65.11	67.14	69.95				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	107.95	107.987	108.248	107.885	107.822	110.059	110.02	110.21	110.387	110.268	110.653	108.956	108.959	108.592	108.509	108.774	108.59	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	90.259	90.229	90.414	91.049	100.082	100.159	100.265	100.048	92.885	92.16	92.144	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	10.80	10.45	9.30	10.55	Orange Oil	0.145	12.70	0.4029	10.72	0.7187	12.83	0.4076	10.87	0.7121	12.91	0.4117	10.91	0.7131	29.99
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	92.212	92.228	92.475	92.846	101.155	101.86	101.729	101.664	92.903	93.197	92.707	92.614	66.33	67.27	69.87				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	107.48	106.178	107.806	107.446	107.399	110.007	109.942	110.254	110.327	110.182	110.599	108.677	108.63	108.218	108.185	108.463	108.284	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	89.071	89.033	89.291	89.96	99.954	100.058	100.174	99.934	91.957	91.19	91.186	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	16.90	16.40	15.30	16.50	Orange Oil	0.217	13.40	0.4248	11.28	0.7570	13.48	0.4285	11.44	0.7489	13.53	0.4323	11.48	0.7482	29.98
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.478	91.483	91.782	92.178	101.158	101.909	101.795	101.741	92.344	92.585	92.102	92.038	68.07	68.02	69.74				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	107.323	105.039	107.62	107.165	107.062	109.917	109.843	110.338	110.279	110.063	110.506	108.301	108.182	107.786	107.743	108.009	107.818	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	88.574	88.456	88.664	89.329	100.177	100.253	100.33	100.102	91.417	90.608	90.628	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	24.85	24.20	21.90	24.50	Orange Oil	0.307	14.06	0.4455	11.94	0.8029	14.15	0.4500	12.04	0.7867	14.21	0.4536	12.03	0.7859	29.98
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.207	89.926	90.23	90.772	102.006	102.73	102.659	102.625	91.152	91.445	90.868	90.803	69.3	68.43	69.78				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	106.497	106.216	106.987	106.432	106.295	109.957	109.867	110.5	110.423	110.102	110.644	107.919	107.771	107.266	107.293	107.651	107.483	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.526	86.413	86.661	87.424	100.937	101.065	101.061	100.854	90.115	89.219	89.239	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	9.80	9.40	9.00	9.60	Red Oil	0.412	14.69	0.4655	12.52	0.8395	14.80	0.4701	12.60	0.8251	14.88	0.4750	12.58	0.8217	29.98
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.306	90.193	90.531	91.04	101.736	102.49	102.402	102.361	91.508	91.755	91.202	91.166	70.6	68.9	69.89				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	106.801	107.537	107.179	106.65	106.558	109.957	109.895	110.295	110.369	110.09	110.605	107.995	107.815	107.408	107.422	107.744	107.566	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.181	87.023	87.3	88.047	100.717	100.805	100.883	100.624	90.52	89.6	89.615	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	12.80	12.40	12.00	12.60	Red Oil	0.540	15.20	0.4817	12.98	0.8700	15.35	0.4870	13.06	0.8550	15.45	0.4920	13.01	0.8493	29.96
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.517	89.874	90.194	90.733	102.001	102.701	102.665	102.602	91.082	91.37	90.803	90.698	72.9	69.2	69.9				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	106.502	104.164	107.003	106.409	106.249	109.888	109.843	110.356	110.372	110.086	110.597	107.809	107.667	107.168	107.183	107.552	107.419	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.623	86.485	86.722	87.455	100.937	101.07	101.106	100.852	90.047	89.152	89.105	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	17.80	17.20	16.40	17.80	Red Oil	0.714	15.70	0.4973	13.35	0.8982	15.83	0.5021	13.50	0.8818	15.90	0.5067	13.42	0.8748	29.97
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.908	89.761	90.043	90.626	102.436	103.142	103.104	103.075	91.105	91.332	90.783	90.727	76	70.6	69.88				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	106.436	103.745	106.889	106.29	106.144	109.984	109.908	110.556	110.416	110.14	110.711	107.662	107.446	106.904	106.983	107.383	107.186	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.407	86.324	86.566	87.322	101.421	101.563	101.601	101.273	89.872	88.976	88.958	7.9E+28							

Test # 3 9 Holes Both-Ends-Open

Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	0.628	0.515	0.460	0.475	H2O	0.111	12.77	0.4047	10.57	0.7088	12.76	0.4054	10.92	0.7162	12.88	0.4106	10.87	0.7097	30.12
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	93.712	93.791	94.115	94.351	101.327	102.047	101.893	101.75	93.834	94.284	93.823	93.618	65.06	67.25	70.04				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.707	110.12	108.887	108.891	109.004	110.014	109.949	110.149	110.187	110.021	110.407	109.755	109.359	109.233	109.244	109.516	109.485	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	92.605	92.342	92.354	93.238	100.163	100.067	100.084	100.13	94.214	93.276	93.364	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	2.75	0.900	0.840	0.860	H2O	0.200	13.86	0.4390	11.45	0.7697	13.87	0.4403	11.88	0.7790	13.96	0.4458	11.78	0.7698	30.07
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	92.743	92.826	93.128	93.364	101.254	102.047	101.862	101.729	92.759	93.285	92.736	92.522	66.41	67.18	70.29				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.441	106.857	108.648	108.673	108.801	109.991	109.922	110.261	110.201	109.944	110.425	109.433	108.974	108.769	108.806	109.235	109.154	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	91.291	90.988	91.042	91.939	99.851	99.724	99.81	99.752	93.055	92.059	92.108	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	4.30	3.70	2.70	3.30	Orange Oil	0.314	14.64	0.4639	12.12	0.8121	14.64	0.4647	12.54	0.8223	14.74	0.4691	12.42	0.8116	30.07
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	92.057	92.07	92.432	92.705	101.389	102.204	102.019	101.887	92.228	92.707	92.147	91.926	68.02	67.49	70.6				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.301	108.322	108.517	108.479	108.574	109.913	109.796	110.389	110.102	109.8	110.295	109.388	108.895	108.695	108.756	109.219	109.12	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	90.709	90.358	90.443	91.408	99.929	99.707	99.805	99.787	92.511	91.391	91.469	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	6.25	5.00	4.00	4.85	Orange Oil	0.450	15.21	0.4818	12.74	0.8531	15.24	0.4834	13.05	0.8542	15.30	0.4881	12.92	0.8437	30.07
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	92.097	91.921	92.326	92.633	101.956	102.787	102.634	102.452	92.135	92.657	92.039	91.881	69.2	68.5	71.2				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.281	109.589	108.464	108.454	108.558	109.998	109.843	110.403	110.165	109.798	110.398	109.427	108.83	108.659	108.673	109.159	109.112	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	90.493	90.119	90.232	91.08	100.129	99.968	100.035	99.985	92.284	91.091	91.233	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	8.75	7.20	6.25	6.80	Orange Oil	0.640	15.84	0.5017	13.27	0.8887	15.87	0.5042	13.58	0.8891	16.11	0.5131	13.45	0.8773	30.03
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.611	91.474	91.852	92.282	102.101	102.989	102.809	102.676	91.775	92.326	91.69	91.519	70.1	69.3	71.2				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.146	106.056	108.324	108.236	108.398	109.937	109.773	110.515	110.11	109.807	110.376	109.534	108.896	108.702	108.758	109.283	109.208	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	90.076	89.642	89.782	90.634	100.177	100.057	100.033	100.037	91.89	90.691	90.806	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	11.50	9.45	8.70	9.00	Orange Oil	0.835	16.53	0.5237	13.89	0.9314	16.60	0.5273	14.22	0.9300	16.85	0.5367	14.10	0.9150	30.03
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.13	90.886	91.276	91.759	102.463	103.367	103.199	103.039	91.526	92.074	91.447	91.22	73	69.4	71.1				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.139	106.297	108.338	108.263	108.419	110.092	109.951	110.641	110.252	109.874	110.403	109.606	108.913	108.661	108.745	109.305	109.195	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	89.68	89.203	89.356	90.205	100.372	100.186	100.202	100.19	91.478	90.245	90.358	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	16.35	13.40	11.50	12.80	Orange Oil	2.950	16.99	0.5374	14.26	0.9545	17.06	0.5413	14.61	0.9550	17.24	0.5492	14.45	0.9398	30.03
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.453	91.141	91.467	91.949	102.928	103.82	103.68	103.502	91.575	92.138	91.516	91.217	76.2	70.7	71				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.065	110.835	108.288	108.166	108.328	110.065	109.888	110.59	110.282	109.847	110.452	109.568	108.758	108.563	108.682	109.271	109.202	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	89.579	89.206	89.325	90.256	100.825	100.679	100.638	100.584	91.607	90.247	90.423	7.9E+28							

Test # 4 9 Holes 2-inlets-2-outlets

Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	0.595	0.518	0.465	0.475	H_2O	0.080	12.22	0.3868	10.00	0.6702	12.50	0.3943	10.30	0.6687	12.46	0.3920	10.53	0.6867	30.15
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	93.157	93.213	93.433	93.551	98.712	99.238	99.009	98.978	92.961	93.226	92.9	92.927	64.68	66.57	69.37				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	110.077	109.526	110.128	109.654	109.852	109.964	110.023	110.507	110.27	110.115	110.322	110.299	110.083	109.912	109.928	110.221	110.014	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	93.116	92.857	93.019	93.683	101.743	101.844	101.927	101.675	95.139	94.367	94.363	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	2.60	0.900	0.835	0.850	H_2O	0.159	13.14	0.4132	10.58	0.7177	13.43	0.4217	11.07	0.7158	13.34	0.4205	11.32	0.7235	30.15
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	92.45	92.398	92.572	92.835	98.582	99.121	98.896	98.851	92.164	92.444	92.02	92.048	66.17	66.85	69.63				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	110.041	107.971	110.027	109.548	109.717	109.967	110.027	110.5	110.313	110.108	110.414	110.21	110	109.823	109.885	110.144	109.874	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	92.097	91.856	91.994	92.718	101.563	101.628	101.734	101.529	94.151	93.301	93.305	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	4.10	3.60	3.20	3.30	Orange Oil	0.210	13.81	0.4350	11.13	0.7545	14.09	0.4434	11.67	0.7534	14.04	0.4428	11.90	0.7704	30.14
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.998	91.928	92.138	92.453	98.703	99.292	99.014	98.959	91.683	92	91.625	91.568	67.99	67.57	69.92				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	110.165	110.689	110.183	109.643	109.838	110.126	110.185	110.786	110.466	110.263	110.558	110.228	109.96	109.814	109.886	110.169	109.897	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	91.458	91.247	91.42	92.16	101.677	101.777	101.855	101.549	93.634	92.797	92.777	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	5.90	4.90	4.65	4.80	Orange Oil	0.315	14.33	0.4540	11.66	0.7815	14.60	0.4641	12.07	0.7902	14.38	0.4605	12.36	0.8050	30.13
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.037	90.983	91.195	91.456	98.131	98.719	98.543	98.447	90.893	91.21	90.815	90.814	66.39	67.84	69.98				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.96	110.513	109.928	109.354	109.566	109.838	109.865	110.452	110.223	109.949	110.185	109.805	109.519	109.386	109.449	109.71	109.438	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	90.601	90.401	90.621	91.314	101.446	101.547	101.63	101.326	93.011	92.128	92.093	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	8.15	7.10	6.70	6.75	Orange Oil	0.408	14.96	0.4739	12.04	0.8076	15.24	0.4837	12.59	0.8230	15.03	0.4782	12.86	0.8372	30.13
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.524	90.446	90.682	90.977	97.974	98.552	98.357	98.296	90.38	90.655	90.295	90.265	69.7	68	69.9				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	110.052	111.629	110.101	109.393	109.525	109.946	109.984	110.756	110.295	109.982	110.268	109.575	109.348	109.159	109.215	109.544	109.231	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	90.319	90.023	90.308	90.979	101.588	101.7	101.767	101.444	92.57	91.674	91.607	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	10.80	9.50	8.80	8.95	Orange Oil	0.524	15.44	0.4892	12.50	0.8377	15.79	0.5015	13.09	0.8570	15.66	0.4993	13.32	0.8684	30.12
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.771	88.52	88.805	89.215	98.298	98.872	98.681	98.6	88.929	89.282	88.781	88.787	72.1	68.3	70.8				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.96	107.381	110.039	109.37	109.586	109.98	109.998	110.858	110.401	110.029	110.327	109.652	109.411	109.224	109.301	109.643	109.354	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	89.732	89.485	89.752	90.439	101.484	101.664	101.713	101.338	92.014	91.071	91.062	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	15.10	12.75	12.45	12.60	Orange Oil	0.660	16.06	0.5088	13.08	0.8760	16.33	0.5185	13.58	0.8871	16.20	0.5164	13.80	0.8972	30.12
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.189	90.155	90.299	90.765	98.78	99.445	99.263	99.238	90.176	90.452	90.022	90.04	72.9	66.8	69.9				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	110.113	109.143	110.11	109.373	109.568	109.996	110.005	111.013	110.381	109.985	110.272	109.505	109.156	109.012	109.12	109.449	109.161	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	89.568	89.327	89.581	90.257	101.788	101.916	101.993	101.66	91.802	90.889	90.85	7.9E+28							

