A CASE FOR INTEGRATED FRONT-END ENGINEERING AND DESIGN – INCREASING VALUE AND REDUCING RISK

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ABSTRACT:

The way in which engineering information is developed and managed during Front-End Engineering and Design (FEED) has major ramifications on quality, cost, and speed of a project. During the FEED phase, the Engineering, Procurement, and Construction (EPC) contractor develops engineering information including Design Basis, Design Criteria, Equipment and Instrument Specifications, Mass and Energy Balance, PFDs, and P&IDs. Of course, this information can be developed and delivered to the owner / operator in separate documents and drawings, or, it can all be integrated using a common database shared by multiple disciplines where high-quality deliverables are the final outcome. This paper makes the case that an integrated, data-driven front-end approach is a cost-effective best practice. This integrated, data-driven approach ensures consistency across deliverables and ensures that changes made in one place are kept consistent with the entire set of engineering information. This approach also helps to facilitate the transfer of information and the transition from engineering systems to operating and maintenance systems where the information can be kept current moving forward. Some examples of the benefits of utilizing an integrated, data-driven approach will be discussed (in contrast to utilizing only traditional practices that do not utilize "smart" technologies), including improved quality and consistency of data and reduced risk of scope creep and schedule delays.

INTRODUCTION:

In the 1970s, the tools that were used for process design were hand calculators and drafting tables. Pumps and piping systems were sized using Crane Technical Paper 410. It took a long time to finish a project when everything was done by hand.

By the 1980s, the process design tools had changed to spreadsheets and computer aided drafting. A full paper machine material and energy balance calculated with a spreadsheet took a process engineer and a process simulation modeler (two full time people) several months to develop. Changes to the calculation were difficult and time consuming but still represented an improvement over using a calculator.

In the 1990s, the tools used were process simulation software and intelligent P&IDs. A full-paper machine material and energy balance could now be developed by a single process engineer in a few weeks. Intelligent P&ID (Piping and Instrumentation Diagram) software made the users more efficient by performing consistency checking and integrating the graphics with a database that was used to create reports from the plant model such as line lists, equipment lists, and instrument lists. This was a significant improvement in efficiency and accuracy compared to computer-aided drafting and added a capability (consistency checking) while eliminating the manual creation of reports that would otherwise take weeks to extract from drawings. Less time was spent in drafting and calculating, allowing engineers and project managers to shift their attention to finding the best solution.

In the 2010s, these same types of process design tools are now more advanced. These advanced tools, if properly applied by qualified users, can now dramatically increase value creation for projects by increasing speed of analysis, reducing costs, increasing quality and accuracy of design deliverables, and improving design capabilities compared to using the previous methods.

Use of today's best-practice tools allows you to reduce risk to your strategic project by evaluating multiple solutions simultaneously. This allows for collaborative effort between the marketing team and the project team. The results from this collaboration can be significant, as the model can be developed to accurately show how minor changes in the final product may only require simple changes in the process, or the reverse can be true where the process may become adversely complex and more expensive. This allows key stakeholders to evaluate each marketing idea individually and assess its value. The speedy identification of an optimal solution (and subsequent execution) provides your company a competitive advantage.

The following section will explore the latest, best-practice tools that are now being leveraged to perform process design and to support efficient project execution, commissioning, and turnover of information for pulp and paper projects.

The process design tools used to create the following Front-End Engineering and Design (FEED) outputs will be discussed:
1. Process Flow Diagrams (PFDs) and Material and Energy Balances
2. Equipment Sizing (Including Pumps and Piping Systems)
3. Piping and Instrumentation Diagrams (P&IDs) and Reports (Lists)

PROCESS FLOW DIAGRAMS AND MATERIAL AND ENERGY BALANCES

The best-practice tools for creating process flow diagrams and material and energy balances for pulp and paper projects are **Process Simulation Software Tools** designed for Pulp and Paper. This kind of software can be used efficiently by experienced modelers to create a full paper machine (or full mill) material and energy balance that can be easily modified as the design changes during development.

