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ELECTRONIC DATA EXCHANGE IN THE PUMP INDUSTRY

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ABSTRACT

In the pump industry, technical information is shared throughout the supply chain—among the purchasers, suppliers, engineering contractors, procurement, operations, and maintenance—playing a crucial role in the life cycle of pumping equipment and pumping

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systems. Using, storing, and managing this technical information contributes to the overall design, procurement, and maintenance costs of the equipment. Electronic data exchange (EDE) is the process of sending and receiving technical and commercial information using digital file transfer methodologies. This information is often created, reviewed, used, and updated with numerous software applications by the stakeholders over the life cycle of the pump and the pumping system. Electronic data exchange is advantageous over conventional paper-based or manual methods because the data are reliably transferred between purchasers and suppliers without time consuming and error prone manual transcription of data. This tutorial examines the overall purpose of electronic data exchange and the work of industry groups toward promoting a common standard for the digital exchange of technical data. Background on pump data sheets, XML as the underlying data exchange technology, and a case study are presented. This tutorial will provide attendees an understanding of the benefits and technology used in electronic data exchange and insights into the EDE pump standards. Attendees will also be given guidelines and strategies for implementing these practices in their own organization.

INTRODUCTION

Information Reuse for Capital Facilities

The design, construction, operation, and maintenance of capital facilities involves the collaboration of many different companies and individuals. These enterprises include owner-operators, architecture, engineering, procurement, and construction contractors, and equipment suppliers. These organizations collaborate in a complex network of work processes, exchanging and sharing information, often through traditional paper or "electronic paper" documents. Throughout the facility life cycle, this information is often developed, used, and reused in many different software systems in the different organizations, usually requiring manual re-entry of data. This practice is repeated multiple times by all the stakeholders over the facility life cycle and is labor-intensive, time-intensive, subject to occasional but costly human transcription errors, and adds significant cost and time to the creation and operation of a capital facility.

Industry Use of Data Sheets

The inability to electronically and reliably exchange information between software applications for the design, procurement and installation of engineered equipment is a major source of inefficiencies and delays in capital facilities projects. Currently, the industry uses various layouts of equipment data sheets to collect, organize, and exchange the technical information about the functional and physical requirements for engineered equipment. These data sheets range from company specific formats to industry standard layouts. In addition to the variation in data sheet layouts, there are inconsistencies in the vocabulary and nomenclature used for describing engineered equipment, and there is no industry standard for the electronic exchange of this information between software applications.

Due to these conditions, contractors, equipment manufacturers, and suppliers must accommodate the different layouts of the equipment data sheets and must expend significant amounts of time and labor to decipher the inconsistencies in filling out the equipment data sheets and to manage the transcription of technical information among organizations and the different software applications. To address these challenges and the need to automate the reliable exchange of equipment information, the FIATECH organization started the AEX (Automating Equipment Information Exchange) Project.

FIATECH

FIATECH is a nonprofit industry consortium with over sixty member and associate organizations. FIATECH's mission is to provide leadership in identifying and accelerating the development, demonstration, and deployment of fully integrated and automated technologies to deliver the highest business value throughout the life cycle of all types of capital facilities projects. FIATECH's vision is a future state where capital facilities projects are executed in highly automated and seamlessly integrated environment across all phases and processes of the capital project life cycle. FIATECH members include owner-operators, engineering companies, equipment suppliers, and software suppliers.

FIATECH AEX Project

The FIATECH AEX Project was initiated with the objective of automating equipment design and delivery through software interoperability. This objective includes streamlining the equipment supply chain, eliminating redundant input of data, and automating information exchange. The initial focus of the AEX Project was to understand the current work processes, software applications, and technical information that describes engineered equipment, such as that found on equipment data sheets, equipment lists, and material properties. To define a viable project plan and to promote broad industry awareness and acceptance, the AEX Project established cooperative working relationships with industry groups with similar interests, including American Petroleum Institute (API), American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), Design Institute for Physical Properties (DIPPR), Hydraulic Institute (HI), and Process Industry Practices (PIP).

The AEX Project was planned as a phased project, where Phase One was devoted to a relatively small scope and designed to successfully show proof of concept before undertaking the large scope of work required to address the many equipment types necessary to meet the broad industry need.

The AEX project strategy is:

- Identify high-value opportunities to automate equipment information transactions
- Focus initially on centrifugal pumps and shell and tube heat exchangers
- Define a practical, repeatable methodology for developing XML specifications (refer to the next section, *"An Enabling Technology—XML,"* for more information).
- Develop partnerships with industry groups
- Produce XML specifications to exchange equipment information
- Obtain broad industry review and support
- Publish XML specifications available on a royalty free basis to the public
- Demonstrate incremental solutions with software pilot tests
- Publish XML schema development guidelines and implementation guidelines that are royalty free and available to the public
- Work with industry to achieve broad implementation and use
- Produce additional XML specifications to exchange equipment data for other priority types of equipment
- Continue with pilot tests and industry deployment

The AEX team initially identified five high-value business processes that involve transmittal of equipment information:

- Request for quote
- Quotation
- Purchase order
- As-built
- Bill of materials

The team then analyzed the technical information included in those transactions for both centrifugal pumps and shell and tube heat exchangers. With the information requirements documented, the AEX Project developed XML models for the basic, reusable information for all equipment types and developed detailed XML models for information on centrifugal pumps and shell and tube heat exchangers. The AEX Project developed trial software implementations using the AEX XML specifications and demonstrated the resulting interoperability prior to concluding Phase One of the project.

The FIATECH member organizations and other industry organizations recognized the success and value of the AEX Phase One results and agreed to provide resources for Phase Two. Activities of AEX Phase Two include:

- Developing extensions to the AEX XML schemas to support additional types of engineered equipment and guidelines to facilitate industry deployment
- Working with equipment manufacturers, software vendors, engineering companies and owners of capital facilities to demonstrate the use of AEX for interoperability across more equipment supply chains
- Working with industry associations and standards organizations to move the AEX results into industry practice and standards

An Enabling Technology—XML

The emergence of Extensible Markup Language (XML) since the late 1990s provides an enabling technology that offers the potential to promote widespread, cost-effective interoperability among software systems. XML is a fundamental Internet technology standard that is becoming broadly recognized and supported. Information, training, tools, and skilled personnel are readily available to build XML support into existing and new software systems. Therefore, the basic XML software implementations are practical and cost effective.

So what is XML exactly? Simply stated, XML is a user-definable text file format that provides the capability to store highly structured digital information in a standard, software neutral text file. XML will work on virtually any computer hardware and operating system platform and with any software program. As a result XML can be used both for software neutral data exchange today, and for long-term data archival and reuse.

Like the HyperText Markup Language (HTML) used on most Internet web sites, XML is derived from the ISO 8879 Standard Generalized Markup Language (SGML). The World Wide Web Consortium (W3C) defined XML as a recommended Internet standard in 1998.

HTML, XML, and SGML are all text-based, computer-interpretable "tag" languages where information is enclosed inside markup tags. For example, Bolded Text is an HTML representation of **Bolded Text.**

To get a feel for how XML differs from HTML consider the following simple pump example.

- HTML tells you what it looks like and is written:

```
<p>Centrifugal pump
<br>Model P280
<br>ABC Pumps
<br>$3,480
```

- XML tells you what it means and is written:

```
<pump>
    <type>Centrifugal</type>
    <model>Model P280 </model>
    <supplier>ABC Pumps</supplier>
    <price>$3,480 </price>
</pump>
```

XML can also be combined with HTML using a technology called XML Stylesheet Language transformations (XSLT) to produce intelligent formatted browser displays and specific layouts of equipment data sheets. XSLT also enables many more uses of XML files, including standardized reports, and translations to external software interfaces that are useful for automating industry work processes.

