Lappeenranta University of Technology

Faculty of Technology Management

Industrial management

Master’s Thesis

Pipework data in design system integration

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ABSTRACT

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This thesis work describes the creation of a pipework data structure for design system integration. Work is completed in pulp and paper plant delivery company with global engineering network operations in mind. User case of process design to 3D pipework design is introduced with influence of subcontracting engineering offices.

Company data element list is gathered by using key person interviews and results are processed into a pipework data element list. Inter-company co-operation is completed in standardization association and common standard for pipework data elements is found.

As result inter-company created pipework data element list is introduced. Further list usage, development and relations to design software vendors are evaluated.

TIIVISTELMÄ

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Diplomityö. Lappeenrannan teknillinen yliopisto, Tuotantotalous

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Diplomityö käsittelee putkiston tietorakenteen määrittelytyön suunnittelujärjestelmien väliseen tiedonsiirtoon liittyen. Työ on toteutettu paperi- ja selluteollisuuden laitostoimittajayrityksessä, jonka suunnittelutoiminnot ovat aidosti globaaleja. Tutkimuskohteena on putkiston prosessitiedon siirto 3D-laitossuunnittelujärjestelmään suunnittelutoimintojen alihankkijayhteydet huomioon ottaen.

Työssä kerätään yrityskohtainen putkiston tietoelementtiluettelo haastattelemalla avainhenkilöitä ja arvioimalla putkiston tiedon sidonnaisuutta yrityksen muihin toimintoihin. Yritysten välillä tehdään yhteistyötä standardisointiyhdistyksen kautta ja työstetään putkiston tiedonsiirtoon tarkoitettu standardi

Työn tuloksena esitellään yritysten välisellä yhteistyöllä luotu tietoelementtiluettelo, jonka käyttöä, jatkojalostamista ja ohjelmistotoimittajille esittelyä tarkastellaan.

Foreword

“Nothing endures but change.”
(Heraclitus according to Diogenes Laërtius.)

In today’s world change is inevitable. Change is a chance given to us by today. For us engineers it is a unique possibility to build the world in a new way: guide it towards better and more sustainable tomorrow and leave a mark for the next builders. Big journeys are started with small steps.

Past four and half years in Lappeenranta University of Technology have marked yet another turning point in my life. Taking a brave step forward to learn new is something I can recommend to anyone who is given this kind of chance. I would like to thank my employer Andritz Oy for the opportunity to explore new worlds of information; Antti Räisänen, Lea Jantunen and Timo Juvonen for enabling this journey. To my friends and student colleagues in LUT I send a special greeting for all the discussions and support.

And with love an especially warm thanks for all the support to two special girls in my life Tessa and Susanna.

Contents

List of symbols and abbreviations

EPC delivery	Engineering, Procurement and Construction. A common form of contracting arrangement within the plant delivery and construction industry.
CRM	Customer relationship management, model for managing company’s interactions with customers, clients, and sales prospects.
CSV	Comma-Separated Values, data format to store text or numeric values in specified format text document where data elements are separated by predefined character, usually comma or semicolon.
ERP	Enterprise resource planning. Business intelligence operation or system to handle finance, manufacturing, sales, service, customer relationship management etc. across the company operations.
Scope of design	Physical or logical selection of units to be designed by one discipline. For example process piping of a paper mill.
Pipe specification	A collection of piping standard components to fulfill a specified media-pressure-temperature requirements.
PDMS	Plant Design Management System. 3D Plant design software, created by AVEVA Ltd.
Comos	Process, automation and electrification design software by Siemens.
ICT	Information and communications technology.

XML	Extensible Markup Language, markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable.

1. Introduction

1.1. Background

Last ten years in pulp and paper plant delivery business have marked a change for the whole industry. In general the manufacturing industry has been under a change for better competitiveness and the search for better profitability has lead plant design and delivery companies to develop ways to better support global engineering network. This applies for both design and manufacturing.