TABLE I: EXAMPLES OF PROCESS SIMULATION SOFTWARE TOOLS DESIGNED FOR PULP AND PAPER

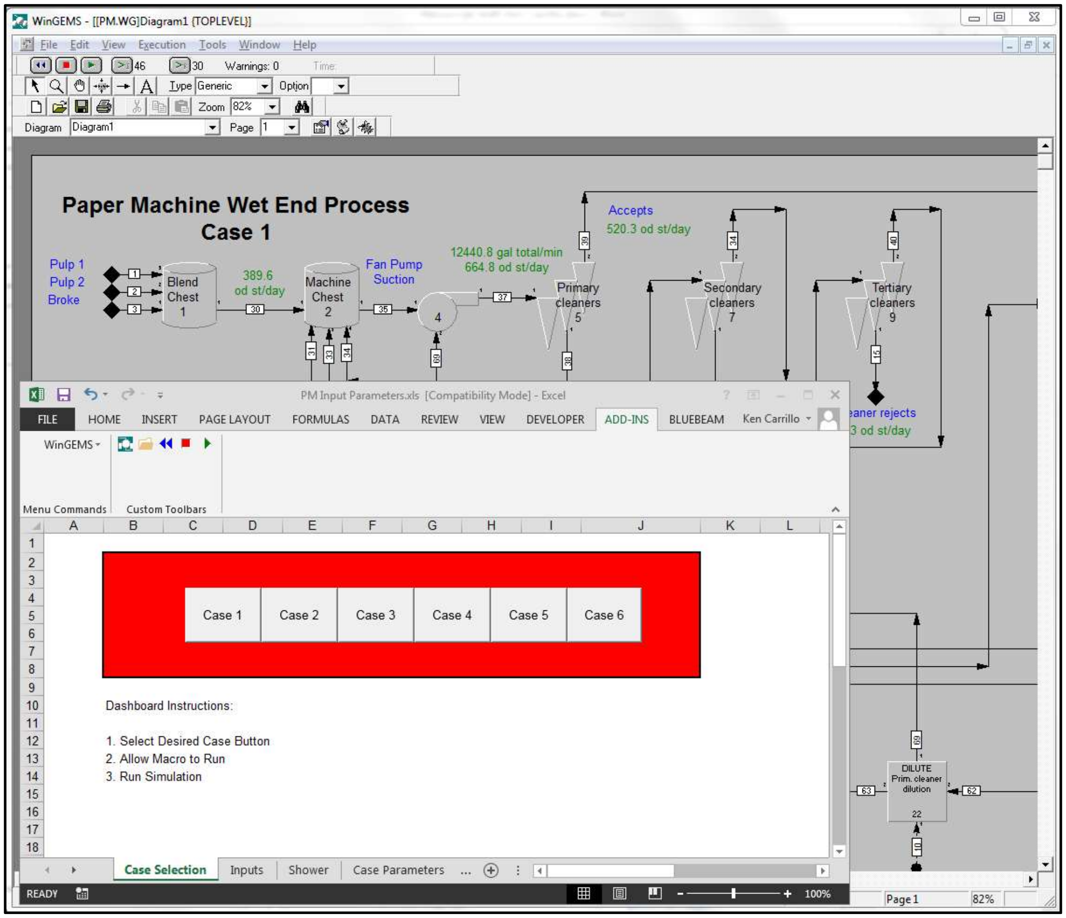
1. Valmet WinGEMS Process Simulator
2. Andritz IDEAS Simulation Software

BENEFITS OF USING PROCESS SIMULATION SOFTWARE TOOLS

Single Model- This type of software allows you to create a model that includes not only the paper machine, but also stock prep and the entire white water system – something that cannot be easily accomplished in a single Excel spreadsheet. Because the plant is a system, when a parameter is changed using the simulation software, it changes all affected aspects of the entire system – paper machine, stock prep and white water system. It is all integrated and takes less work to converge on a solution.

