JOINT INSTITUTE FOR NUCLEAR RESEARCH

Frank Laboratory of Neutron Physics, Sector of the new source and complex of moderators (Group №1 New neutron source)

FINAL REPORT
ON START Program

Pulsed Periodic Research Reactors

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Contents

Abstract

The main objectives of the training are to identify the different types of the pulsed research reactors, and learning how to perform basic computational fluid dynamics simulations by (ANSYS program) in order to conduct a thermal hydraulic analysis of reactor core. During the practice, the concept of pulsed reactors was introduced, there parameters and uses for conducting researches in extracted neutron beams.

Pulsed research reactors, are a nuclear reactor that operate in the power pulse mode. In contrast to a stationary nuclear reactor, whose power level is constant with respect to time, in a pulse reactor short power pulses and, correspondingly, neutron flux pulses are generated.

The pulse reactor is able to produce high power and an intensive neutron flux in short time intervals. This mode of operation is advantageous for some research purposes, such as experiments involving the measurement of the speed of neutrons during their traversal of a known distance (time to fly method).

ANSYS develops and markets engineering simulation software for use across the product life cycle. ANSYS Mechanical finite element analysis software is used to simulate computer models of structures, electronics, or machine components for analyzing the strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes.

1. Introduction

A nuclear reactor is a system in which a chain process of neutron fission of heavy nuclei is carried out. Nuclear reactors are designed to generate electrical and thermal energy, to produce various trans-uranium elements, for scientific and experimental purposes and other tasks.

Nuclear reactors can be classified into many classifications;

- I. By purpose, reactors are divided into power, research, transport, materials science;
- II. According to the energy spectrum of neutrons, reactors based on thermal, fast and intermediate neutrons are distinguished;

III. According to the type of moderator, thermal neutron reactors are divided into light water, heavy water and graphite;
IV. According to the coolant, reactors are classified into light water, gas-cooled, heavy water and liquid metal;
V. According to the structure of the core, heterogeneous and homogeneous reactors are distinguished;
VI. According to the design, the reactors are divided into vessel and channel;
VII. According to the energy release mode, the reactors are divided into stationary steady state and pulsed reactors.

Pulsed reactors, are a nuclear reactor that operates in the pulse mode. In contrast to a stationary nuclear reactor, whose power level is constant with respect to time, in a pulse reactor short power pulses and, correspondingly, neutron flux pulses are generated. The duration of the pulses could be short -less than 10 μs or long -more than 100 μs.

Pulsed reactors can be classified into three types

i. **Pulsed Aperiodic reactor**, in which the fission burst is initiated by the rapid insertion of excess reactivity with transition of the reactor to the super prompt critical state, and which is quenched by negative temperature - reactivity feedback. In future, these reactors will be called burst reactors (abbreviation BR). Reactors of this type operate on both thermal and fast neutrons; the latter are called fast burst reactors - FBR

ii. **Pulsed Periodic Reactors** (PPR), in which the fission bursts are formed entirely with external reactivity modulation and with a specified periodicity. Periodic pulsed reactors stand closer to reactors with a steady - state flux than to fast burst reactors, in their Thermophysical and dynamic properties

iii. **Booster- reactors** (Periodic reactor + Spallation source), which are reactors existing in the subcritical state on prompt neutrons, and in which the power pulse is developed because of the multiplication of neutrons from an external pulsed source, mainly the targets of electron accelerators.

The pulsed reactor makes possible the production of high power and an intensive neutron flux in short time intervals can be used for studying fundamental symmetries and interactions, structure and properties of nuclei. Nowadays neutrons are mostly required in investigations of condensed matter including solid states,

liquids, biological systems, polymers, colloids, chemical reactions, engineering systems, etc.

2. History of pulsed reactors

The history of pulsed reactors started during the Manhattan Project when, at January 1945 under the direction of Otto Frisch, the first controlled prompt neutron fission chain reaction was achieved. The moving part of the reactor was raised by of an electromagnet in the upper part of a girder of height about 6 m, and the fixed part of the core rested at the base of the girder. When the electromagnet was switched off, a piece of uranium descended from above, slid along the guides and, with a velocity close to free - fall velocity, passed through the core close to its center. The weight of the assembly was so adjusted that the maximum value of the multiplication factor, allowing only for the contribution from prompt fission neutrons, was greater than unity.

According to the shape of the neutron pulse, which was developed during the flight of the moving part past the fixed part, the experimenter could estimate the lifetime of the fission neutrons. These experiments, with the light touch of the ingenious R. Feinman who compared them metaphorically with "tickling the tail of the sleeping dragon", received the conventional designation of "Dragon" compared them metaphorically with "tickling the tail of the sleeping dragon", received the conventional designation of "Dragon".

 " The majesty of its occurrence " gave impetus to the creation of a large series of fast neutron pulsed reactors, generating power pulses on another principle by the self - quenching of the fission reaction. In 1952 in the Los Angeles Scientific Laboratory (USA), an unplanned runaway of the " Jemima " prompt neutron " bare " uranium assembly occurred. The energy of the accidental burst was $1.5 \cdot 10^{16}$ fissions.

Neither part of the assembly came to any harm, nobody was irradiated, and no discharge of radioactive products occurred. This precedent revealed the self - quenching property of small metal assemblies and stimulated the modification of the already existing Godiva - I assembly ("Lady Godiva ") for the production of short, powerful neutron bursts. This mode of operation of a reactor is reminiscent of a miniature nuclear explosion and is very convenient for studying radiation damage and the nature of irradiation of a locality. But the FBR has been used not only for

military purposes. The small duration of the pulse of a self - quenched fast neutron reactor, in conjunction with the high intensity, has opened up an extremely broad field of applications, as a source of neutrons and y - quanta for the investigation of short - lived radioactive isotopes, rapidly - changing radiation damage in materials, electronic components and biological units. Because of their small size, FBR are very suitable for the irradiation of samples of any size in the external radiation field. Highly accurate experiments are possible because of the excellent reproducibility of the reactor power bursts.

3. History of pulsed reactors in Dubna

In 1955, D. L. Blokhintsev suggested the idea of a pulsed reactor with a periodic reactivity modulation, by the rotation of part of the active zone, and he noted that this reactor itself is a modulator of the neutron flux with time, and does not require choppers. It combines the best (in the sense of application to neutron spectroscopy) features of the FBR and the stationary reactor - a pulsed nature and a high level of the average intensity of the neutron emission. The neutron beam utilization efficiency for neutron spectroscopy on this reactor is close to 100%. In the Obninsk Physico - Power Generation Institute (FEI), the approximate theory of a periodic pulsed reactor was developed, a project for building it in Dubna was originated by the joint efforts of the scientists of the Physico - Power Generation Institute and the Joint Institute of Nuclear Research (JINR).

3.1. IBR-1 reactor

In July 1960, in the Neutron Physics Laboratory of the Joint Institute of Nuclear Research (JINR). under supervising Academician I. M. Frank, operation of the IR was started a fast neutron periodic pulsed reactor. This was the world's first reactor of a new type, in which pulses were generated periodically by the rotation of part of the active zone. The half - width of the fast neutron pulse in the 1BR was about $40 \, \mu s$; the repetition frequency of the bursts was from 5 to 50 Hz. The average power, in other words the total energy released during each period, divided by the duration of the period, in the first year of operation of the IBR amounted to 1 kW.

The instantaneous power at the pulse maximum, with a repetition frequency of 3 Hz amounted to 5 MW. In conjunction with the large neutron flight base - 1000 these characteristics established the comparability of the IBR spectrometer in a single step with the best spectrometers in stationary reactors. After improvement of the cooling system, the reactor power was increased to 6 kW.

New pulsed reactor operating cycles were investigated: with pulses of variable amplitude and with low pulse repetition frequency, when the peak power reached 500 MW. The IBR was redesigned in 1969; the new version of the reactor was designated the IBR - 30, with an average power of 30 kW. The special feature of the IBR - 30 is the presence of two moveable zones, which enables the thermal load on each of them to be reduced.

- Average power was $\cong 1\ Kwatt$
- Maximum power was $\cong 5\ Mwatt$
- Neutron pulse from $(5 - 50\ Hz)$
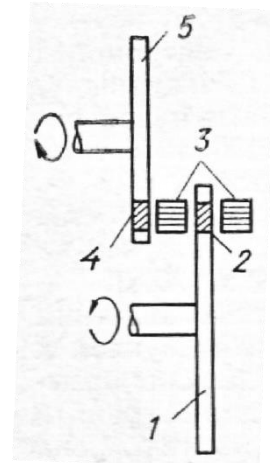- Pulse time period is $\cong 40\ \mu sec$

Fig.1. The photo shows the world's first research pulsed fast neutron reactor of periodic operation (IBR).