Test # 5 8 Holes Parallel

Pven	**Psup**	**Pjet**	**$P_{L.E.\ in}$**	**$P_{L.E.\ out}$**	**Man. Liquid**	**ΔPjet**	**V_1**	**I_1**	**V_2**	**I_2**	**V_3**	**I_3**	**V_4**	**I_4**	**V_5**	**I_5**	**V_6**	**I_6**	**Pamb**
19.000	5.25	4.90	3.70	4.65	Orange Oil	0.095	12.60	0.3997	10.44	0.7000	12.78	0.4062	10.74	0.7033	12.84	0.4095	10.85	0.7088	30.34
	C101	**C102**	**C103**	**C104**	**C105**	**C106**	**C107**	**C108**	**C109**	**C110**	**C111**	**C112**	**Tven**	**Tjet**	**Tamb**				
	91.46	91.386	91.501	91.949	97.439	97.981	97.691	97.684	91.078	91.247	90.853	91.013	62.647	63.94	69.104				
	C201	**C202**	**C203**	**C204**	**C205**	**C206**	**C207**	**C208**	**C209**	**C210**	**C211**	**C212**	**C213**	**C214**	**C215**	**C216**	**C217**	**C218**	
	7.9E+28	109.064	107.518	109.363	109.148	109.276	109.951	110.032	110.556	110.425	110.171	110.389	109.379	109.022	108.691	108.594	109.161	108.832	
	C301	**C302**	**C303**	**C304**	**C305**	**C306**	**C307**	**C308**	**C309**	**C310**	**C311**	**C312**							
	91.719	91.586	91.724	92.578	101.711	101.968	102.04	101.612	93.375	92.482	92.392	7.9E+28							
Pven	**Psup**	**Pjet**	**$P_{L.E.\ in}$**	**$P_{L.E.\ out}$**	**Man. Liquid**	**ΔPjet**	**V_1**	**I_1**	**V_2**	**I_2**	**V_3**	**I_3**	**V_4**	**I_4**	**V_5**	**I_5**	**V_6**	**I_6**	**Pamb**
30.000	9.40	8.90	8.65	8.45	Orange Oil	0.221	13.40	0.4249	11.10	0.7441	13.63	0.4323	11.39	0.7475	13.63	0.4356	11.55	0.7536	30.34
	C101	**C102**	**C103**	**C104**	**C105**	**C106**	**C107**	**C108**	**C109**	**C110**	**C111**	**C112**	**Tven**	**Tjet**	**Tamb**				
	91.168	90.956	91.075	91.557	97.758	98.284	98.008	97.981	90.65	90.74	90.333	90.466	64.562	64.854	69.743				
	C201	**C202**	**C203**	**C204**	**C205**	**C206**	**C207**	**C208**	**C209**	**C210**	**C211**	**C212**	**C213**	**C214**	**C215**	**C216**	**C217**	**C218**	
	7.9E+28	109.195	110.353	109.55	109.255	109.348	110.144	110.245	110.945	110.678	110.423	110.662	109.386	109.049	108.661	108.646	109.177	108.923	
	C301	**C302**	**C303**	**C304**	**C305**	**C306**	**C307**	**C308**	**C309**	**C310**	**C311**	**C312**							
	90.994	90.855	91.042	91.901	102.04	102.323	102.362	101.939	92.909	91.949	91.93	7.9E+28							
Pven	**Psup**	**Pjet**	**$P_{L.E.\ in}$**	**$P_{L.E.\ out}$**	**Man. Liquid**	**ΔPjet**	**V_1**	**I_1**	**V_2**	**I_2**	**V_3**	**I_3**	**V_4**	**I_4**	**V_5**	**I_5**	**V_6**	**I_6**	**Pamb**
41.000	14.70	13.90	13.60	13.25	Orange Oil	0.332	14.07	0.4462	11.64	0.7817	14.31	0.4539	11.82	0.7751	14.35	0.4581	12.14	0.7915	30.30
	C101	**C102**	**C103**	**C104**	**C105**	**C106**	**C107**	**C108**	**C109**	**C110**	**C111**	**C112**	**Tven**	**Tjet**	**Tamb**				
	90.871	90.617	90.772	91.325	98.156	98.692	98.492	98.447	90.544	90.626	90.29	90.382	66.708	66.073	69.692				
	C201	**C202**	**C203**	**C204**	**C205**	**C206**	**C207**	**C208**	**C209**	**C210**	**C211**	**C212**	**C213**	**C214**	**C215**	**C216**	**C217**	**C218**	
	7.9E+28	109.31	111.433	109.598	109.24	109.409	110.191	110.331	110.983	110.824	110.498	110.671	109.458	109.109	108.684	108.716	109.305	108.999	
	C301	**C302**	**C303**	**C304**	**C305**	**C306**	**C307**	**C308**	**C309**	**C310**	**C311**	**C312**							
	90.614	90.454	90.634	91.508	102.447	102.737	102.856	102.319	92.614	91.724	91.64	7.9E+28							
Pven	**Psup**	**Pjet**	**$P_{L.E.\ in}$**	**$P_{L.E.\ out}$**	**Man. Liquid**	**ΔPjet**	**V_1**	**I_1**	**V_2**	**I_2**	**V_3**	**I_3**	**V_4**	**I_4**	**V_5**	**I_5**	**V_6**	**I_6**	**Pamb**
52.000	21.20	20.05	20.30	19.15	Orange Oil	0.475	14.56	0.4617	12.08	0.8100	14.81	0.4700	12.35	0.8079	14.83	0.4735	12.55	0.8176	30.28
	C101	**C102**	**C103**	**C104**	**C105**	**C106**	**C107**	**C108**	**C109**	**C110**	**C111**	**C112**	**Tven**	**Tjet**	**Tamb**				
	90.596	90.304	90.434	91.033	98.302	98.901	98.667	98.642	90.313	90.367	90.036	90.193	67.48	67.234	70.463				
	C201	**C202**	**C203**	**C204**	**C205**	**C206**	**C207**	**C208**	**C209**	**C210**	**C211**	**C212**	**C213**	**C214**	**C215**	**C216**	**C217**	**C218**	
	7.9E+28	108.916	109.494	109.262	108.893	109.031	109.919	110.097	110.918	110.592	110.237	110.502	109.053	108.628	108.279	108.299	108.911	108.61	
	C301	**C302**	**C303**	**C304**	**C305**	**C306**	**C307**	**C308**	**C309**	**C310**	**C311**	**C312**							
	89.998	89.798	90.036	90.905	102.353	102.683	102.778	102.242	92.151	91.174	91.193	7.9E+28							
Pven	**Psup**	**Pjet**	**$P_{L.E.\ in}$**	**$P_{L.E.\ out}$**	**Man. Liquid**	**ΔPjet**	**V_1**	**I_1**	**V_2**	**I_2**	**V_3**	**I_3**	**V_4**	**I_4**	**V_5**	**I_5**	**V_6**	**I_6**	**Pamb**
63.500	29.80	28.25	28.50	27.00	Orange Oil	0.621	15.30	0.4820	12.69	0.8525	15.54	0.4913	12.96	0.8443	15.60	0.4947	13.14	0.8530	30.28
	C101	**C102**	**C103**	**C104**	**C105**	**C106**	**C107**	**C108**	**C109**	**C110**	**C111**	**C112**	**Tven**	**Tjet**	**Tamb**				
	90.866	90.283	90.4	91.082	98.906	99.392	99.225	99.266	90.306	90.4	89.986	90.144	70.7	67.8	70.4				
	C201	**C202**	**C203**	**C204**	**C205**	**C206**	**C207**	**C208**	**C209**	**C210**	**C211**	**C212**	**C213**	**C214**	**C215**	**C216**	**C217**	**C218**	
	7.9E+28	108.976	107.136	109.354	108.911	109.024	109.942	110.108	110.891	110.646	110.25	110.497	108.956	108.56	108.106	108.167	108.79	108.502	
	C301	**C302**	**C303**	**C304**	**C305**	**C306**	**C307**	**C308**	**C309**	**C310**	**C311**	**C312**							
	89.541	89.311	89.582	90.436	102.598	102.985	103.075	102.481	91.854	90.801	90.815	7.9E+28							
Pven	**Psup**	**Pjet**	**$P_{L.E.\ in}$**	**$P_{L.E.\ out}$**	**Man. Liquid**	**ΔPjet**	**V_1**	**I_1**	**V_2**	**I_2**	**V_3**	**I_3**	**V_4**	**I_4**	**V_5**	**I_5**	**V_6**	**I_6**	**Pamb**
74.500	10.80	10.20	10.20	9.80	Red Oil	0.810	16.12	0.5040	13.37	0.8851	16.36	0.5130	13.65	0.8809	16.42	0.5159	13.84	0.8889	30.24
	C101	**C102**	**C103**	**C104**	**C105**	**C106**	**C107**	**C108**	**C109**	**C110**	**C111**	**C112**	**Tven**	**Tjet**	**Tamb**				
	90.65	89.705	89.786	90.569	99.05	99.549	99.358	99.382	89.869	89.921	89.53	89.683	73.5	67.9	70.4				
	C201	**C202**	**C203**	**C204**	**C205**	**C206**	**C207**	**C208**	**C209**	**C210**	**C211**	**C212**	**C213**	**C214**	**C215**	**C216**	**C217**	**C218**	
	7.9E+28	108.837	111.539	109.283	108.797	108.985	109.951	110.126	111.076	110.687	110.286	110.578	108.898	108.418	107.991	108.054	108.763	108.463	
	C301	**C302**	**C303**	**C304**	**C305**	**C306**	**C307**	**C308**	**C309**	**C310**	**C311**	**C312**							
	88.909	88.675	88.969	89.816	102.848	103.205	103.232	102.632	91.328	90.275	90.27	7.9E+28							
Pven	**Psup**	**Pjet**	**$P_{L.E.\ in}$**	**$P_{L.E.\ out}$**	**Man. Liquid**	**ΔPjet**	**V_1**	**I_1**	**V_2**	**I_2**	**V_3**	**I_3**	**V_4**	**I_4**	**V_5**	**I_5**	**V_6**	**I_6**	**Pamb**
90.000	14.80	14.00	14.00	13.60	Red Oil	2.750	16.93	0.5242	14.10	0.9231	17.24	0.5342	14.35	0.9187	17.23	0.5354	14.55	0.9250	30.24
	C101	**C102**	**C103**	**C104**	**C105**	**C106**	**C107**	**C108**	**C109**	**C110**	**C111**	**C112**	**Tven**	**Tjet**	**Tamb**				
	89.714	89.264	89.429	90.216	99.322	99.819	99.682	99.749	89.606	89.654	89.246	89.433	77.3	68.7	70.8				
	C201	**C202**	**C203**	**C204**	**C205**	**C206**	**C207**	**C208**	**C209**	**C210**	**C211**	**C212**	**C213**	**C214**	**C215**	**C216**	**C217**	**C218**	
	7.9E+28	108.677	106.259	109.141	108.616	108.796	109.948	110.133	111.217	110.66	110.266	110.534	108.688	108.176	107.705	107.807	108.535	108.257	
	C301	**C302**	**C303**	**C304**	**C305**	**C306**	**C307**	**C308**	**C309**	**C310**	**C311**	**C312**							
	88.303	88.009	88.261	89.186	103.039	103.43	103.394	102.811	90.839	89.779	89.744	7.9E+28							