Evaluate Multiple Design Cases- This type of software also supports studying a range of cases. The case parameters can be chosen to represent the range of different products, furnish ratios, production rates, and levels of broke (recycle) expected for the project. The case parameters can also be chosen to support process optimization for quality, cost, energy, and water. For example, Jedson Engineering looked at a number of cases to optimize the process for a confidential client to achieve an industry benchmark for water consumption per ton of finished product. The basis for each case to be run in the simulation model can be calculated in Excel and then the case basis information transferred from Excel to the simulation model**.** This transfer process is preformed using the Excel add-in supplied with the first software tool listed in **Table I** and is illustrated in **Figure I**. The results from the converged simulation for each case can be used to establish the flow rate ranges for sizing piping and equipment.

FIGURE I: DATA TRANSFER BETWEEN EXCEL & PROCESS SIMULATION MODEL



Eliminate The Step Of Creating Separate Process Flow Diagrams- Another benefit of this type of software is that the output diagrams are acceptable to be used as the project's process flow diagrams (PFDs), eliminating the step of creating process flow diagrams in another graphics or CAD tool. How much time would your team save if you didn't have to create process flow diagrams separately? A few weeks? A few months? Now, you can cut that step out of your budget.

The output from the material and energy balance calculations are used for sizing equipment and piping systems.

EQUIPMENT SIZING (PUMPS AND PIPING SYSTEMS)

Consider tools for sizing pumps and piping systems for pulp and paper projects. **Pipe Flow Analysis and System Modeling Software Tools** are well suited for these types of calculations.

TABLE II: EXAMPLES OF PIPE FLOW ANALYSIS AND SYSTEM MODELING SOFTWARE TOOLS

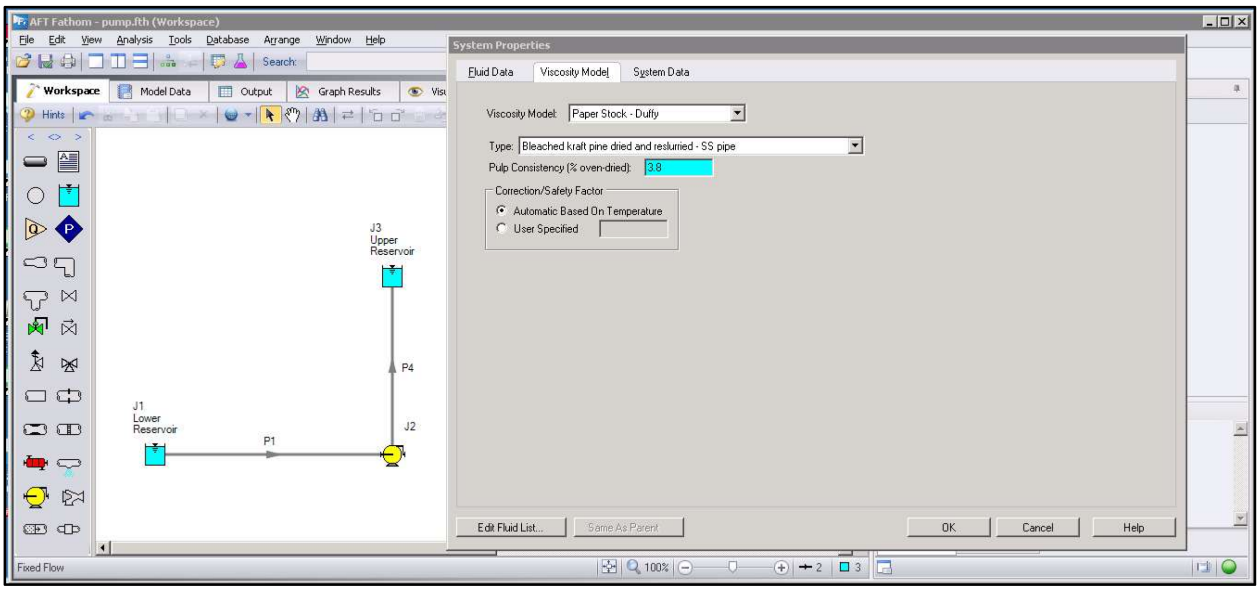
1.	AFT Fathom by Applied Flow Technology
2.	PIPE-FLO by Engineered Software, Inc.