Fig.2. Schematic diagram of IBR. *1 – reactivity modulator disk; 2 – uranium insert (main movable core); 3 – two parts of plutonium core, 4 – uranium insert (additional movable core); 5 – additional reactivity modulation disk.*

3.2. IBR-30 reactor

The first IBR stopped its operation in August 1968. It is particularly remarkable that the last experiment on this reactor was a well-known experiment on the first observation of ultra-cold neutrons carried out in a rare pulse mode. In 1969, a more powerful linear electron accelerator with a pulse current of 200 mA and pulse duration of about 1 μs was installed in place of the microtron. A tungsten target was placed in the reactor core. Until 1996, the IBR-30 reactor operated in two modes: as a pulsed reactor and pulsed superbooster, and the properties of IBR-30 were:

- Average power was $\cong 30\ Kwatt$
- Neutron pulse from $(100\ Hz)$
- Pulse time period is $\theta \cong (55 - 60\ \mu sec)$

From 1996 and until 2001 the IBR-30 operated only as a booster-multiplier with a pulse frequency of 100 pulses per second, an average power of the multiplying target of 12 kW, and a pulse half-width of 4 μs, IBR-30 booster was taken out of service in 2001.
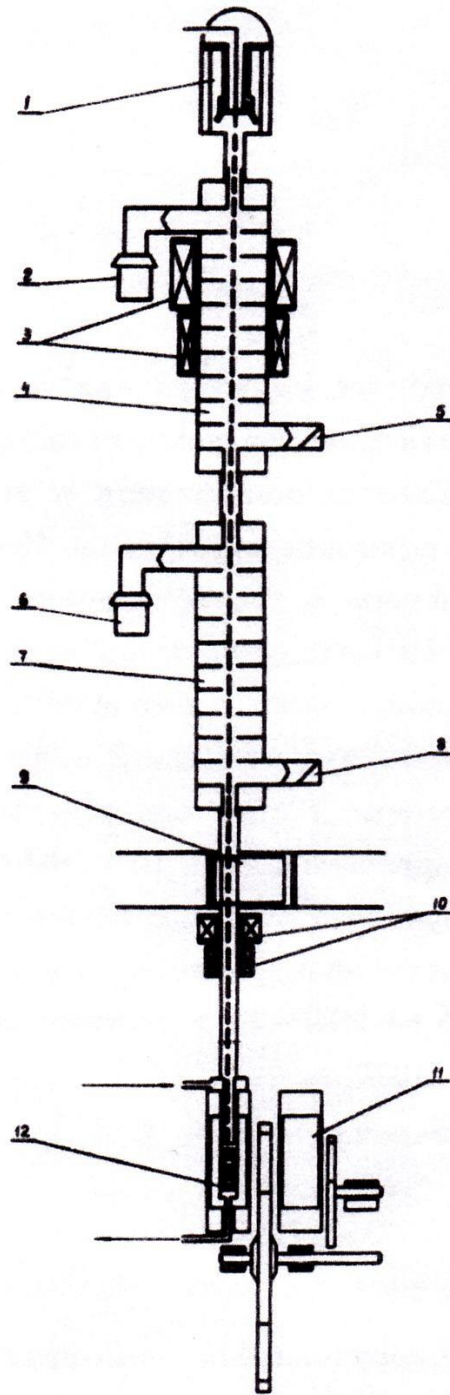
Fig.3. Schematic diagram of IBR-30 with an injector – linear electron accelerator. *1 – electron gun; 2, 6 – klystrons; 3 – focusing solenoids; 4, 7 – diaphragm waveguides of sections № 1 and № 2; 5, 8 – water loads; 9 – vacuum protective shutter; 10 – quadrupole lenses; 11 – IBR-30 core; 12 – neutron-producing target.*

3.3. IBR-2 reactor

IBR-2 is a fast pulsed reactor with mechanical reactivity modulation by movable reflectors. The IBR-2 reactor is the world's highest flux pulsed source. Included in the European network of leading neutron centers.

Officially, work on the IBR-2 project started in 1966, and actual construction – in 1969. The first critical assembly was manufactured at IPPE in 1968, and from 1970 to 1975 the model of the movable reflector was investigated at a test bench in Dubna. The physical startup of the reactor (without a coolant) was conducted 8 years after the start of the construction (in late 1977– early 1978). Then the preparation and implementation of power startup (with sodium) began, which was actually completed on April 9, 1982, when the average power attained was 2 MW for a pulse repetition rate of 25 Hz, and first physical experiments were performed with extracted beams. After the death of D.I. Blokhintsev in January 1979, I.M. Frank became the scientific supervisor of IBR-2. Officially, the reactor was commissioned on February 10, 1984, and the implementation of the program of physical experiments started on April 9, 1984 after the power reached 2 MW at a pulse frequency of 5 Hz.

Reactivity modulation was realized by a steel movable reflector consisting of two parts rotating with different velocities (1500 and 300 revolutions per minute). When both parts of the reflector traversed the core, a power pulse was generated (1500 MW). At a regular mode of operation of the reactor (2500 hours for experiments per year) the service life of the core without fuel exchange was expected to be no less than 20 years, the service lifetime of the movable reflector 5-7 years. In 1995, IBR-2 started operating with a new movable reflector (the third in succession), and in 2004, a nickel reflector of complex configuration was installed,

the expected service life of which is 25 years. In 2011, the modernization of the IBR-2 reactor was completed.

Core parameters of the IBR-2 reactor (basic)

- IBR-2 reactor pulse frequency 5 Hz
- Thermal neutron pulse width 320 μsec
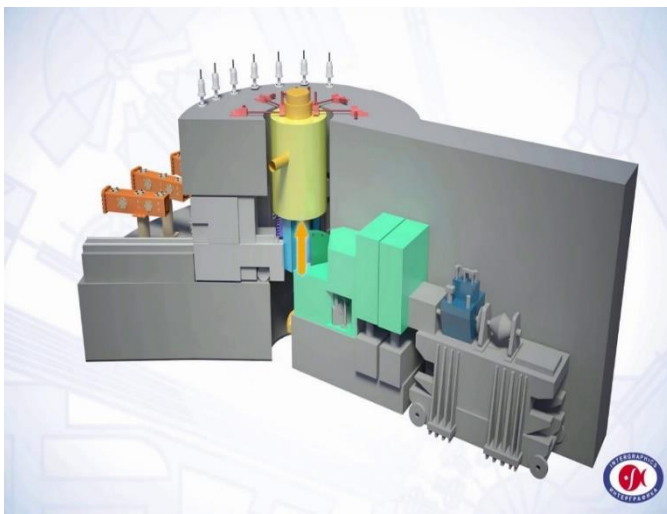- Neutron flux density from the moderator surface $2.4 \cdot 10^{16}$ n/cm^2/sec
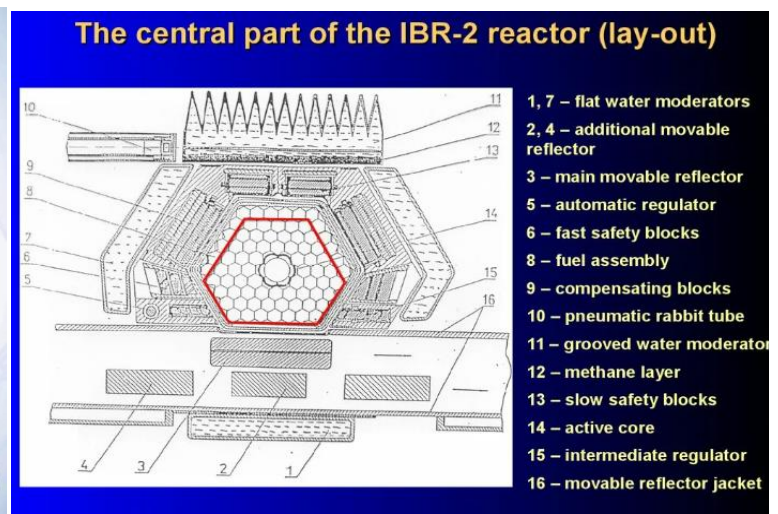