In May, 2001, W3C defined a related standard, called XML schema, which provides the ability to define tag structures that support rich data types such as real numbers, integers, Booleans, dates, etc., and object-oriented complex data structures.

XML and XML schema by themselves are not sufficient to achieve software interoperability, however, because anyone has complete freedom to define XML tag labels any way they wish. Someone may choose to define XML schema tags in German, another in French, and still another in English. Even in a single language such as English, it is possible to use different tag labels to mean the same thing, for example, <T>, <Temp>, <Temperature>, and <temperature> are all acceptable tags for temperature. In order for XML to be an effective technology for software interoperability, industry users need to agree upon common XML tags, tag structures, and definitions—an electronic vocabulary.

Industry Partnerships—Shared Vision and Commitment

The AEX Project recognized that to be successful the stakeholders across the equipment supply chains must be participants and advocates for the deployment and use of the AEX XML schemas for automating equipment information exchanges. Pivotal industry organizations for achieving broad adoption across the pump supply chains are:

- The American Petroleum Institute and its Subcommittee on Mechanical Equipment.
- The Hydraulic Institute, an association of pump manufacturers and related equipment suppliers who develop industry standards and provide a forum for the exchange of industry information.
- Process Industry Practices, the consortium of process industry owners and engineering construction contractors who serve the industry and related equipment and software suppliers.

HI monitored the early work of the AEX Project and reviewed the initial XML schemas and example files. After concluding that the AEX work had significant value to the pump industry, HI established the Electronic Data Exchange (EDE) committee to work with the AEX Project and develop recommendations on the use of the AEX XML schemas for the specification and procurement of pumps. Pump companies that are members of HI committed resources to develop trial software implementations of the AEX XML schemas and participated in the AEX centrifugal pump interoperability demonstrations in 2005. Building on those successes, HI EDE established subgroups to extend the AEX work to support positive displacement pumps and vertically suspended pumps.

INFORMATION FLOW IN THE PUMPING EQUIPMENT LIFECYCLE

Early in the AEX project, the equipment lifecycle work process for major capital facilities was studied (Figure 1). These work processes require a flow of information between each of the major work process steps. Software systems have emerged to reduce the time and labor involved in the work processes and to improve the quality of these information flows. As a consequence, these information flows increasingly include "electronic documents" produced by the software systems instituted throughout the equipment lifecycle (Figure 2).

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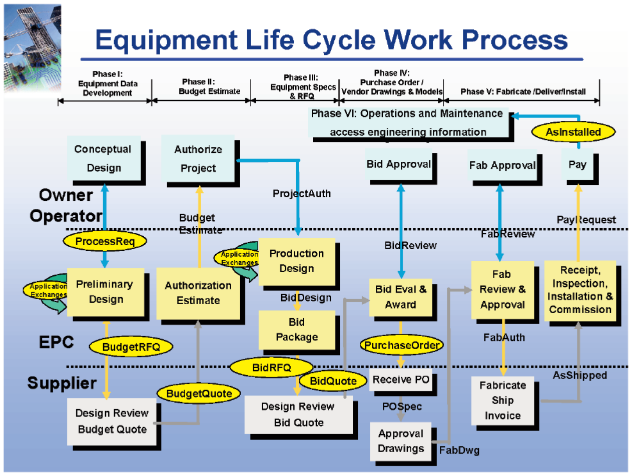

Figure 1. Equipment Lifecycle Work Process for Capital Equipment. (Courtesy FIATECH)

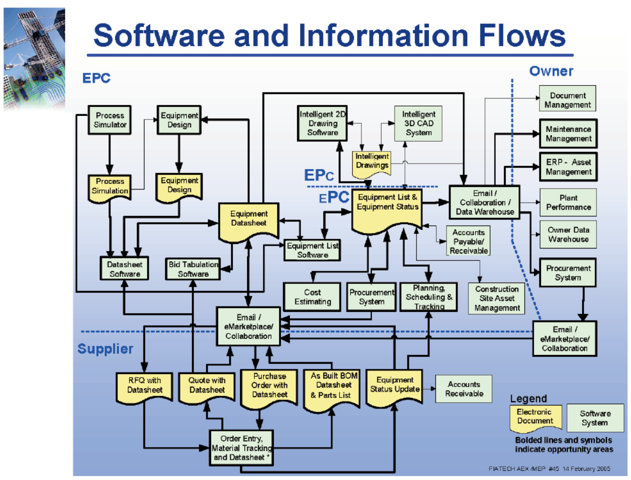

Figure 2. Software and Information Flow. (Courtesy FIATECH)

Purchaser to Supplier Interface for Pumping Equipment

The collaborative process between trading partners (i.e., purchasers and suppliers) in the procurement of pumping equipment and services is described as the inquiry/quotation process (Figure 3). In the case of complete (new) pumping equipment, the process involves the following six major steps (Patel and Dahl, 2000):

1. Engineering the pumping system,

2. Selecting the pump and driver type,

3. Pump specification and data sheet preparation,

4. Inquiry and quotation (proposal),

5. Evaluation of bids and negotiation, and

6. Purchasing the selected pump and driver

The entire process is information intensive, consisting of both technical and commercial information and numerous exchanges between buyer and supplier. The first three steps of the process (steps one through three) are technical in nature, involving the exchange of system design, pump specifications, and performance and construction details of the pump. The last three steps of the process (steps four through six) transition toward the commercial elements of the purchasing decision such as equipment costs, life cycle cost evaluations, terms and conditions, and delivery lead-times (Figure 4).

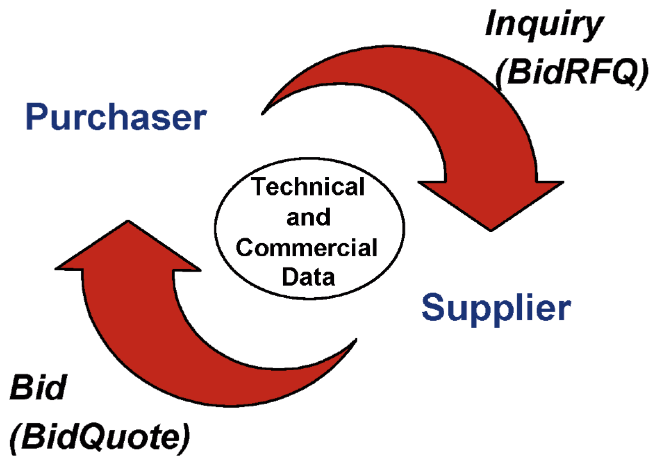

Figure 3. Information Flow Between Purchaser and Supplier.

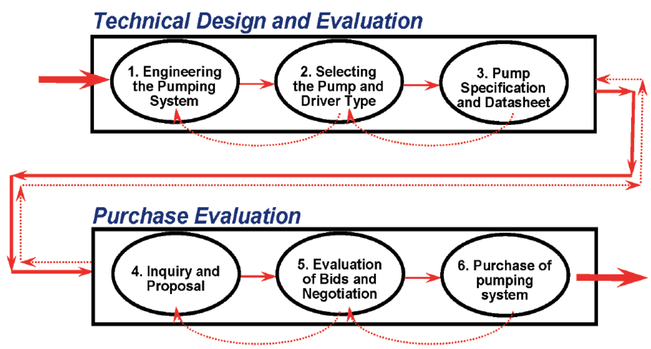

Figure 4. Steps in the Pump Procurement Process.