As pulp and paper mill customers set up new plants in low-cost countries there is a pressure for faster delivery times. In plant design operations this means more active co-operation between different design groups and engineering offices. Changes in design culture come down to engineers and design tools as new requirements – new kind of co-operation requires new thinking and operation process re-evaluation. Development in design tools has been remarkable during last decade and software vendors have taken good advantage of the ever growing computing power growth. Modern plant design software operates in 3D and can combine data and operations from many design disciplines in same design project. Seeing the big picture gives more control over the project delivery.

As design systems integrate better there has been more demand on better structured design data. During the transfer from drawing boards to advanced CAD tools there has been a great number of design data structure development projects lead by either software vendors or standardization organizations. Many of these have focused on finding a common way to present and store pipework design data. However, the existing pipework data structure standards do not completely cover the needs of plant delivery and engineering companies. For Finnish companies involved in pulp and paper plant design this has been an acute question for a long time. Data exchange co-operation between companies is not fluent enough.

There is a need to define common data elements better, so each participant would know exactly what is meant by each data element, for example design pressure or material code. Unifying the terms brings clarity to data exchange and enables easier work flow between companies. Common rules for data structure also mitigate the risk of data being misinterpreted by the receiver and therefor it cuts down quality costs.

Selection of this thesis work subject is based on discussion, requests and experiences of Andritz Oy, other plant delivery companies and subcontracting engineering offices in pulp and paper plant design business. It is not uncommon for one pulp mill project to have five to ten different plant delivery and engineering companies working in the same project for pipework detail design. Keeping the design operations efficient means rule setting in both pipework data content and structure. Multi-company co-operation sets a recognized need to manage design data in a sophisticated way.

1.2. Target and limits

Target or this thesis work is to define the pipework data structure in design system integration in given business environment case.

Defining the data structure consists of following two main tasks. Firstly it is defining what exactly is meant by pipework data. This is limited by the environment where it is used and who is using it. Secondly it is defining how pipework data is presented in data transfer. This is a matter of defining the individual elements of pipework data in a way that can be used in data transfer between pipework design disciplines. A secondary third task of this thesis work is to define how and by whom the presented data structure can be used. This is naturally closely linked to second task.

The work is completed with global pulp and paper industry business operation and environment in mind. This is a global business environment with many technical and business related regulations and demands, for example national standards, commercial agreements, design data exchange practices and rules. The influence of software vendors in practical design work is also considered. Technical standards used in thesis work examples are according to normal plant delivery projects of pulp and paper business area. Pulp and paper plant mill areas and departments considered in this thesis work are: wood yard, fiber line, cooking, caustization and lime kiln, evaporation and recovery boiler. Power boilers are also considered as their technical and design operational requirements are close to recovery boilers'.

Pipework in this thesis work is defined as process relevant pipework that can be defined, designed, manufactured and purchased by the plant delivery company. Roughly it can be described as all pipes needed to complete the main and supporting processes of a chemical pulp plant or power boiler. This rules out mill service piping, drainage piping and other plant delivery project-wise insignificant pipework. These secondary-to-process pipes are usually delivered by building contractor or mill owner. The data required is defined by piping related design disciplines - process design and pipework detail design. Data element requirements vary according to mentioned mill areas.

This thesis work uses pipework process design data transfer to 3D plant design as the study case. In practice this means transferring the pipework process data from process design system, where the technical process is designed, to 3D plant design system, where pipework detail design is completed. The process design department calculates and defines values for each pipeline and sends it over to 3D pipework detail design where the pipeline is modeled in 3D. Results of 3D design are then transferred to procurement and manufacturing by using a set of different documents. This data transfer from process to detail design is basic procedure in pipework design operation. Data structure and transfer rules to be defined are universally applicable for any two design systems used in this operation. Even with the strong influence of design systems in every day design work, the results must be kept software independent.