BENEFITS OF USING PIPE FLOW ANALYSIS AND SYSTEM MODELING SOFTWARE TOOLS

Lower Risks by Avoiding Manual Calculation Errors- by performing the sizing calculations using proven and verified software tools, engineering errors caused by mistakes in manual calculations can be avoided. Errors in pipe and pump sizing can have an impact on startup and commissioning, energy consumption, pump efficiency, operational flexibility, pump reliability, and pump vibration. Think about how engineering errors impact the construction team: delays in start-up (impact to schedule), additional costs (correct the solution in the field – piping, equipment, electrical), process reliability, and optimization.

Calculation of Friction Loss Using Duffy Method- Pipe Flow Analysis and System Modeling Software tools can be used to apply the Duffy method as described in TIS 0410-14, “Generalized Method for Determining the Pipe Friction Loss of Flowing Pulp Suspensions,” Revised 1988. The Duffy method is applied using the first software tool listed in **Table II** by selecting “Paper Stock – Duffy” for the Viscosity Model field in System Properties and the appropriate Pulp Type in the Type field as illustrated in **Figure II**. If the friction loss is calculated manually according to the steps outlined the Technical Information Sheet (TIS), it is an arduous process, with each analysis taking about 1.5 hours and there are many analyses required for a large strategic project. When you are using state-of-the-art tools, each analysis takes only minutes.

FIGURE II: CALCULATION OF FRICTION LOSS USING DUFFY METHOD



The results of the sizing calculations can be entered into the plant model that is used to create the P&IDs.

CREATING P&IDS AND LISTS

The best-practice tools for creating P&IDs and Lists are **Intelligent Engineering Schematics Software Tools** (Smart P&IDs).

TABLE III: EXAMPLES OF INTELLIGENT ENGINEERING SCHEMATICS SOFTWARE TOOLS

1.	Intergraph SmartPlant P&ID
2.	Intergraph CadWorx
3.	Bentley OpenPlant PowerPID
4.	Aspen Basic Engineering
5.	Siemens COMOS P&ID
6.	Autodesk AutoCAD P&ID

The selection of the software tool is usually based on the owner’s standards and requirements. Intelligent Engineering Schematics Software integrates the schematic drawings with a plant model database and unlocks the power of P&IDs by making diagrams, and the information locked within them, available to all stakeholders.

BENEFITS OF USING INTELLIGENT ENGINEERING SCHEMATICS SOFTWARE TOOLS

Cost Savings Due To Increased Efficiency- The difference between using the CAD software that was state-of-the-art in the 1990s and today's intelligent P&ID integrated software is akin to dicing your vegetables by hand versus throwing them into a food processor. The intelligent software not only does the job more efficiently, but also makes changes quickly and efficiently. Using the old version, initial costs are low, but the costs associated with doing everything by hand are significantly higher. Also, when changes are made those reports need to be re-generated manually all over again.

Design Reuse- Use of Intelligent Engineering Schematics Software facilitates reuse of previous design modules, which can result in major cost savings compared to recreating the design information without the aid of automation.