Test # 6   8 Holes Circular

Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	6.05	5.85	4.55	5.90	Orange Oil	0.078	12.38	0.3923	10.29	0.6908	12.51	0.3985	10.52	0.6902	12.35	0.3945	10.64	0.6949	30.4
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.91	91.958	92.257	92.525	100.319	101.036	100.811	100.782	92.612	92.853	92.396	92.309	62.185	64.132	68.209				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	107.78	108.963	108.097	107.791	107.759	110.027	109.969	110.333	110.351	110.162	110.549	108.598	108.511	108.175	108.135	108.337	108.072	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	88.765	88.744	88.958	89.635	99.527	99.583	99.718	99.504	91.64	90.94	90.819	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	10.50	10.15	9.40	10.30	Orange Oil	0.135	13.10	0.4148	10.91	0.7315	13.27	0.4221	11.16	0.7315	13.25	0.4232	11.28	0.7361	30.4
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.832	90.882	91.156	91.472	100.229	100.908	100.705	100.697	91.719	92.036	91.494	91.393	63.486	64.422	68.42				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	107.55	109.3	107.872	107.492	107.462	110.047	109.964	110.221	110.41	110.156	110.626	108.571	108.482	108.031	108.027	108.299	108.079	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.835	87.772	88.043	88.745	99.526	99.623	99.758	99.531	90.972	90.155	90.099	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	16.50	16.00	14.75	16.20	Orange Oil	0.203	13.85	0.4381	11.57	0.7748	14.02	0.4456	11.80	0.7723	14.03	0.4481	11.89	0.7757	30.40
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.955	89.941	90.248	90.63	100.186	100.895	100.755	100.703	91.051	91.386	90.839	90.715	64.985	65.029	68.625				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	107.395	109.611	107.739	107.24	107.167	110.047	109.964	110.317	110.425	110.128	110.641	108.439	108.311	107.897	107.838	108.16	107.935	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.037	87.001	87.307	87.986	99.761	99.828	99.922	99.718	90.383	89.519	89.518	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	24.00	23.30	22.00	23.55	Orange Oil	0.285	14.47	0.4587	12.10	0.8098	14.67	0.4658	12.36	0.8079	14.67	0.4684	12.46	0.8124	30.4
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.275	89.267	89.617	90.022	100.139	100.87	100.719	100.696	90.594	90.905	90.392	90.286	66.643	65.806	68.884				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	107.239	105.716	107.611	107.066	106.927	110.056	109.991	110.482	110.488	110.191	110.678	108.392	108.229	107.798	107.795	108.119	107.865	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.661	86.499	86.816	87.556	100.123	100.273	100.336	100.096	90.122	89.181	89.185	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	9.40	9.20	8.70	9.30	Red Oil	0.379	15.24	0.4832	12.68	0.8516	15.46	0.4910	12.99	0.8503	15.43	0.4918	13.08	0.8532	30.4
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.794	88.274	88.603	89.091	100.157	100.822	100.748	100.705	89.689	90.023	89.442	89.312	67.9	65.1	68.9				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	107.015	107.897	107.343	106.74	106.636	110.111	110.039	110.641	110.547	110.239	110.79	108.146	108	107.53	107.521	107.89	107.654	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.482	85.322	85.718	86.382	100.303	100.424	100.458	100.242	89.276	88.252	88.292	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	12.30	12.00	11.40	12.20	Red Oil	0.483	15.51	0.4914	12.90	0.8655	15.72	0.4993	13.20	0.8661	15.73	0.5015	13.32	0.8683	30.4
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.961	88.715	89.037	89.451	100.573	101.29	101.203	101.133	90.094	90.409	89.836	89.721	71.5	67.4	69				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	106.702	107.185	107.091	106.387	106.261	109.89	109.809	110.288	110.309	109.984	110.57	107.874	107.692	107.228	107.248	107.611	107.397	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.772	85.604	85.847	86.647	100.742	100.789	100.885	100.586	89.575	88.58	88.623	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	17.20	16.80	14.00	17.10	Red Oil	0.652	16.00	0.5069	13.32	0.8936	16.23	0.5151	13.62	0.8924	16.30	0.5199	13.72	0.8934	30.4
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.215	88.783	89.019	89.582	101.369	102.024	101.992	101.921	90.315	90.63	90.05	89.917	75.1	68.9	69				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	106.711	104.733	107.066	106.369	106.222	110.039	109.973	110.623	110.533	110.225	110.741	108.167	107.933	107.491	107.528	107.928	107.701	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.631	85.484	85.802	86.521	101.383	101.558	101.572	101.255	89.546	88.528	88.589	7.9E+28							

Test # 7 8 Holes both-ends-open

Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	0.627	0.516	0.159	0.485	H2O	0.111	13.19	0.4183	11.02	0.7374	13.39	0.4240	11.32	0.7401	13.40	0.4273	11.34	0.7417	30.16
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	92.088	92.142	92.459	92.666	99.896	100.627	100.341	100.224	92.068	92.518	91.973	91.795	60.572	62.545	68.33				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.013	109.881	109.193	109.233	109.424	110.079	109.953	110.174	110.025	109.796	110.281	109.807	109.215	109.024	108.972	109.463	109.301	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	90.497	90.209	90.284	91.197	99.083	98.942	98.998	98.951	92.484	91.503	91.519	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	2.70	0.915	0.300	0.855	H2O	0.175	14.22	0.4509	11.79	0.7900	14.37	0.4571	12.17	0.7989	14.37	0.4589	12.22	0.7984	30.16
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.145	91.188	91.483	91.71	99.929	100.724	100.372	100.282	91.091	91.544	90.994	90.785	62.008	62.663	68.643				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.929	110.93	109.125	109.143	109.357	110.09	109.935	110.201	110.023	109.786	110.329	109.741	109.094	108.833	108.851	109.4	109.256	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	89.343	89.068	89.138	90.077	98.899	98.75	98.822	98.8	91.472	90.434	90.445	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	4.20	3.50	2.00	3.30	Orange Oil	0.283	14.90	0.4729	12.53	0.8388	15.09	0.4784	12.76	0.8367	15.11	0.4836	12.80	0.8352	30.16
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.724	90.749	91.021	91.292	100.292	101.032	100.723	100.602	90.682	91.219	90.625	90.47	63.864	63.614	68.452				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.794	111.179	108.938	108.9	109.112	109.998	109.818	110.198	110.007	109.688	110.268	109.714	109.021	108.83	108.86	109.454	109.321	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	88.767	88.465	88.51	89.503	98.93	98.761	98.809	98.773	90.959	89.833	89.881	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	6.00	5.05	3.75	4.70	Orange Oil	0.404	15.50	0.4911	12.96	0.8677	15.65	0.4978	13.26	0.8674	15.77	0.5029	13.27	0.8645	30.16
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.373	90.313	90.616	90.887	100.534	101.362	101.056	100.894	90.367	90.844	90.256	90.081	65.632	64.429	68.546				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.695	106.778	108.873	108.853	109.087	110.066	109.908	110.506	110.108	109.789	110.351	109.82	109.012	108.819	108.855	109.48	109.399	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	88.403	88.101	88.164	89.174	99.164	98.989	99.038	99.004	90.635	89.498	89.546	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	8.45	7.10	5.50	6.70	Orange Oil	0.515	16.14	0.5110	13.48	0.9038	16.29	0.5180	13.80	0.9028	16.41	0.5229	13.84	0.9017	30.16
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.739	89.66	90.045	90.344	100.413	101.218	100.98	100.841	89.883	90.463	89.795	89.588	66.3	64.8	68.9				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.149	105.881	108.351	108.29	108.571	109.618	109.46	110.041	109.618	109.294	109.921	109.321	108.506	108.256	108.344	109.037	108.922	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	88.07	87.716	87.775	88.796	99.126	98.935	98.987	98.887	90.202	89.003	89.093	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	11.05	9.25	7.80	8.80	Orange Oil	0.727	16.60	0.5258	13.73	0.9196	16.81	0.5341	14.22	0.9295	16.95	0.5407	14.23	0.9269	30.16
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.755	89.431	89.851	90.203	100.62	101.455	101.194	101.072	89.899	90.463	89.829	89.627	69.9	65.9	69.1				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.515	109.13	108.743	108.679	108.846	110.063	109.933	110.473	110.066	109.73	110.403	109.849	108.934	108.718	108.824	109.593	109.517	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	88.069	87.674	87.761	88.794	99.637	99.448	99.475	99.45	90.315	89.075	89.208	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	15.55	13.15	11.75	12.50	Orange Oil	2.500	17.19	0.5441	14.31	0.9582	17.38	0.5520	14.66	0.9591	17.46	0.5573	14.71	0.9584	30.16
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.178	89.935	90.317	90.724	101.705	102.559	102.299	102.17	90.173	90.752	90.133	89.881	73.7	68	69.1				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	108.486	110.738	108.698	108.58	108.805	110.034	109.881	110.594	110.164	109.654	110.419	109.768	108.853	108.643	108.796	109.528	109.46	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	88.328	87.917	87.997	89.059	100.249	100.055	100.051	99.983	90.52	89.197	89.357	7.9E+28							

Test # 8 8 Holes 2-inlets-2outlets

Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	0.618	0.534	0.335	0.497	H2O	0.095	12.48	0.3955	10.37	0.6963	12.55	0.3986	10.64	0.6974	12.71	0.4058	10.64	0.6951	30.01
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	92.304	92.311	92.468	92.619	98.474	99.065	98.77	98.735	92.043	92.34	91.973	91.908	61.567	64.267	69.64				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.636	110.506	109.759	109.382	109.534	110.02	110.027	110.529	110.317	110.2	110.421	110.237	109.969	109.809	109.859	110.165	109.951	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	91.274	91.118	91.287	91.967	100.136	100.204	100.307	100.067	93.136	92.329	92.313	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	2.60	0.925	0.814	0.864	Orange Oil	0.156	13.43	0.4257	11.12	0.7474	13.50	0.4290	11.46	0.7501	13.70	0.4369	11.45	0.7471	30.01
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.042	90.985	91.195	91.471	98.078	98.721	98.485	98.393	90.995	91.294	90.886	90.859	63.146	64.375	69.572				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.589	108.455	109.692	109.289	109.463	110.03	110.048	110.66	110.381	110.2	110.533	110.326	110.011	109.766	109.809	110.23	109.987	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	90.097	89.973	90.146	90.805	99.922	100.039	100.103	99.828	92.138	91.296	91.292	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	4.10	3.55	3.10	3.30	Orange Oil	0.220	14.18	0.4487	11.77	0.7889	14.25	0.4523	12.09	0.7915	14.47	0.4613	12.08	0.7879	30.01
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.386	89.147	89.375	89.716	97.868	98.518	98.253	98.156	89.156	89.483	88.987	89.001	64.72	64.76	69.48				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.573	108.895	109.651	109.118	109.244	110.052	110.012	110.819	110.365	110.097	110.437	110.176	109.775	109.564	109.66	110.162	109.845	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	88.042	87.77	88.054	88.749	99.545	99.715	99.729	99.389	90.247	89.275	89.294	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	5.85	5.05	4.00	4.80	Orange Oil	0.322	14.88	0.4717	12.40	0.8305	14.99	0.4755	12.71	0.8323	15.24	0.4858	12.71	0.8287	30.01
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.928	89.564	89.824	90.131	98.091	98.748	98.503	98.426	89.696	90.038	89.582	89.53	62.75	64.34	69.6				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.658	109.435	109.724	109.274	109.391	110.185	110.227	110.993	110.565	110.279	110.659	110.358	109.962	109.728	109.831	110.281	109.998	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	88.549	88.326	88.556	89.269	99.77	99.871	99.965	99.614	90.765	89.824	89.807	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	8.25	7.20	6.30	6.75	Orange Oil	0.453	15.54	0.4924	12.98	0.8704	15.67	0.4976	13.29	0.8701	15.93	0.5080	13.30	0.8661	30.02
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.961	88.83	89.08	89.503	98.068	98.741	98.532	98.469	89.141	89.518	89.035	88.992	64.825	65.248	69.878				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.462	110.457	109.593	109.035	109.177	110.012	110.038	110.695	110.439	110.088	110.47	110.182	109.759	109.483	109.586	110.081	109.845	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.777	87.613	87.829	88.562	99.581	99.718	99.803	99.448	90.079	89.102	89.134	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	10.80	9.40	8.60	8.90	Orange Oil	0.595	16.04	0.5083	13.39	0.8969	16.15	0.5132	13.69	0.8967	16.43	0.5238	13.68	0.8910	30.02
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.771	88.52	88.805	89.215	98.298	98.872	98.681	98.6	88.929	89.282	88.781	88.787	70.1	65.7	69.7				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.373	107.348	109.505	108.902	109.048	109.982	109.991	110.911	110.371	110.005	110.453	110.079	109.557	109.357	109.471	110.002	109.696	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.5	87.251	87.543	88.236	99.688	99.891	99.918	99.518	89.764	88.812	88.79	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	15.10	13.15	12.40	12.50	Orange Oil	0.810	16.69	0.5288	13.92	0.9337	16.81	0.5339	14.25	0.9320	16.86	0.5377	14.23	0.9280	30.02
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.186	88.45	88.749	89.197	98.744	99.38	99.167	99.121	88.798	89.15	88.645	88.675	72.9	66.8	69.9				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	7.9E+28	109.456	107.667	109.557	108.904	109.129	109.93	109.933	110.911	110.309	109.84	110.293	109.571	109.049	108.81	108.968	109.512	109.217	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.399	87.233	87.449	88.202	100.247	100.438	100.462	100.084	89.735	88.758	88.767	7.9E+28							

