AACE INTERNATIONAL

CONFERENCE & EXPO 2021

VIRTUAL+ BOSTON RETREAT

AACE INTERNATIONAL 2021 CONFERENCE & EXPO TRANSACTIONS

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Better Project Control Through Better Project Execution

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Abstract

Project controls have been a primary focus of project improvement for decades. Organizations such as AACE have published a library of knowledge and recommended practices on estimating, cost control, scheduling, and risk management. Each year, new software capabilities are introduced promising more data integration and collaboration than ever before. Experts in CPM scheduling and risk management have developed sophisticated algorithms to attempt to correct for inaccurate estimating and project controls information. Perhaps it is time to think beyond collecting data, performing analysis and publishing reports or charts. Interestingly, the most recent updates to AACE recommended practices are revised to include more granular definitions of deliverables. What if there were much better definition of deliverables? And what if those deliverables could be chronologically mapped; showing internal and external dependencies – all in a stage gated environment? This paper will focus on how to improve project controls reliability using project execution processes for engineering, procurement, construction, and commissioning. Project execution processes qualitatively prescribe criteria required to earn progress. Subsequently, this yields improved reliability of progress data collected, which subsequently results in increased reliability of project controls analysis and reporting.

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Introduction

Project controls is a mature discipline. There are rules of credit for determining percent complete. There are formulas for calculating earned value, cost indices, schedule indices, and other metrics. Algorithms for calculating critical path method schedules are embedded in scheduling software. The industry has produced many commercially available and proprietary software products with dashboards for presenting project performance.

But, what about the reliability of the data provided in engineering and supplier documents that project controls professionals use for their forecasts? When an engineer issues a set of process piping design drawings or foundation drawings for equipment, what is the level of confidence that it will be free of revisions?

This paper will focus on a way to qualitatively define engineering and procurement deliverables at multiple points in time over the project life cycle so that there is confidence that the work earns the progress credit.

Perhaps this can be summarized as "rules for rules of credit".

Definitions

To begin, a few definitions need to be restated. According to AACE Recommended Practice No. 10S-90; a deliverable is "…another name for products, services, processes…created as a result of doing a project."

Work breakdown structure (WBS), from AACE Recommended Practice No. 10S-90 is defined as a "Framework for organizing and ordering the activities that makes up a project. Systematic approach to reflect a top-down product-oriented hierarchy structure with each lower level providing more detail and smaller elements of the overall work"

New terms introduced here:

1ST PRIORITY EQUIPMENT – 1) equipment essential to confirm the conceptual design (i.e. packages with major impact on the system and area design which are needed to freeze the overall layout). 2) Equipment essential for the project with respect to;
- delivery of supplier information
- site need for installation of physical package (long lead item).

2nd PRIORITY EQUIPMENT – 1) equipment essential for development of system and/or area design. Requires engineering information input to:
- system design, (P&ID's EPC2 – EPC3)
- area design, (3D CAD model EPC2-EPC3) 2) site need for installation of physical package (long lead item).

FIRST (SUPPLIER) INFORMATION – The first deliverable of equipment or fabricated assembly information issued by the supplier, accurate within tolerances shown, that the engineer can rely upon to commence site/facility/utility calculations or engineering.
Includes, but is not limited to:

- Weight and Center of Gravity - +/-10%
- Bending Moments, Shear Strength - +/- 10%
- General Arrangement Plan & Section – Issued For Approval
- Equipment Centerline Dimensions: Heights – Issued For Approval
- Process Control Room Layouts – All Tagged ID Equipment Shown – Issued For Approval
- Pulpit Layouts – All Computers, Printers, Racks shown – Issued For Approval
- Equipment Support & Access Steel Dimensions – Issued For Design
- Utilities Requirements – Issued For Design

Any change, revision or deviation beyond the parameters specified for the above information after issuance of 1st Information is considered an engineering and/or design change.

FROZEN (SUPPLIER) INFORMATION – The second deliverable of equipment or fabricated material information issued by the supplier, that the supplier certifies can be relied upon the engineer to commence or finalize design.
Includes, but is not limited to:

- Anchor Bolt Size – Issued For Design
- Anchor Bolt Layout – Issued For Design
- Foundation Arrangements, Sections and Details (dimensioned) – Issued For Design
- Assembly Drawing (Equipment General Arrangements showing Range of Motion) – Issued For Design
- Process Control Room Arrangements, Sections and Details – Issued For Design
- Pulpit Arrangements, Sections and Details – Issued For Design
- 3D Model Information ("Dumb" – all outside dimensions)
- Equipment Support and Access Steel Drawings – Issued For Design
- Piping Take Over Points
- Electrical/Controls Connections
- Schematics

Any change or revision in the above information after issuance of frozen Information is considered an engineering and/or design change.

Quality of Information - term used to describe the technical development completeness of a deliverable at a specific stage gate. Describing a deliverable based on its quality of information confirms the prerequisite engineering and/or supplier information inputs necessary has been relied upon. Expedient way to communicate status of a deliverables development status.

Secondary Process Piping – process piping from 2nd priority equipment tie point or piping tie point to 2nd priority equipment or piping tie point.

Focus on Engineering and Procurement

Engineering and procurement activities can be quantified and managed the same way construction activities are managed. Rules of credit for deliverables are established and in its simplistic use; 0% or 100% values can be assigned to each rule to calculate an actual percent complete and subsequently earned man hours.

However, applying project controls to engineering and procurement activities is only as accurate as the reliability of the information on the design documents. Project controls can track, identify trends, and forecast quantitatively, but its reliability depends on information shown on design documents as being complete and correct.

The following is an example of how project controls can inadvertently report an unreliable forecast on a lump sum EPC project: The engineer issues P&ID for design showing piping between 2nd priority equipment pump; routed through main building to tank before either supplier submits frozen information. Piping discipline design then routes and develops isometric drawing (ISO): issues for construction. Subsequently, the pump supplier's frozen information shows outlet flange size and orientation different than that for first information submittal. The engineer must revise the layout and ISO to reflect corrected pump information. Then, the tank supplier's frozen information is submitted. The tank now has a base, inlet orientation and elevation different than shown on first information. The engineer again must revise the layout and ISO to reflect corrected tank information and issue Rev 2 for construction. Also, the 3D model, facility layout, foundation layout and foundation details require revision.

Unfortunately, project controls will have relied upon the drawing status report that shows this deliverable issued for construction. The engineer will have claimed 100% credit for this work account, which subsequently is used to calculate project actual percent complete. Separately, the quantities shown on the isometric drawing will have been taken off and used to confirm the piping installation quantities for that work account. And the concrete quantities will have been taken off from detail sheets.

As engineering man hours are expended revising documents, the additional work for the engineer increases the costs without earning any progress. If the installation contractor is different than the EPC contractor, revisions will translate into change orders with no additional compensation from the owner.

If this scenario is repeated, it can result in a significant deviation from budget man hours and quantities. There is no cost forecasting or risk management process that can anticipate errors and omissions.