Fig.4. IBR-2 reactor   *Fig.5. Main part of the IBR-2 reactor*

3.4. IBR-2M Reactor

The IBR-2M is a modification version of the IBR-2 (2 MW nominal power) pulsed research fast reactor with PuO$_2$ fuel elements. The reactor coolant is liquid sodium. The pulsed mode operation is enabled by a reactivity modulator consisting of two rotating parts—a main movable reflector (OPO, at 1500 rpm) and an auxiliary movable reflector (DPO, at 300 rpm), that create reactivity pulses. For nominal DPO rotation speed, the reactivity of every fifth pulse is positive; that is, the reactor becomes prompt neutron supercritical for ca. 0.400 ms (0.215 ms half-width), with

a repetition frequency of 5 Hz (Figure 6). As a result, powerful power pulses of 5 Hz repetition frequency take place in the reactor. The energy range of the fast neutrons is up to 10 MeV, with an almost linear logarithmic distribution versus energy. The pulsed operation mode of the reactor is established when the prompt neutron supercriticality reaches the "equilibrium" value (at 5 Hz) at which the reactor can be periodically pulsed. For supercriticality smaller than the "equilibrium" value, the amplitude (and consequently the energy) of each subsequent pulse is smaller than that of the previous one, which means that the reactor is attenuating. In the pulsed reactors the energy of neutron is very high so we need to moderate it very well to get cooled neutrons.
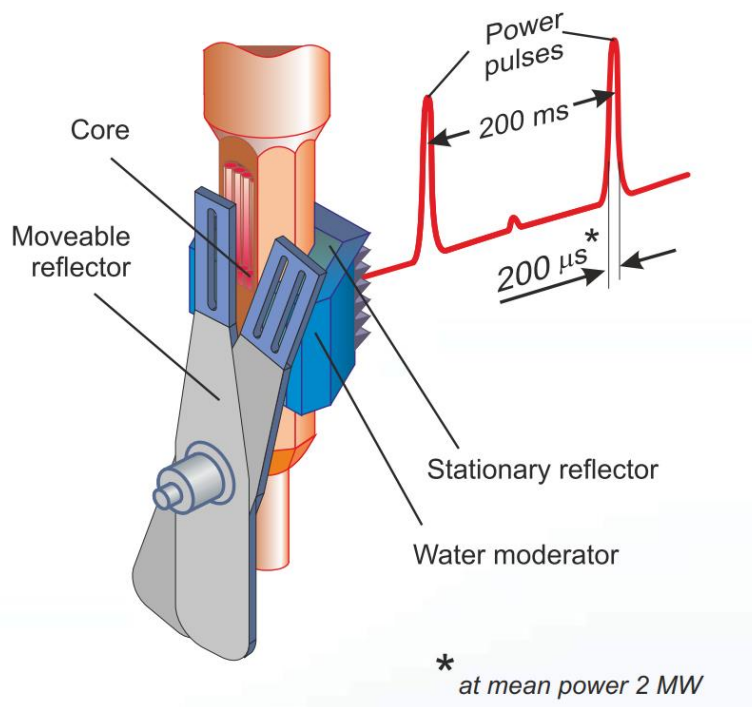

Fig.6. Details of the IBR-2M reactor showing the active core and the two movable reflectors

4. Neutron Moderator

Neutrons from fission reaction in reactor's core born with high energy (about 2 MeV). To be able to use these neutrons in different experiments, reduction its energy to thermal or may be cold energy region is needed. The neutron moderator is used to shift the fast neutron energy spectrum to thermal one.

Neutron Moderator is a medium that reduces the energy of fast neutrons, ideally without capturing any, leaving them as thermal neutrons with only minimal (thermal) kinetic energy. The good neutron moderator should be characterized by the following; large scattering cross section, small absorption cross section and large energy loss per collision.

Around the IBR-2 reactor there are 3 water moderator and pre-moderator at ordinary room temperature used to get thermal moderators in extracted beams, and 3 cold moderators chambers (from mesitylene) to get cold neutrons (see figure 7).
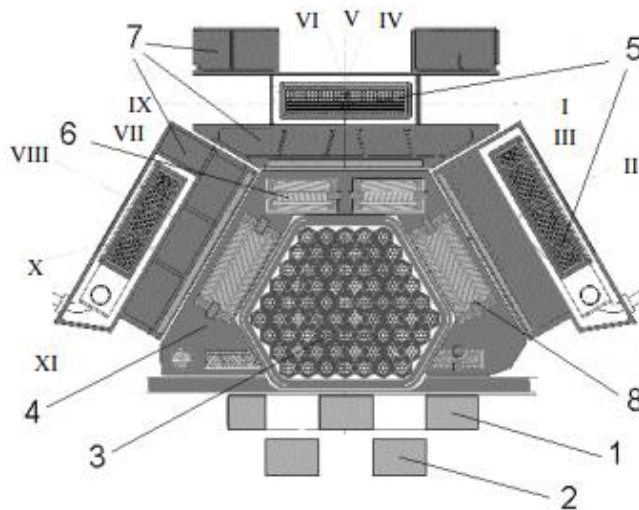

***Fig. 7. – Design scheme of the IBR-2M core with complex of moderators. Horizontal cut-off** (1. Main moveable reflector, 2. Auxiliary moveable reflector, 3. Fuel assembly, 4. Stationary reflector, 5. Cold moderators, 6. Emergency system, 7. Water moderators, 8. Control rods; Roman characters mark numbers of extracted neutron beams).*

5. Uses of neutrons

Neutrons are used for studying fundamental symmetries and interactions, structure and properties of nuclei, but nowadays neutrons are mostly required in investigations of condensed matter including solid states, liquids, biological systems, polymers, colloids, chemical reactions, engineering systems, etc.

What mainly underpins our present-day quality of life depends upon our understanding and control of the behavior of materials. The neutron in many ways is an ideal probe for investigating materials, having significant advantages over other forms of radiation in the study of microscopic structure and dynamics.

5. Ansys

Ansys develops and markets engineering simulation software for use across the product life cycle. Ansys Mechanical finite element analysis software is used to simulate computer models of structures, electronics, or machine components for analyzing the strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, Ansys software may simulate how a bridge will hold up after years of traffic.

Most Ansys simulations are performed using the Ansys Workbench system, which is one of the company's main products. Typically, Ansys users break down larger structures into small components that are each modeled and tested individually. A user may start by defining the dimensions of an object, and then adding weight, pressure, temperature and other physical properties. Finally, the Ansys software simulates and analyzes movement, fatigue, fractures, fluid flow, temperature distribution, electromagnetic efficiency and other effects over time.

5.1.   Workshop 1: Mixing Tee

This workshop assumes no prior experience of ANSYS Meshing

Objectives

- Opening a ready mesh in ANSYS Worbench
- Getting familiar with the Outline tree, Named Selections and the graphics window