In practice the product of this thesis work is a list of pipework data elements. The list to be defined is required to contain information that can be used by both plant delivery company’s own pipework design disciplines and the subcontracting engineering company when working in the described data transfer case. This is because the case of data transfer between process and 3D pipework design can take place either in-house or between two companies. Emphasis for the study is in inter-company data transfer, because there is usually more to develop. History has shown that internal data exchange operations are normally easier to complete than inter-company ones. Internal operations are normally completed with less defining.

Target of this thesis work is not to create an unchangeable and complete data element list but to use the results and existing knowledge of data elements to create a usable list, which can be left open for future additions. There is an actual need for a concrete result and it must be fulfilled as good as possible.

Thesis work results are limited to design data management only. This thesis work does not define data structure for other business operations as material management, customer requirements, purchasing, manufacturing, installation or maintenance. All of these operations have connections to pipework design, but in the given case their influence is not affecting the results directly. It is easier to limit the scope of data elements that way and the results are more reliable when the usage is better defined. A wider look to plant delivery data management is too challenging a task to be covered in one thesis work. Even from only pipework point of view.

1.3. Completion and methods

Main targets for the thesis work is to study what is pipework data and how it should be defined in data transfer. In practice defined targets are met by a number of subsequent steps which together define a development project. Thesis work studies are included in the project as essential part of it. Work is started by studying the background information of the company and the design work processes. This gives the needed initial information about the business environment. Global engineering operations must be supported by the resulting selections and the co-operation with subcontracting engineering offices may not be negatively affected by the choices made in development. Therefor an active co-operation between companies is essential.

Quality of the development work is ensured by setting the right persons as internal project customers. The ones who need the data structure will be the ones defining the work requirements. They are also the ones accepting the final results. Data structure definition is completed together with plant design process owners, in other words the engineering department managers, who are responsible of the affected plant operations. Design department managers to be interviewed are:

- Henri Lähdeniemi, Engineering Manager, KR division, Varkaus
- Sami Nisula, Global Plant Engineering Manager, KF division, Kotka

Both Lähdeniemi and Nisula have experience in plant design operations of their divisions. They both have worked with pipework project delivery and have good enough vision over plant and process design practicalities. For a wider perspective of the subject connecting operations involvement is evaluated and their requirements gathered if needed. There is also a number of engineering and pipework data experts in Finland and globally. (Lahdeniemi 2012) (Nisula 2012)

Selecting the right roles in project team is important for the success of the project. This is done according to selected user case, process data transfer to 3D plant detail design. Design systems are involved by including system administrators in project team. They are responsible for the connection to their own design software and that way they can also define the technical boundaries for the data elements and transfer. Later on in the project design software vendors are contacted and their consultancy is required to define further connections between the defined pipework data structure and design software data structure.

As requirements for the development project are set, the initial pipework data element list is gathered, processed, discussed, comments are gathered and this leaves the project team with an initial list of Andritz Oy data elements. This list is then taken to subcontracting engineering offices for co-operation discussion and a common data element list is finalized in a common development.

The study is completed as a qualitative study using interviews and discussions. First an initial discussion was held with both Lähdeniemi and Nisula to ensure they know the target of the following query task: which data elements are required from their division point of view when exchanging data between process design and 3D plant design. Discussion was held over phone and completed by the end of December 2011. Then an email about a data element query was sent to managers and their replies were gathered. Lähdeniemi and Nisula were asked to complete the following task. (Translated from Finnish email.):

"… Here is the empty excel list. As mentioned in our conversation earlier, the target is to transfer pipework data from Comos to PDMS. Could you fill in the data attributes you need for this kind of data transfer.

Included also the data structure document PSK 5981, which includes the known data elements that can be used. All pipework items are not there, but you can use it as a reference table for the elements you find. "

The selection of required data elements was gathered into an updatable Excel list, which was then updated according to further requirements and development work. After department managers have given their answers, both were interviewed so the content gathered is understood correctly by the interviewer. Nisula was interviewed face-to-face and Lähdeniemi by phone. In both interviews the initial data elements were discussed one by one and the description for each element is gathered.