What can be used to improve the reliability of engineering and procurement data is the implementation of standardized engineering and procurement workflows, having well defined prerequisite information and resulting in well-defined outputs, or deliverables. To obtain even better certainty, the workflows can be interlocked in a project life cycle timeline that is periodically assessed for compliance to the workflow requirements. Rules for rules of credit.

Detailed Deliverables

AACE published Recommended Practice 18R-97 more than twenty years ago. As with all recommended practices, they are guidelines for applying general principles. These general principles in turn can be used in develop individual company processes and requirements.

The chart below is the 2016 revision of Table 3 from AACE RP 18R-97. As seen below, there are two groupings of deliverables: General Project Data and Technical Deliverables. There are ten General Project Data deliverables and sixteen Technical Deliverables. Table 3 is substantially the same in the 2016 version as it was in the original version.

Figure 1 – Table 3, AACE Recommended Practice, 2016

	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
General Project Data:					
Project Scope Description	Preliminary	Preliminary	Defined	Defined	Defined
Plant Production/Facility Capacity	Preliminary	Preliminary	Defined	Defined	Defined
Plant Location	Preliminary	Preliminary	Defined	Defined	Defined
Soils & Hydrology	Not Required	Preliminary	Defined	Defined	Defined
Integrated Project Plan	Not Required	Preliminary	Defined	Defined	Defined
Project Master Schedule	Not Required	Preliminary	Defined	Defined	Defined
Escalation Strategy	Not Required	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	Not Required	Preliminary	Defined	Defined	Defined
Project Code of Accounts	Not Required	Preliminary	Defined	Defined	Defined
Contracting Strategy	Not Required	Preliminary	Defined	Defined	Defined
Technical Deliverables:					
Block Flow Diagrams	S/P	P/C	C	C	C
Plot Plans	NR	S/P	C	C	C
Process Flow Diagrams (PFDs)	NR	P/C	C	C	C
Utility Flow Diagrams (UFDs)	NR	S/P	C	C	C
Piping & Instrument Diagrams (P&IDs)	NR	S/P	C	C	C
Heat & Material Balances	NR	P/C	C	C	C
Process Equipment List	NR	S/P	C	C	C
Utility Equipment List	NR	S/P	C	C	C
Electrical One-Line Drawings	NR	S/P	C	C	C
Design Specifications & Datasheets	NR	S/P	C	C	C
General Equipment Arrangement Drawings	NR	S	C	C	C
Spare Parts Listings	NR	NR	P	P	C
Mechanical Discipline Drawings	NR	NR	S/P	P/C	C
Electrical Discipline Drawings	NR	NR	S/P	P/C	C
Instrumentation/Control System Discipline Drawings	NR	NR	S/P	P/C	C
Civil/Structural/Site Discipline Drawings	NR	NR	S/P	P/C	C

Figure 2 below is the 2020 revision of Table 3 from AACE RP 18R-97.

Figure 2 – Table 3, AACE Recommended Practice 18R-97, 2020

MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
GENERAL PROJECT DATA:					
A. SCOPE:					
Non-Process Facilities (Infrastructure, Ports, Pipeline, Power Transmission, etc.)	P	P	D	D	D
Project Scope of Work Description	P	P	D	D	D
Byproduct and Waste Disposal	NR	P	D	D	D
Site Infrastructure (Access, Construction Power, Camp etc.)	NR	P	D	D	D
B. CAPACITY:					
Plant Production / Facility (includes power facilities)	P	P	D	D	D
Electrical Power Requirements (when not the primary capacity driver)	NR	P	D	D	D
C. PROJECT LOCATION:					
Plant and Associated Facilities	P	P	D	D	D
D. REQUIREMENTS:					
Codes and/or Standards	NR	P	D	D	D
Communication Systems	NR	P	D	D	D
Fire Protection and Life Safety	NR	P	D	D	D
Environmental Monitoring	NR	NR	P	P	D
E. TECHNOLOGY SELECTION:					
Process Technology	P	P	D	D	D
F. STRATEGY:					
Contracting / Sourcing	NR	P	D	D	D
Escalation	NR	P	D	D	D
G. PLANNING:					
Logistics Plan	P	P	P	D	D
Integrated Project Plan[1]	NR	P	D	D	D
Project Code of Accounts	NR	P	D	D	D
Project Master Schedule	NR	P	D	D	D
Regulatory Approval & Permitting	NR	P	D	D	D
Risk Register	NR	P	D	D	D
Stakeholder Consultation / Engagement / Management Plan	NR	P	D	D	D
Work Breakdown Structure	NR	P	D	D	D
Startup and Commissioning Plan	NR	P	P/D	D	D
H. STUDIES:					
Environmental Impact / Sustainability Assessment	NR	P	D	D	D
Environmental / Existing Conditions	NR	P	D	D	D
Soils and Hydrology	NR	P	D	D	D
TECHNICAL DELIVERABLES:					
Block Flow Diagrams	S/P	C	C	C	C
Equipment Datasheets	NR/S	P	C	C	C
Equipment Lists: Electrical	NR/S	P	C	C	C

MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
Equipment Lists: Process / Utility / Mechanical	NR/S	P	C	C	C
Heat & Material Balances	NR	C	C	C	C
Process Flow Diagrams (PFDs)	NR	C	C	C	C
Utility Flow Diagrams (UFDs)	NR	C	C	C	C
Design Specifications	NR	S/P	C	C	C
Electrical One-Line Drawings	NR	S/P	C	C	C
General Equipment Arrangement Drawings	NR	S/P	C	C	C
Instrument List	NR	S/P	C	C	C
Piping & Instrument Diagrams (P&IDs)	NR	S/P	C	C	C
Plot Plans / Facility Layouts	NR	S/P	C	C	C
Construction Permits	NR	S/P	P/C	C	C
Civil / Site / Structural / Architectural Discipline Drawings	NR	S/P	P	C	C
Demolition Plan and Drawings	NR	S/P	P	C	C
Erosion Control Plan and Drawings	NR	S/P	P	C	C
Fire Protection and Life Safety Drawings and Details	NR	S/P	P	C	C
Electrical Schedules	NR	NR/S	P	P/C	C
Instrument and Control Schedules	NR	NR/S	P	P/C	C
Instrument Datasheets	NR	NR/S	P	P/C	C
Piping Schedules	NR	NR/S	P	P/C	C
Piping Discipline Drawings	NR	NR/S	S/P	C	C
Spare Parts Listings	NR	NR	P	P/C	C
Electrical Discipline Drawings	NR	NR	S/P	P/C	C
Facility Emergency Communication Plan and Drawings	NR	NR	S/P	P/C	C
Information Systems / Telecommunication Drawings	NR	NR	S/P	P/C	C
Instrumentation / Control System Discipline Drawings	NR	NR	S/P	P/C	C
Mechanical Discipline Drawings	NR	NR	S/P	P/C	C

This significantly expanded table now has eight subgroups under General Project Data with a total of twenty-six deliverables. There are now twenty-nine Technical Deliverables. Interestingly, the Table 3 above has no categories for Technical Deliverables. This table is a dramatic expansion from the previous table, which reflects a consistent evolvement with the industry, to provide further granularity in defining data sets required to meet key project events or milestones.