5.1.1. Problem Description

- Mixing tees are commonly used for static mixing of two fluid streams
- In this problem, a mixing tee is used to mix two water streams, one at 10 °C and the other at 90 °C
- The goal of the simulation is to evaluate how effectively the two streams are mixed by examining temperature profile on the cross section of the tee's exit
- A more uniform profile indicates more effective mixing
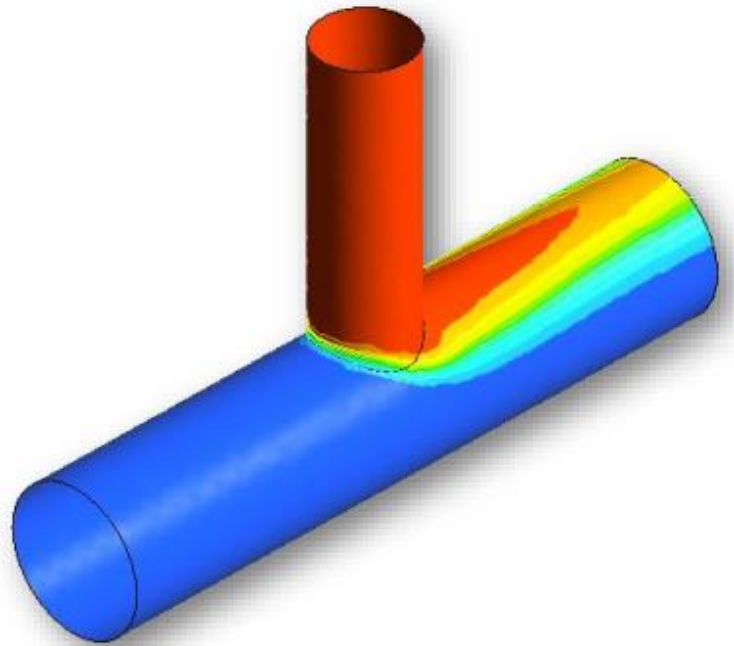
5.1.2. Geometry and Operating Conditions
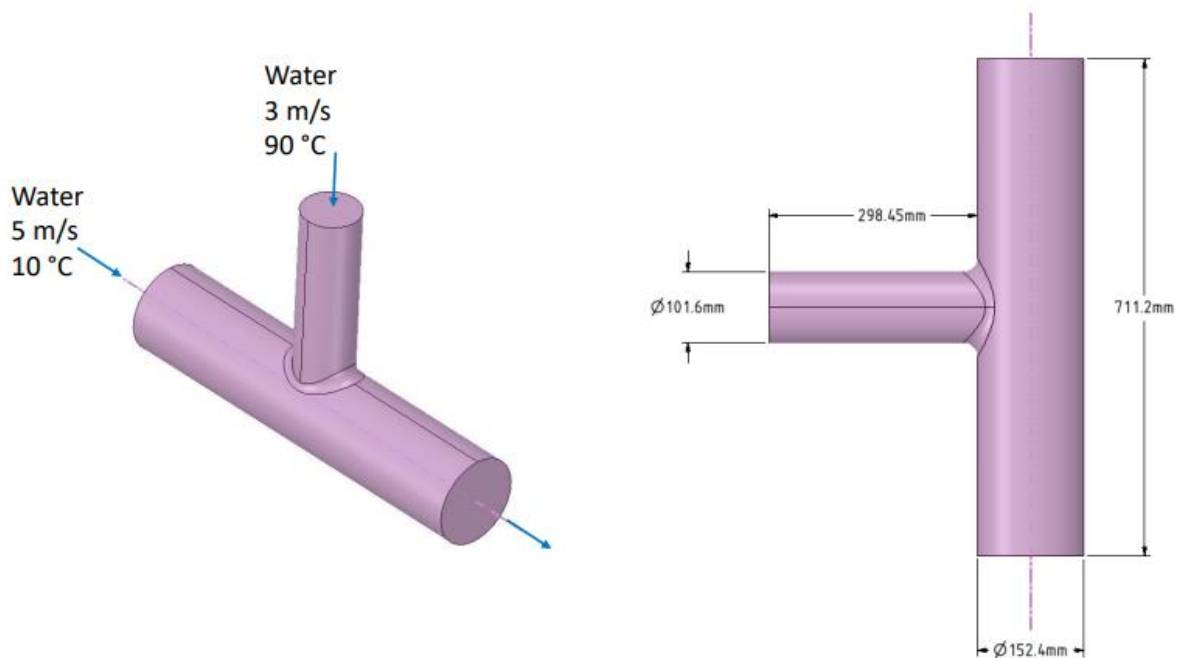
5.1.3. Boundary Conditions

The next step is to create the boundary conditions. Is to create a cold inlet, a hot inlet and an outlet. The remaining faces will be set to adiabatic walls. Currently all external 2D regions are assigned to the junction Default boundary condition n.

Each domain has an automatic default boundary condition for external surfaces. The default boundary condition is a No Slip, Smooth, Adiabatic wall. when creating new boundary conditions, those regions are automatically removed from the default boundary condition
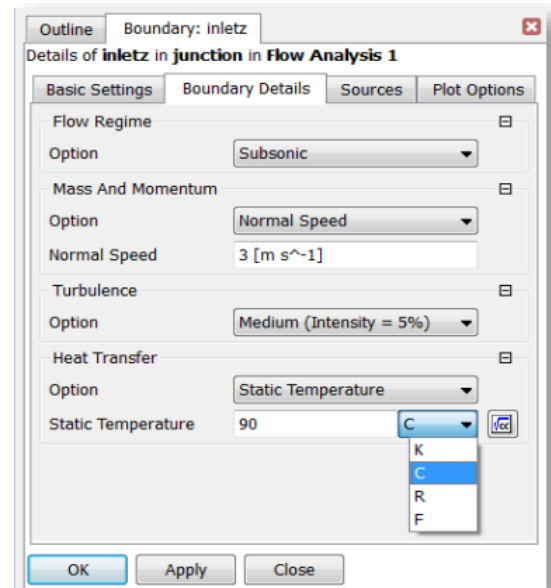
5.1.4. CFX-Pre – Inlet boundary conditions

This inlet will have a normal speed of 5m/s and temperature of 10°C.

- Click the Boundary Details tab.
- Enter a value of 5 for Normal Speed. The default units are [m s^-1].
- Enter a value of 10 for Static Temperature.
- You might need to change the units.
  - Use the drop-down menu to the right of the field to change the units to C (Celsius).
 - Click OK to apply the boundary and close the form.
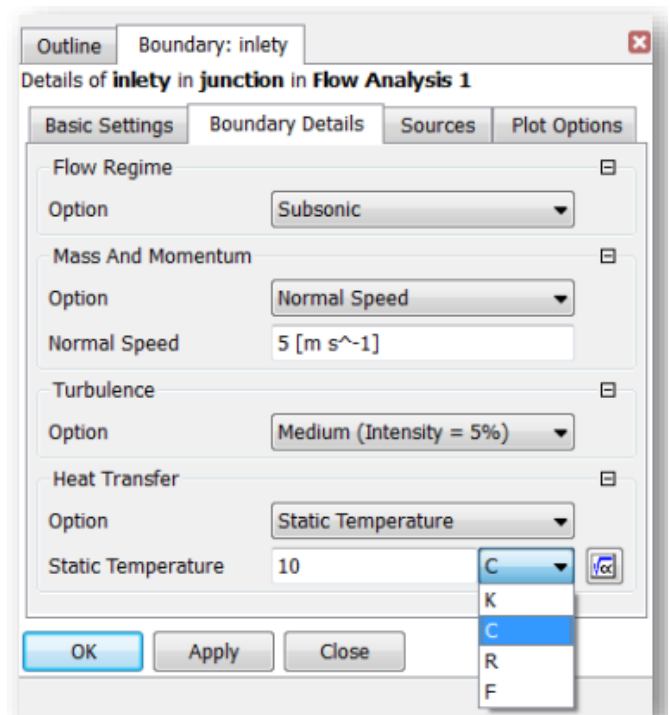
Hot Inlet

- Repeating the steps used for the previous boundary condition, create a new Inlet boundary called inletz, located on inlet z.
- The Normal Speed will be 3 [m s^-1] and the Static Temperature, 90 [C].

### 5.1.5. CFX-Pre – Outlet boundary conditions

- Create an Outlet boundary called outlet and located on outlet.
- Click the Boundary Details tab.
- Set Relative Pressure to 0 [Pa].
  - This is relative to the domain Reference Pressure, which is 1 [atm] (set as default value in a previous slide).
- Leave all other settings at their default values.
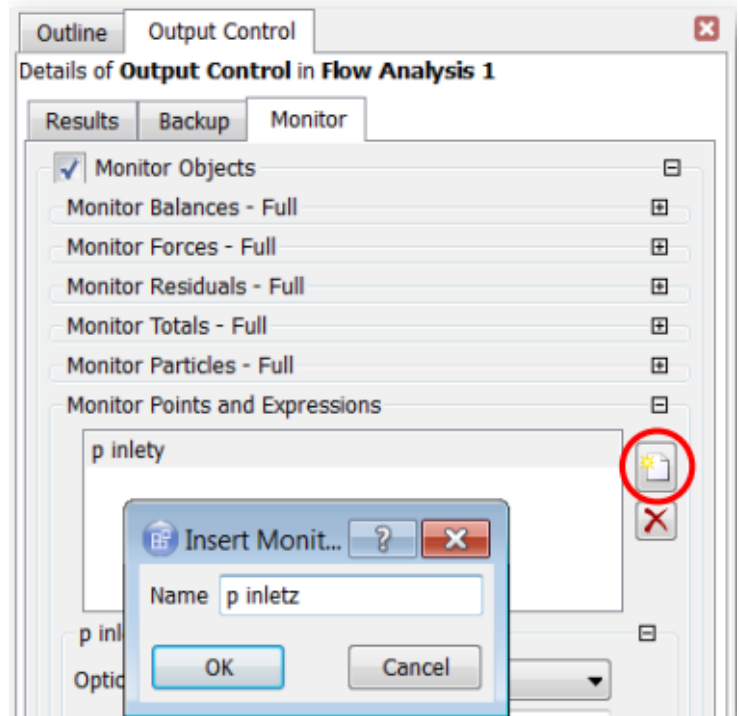- Click OK.
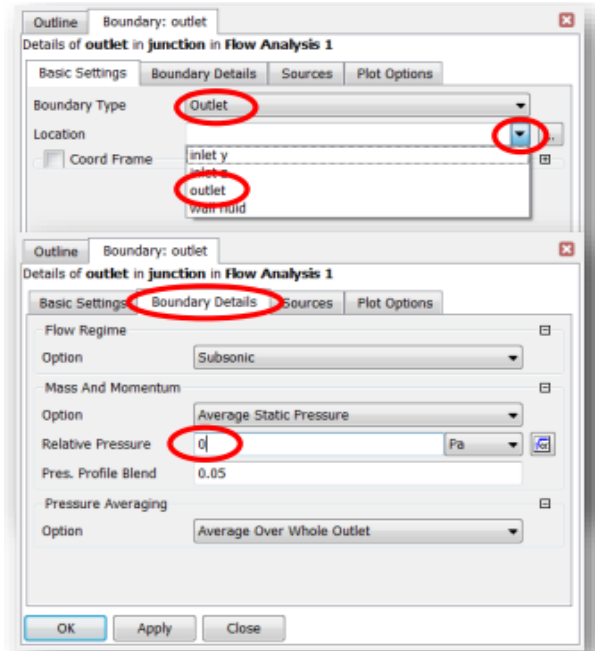
5.1.6. CFX-Pre – Monitor points