Test # 9   7 Holes parallel

Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	5.30	5.00	5.05	4.75	Orange Oil	0.118	13.45	0.4264	11.27	0.7569	13.36	0.4244	11.47	0.7512	13.65	0.4342	11.24	0.7326	29.93
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.23	88.02	88.242	88.895	96.596	97.29	96.855	96.891	88.156	88.108	87.736	87.138	52.9	55.68	64.36				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.372	107.942	111.911	108.453	108.27	108.38	109.65	109.71	110.479	110.417	110.191	110.471	108.85	108.678	108.238	108.176	108.46	108.738	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.631	86.385	86.497	87.555	98.64	99.269	99.246	98.779	88.779	87.632	87.893	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	9.50	9.00	9.05	8.55	Orange Oil	0.215	14.36	0.4555	12.09	0.8117	14.28	0.4540	12.29	0.8032	14.57	0.4644	12.03	0.7837	29.94
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.283	88.029	88.22	88.855	96.566	97.189	96.955	96.881	88.056	88.108	87.746	87.838	54.889	56.479	64.757				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.362	107.932	111.611	108.452	108.137	108.18	109.75	109.811	110.479	110.417	110.171	110.371	108.95	108.698	108.158	108.196	108.86	108.538	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.611	86.285	86.497	87.565	98.84	99.169	99.216	98.789	88.769	87.732	87.793	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	14.80	14.00	14.10	13.35	Orange Oil	0.325	15.13	0.4798	12.76	0.8556	15.03	0.4777	12.96	0.8468	15.34	0.4889	12.71	0.8288	29.94
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.243	87.793	88.016	88.702	97.231	97.834	97.535	97.528	87.851	87.937	87.505	87.586	57.352	57.771	65.677				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.664	108.232	111.856	108.731	108.436	108.513	110.214	110.304	111.035	110.909	110.587	110.842	109.278	108.911	108.356	108.367	109.136	108.83	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.182	85.865	86.006	87.093	99.369	99.707	99.769	99.151	88.432	87.302	87.35	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	21.50	20.40	20.60	19.45	Orange Oil	0.460	15.65	0.4963	13.20	0.8851	15.43	0.4929	13.39	0.8759	15.85	0.5045	13.13	0.8545	29.93
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.13	87.593	87.768	88.549	97.6	98.181	97.967	97.947	87.647	87.716	87.264	87.399	58.403	58.786	65.923				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.378	107.933	104.515	108.506	108.151	108.225	109.978	110.119	110.986	110.734	110.378	110.597	108.756	108.369	107.78	107.851	108.589	108.288	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.601	85.228	85.489	86.535	99.347	99.794	99.733	99.257	87.908	86.812	86.83	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	30.40	28.95	29.20	27.70	Orange Oil	0.625	16.25	0.5150	13.70	0.9176	16.10	0.5118	13.89	0.9079	16.42	0.5224	13.60	0.8854	29.94
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	87.898	87.449	87.626	88.492	98.154	98.78	98.581	98.608	87.775	87.844	87.394	87.575	61.078	61.043	66.94				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.398	107.903	111.735	108.45	108.081	108.135	110.047	110.099	111.04	110.821	110.405	110.689	108.673	108.335	107.728	107.804	108.612	108.196	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.414	85.149	85.394	86.405	99.902	100.402	100.33	99.787	87.966	86.899	86.947	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	11.00	10.40	10.60	10.00	Red Oil	0.761	17.22	0.5459	14.57	0.9761	17.08	0.5427	14.68	0.9592	17.43	0.5542	14.44	0.9384	29.98
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	86.206	85.581	85.739	86.782	97.769	98.453	98.35	98.228	86.234	86.24	85.801	86.029	60.595	59.231	66.47				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.022	107.595	110.808	108.22	107.631	107.674	109.984	110.083	111.244	110.979	110.534	110.664	108.342	108.054	107.424	107.507	108.292	107.899	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	84.004	83.714	83.993	85.061	100.355	100.825	100.8	100.17	86.879	85.684	85.714	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	15.00	14.20	14.40	13.60	Red Oil	2.500	17.88	0.5765	15.17	1.0150	17.78	0.5639	15.27	0.9667	18.11	0.5763	14.99	0.9754	29.98
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	86.542	85.862	85.97	87.055	98.626	99.257	99.194	99.031	86.38	86.386	85.905	86.108	62.737	60.863	66.006				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.054	107.631	108.333	108.236	107.645	107.663	110.032	110.196	111.508	111.105	110.599	110.759	108.202	107.915	107.233	107.348	108.112	107.701	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	84.163	83.889	84.15	85.198	101.023	101.461	101.41	100.705	86.742	85.612	85.63	7.9E+28							

Test # 10   7 Holes Circular

Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	5.75	5.55	5.25	5.65	Orange Oil	0.090	13.60	0.4315	11.40	0.7670	13.50	0.4294	11.54	0.7546	13.46	0.4278	11.44	0.7489	30.39
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.963	88.99	89.375	89.782	99.585	100.341	100.087	100.033	89.775	90.173	89.496	89.284	51.307	54.693	63.002				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	106.909	107.066	105.838	107.53	107.186	107.122	110.002	109.906	110.237	110.264	110.02	110.448	107.78	107.798	107.262	107.163	107.354	107.041	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	84.832	84.742	84.987	85.88	97.425	97.544	97.634	97.375	87.415	86.589	86.531	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	10.00	9.60	9.10	9.80	Orange Oil	0.153	14.47	0.4593	12.17	0.8161	14.39	0.4569	12.29	0.8039	14.34	0.4568	12.16	0.7930	30.39
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	87.869	87.813	88.166	88.621	99.607	100.418	100.217	100.075	88.589	88.978	88.268	88.103	53.861	55.526	63.358				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	106.592	106.677	104.279	107.154	106.686	106.6	109.917	109.802	110.252	110.183	109.924	110.425	107.14	107.129	106.591	106.511	106.776	106.517	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	83.714	83.644	83.882	84.692	97.349	97.463	97.556	97.319	86.155	85.291	85.266	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	15.85	15.25	15.50	15.65	Orange Oil	0.232	15.29	0.4850	12.87	0.8631	15.21	0.4830	12.97	0.8498	15.17	0.5837	12.88	0.8393	30.41
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	87.178	87.075	87.453	87.952	99.877	100.705	100.512	100.413	88.018	88.423	87.66	87.534	56.176	56.693	63.414				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	106.454	106.551	104.459	106.994	106.468	106.328	110.002	109.895	110.383	110.329	110.104	110.614	107.357	107.316	106.713	106.668	107.032	106.767	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	82.827	82.728	82.982	83.882	97.58	97.704	97.787	97.573	85.66	84.766	84.735	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	23.30	22.50	21.25	22.75	Orange Oil	0.330	16.01	0.5079	13.46	0.9035	15.88	0.5040	13.61	0.8894	15.93	0.5072	13.47	0.8785	30.41
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	86.328	86.155	86.492	87.082	99.86	100.688	100.49	100.42	87.149	87.554	86.809	86.643	57.731	57.272	63.351				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	106.164	106.303	107.514	106.79	106.151	105.989	109.903	109.784	110.385	110.263	109.942	110.493	106.994	106.916	106.313	106.333	106.639	106.427	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	81.997	81.869	82.109	83.045	97.87	98.003	97.988	97.738	85.05	84.042	84.022	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	9.00	8.70	8.30	8.80	Red Oil	0.436	16.56	0.5250	13.96	0.9351	16.43	0.5210	14.01	0.9127	16.44	0.5238	13.89	0.9061	30.41
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	86.445	86.126	86.515	87.16	100.456	101.318	101.178	101.137	87.413	87.777	87.066	86.929	59.468	59.582	63.812				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	106.114	106.259	105.824	106.769	106.106	105.934	110.059	109.998	110.617	110.516	110.243	110.828	107.37	107.276	106.65	106.636	107.01	106.798	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	82.201	81.986	82.318	83.18	98.699	98.798	98.806	98.512	85.621	84.643	84.676	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	11.90	11.50	10.90	11.70	Red Oil	0.535	17.04	0.5407	14.29	0.9590	16.90	0.5364	14.43	0.9414	16.97	0.5397	14.32	0.9326	30.39
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	85.255	85.016	85.435	86.076	100.067	100.94	100.892	100.762	86.49	86.843	86.148	85.97	63.1	59.062	64.9				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	105.602	105.736	106.047	106.297	105.601	105.399	109.958	109.845	110.556	110.41	110.038	110.675	107.003	106.909	106.252	106.263	106.661	106.423	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	80.98	80.782	81.079	82.035	98.573	98.793	98.716	98.424	84.85	83.813	83.846	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	16.50	16.10	15.30	16.30	Red Oil	0.723	17.83	0.5650	14.98	1.0042	17.65	0.5611	15.20	0.9922	17.71	0.5640	14.96	0.9745	30.39
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	85.003	84.235	84.613	85.343	100.435	101.344	101.335	101.149	85.894	86.206	85.478	85.37	66.2	59.4	64.8				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	104.933	105.025	103.144	105.617	104.872	104.65	109.784	109.643	110.385	110.281	109.886	110.551	106.538	106.481	105.71	105.723	106.204	105.937	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	79.826	79.594	80.199	80.793	98.761	98.968	98.84	98.536	83.858	82.746	82.827	7.9E+28							

Test # 11 7 Holes Both-Ends-Open

Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	0.620	0.515	0.471	0.482	H_2O	0.105	14.39	0.4564	12.10	0.8118	14.31	0.4541	12.22	0.8006	14.24	0.4535	12.10	0.7909	30.05
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.896	90.907	91.294	91.534	100.768	101.653	101.273	101.158	90.85	91.381	90.725	90.398	51.601	54.666	63.428				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.499	108.302	110.493	108.592	108.621	108.76	110.009	109.888	110.198	110.081	109.805	110.3	109.267	108.751	108.486	108.466	108.83	108.686	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.599	87.228	87.26	88.367	97.097	96.998	97.004	97.009	89.381	88.22	88.274	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	2.70	0.905	0.725	0.855	H_2O	0.192	15.29	0.4850	12.86	0.8629	15.19	0.4852	13.02	0.8515	15.23	0.4851	12.89	0.8404	29.98
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.288	90.211	90.58	90.875	101.214	102.08	101.828	101.651	90.396	90.994	90.322	89.966	54.364	55.942	63.855				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.448	108.155	107.98	108.382	108.443	108.511	110.162	110.003	110.432	110.284	110.018	110.488	109.541	108.979	108.68	108.707	109.21	109.129	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.56	86.152	86.206	87.298	97.033	96.903	96.91	96.939	88.6	87.385	87.529	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	4.20	3.50	3.10	3.30	Orange Oil	0.293	16.11	0.5110	13.56	0.9096	15.98	0.5082	13.72	0.8950	16.06	0.5116	13.57	0.8847	29.98
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.566	89.447	89.881	90.241	101.466	102.384	102.132	101.966	89.827	90.459	89.712	89.377	56.925	57.238	64.361				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.281	108.04	109.337	108.293	108.245	108.347	110.101	109.937	110.491	110.27	109.949	110.5	109.436	108.848	108.533	108.599	109.159	109.096	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.011	85.586	85.579	86.733	97.249	97.097	97.056	97.099	88.119	86.832	86.963	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	6.00	5.00	4.60	4.75	Orange Oil	0.413	16.78	0.5319	14.11	0.9467	16.64	0.5287	14.28	0.9333	16.72	0.5320	14.11	0.9212	29.97
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.206	89.037	89.464	89.82	101.776	102.724	102.497	102.366	89.541	90.202	89.402	89.033	58.088	58.054	64.562				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.182	107.784	110.252	108.097	108.101	108.214	110.176	109.953	110.554	110.372	110.018	110.632	109.661	109.003	108.688	108.767	109.355	109.269	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.86	85.336	85.405	86.587	97.762	97.508	97.573	97.522	88.047	86.648	86.832	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	8.40	7.05	6.50	6.65	Orange Oil	0.558	17.71	0.5616	14.91	0.9993	17.57	0.5581	15.01	0.9797	17.62	0.5604	14.86	0.9674	29.96
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.038	87.646	88.085	88.519	101.381	102.415	102.15	102.002	88.357	89.012	88.231	87.838	60.34	57.742	64.751				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.032	107.651	109.318	107.919	107.894	108.02	110.032	109.845	110.511	110.18	109.802	110.491	109.442	108.625	108.286	108.405	109.087	109.075	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	84.73	84.172	84.235	85.451	97.414	97.171	97.169	97.214	87.059	85.603	85.788	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	11.00	9.20	8.60	8.75	Orange Oil	0.722	18.18	0.5764	15.30	1.0254	18.04	0.5730	15.49	1.0120	18.17	0.5782	15.28	0.9954	29.97
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	87.329	86.936	87.412	87.829	101.146	102.121	101.956	101.797	87.705	88.362	87.556	87.206	64.7	58.167	64.958				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.743	107.212	110.153	107.537	107.494	107.645	109.825	109.562	110.309	109.971	109.571	110.25	109.228	108.347	107.986	108.128	108.85	108.797	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	84.202	83.615	83.7	84.881	97.267	97.033	96.988	96.982	86.481	85.064	85.23	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	15.35	12.90	11.80	12.25	Orange Oil	0.995	19.05	0.6401	16.07	1.0753	18.89	0.6001	16.22	1.0601	19.08	0.6068	16.02	1.0428	29.96
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	87.536	87.107	87.593	88.076	102.046	103.027	102.901	102.724	88.164	88.808	87.962	87.61	68.5	59.751	65.696				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.818	107.42	106.783	107.683	107.599	107.784	110.016	109.712	110.563	110.237	109.744	110.405	109.631	108.805	108.448	108.572	109.289	109.226	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.187	84.487	84.452	86.143	97.105	97.133	97.061	97.054	86.524	84.956	85.171	7.9E+28							

