Engineering Practice

How to Prepare a Process Design Basis

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Take care not to overlook anything when preparing this document, which is vital for spelling out a well-planned chemical-process project. The checklists and tables in this article can serve as reminders

Intelligent — and thorough — preparation of a process-design-basis document can make the difference between a high-quality design for a chemical-process project and a poor one. The process-design-basis document represents the owner's instructions to the design engineering organization about what the owner wants designed, and how the owner wants the process design to be done. Note that these instructions to the process design engineering effort are different from what the owner would provide to the basic design/mechanical engineering organization, or the design-construct organization.

Note also the distinction between a process-design-basis document and a scope-of-work document. The scope of work is an integral part of the design basis, but the design basis also contains much more. The scope of work defines what is to be done, and what are the limits of that activity. The design basis also provides the who, the how, the why, and the when. Furthermore, the scope of work rarely addresses the design philosophy, the design standards, the execution plan, the format of deliverables, or the commercial terms.

Don't leave anything out

A fundamental attribute of a good process-design-basis document is that nothing important be omitted. The owner's engineer who is charged with producing such a document accordingly must give at least initial, if not detailed, attention to all of an extensive list of project aspects:

- ✔ The overall plant objective
- ✔ The products that the plant will produce
- ✔ The process technology to be used
- ✔ Process control philosophy
- ✔ The management of the project
- ✔ The project contract
- ✔ The process design deliverables, and their format
- ✔ How information will flow between the parties during the project
- ✔ Preferred vendors, if any
- ✔ Conduct of the process design engineers
- ✔ The nature of the plantsite
- ✔ Any unusual economic criteria
- ✔ The offsite facilities and the infrastructure requirements
- ✔ Brownfield-site compatibility
- ✔ Environmental, safety and vessel- and structural-design standards, permits and requirements
- ✔ Plant operation and maintenance philosophy
- ✔ Owner's wishes regarding working capital
- ✔ The communication system for the completed plant
- ✔ The security of the project, and of the completed plant
- ✔ Project execution expectations

Objectives, products, control, management

Some projects are financed with investment adequate to encourage a long plant operating-life, maximum run-time between turnarounds, minimal labor intensity, easy switches between product grades, and minimal bottlenecks during operation. At the other extreme, the owner's objective is instead to build the lowest-capital-cost plant that can meet capacity and product specifications. It is important for the process design organization to know the owner's intentions over this capital-outlay spectrum.

Also of primary importance is the product slate that the finished plant is to produce. How much of each product is to be made (in tons/year, bottles/day, or other units)? What specifications must the product satisfy? Are there different product grades to be made; if so, what are the specifications, and how much of each grade is to be made? How are the final products to be stored, packaged, and then transported to customers?

If a particular process technology is to be used, say so in the document. On the one hand, this might be a particular, licensed commercial technology; on the other hand, the specifics of the process might not be known at this early stage.

The standards to be used for the process design are set by the owner, not the design organization. These standards include the following:

- ✔ Load bearing standards (piling, spread footings)
- ✔ Structural support standards
- ✔ Structural integrity standards
- ✔ Pressure-vessel design standards (ASME)
- ✔ Fire protection standards (NFP, UL)
- ✔ Equipment standards (API, DIN, ANSI other)
- ✔ Testing standards (e.g., ASTM)

TABLE 1. KEY CONTRACT ELEMENTS
Owner's scope of work for process design engineer
Owner's list of project deliverables
Owner's schedule for project completion
Agreed-upon terms for reimbursement (lump sum, reimbursable cost, cost plus fixed fee, percentage of total capital cost)
Schedule for partial payments during term of contract
Location where design work will be undertaken
Terms for subcontracting
Terms for cancellation
Force majeure provisions
Dispute-resolution/ form and forum
Insurance
Confidentiality/nondisclosure agreement
Intellectual property discovery/inventions/ownership
Mutual indemnification
Taxes

TABLE 2. KEY PROCESS DESIGN DELIVERABLES	
List of engineering deliverables	Construction vehicle list
Accounting records	Tie-in list
Correspondence records	Site layout plan
Project status reports	Site civil drawings (plot plan, concrete, structural steel, roadways, drainage, piping runs above and below ground and data highways)
Change orders	
Feedstock and product specifications	
Input/output diagram	Firewater grid
Block flow diagrams	Electrical supply grid
Process flow diagrams	Safety shower and eyewash map
Piping & instrumentation diagrams	Nighttime plant lighting plan
Motor control center map and specifications	One-line electrical drawings
Working capital list and specification (volume and value)	Process & utility piping list
Substation map and specifications	Control house layout and equipment
Heat and material balances	Site-wide steam network drawing
Control loop drawings	HAZOP report
Piping specification list	One-page process and utility equipment specification sheets
Process laboratory specifications	One-page instrumentation specification sheets
Administration building specifications	
Maintenance shop and equipment	Vessel drawings
Fleet vehicles	Tankage capacity