Design system related challenges were expected since process and 3D plant design manage even same data elements in a different ways and formats. The completed list was checked by the design system administrators only after the required data elements were defined in September 2012. This ensures the system limitations do not affect the data definition. Eventually it was studied where and in which format the data is found and usable in target systems.

Requirement differences between design departments were solved case by case. There are different requirements since the design environment conditions are different and there is a lot of history in defining the data in certain way. Target was to set the number of elements to minimum, but it was anticipated there would be some overlapping data elements. Design is the master in this case and systems must bend to its will. Requirement differences between companies require further study of design processes and co-operation between companies. The pipework process data in the study case was mostly defined by the process department, so it is a starting point, that they define the data content as well.

After internal qualitative study thesis work was continued with focus group study. Internal study results were introduced to a group of connecting engineering and co-operative companies. Comments were gathered with email, phone interviews and face-to-face meetings. Following companies and their representatives were used in group study as they are main co-operative companies for the field of design to be studied:

- Pöyry Oy, Jari Laitinen, Kuopio
- SWECO Oy, Heikki Pyykkönen, Vantaa
- YIT Oy, Harri Lukkala, Helsinki
- CTS engtech Oy, Jussi Järvelä, Kouvola
- SAV Oy, Mikko Johansson, Kouvola
- Kymtec Oy, Antto Kurri, Kouvola

- Jimexo Oy, Hannu Suominen, Tampere.

Internal pipework data element list was then modified according to engineering office comments and study results processed with division design managers to complete the data element list. This was completed by the end of September 2012. After that there is expected to be comments and additions to the list. These are added and as the inter-company co-operation is finished, the resulting complete list of transferrable data elements is to be implemented.

Thesis work project schedule is 14 months, but the co-operation to create a common pipework data transfer standards will take longer time. The results of the latter development work are expected in the spring of 2013. Results of this thesis work are processed and presented according to Andritz Oy immaterial rights regulations. Some company details and study results are hidden. Further and more detailed analysis of results is presented to Andritz Oy engineering departments in a separate report document.

As the result of analysis Andritz Oy is presented with a list of suggestions for further study and technics to be implemented. However, this document is not included in this thesis work. Studies are to be later utilized in live plant design projects and engineering development.

1.4. Structure

This thesis work is structured in four separate ensembles: Andritz Oy operations description, three supporting theory studies (business environment megatrends, pipework data management and co-operation possibilities), case description of Andritz Oy pipework data element study and resulting procedures.

Andritz Oy operations presentation outlines the thesis work by defining the practical environment and setup for the required work. Business environment and thesis work relevant background information is presented as it is. There is a practical request for this thesis work and a strong emphasis is put to both clarifying the requirements and limiting the scope of the study. Current pipework related design practices and limitations are described. These company core operations depend much on surrounding business environment. In the last decade the changes in manufacturing industry have affected the practices heavily. These changes are described from global and company point of view. The case study of this thesis work is affected by the influence of changing business environment, Andritz Oy internal data management requirements and global operation related co-operational practices.

The given thesis work subject requires a theoretical and practical approach from three different angles: business environment, data management and inter-company co-operation. The three-way approach for apparently simple list of data elements is important, because of the nature of this design area and Andritz Oy operations. Otherwise the results of study may run a risk of being too simplified for the request and thus not practical in use. Research problems are selected to cover the studied issue thoroughly from company point of view and the selected clarifying sub problems direct both the theory and the practice towards common goal – and main research problem – finding the usable list of defined data elements.

Three practice supporting theory studies are presented to cover the research problems. Business environment megatrends open the basis for today’s way of working in global engineering environment. This gives a non-industry-related viewpoint on which way plant delivery and design is developing today and points out issues that should be considered when operating in the changing business environment. For thesis work this is valuable background information that must be noted when designing data structure, which is dependent of practical working procedures of the industry. Global engineering practices also affect the way data structures should be built and who would be the right co-operational partner when defining the data structure.