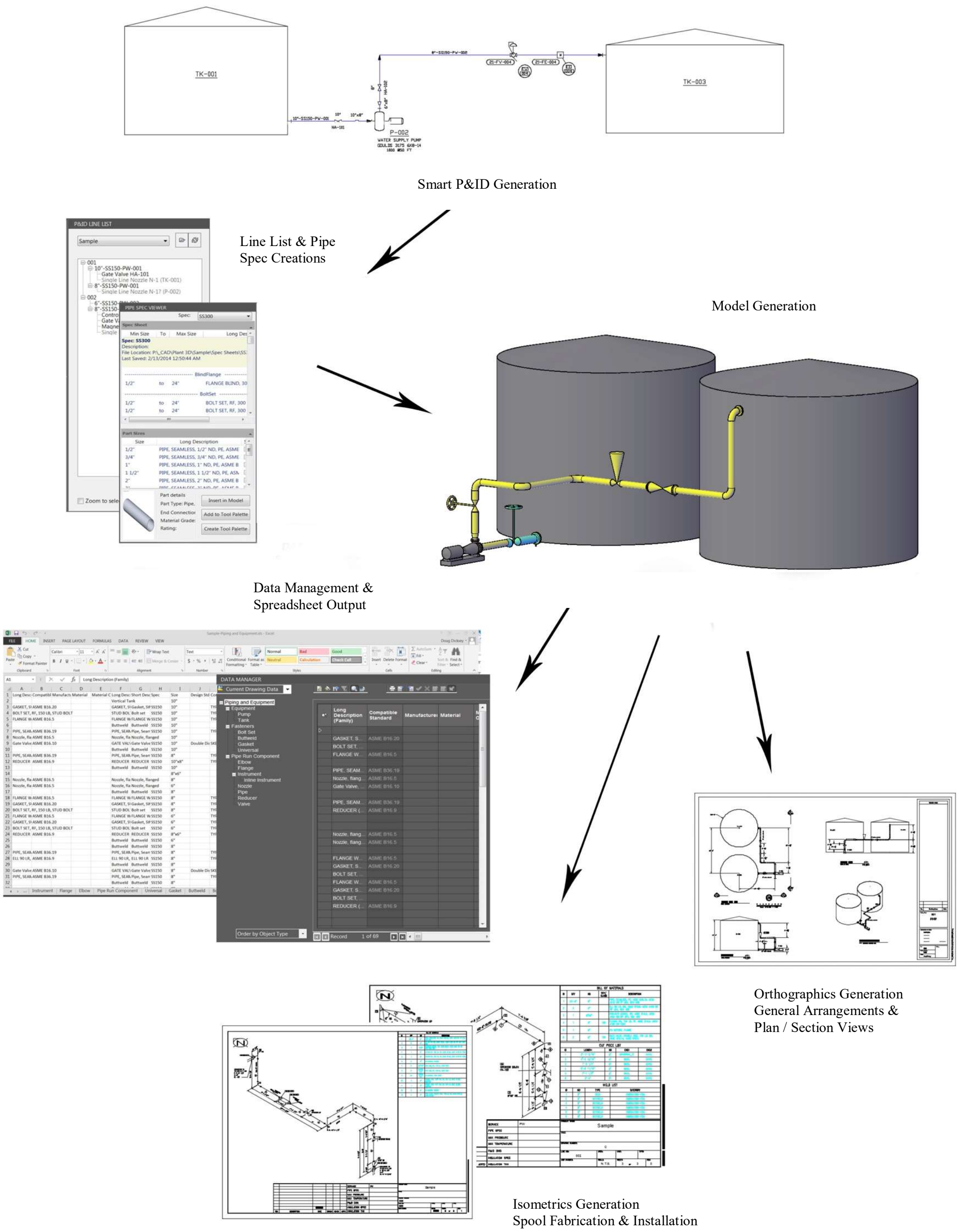
Data Import from Excel- Data from Excel can be imported into the plant model where it can be displayed in the P&IDs. This allows input from the engineer to be imported without manual data entry, increasing speed and accuracy.

Configuration- These tools can be configured for compliance with the owner's drawing standards, numbering rules, and design guidelines. Rules can be established for consistency checking, which reduces user errors.

Report Generation- These reports include Equipment List, Instrument List, Piping Line List, Manual Valve List, Specialty Item List, and Motor List. Reports are generated from the same plant model that is used to create the P&IDs, so they are always in sync. This is illustrated in

Figure III below. When changes are made to the P&IDs in the plant model, the information in the lists is changed simultaneously. It is important that the information in these lists be current and accurate as it is used by a variety of different sources including estimating, procurement, construction, commissioning teams, reliability teams, operations training, plant work systems, and maintenance information in the plant Computerized Maintenance Management System (CMMS).