- ✔ Electrical standards (IEEE, NEC, UL)

The process control philosophy to be used in the finished plant, as well as the type of system to be considered for supervisory control and data acquisition (SCADA) system, should be specified in terms of either performance or specific selection by the owner. The level of data communication between the process control function, the onsite engineering and the maintenance facilities is also to be defined. In many cases, an operating company will standardize on one particular process-control vendor in order to avoid the need for staff cross-training. If a vendor has been designated by the owner, this should of course be specified in the design basis document.

With respect to the management of the project, the process-design-basis document should identify the owner's authorized person for approving all design activities. The management chains of command on both the owner's side and the engineering organization's side should likewise be spelled out. Approval mechanisms (embodied in, for instance, change orders) for all activities (changes inside scope and changes outside scope) that would incur additional cost for the project are defined. The nature and format of the design deliverables are to be defined (these two topic are each discussed in more detail below). The frequency of progress reports, and how they are to be presented, must be spelled out. The project schedule must be defined. And for most projects, the document should insist on prior approval in writing before any commitments are made to outside vendors that could incur future costs or liabilities to the project.

The legal contract between the owner and the process design engineer must incorporate all the relationship requirements for a successful outcome. In addition to ones specified in the preceding paragraph, these involve details concerning the periodic and end-of-job payments, as well as, conversely, the interim and final process engineering deliverables to justify those payments. Several elements that should be addressed in a good contract include those listed in Table 1.

Deliverables: content, format

The specifics and the format of the process design deliverables need to be explicitly stated in the design basis document. Key elements include those shown in Table 2.

As noted in Table 2, one of the items among the deliverables should be an input/output diagram that defines the major inputs to this plant (what feedstocks and their specifications, what utilities, and other production inputs such as additives and catalysts), as well as the major outputs. In most cases, the quantification of all of these materials is not yet known at this stage, but the nature of the inputs and outputs should be defined to the process design organization.

Format: Owners are entitled to conformance with specific formats for engineering deliverables, in order to satisfy companywide and industrially recognized standards. The format generally addresses such aspects as the following criteria and guidelines:

- ✔ Units of measure to be used (metric, English)
- ✔ Standardized engineering-drawing symbols
- ✔ Equipment numbering and tagging nomenclature
- ✔ Instrumentation and control symbols
- ✔ Units of identification for bulks and non-E's (bulk equipment represents simple hardware bought in large amounts without specific equipment numbers. These items often include block valves, sample and drain valves, piping, switches, illumination, walkways and railings, cable and its housing. Non-E's, or non-equipment, represent other materials required to be purchased and consumed on a job, such as concrete, asphalt, structural

and reinforcing steel, insulation, coatings, and welding rod)
- ✔ Standardized piping line lists and tie-in lists
- ✔ Material balance formats
- ✔ Equipment and piping one-page process spec sheets
- ✔ Pressure vessel and tank drawings
- ✔ Electrical one-line drawings
- ✔ Control loop drawings
- ✔ The size paper to be used for reports
- ✔ The size paper to be used for drawings
- ✔ Type-font and letter size
- ✔ Requirement and format for vendor cuts (paper drawings, pictures, descriptive material, dimensions and specifications of specific equipment provided by a specific vendor)

Owners are also entitled to demand the use of industry-wide, non-proprietary computer software for generating engineering deliverables. One reason for this standardization is to allow computerized translation from one software package to another. This entitlement pertains to the software used for planning and scheduling, cost estimating, process design, piping network analysis, process simulation, computer-aided 2D and 3D design, and the preparation of written reports.

Project communication

The process design basis document should include a contract communication specification (CCS). It defines how information will flow and be shared during project execution.