Oracle Primavera, an industry leader in project management software, has issued annual upgrades over the same period. However, the upgrades to the front end have been minor. This reinforces the point that project controls software has been very mature for many years. Updates spanning the last few years are required to keep up with hardware specification changes. The hypothesis of this paper is that the focus of the industry appears to be moving towards qualitative improvements.

"People – process - tools" are the foundational elements of an organization project management model. AACE and other organizations have long advocated for developing job descriptions and career progression training which includes many professional certification programs. It can be argued that the answer is "process". AACE Total Cost Management Framework (TCM), includes graphic process maps for several project management activities performed during the planning and execution phases of a project. Project Management Institute (PMI) PMBOK Guide, also includes graphical processes for project management activities.

While the new Table 3 does not specifically address process, the significantly increased number of deliverables and descriptions of their respective maturity implies a pseudo process. AACE recommends the list of deliverables developed to the prescribed maturity is a prerequisite to developing the estimate. And if the estimate is developed using recommended practices, the result is expected to meet the class definitions and fall within the expected accuracy range.

This methodology can be applied to the technical deliverables of a project. First: identify "what" is to be done – for example, develop a set of piping design drawings. Subsequently, the prerequisite information necessary to perform that piping design can be prescribed. A set of piping design documents are issued several times as they develop; much like a Class 5 Estimate develops incrementally until it becomes a Class 1 Estimate. And if the design is performed using a process analogous to using an estimating process, the output can be expected to meet the requirements for a complete and correct deliverable. It becomes an exercise in defining all the processes and their prerequisite input information and their outputs or deliverables. Specifically, with respect to the input information, the level of maturity at each incremental deliverable needs to meet the prerequisite maturity, or the process should not proceed. Rules for rules of credit.

Technical Process Maps

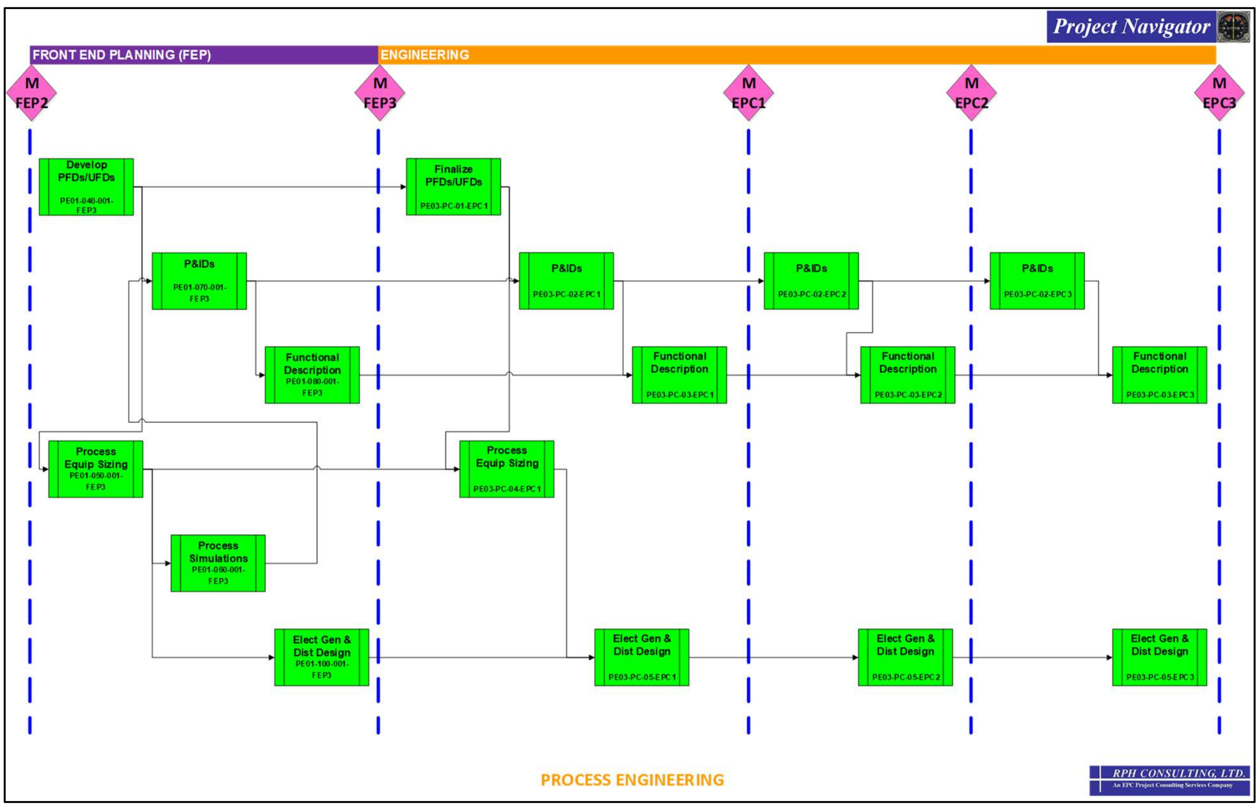
In some industries, such as upstream oil and gas, major assemblies defined as 1st Priority and 2nd Priority equipment are outsourced. Accordingly, commercial agreements are not executed in the FEP phase of a project. While AACE indicates PFDs and P&IDs are finalized for a Class 3 Estimate (aka FEP3), in some industries these documents may not be finalized until the execution phases have commended. Keeping this in mind, assume the critical path of an example EPC project runs from PFDs, through P&IDs, through the 1st priority equipment – from detailed design to delivery on site; then through process piping, commissioning and start up. Civil work, foundations, process steel, equipment installation and buildings all need to be designed, supplied, and installed, but if they are sequenced properly and absent of unusual circumstances, it can be assumed they will not become critical path activities.

With forethought, these engineering activities could be organized into common processes. After engineering processes are identified, they are placed on the process map within stage gates, or milestones. Each process has inputs with required level of maturity, requirements for what is performed and the required outputs. To provide more confidence, stage gate or milestone reviews are conducted to ensure processes are complied with. Checklists for each discipline are used to prepare for the gate review.

The specifics of an example environment are described in detail and graphically shown in figures throughout technical paper PM-2337, A Template for EPC Project Management and Execution, AACE, 2016. To reiterate, AACE RP18R-97 does in fact align deliverables, or information maturity of Class estimates to milestones; Class 5 aligns to FEP1 (FEL1); Class 4 aligns to FEP2 (FEL2) and Class 3 aligns to FEP3 (FEL3). Construction Industry Institute implementation resource 213-2 also aligns deliverables to FEP milestones. The template and graphics referenced in technical paper PM-2337 are specific to the author's organizational requirements.

Figure 3 shows an excerpt from an engineering process map that shows the processes that comprise the discipline of process engineering during the FEP and engineering phases.