Among all of the work processes described, the inquiry/quotation information exchange is of particular interest due to the large volume of information transactions that occur in the industry. The inquiry/quotation information exchange is not limited to only one purchaser-supplier interaction since each new procurement opportunity requires an information exchange between numerous levels of trading partners in the entire supply chain. Consider the simplified example shown in Figure 5. An operating company gives three engineer/procure/construct (EPC) contractors the opportunity to bid on new pumping equipment for a process plant. If each of these EPC's issues three inquiries to pump manufacturers, a total of nine inquiries is now issued. If each pump manufacturer similarly issues three inquiries to their subsuppliers (say for motors or shaft seals), a total of 27 inquiries is being transacted for this single purchasing opportunity. Only one EPC, one pump manufacturer, and one subsupplier will eventually obtain a purchase commitment and deliver "useful" work in the form of products and services. Thus, only three quotations out of 27, representing 11 percent of the total quotation effort can represent "useful" work. These upfront engineering costs are recovered only when equipment is actually purchased. The cost of the other 89 percent of effort by those participants in the inquiry/proposal process who did not receive a purchase order are "wasted" and realized as an overhead cost in conducting business. Unfortunately, only a fraction of the total inquiry/quotation effort exerted by purchasers and suppliers is used in the downstream order engineering effort (Dahl and Ochs, 1997). These engineering costs, for both the "useful" and "wasted" effort represent a significant cost to the firms involved in the inquiry/quotation process.

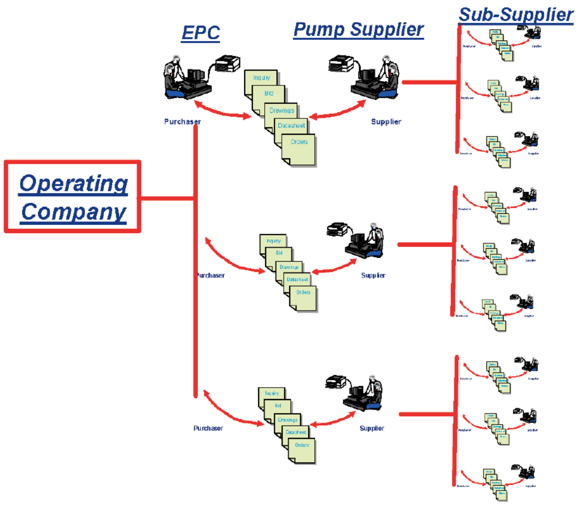

Figure 5. Multi-Firm Information Flow.

Each of the interactions between buyer and supplier represents one or more information transactions. Savings are obtained by either eliminating a transaction, or substantially reducing the time or effort involved in performing that transaction. The approach outlined in this tutorial is to reduce the time and effort, and improve the accuracy, of the transactions via data exchange standards. Note that this tutorial does not address elimination of transactions.

Data Exchange Standards

Exchange of centrifugal pump technical data has been traditionally handled using the pump data sheet. Both purchaser and supplier have developed their own personalized data sheet formats. Each data sheet exchange requires a laborious translation and interpretation of technical information from one data sheet format to another. With the implementation of computerized selection programs and bid-tab programs, organizations can generate data faster than ever, but sharing that information across organizational boundaries is still inefficient (Figure 6).

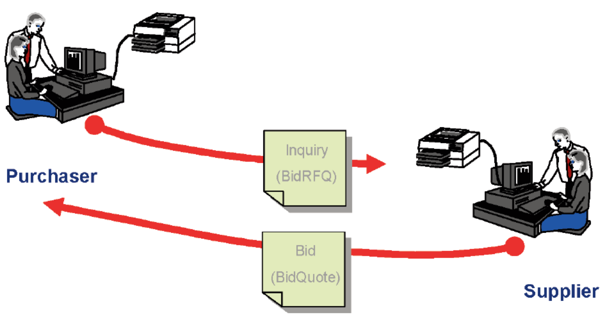

Figure 6. Technical Data Exchanged Using Manual Methods.

In response, some firms have developed proprietary data exchange formats to leverage their own proprietary software systems. This approach benefits the company promoting the standard but creates a burden for their trading partners who must develop special data translators. Consider a situation where three firms share data using a proprietary data exchange standard between each firm. This requires three unique data exchange standards and six translators (one for import and one for exporting the data) as shown by the six arrows in Figure 7. Extending this situation further, one can see that the total number of translators needed for M data exchange formats follows the relationship, $M \bullet (M-1)$. Therefore, 10 firms with their own data exchange format will require 90 translators!

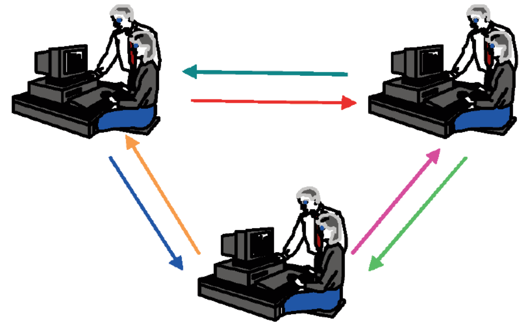

Figure 7. Proprietary Data Exchange Formats.

The disadvantages of multiple proprietary data exchange formats are conveniently addressed through the development of a single industry recognized standard, or "neutral data exchange specification." In this way, software systems are only required to import/export to one standard allowing adopters to leverage their investment to hundreds of trading partners without additional effort (Figure 8). One such standard was published in the American Petroleum Institute's standard for Centrifugal Pumps (API 610, Eighth Edition, 1995). In addition, other standards bodies, such as the ASME, PIP, Hydraulic Institute, and the Verband Deutscher Maschinen-und Anlagenbau (VDMA) have similar initiatives underway (Hart, 2002). These early initiatives were not easily adopted as they lacked a standardized format for electronically exchanging the information. The new XML technology described earlier has created a standard method for communicating structured business documents across the Internet. XML is the de-facto technology of choice to promote disparate purchaser, EPC, and supplier software applications to seamlessly transfer pump data. This is the approach described in the next section, as developed by the AEX project and supported by the Hydraulic Institute.

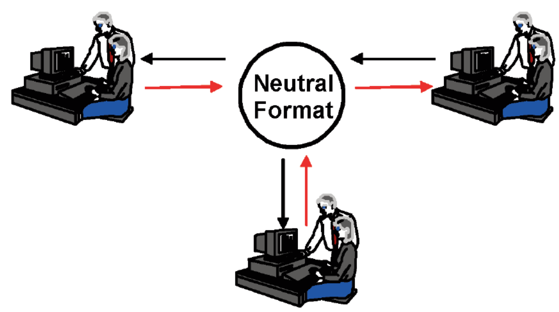

Figure 8. Neutral Data Exchange Formats.

DEFINING THE PUMP DATA TRANSACTION

Software Systems and Documents
Used in the Equipment Work Process

The work process and information flows in Figure 2 delineate the breadth of technical data that is considered part of the overall information flow in the pumping equipment lifecycle. These work process usage scenarios and corresponding software systems were then analyzed. Sixteen types of software systems and seven key documents that convey equipment information throughout the facility life cycle were identified. These were mapped to understand the data flows and used to identify the key software systems that need to support XML based data exchanges to provide business value. The software system types included:

- Process simulation
- Equipment design
- Equipment data sheet production
- Intelligent process and instruments diagram (P&ID) production

- Cost estimating
- Procurement
- Bid tabulation
- Order entry and tracking
- Collaboration
- E-Marketplace
- Planning, scheduling, and tracking
- Enterprise resource planning (ERP)—asset management
- Maintenance management
- Integration
- Data warehouse

The key document types included:

- Process simulation reports
- Equipment design reports
- Equipment data sheet
- Equipment list
- Bill of material
- Intelligent drawing
- Equipment status update

Using this information, the AEX project team elected to use the pumping equipment data sheets developed and published by the American Petroleum Institute and Process Industry Practices for centrifugal pumps and heat exchangers as a first step toward defining the detailed equipment data and terminology.