The CCS is designed to minimize communication misunderstandings and misinterpretations, and to assure that all members of the project organization are continuously working off the most current set of design documents. The CCS is also intended to optimize the amount of time and effort expended for communication between client and engineer, between members of the design engineering organization, and with third parties that are involved in the process design. These third parties typically include governmental regulators, subcontractors, client employees not directly involved in the project, financial institutions, vendors and suppliers. Key elements of the CCS include those shown in Table 3. (Communication involving the plant operating personnel after the plant is up and running is a separate issue also to be addressed in the process design basis document, as discussed below.)

TABLE 3. CONTRACT COMMUNICATION SPECIFICATIONS

Documents the goals and objectives of the project
Specifies the scope of the job
Identifies the members of the team and their coordinates
Establishes the formats for hard-copy and electronic project deliverables
Defines the roles and responsibilities of each team member
Defines the formats of communication elements, data
Defines what information is to be kept and archived
Defines binding contractual terms
Formalizes project schedule and budget

Vendors and engineers

Owners are entitled to provide to the design engineering organization a list of preferred or approved vendors, provided that these vendors operate where the plant is to be built and that their products conform to internationally recognized engineering standards (API, DIN, EU, for instance). The engineering organization is required to develop its design in a manner consistent with the use of such preferred vendors; conversely, the owner is required to provide at least three preferred vendors for each major kind of equipment, to avoid issues involving monopoly pricing or proprietary equipment designs.

Meanwhile, the design basis document should also address any issues regarding the conduct that is expected of the design organization's personnel. Key elements to be addressed include the following:
- ✔ Authorizations to visit plantsite
- ✔ Authorizations to visit owner's headquarters site
- ✔ Suitable attire for visits to plant and owner's site
- ✔ Personnel protective equipment for plantsite visits
- ✔ Issues involving any cultural sensitivities; non-discrimination standards
- ✔ Owner's policy on ethics
- ✔ Design-team company's policy on ethics

TABLE 4. KEY CHARACTERISTICS OF PLANTSITE

Subsoil characteristics
Existing facilities that may need to be demolished or removed
Existing facilities that are to be used/ debottlenecked
Climate
Meteorology
Design for storm intensity (usually 100-year basis)
Wind design requirements
Floodplain design requirements
Earthquake design criteria
Sandstorm propensity and intensity
Proximity to airports that would affect equipment height
Contaminated soils
Snow load and intensity
Corrosive ambient air (e.g., seawater spray, acid, chlor/alkali environment)

TABLE 5. UNUSUALLY HIGH COSTS TO WATCH FOR

Economic factor	Design impact
High cost of land	Equipment spacing
Cold climate	Insulation and freezing criteria
High water cost	Desalting/ water recycle/air cooling
High electricity cost	Piping design pressure drop/alternative drivers
High feedstock/ product cost	Max. conversion/max. recycle/custody transfer metering
High labor cost	High automation levels/high equipment reliability
High capital cost	Materials selection/ process intensification/ design standards
High envi-ronjmental liabilities	Zero discharge/onsite treatment & disposal

- ✔ Drugs and alcohol policy and standards
- ✔ Controlled-substance policy and standards
- ✔ Policy and reporting requirements for bribery (Business Roundtable standards)

Plantsite, offsites, infrastructure

The site chosen for the production facility is to be defined exactly. Where is it? Why was it chosen? What are the particular characteristics of this site that have led the owner's man-

TABLE 6. TYPICAL OFFSITE FACILITIES
Storage facilities for feedstock, products, intermediates, additives and catalysts
Administration building
Maintenance building
Spare parts warehouse
Medical facilities
Process laboratory and equipment
Training facility
Loading racks (truck and rail)
Religious/cultural facilities
Process flare and flare gas header
Vacuum line (to fuel gas header)
Marine facilities (piers, docks, cranes)
Waterborne plant-support vessels
Wastewater treatment facility
Sludge drying, treatment and disposal facilities
Process incinerator
Raw water treatment
Obsolete-equipment storage
Lockers/change facilities for O&M personnel
Cafeteria
Sanitary facilities and smoking sheds
Fencing and plant security
Fire house, fire water, deluge and monitors
Emergency showers, eye wash
Process flares and flare headers
Utilities

TABLE 7. MAJOR LIKELY ISSUES ENTAILING ENVIRONMENTAL STANDARDS
Wastewater treatment standards
Process gas discharges to the air
Combustion gas design/emissions requirements e.g., (low-NOx burners, two-stage lean burn
Solid waste treatment/incineration/ onsite disposal
Particulates in air
Noise
Traffic during construction and operation
Dust/dirt generation during construction
Spill prevention standards
Rainwater capture and rainwater overflow
Hazardous materials storage
Tank breathing/floating-roof standards
Planning standards (hazard communication, community notification)
Emergency planning/evacuation
Fugitive emissions
Periodic emissions (steam air decoking, soot blowing, etc.)