Figure 3 - Process Engineering Map



The P&IDs in Figure 3 are shown separately four times. In the same way an estimate could be shown as Class 3 under the FEP phase; then progressing in development to Class 1 late in the engineering phase. Each separate iteration of P&IDs has different inputs with different levels of maturity.

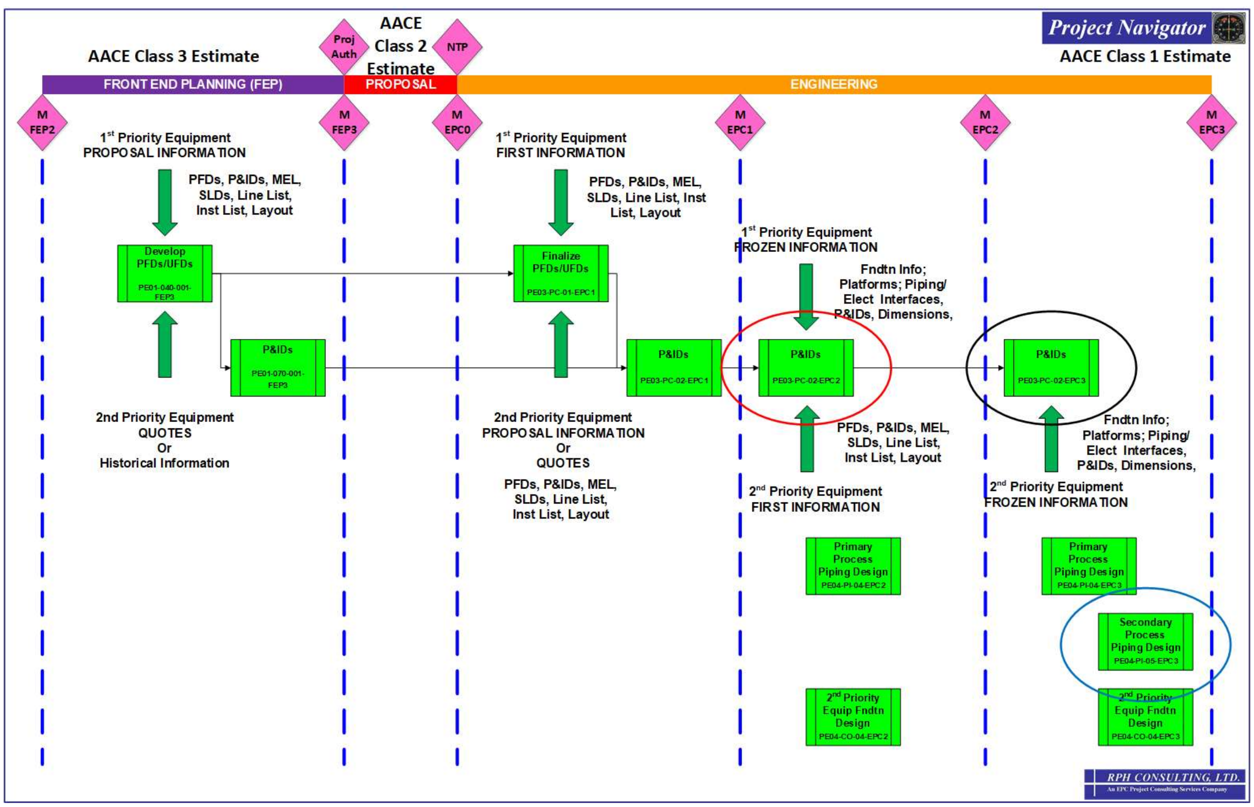
Engineering and Procurement Information

It is important for EPC project managers and project controls leads to understand the relationships, definitions of terminology and deliverables for supplier information and the iterative nature of how that supplier information is required to progress engineering deliverables.

Engineering development on EPC process projects relies heavily upon equipment supplier information. Whether the 1st priority equipment is provided by the EPC contractor, or they source it outside their organization, the supplier equipment is the essence of the facility's product. There is also a significant contribution from 2nd priority equipment. This information also needs to be integrated into the overall facility engineering, but it will have a dependency on 1st priority equipment information.

After notice to proceed (NTP); 1st priority equipment supplier submits first information. Engineer integrates into P&IDs; issues for design; confirms perf requirements/spec for 2nd priority equipment. 1st priority equipment supplier submits frozen information; 2nd priority equipment supplier submits first information. Engineer integrates into P&IDs, issues for design. 2nd priority equipment supplier submits frozen information. Engineer integrates into P&IDs, issues for design.

Figure 4 – Engineering and Equipment Supplier Information Flow



Detailed Engineering and Procurement Processes

As a reference point, the author's EPC template includes one hundred thirty-nine engineering and one hundred procurement processes defined, which cover all disciplines. This paper will focus on P&IDs, secondary process piping, and 2nd priority equipment foundations processes.

Process Engineering

Figure 4 shows the supplier information inputs required to advance the development of the engineer's P&IDs. The project phases are color coded bars that span the top of the figure. The magenta diamonds below the phase designations depict the stage gate milestones where the project is reviewed for completion of required deliverables developed in conformance with the work processes.

A process, as defined in the EPC template is replicated as many times as required by the WBS. For example, there may be a single P&ID for each piping system on a project. Or, there may be a single P&ID for all piping in an area. However, all P&IDs require the same input information at the same time, which is why they can be developed utilizing a common work process. A project will probably have numerous WBS accounts for P&IDs, but they will all advance using the same process and within the same stage gate milestones.

Figure 5 shows a detailed work process for the P&ID process highlighted by the red ellipse in the previous figure. It shows the individual information inputs from the 1st priority equipment frozen information and 2nd priority equipment first information. It also shows the master equipment list, motor list, process line list, valve list, and instrument list as outputs, or deliverables.

The process shows that this is a continuation process from P&ID development completed in the previous stage and continues into the following stage. It also shows successor processes of utility piping design and primary process piping design, also required to be advanced before the stage gate milestone is achieved.

