INTERDISCIPLINARY INTERACTION IN CHEMICAL ENGINEERING DESIGN

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INDEX

DESIGN PATHWAY

The Institute of Chemical Engineers defines chemical engineering as 'that branch of engineering, which is concerned with processes, which change the chemical composition or physical properties of material in bulk.' (1)

In developing the complete process specification (10) for a plant, the engineer goes through the stages of process development to plant design. Process development involves feasibility studies, raw material and product specifications, evaluation of alternate process routes and profitability analysis. This process design stage includes all the necessary process flow diagrams, material and energy balances and physical property data (2).

Plant design involves preparation of all detailed P & I and utility diagrams, providing process data for instrumentation and the control strategy, performance specification for equipment, utilities summary, environmental impact information, operating procedures and safety and hazard analyses (2,3,10). In addition, a lot of time is devoted to process review of equipment information from vendors and detailed piping, mechanical, electrical and instrumentation drawings.

HISTORICAL COURSE ROLE

At the University of Auckland, chemical engineering design covers two years in the curriculum with some service lectures from other departments and practising engineers. The basis for the course is teaching process development in the first year, plant design in the second, as applied to a case study of a major process. In addition there are a number of half-day plant visits required.

In the U.S., design has shrunk to one-eighth of the total course compared with one-third a quarter of a century earlier (2,4). However, their course is not any less full, as the engineering science component has increased from one-tenth to one-fourth. To chemical (or should we say process) engineers, engineering science is such topics as thermodynamics, transport processes, continuous and stagewise processes, energy and material balances, chemical kinetics and chemical process dynamics. Also included would be some materials, mechanics of solids and fluids, and electrical circuit behaviour.

In the U.K., design comprises one-fourth of the course (5). This includes industrial and business principles, measurement and control and a separate design project. Again the engineering sciences are a major part of the course, one-fourth going to process principles and analysis, thermodynamics, chemical kinetics and reactor design.

Our course at Auckland has become overly full for our students. This can be partially helped by improved sequence of teaching the course, review of the course content at Intermediate, and by providing some self paced resource based instructional and tutorial material for the students. Some universities are considering computer- and videoaided learning resources (6,9). Use of computers for calculating both overall plant simulation and individual equipment sizing is now mandated by I.Chem.E. (5,8). All of the Australasian universities are looking to share in acquisition of the computerised PPDS physical property data base of over 600 compounds (2,7).

The following four sections discuss typical interaction of process engineering with other disciplines in a design firm. Examples are given for elements of design requiring process engineering coordination, planning, input or review.

CIVIL

Process plants have significant civil involvement in drainage, spill control, fire protection, foundations, buildings, structural steel and waste treatment.

Drainage

Commonly separate storm, process sewer systems are installed. This minimises hydraulic surges to the waste treatment plant, and can significantly reduce its size. The process sewer should be able to carry the deluge firewater flows. Process fluids can damage the flexible seals used in gravity piping systems.

Spill Control

Often vertical concrete curbs or walls in confined areas, with earth berms around storage areas. Usually designed to hold the capacity of the largest tank plus rainwater.

Fire Protection

The mains are typically installed underground, often in a looped network. Process vessels with large external surface require massive deluge flows to maintain safetry in a fire. Some underground pressure piping systems require large thrust blocks, affecting plant layout.

Foundations

Many process plants have tall concentrated loads from multi-level equipment structures, distillation columns, reactors; requiring specialised foundation and geomechanics knowledge to design the most economic foundation. Accurate knowledge of highest process fluid weight is vital. Very large rotating equipment require design of combined mass of equipment and foundation to avoid destructive harmonics, plus some expertise in grout system selection and installation.

Buildings

Processes conducted in a building are so often those where fugitive patricles are a problem. These buildings require special attention to non-corrodable materials of construction, explosion hatches, appropriate lighting and ventilation systems, monorails for equipment maintenance. Process laboratories have specialised needs in workbenches, sewers and ventilation. Vital plant control rooms need construction or location safe from external explosions and fires, plus special floor, wall and ceiling systems for communications and instrument cabling.

