## TEE-820-Process Intensification- 3 CHs

### Background

1. Give brief rundown of the existing programme.

   a. Engineers at many universities and industrial research centers are working on novel equipment and techniques that potentially could transform the concept of process plants and lead to compact, safe, energy-efficient, and environment-friendly sustainable processes.

   b. Approximately 20% of the cost of a new plant is process equipment with the balance being structural steel, piping, conduit, wire and instrumentation. Smaller unit operations mean less size, less weight and less structural steel, piping, conduit and wire. This means lower cost plants with smaller footprints.

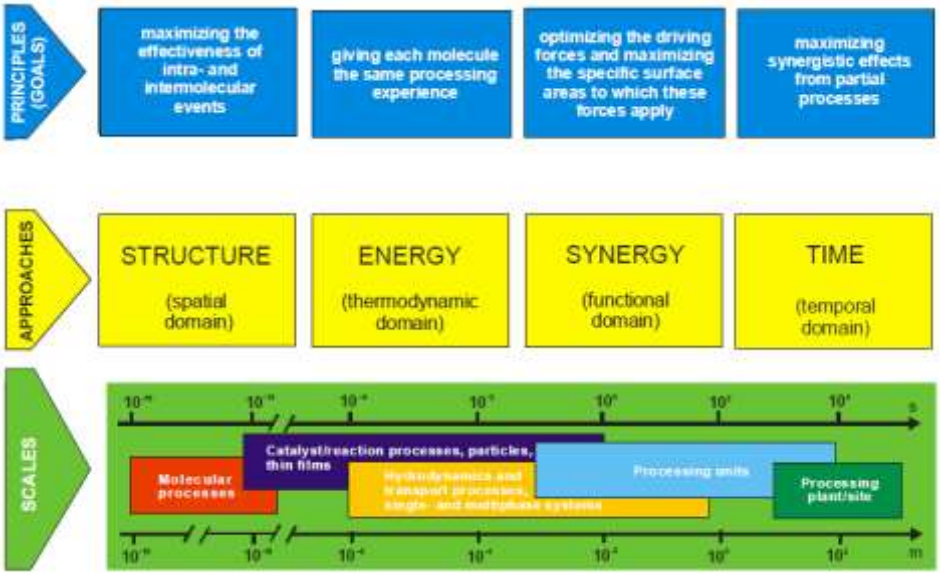


**Figure 1. Fundamentals of Process Intensification**

   c. Process intensified technologies crosscut energy-intensive industries with opportunity space in chemicals, petroleum refining, plastics, forest products, oil and gas production, and food industries among others. PI innovation could deliver solutions to energy security, environmental, and economic challenges in areas ranging from stranded gas recovery, carbon capture, and water treatment.

   d. Process Intensification provides radically innovative principles in process and equipment design. It significantly benefits process and

chain efficiency, capital and operating expenses, quality, wastes, process safety and much more.

e. The post graduate course “Process Intensification” will be launched first time in Pakistan. In view of the recent developments in process engineering, this course will provide a sound base for newly thermal energy engineering graduates.

**Rationale**

2. Rationale for offering/launching the new course:

a. Due to old technologies and poor equipment designs, there is considerable scope in existing process industries of Pakistan for introduction of new intensified technologies.

b. It is essential to guide thermal energy engineers for both the design and selection of the steps as individual operations and their integration to form an efficient process or equipment employing process intensification principles.

a. To design and develop the intensified novel equipment for energy conservation and inherent safety.

**Educational Objectives**

3. Objectives of the program under which the proposed course will be conducted are:

a. To discuss the fundamentals and generic principles of process intensification.

b. To design a sustainable chemical plant, including the elements of inherent safer process design.

c. To explain the boundaries of PI and interrelations with other engineering disciplines.

d. To provide the essential knowledge of different approaches use in process intensification

e. To enlighten with the concept of energy conservation through process intensification.

f. To describe the current engineering applications of PI in all development stages in the world.

g. To enable students to design an intensified equipment considering optimum energy consumption.

**Input Obtained from Industry/Corporate Sector/Subject Specialists/Academia**

4. The working paper has been sent to the Attock oil Refinery and Power Gen. Limited in order to obtain relevant feedback from the subject/Academia specialist.

