Piping Design,Modelling & Detailing (Design & Software based Flexibility Analysis of Industrial Piping Systems)

Course Objectives	• Principles of designing industrial piping systems for optimal performance. • Proficiency in using software tools for conducting flexibility analysis of piping systems. • Skills to determine optimal pipe diameters for various pipe routing using spreadsheets. • Designing pipes for internal pressure and creating comprehensive pipe material specifications. • Acquire the ability to perform and modify flexibility analyses for both simple and complex pipe routings.
Course Outcomes	• Determination of optimum Pipe Diameters for a given Pipe Routing using Spreadsheet. • Design of Pipe for Internal Pressure using Spreadsheet. • Development of Pipe Material Specification using Spreadsheet & Pipe Spec. Template. • Performing Flexibility Analysis of a Simple Pipe Routing & its Modification • Performing Flexibility Analysis of a Complex Pipe Routing & its Modification

Course Duration: 45 Hours

<u>Course Content:</u>

Unit 1: Single-Phase Pipe Flow

Single-Phase flow Regime identification; Skin friction pressure drop calculation in straight pipe using Darcy friction factors for Single-phase; Single phase friction factor correlations; Calculation of Minor losses, Pipe diameter calculation

Unit 2: Pipe Specification

Design of Pipe Size for internal pressure; Selection of standard pipe size (Nominal Diameter, DN); Selection of Schedule Number considering corrosion allowance and mill Tolerance; Selection of Manufacturing type; Pipe end connections

Unit 3: Selection of MoC for Valve, Flange, Gasket and Nut & Bolts & Class for Flanges & Valves

MoC for Valves, Flanges, Pipe Fittings, and Nut & Bolts; Selection of pressure-temperature rating of Valve i.e., Valve Class; Selection of valve face; Selection of pressure- temperature rating of Flange, i.e., Flange Class; Selection of flange face

Unity 4: Pipeline Stresses

Primary Loads; Secondary Loads; Theories of Failure; Fatigue; Design for Sustained Loads; Design for Expansion Loads

Unit 5: Pipe Flexibility Analysis using Stress Analysis Software

Introduction to Software; Exploring Software Tool Bar; Performing Flexibility Analysis for Moderate Piping System

Test Projects:

Use Cases

OVERALL COURSE LEARNING OUTCOME ASSESSMENT CRITERIA AND USECASES		
LEARNING OUTCOME	**ASSESSMENT CRITERIA**	**USE CASES**
1. Determination of Optimum Pipe Diameters for a given Pipe Routing using spreadsheet.	• Identification of Single- Phase Flow Regime • Determination of a Pressure Drop in a Straight Pipe • Determination of Pressure Drop in various Fittings. • Determination of Total Static Pressure Drop • Finalization of optimum pipe diameters for a given preliminary pipe routing	**Use Case 1:** Optimum Pipe Diameters determination for ***<u>Category D</u>*** Fluid Service. **Scenario:** Certain flow rate (Mass/Volumetric flow rate) of Category D Fluid Service with allowable pressure drop for a given process flow parameters. (Mass/Volumetric flow rate) of Elevated Temperature/Pressure Fluid Service with allowable pressure drop for a given process flow parameters. **Task:** Students must perform the similar tasks mentioned in the above **use case 1.** **Use Case 2:** Optimum Pipe Diameter

		determination for ***Normal*** Fluid Service. **Scenario:** Certain flow rate (Mass/Volumetric flow rate) of Normal Fluid Service with allowable pressure drop for a given process flow parameters. **Task:** Students must perform the similar tasks mentioned in the above **use case 1.**
2. Design of Pipe for Internal Pressure using ***Spreadsheet***.	● Selection of the appropriate Material of Construction (MoC) ● Determination of Pipe thickness for a given internal operating pressure to comply with **ASME B31.3/B31.1** code section ● Selection of pipe schedule number to comply with **ASME B36.19M** & **ASME B36.10M** standards ● Determination of Extra Life of the pipe ● Prediction of maximum pressure holding for new pipe as well as old pipe after service life	**Use Case 1:** MoC selection, Pipe Thickness calculation and selection of Schedule Number for ***Category D*** Fluid Service & its Design Pressure & Temperature. **Scenario:** For the process driven Design Pressure & Temperature of Category D Fluid Service. **Task:** Students must select the appropriate Material of Construction to suit the Fluid Service & Operating conditions. They should calculate the pipe thickness for the design pressure & temperature to comply with code. They should find out the minimum pipe thickness considering corrosion allowance and mill tolerance. They should