Figure 5 – P&ID Process Diagram 1

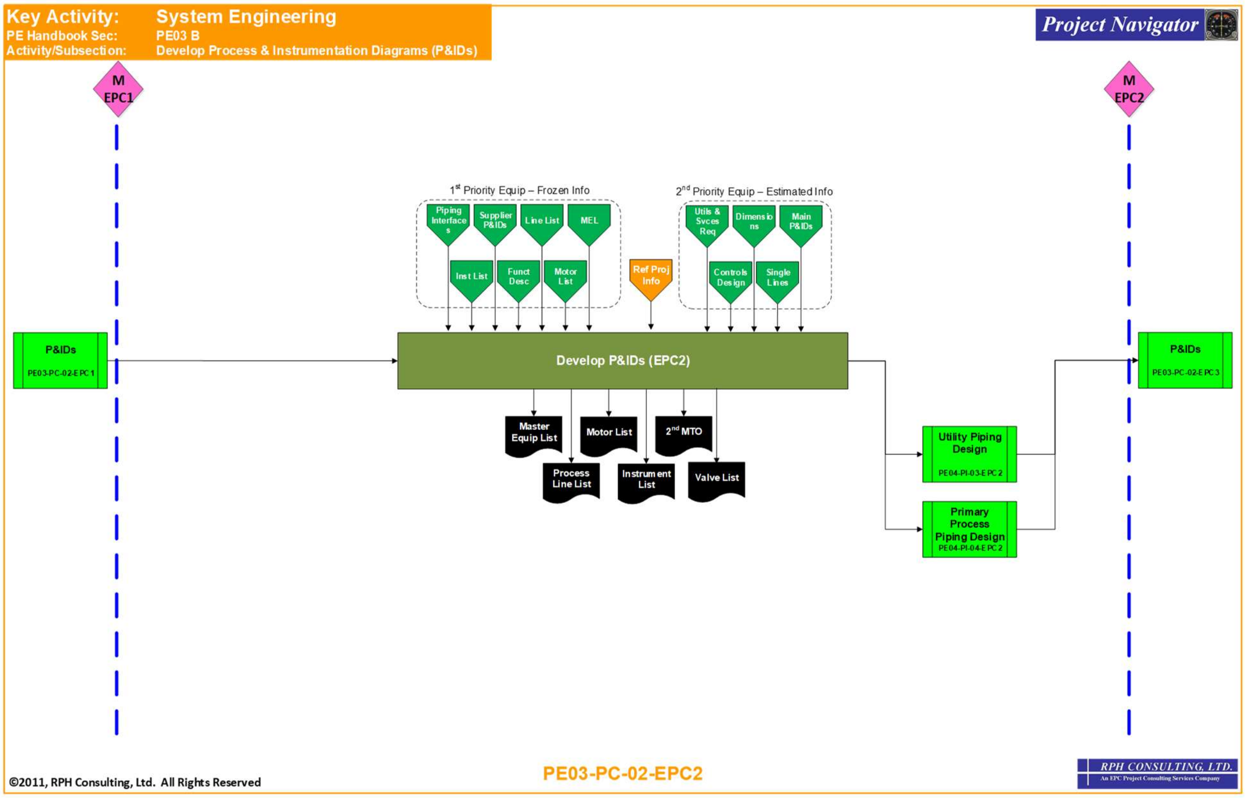


Figure 6 is the activity description for the work process shown in Figure 5. It is a detailed description of the parameters of the work for this process. It also clarifies the conditions that must be satisfied before starting this process. And it provides a more comprehensive list of the input requirements and outputs.

Figure 6 – P&ID Activity Description 1

ACTIVITY DESCRIPTION

Project Navigator

ENGINEERING

PE03 System Engineering

Activity Title

P&IDs

Process

PE03-PC-02-EPC2

ACTIVITY DESCRIPTION:

Develop Piping and Instrument Diagrams for WBS Level 4 "Issued for Design" deliverables package that meets the requirements for Milestone EPC2

Review and incorporate approved comments from Owner and/or first HazOp

Verify whether or not comments reflect scope changes. Scope changes resulting from comments must be documented in a Change Order Request (PM08-02) and submitted to the client in accordance with the contractual requirements.

DO NOT PROCEED UNTIL COR IS APPROVED OR REJECTED

Incorporate Approved Changes into design OR disregard client comments that initiated the COR

The work product can begin upon validation of 1st Priority Equipment Supplier - Frozen Information
AND
2nd Priority Equipment Supplier - First Information

P&IDs Issued for Design at EPC2 must include the following information
- Critical Lines sized
- Control Valves and Inline Devices Sized

Upoin completion, drawing(s) should be "Issued for Design: EPC2"; MDL updated to reflect status

REF. DOC

PN Handbook Section PE03-PC-02

INPUT REQUIREMENTS:	ISSUE:	STATUS:
P&IDs	Issued for Design	EPC1
MEL	Issued for Design	EPC2
Facility Layout	Issued for Design	EPC2
Terminal Points List	Issued for Design	EPC2
1st Priority Equipment	Issued for Design	Frozen Information
2nd Priority Equipment	Issued for Design	First Information
Interface Matrix	Issued for Design	EPC2
Functional Description	Issued for Design	EPC2
Owner Comments		
HazOp		

OUTPUTS:	ISSUE:	STATUS:
P&ID	Issued for Design	EPC2
Process Line List	Issued for Design	EPC2
Valve List	Issued for Design	EPC2
Specialties List	Issued for Design	EPC2
Instrument List	Issued for Design	EPC2

The design work performed in this activity has been checked and verified to have relied upon the prerequisite quality of information required.
The completed design documents meet the requirements for "**Issued for Design**" at Milestone EPC2

Engineering Manager Date

The activity description includes a certification that must be signed by the lead discipline designer to issue the documents for their intended purpose. Without this sign off, the documents cannot be issued, nor can progress be credited.

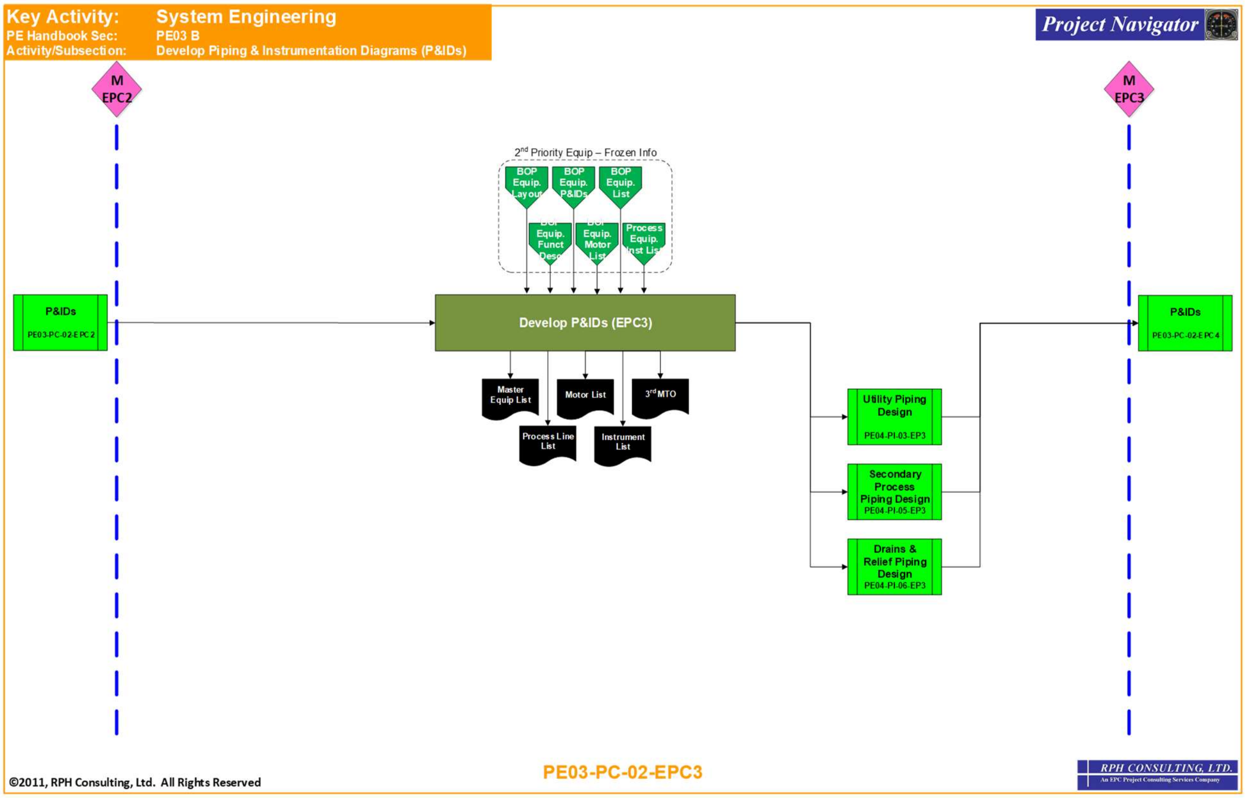
The P&IDs must be developed to this "quality of information" to successfully pass the stage gate milestone review. After P&IDs pass this stage gate milestone, discipline design of primary process piping is permitted to begin. This is because the 1st priority equipment frozen information has been received by the suppliers and integrated into the overall design. Discipline design should always begin after all the input information is frozen to avoid errors and omissions.