Test # 12 6 Holes Parallel

Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	5.25	4.90	4.95	4.65	Orange Oil	0.146	14.06	0.4455	12.32	0.8286	14.14	0.4494	12.03	0.7881	14.25	0.4557	11.98	0.7827	30.31
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.256	90.902	90.999	91.669	99.281	99.58	99.423	99.641	92.338	92.547	92.268	92.171	51.604	54.214	62.8				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	109.01	108.47	105.986	108.862	108.812	108.952	109.991	110.081	110.597	110.547	110.399	110.57	110.61	109.903	109.471	109.521	110.41	110.255	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.856	87.462	87.604	88.799	98.935	99.202	99.337	98.957	89.568	88.466	88.533	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	9.50	8.90	8.85	8.45	Orange Oil	0.251	15.13	0.4795	13.29	0.8909	15.20	0.4837	12.96	0.8493	15.17	0.4845	12.82	0.8372	30.32
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.239	89.809	89.93	90.675	99.389	99.729	99.569	99.841	91.512	91.674	91.388	91.355	53.597	54.99	63.486				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.931	108.373	110.459	108.805	108.796	108.92	110.038	110.088	110.777	110.63	110.425	110.669	110.405	109.651	109.127	109.229	110.182	110.025	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.855	86.409	86.596	87.817	99.04	99.32	99.463	99	88.63	87.505	87.541	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	14.70	13.80	13.75	13.15	Orange Oil	0.375	15.93	0.5046	13.99	0.9365	16.03	0.5094	13.70	0.8974	16.10	0.5139	13.58	0.8861	30.32
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.582	89.068	89.186	90.052	99.632	99.918	99.815	100.12	90.905	91.044	90.74	90.727	55.242	55.732	63.603				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.909	108.338	105.534	108.812	108.761	108.898	110.191	110.309	111.056	110.862	110.61	110.862	110.405	109.553	108.977	109.075	110.189	110.038	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.995	85.601	85.729	87.021	99.268	99.698	99.752	99.232	88.047	86.805	86.888	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	21.35	20.05	20.15	19.10	Orange Oil	0.532	16.67	0.5284	14.64	0.9803	16.77	0.5319	14.34	0.9391	16.92	0.5399	14.20	0.9257	30.32
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.902	88.382	88.493	89.476	99.877	100.111	100.055	100.359	90.306	90.497	90.175	90.158	55.948	56.732	64.48				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.738	108.193	104.445	108.632	108.508	108.675	110.113	110.198	111.006	110.794	110.466	110.77	110.367	109.427	108.902	109.012	110.131	109.969	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.284	84.85	85.081	86.299	99.475	99.891	99.938	99.364	87.653	86.368	86.434	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	29.90	28.20	28.40	26.90	Orange Oil	0.715	17.44	0.5533	15.31	1.0241	17.56	0.5575	14.99	0.9828	17.74	0.5661	14.87	0.9694	30.32
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.13	87.399	87.511	88.65	99.896	100.136	100.096	100.435	89.559	89.716	89.363	89.428	57.7	57	64.7				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.677	107.966	103.768	108.432	108.308	108.504	110.07	110.147	111.091	110.855	110.533	110.79	110.225	109.256	108.621	108.788	110.018	109.834	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	84.123	83.585	83.821	85.16	99.419	99.932	99.956	99.337	86.654	85.336	85.453	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	10.70	10.20	10.20	9.74	Red Oil	0.911	18.14	0.5751	15.88	1.0630	18.27	0.5804	15.65	1.0223	18.55	0.5918	15.47	1.0071	30.32
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	87.529	86.899	86.971	88.094	99.956	100.132	100.089	100.474	88.828	88.888	88.582	88.63	59.5	57	65.4				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.619	107.924	107.636	108.5	108.295	108.49	110.102	110.151	111.215	110.945	110.466	110.794	110.286	109.265	108.641	108.821	110.061	109.946	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	83.309	82.793	82.942	84.346	99.59	100.057	100.116	99.421	86.144	84.796	84.892	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	14.80	14.00	14.10	13.40	Red Oil	3.750	18.92	0.6025	16.68	1.1155	19.11	0.6067	16.37	1.0684	19.42	0.6196	16.16	1.0514	30.31
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	87.293	86.499	86.548	87.851	100.669	100.861	100.827	101.236	88.612	88.699	88.353	88.452	62.3	57.5	65.7				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.497	107.645	103.264	108.187	108.045	108.252	110.101	110.214	111.31	110.988	110.603	110.862	110.336	109.112	108.488	108.691	110.059	109.863	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	82.573	81.999	82.211	83.524	100.012	100.6	100.555	99.803	85.642	84.254	84.389	7.9E+28							

Test # 13   6 Holes Circular

Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	5.95	4.95	4.90	5.75	Orange Oil	0.110	13.76	0.4370	12.04	0.8072	13.83	0.4383	11.78	0.7728	14.01	0.4478	11.73	0.7661	30.42
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.798	89.793	90.09	90.533	101.452	102.22	102.017	101.943	90.369	90.754	90.047	89.825	53.136	56.851	65.266				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	106.745	106.85	104.728	107.298	106.846	106.697	110.122	109.991	110.308	110.468	110.255	110.693	108.153	108.103	107.602	107.6	107.883	107.59	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	84.967	84.922	85.16	85.981	97.393	97.463	97.621	97.466	87.377	86.593	86.542	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	10.35	9.00	9.35	10.00	Orange Oil	0.195	14.76	0.4680	12.90	0.8657	14.81	0.4706	12.63	0.8277	14.94	0.4770	12.52	0.8175	30.42
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.196	88.15	88.542	89.035	101.272	102.071	101.923	101.848	89.1	89.485	88.765	88.533	55.125	57.494	65.954				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	106.13	106.306	109.235	106.781	106.274	106.099	109.973	109.791	110.25	110.374	110.111	110.633	107.77	107.692	107.122	107.149	107.483	107.224	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	83.633	83.561	83.878	84.713	97.353	97.438	97.591	97.371	86.341	85.455	85.439	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	16.40	14.95	14.80	15.90	Orange Oil	0.275	15.47	0.4908	13.56	0.9077	15.56	0.4939	13.33	0.8731	15.80	0.5040	13.20	0.8619	30.39
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	87.338	87.223	87.656	88.223	101.394	102.245	102.132	102.056	88.459	88.873	88.166	87.968	57.076	58.671	66.416				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	105.878	106.061	102.969	106.535	105.997	105.793	110.016	109.892	110.39	110.466	110.23	110.749	107.827	107.703	107.149	107.149	107.552	107.183	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	82.847	82.777	83.039	83.981	97.749	97.954	97.981	97.767	86.285	85.363	85.37	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	23.85	22.75	21.70	23.15	Orange Oil	0.377	16.03	0.5082	14.09	0.9436	16.13	0.5128	13.85	0.9063	16.38	0.5233	13.66	0.8926	30.39
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	86.47	86.324	86.711	87.372	101.349	102.224	102.179	102.058	87.545	87.889	87.151	86.935	58.169	59.31	66.802				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	105.469	105.665	106.159	106.184	105.536	105.264	109.861	109.714	110.363	110.353	110.077	110.63	107.293	107.195	106.52	106.601	107.017	107.237	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	81.974	81.797	82.064	82.984	97.828	98.035	98.032	97.769	85.421	84.434	84.442	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	9.30	8.70	8.50	9.10	Red Oil	0.495	16.83	0.5336	14.90	0.9976	16.92	0.5377	14.60	0.9557	17.21	0.5489	14.32	0.9342	30.39
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	86.301	85.932	86.319	87.034	102.112	103.009	102.89	102.82	87.217	87.577	86.836	86.672	60.12	60.2	67.5				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	105.377	105.566	107.762	106.139	105.426	105.167	110.029	109.859	110.45	110.52	110.192	110.763	107.321	107.161	106.526	106.589	107.033	107.287	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	81.283	81.029	81.333	82.321	98.199	98.41	98.449	98.096	84.94	83.945	83.981	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	12.20	11.70	11.10	11.90	Red Oil	0.600	17.45	0.5537	15.45	1.0339	17.55	0.5570	15.16	0.9913	17.87	0.5691	14.84	0.9691	30.39
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	85.387	85.234	85.536	86.431	102.332	103.244	103.169	103.082	86.603	86.978	86.195	86.072	62.3	60.4	67.3				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	105.046	105.246	102.418	105.853	105.12	104.875	110.187	109.989	110.673	110.612	110.297	110.947	107.084	106.936	106.263	106.348	106.798	106.573	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	80.663	80.44	80.797	81.675	98.501	98.743	98.701	98.372	84.325	83.27	83.297	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	16.80	16.10	15.40	16.30	Red Oil	0.871	18.08	0.5729	15.99	1.0692	18.17	0.5762	15.68	1.0261	18.45	0.5877	15.35	1.0020	30.32
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	85.365	84.962	85.302	86.144	102.595	103.477	103.379	103.325	86.299	86.612	85.882	85.725	64.9	61.6	67.5				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	104.765	104.886	108.016	105.476	104.585	104.299	109.971	109.755	110.437	110.444	110.03	110.7	106.735	106.54	105.8	105.939	106.412	106.211	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	80.293	80.122	80.381	81.338	98.856	99.032	99.007	98.672	83.97	82.939	82.993	7.9E+28							

Test # 14 6 Holes Both-Ends-Open

Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	0.635	0.545	0.465	0.450	H_2O	0.115	14.49	0.4593	12.59	0.8437	14.56	0.4632	12.46	0.8170	14.64	0.4675	12.31	0.8039	29.51
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.721	91.728	92.169	92.486	103.097	104.018	103.721	103.61	92.038	92.668	91.978	91.654	53.768	56.12	65.317				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.081	107.957	110.234	108.218	108.23	108.401	110.243	110.084	110.423	110.545	110.282	110.68	110.102	109.805	109.546	109.544	109.827	109.51	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	88.018	87.55	87.638	88.717	97.481	97.279	97.295	97.355	89.485	88.252	88.34	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	2.80	0.885	0.840	0.860	H_2O	0.245	15.41	0.4887	13.42	0.8993	15.49	0.4925	13.21	0.8647	15.30	0.4884	13.09	0.8546	29.4
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.094	90.958	91.381	91.715	103.669	104.605	104.359	104.24	91.368	91.958	91.247	90.902	56.864	57.52	65.617				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.899	107.694	108.655	108.02	107.878	107.964	110.025	109.849	110.405	110.369	110.043	110.455	109.44	109.08	108.788	108.855	109.224	108.952	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.205	86.738	86.827	87.892	97.708	97.504	97.578	97.627	88.979	87.746	87.871	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	4.40	3.65	3.25	3.30	Orange Oil	0.305	16.30	0.5159	14.22	0.9526	16.36	0.5203	14.18	0.9285	16.63	0.5305	13.90	0.9062	29.4
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.676	89.417	89.951	90.374	103.833	104.848	104.693	104.506	90.113	90.857	90.011	89.647	57.6	58.34	66.7				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.692	107.336	105.095	107.636	107.608	107.678	110.146	109.903	110.479	110.5	110.178	110.626	109.661	109.267	108.934	109.031	109.463	109.267	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.792	85.259	85.372	86.481	97.447	97.171	97.22	97.267	87.806	86.431	86.58	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	6.30	5.00	4.65	4.75	Orange Oil	0.540	16.84	0.5337	14.69	0.9845	16.97	0.5381	14.47	0.9469	16.96	0.5403	14.34	0.9354	29.33
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.087	88.907	89.345	89.811	103.448	104.459	104.371	104.177	89.755	90.502	89.633	89.242	60.3	60.8	67.3				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.098	106.706	103.912	107.071	107.109	107.156	110.029	109.795	110.426	110.561	110.23	110.644	110.083	109.613	109.345	109.429	109.861	109.73	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.574	85.052	85.108	86.31	97.429	97.153	97.223	97.243	87.473	86.074	86.229	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	8.85	7.00	6.60	6.70	Orange Oil	0.735	17.41	0.5517	15.14	1.0138	17.49	0.5560	14.93	0.9766	17.47	0.5572	14.79	0.9641	29.33
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.762	89.62	90.121	90.628	104.564	105.581	105.435	105.296	90.626	91.238	90.481	90.094	64.1	62.7	68.1				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.552	107.269	108.171	107.557	107.424	107.449	110.081	109.816	110.596	110.491	110.111	110.47	109.69	109.183	108.927	109.055	109.494	109.39	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.526	86.013	86.132	87.298	98.692	98.413	98.491	98.518	88.888	87.464	87.628	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	11.65	9.70	8.75	8.90	Orange Oil	0.955	18.12	0.5744	15.81	1.0581	18.24	0.5790	15.57	1.0179	18.23	0.5809	15.41	1.0034	29.29
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.927	88.816	89.327	89.912	104.656	105.664	105.597	105.433	89.955	90.684	89.813	89.422	66.9	63	68.3				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.222	106.88	103.889	107.215	107.122	107.185	109.964	109.672	110.524	110.426	110.063	110.45	109.647	109.003	108.76	108.869	109.388	109.204	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.788	85.205	85.32	86.544	98.663	98.478	98.428	98.437	88.211	86.764	86.945	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	16.40	12.55	12.25	12.55	Orange Oil	3.400	18.81	0.5958	16.46	1.1002	18.91	0.6006	16.18	1.0572	18.93	0.6032	16.01	1.0420	29.28
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	88.96	88.6	89.12	89.703	105.215	106.272	106.187	106.004	89.779	90.466	89.642	89.195	70.4	63.7	68.5				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.176	106.794	109.627	107.113	107.008	107.055	109.953	109.647	110.542	110.439	109.982	110.41	109.557	108.945	108.655	108.846	109.355	109.233	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.439	84.89	85.014	86.222	99.059	98.8	98.807	98.788	87.986	86.497	86.71	7.9E+28							