		select the appropriate schedule number from the standards. They should deduce the extra life of the pipe. They should predict the maximum holding pressure of New Pipe as well as old pipe after its service life. Finally, they should specify the "Pipe Specifications" of the pipe routing.
		Note: *All above tasks will be performed by the students using the provided* ***Spreadsheet****.* **Use Case 2:** MoC selection, Pipe Thickness calculation and selection of Schedule Number for ***Category M*** Fluid Service & its Design Pressure & Temperature. **Scenario:** For the process driven Design Pressure & Temperature of Category M Fluid Service. **Task:** Students must perform the similar tasks mentioned in the above **use case 1.** **Use Case 3:** MoC selection, Pipe Thickness calculation

		and selection of Schedule Number for ***<u>Elevated Temperature/Pressure</u>*** Fluid Service & its Design Pressure & Temperature. **Scenario:** For the process driven Elevated Temperature & Pressure of Fluid Service. **Task:** Students must perform the similar tasks mentioned in the above **use case 1.** **Use Case 4:** MoC selection, Pipe Thickness calculation and selection of Schedule Number for ***<u>Normal</u>*** Fluid Service & its Design Pressure & Temperature. **Scenario:** For the process driven Design Pressure & Temperature of Normal Fluid Service. **Task:** Students must perform the similar tasks mentioned in the above **use case 1.**

3. Development of Pipe Material Specification using ***Spreadsheet & Pipe Spec. Template.***	• Selection of the appropriate Material of Construction (MoC) for "Flanges", "Valves" and "Pipe Fittings" • Selection of pressure and temperature rating of flanges to comply with **ASME B16.5** standard • Selection of pressure and temperature rating of valves to comply with **ASME B16.34** standard • Selection of pipe fittings, gaskets, nut & bolts to comply with **ASME B16.20**, **ASME B18.2.1**, & **ASME 18.2.2** standards • Preparation of pipe material specification sheet	**Use Case 1:** MoC selection, selection of Pressure & Temperature Rating (Class) of Flanges, Valves and Pipe Fittings for ***<u>Category D</u>*** Fluid Service & its Design Pressure & Temperature. **Scenario:** For the process driven Design Pressure & Temperature of Category D Fluid Service. **Task:** Students must select the appropriate Material of Construction for Flanges, Valves and Pipe Fittings to suit the Fluid Service & Operating conditions. They should select the right pressure and temperature ratings (class) of flanges from the standard. They should select the right pressure and temperature ratings (class) of valves from the standard. They should select the right

		gaskets, MoC for Gaskets, and number of nut and bolts, and MoC from the standard. Finally, they should prepare the "Pipe Specification Sheet" based on the given "Pipe Spec. template". **Use Case 2:** MoC selection, selection of Pressure & Temperature Rating (Class) of Flanges, Valves and Pipe Fittings for ***Category M*** Fluid Service & its Design Pressure & Temperature. **Scenario:** For the process driven Design Pressure & Temperature of Category M Fluid Service. **Task:** Students must perform the similar tasks mentioned in the above **use case 1.** **Use Case 3:** MoC selection, selection of Pressure & Temperature Rating (Class) of Flanges, Valves and Pipe Fittings for ***Elevated Temperature/Pressure*** Fluid Service. **Scenario:** For the process driven Design Pressure & Temperature

		of Fluid Service. **Task:** Students must perform the similar tasks mentioned in the above **use case 1.** **Use Case 4:** MoC selection, selection of Pressure & Temperature Rating (Class) of Flanges, Valves and Pipe Fittings for ***<u>Normal</u>*** Fluid Service & its Design Pressure & Temperature. **Scenario:** For the process driven Design Pressure & Temperature of Normal Fluid Service. **Task:** Students must perform the similar tasks mentioned in the above **use case 1.**
4. Performing Flexibility Analysis of a Simple Pipe Routing & its Modification	• Identification of various loads that are acted on a piping system based on process requirement and given geographical location • Exploring of ***<u>CAEPIPE software</u>*** (freeware) tool bar • Preparation of software setup including defining of MoCs, Pipe Sections, Loads, etc. • Modelling of Preliminary given Simple Pipe Routing using ***<u>CAEPIPE software</u>***	**Use Case 1:** Flexibility analysis of Simple Pipe Routing for ***<u>Category D</u>*** Fluid Service & its Design Pressure & Temperature. Scenario: For a given preliminary Pipe Routing, category D fluid service and operating conditions. Task: Students must identify all the possible loads acting on the given pipe routing including dynamic loads such as wind loads, seismic loads,