TABLE 8. MAJOR ISSUES RELATED TO ENVIRONMENTAL PROTECTION
Design standards for noise
Layout standards for buffer zones
Endangered species/habitat evaluation
Plant construction and operation traffic management
Visual standards (height, color, fencing, etc.)
Emergency planning, response and evacuation
Automatic sensing and alarms for toxic discharges
Hazardous chemical storage inventory and management
Spill prevention, countermeasures, and secondary containment
Process wastewater treatment and disposal
Sanitary wastewater treatment and disposal
Rainfall/runoff capture and treatment
Wastewater sludge treatment and disposal
Nonhazardous solid waste treatment and disposal
Incineration requirements
Hazardous solid waste treatment and disposal
Combustion gas low-NOx burners and two-stage lean-burn systems
Process gas treatment prior to venting
Tank breathing loss treatment before venting; req'ts. for floating roofs
Flare tip design, steam control, and flare opacity requirements
Level of treated wastewater recycle
Cooling-water system management

agement team to select it? Is the site a greenfield one or a brownfield one? Issues related to brownfield sites are discussed separately, in detail, below.

Site-specific and unusual characteristics of the plantsite need to be communicated to the project organization. Key characteristics of the site that need to be spelled out include those in Table 4.

Unusual economic criteria: Most engineering-design criteria implicitly contain assumptions dealing with prevailing economic conditions. These assumptions are rarely documented. If a particular plantsite involves unusually high cost elements, these should be identified such that the design organization can modify its design criteria accordingly. Some common economic factors, and the design criteria they affect, are listed in Table 5.

Offsites: Offsites for utilities and accessory facilities are to be defined by the owner in terms of performance. The design engineering organization will convert this input into engineering design specifications. Typical offsite facilities include those in Table 6.

Infrastructure requirements. If facilities outside of the main process plant plus its offsite utility facilities are required, these need to be specified to the design organization. These infrastructure requirements may well include outside docks/piers/siding facilities, transshipment and other receiving facilities for feedstock and chemicals, and facilities to ship product to the customer. If intermediate warehousing facilities are required away from the plant site, this requirement needs to be defined. Cogeneration, seawater-desalting or other facilities providing utilities to the site are likewise to be spelled out. Any sharing of facilities between industrial plants in a community (fire protection, security, utilities) should also be defined and specified by the owner.

Brownfield site compatibility: If the project is to be built at a site with existing facilities, such that these existing facilities are expected to be used or available to the project, the demonstrated — not design — capabilities of the existing facilities are to be documented so that the engineering organization can design the new plant to be consistent with existing facilities.

A key component of the design basis document is a tie-in list that shows what facilities are available, exactly where they are available (location specific battery limits), and their capabilities. Existing-facility availability should include these items:

- ✔ Spare infrastructure capacity
- ✔ Spare utility capacity
- ✔ Spare tankage capacity
- ✔ Firewater availability and pressure
- ✔ Potable-water availability, pressure
- ✔ Process-water availability, pressure
- ✔ Raw-water and/or seawater availability and pressure
- ✔ Boiler-feedwater availability, pressure, composition (TDS, conductivity)

TABLE 9. MAJOR SAFETY-RELATED ELEMENTS
Formal statement of management safety philosophy
Process safety management system
Accountability
Process safety objectives and goals
Process knowledge
Technical documentation requirements
Process risk management
HAZOP analysis
Change-order management
Process & equipment integrity
Human factors engineering
Initial and periodic training
Safety performance auditing
Company standards and codes
Prevailing legal standards and codes
Incident investigation and remedial action
Audits and corrective action
Enhancement of corporate safety knowledge & performance