Test # 15 5 Holes Parallel

Pven	Psup	Pjet	$P_{L.E. in}$	$P_{L.E. out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	5.50	5.00	4.75	4.70	Orange Oil	0.193	13.55	0.4293	11.84	0.7938	13.55	0.4302	11.49	0.7539	13.61	0.4347	11.59	0.7561	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	106.07	105.946	105.997	106.531	113.377	113.751	113.506	113.672	105.682	105.784	105.44	105.403	57.386	59.747	67.403				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	110.707	110.381	112.291	110.435	110.572	110.993	109.98	109.728	109.762	109.204	109.132	109.91	111.163	110.097	110.005	110.097	110.813	110.824	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	89.001	88.418	88.54	89.721	98.242	98.341	98.438	98.168	90.097	88.749	88.796	7.9E+28							
Pven	Psup	Pjet	$P_{L.E. in}$	$P_{L.E. out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	9.75	9.00	9.05	8.55	Orange Oil	0.327	14.60	0.4629	12.78	0.8571	14.47	0.4602	12.44	0.8141	14.64	0.4679	12.49	0.8144	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	105.424	105.183	105.284	105.917	113.915	114.406	114.131	114.305	105.244	105.404	104.998	105.052	59.342	60.232	67.284				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	110.606	110.219	108.457	110.27	110.441	110.853	110.032	109.809	109.94	109.276	109.172	110.074	111.373	110.155	109.998	110.149	111.038	111.038	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.813	87.178	87.275	88.502	98.194	98.348	98.368	98.113	89.239	87.844	87.899	7.9E+28							
Pven	Psup	Pjet	$P_{L.E. in}$	$P_{L.E. out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	15.25	14.00	14.10	13.30	Orange Oil	0.501	15.40	0.4875	13.45	0.8995	15.28	0.4860	13.11	0.8588	15.39	0.4915	13.13	0.8564	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	105.025	104.801	104.915	105.511	114.349	114.71	114.464	114.739	104.899	105.021	104.693	104.692	61.375	61.211	67.815				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	110.898	110.473	112.691	110.441	110.561	110.936	110.122	109.807	110.047	109.292	109.123	110.115	111.321	109.946	109.793	109.939	110.927	111.071	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.268	86.569	86.686	87.964	98.384	98.604	98.568	98.267	88.931	87.422	87.543	7.9E+28							
Pven	Psup	Pjet	$P_{L.E. in}$	$P_{L.E. out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	21.95	20.30	20.10	19.30	Orange Oil	0.705	15.95	0.5045	13.93	0.9328	15.91	0.5059	13.57	0.8892	15.95	0.5027	13.59	0.8863	29.72
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	104.22	103.941	104.018	104.76	114.152	114.469	114.311	114.55	104.186	104.292	103.941	103.97	63.65	62.788	67.819				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	110.673	110.304	108.787	110.313	110.471	110.893	110.003	109.694	110.052	109.098	108.952	110.016	111.281	109.94	109.811	110.045	110.979	110.963	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.987	86.202	86.299	87.642	98.647	98.858	98.784	98.417	89.028	87.403	87.579	7.9E+28							
Pven	Psup	Pjet	$P_{L.E. in}$	$P_{L.E. out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	30.80	28.30	28.70	27.10	Orange Oil	0.875	16.69	0.5287	14.60	0.9755	16.65	0.5287	14.22	0.9323	16.77	0.5353	14.21	0.9263	29.72
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	103.736	103.331	103.399	104.197	114.316	114.676	114.52	114.773	103.642	103.81	103.48	103.399	64.54	63.652	68.087				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	110.819	110.192	111.641	110.293	110.403	110.849	110.054	109.708	110.158	109.152	108.983	110.03	111.474	109.994	109.944	110.173	111.172	111.263	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.36	85.588	85.743	87.039	98.698	98.896	98.897	98.512	88.868	87.224	87.385	#######							
Pven	Psup	Pjet	$P_{L.E. in}$	$P_{L.E. out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	11.20	10.40	10.50	9.90	Red Oil	3.000	17.39	0.5502	15.15	1.0134	17.46	0.5540	14.90	0.9741	17.50	0.5581	14.76	0.9629	29.74
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	103.189	102.613	102.69	103.534	114.183	114.505	114.374	114.575	102.829	102.978	102.526	102.521	68.6	63.1	68.9				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	111.087	110.394	107.708	110.367	110.459	110.891	109.987	109.674	110.097	108.995	108.806	109.863	111.325	109.778	109.692	109.998	111.015	111.085	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.54	84.64	84.852	86.179	98.462	98.672	98.66	98.249	88.045	86.337	86.513	7.9E+28							
Pven	Psup	Pjet	$P_{L.E. in}$	$P_{L.E. out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	15.40	14.20	14.20	13.60	Red Oil	4.050	18.09	0.5721	15.79	1.0555	18.16	0.5767	15.51	1.0135	18.13	0.5779	15.39	1.0015	29.74
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	102.35	101.887	101.961	102.866	114.419	114.691	114.586	114.887	102.42	102.524	102.145	102.155	71.7	64.3	69.1				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	111.404	110.653	112.136	110.644	110.614	111.074	109.982	109.679	110.257	109.024	108.788	109.863	111.168	109.535	109.512	109.789	110.817	110.621	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.448	84.589	84.706	86.092	99.029	99.245	99.18	98.759	88.024	86.188	86.38	7.9E+28							

Test # 16 5 Holes Circular

Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	6.05	5.60	5.60	5.35	Orange Oil	0.190	13.54	0.4293	11.77	0.7899	13.53	0.4313	11.61	0.7605	13.72	0.4380	11.52	0.7516	29.68
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	94.104	93.776	94.007	94.705	103.858	104.535	104.328	104.395	93.92	93.992	93.521	93.625	60.19	63.139	70.627				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	106.513	106.637	108.257	107.051	106.706	106.603	110.007	109.868	110.18	110.345	110.205	110.666	108.419	108.277	107.789	107.752	108.167	107.96	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.555	86.528	86.794	87.523	98.721	98.78	98.955	98.737	89.867	89.051	89.001	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	10.90	10.10	9.55	10.35	Orange Oil	0.329	14.73	0.4671	12.86	0.8645	14.80	0.4708	12.68	0.8321	14.91	0.4765	12.54	0.8172	29.68
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	92.797	92.342	92.576	93.411	103.887	104.546	104.436	104.465	92.693	92.747	92.18	92.279	61.825	63.313	70.452				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	106.268	106.429	104.715	106.861	106.396	106.177	110.068	109.957	110.423	110.479	110.255	110.723	108.194	107.995	107.465	107.471	107.944	107.73	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.358	85.309	85.651	86.359	98.968	99.072	99.173	98.989	88.848	87.925	87.943	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	17.20	16.00	15.30	16.35	Orange Oil	0.501	15.68	0.4971	13.70	0.9171	15.69	0.4979	13.48	0.8818	15.87	0.5072	13.34	0.8707	29.68
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	91.586	91.129	91.359	92.326	103.833	104.521	104.449	104.45	91.71	91.73	91.199	91.397	62.723	63.634	70.596				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	105.773	105.95	108.468	106.432	105.93	105.725	110.029	109.791	110.369	110.511	110.18	110.767	108.031	107.791	107.215	107.266	107.762	107.53	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	84.263	84.157	84.481	85.252	99.272	99.457	99.553	99.299	88.087	87.116	87.176	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	25.15	23.45	22.25	24.00	Orange Oil	0.708	16.42	0.5207	14.37	0.9609	16.48	0.5224	14.12	0.9228	16.66	0.5315	13.97	0.9106	29.64
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.905	90.31	90.522	91.523	103.896	104.571	104.557	104.506	90.902	90.922	90.385	90.589	63.022	64.357	70.47				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	105.552	105.745	107.906	106.245	105.622	105.417	109.975	109.791	110.401	110.441	110.115	110.707	107.636	107.408	106.781	106.819	107.35	107.125	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	83.479	83.315	83.61	84.427	99.715	99.923	99.914	99.679	87.543	86.524	86.591	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	9.80	9.10	8.70	9.30	Red Oil	0.950	17.31	0.5485	15.15	1.0125	17.35	0.5477	14.80	0.9677	17.50	0.5575	14.71	0.9579	29.64
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	90.236	89.521	89.739	90.869	104.229	104.868	104.818	104.792	90.185	90.193	89.586	89.782	66.4	64.5	70.6				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	105.329	105.53	104.596	106.088	105.397	105.183	109.98	109.85	110.452	110.489	110.129	110.761	107.546	107.26	106.6	106.718	107.302	107.116	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	82.73	82.582	82.877	83.723	100.238	100.395	100.409	100.082	86.787	85.729	85.772	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	12.70	11.90	11.40	12.20	Red Oil	3.000	18.03	0.5706	15.79	1.0559	17.90	0.5693	15.47	1.0104	18.23	0.5813	15.32	0.9988	29.64
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.494	88.816	89.023	90.207	104.492	105.197	105.16	105.138	89.568	89.539	88.911	89.156	69.2	64.3	70.5				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	105.185	105.188	103.867	105.694	104.954	104.692	110.011	109.775	110.473	110.471	110.065	110.698	107.206	106.897	106.205	106.308	106.978	106.769	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	81.936	81.736	82.069	82.895	100.42	100.674	100.64	100.251	85.961	84.861	84.947	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\ in}$	$P_{L.E.\ out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	17.60	16.40	16.00	16.80	Red Oil	4.000	18.71	0.5929	16.42	1.0978	18.60	0.5924	16.07	1.0499	19.02	0.6049	15.94	1.0372	29.64
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	89.316	88.457	88.663	89.87	104.911	105.604	105.617	105.644	89.406	89.408	88.767	89.006	72.6	65.2	70.4	\			
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	104.627	104.744	107.937	105.302	104.468	104.29	109.987	109.771	110.443	110.423	110.012	110.702	107.071	106.612	105.98	106.11	106.803	106.601	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	81.927	81.781	82.019	82.849	101.128	101.299	101.225	100.841	85.651	84.517	84.613	7.9E+28							