The Pump Data Sheet

Among the myriad data sheets, the PIP (PIP RESP 73/ASME B73) and API 610 data sheets are published as part of these pump industry standards and used in North American and in many international pumping specifications. Examples of these data sheets are found in Figure 9 and Figure 10, respectively. Many other data sheets in use are actually found to be close derivatives of these two prominent examples.

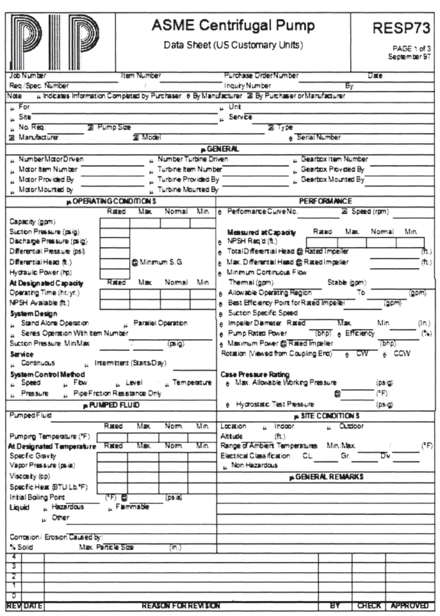

Figure 9. PIP Data Sheet (Page 1 of 3). (Courtesy PIP)

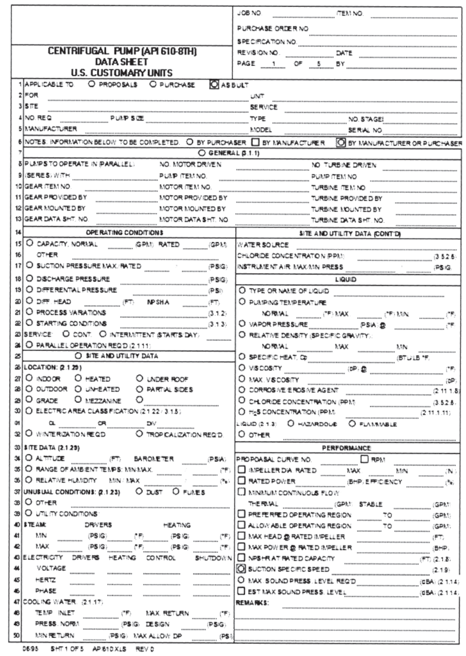

Figure 10. API 610, Eighth Edition Data Sheet (Page 1 of 5). (Courtesy API)

The notion of a "neutral data exchange file" presupposes that there is a universal way of digitally capturing the content of these two standard data sheets, as well as any other relevant data sheet in use. Once this information is captured in a neutral data exchange file (the XML file), then the interfacing software tools can freely display the data in any data sheet view/report desired. The next sections describe the crucial process of mapping or "mining" the important technical content contained within a data sheet in order to support a digital file structure.

Data Categorization Definitions

The data found on a data sheet are categorized as data items, units of measure, and data groups. Data can also be categorized by who is responsible for completing that data item (information completed by). For the sake of example, consider the subsets of data found in both the PIP and API data sheets, shown in Figure 11 and Figure 12. One observes the following data categorizations.

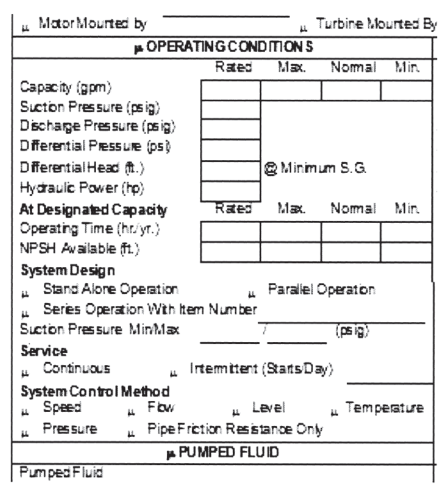

Figure 11. Subset of PIP Data Sheet—Operating Conditions. (Courtesy PIP)

14	OPERATING CONDITIONS
15	O CAPACITY, NORMAL .... (GPM) RATED .... (GPM)
16	OTHER ....
17	O SUCTION PRESSURE MAX./RATED .... / .... (PSIG)
18	O DISCHARGE PRESSURE .... (PSIG)
19	O DIFFERENTIAL PRESSURE .... (PSI)
20	O DIFF. HEAD .... (FT) NPSHA .... (FT)
21	O PROCESS VARIATIONS .... (3.1.2)
22	O STARTING CONDITIONS .... (3.1.3)
23	SERVICE: O CONT. O INTERMITTENT (STARTS/DAY) ....
24	O PARALLEL OPERATION REQ'D (2.1.11)

Figure 12. Subset of API 610 Data Sheet—Operating Conditions. (Courtesy API)

Data Item

A data item is an individual data field element. Examples in these figures include "Capacity," "Suction Pressure," "Discharge Pressure," and "Service." There are different classes of data items as well, as described in the following:

Numeric field—A numeric field contains only numeric data. "Capacity" and "Suction Pressure" are examples of numeric data. Example: Capacity = 100.0 gpm. Numeric fields are further decomposed into integer or real numbers.

Character string field—A character string field contains alpha or numeric data, typically limited by field length (e.g., 20 characters). Example: General remarks = "This pump shall conform to paint standard 123 as provided separately."

Choice field—A choice field offers one or more predefined choices, provided as a "choice list." A choice list is useful when one choice among many choices is selected. For example: Service = list (continuous or intermittent). Another type of choice list is a "yes-no" list. The example above can be restated into a yes-no choice as follows: Continuous Service = Yes/No. In general, a choice field is more appropriate than a character string field when the list choices can be standardized ahead of time, since syntax and terminology differences are avoided. As an example, if "Service" is a character string field, users might describe the field as "Constant" or "On/Off," which is not as rigorous as "Continuous" or "Intermittent."

Units of Measure—Physical Quantity

Many numeric fields have an associated unit of measure. The "capacity" data item has a unit of measure of gpm (gallons per minute). This unit of measure, gpm, is a physical quantity belonging to the group, "flow-volume liquid." By labeling each numeric field with a specific unit of measure, the value is readily interpreted by a digital program and conversions to different units of measure within the same physical quantity group is supported (e.g., gpm, m3/hr, liters/sec are all units of measure within the flow-volume liquid group).

In addition, each physical quantity group has preferred units of measure for either US Customary Units or Metric Units. This is also evident in the US customary versus metric data sheet types supported by API or PIP.

Data Group

The data group observed in these examples is "Operating Conditions." This is used to group similar data fields together. Example: capacity, suction pressure, discharge pressure, and service are all grouped into operating conditions.

Information Completed by

Another data categorization is information completed by. Both the PIP and API data sheets designate each data item according to the entity responsible for completing that data item: the purchaser, the manufacturer, or the manufacturer or purchaser. These are useful designations toward defining the role of the purchaser or manufacturer with respect to the completion of the data items.

Forming a Data Exchange Structure

Using the process outlined above, one can readily map a complete list of data items that comprise the union of all data items in both the API 610 and PIP data sheets. Through this process, multiple data groups are recognized, with their associated data items and attributes (data item types, units of measure, and information completed by designations). These are tabulated into a data exchange structure as shown in Figure 13. By introducing other data sheets, the union of data items can grow quite large. However, the benefit of such a structure is significant since all the data items in those data sheets are fully represented in the data exchange structure. This avoids the need for multiple, proprietary neutral data exchange standards since one standard contains all relevant data included in multiple data sheets.