Pipework data and standardization chapter opens viewpoints to the world of pipework data management principles. Different project work related operators and design disciplines are studied and their requirements for pipework data are discussed. Study relevant pipework data structure standards are introduced as they are the corner stones of pipework data in both design operational and design software point of view. This chapter presents background information for practical study of pipework elements and directs the study to towards more relevant solutions.

Third theory chapter clarifies the possibilities of inter-company co-operations in the field of data structure definition. In the given business environment there are many co-operational possibilities to utilize and Andritz Oy has a lot of practical experience in this field. Known case studies are used as background information to find a suitable way for co-operation. Partner lists are gathered according to the study requirements. Selected practical solution for the given challenge is estimated and outcome hypothesis is stated. This helps setting the target and defining the practical operations for case study.

Case description is divided into two parts. Andritz Oy pipework data element study reveals the practical work completed to gather and evaluate the required data elements within company operations. This work is based on current design operations. Definition work started in-house as internal work is continued with a specified case of inter-company co-operation. Co-operational practices are described and path to resulting pipework data structure is described. Data element development from Andritz Oy requirement list to commonly recognized standard list is described through relevant case examples.

Thesis work results are presented, discussed and analyzed in fourth part. Results are presented in a form of data element lists equipped with data element descriptions and links to existing pipework data standard. Presented theory influence in practical case study is evaluated and result for hypothesis is given. Follow-up and recommendations for Andritz Oy are presented according to result analysis.

2. Andritz Oy

2.1. Pulp and paper and energy

Company history runs deep in Finland’s industrial history. Founded in 1851 Ahlström grew to become Finland’s greatest technology concerns by the 1930’s. Through the years of 20^{th} century Ahlström grew in many fields of technology, from glass products to ship building and paper mills. In late 1990’s company concentrated on fiber products and sold the energy technology operations to American Foster Wheeler and pulp and paper operations to Austrian Andritz.

Today Andritz Oy is a subsidiary for Andritz AG, an Austrian based technology concern employing over 17 000 people globally. Andritz Group has strong market share in hydro power, pulp and paper technology and metal processing machinery markets. It also operates in solid-liquid separation and pelleting machine technologies. Group strategy is to expand the technology leadership by acquisitions and utilize the new company specialties in developing a stronger scope of supply. At the same time Andritz Group emphasizes heavily on technology development. (Andritz Oy 2012)

Andritz Oy is a global operator in engineering business delivering plants, process and technology solutions for pulp and paper industry. Andritz Group products include chemical and mechanical pulp mills, chemical recovery, energy technology solutions for enhanced mill energy efficiency and power boilers. Andritz Oy is based in Finland with headquarters located in Helsinki and circa one thousand employees in various offices around Finland.

Andritz Oy pulp and paper scope of delivery covers main processes and departments in chemical pulp mill delivery. Company operations are divided into two main parts: capital business delivers new mills and processes and service business operates in renewals and capacity lift projects in existing mills. Both operations use common product management resources, but plant design resources are separate.

Andritz Oy has a long history in inter-company co-operation in many levels. The pulp and paper business environment and multi-company project work throughout the history of the industry have lead Andritz Oy (and its predecessors all the way to Ahlström Machinery) to operate closely in contact with customer mills, consulting companies, engineering offices and other specialists. Through the times there has been a need to agree on common issues between companies and Andritz Oy has seen it important to participate in rule and standard setting.