In all engineering flows there are specific variables or quantities of interest. Sometimes they do not reach a satisfactory value by the time the overall solution has reached the convergence criteria. So it is always a good idea to monitor them as the solution progresses. For a steady-state simulation we want the monitors to settle to a constant value. Variation, particularly if it follows a repeated pattern, can indicate time dependency. In this simulation pressure will be monitored at both inlets.

- An expression will be used to define the monitor point. Expressions are written usin CFX Expression Language, CEL, which i covered in a later module.
- Set Option to Expression so that you can enter the following expression in the Expression Value field: areaAve(Pressure)@inlety
  - The expression calculates the area-weighted average of pressure at the boundary inlet.
- Click Apply

16
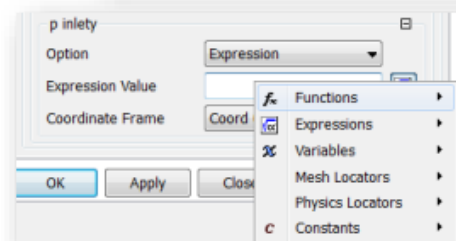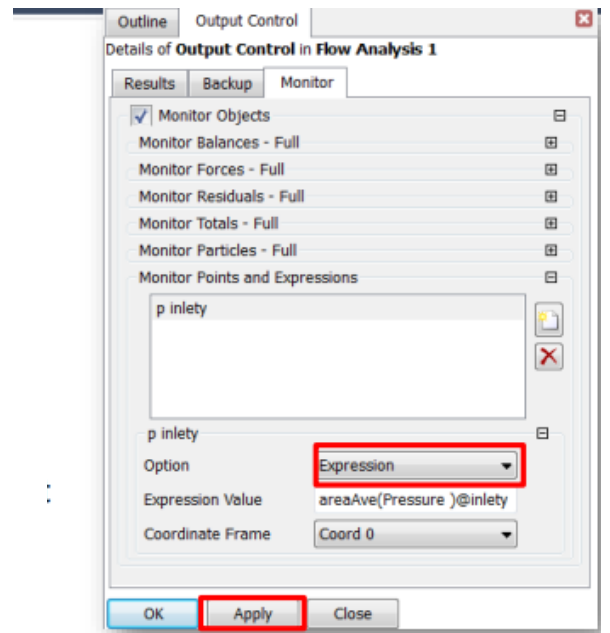
Note that expressions are case sensitive.

- ▪ To avoid syntax errors, right-click in the box to obtain drop down menus.
  - o areaAve is a locator-based function
  - o Pressure is a variable
  - o inlety is a physics locator
- • A second monitor point will be used to monitor the pressure at the second inlet, inletz.
- • Click the New icon.
- • Set the Name to (p inletz) and click OK.
- • Set Option to Expression.
- • For Expression Value enter: areaAve(Pressure)@inletz
- • Click OK. This will apply the settings and will close the Output Control form.

5.1.7. Obtaining a solution

Approximately 60 iterations are required to reduce the RMS residuals to below the target of 1.0x10-4. The pressure monitor points approach steady values.