		etc. They should explore the CAEPIPE software tool bar. They should prepare and complete the software setup. They should model the given preliminary pipe routing. They should perform the flexibility analyses, modify the pipe routing to ensure the pipe routing has enough flexibility. They should suggest the right supports. Finally, they should recommend the optimum pipe routing and generate the stress analysis report from the software.
	• Analyzation of induced stresses, pipe flexibility, modify the pipe routing along with supports • Recommendation of final Pipe Routing & Stress Analysis Report Generation	
		Use Case 2: Flexibility analysis of Simple Pipe Routing for Category M Fluid Service & its Design Pressure & Temperature. Scenario: For a given preliminary Pipe Routing,

		category M fluid service and operating conditions. **Task:** Students must perform the similar tasks mentioned in the above use case 1. **Use Case 3:** Flexibility analysis of Simple Pipe Routing for Elevated Temperature/Pressure Fluid Service. **Scenario:** For a given preliminary Pipe Routing, Elevated Temperature/Pressure fluid service and flow rate. **Task:** Students must perform the similar tasks mentioned in the above use case 1. **Use Case 4:** Flexibility analysis of Simple Pipe Routing for Normal Fluid Service & its Design Pressure & Temperature. Scenario: For a given preliminary Pipe Routing, Normal fluid service and operating conditions. **Task:** Students must perform the similar tasks mentioned in the above use case 1.
5.Performing Flexibility Analysis of a Complex Pipe Routing & its Modification	• Identification various loads that are acted on a piping system based on process requirement and given geographical location Exploring of ***CAEPIPE software*** (freeware) tool bar • Preparation of software setup including defining of MoCs, Pipe Sections, Loads, etc.	**Use Case 1:** Flexibility analysis of Complex Pipe Routing for ***Category D*** Fluid Service & its Design Pressure & Temperature. **Scenario:** For a given preliminary Pipe Routing, category D fluid service and operating conditions. **Task:** Students must

	• Modelling of Preliminary given Complex Pipe Routing using ***<u>CAEPIPE software</u>*** • Analyzation of induced stresses, pipe flexibility, modify the pipe routing along with supports • Recommendation of final Pipe Routing & Stress Analysis Report Generation	identify all the possible loads acting on the given pipe routing including dynamic loads such as wind loads, seismic loads, etc. They should explore the ***<u>CAEPIPE software</u>*** tool bar in detail. They should prepare and complete the software setup. They should model the given preliminary pipe routing. The should perform the flexibility analyses, modify the pipe routing to ensure the pipe routing has enough flexibility. They should suggest the right supports. Finally, they should recommend the optimum pipe routing and generate the stress analysis report using the software. **Use Case 2:** Flexibility analysis of Pipe Routing for ***<u>Category M</u>*** Fluid Service & its Design Pressure & Temperature. **Scenario:** For a given preliminary Pipe Routing, category M fluid service and operating conditions. **Task:** Students must perform the similar tasks mentioned in the above **use case 1.** **Use Case 3:** Flexibility analysis of Pipe Routing for ***<u>Elevated Temperature/Press</u>***

		ure Fluid Service. **Scenario:** For a given preliminary Pipe Routing, Elevated Temperature/Pressure fluid service and flow rate. **Task:** Students must perform the similar tasks mentioned in the above **use case 1.** **Use Case 4:** Flexibility analysis of Pipe Routing for ***Normal*** Fluid Service & its Design Pressure & Temperature. **Scenario:** For a given preliminary Pipe Routing, Normal fluid service and operating conditions. **Task:** Students must perform the similar tasks mentioned in the above **use case 1.**