Centrifugal Pump Data Definition Requirements for Pump Design and Procurement
Date: 23-Jul-2006

Data item is a part of	Data Item Name	Data Item Definition	Data Item Type	Data Item Dim.	Sample Value (+ Units)	Valid pick-list values (enumerations)	Physical Quantity
Operating Condition	Capacity, Maximum	Maximum volumetric flow rate	number - real + units	scalar			Flow - volume liquid
Operating Condition	Capacity, Normal	Normal volumetric flow rate	number - real + units	scalar			Flow - volume liquid
Operating Condition	Capacity, Minimum	Minimum volumetric flow rate	number - real + units	scalar			Flow - volume liquid
Operating Condition	Suction Pressure Rated	The rated suction pressure	number - real + units	scalar	27.01 PSIA		Pressure
Operating Condition	Suction Pressure Maximum	The maximum suction pressure	number - real + units	scalar	13.1 FT (5.679 psia)		Pressure
Operating Condition	Suction Pressure Normal	The normal suction pressure	number - real + units	scalar			Pressure
Operating Condition	Suction Pressure Minimum	The minimum suction pressure	number - real + units	scalar			Pressure
Operating Condition	Discharge Pressure Rated	The rated discharge pressure in pressure units	number - real + units	scalar	81.85 PSIA		Pressure
Operating Condition	Discharge Pressure Maximum	The maximum discharge pressure in pressure units	number - real + units	scalar			Pressure
Operating Condition	Discharge Pressure Normal	The normal discharge pressure in pressure units	number - real + units	scalar			Pressure
Operating Condition	Differential Pressure, Rated	The rated pressure difference measured in pressure units	number - real + units	scalar			Pressure
Operating Condition	Discharge Pressure Minimum	The minimum discharge pressure in pressure units	number - real + units	scalar			Pressure
Operating Condition	Differential Pressure Maximum	The maximum pressure difference measured in pressure	number - real + units	scalar			Pressure
Operating Condition	Differential Pressure Normal	The normal pressure difference measured in pressure units	number - real + units	scalar			Pressure
Operating Condition	Differential Pressure Minimum	The minimum pressure difference measured in pressure	number - real + units	scalar			Pressure
Operating Condition	Differential Head, Rated	The rated pressure difference measured in height of fluid	number - real + units	scalar	125 FT		Pressure - column
Operating	Differential Head, Normal	The normal pressure difference	number - real +	scalar			Pressure - column

Figure 13. Table of Data Items Included in the Operating Conditions Data Group.

A STANDARDIZED TRANSACTION

A strategic relationship between AEX and the Hydraulic Institute formed such that the HI would assess the AEX schemas and adapt them for practical use in the pump industry. Early trial implementations using the AEX XML schema developed confidence in the technical constructs of the XML schema and the approach. During this assessment, it was observed that the roughly 1000 data items supported in the XML schema for centrifugal pumps were sufficiently broad to cover virtually all practical centrifugal pumping applications. However, the large number of data items in the XML schema made it challenging for integrators to confidently implement the complete set of all data items in their software applications. Consequently, a minimum set of data in a transaction between purchaser and supplier was proposed. In this way, trading partners are assured that their data will be reliably processed since the sending and receiving entities both support the same minimum transaction dataset.

The Minimum Transaction Dataset

The minimum transaction dataset comprises two transactions. The first transaction, BIDRFQ, is defined as the transmittal of technical requirements from purchaser to supplier to initiate a request for quotation (RFQ). This transaction requires the purchaser to convey all critical information needed for the supplier to understand the application, select a pump, and respond with a qualified pump quotation, with complete confidence. The second transaction, BIDQUOTE, is defined as the transmittal of pump performance and configuration data typically contained in a technical quotation. This transmittal must have sufficient detail to

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permit the purchaser to assess technical quotations from different suppliers, usually through a bid-tab, in order to make a sound purchase decision.

In formalizing the data items that must be communicated during the BIDRFQ or BIDQUOTE process, the process of establishing the absolute minimum required fields became difficult. The HI/AEX team observed that some fields are always needed while other fields are convenient, but not required. Required data is the minimum data that must be transmitted in order to provide the necessary information to the recipient of the BIDRFQ or the BIDQUOTE transaction. However, there are cases where additional desired data are useful to enhance the quality of the transaction, by providing that data when it is available. Further, there is supplementary data that is interesting, but considered informative in the transaction. Fields were thus given the distinction of being a required, desired, or supplementary field. These are known as the R-D-S designations and defined as follows:

Required Data

- These data are required to be transmitted by the initiator to the recipient of the transaction.
- Provisions must be made in both the sending/receiving systems to process this information.
- The recipient has the option of rejecting the transaction if the value of a required field is left blank.

Desired Data

- These data are not required to be transmitted by the initiator to the recipient of the transaction.
- While it is not required to be transmitted, provisions must be made in both sending/receiving systems to process this information.
- The recipient cannot reject the transaction if the value of a desired field is left blank.

Supplementary Data

- These data are not required to be transmitted by the initiator to the recipient of the transaction.
- While it is not required to be transmitted, provisions must be made in both sending/receiving systems to map this data field. The data field is considered informative, but the recipient may/may not actually process (i.e., take action) the field in their system.
- The recipient cannot reject the transaction if the value of a supplementary field is left blank.

The draft version of the Hydraulic Institute Minimum Transaction Dataset (December 2006) currently has a total of 282 data fields supported. The number of data fields, as segmented by R-D-S designations, is found in Figure 14 and 15. Accordingly, a software implementation must assure that 22 fields of data (the required fields) are transmitted during the BIDRFQ transaction. The supplier is obligated to transmit 121 fields of data (the required fields) back to the purchaser as part of the BIDQUOTE transaction. The software systems must also be capable of mapping all 282 fields of data during either the BIDQUOTE or BIDRFQ process.

	Supplimentary	Desired	Required	Total
BidRFQ	86	174	22	282
BidQuote	21	140	121	282

Figure 14. R-D-S Designations Within the HI Transaction Dataset.

Centrifugal Pump Data Definition Requirements for Pump Design and Procurement
Date: 23-Jul-2006

Data item is a part of	Data Item Name	Data Item Definition	Data Item Type	Data Item Dim.	Sample Value (+ Units)	Valid pick-list values (enumerations)	BidRFQ Transaction Requirement	BidQuote Transaction Requirement
Operating Condition	Capacity, Rated	Rated volumetric flow rate	number - real + units	scalar	7014 GPM		R	R
Operating Condition	Capacity, Maximum	Maximum volumetric flow rate	number - real + units	scalar			D	D
Operating Condition	Capacity, Normal	Normal volumetric flow rate	number - real + units	scalar			D	D
Operating Condition	Capacity, Minimum	Minimum volumetric flow rate	number - real + units	scalar			D	D
Operating Condition	Suction Pressure Rated	The rated suction pressure	number - real + units	scalar	27.01 PSIA		R	R
Operating Condition	Suction Pressure Maximum	The maximum suction pressure	number - real + units	scalar	13.1 FT (5.679 psia)		R	R
Operating Condition	Suction Pressure Normal	The normal suction pressure	number - real + units	scalar			D	D
Operating Condition	Suction Pressure Minimum	The minimum suction pressure	number - real + units	scalar			D	D
Operating Condition	Discharge Pressure Rated	The rated discharge pressure in pressure units	number - real + units	scalar	81.85 PSIA		R	R
Operating Condition	Discharge Pressure Maximum	The maximum discharge pressure in pressure units	number - real + units	scalar			D	R
Operating Condition	Discharge Pressure Normal	The normal discharge pressure in pressure units	number - real + units	scalar			D	D
Operating Condition	Differential Pressure, Rated	The rated pressure difference measured in pressure units	number - real + units	scalar			D	R
Operating Condition	Discharge Pressure Minimum	The minimum discharge pressure in pressure units	number - real + units	scalar			D	D
Operating Condition	Differential Pressure Maximum	The maximum pressure difference measured in pressure	number - real + units	scalar			D	D
Operating Condition	Differential Pressure Normal	The normal pressure difference measured in pressure units	number - real + units	scalar			D	D
Operating Condition	Differential Pressure Minimum	The minimum pressure difference measured in pressure	number - real + units	scalar			D	D
Operating Condition	Differential Head, Rated	The rated pressure difference measured in height of fluid	number - real + units	scalar	125 FT		R	R
Operating Condition	Differential Head, Normal	The normal pressure difference measured in height of fluid	number - real + units	scalar			D	D
Operating Condition	Differential Head, Minimum	The minimum pressure difference measured in height of	number - real + units	scalar			D	D
Operating Condition	Differential Head, Maximum	The maximum pressure difference measured in height of	number - real + units	scalar			D	R

Figure 15. Table of Data Items with R-D-S Designations.