- • Click on the tabs to view the plots of RMS residuals for each equation and the User Points tab to see the monitor plot.
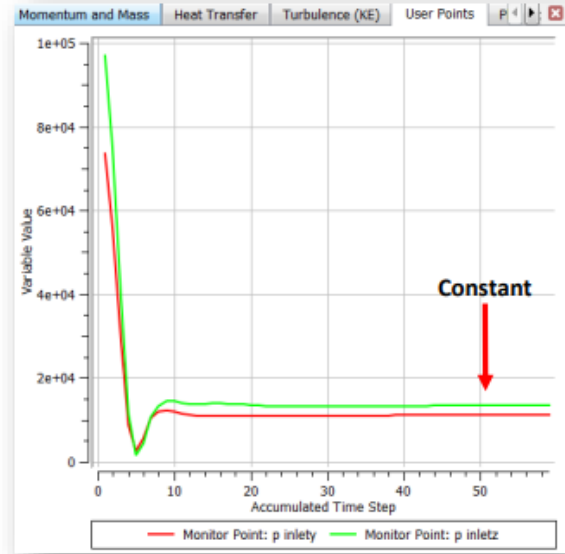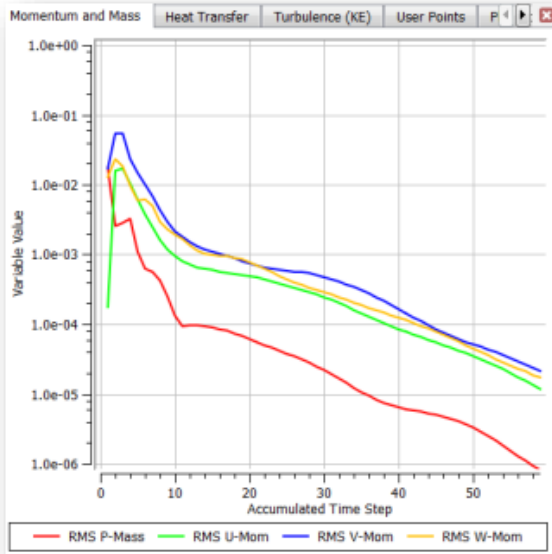
- To view plots of imbalances, continued
    - To see the plots at the end of the run in more detail, right-click in the window and select Monitor Properties.
    - On the Range Settings tab set Timestep Range Mode to Most Recent & Timestep Window Size to 10.
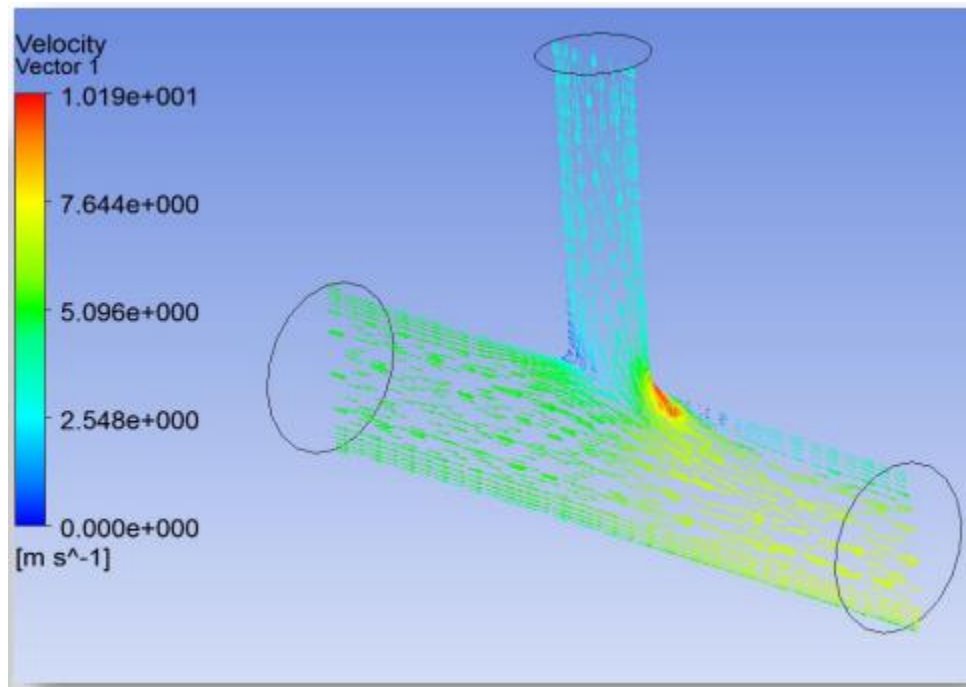   - The Energy Imbalance is still decreasing but is of the order of 0.15 % (quite small)
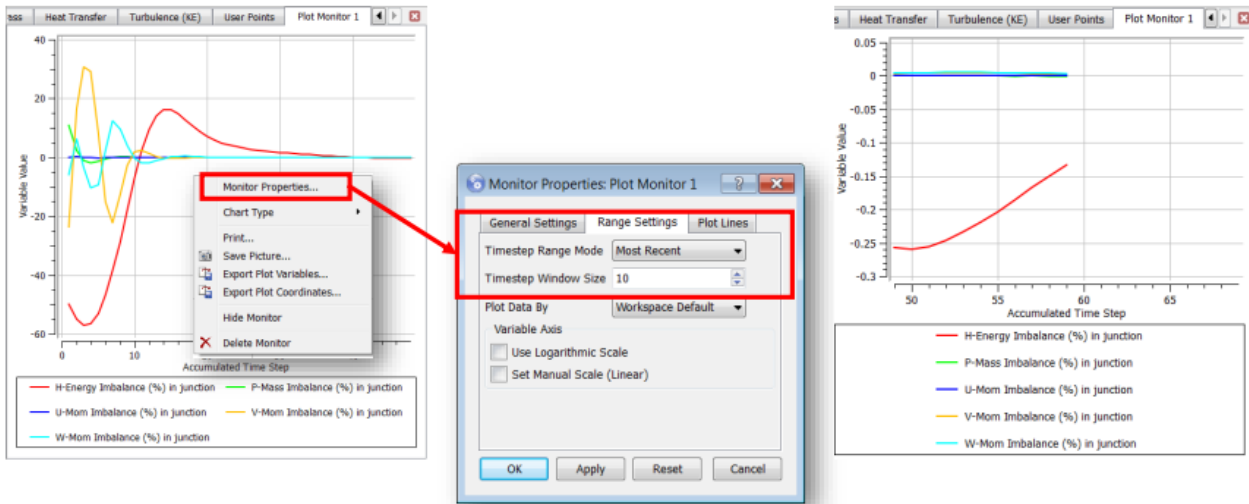
5.1.8. CFD-Post - Temperature contour plot
- A temperature contour plot on the walls is now visible.
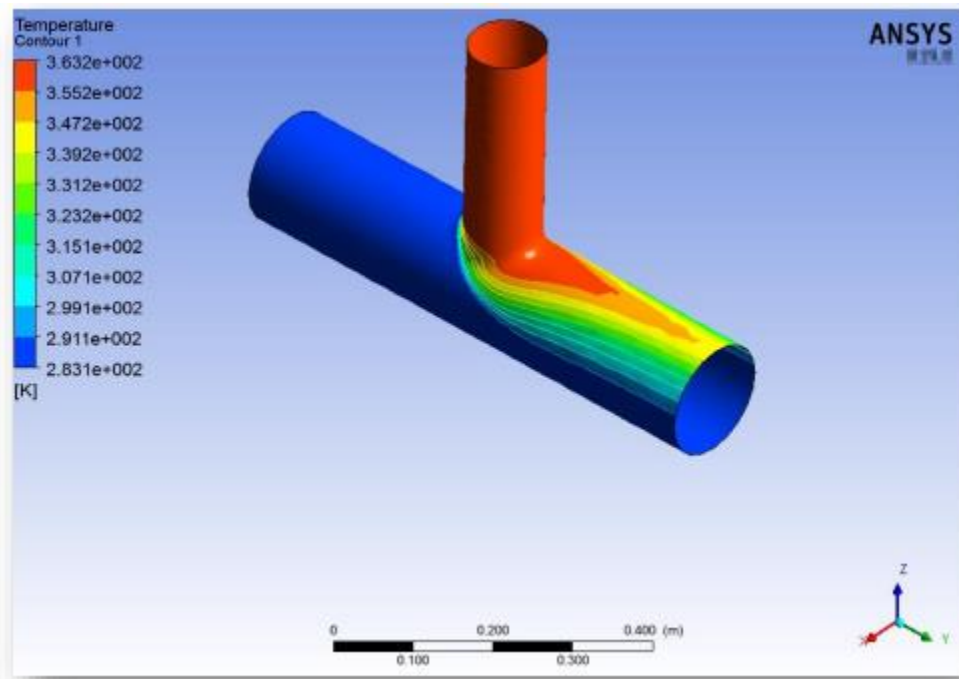
5.1.9. Post – Velocity vector plot

5.1.10.   Summary

In this problem one have learned the basic steps for CFD analysis with ANSYS CFX

- Start with a CAD file of your geometry
- This geometry must be the fluid volume
  - Create a Meshing Component System in Workbench and import your CAD file
  - Connect a CFX component system to the Mesh cell
- Set Domain parameters, Boundary conditions and Solver settings
- Run the simulation whilst monitoring quantities of interest
- Post-process the results in CFD-Post

One of the important things to remember in your own work is, before even starting the ANSYS

software, is to think WHY you are performing the simulation:

– What information are you looking for?

–What do you know about the inlet conditions?

In this case we were interested in checking the pressure drop, and assessing the amount of mixing present around this T-piece.

5.2.   Workshop 2: Flow Distribution in an Air Manifold

Introduction

- Simulation of Flow Distribution in a Manifold
- You will start by importing a CAD file in Workbench
- Named Selections will be assigned and you will mesh the geometry from the CAD file
- Solve problem in CFX
- Examine Results
- Check flow distribution
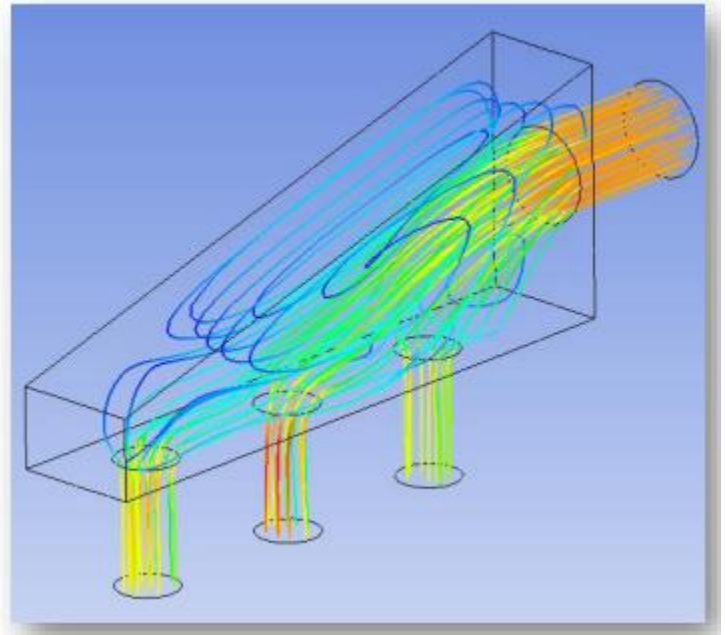
5.2.1. Problem Description

Manifold is connected to an air supply pumping 30 liters per minute

- Goal is to split the airstream into three streams each at 10 liters per minute

-Within +/- 2%

- Gauge pressure = 0 Pa at each of the three outlets
- Simulation will predict whether the desired flow uniformity can be achieved with the existing design