Next, Figure 7 shows a detailed work process for the P&ID process between M EPC2 and M EPC3. This was previously highlighted by the black ellipse in the Figure 4. It shows the individual information inputs from the 2nd priority equipment frozen information. As with the previous P&ID process, this too shows the master equipment list, motor list, process line list, valve list, and instrument list. However, all these output documents are issued with more information than included in the previous stage gate issue.

As with the previous P&ID, this process shows that this is a continuation process from P&ID development completed in the previous stage and continues into the following stage. It also shows successor processes of utility piping design and primary process piping design, but now includes secondary process piping design because the 2nd priority equipment frozen information is reflected in these P&IDs.

Without formal work processes, P&IDs would have been issued for design and their progress credited. With formal processes, the P&IDs are certified to have been completed to the prescribed requirements using inputs with prescribed quality of information.

Figure 7 – P&ID Process Diagram 2



As with the previous P&ID, this P&ID also has an activity description. Figure 8 is the detailed description of the parameters of the work for this process with its respective conditions that must be satisfied before starting this process.

Figure 8 – P&ID Activity Description 2

ACTIVITY DESCRIPTION

Project Navigator

ENGINEERING

PE03 System Engineering

Activity Title: **P&IDs**

Process: **PE03-PC-02-EPC3**

ACTIVITY DESCRIPTION:

Develop Piping and Instrument Diagrams for WBS Level 4 "Issued for Design" deliverables package that meets the requirements for Milestone EPC3

Review and incorporate approved comments from Owner

Verify whether or not comments reflect scope changes. Scope changes resulting from comments must be documented in a Change Order Request (PM08-02) and submitted to the client in accordance with the contractual requirements.

DO NOT PROCEED UNTIL COR IS APPROVED OR REJECTED

Incorporate Approved Changes into design OR disregard client comments that initiated the COR

The work product can begin upon validation of 2nd Priority Equipment Supplier - Frozen Information
AND
3rd Priority Equipment Supplier - Reference / Quoted information

P&IDs Issued for Design at EPC3 must include the following information
- All Lines Sized
- Vents and Drains Identified
- P&ID / 3D Model comparison completed

Upoin completion, drawing(s) should be "Issued for Design: EPC3"; MDL updated to reflect status

REF. DOC

PN Handbook Section PE03-PC-02

INPUT REQUIREMENTS:	ISSUE:	STATUS:
P&IDs	Issued for Design	EPC2
MEL	Issued for Design	EPC3
Facility Layout	Issued for Design	EPC3
Terminal Points List	Issued for Design	EPC3
2nd Priority Equipment	Issued for Design	Frozen Information
Interface Matrix	Issued for Design	EPC3
Functional Description	Issued for Design	EPC3
Owner Comments		
Final HazOp		

OUTPUTS:	ISSUE:	STATUS:
P&ID	Issued for Design	EPC3
Process Line List	Issued for Design	EPC3
Valve List	Issued for Design	EPC3
Specialties List	Issued for Design	EPC3
Instrument List	Issued for Design	EPC3

The design work performed in this activity has been checked and verified to have relied upon the prerequisite quality of information required.
The completed design documents meet the requirements for "**Issued for Design**" at Milestone EPC3

Engineering Manager   Date

Upon completion of these P&IDs, all lines are sized, vents and drains are identified. This opens the piping design to proceed as fast as resources allow. And like all activity descriptions, it includes the certification that all prerequisites were relied upon to perform the work and that the work and outputs meet the requirements for issuance.

P&IDs are one of the most significant engineering deliverables of an EPC project. However, the installation contractor doesn't build from them nor do the project controls professions collect quantities from them. However, they must be developed as a prerequisite for their respective piping discipline design drawings – namely orthometric or isometric drawings.

Piping Design

Figure 9 shows an example process for secondary piping design from the author's project template. Using this template, discipline design drawings are issued in four revision, each of which are represented in the rules of credit below:

Issued for Concept	30%
Interdiscipline Checked (internal issue to engineer only)	20%
Issued for Approval	40%
Issued for Construction	10%

Keep in mind, other industries or organizations may use different terminology for their drawing issues.