PRACTICAL TESTING

Practical testing and deployment of XML schemas for data exchange are crucial for successful implementation and acceptance of this technology. This testing and deployment has been coordinated through the AEX project. The first phase of the AEX project was successful, with results that included:

- XML schemas for mechanical equipment, including detailed schemas for centrifugal pumps.
- XML schema development guidelines that are royalty free and available to the public.
- XML schemas that are royalty free and available to the public.

AEX Pump Pilot

The first phase of the AEX project successfully showed proof of concept. But for AEX project success, software interoperability must also be practical and robust. Therefore, a pump pilot was implemented. The formal objective of the AEX Pump Pilot was to demonstrate software interoperability in support of a pump user's collaborative work processes with centrifugal pump and software providers using actual capital project data. This would establish whether the concept was not just possible, but also practical and robust.

The steps followed in the execution of the AEX Pump Pilot are summarized below and illustrated in Figure 16.

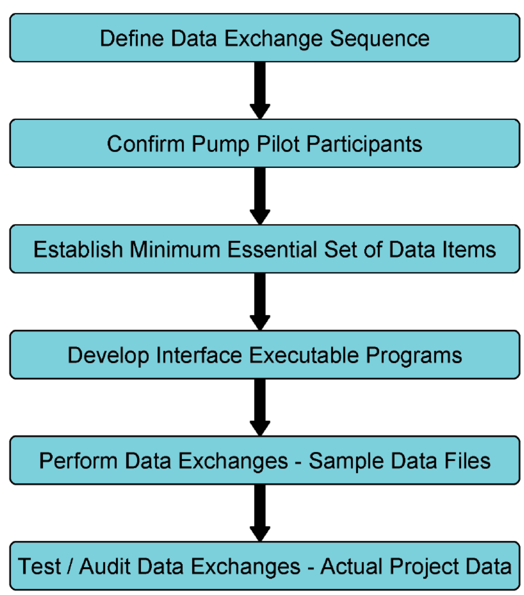

Figure 16. AEX Pump Pilot Project Steps.

- Define the data transaction sequence
- Confirm participants for the AEX Pump Pilot
- Establish a minimum essential set of data items for a valid demonstration
- Develop the interface executable programs to convert to/from XML and each software program
- Perform data transactions using sample data files
- Test and audit data transactions using actual project data from the user

Data Transaction Sequence

The scope of the AEX Pump Pilot was selected to include a typical sequence of data transactions related to the specification, sizing, and quotation of an ASME B73.1 centrifugal pump. This transaction sequence is illustrated in Figure 17. The sequence required electronic data to be freely exchanged between several unrelated software programs. These programs were:

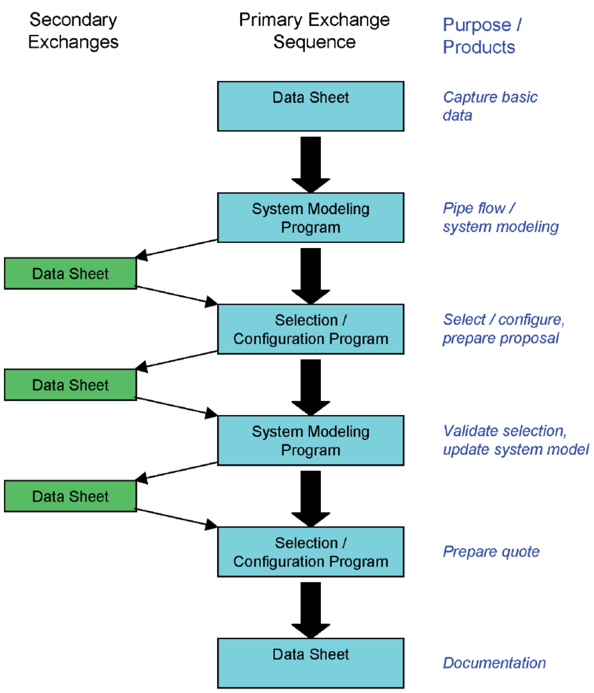

Figure 17. AEX Pump Pilot Exchange Sequence.

- A user's Microsoft® Excel based pump data sheet.
- A commercially available pipe flow analysis and system modeling software program.
- A pump supplier's in-house selection and configuration program.

Actual transactions of data on capital projects are often iterative in nature and involve progressively adding more data. And many variations of the transaction sequence are possible. To address this, the transaction sequence was chosen so that it was not overly simple. The goal was to run the transactions "through their paces."

The transaction sequence started out with a Microsoft® Excel based user data sheet to capture basic data such as rated flow and fluid properties. Data were exchanged with the commercial system modeling program. The system modeling program added system data such as rated total dynamic head (TDH) and maximum suction pressure. Data were then exchanged with the pump supplier's selection/configuration program. The selection/configuration program added pump specific data (pump model, impeller, and flange sizes, etc.) and provided an initial proposal. Data were then sent back to the system modeling program to validate the pump selection and update the system model. At this point, the data were sent back to the selection/configuration program to generate an updated quote. Along with quote generation, data were sent back to the data sheet as part of the documentation.

To further validate the robustness and practicality of the transactions, a secondary set of transactions was tested. The secondary transactions, also illustrated in Figure 17, involved sending data to/from the user's data sheet between each of the other transaction steps.

During each of the primary transactions, additional data items were added to the XML file, resulting in a more and more complete data set.

AEX Pump Pilot Participants

The data transaction sequence was used to help identify participant organizations for the AEX Pump Pilot. Participant organizations included an end-user, a software supplier, and a pump supplier. XML technology specialists were also included. An engineering company was not used during this pilot, although they were involved in Phase One of the AEX project.

Minimum Essential Set of Data Items

The participants in the AEX Pump Pilot collaborated to establish a minimum essential set of data items for the data transaction testing. Fifty-four data items were selected. These data items were selected to provide meaningful data for the import and export transactions of each software program. Some data items were chosen that were free-form character string entries, such as project title. Other data items were chosen that were numeric and required association with specific units of measure, such as rated capacity. The project participants then identified how the data items would be handled by each software program. For example, would the data be created, modified, read only, or remain unused by the software.

Note that for the AEX Pump Pilot, only a subset of the HI transaction dataset was used. The pilot was focused on transaction testing, not on a production-ready system using the minimum set of data necessary to make commercial transactions. The pilot data set had to include just enough data items used by each software program to validate the data transactions by each program and allow a minimum level of functionality for each program to convert to/from XML.

Converting to/from XML

Each software program requires an "interface executable" file to convert data from the software program to an XML file, and similarly to convert data from an XML file to the software program. The tools to build these interface executable files are readily available, including much of the needed functionality already built into Windows. The owner of each software program was responsible for developing the interface executable files for their program.