5.2.2. Geometry and Operating Conditions

3 outlets @ gauge pressure = 0 Pa
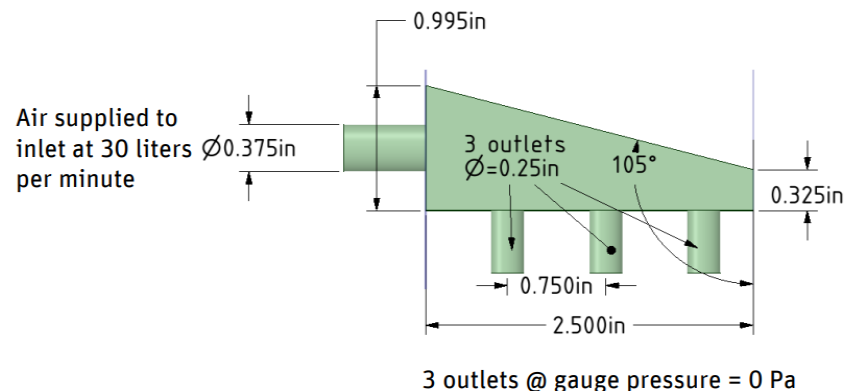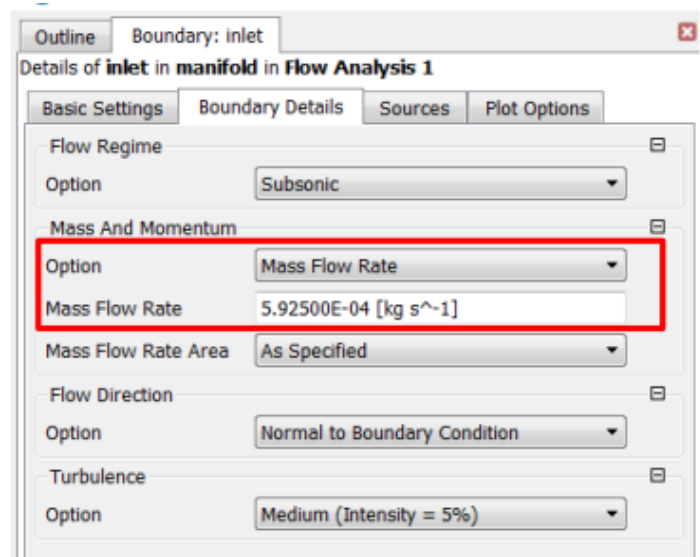
5.2.3. Boundary Conditions

The next step is to create the boundary conditions. You will create a velocity specified inlet, and 3 pressure outlets. The remaining faces will be set to adiabatic walls. Currently all external 2D regions are assigned to the manifold Default boundary condition.

Each domain has an automatic default boundary condition for external surfaces. The default boundary condition is a No Slip, Smooth, Adiabatic wall. As you create new boundary conditions, those regions are automatically removed from the default boundary condition.

5.2.4. CFX-Pre – Inlet boundary conditions

This inlet will have a Mass Flow Rate of $5.925\ e-04\ kg/s$

- Click the Boundary Details tab.
- Set the Mass and Momentum Option to Mass Flow Rate.
- Enter a value of $5.925e-04$ for Mass Flow Rate. * The default units are $[kg\ s\char`\^-1]$.
- Click OK to apply the boundary and close the form.

The given condition at the inlet boundary is that Air flows at 30 liters per minute. For a density of Air at $25°\ C$ of $1.185\ [kg/m\char`\^3]$ this Volume Flow Rate corresponds to an inlet Mass Flow Rate of $5.9250E-04\ [kg/s]$.

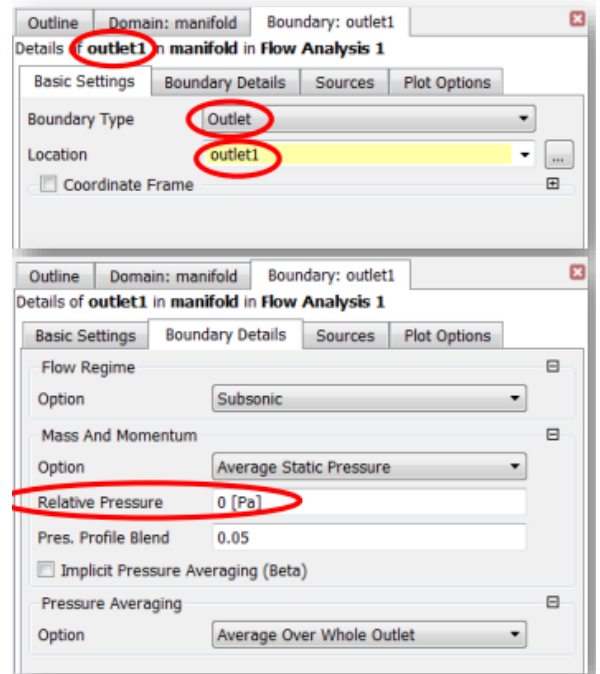### 5.2.5. CFX-Pre – Outlet boundary conditions

- Create an Outlet boundary called outlet1 and located on outlet1.
- Click the Boundary Details tab.
- Set Relative Pressure to 0 [Pa].

This is relative to the domain Reference Pressure, which is 1 [atm] (set as default value in a previous slide).

- Leave all other settings at their default values.

- Click OK.

The Average Static Pressure boundary condition allows pressure to float locally on the boundary while preserving a specified average pressure. If Static Pressure had been chosen, a fixed pressure would be applied at every nodal location on the outlet boundary.

### 5.2.6. CFX-Pre – Remaining Outlet boundary conditions

- Repeating the steps used for the previous boundary condition, create two more Outlet boundaries called outlet2 and outlet3 located on outlet2 and outlet3, respectively.

- Set Relative Pressure to 0 [Pa] in the Boundary Details tab of outlet2 and outlet3
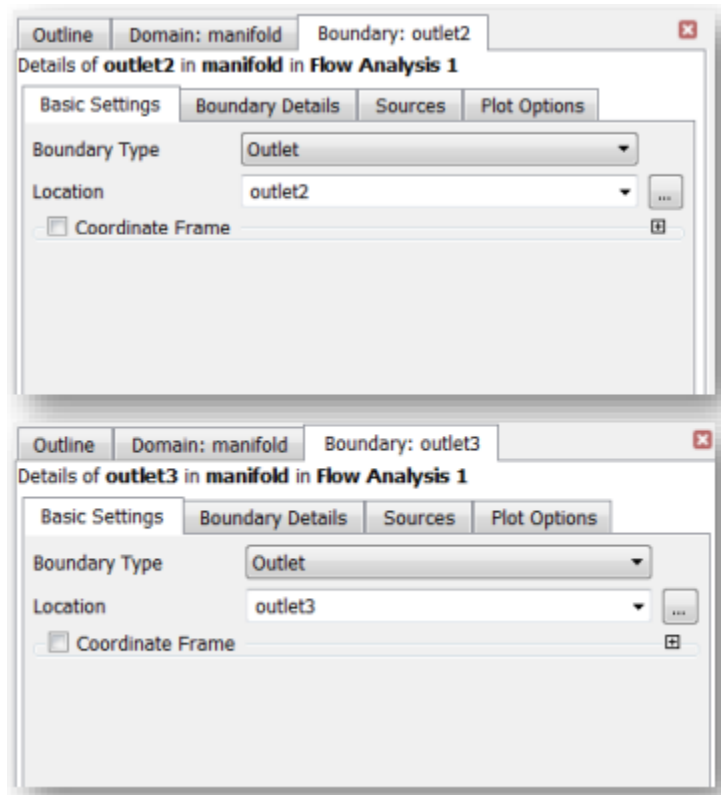
5.2.7. Obtaining a solution

Approximately 95 iterations are required to reduce the RMS residuals to below the target of 1.0x10-5. The mass monitor points approach steady values.

- Click on the tabs to view the plots of RMS residuals for each equation and the Mass tab to see the monitor plot.
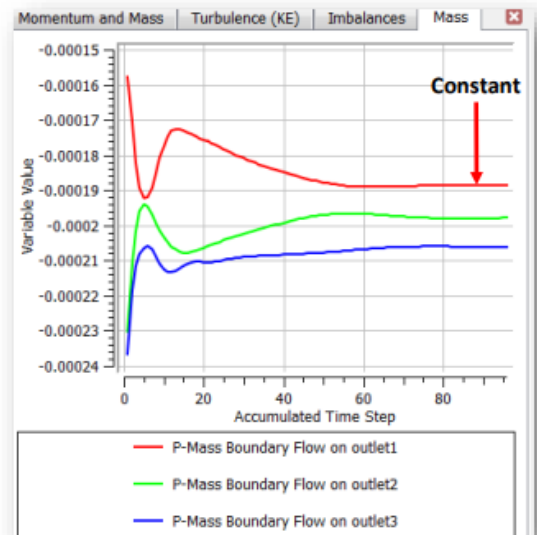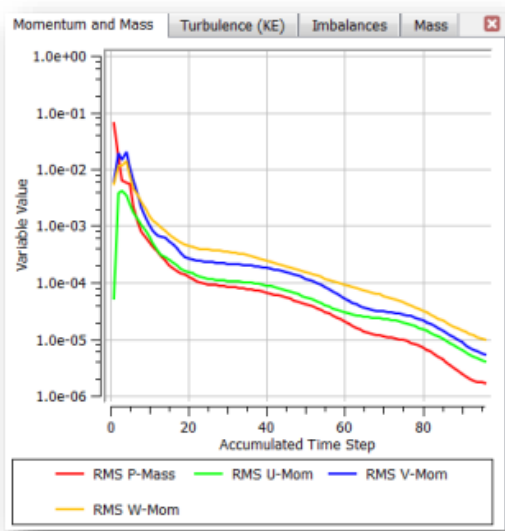
5.2.8. Flow Distribution

- The mass flow rates at all boundaries are shown in the following table:

| Boundary	Mass Flow Rate [kg/s]
Inlet	5.9250E-04
outlet1	-1.9026E-04
outlet2	-1.9653E-04
outlet3	-2.0571E-04

- The inlet flow rate is $5.9250E - 04 \, [kg/s]$ so if the flow were uniformly distributed between each of the three outlets, the flow rate at each outlet would be $1.9750E - 04 \, [kg/s]$.