Structures

Specialised structures include multi-level equipment support and pipe support. The equipment may have high vibrational loads, or be unable to tolerate delection. Pipe supports can be subject to large horizontal loads from expansion of hot pipes. In addition they often have support significantly above grade for access by maintenance (typ. 4.5m) and over roads for construction equipment (typ 6m, with 20m span).

ELECTRICAL

On the high voltage side, this involves process engineers in area schedules, equipment enclosures, motor schedules, lighting and grounding. On the low voltage side, it involves process data for instrumentation, control strategy.

Area Classification

A division of a site into areas requiring explosion proof, totally enclosed, ventilated etc. equipment versus unclassified areas. A third option is location of unclassified switchgear in positively pressurized rooms.

Equipment Enclosures

About a dozen different possibilities, in various combinations of dust-proof, rain-proof, explosion-proof etc.

Motor Schedules

A list from process operations design on motor ratings, no. of full-load versus no-load starts, critical motors for emergency power, fully spared versus parallel operation pair, frequency of start and stop.

Lighting

Often specialised housings and lens required for corrosive or explosive atmospheres. Also special colour rendition may be required for visual quality control.

Grounding

Increasingly critical with use of non-conducting materials of construction. Also a problem of static build-up in truck-loading non-polar fluids.

Process Data For Instrumentation (10)

Typically all the "wetted end" information on the process fluid in contact with an instrument. This schedule will also include anticipated ranges for measurement and control, alarm and switch points.

Control Strategy

Such details as signal type, emergency power provision, first-out alarm, distributed/supervisory control policy, data logging and presentation will all fall in this category.

MECHANICAL

Mechanical engineers are traditionally responsible for analysis in pipe stress, vessel design, specialised equipment specification, ventilation and materials handling, and rotating equipment.

Pipe Stress

Arising from a combination of temperature, pressure, span and fluid load, stresses are brought below allowable limits by suitable routing with appropriate guides and stops to give controlled deflections and tolerable anchor loads.

Vessel Design

Has become increasingly more sophisticated in Europe, U.K., U.S., and Japanese analysis techniques. These are now embodied in greatly more detailed codes, with significantly more alternative designs. Process engineering usually provides a detailed sketch of all the vessel internals and appurtenances, with mechanical doing all the strength of materials calculations.

Specialised Equipment Specifications

Typically the process engineer provides the performance portion of the specification, with the mechanical and electrical engineers adding appropriate information on standardising details such as blast and finish required, voltage and type of motor drives, couplings and lubrication, spare parts required, operations and maintenance manuals needed, etc.

Ventilation and Materials Handling

Two examples of equipment which are not concentrated in one location, but spread across the plant site. There is considerable process input required on product degree of repose, friability, moisture content, friability, temperature and humidity control. There is significant civil role in supports and vibration control, electrical on safety, controls, grounding and switchgear location.

Rotating Equipment

In large equipment often a specialist position, requiring expertise in control systems, vibration monitoring, knowledge of potential process upsets,allowable speed and capacity range.

ENGINEERING SCIENCE

This has not been a traditional employment discipline in design firms, instead senior process engineers have been expected to provide these skills. (2) In research, there are some notable partners between chemical engineering and engineering science, such as in dynamic simulation at Imperial College (8), chemical reaction equilibrium analysis in Ontario (11), mass and energy balancing in Houston (12).

SUMMARY

Chemical engineers make decisions at the process development phase that will affect the other disciplines that do not normally become involved until the detailed plant design phase. These few pages are a brief attempt to illustrate the to-and-fro flow of information between the disciplines.

Its purpose is to provoke thought and discussion on the vital contribution of other departments, practising engineers to the teaching of the chemical engineering design courses; and of a chemical engineering design role that may be useful for students, staff of other departments to be aware of in their own training.

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