Data Transactions Using Sample Data Files

A simplified data transaction was performed to individually test the interface executable files for each software program. Sample XML data files were created for each software transaction. This included a sample XML file for exchange between:

- User's Microsoft® Excel based data sheet → pipe flow analysis/modeling program
- Pipe flow analysis/modeling program → pump supplier selection/configuration program
- Pump supplier selection/configuration program → pipe flow analysis/modeling program

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This data transaction gave the software program owners the opportunity to troubleshoot and evaluate their own XML interface with known data. The sample XML data files were read into each of the software programs by the program owner. The program owner compared whether correct data were read into the program and whether they got the "right answers." Since individual sample data files were created for each data transaction, the data transaction sequence did not need to be followed in order, and testing of each of the software programs was done in parallel. Each of the software programs successfully imported and exported the XML data, validating the functionality of the interface executable files.

Data Exchange Using Actual Capital Project Data

Once the functionality of the interface executable files was validated with the sample data files, the data transaction sequence outlined in Figure 17 was used. This data transaction testing and auditing was done using actual data from a user's capital project, and was done completely by the user, using each of the software programs in the correct sequence. Data were manipulated in each of the software programs to test the robustness of each interface. The results of each transaction were audited for completeness and accuracy. This testing was completed successfully.

Lessons from the AEX Pump Pilot to Aid Implementation

- XML data exchange among various software programs used in the process industry works.
- A standard set of XML schemas is essential. The XML schemas evolved during the course of the AEX Pump Pilot. While problems were relatively few, the problems encountered during the pilot were generally related to the schema revisions. This highlights why the AEX work to develop royalty free XML specifications is important.
- Investment of resources (time, programming) occurs initially when the XML interface executable is developed and implemented into the software program. Once it has been implemented, the benefits will be realized without additional investment of resources.
- As with any software, the functionality of the interface executable files must be validated, preferably using a variety of data sets.
- No knowledge of XML is necessary to use a software program that has an existing XML interface (only the programmers will need to know details about XML). The average user of a software program will not be negatively impacted by the XML interface.
- Using a software program that interfaces with XML is easier than if the software does not interface with XML. An import/export step is added with XML, eliminating a significant amount of data entry effort. Data entry errors will also be eliminated.
- Creating and implementing the XML interface executable files is not too difficult, once you have learned to work in XML. Once the basic functionality of an XML interface executable file is established, adding data fields is not difficult.
- Casual users will not create their own XML interface executable files since they will not learn to use XML. Of course, this does not hinder their ability to use the software programs that interact with XML.
- The XML interface does not require a special look or otherwise detract from the existing software program.
- Based on their experience to date, all AEX Pump Pilot participants believe that full implementation of XML interfaces will be advantageous for their respective organizations.
- Special care must be given to units of measure when creating the XML interface executable file.
- Some software programs may need to handle additional units of measure beyond the ones they currently use (before implementing XML interfaces).
- Software programs can be structured such that the data imported from XML are editable. Or they can be protected from change. There are circumstances where both these methods of handling data are appropriate. However, the data users are advised to understand whether data has been modified since they last used it. One solution to this issue may be to compare XML files and identify differences in the data. Software is commercially available to compare two XML files.
- Software programs must be robust in their handling of imported XML data. It is possible that other software programs have created noncompliant XML data files. One suggestion is to have software programs first validate the import file prior to processing, and have the program generate a report of invalid data as part of processing the valid data.
- When a software program imports or exports a limited amount of data, it was found to be helpful to have a data preview or verification screen. However, this may not be practical when there is transfer of a large number of data items.

IMPLEMENTATION GUIDELINES

Each of the AEX software implementations and each phase of the AEX project developed insights for improving the XML schemas and/or the AEX implementation guidelines. The AEX Project incorporated these improvements and the insights from the AEX Pump Pilot Project in the new release of the schemas. AEX release version 2.0 was distributed in December 2006.

AEX is working actively with individual companies and industry associations to broaden the implementation and use of the AEX schemas. Additionally, the AEX Project publishes technical documentation for:

- XML schema developers working in the capital facilities industries.
- Application developers who wish to build XML interfaces into their industry application software to support interoperability.
- Anyone in the capital facilities industry who wishes to understand the detailed object-oriented structure of the capital facilities industry XML (cfiXML) and how to use this technology to solve interoperability problems.

The "AEX XML Schema Reference Guide" (to be published in January 2007) is the primary reference document for "XML schema developers." These schema developers may be seeking to develop XML-based software interoperability solutions, and wish to leverage and build upon a large base of previous work to extend this work into new subject domains. Alternatively, these developers may wish to extend the already developed subject domains into more details to support additional usage scenarios and information requirements.

This reference guide is also intended as a resource document for "application interface developers." These software developers may wish to understand how to implement AEX data exchange and sharing interfaces into their specific application software to support a specific usage scenario. These interfaces will include "mapping interfaces" between internal application specific data storage structures and the industry consensus object structure of AEX files for the purpose of electronically exchanging data between software applications.

Since the AEX Project is collaborating with other organizations to develop a common set of XML structures for information on engineered equipment for capital facilities, the formal name for the full set of these XML schemas is "cfiXML" (capital facilities industry XML). Version 2.0 and any future working release versions are available from the cfiXML web site. Three key recommendations related to working with the schema are:

- Before undertaking schema development work or using the schema for application interface development, it is recommended that the developer have access to XML schema development and viewing software tools.

- Before starting work on schema development, or developing application mapping interfaces, developers should obtain at least a basic working knowledge of XML, XML Schema, Xpath, and object-oriented information modeling principles, especially the concepts of inheritance, containment, and references.

- Before undertaking a schema extension or a schema mapping interface, developers need to first familiarize themselves with cfiXML schema structure. The "AEX XML Schema Reference Guide" is the best resource for this purpose.

For additional information on schema, refer to APPENDIX A.

CONCLUSION

The foundation now exists to support electronic data exchange in the pump industry and to streamline (or automate) transactions among stakeholders in the pump supply chain. The convergence of a number of key factors bodes well for adopting electronic data exchange into industry accepted business processes. First, XML technology is superior to other flat file or proprietary data transfer methods. It is flexible, robust, and designed for use in today's digital enterprise. More importantly, the technology is capable of adapting to new requirements that become evident through ongoing commercial implementations. Second, the AEX project has provided a credible contribution to the industry through the XML schema definitions and emerging implementation guides. These are being shared openly with the industry with the expectation that widespread adoption will help all participants who adopt the technology. Third, major purchasers of pumps are investing resources to automate data exchange in their pump supply chains. Fourth, momentum for broad adoption of the AEX XML schema is building among well-known standards organizations that are influential in the pump industry: the Hydraulic Institute, Process Industry Practices, and the American Petroleum Institute. Through these standards' bodies, connections to other international standards organizations such as ISO and the VDMA are also being nurtured. Fifth, pumping equipment is only one of many mechanical equipment types that the construction, process, and capital equipment industries specify, design, and build each day. The EDE technology described here is not only harmonious with these other equipment types, but AEX, API, and PIP are specifically involved in specifications for these other types as well (compressors, fans, motors, valves, heat exchangers, etc.).

Leaders in the industry agree that implementing the AEX schemas to enable automated and reliable information exchange will benefit all participants in the equipment supply chains. Other industries, including aerospace, automotive, chemicals, and electronics, are already reaping the benefits of electronic data exchange. These successes were achieved either by the predominant companies mandating the change for their enterprises or because industry associations were driven to action by global competition.

To achieve these benefits and get industry to the "tipping point," where EDE becomes part of standard working practices, more companies will need to take an active role in advocating and deploying AEX results.

Trading partners involved in the buying and selling of pumps and associated mechanical equipment are participating in a decade long period of change that is unprecedented in industry. Industry consolidation, expanding markets overseas, and worldwide competition are all fueling these rapid changes. Information technology, including electronic data exchange, is positioned as an "enabler" or a "catalyst" for many of the improved service levels, reduced cycle times, and business changes that are taking place in the industry today. Provided the convergence of technology, organization, and standards continues, those that adopt electronic data exchange are sure to benefit with improved business processes, workflow, and quality.