From Andritz Oy point of view communication and common rule setting has been completed in many forums on many levels. Project organizations are most commonly a setting to start discussions and exchange ideas how things could and should be completed. Andritz Oy has been active member in Finnish Bioeconomy Cluster FIBIC Oy, earlier known as Forestcluster Ltd or Metsäklusteri Oy. 2007 established joined venture company has set the target to “participate in the renewal of the forest cluster by creating new forms of networking and by boosting top-level research and innovation.” (Forestcluster Ltd. 2012)

Plant delivery operations follow a common operation procedure of plant delivery. Core competence i.e. project management, process, layout and product design is kept in-house and detail engineering is outsourced to specialized subcontracting engineering companies. These subcontractors are located mostly in Finland, but a growing number of design tasks are given to engineering companies in South America and India as part of company engineering strategy. Mill delivery business is backed up by full mill life cycle service business where the plant owner can purchase the whole mill maintenance from same company that delivered the mill.

Main part of company’s pulp mill green field delivery projects during the last years have been delivered in growing economies in South America and China whereas energy technology projects have been completed more evenly around the globe. Andritz Group has set a strategy of emphasized focus on renewable energy. (Andritz Oy 2012) Energy efficiency is seen as growing trend in plant delivery industry during the last years.

Andritz Oy is capable of delivering complete pulp mills, mainly as EPC deliveries. Usually in these projects Andritz Oy carries the main responsibility for project management and engineering both project-wise and technically. With a long history in plant design management, Andritz Oy has developed a number of data management routines to support the main functions and to deliver needed data between operations. Naturally there is also a long history in co-operation with subcontracting engineering offices.

Plant delivery requires many different fields of design and engineering. Each field of design has its own set of specified tools and data management systems. Main engineering disciplines for Andritz Oy are:

- *process design,*
- *plant design,*
- *mechanical design linked to product management* and
- *automation and electrification design.*

Design disciplines manage data of many different products: equipment, structural, pipework, automation, electrification, ductwork etc. Design systems have also a number of connections to other major business systems as CRM, ERP, document management and project management tools. In the global business environment the design and delivery operations are completed according to project requirements. Nowadays a lot of project work is completed near the plant site by either Andritz own offices or subcontractors. Design and manufacturing resources are utilized globally and goods delivered to site from all over the world. This makes Andritz Oy operations genuinely global.