FIGURE III: DATABASE DESIGN USING SMART P&IDS AND 3D MODEL



Filters- The data can be filtered for different views and reporting of the data. For example, by applying a filter for plant items "supplied by contractor," the manual valve list can be filtered to only include valves to be supplied by the contractor and exclude valves supplied by others such as skid vendors.

KEYS TO ACHIEVING THE BENEFITS OF USING INTELLIGENT ENGINEERING SCHEMATICS SOFTWARE TOOLS

Experienced Team Members- In order to ensure that these benefits can be delivered using these tools, Jedson Engineering includes on our process design team an application administrator / application support specialist who configures the project to the owner's requirements and provides ongoing support to the users. We also allow time in the project schedule (at least two weeks) for the configuration effort prior to starting development of P&IDs. Jedson includes on the process design team qualified senior process engineers who are experienced in pulp and paper design as well as in using these Intelligent Engineering Schematics Software tools. The senior engineers are empowered to provide training and support to the less experienced engineers on the team.

Reports from the Plant Model- At the end of the process design phase, design information from the plant model used to create P&IDs can be exported to reports and lists. The clear reporting of this design information output helps the project to manage engineering changes and avoid unconscious scope creep and schedule delays.

Data Transfer- At the end of the project, the design information can be transferred to plant work systems – safety valves, storeroom stock items, instrument lists for calibration, and equipment lists for maintenance PM schedules. Loading the plant work systems by importing the design information is faster and more accurate than manual entry.

CONCLUSION

BEST PRACTICES FOR A STRATEGIC PROJECT THAT REQUIRES COST-EFFECTIVE FEED

1. **Software Tools-** Use best practice tools for Process Design, including **Process Simulation Software Solutions Tools**, **Pipe Flow Analysis and System Modeling Software Tools**, and **Intelligent Engineering Schematics Software Tools**. Use of these tools ensures consistency across deliverables and ensures that changes made in one place are kept consistent with the entire set of engineering information. Use of these tools also offers benefits in efficiency and accuracy, provides increased capability of evaluating multiple options, and provides data output that can be transferred to other tools and to plant work systems. The benefits extend to the full range of deliverables throughout the capital delivery process (not just FEED), including check-out, commissioning, and optimization. All the teams and work systems within the plant can benefit.

2. **Project Team-** Include application support specialists with the necessary training and expertise for configuring the software tools to the owner's requirements as well as providing training and support for the team members using the software tools. Also, include qualified senior process engineers on your process design team. Lack of this level of experience may mean the staff will be learning by trial and error on your project, increasing risk, which could result in cost overruns and schedule delays.

3. **Configuration-** Allow time in the project schedule (at least two weeks) for the configuration effort prior to starting development of P&IDs. This effort ensures compliance with the owner's drawing standards, numbering rules, and design guidelines. Rules are configured for consistency checking, which reduces user errors.

4. **Budget-** Don't limit your options for project success with an inadequate FEED budget. The investment in the FEED Process Design effort provides returns in the form of an optimized design, fewer engineering errors leading to cost overruns and schedule delays, and reduced total installed cost.

REFERENCES

1. Crane Technical Paper 410: Flow of Fluids Through Valves, Pipes and Fittings, Crane Co., 2009, Stamford, CT.
2. TIS 0410-14, "Generalized method for determining the pipe friction loss of flowing pulp suspensions," Revised 1988, TAPPI, Atlanta, GA.

ABOUT THE AUTHOR

Ken Carrillo is a Senior Process Engineer for Jedson Engineering headquartered in Cincinnati, Ohio. He has over 20 years of experience in Tissue and Paper Front-End Engineering and Design. He has completed FEED of 8 new tissue machines and worked on strategic paper projects worth over $1 Billion Total Installed Cost (TIC). He has a Chemical Engineering Degree from Georgia Institute of Technology.