Figure 9 – Piping Design Process Diagram

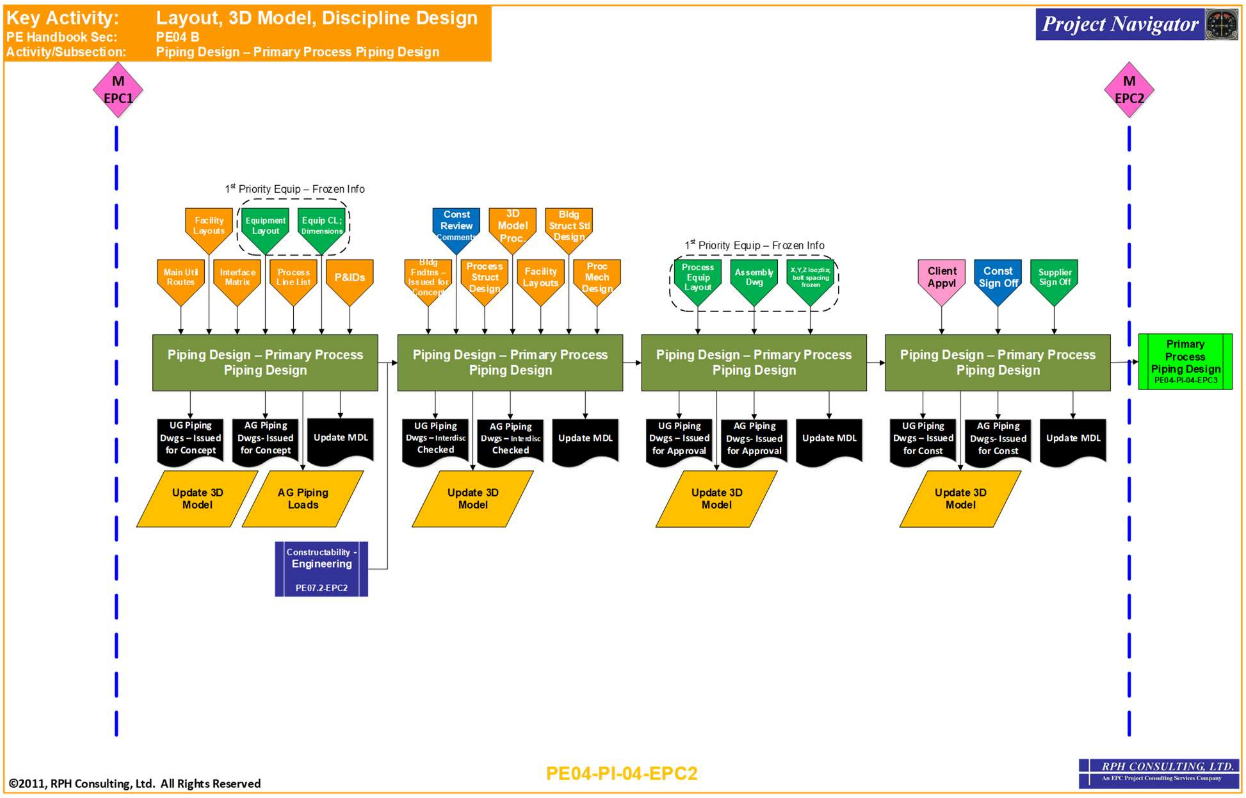


Figure 10 below describes the work performed to develop secondary piping design documents to issued for concept requirements. It also identifies the input documents and the quality of information they must be developed to prior to starting this activity. This is the first version of the design deliverable; it takes size and valve information from P&IDs and routes the pipe between equipment and/or tie points. Dimensions are added; valves, specialties and fittings are shown. Engineered and non-engineered hangers are located. Note that not all processes are referenced in this paper. For example, some lines will require stress analysis, which is defined as a separate process. At the completion of this work, the discipline engineer certifies that the inputs at their level of maturity were relied upon to perform this work and that the work was performed in accordance to the approved process. Without this certification, the deliverables cannot be issued for concept nor can the 30% progress be taken. Without project execution processes, the issued for concept deliverables would earn 30% credit upon issuance.

With project execution processes, the issued for concept deliverables would be documented by the certification by the discipline engineer. The activity description can be referred to at any time to further verify the completion requirements and the status of each input document.

Figure 10 - Piping Design Activity Description – Issued for Concept

Activity Description

Project Navigator

ENGINEERING

PE04 Layout, 3D Modelling, Discipline Design

Activity Title	Process
Secondary Process Piping Design	**PE04-PI-05-EPC3**

ACTIVITY DESCRIPTION:	WORK METHOD REF. DOC
Develop Secondary Process Piping Design for WBS Level 4 "Issued for Concept" deliverables package Using inputs, provide detailed routing (x, y, z) for entire scope of devliverables package. Layout priority should consider 3D priorities agreed to for the specific project Layout should consider clearances required by material selection in piping specification for installation, maintenance and repair (e.g. Victaulic/Tube-mac joints, etc.) Completed product will start at frozen (x,y,z, diameter, bolt spacing) connection from tie point or 1st Priority Equipment tie point and end at frozen connection to tie point or 2nd Priority Equipment tie point and show dimensions for all straight runs; locations for all fittings, valves and specialties and support / hangar locations and types. It will also be assigned a unique ISO number. Upon completion, drawing(s) should be "Issued for Concept"; MDL updated to reflect status.	

INPUT REQUIREMENTS:	ISSUE:	STATUS:
P&ID		EPC3
Equipment Layout		EPC1
Facility Layout		EPC2
Process Line List		EPC3
2nd Priority Equipment		Frozen Information
Tie Point List		EPC3
Piping Specification		Issued for Construction

OUTPUTS:	ISSUE:	STATUS:	QUALITY REF. DOC.
Piping Isometric Drawing		Issued for Concept	
Master Document List (MDL)		Updated	
3D Model		Updated	
AG Piping Loads			

The design work performed in this activity has been checked and verified to have relied upon the prerequisite quality of information required.
The completed design documents meet the requirements for **"Issued for Concept"**

Lead Discipline Engineer	Date

issued for concept drawings are used for constructability reviews. Constructability is a formal process and is required before the engineering can continue. This provides the mechanism for the project team to contribute their expertise into the design process before most design hours are consumed. It is used to verify quantities against the original budget and look for opportunities to improve productivity and cut costs.

Figure 11 describes the work performed to develop secondary piping design documents to interdiscipline checked requirements. This revision of the deliverables package is an internal review by the engineer to check for dimensional clearances for the pipe route against all discipline work that has been previously designed. Note that the input documents reflect the same quality of information as required for issued for concept. It is because this revision does not develop engineering further; it is a confirmation of work developed to date. Constructability review comments that are accepted by project management are included in the interdiscipline checked revision.

While this version of the drawings are not issued to the team, the documents register is updated to reflect the development status and to earn the 20% progress credit. Once again, it must be certified by the discipline engineer before moving to the next activity. Without project execution processes, the interdiscipline checked deliverables would earn 20% credit upon issuance.

With project execution processes, the interdiscipline checked deliverables would be documented by the certification by the discipline engineer. The activity description can be referred to at any time to further verify the completion requirements and the status of each input document.

Figure 11 - Piping Design Activity Description - Interdispline Checked

Activity Description

Project Navigator

ENGINEERING

PE04 Layout, 3D Modelling, Discipline Design

Activity Title

Secondary Process Piping Design

Process

PE04-PI-05-EPC3

ACTIVITY DESCRIPTION:

Interdiscipline check Secondary Process Piping Design for WBS Level 4 deliverables package

Review and incorporate approved comments from Constructability Report (PE07.5-EPC3)

Verify whether or not client comments reflect scope changes. Scope changes resulting from Constructability Review must be documented in a Change Order Request (PM08-02) and submitted to the client in accordance with the contractual requirements.
DO NOT PROCEED UNTIL COR IS APPROVED OR REJECTED

Incorporate Approved Changes into design OR ignore client comments that initiated the COR

Any approved comments by constructor that can not be incorporated must be approved by the Project Manager

Using "Issued for Concept" design; verify routing against:
- Foundations / Floor Trenches
- Structural Steel Members / Connections
- 1st Priority Equipment
- 2nd Priority Equipment
- HVAC ductwork
- Process ductwork
- other Primary and Secondary Process Piping

Upon completion, drawing(s) should be issued (internally) "Interdiscipline Checked".
MDL updated to reflect status