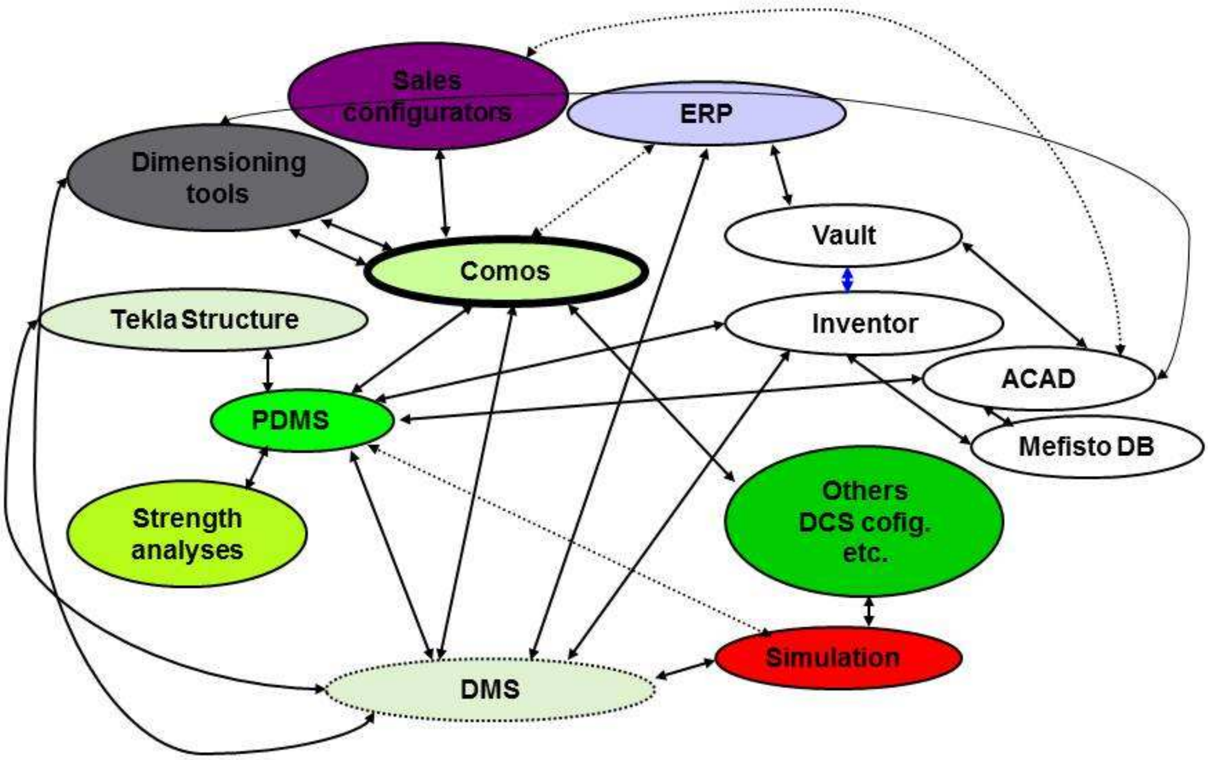

Diagram 1. Andritz Oy engineering and design system landscape. Comos is a process and automation/electrification design tool; PDMS is a 3D plant design tool; Vault, Inventor, ACAD and Mefisto DB are mechanical design tools; Tekla Structure is a steelwork detail design tool and DMS stands for document management system.

Majority of required engineering tools is implemented not longer than ten years ago and the versions in use are updated constantly. It is fair to say Andritz Oy operates with most modern and suitable tools in its field of business. In plant delivery project one major part of engineering is the pipework design. There can be over 100 kilometers of pipe in a pulp mill and the number of pipes can reach thousands. (Aarrelampi 2012) Plant pipes are the product of many fields of engineering.

The pipe life cycle starts in preliminary engineering phase (pre-engineering) in process and layout design systems. As the scope of the design is cleared and process gets defined more precisely, pipes get preliminary process values. These values include temperature, pressure, fluid and material requirements. Process values are transferred to pipework detail design where the physical form of pipe is modeled in 3D design tool and the documentation is created according to the design. Pipe data is then taken to manufacturing or purchasing and the actual pipe is installed according to pipework documentation.

Each mill - a customer from Andritz Oy point of view - has an own set of mill standards, which define what kind of pipes can be used within the mill. Normally these mill standards are created according to local national standards with mill specific modifications. For example mills in Europe use commonly EN standards for piping under 64 bar. Respectively mills in South America are normally using mainly ASME standards for their piping. Pipe data requirements (i.e. number of pipeline attributes) for high pressure boiler piping is usually tougher than for pulp process piping. This is because high pressure and temperature piping goes through more calculation and detailed engineering than pulp process piping. As design requirements grow, the number of attributes grow.

In early process definition phase of project there is seldom certainty what the final piping standard for a pipeline will be. Solutions for local usage of standards can vary from mill to another. Also there are commercial decisions which pipe standard is to be used. A mill piping standard consists of pipe specs, which are a collection of suitable pipe components for each fluid-temperature-pressure mix run in the mill. Each pipe is given a matching pipe spec reference and that gives the pipework engineer the information needed to design, route and equip the pipe.

2.2. Design data management and development

The scope of data management in Andritz Oy design operations is wide. Design disciplines are using design data from many sources, company internal and external and the data exchange routines between groups and systems are taking new forms all the time. In late years there has been a lot of talk in design business forums about more structured data management and transfer. XML has been pointed out many times as the solution and many in design world applications have been built on top of this markup language.