LIST OF FINAL PROJECTS (20 PROJECTS THAT COMPREHENSIVELY COVER ALL THE LEARNING OUTCOME)	
"Category M" Fluid Service	
S No.	**FINAL PROJECT**
1.	Hydrofluoric acid, HF at a pressure of 31.50 bar and at a temperature of 130°C is flowing through a piping system connected between a nozzle (N1) of a vertical tank to a nozzle (N2) of a horizontal tank as shown in the isometric here. The flow rate of Hydrofluoric acid, HF is 0.06m^3/s. Nozzles are connected to the storage tanks with the ends of re-entrants. A maximum of 5% pressure drop is allowed. Design the pipe using the ASME B31.3 code section and perform the stress analysis using CAEPIPE Software. Use appropriate friction factor correlation to determine Darcy's friction factor. A sharp-edged orifice plate is placed in between Nodes 5 and 6. No support is placed between nodes 5 to 8. Place suitable support during stress analysis activity, and relocate/ move the given supports to keep the induced stresses within the allowable stresses, if required. Select the appropriate density and dynamic viscosity of Hydrofluoric acid, HF at the given operating pressure and temperature.

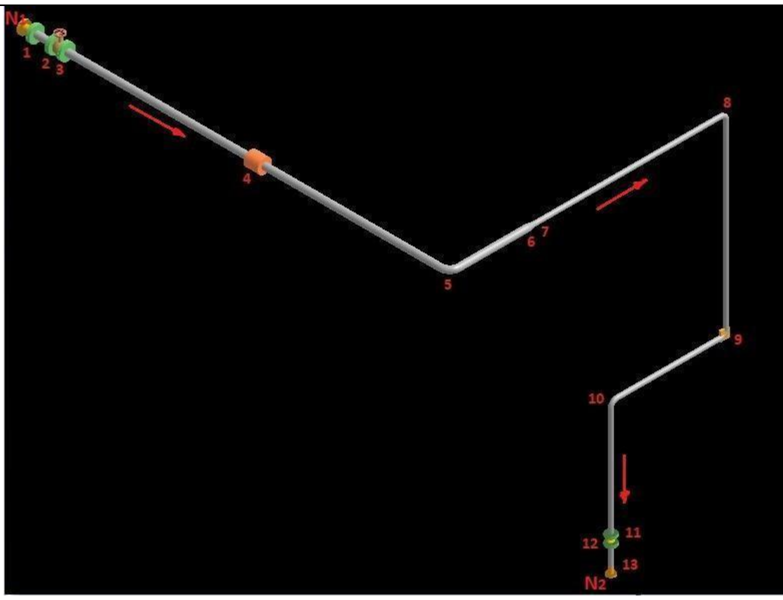

Fig.1. Pipe Routing

Table.1. Line Data

Nodes	Length (Along the Centre Line of the Pipe) in mm	Remarks
N1-1	100	After nozzle Pipe Segment Length
1-2	500	Pipe Segment Length
2-3	229	Gate Valve Length
3-4	5000	Pipe Segment Length (At node 4 Guide is placed)
4-5	5000	Pipe Segment Length
5-6	2000	Pipe Segment Length (Sharp- Edged Orifice is Placed)
6-7	200	Reducer Length
7-8	5000	Pipe Segment Length
8-9	5000	Pipe Segment Length (At node 9 Anchor is placed)
9-10	3000	Pipe Segment Length
10-11	3000	Pipe Segment Length
11-12	200	Bellow Length
12-13	500	Pipe Segment Length (N2)

2. Hydrochloric acid, HCl at a pressure of 55bar and a temperature of 22°C is flowing through a piping system connected between a nozzle (N1) of a vertical tank to a nozzle (N2) of a horizontal tank. Design the piping system with a sharp-edged orifice using the ASME B31.3 code section and perform the stress analysis using CAEPIPE Software. Assume suitable piping layout, pipe fittings, valves, friction factor correlation, supports, hangers, flow rate, percentage of pressure drop, and physical properties of HCl.