**International Practice**

5. Specify the universities of repute where the proposed course is being conducted.
   a. University of Guelph, Canada
   b. Technical University of Delft, The Netherlands
   c. Clarkson University, New York, USA

**Proposed Timeframe of Commencement**

6. Spring semester 2016.

**Course Contents**

7. Give details of the course, on the following lines:
   a. Course Code TEE-820
   b. Title Process Intensification
   c. Credit Hours 3
   d. Objectives

8. The objectives of this course are:
   a. To elaborate the generic principles of process intensification.
   b. To design a sustainable chemical plant, including the elements of inherent safer process design.
   c. To explain the boundaries of PI and interrelations with other engineering disciplines.
   d. To enlighten with the concept of energy conservation through process intensification.
   e. To describe the current engineering applications of PI along with their status of development.
   f. More specifically, the aim is to: (i) recognize and explain technical challenges and limitations for a particular process, (ii) assess alternative technologies to improve the process, by upgrading process steps or re-designing the overall process, (iii) 4 evaluate the options to arrive at an optimal process configuration; and (iv) perform a feasibility design.
   e. **Outcomes**. The course should enable the student to:

a. Comprehend process Intensification technologies, their characteristics and industrial applications.

b. Grasp the business drivers, rules of thumb, heuristics and quantitative economic information for when to choose micro reactors, multi-function integrated columns or external field forced reactors, or conventional technologies.

c. Consider 'out-of-the-box' concepts in processing technology, where knowledge from multi-disciplinary domains (e.g. physics, electronics, mechanics, thermodynamics, etc.) is incorporated in new solutions.

9. **General Competence**. The course will give the student insight on:

a. Systems thinking, the interaction between process equipment units and efficiencies.

b. Reasons for process intensification in industrial processes.

c. Operational aspects in process plants.

d. Structure of typical (generic) industrial processing plants.

e. Brief introduction to the use of PI principles within process design.

f. Contents with suggested contact hours

| No. | Topics | Book | Contact Hours |
|---|---|---|---|
| 1. | **Introduction and fundamentals of process intensification**<br>• Genesis of process intensification<br>• Issues of concern for process industries<br>• History of process intensification<br>• Generic principles of process intensification<br>• Scales and fundamental approaches<br>• Design approach | SM | 3 |
| 2. | **Process intensification in temporal domain (Time)**<br>• Manipulation of time<br>Reverse flow<br>• Wrong way flow | SM | 6 |

| | | | |
|---|---|---|---|
| | • Regenerative processes<br>• Desorptive cooling<br>• Forced dynamical operation<br>• Oscilatting flow reaction<br>• Continous and oscillatory | | |
| 3. | **PI in spatial domain (structural)**<br>• Molecular scale<br>• Mesoscale<br>• Macroscale; heat exchange<br>• Macroscale; mixing concepts<br>• Example of structure vs. randomness<br>• Industrial examples | SM | 6 |
| 4. | **PI in thermodynamic domain**<br>• Molecular and meso scale<br>• Electric field<br>• Magnetic<br>• Microwaves<br>• Ultrasound<br>• Cavitation forming<br>• Hold-up, flooding & residence time<br>• Mass transfer<br>• Pressure drop & heat<br>• Mechanical design<br>• Applications<br>• Spinning discs | SM | 8 |
| 5. | **Synergy domain**<br>• Combining energy forms<br>• Multifunctional reactors<br>• Reaction & mixing<br>• Reaction & heat exchange<br>• Convective heat transfer<br>• Recaptive | SM | 8 |

| | | | |
|---|---|---|---|
| | • Regenerative<br>• Desorptive cooling<br>• Reactive heat transfer<br>• Heat exchange in industry<br>• Hybrids | | |
| 6. | **Reactive separations and hybrids**<br>• Distillation<br>• Membrane<br>• Adsorption<br>• Extraction<br>• Crystallization<br>• Absorption<br>• Extractive distillation<br>• Adsorptive distillation<br>• Membrane<br>• Membrane absorption<br>• Adsorptive membrane | - | 5 |
| 7. | **Light in process intensification**<br>• Photochemistry<br>• Photo-catalysis<br>• Case 1, OFR<br>• Case 2, IIMR<br>• Photosynthesis<br>• Case 3, LEF | - | 3 |
| 8. | **Rotating fluidized beds**<br>• Hydrodynamic aspects<br>• Experimental study<br>• theoretical considerations<br>• design considerations<br>• Potential and applications | - | 3 |
| 9. | **Process Intensification design problems** | - | 3 |
| Total | | | 45 |

g. Details of lab work, workshops practice (if applicable). No lab is required.

h. Recommended Reading (including Textbooks and Reference books).

| S/No | Title | Author(s) | Assigned Code | Remarks |
|---|---|---|---|---|
| 1. | Re-Engineering the Chemical Processing Plant: Process Intensification, CRC Press, New York, 2005. | A. Stankiewicz, J. A. Moulijn | SM | Text Book |
| 2. | Process Intensification Engineering for Efficiency, Sustainability and Flexibility, Elsevier Ltd, 2008. | D. Reay, C. Ramshaw, A. Harvey | RH | Reference Book |
| 3. | Process Intensification Technologies for Green Chemistry: Engineering Solutions for Sustainable Chemical Processing, John Wiley & Sons, New York, 2013. | K. Boodhoo, A. Harvey | BH | Reference Book |
| 4. | Process Intensification for Sustainable Energy Conversion, John Wiley & Sons, New York, 2015. | F. Gallucci, M. V. S. Annaland | GA | Reference Book |