TABLE 10. KEY ISSUES RELATED TO PROJECT EXECUTION
Project schedule preparation
EPC contractor selection
Construction management team selection
Basic engineering
Detailed mechanical design
Construction safety and training program
Ongoing monthly project cost estimates (capital expend. + op.-cost expend.)
Governmental permits
Environmental impact statement preparation
Site layout drawing for construction phase
Equipment receiving, lay down and warehousing strategy
Procurement strategy and standards (preferred vendors, local content, other.)
Operating plant organization chart + head count
Operating organization process training
Operating organization EH&S training
Construction punch-listing
Weld certifications reviewed and approved
Hydrotesting and pipeline blow-out
Safety facility startup (firewater, flare, etc.)
Utility facility startup
Pre-startup process equipment testing
Instrumentation, electrical and SCADA checkout
No-load process equipment run-in
Catalyst loading and feedstock fill
Process plant startup
Steady state operation achieved
Product specifications achieved
Design and turndown capacity achieved
Performance guarantees achieved
Plant commissioned
Plant demonstrated capabilities determined
As-built drawings completed and turned over
EPC contractor deliverables completed and turned over
Plant acceptance and EPC contractor project turn over to owner

✔ Flare and flare-header availability and spare capacity
✔ Available steam flowrates, pressures and degrees of superheat
✔ Available capacity and pressure of inert gas and instrument air
✔ Fuel-gas and fuel-oil availability and pressure
✔ Electric system availability (substation location, capacity, voltage, phase, frequency)

Environment, safety

The prevailing legal standards covering environmental protection need to be indicated. These are likely to include some or all of the issues in Table 7. The consequent plant-performance requirements and environmental-permit requirements must also be spelled out by the owner . Likely major requirements to be addressed include some or all of those related to the list in Table 8.

With respect to safety, the design standards and the procedures to be utilized to assure inherently safe design, construction and operation are to be specified by the owner. Elements incorporated in many design basis documents include those in Table 9.

Operation, maintenance

The owner is required to inform the engineering organization of the operation-and-maintenance (O&M) philosophy to be reflected by the process design. Components of this philosophy include the following:

✔ Expected run length between scheduled turnarounds
✔ Expected equipment runtime between mean failure
✔ Level of automatic instrumentation to be provided that is not needed for control
✔ Redundant online equipment
✔ Redundant offline equipment
✔ Level of equipment sparing that is inline
✔ Level of equipment sparing that is warehoused
✔ Equipment-driver selection and philosophy
✔ Dual drivers for critical process equipment
✔ Facilities to be provided with un-interruptible power supplies (UPS)
✔ Equipment-rebuild capabilities onsite

✔ Equipment rebuild capabilities to be shopped out

Turndown capability: The plant is designed for a nameplate capacity (in, for instance, metric tons per year) at a particular service factor (operating hours per year divided by 8,760 hours per year). Although the plant is designed for optimal operation at a particular throughput rate (stream-day flowrate), business conditions may dictate that the plant run at substantially lower-than-design rate for an indefinite period of time. This turndown ratio should be specified by the owner. There may also be short-term periods (days, not weeks) in which the plant should be capable of running above nameplate capacity in order to recover from outages, or build inventory in preparation for turnaround. This turnup ratio should also be specified.

Working capital: The owner must provide instructions to the engineering organization as to the design basis philosophy for the working capital to be maintained in the plant. Such working capital includes: the number of days storage for feedstock, intermediate and final products; the additives inventory, in-process and in-storage catalyst quantities and spare-catalyst charge requirements; and the inline equipment spares, warehoused equipment spares, parts spares, and construction/maintenance equipment. The owner should provide instructions on the choice of purchased equipment versus leased equipment, especially for fleet and construction vehicles, distributor held spares and OEM held spares.

Communication system: The owner should provide guidance as to the preferred system for in-plant and ex-plant communication for the completed and operating facility, including both fixed-line and mobile-line capability and capacity. If a system operator is required, the owner should specify the reporting requirements for that operator (usually part of plant security). External communications capabilities with the owner's headquarters, and with local law enforcement, environmental regulators, coast-guard and marine officials, and governmental officials should be specified in terms of who is to be contacted, how, by whom, and under what circumstances. Documentation needs for ex-plant communications are also to be specified.

Security. Standards to protect the plant from unauthorized destructive actions by either local malcontents or national or international terrorists need to be addressed. The primary issues affect the following:

✔ Equipment layout
✔ Plant access
✔ Emergency and countermeasure plans
✔ Security fencing
✔ Security people
✔ Personnel hiring/screening procedures
✔ Security communications network (ex-plant)
✔ Coordination with local law enforcement

Project execution

The focus of this article has been upon process design. But the process design organization is in many instances contracted to provide to the owner a plan for executing the balance of the project, including mechanical and structural design, construction, startup and commissioning. The owner's expectations as to the level of detail required is to be specified to the engineer, and guidance should be provided for the planning components in Table 10. ■

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