Test # 17   5 Holes Both-Ends-Open

Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	0.699	0.501	0.330	0.485	H_2O	0.197	14.42	0.4569	12.55	0.8423	14.43	0.4576	12.36	0.8117	14.59	0.4660	12.33	0.8039	29.74
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	102.283	101.945	102.076	102.836	111.073	111.454	111.101	111.346	100.822	100.757	100.35	100.555	58.786	61.634	70.348				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.649	107.672	109.489	107.903	107.788	107.935	109.858	109.696	110.129	110.187	109.899	110.194	108.983	108.648	108.446	108.441	108.608	108.493	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.939	87.509	87.642	88.646	97.749	97.65	97.654	97.618	89.222	88.137	88.081	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	3.05	0.890	0.635	0.858	H_2O	0.345	15.54	0.4921	13.57	0.9075	15.53	0.4933	13.24	0.8671	15.74	0.5023	13.27	0.8659	29.74
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	101.777	101.353	101.493	102.335	111.735	112.153	111.74	112.041	100.307	100.208	99.788	99.977	60.653	62.14	70.313				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.512	107.438	107.485	107.681	107.597	107.728	109.838	109.548	110.273	110.203	109.856	110.176	108.761	108.531	108.263	108.304	108.466	108.38	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.071	86.571	86.704	87.82	98.051	97.942	97.985	97.949	88.571	87.379	87.359	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	4.75	3.45	2.80	3.30	Orange Oil	0.540	16.48	0.5217	14.42	0.9646	16.51	0.5247	14.09	0.9196	16.70	0.5331	14.08	0.9176	29.74
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	101.417	100.903	100.953	101.954	112.37	112.75	112.432	112.691	99.916	99.821	99.315	99.614	62.662	63	70.448				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.613	107.579	105.113	107.867	107.685	107.827	110.18	109.937	110.707	110.615	110.227	110.565	108.902	108.671	108.387	108.428	108.664	108.556	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.827	86.321	86.445	87.565	98.626	98.429	98.435	98.404	88.429	87.059	87.127	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	6.75	4.90	4.65	4.80	Orange Oil	0.758	17.12	0.5424	14.96	1.0008	17.11	0.5438	14.66	0.9582	17.37	0.5538	14.60	0.9534	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	100.721	100.138	100.222	101.272	112.241	112.675	112.268	112.675	99.27	99.047	98.656	98.905	64.246	64.022	70.583				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.37	107.395	109.98	107.597	107.329	107.428	109.933	109.717	110.637	110.41	109.98	110.318	108.518	108.198	108	108.077	108.239	108.169	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.386	85.905	86.045	87.165	98.802	98.676	98.642	98.588	88.187	86.825	86.857	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	9.50	6.95	6.15	6.75	Orange Oil	2.550	18.10	0.5729	15.86	1.0596	18.13	0.5747	15.51	1.0140	18.37	0.5857	15.46	1.0060	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	99.94	99.09	99.198	100.35	112.522	112.946	112.57	112.991	98.393	98.147	97.733	98.039	65.5	62.7	70.6				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.284	107.201	109.906	107.377	107.089	107.19	109.841	109.611	110.581	110.349	109.809	110.183	108.086	107.726	107.464	107.582	107.847	107.75	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.252	84.613	84.847	85.977	98.588	98.444	98.392	98.366	87.145	85.624	85.745	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	12.50	9.10	8.35	8.85	Orange Oil	3.400	18.94	0.5998	16.59	1.1077	19.01	0.6021	16.20	1.0586	19.14	0.6106	16.13	1.0483	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	99.504	98.555	98.705	99.983	113.143	113.602	113.22	113.647	98.037	97.774	97.321	97.706	68.8	63.3	70.6				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.449	107.408	106.101	107.579	107.217	107.302	110.075	109.782	110.966	110.491	109.987	110.349	108.023	107.611	107.422	107.496	107.732	107.645	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	84.929	84.256	84.47	85.633	99	98.84	98.78	98.678	86.746	85.178	85.203	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	17.25	12.70	12.20	12.40	Orange Oil	4.550	19.24	0.6093	16.85	1.1244	19.27	0.6105	16.52	1.0793	19.46	0.6196	16.36	1.0680	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	99.068	98.411	98.53	99.794	113.09	113.485	113.143	113.573	98.032	97.803	97.297	97.679	72.8	66.5	70.7				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.3	107.258	104.209	107.426	107.08	107.17	110.039	109.822	110.981	110.524	110.007	110.383	108.05	107.604	107.399	107.5	107.813	107.645	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.783	85.126	85.295	86.499	99.977	99.817	99.693	99.585	87.806	86.162	86.315	7.9E+28							

Test # 18 5 Holes 2-Inlets-2-Outlets

Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
19.000	0.730	0.505	0.255	0.480	H_2O	0.225	14.70	0.4656	12.74	0.8532	14.76	0.4690	12.52	0.8208	14.76	0.4715	12.53	0.8180	29.75
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	102.276	101.866	101.966	102.715	110.776	111.08	110.669	110.957	100.498	100.499	100.08	100.269	58.867	62.059	69.518				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.191	108.106	105.608	108.277	108.103	108.322	109.712	109.566	110.18	110.029	109.807	110.012	109.55	109.433	109.165	109.202	109.381	109.168	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	88.243	87.907	88.036	88.922	97.981	97.988	98.057	97.922	89.359	88.288	88.315	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
30.000	3.15	0.890	0.685	0.855	H_2O	0.386	15.83	0.5015	13.77	0.9216	15.91	0.5055	13.53	0.8863	15.96	0.5094	13.50	0.8805	29.74
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	101.506	101.066	101.189	102.024	111.317	111.658	111.256	111.577	99.713	99.691	99.265	99.455	60.779	62.606	69.498				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.119	108.16	107.365	108.365	108.058	108.23	109.985	109.832	110.567	110.513	110.216	110.432	109.958	109.762	109.521	109.616	109.872	109.647	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	87.428	87.044	87.278	88.187	98.411	98.435	98.503	98.305	88.906	87.8	87.802	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
41.000	4.90	3.50	3.10	3.25	Orange Oil	0.600	16.83	0.5331	14.56	0.9746	16.93	0.5375	14.40	0.9424	16.65	0.5315	14.33	0.9342	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	100.775	100.265	100.357	101.288	111.321	111.618	111.218	111.566	98.944	98.811	98.384	98.599	62.555	63.164	69.665				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	108.059	108.052	110.025	108.315	107.98	108.103	110.011	109.816	110.682	110.506	110.151	110.41	109.762	109.523	109.278	109.379	109.656	109.408	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.891	86.51	86.661	87.629	98.728	98.694	98.766	98.537	88.391	87.208	87.241	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
52.000	7.05	4.95	4.35	4.80	Orange Oil	0.855	17.59	0.5577	15.26	1.0198	17.70	0.5120	15.09	0.9869	17.88	0.5695	14.98	0.9752	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	100.118	99.482	99.628	100.694	111.674	112.032	111.578	111.98	98.365	98.246	97.785	98.026	64.109	63.974	70.063				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.903	107.87	106.193	108.146	107.795	107.923	110.142	109.901	111.002	110.788	110.392	110.599	110.408	110.099	109.888	109.994	110.308	110.088	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.688	86.26	86.427	87.406	99.259	99.29	99.331	99.061	88.274	87.057	87.111	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
63.500	9.70	6.90	6.20	6.70	Orange Oil	2.800	18.25	0.5778	15.98	1.0679	18.35	0.5828	15.67	1.0247	18.46	0.5894	15.53	1.0118	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	99.652	98.95	99.083	100.181	112.03	112.358	111.931	112.383	97.803	97.655	97.187	97.456	65.84	64.649	70.151				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.645	107.566	106.682	107.831	107.444	107.595	110.011	109.793	110.878	110.738	110.347	110.507	110.034	109.784	109.532	109.679	109.985	109.714	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	86.033	85.597	85.847	86.821	99.533	99.576	99.56	99.232	87.907	86.609	86.699	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
74.500	12.90	9.15	8.80	8.90	Orange Oil	3.750	19.09	0.6054	16.74	1.1193	19.20	0.6095	16.41	1.0722	19.40	0.6183	16.25	1.0583	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	99.067	98.314	98.345	99.666	112.441	112.786	112.291	112.757	97.204	96.98	96.543	96.824	69.8	64.6	70.3				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.519	107.298	106.884	107.636	107.33	107.442	110.111	109.881	111.146	110.902	110.495	110.614	110.551	110.288	110.014	110.23	110.554	110.167	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.365	84.879	85.099	86.15	99.806	99.905	99.833	99.446	87.424	86.051	86.087	7.9E+28							
Pven	Psup	Pjet	$P_{L.E.\,in}$	$P_{L.E.\,out}$	Man. Liquid	ΔPjet	V_1	I_1	V_2	I_2	V_3	I_3	V_4	I_4	V_5	I_5	V_6	I_6	Pamb
90.000	18.00	12.95	12.40	12.50	Orange Oil	5.150	19.72	0.6243	17.28	1.1535	19.85	0.6295	16.94	1.1064	20.04	0.6383	16.77	1.0911	29.73
	C101	C102	C103	C104	C105	C106	C107	C108	C109	C110	C111	C112	Tven	Tjet	Tamb				
	98.813	97.988	98.095	99.391	112.608	112.878	112.433	112.927	97.009	96.763	96.336	96.622	73.4	66.7	70.4				
	C201	C202	C203	C204	C205	C206	C207	C208	C209	C210	C211	C212	C213	C214	C215	C216	C217	C218	
	107.59	107.442	110.444	107.78	107.359	107.476	110.25	109.996	111.301	111.132	110.61	110.786	110.597	110.306	110.093	110.277	110.646	110.254	
	C301	C302	C303	C304	C305	C306	C307	C308	C309	C310	C311	C312							
	85.617	85.108	85.28	86.465	100.73	100.829	100.78	100.325	87.822	86.36	86.519	7.9E+28							

APPENDIX D
Reduced Data Test#1 through Test# 18

Test# 1 9 Holes Parallel

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
8002	104.30	104.35	101.47	3.62	3.58	2.99
10590	120.22	121.49	118.27	3.53	3.50	2.96
13150	137.07	138.47	133.99	3.52	3.48	2.98
15710	149.58	154.53	149.29	3.45	3.45	2.98
18390	164.87	167.28	161.86	3.46	3.43	2.98
20900	183.76	186.25	178.69	3.46	3.43	2.99
24410	201.67	206.39	197.31	3.47	3.46	3.04

Test#2 9 Holes Circular

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
7971	94.79	94.61	89.31	3.91	3.86	3.18
10560	109.99	108.64	102.65	3.83	3.76	3.12
13120	125.21	123.17	115.86	3.80	3.73	3.11
15680	140.92	138.68	129.16	3.77	3.70	3.09
18340	154.04	153.60	143.61	3.71	3.65	3.08
20870	170.90	167.38	155.48	3.73	3.63	3.07
24370	189.50	184.91	170.97	3.81	3.70	3.13

Test#3 9 Holes Both-Ends-Open

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
7985	103.83	105.40	103.94	3.75	3.71	3.11
10570	125.21	125.23	123.09	3.64	3.58	3.04
13140	140.13	140.46	138.52	3.56	3.52	3.01
15690	154.59	155.53	153.11	3.55	3.52	3.04
18350	175.03	175.21	169.09	3.58	3.49	3.06
20870	191.80	192.26	185.26	3.53	3.44	3.03
24370	204.43	208.15	201.68	3.53	3.50	3.10

Test#4 9 Holes 2-Inlets-2-Outlets

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
9433	95.69	94.30	89.82	3.74	3.75	3.15
12480	111.89	109.42	104.15	3.64	3.63	3.09
15500	123.66	123.38	117.09	3.56	3.57	3.07
18570	135.84	133.73	128.87	3.51	3.54	3.06
21700	147.48	146.55	140.24	3.44	3.50	3.03
24680	163.06	160.34	152.77	3.45	3.45	3.02
29010	167.09	166.75	158.81	3.32	3.34	2.91

Test#5 8 Holes Parallel

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
8856	97.53	98.65	93.27	3.62	3.60	2.97
11690	111.36	113.69	106.69	3.51	3.52	2.94
14500	125.40	129.19	117.70	3.47	3.49	2.96
17300	140.21	143.16	132.18	3.50	3.51	3.00
20200	157.63	160.01	146.89	3.49	3.48	2.99
22970	170.43	176.57	161.70	3.39	3.44	2.96
26820	196.41	197.26	180.60	3.45	3.45	2.98

Test#6 8 Holes Circular

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
8865	95.71	93.01	89.98	3.70	3.71	3.00
11720	108.76	108.09	101.95	3.60	3.59	2.96
14560	123.41	123.42	115.39	3.54	3.52	2.93
17370	140.60	137.59	128.49	3.55	3.49	2.93
20350	153.09	150.63	139.97	3.43	3.40	2.85
23050	168.69	166.20	153.09	3.55	3.50	2.97
26890	189.06	183.85	167.55	3.63	3.52	3.02

Test#7 8 Holes Both-Ends-Open

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
8869	102.73	103.74	101.23	3.47	3.46	2.87
11740	119.00	120.26	117.98	3.34	3.34	2.81
14570	133.81	136.02	132.37	3.30	3.30	2.81
17390	150.11	150.17	144.71	3.32	3.27	2.82
20360	166.37	165.77	159.73	3.31	3.26	2.83
23110	177.47	179.27	171.75	3.28	3.24	2.84
26930	197.55	199.83	191.27	3.33	3.31	2.94

Test#8 8 Holes 2-Inlets-2Outlets

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
8818	92.69	95.11	92.21	3.64	3.60	3.00
11670	108.93	110.82	107.17	3.52	3.46	2.93
14520	122.40	125.20	120.46	3.44	3.39	2.90
17420	133.74	137.34	131.65	3.34	3.28	2.83
20360	149.10	153.83	147.41	3.31	3.27	2.85
23090	162.79	165.76	158.09	3.32	3.25	2.85
26980	180.27	181.05	175.56	3.31	3.29	2.88

Test#9 7 Holes Parallel

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
8665	91.11	95.98	91.69	3.28	3.25	2.62
11460	106.10	111.26	106.69	3.18	3.14	2.58
14220	119.72	125.78	120.37	3.12	3.09	2.56
16980	133.19	138.25	131.54	3.15	3.09	2.57
19790	147.21	155.15	147.38	3.13	3.12	2.63
22650	161.68	169.98	159.16	3.00	2.99	2.52
26470	182.14	190.38	171.58	3.03	3.01	2.56