WORK METHOD REF. DOC

INPUT REQUIREMENTS:	ISSUE:	STATUS:
P&ID		EPC3
Equipment Layout		EPC2
Facility Layout		EPC2
Process Line List		EPC3
2nd Priority Equipment		Frozen Information
Tie Point List		EPC3
Constructability Report		EPC3
Piping Specification		Issued for Construction

OUTPUTS:	ISSUE:	STATUS:	QUALITY REF. DOC.
Piping Isometric Drawing		Issued for Concept	
3D Model		Updated	
MDL		Updated	
Technical support for Change Order Request			

The design work performed in this activity has been checked and verified to have relied upon the prerequisite quality of information required.
The completed design documents meet the requirements for **"Interdiscipline Checked"**

Lead Discipline Engineer   Date

Figure 12 describes the work performed to develop secondary piping design documents to issued for approval requirements. It also identifies the input documents and the quality of information they must be developed to prior to starting this activity. Note that the quality of information of the inputs has advanced from what was used to develop issued for concept drawings. This revision adds valves, specialties and details. It also is a technical check for dimensions, off page references and title block information. Without project execution processes, the issued for approval deliverables would earn 40% credit upon issuance.

With project execution processes, the issued for approval deliverables would be documented by the certification by the discipline engineer. The activity description can be referred to at any time to further verify the completion requirements and the status of each input document.

Figure 12 - Piping Design Activity Description - Issued for Approval

Activity Description

Project Navigator

ENGINEERING

PE04 Layout, 3D Modelling, Discipline Design

Activity Title	Process
Secondary Process Piping Design	**PE04-PI-05-EPC3**

ACTIVITY DESCRIPTION:

Develop Main Process Piping Design for WBS Level 4 deliverables package to "Issued for Approval" status

Using "Interdiscipline Checked" design; update to reflect
- Hangar / Support details
- Valves
- Fittings
- Specialties

Perform technical check
- dimensions
- references to tagged equipment
- references to process lines, P&IDs, etc.
- Title Block information

Upon completion, drawing(s) should be "Issued for Approval"
MDL updated to reflect status

WORK METHOD REF. DOC

INPUT REQUIREMENTS:	ISSUE:	STATUS:
Hangar / Support Details		
Stress Analysis		
P&ID		EPC3
Equipment Layout		EPC1
Facility Layout		EPC2
Process Line List		EPC3
2nd Priority Equipment		Frozen Information
Tie Point List		EPC3
Pipng Specification		Issued for Construction
Approved Change Order / Rejected COR		Approved/Rejected
"Interdiscipline Checked" design documents		

OUTPUTS:	ISSUE:	STATUS:	QUALITY REF. DOC.
Piping Isometric Drawing		Issued for Approval	
3D Model		Updated	
MDL		Updated	

The design work performed in this activity has been checked and verified to have relied upon the prerequisite quality of information required.
The completed design documents meet the requirements for **"Issued for Approval"**

Lead Discipline Engineer   Date

Figure 13 below describes the work performed to develop secondary piping design documents to issued for construction requirements. Final owner comments are approved and reflected; the final issued for construction deliverables are issued.

Note that the quality of information of the input documents is the same as for issued for approval. The reason is that secondary piping relies upon 2nd priority equipment frozen information which was required for issued for approval drawings. Without project execution processes, the issued for construction deliverables would earn 10% credit upon issuance.

With project execution processes, the issued for construction deliverables would be documented by the certification by the discipline engineer. The activity description can be referred to at any time to further verify the completion requirements and the status of each input document.

Figure 13 - Piping Design Activity Description - Issued for Construction

Activity Description

Project Navigator

ENGINEERING

PE04 Layout, 3D Modelling, Discipline Design

Activity Title	Process
Secondary Process Piping Design	**PE04-PI-05-EPC3**

ACTIVITY DESCRIPTION:

Develop Secondary Process Piping Design for WBS Level 4 "Issued for Construction" deliverables package

Review and incorporate applicable comments / corrections from client, constructor, OEM and other stakeholders

Upon completion, drawing(s) should be "Issued for Construction"

MDL updated to reflect status

WORK METHOD REF. DOC

INPUT REQUIREMENTS:	ISSUE:	STATUS:
P&ID		EPC3
Equipment Layout		EPC1
Facility Layout		EPC2
Process Line List		EPC3
2nd Priority Equipment		Frozen Information
Tie Point List		EPC3
"Issued for Approval" design documents		Issued for Approval
Owner Comments		
Constructor Comments		
Piping Specification		Issued for Construction

OUTPUTS:	ISSUE:	STATUS:	QUALITY REF. DOC.
Piping Isometric Drawing		Issued for Construction	
3D Model Update		Updated	
MDL		Updated	

The design work performed in this activity has been checked and verified to have relied upon the prerequisite quality of information required.
The completed design documents meet the requirements for **"Issued for Construction"**

Lead Discipline Engineer　　　　Date

Conclusion

Upon receiving a pipe design deliverables package that has been developed in accordance with a defined process, using defined prerequisite inputs, the project controls engineer can confidently take off quantities shown on these IFC documents. Behind these drawings is the documentation that verifies:

- ✓ All equipment that this piping deliverable connects to is certified frozen.
- ✓ Pipe sizing is assured to be correct
- ✓ The routing has been checked for clashes with steel, equipment, and other facility components
- ✓ Dimensions have been verified

As a result of development activities being formally documented, there is a higher confidence that the actual percent complete and man-hours expended will be more accurate. Subsequently, when the WBS account is 100% completed, there will not be an additional charge of engineering man hours to correct errors and omissions. This will result in a more reliable forecast.

The P&IDs and secondary process piping design examples used can be applied to all processes of all disciplines.

The many figures included in this publication are intended to provide the reader with takeaways for consideration:

1) Engineering and procurement can and should be formally structured to reduce rework and improve reliability of information.
2) A structured approach to developing discipline design deliverables provides the project with higher confidence when reporting actual percent complete and forecasting quantities and costs.
3) Figures shown throughout this paper can be used to inspire the reader to develop their own EPC template, or at a minimum, checklist requirements for accepting engineering deliverables before crediting their progress.

Project controls tools are mature. To continue the pursuit of better predictability of project outcomes and to manage projects to better outcomes, a deeper dive into the quality of information of data used in measuring progress is the logical path forward. Developing standardized engineering, procurement and construction work processes with prescribed input information and outputs, verified by an audit, is one way to qualify of information the data relied upon in project controls.

Using project execution processes will result in better project controls.

References

[1] AACE International, Recommended Practice No. 10S-90, Cost Estimating Terminology, Morgantown, WV: AACE International, Latest revision.

[2] AACE International, Recommended Practice No. 18R-97, Cost Estimate Classification System - As Applied in EPC for the Process Industries, Morgantown, WV: AACE International, 2016.

[3] AACE International, Recommended Practice No. 18R-97, Cost Estimate Classification System - As Applied in EPC for the Process Industries, Morgantown, WV: AACE International, Latest revision.

[4] AACE International, PM-2337, A Template for EPC Projects, Morgantown, WV: AACE International, 2016.