Ultimately, the entire supply chain and pump end-users benefit from the adoption of electronic data exchange—ensuring that pumps and pumping systems are designed, selected, operated, and maintained for optimal efficiency, performance, lowest life cycle costs, and bottom-line savings. Electronic data exchange is a major catalyst for change in the pump industry. Early adopters will gain unique competitive advantages by embracing EDE as a standard practice in their pump selection and procurement processes.

NOMENCLATURE

AEX	= Automating Equipment Information Exchange
API	= American Petroleum Institute
ASME	= American Society of Mechanical Engineers
BIDQUOTE	= Bid quote
BIDRFQ	= Bid request for quotation
cfiXML	= Capital facilities industry XML
EDE	= Electronic data exchange
ERP	= Enterprise resource planning
EPC	= Engineer/procure/construct
FIATECH	= Fully Integrated and Automated Technology
HI	= Hydraulic Institute
HTML	= HyperText Markup Language
ISO	= International Organization for Standardization
P&ID	= Piping and instrumentation diagram
PIP	= Process Industry Practices
RFQ	= Request for quotation
SGML	= Standard Generalized Markup Language
UML	= Unified Modeling Language
VDMA	= Verband Deutscher Maschinen-und Anlagenbau
W3C	= World Wide Web Consortium
XML	= Extensible Markup Language
XSLT	= XML Stylesheet Language Transforms

APPENDIX A

cfiXML Schema Overview

cfiXML is constructed using XML Schema as its basis, building extensions onto the W3C standard to handle the technical information requirements of the capital facilities industry. cfiXML provides a cohesive object-oriented framework to describe capital facilities equipment and material data over the life cycle of a capital facility. The facilities equipment XML schemas consist of many related and interdependent XML namespaces, schema files, and complex type definitions, covering a variety of subject areas. The cfiXML architecture provides a flexible architecture that can be readily used to construct any electronic exchange document that is needed to support any usage scenario involving the exchange of facility equipment data.

There are four basic parts to the capital facilities industry XML architecture as illustrated in Figure A-1.

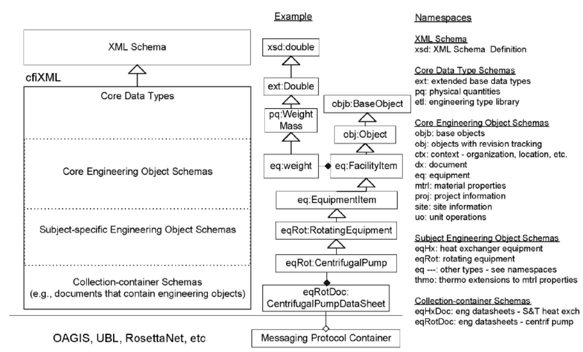

Figure A-1. Capital Facilities Industry XML Structure Overview.

- Core data type schemas for essential extensions to the W3C XML Schema Standard basic data types to support engineering requirements
- Core engineering object schemas for reusable base engineering objects that can be used by multiple engineering disciplines and subject domains
- Subject engineering object schemas that provide schemas related to specific equipment items
- Collection-container schemas that are used to allow core and subject-specific engineering objects to be combined in various ways to support various data transactions and usage scenarios

Figure A-1 illustrates how these parts relate to each other, to standard XML schema definitions, and to various messaging protocol containers that are currently being developed by various industry groups.

XML documents need to have unique names for XML global elements that have specific meanings. In a small schema, with relatively few elements, it is relatively easy to define and maintain unique tags. In large systems, such as the capital facilities industry XML, where multiple collaborating groups working independently could potentially define thousands of global element definitions, it becomes more difficult to ensure uniqueness across the various parts of the schema. The cfiXML schemas use XML namespaces to allow multiple reusable core and subject-specific schemas to be used together in a single XML "container" document.

In order to ensure interoperable XML documents that use multiple namespaces, the namespaces themselves are required to be named uniquely. It is a common usage convention to use a common globally unique identifier string that is composed of a URL that is "owned" by the organization developing the schema. Just to be clear, this is a unique way to name the namespaces, not the location of the schema files.

For the capital facilities industry XML, all namespaces belong to a common "root" URL, specifically "http://www.cfixml.org." To the end of this common root, a short identifier is put at the end separated by a forward slash. For example, the "pq" namespace would have a full unique identifier of "http://www.cfixml.org/pq." By convention, we assign the shorthand prefix tag "pq:" is typically assigned in a schema declaration to mean the same thing as "http://www.cfixml.org/pq" so that the XML files are much more human readable, yet maintain uniqueness for the XML parsing program. In this document the file name, namespace prefix, and full namespace qualifier will often be treated as synonymous, for convenience and simplicity. Figure A-2 illustrates the 20 capital facility industry namespaces and their relationships to each other.

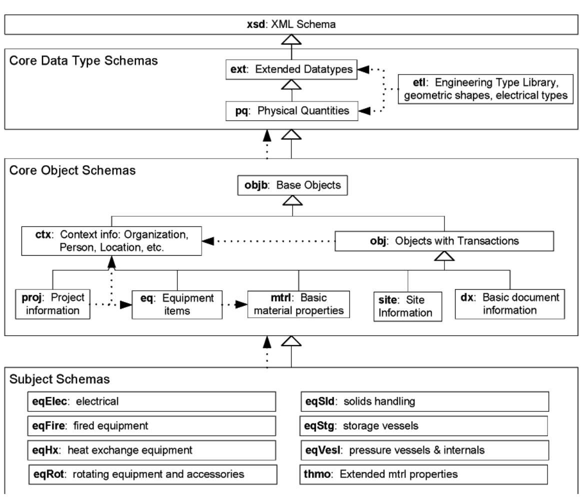

Figure A-2. Capital Facilities Industry XML Namespace Overview.

The namespaces shown in Figure A-2 were defined to meet the following general requirements:

- To enable conceptually-related schema elements to reside in the same namespace
- To enable namespaces to be easily imported and reused in other derivative schemas
- To separate domains that are likely to be developed and maintained by separate organizational groups
- To anticipate the need for collection-container XML documents to use only the relevant portions of a potentially very large suite of cfiXML schemas

Figure A-2 uses Unified Modeling Language (UML) notation, where the dashed arrow lines indicate a usage dependency of a namespace upon the namespace that is pointed to. For example, the "eq" namespace depends on the "mtrl" namespace to define the construction material of an equipment item. The open arrow lines indicate that complex types in a namespace extend complex types in the namespace that is pointed to. For example, the "ext" extended data types are extension types from the base "xsd" namespace, and the "eq" EquipmentItem complex type extends from the "obj:Obj" complex type.

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Hart, R. J., 2002, "Pumps and Their Systems—A Changing Industry," *Proceedings of the Nineteenth International Pump Users Symposium*, Turbomachinery Laboratory, Texas A&M University, College Station, Texas, pp. 141-144.

Patel, V. and Dahl, T., 2000, "Chapter 11: Selecting and Purchasing Pumps," edited by Karassik, I. J., Messina, J. P., Cooper, P., and Heald, C.C., *Pump Handbook*, Third Edition, New York, New York: McGraw Hill Book Company.

BIBLIOGRAPHY

The Internet has made it possible to access a wide range of information on electronic data exchange. The list below contains some sites that may be useful to the reader.

FIATECH (also provides access to the AEX page)
www.fiatech.org

Hydraulic Institute
www.pumps.org

cfiXML
www.cfixml.org

World Wide Web Consortium
www.w3.org

XML
www.xml.org.