Test#10 7 Holes Circular

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
8751	95.10	93.61	91.17	3.28	3.28	2.59
11540	111.03	109.63	105.22	3.21	3.20	2.55
14320	127.27	151.36	119.63	3.16	2.90	2.53
17090	139.52	140.52	133.10	3.10	3.09	2.52
19920	157.23	155.51	145.89	3.15	3.11	2.57
22650	166.27	165.13	154.03	3.10	3.07	2.54
26490	187.41	183.34	172.79	3.11	3.04	2.52

Test#11 7 Holes Both-Ends-Open

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
8705	102.87	102.48	102.78	3.13	3.13	2.53
11480	120.77	119.40	118.79	3.06	3.04	2.51
14240	136.08	136.29	134.77	3.03	3.00	2.51
17010	149.71	149.33	148.30	2.99	2.96	2.50
19910	167.10	166.01	163.34	2.92	2.89	2.47
22600	178.25	179.04	176.33	2.91	2.88	2.47
26360	203.49	201.56	198.41	2.93	2.86	2.50

Test# 12 6 Holes Parallel

Rej	Nu_Side_Fr	Nu_Side_ back	Nu_Nose	UncerSf	UncerSb	UncerN
9227	100.79	99.87	98.24	3.15	3.09	2.52
12190	116.87	115.26	115.62	3.02	3.00	2.47
15130	133.77	131.75	130.42	2.98	2.93	2.45
18070	149.91	148.36	145.70	2.96	2.89	2.45
21130	166.33	164.59	160.20	2.92	2.84	2.42
24050	178.04	179.91	174.02	2.85	2.78	2.40
28130	200.29	199.40	191.78	2.84	2.75	2.39

Test#13 6 Holes Circular

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
9190	104.38	105.29	98.65	3.32	3.24	2.62
12130	121.01	122.25	115.05	3.20	3.16	2.58
15040	140.37	139.80	130.71	3.21	3.12	2.57
17970	152.56	153.91	143.09	3.18	3.10	2.57
20990	170.29	172.75	161.42	3.14	3.07	2.57
23870	188.64	188.15	174.10	3.16	3.05	2.55
27880	204.63	207.51	191.64	3.15	3.08	2.58

Test#14 6 Holes Both-Ends-Open

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
9073	110.31	109.42	108.99	3.14	3.09	2.54
11980	129.45	124.17	125.92	3.09	3.08	2.55
14910	149.40	148.44	147.18	3.07	2.97	2.52
17750	170.75	160.12	160.33	3.14	3.02	2.60
20690	184.77	178.06	177.11	3.14	3.06	2.66
23530	206.68	195.64	194.12	3.15	3.03	2.65
27510	221.21	214.33	212.67	3.10	3.02	2.66

Test#15 5 Holes Parallel

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
10500	96.87	99.13	100.15	3.31	3.30	2.77
13910	113.59	115.76	118.19	3.22	3.18	2.71
17280	126.95	130.68	133.95	3.14	3.14	2.70
20600	144.22	142.86	148.52	3.16	3.16	2.75
24110	159.02	162.30	166.03	3.11	3.10	2.75
27420	175.05	175.51	180.35	3.05	3.03	2.71
32040	190.35	193.98	200.16	3.01	3.05	2.74

Test#16 5 Holes Circular

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
10410	112.85	113.37	107.67	3.55	3.48	2.87
13800	138.19	135.60	129.12	3.45	3.36	2.79
17180	155.33	155.60	146.74	3.37	3.29	2.76
20550	175.37	175.71	163.50	3.36	3.29	2.77
24020	197.85	194.81	180.24	3.35	3.24	2.74
27340	213.54	212.63	196.19	3.32	3.20	2.71
31950	234.16	236.82	215.96	3.32	3.22	2.74

Test#17 5 Holes Both-Ends-Open

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
10460	120.92	123.12	119.57	3.35	3.30	2.76
13850	143.56	145.36	138.43	3.27	3.21	2.72
17210	166.57	166.21	157.78	3.23	3.16	2.70
20550	180.57	185.25	175.49	3.21	3.17	2.73
24120	197.64	203.83	191.99	3.09	3.07	2.64
27410	222.53	224.77	211.02	3.10	3.06	2.64
31900	248.25	248.70	234.28	3.27	3.21	2.79

Test#18 5 Holes 2-Inlets-2-Outlets

Rej	Nu_Side_Front	Nu_Side_back	Nu_Nose	UncerSf	UncerSb	UncerN
10460	128.81	125.19	123.82	3.34	3.27	2.77
13840	150.64	146.80	145.14	3.24	3.16	2.72
17210	171.19	162.51	166.25	3.16	3.13	2.70
20560	176.52	187.71	184.73	3.28	3.05	2.70
24040	212.54	205.02	202.45	3.18	3.06	2.71
27330	233.08	223.40	221.06	3.14	2.99	2.68
31870	256.79	248.68	245.22	3.18	3.05	2.77

REFRENCES

1) Metzger, D.E., Yamashita,T., and Jenkins, C.W., 1969, ‘‘Impingement Cooling of Concave Surfaces With Lines of Circular Air Jets,’’ *J. Engr. for Power*, Vol. 93, No. 3, pp. 149-155.

2) Kercher, D.M., and Tabakoff, W., 1970,"Heat Transfer by a Square Array of Round Air Jets Impinging Perpendicular to a Flat Surface Including the Effect of Spent Air," Ji. Eng. Power, Vol. 92. pp. 73-82,

3) Akella, K. V., and Han, J. C., 1999,’’ Impingement cooling in rotating two-pass rectangular channels with ribbed walls’’. AIAA Journal of Thermophysics and Heat Transfer 13(3):364–371.

4) J.J. Hwang, D.Y. Lai and Y.P. Tsia, 1999,’’Heat transfer and pressure drop in pin-fin trapezoidal ducts’’. Trans. ASME J. Turbomach. 21 (1999), pp. 264–272

5) STRIEGEL, S.A. and DILLER, T.E. 1984, “The effect of entrainment temperature on jet Impingement heat transfer“, ASME Journal of Heat Transfer, Vol. 106, pp 27-33,
Journal of February 1984-a

6) Trabold, T.A. and Obot, N.T., 1987, ‘‘Impingement heat transfer within arrays of circular jets’’. Part II: Effects of crossflow in the presence of roughness elements’. ASME Paper 87-GT-200.

7) Hollworth, B. R., and Cole, G. H., 1987,’’ Heat-transfer to arrays of impinging jets in a crossflow’’, Journal of Turbomachinery - Transactions of the ASME, Vol. 109, pp 564-571.

8) Sparrow et al,1984,’’ Jet-Impingement Heat Transfer for a Circular Jet Impinging in Crossflow on a Cylinder’’ J. Heat Transfer -- August 1984 -- Volume 106, Issue 3, 570 (8 pages)

9) FLorschuetz et al. ,1984, ‘’Heat Transfer Characteristics for Jet Array Impingement With Initial Crossflow’’ J. Heat Transfer -- February 1984 -- Volume 106, Issue 1, 34 (8 pages)

10) Florschuetz L, Truman C, Metzger D, 1981,” Streamwise flows and heat transfer distributions for jet array impingement with crossflow”. ASME J Heat Transfer 103:337–342

11) Holloworth, B. R., and Wilson, S. I., 1984, “ Entrainment Effects on Impingement Heat Trasnfer: Part I – Measurements of Heated Jet Velocity and Temperature Distributions and Recovery Temperatures on Target Surfaces, “J.Heat Trasnfer, 106,pp. 797-805.

12)BRAHMA, PADHY & PRADHAM ,1994, “Experimental studies of heat transfer by slot jet and single/triple row of round jets impinging on semi-cylindrical concave surfaces”. Heat Transfer Engineering, vol.15 n°4, pp 66-74, (1994).

13) Gau and Chung, 2003,’’Surface Curvature Effect on Slot-Air-Jet Impingement Cooling Flow and Heat Transfer Process’’, Heat and Mass Transfer, Volume 39, Number 2 / January, 2003

14) Gau and Lee, c. c., 1992,’’ Impingement Cooling Flow Structure and Heat Transfer along Rib Roughened Walls’’, Int. Journal of heat and Mass Transfer 35(11), 3009-3020.

15) Sarkar, Alok; Florschuetz, L. W., 1992 ,’’Entrance region heat transfer in a channel downstream of an impinging jet array’’, International Journal of Heat and Mass Transfer (ISSN 0017-9310), vol. 35, no. 12, p. 3363-3374.

16)Al-Sanea., S.,1992,’’A Numerical Study of The Flow and Heat Transfer Characteristics of Impinging Laminar Slot-Jet Including Crossflow Effects’’ Int. Heat and Mass Trans. 35 (10) 2501-2513.

17) P.W. Lia and W.Q. Tao,1993,’’Numerical and experimental investigations on heat/mass transfer of slot-jet impingement in a rectangular cavity’’, 'International Journal of Heat and Fluid FlowVolume 14, Issue 3, September 1993, Pages 246-253

18) Seyedein et al., 1994, S.H. Seyedein, M. Hasan and A.S. Mujumdar,’’ Modeling of a single confined turbulent slot jet impingement using various *k-ε* turbulence models’’, Applied Mathematical Modeling 18 (1994), pp. 526–537

19) Lytle, D., Webb, B.W., 1994,’’ Air jet impinging heat transfer at low nozzle-plate spacings. Int.J. Heat and Mass Transfer 39, pp. 3655-3706, 1994.

20) Z.H. Lin, Y.J. Chou and Y.H. Hung, 1997, ‘’Heat transfer behaviors of a confined slot jet impingement’’. Int. J. Heat Mass Transfer 40 5 (1997), pp. 1095–1107

21) W.M. Chakroun, A.A. Abdel-Rahman and S.F. Al-Fahed, 1998, ‘’Heat transfer augmentation for air jet impinged on a rough surface’’. Appl. Thermal Eng. 18 (1998), pp. 1225–1241

22) Parsons, J. A., Han, J. C., and Lee, C. P. 1998.’’ Rotation effect on jet impingement heat transfer in smooth rectangular channels with heated target walls and radially outward crossflow’’. International Journal of Heat and Mass Transfer 41(13):2059–2071.

23) P. T., Neely, A. J., Gillespie, D. R. H., and Robertson, A. J., 1999,‘‘Turbulent Heat Transfer Measurements Using Liquid Crystals,’’ Int. J. Heat Fluid Flow, 20, pp. 355–367.

24) Taslim, M. E., Setayeshgar, L., and Spring, S. D., 2001, ‘‘An Experimental Investigation of Advanced Leading Edge Impingement Cooling Concepts,’’ ASME J. Turbomach., 123, pp. 1–7.

25) Taslim,Pan and Bakharati, 2002,’’ Experimental Racetrack Shaped Jet Impingement on a Roughened Leading-Edge Wall With Film Holes’’, ASME Turbo Expo 2002: Power for Land, Sea, and Air (GT2002), Paper no. GT2002-30477 pp. 897-906.

26) Mohammad Al-Qahtani a, Yong-Jun Jang a, Hamn-Ching Chen b,*, Je-Chin Han 2002,’’Flow and heat transfer in rotating two-pass rectangular channels by Reynolds stress turbulence model’’. International Journal of Heat and Mass Transfer 45 (2002) 1823–1838

27)Yoji Okita and Hector Lacovides ,2003,''Comparisons of High-Reynolds-Number EVM and DSM Models in the Prediction of Heat and Fluid Flow of Turbine Blade Cooling Passages'', J. Turbomach. -- July 2003 -- Volume 125, Issue 3, 585 .

28) Sewall, E. A., and Tafti, D. K., 2004, "Large Eddy Simulation of the Developing Region of a Stationary Ribbed Internal Turbine Blade Cooling Channel,"ASME Paper No. GT2004-53832.

29) R. Jia, B. Sunden and M. Faghri, 2005, "Computational Analysis of Heat Transfer Enhancement in Square Ducts with V-Shaped Ribs: Turbine Blade Cooling'', ASME Journal of Heat Transfer, Vol. 127, pp. 425-433, 2005.

30) Taslim et al., 2005,'' Experimental and Numerical Study of Impingement on an Airfoil Leading-Edge With and Without Showerhead and Gill Film Holes'', Paper no. GT2005-68037 pp. 49-60 (12 pages) ASME Turbo Expo 2005: Power for Land, Sea, and Air (GT2005)

31) Jose Martinez Lucci, Amano, R.S., and Krishna S. Guntur, 2007,"Turbulent Flow and Heat Transfer in Variable Geometry U-Bend Blade cooling Passage," ASME Turbo & Expo, GT2007-27120, May 2007, Montreal, Canada.

32) Taslim et al., 2009,'' Experimental and Numerical Impingement Heat Transfer in an Airfoil Leading-Edge Cooling Channel With Cross-Flow'', J. Turbomach. -- January 2009 -- Volume 131, Issue 1, 011021 (7 pages)

33) Elebiary.k, 2010 "Numerical Investigation of Impingement Cooling in an Airfoil Leading-Edge Cavity" M.S.-Thesis, Mechanical and Industrial Engineering Department, Northeastern University, Boston, MA.