3.	Hydrogen sulfide, H_2S at a pressure of 70bar and at a temperature of 150°C is flowing through a piping system connected among a nozzle (N1) of a vertical tank to a nozzle (N2) of a vertical tank and a nozzle (N3) of a vertical tank. Design the piping system with a sharp-edged orifice using the ASME B31.3 code section and perform the stress analysis using CAEPIPE Software. Assume suitable piping layout, pipe fittings, valves, friction factor correlation, supports, hangers, flow rate, percentage of pressure drop, and physical properties of Hydrogen sulfide, H_2S.
4.	Carbon tetrachloride, CCl_4 at a pressure of 31.60bar and at a temperature of 240°C is flowing through a piping system connected among a nozzle (N1) of a vertical tank to a nozzle (N2) of a vertical tank and a nozzle (N3) of a vertical tank. Design the piping system with a sharp-edged orifice using the ASME B31.3 code section and perform the stress analysis using CAEPIPE Software. Assume suitable piping layout, pipe fittings, valves, friction factor correlation, supports, hangers, flow rate, percentage of pressure drop, and physical properties of Carbon tetrachloride, CCl_4.
5.	Propylene at a pressure of 32bar and a temperature of 65°C is flowing through a piping system connected between a nozzle (N1) of a vertical tank to a nozzle (N2) of a horizontal tank. Design the piping system with a sharp-edged orifice using the ASME B31.3 code section and perform the stress analysis using CAEPIPE Software. Assume suitable piping layout, pipe fittings, valves, friction factor correlation, supports, hangers, flow rate, percentage of pressure drop, and physical properties of Propylene.
	"Category D" Fluid Service
6.	n-Octane at a pressure of 22bar and at a temperature of 250°C is flowing through a piping system connected among a nozzle (N1) of a vertical tank to a nozzle (N2) of a vertical tank and a nozzle (N3) of a horizontal tank. Design the piping system with a sharp-edged orifice using the ASME B31.3 code section and perform the stress analysis using CAEPIPE Software. Assume suitable piping layout, pipe fittings, valves, friction factor correlation, supports, hangers, flow rate, percentage of pressure drop and physical properties of n-Octane.

7.	Cyclohexane at a pressure of 37.23bar and at a temperature of 250°C is flowing through a piping system connected among a nozzle (N1) of a vertical tank to a nozzle (N2) of a vertical tank and a nozzle (N3) of a vertical tank. Design the piping system with a sharp-edged orifice using the ASME B31.3 code section and perform the stress analysis using CAEPIPE Software. Assume suitable piping layout, pipe fittings, valves, friction factor correlation, supports, hangers, flow rate, percentage of pressure drop, and physical properties of Cyclohexane.
8.	Methyl acetate at a pressure of 37.23bar and at a temperature 200°C is flowing through a piping system connected among a nozzle (N1) of a vertical tank to a nozzle (N2) of a vertical tank and a nozzle (N3) of a horizontal tank. Design the piping system with a sharp-edged orifice using the ASME B31.3 code section and perform the stress analysis using CAEPIPE Software. Assume suitable piping layout, pipe fittings, valves, friction factor correlation, supports, hangers, flow rate, percentage of pressure drop, and physical properties of Methyl acetate.
9.	n-Octane at a pressure of 20.52bar and at a temperature of 270°C is flowing through a piping system connected between a nozzle (N1) of a vertical tank to a nozzle (N2) of a horizontal tank. Design the piping system with a sharp-edged orifice using the ASME B31.3 code section and perform the stress analysis using CAEPIPE Software. Assume suitable piping layout, pipe fittings, valves, friction factor correlation, supports, hangers, flow rate, percentage of pressure drop, and physical properties of n-octane.
10.	n-Decane at a pressure of 16.5bar and at a temperature of 310°C is flowing through a piping system connected among a nozzle (N1) of a vertical tank to a nozzle (N2) of a vertical tank and a nozzle (N3) of a vertical tank. Design the piping system with a sharp-edged orifice using the ASME B31.3 code section and perform the stress analysis using CAEPIPE Software. Assume suitable piping layout, pipe fittings, valves, friction factor correlation, supports, hangers, flow rate, percentage of pressure drop, and physical properties of n-Decane.

Elevated Temperature/Pressure Fluid Service	
11. to 15.	Design the piping system using either ASME B31.3 or ASME B31.1 code section and perform the flexibility analysis using CAEPIPE Software for elevated temperature/pressure fluid service at its operating conditions.
Normal Fluid Service	
16. to- 20.	Design the piping system using either ASME B31.3 or ASME B31.1 code section and perform the flexibility analysis using CAEPIPE Software for normal fluid service at its operating conditions.