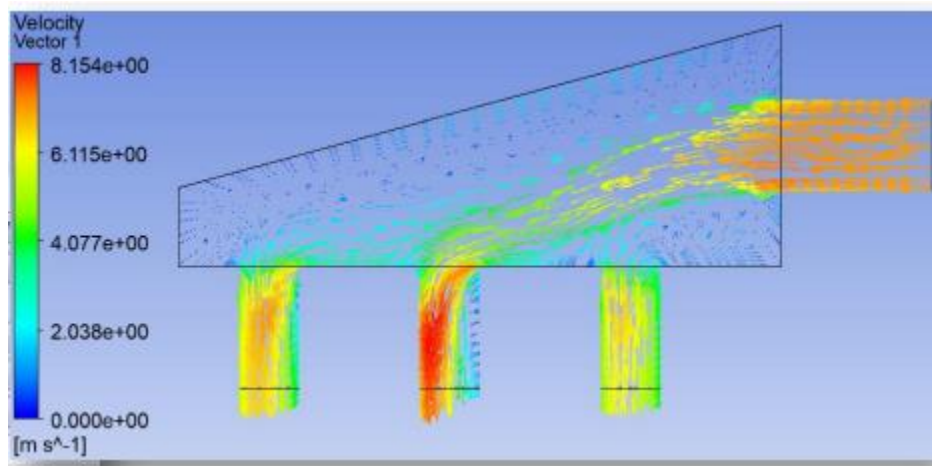| Boundary	Deviation from Uniform Flow %
outlet1	-3.67%
outlet2	-0.49%
outlet3	4.16%

- There is a significant (>2%) difference between the flow rate through outlet1 and outlet3.

5.2.9. CFD-Post - Temperature Contour Plot
A Pressure contour plot on the walls is now visible.
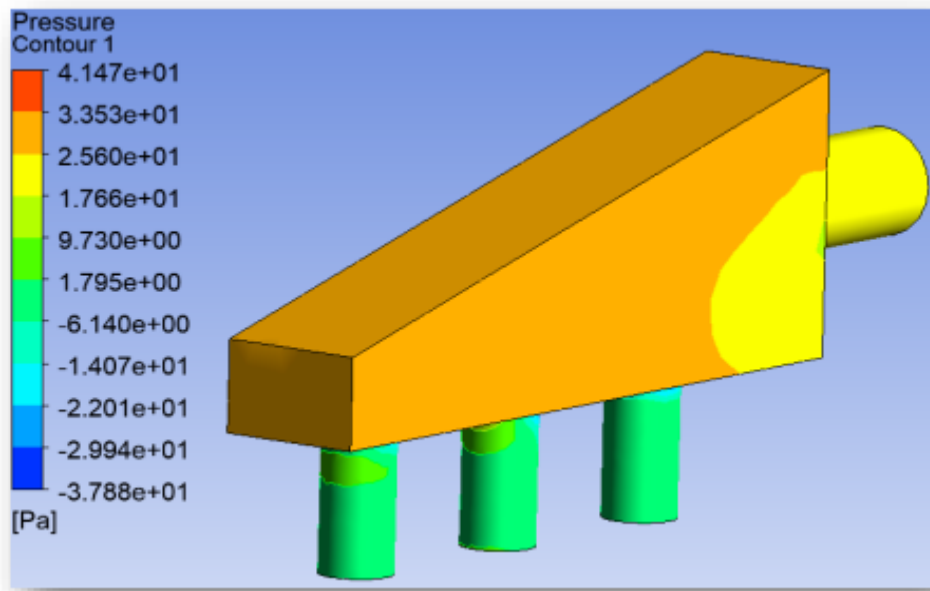
5.2.10.   CFD-Post – Velocity Vector Plot


5.2.11.   CFD-Post – Velocity Streamlines
- The ribbons give a 3-D representation of the flow direction.
- Their color indicates the velocity magnitude.
- Velocity streamlines may be colored using other variables e.g. temperature.
- The inlet flow mostly bypasses outlet1 and feeds directly into outlet3, which is probably the reason for the non-uniform flow distribution

Velocity
Streamline 1
8.154e+00
6.117e+00
4.080e+00
2.043e+00
5.728e-03
[m s^-1]
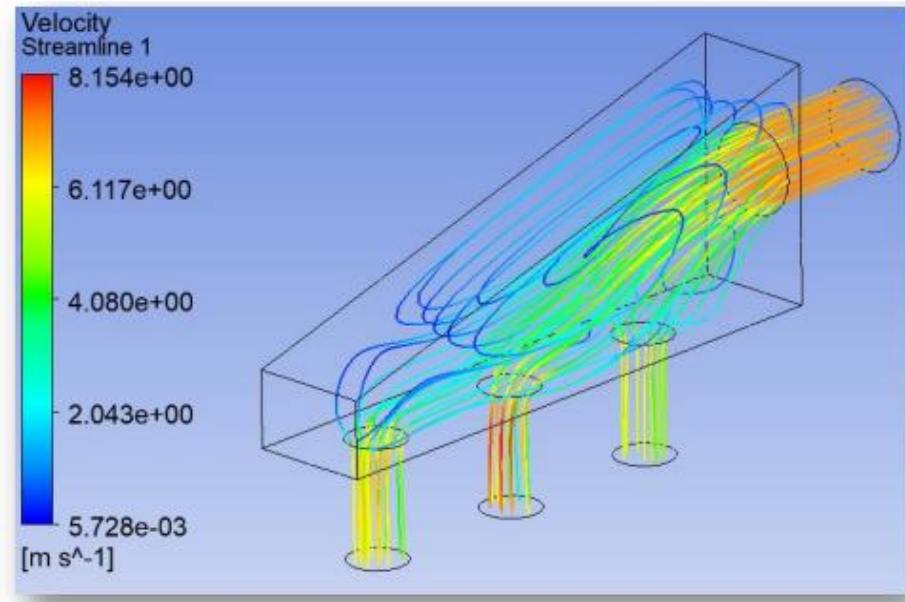
5.2.12. Summary

In this problem one have learned the basic steps for CFD analysis with ANSYS CFX

- Start with a CAD file of your geometry
- This geometry must be the fluid volume
- Create a Meshing Component System in Workbench and import your CAD file
- Connect a CFX component system to the Mesh cell
- Set Domain parameters, Boundary conditions and Solver settings
- Run the simulation whilst monitoring quantities of interest
- Post-process the results in CFD-Post

5.2.13. Summary of Results

The results showed that for this design, there was significant variation in the flow rate at each outlet

- This was qualitatively verified by monitoring the Mass Flow Rates @ all outlets in using the Solver Manager
- The use of pathlines to visualize the flow helped to provide insight to the root cause of the non-uniform distribution in this design
- Much of the flow entering the manifold passes over the openings for the first outlet and goes directly into outlet3
- This effect should be reduced in order to be able to achieve the design goal of uniform flow at each outlet

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6. Conclusion

During the training, I learned a lot about the pulsed reactors, their types, characteristics, how they work, and the reason of building these pulsed reactors as a neutron source. Also, we saw the neutron channels that is coming from the active zone of the reactor and the accelerator and it is mechanism. In addition, we began to learn Ansys and how to use it to analyze the thermal hydraulics of the reactor core and the reactivity moderator[1-12].

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