Andritz Oy plant delivery operations have also been changing lately. According to Engineering Manager Timo Juvonen, Andritz Oy's role in plant delivery projects has been growing during the last years. Fewer customers are interested in participating plant delivery on detail level after scope definition. This gives plant delivery companies like Andritz Oy more responsibility on managing the whole design scope. At the same time Andritz Oy delivery scope has grown significantly. This creates more connections between Andritz Oy departments and requires more interaction and internal rule setting within Andritz Oy engineering and design operations. We need to re-think our operations and move our focus from interface definition to managing larger data structures. (Juvonen 2012)

Main part of Andritz Oy pipework design is completed in 3D plant design system. Andritz Oy uses an AVEVA product PDMS, which can combine 3D material from many different design systems. In principle all disciplines of design are put into same project model where the whole project can be followed and designed simultaneously. PDMS enables users from different areas to work together in real time. Pipes are routed in 3D environment with actual pipe components. This means each component designed equals a real life component that can be found in a shop or can be manufactured. As result pipework design produces documents and lists required to purchase and manufacture the pipes. Today 3D pipework design is a de-facto operation in modern plant design in any industry sector and AVEVA's PDMS is the leading system in many industries, for ex. pulp and paper.

Andritz Oy utilizes many different subcontractors in projects. There is a number of engineering companies specialized in piping detail engineering. Majority of them use the same PDMS system as Andritz Oy as the project pipework design operations are based on working in the same 3D model. AVEVA provides a data exchange tool called Global to transfer the 3D model between companies. Other data exchange between companies is usually less automated than inside Andritz Oy.

Automation designers work also in 3D model. Pipeline parameters and spec information define the interfaces for pipework automation equipment. There are a number of general types of automation equipment in pipelines: for example in-line components, measurement nozzles and connections and control valves. Automation design requires information from pipeline to be able to select the correct equipment for each case.

The plant design process is an iterative play between engineering disciplines, purchasing, manufacturing and project management. Any project can have dozens of data transfers from one discipline to another or normally from one to all others. This data exchange is currently managed with a different set of lists prepared for each occasion. For example pipework designers receive a valve list from process design and select the valves for each pipeline according to that information.

Some data exchange has been automated a bit better to fit a specified need. For example instrumentation measurement equipment data comes from automation design system Comos as an automated list and it is then read into 3D plant design model as 3D elements. Automation designers then proceed to place the automation equipment in 3D environment. As this is done, the position information is taken back to automation engineering tool for further use in documentation.

Different design systems are normally built with a different approach to design work. As the requirements and hierarchies are different, the naming conventions may also vary. In the end the delivered documents are the only environment where for ex. the pipeline names must be named exactly after customer standards. Internally in design systems there can be internal names and references which are then replaced with correct aliases in the drawing creation phase. In general all design system hierarchies are built according to Andritz Oy own working procedures and not customer mill hierarchies. This way all the departments and delivered mill processes have their standard locations in systems and are easily accessible for designers. To enable a centralized design project management, the working routines in tools must be kept as efficient as possible.

After manufacturing and erection phase the mill is put to life and as the customer has finally approved the plant, the project data is moved to the end of the life cycle. Plant project data is delivered to maintenance and mill service business units. It is very common for customer to leave room for capacity raise options in the design. Process change and reparation projects are common too and it is important to have the design data available in native design systems when bids for new project are due.

In general design data in Andritz Oy is managed mostly in design software systems and the exchange is completed case by case. For the starting point of this work there is no common design data structure or strategy that would go through the whole lifecycle of a plant delivery. This opens a possibility to evaluate the required data elements only dependent on the two systems linked together. On the other hand defining a new data element structure has to consider the possibilities of new items being added to the element list later.

2.3. Challenges

The described project environment presents a clear need for better controlled data exchange between key design areas. Pipework design operations in Andritz Oy departments KR and KF is mostly similar, because the used systems are same for both. Documentation delivered from the systems is being unified and common target is to deliver Andritz Oy documents that look the same independent on the department. Naturally the pipework design principles and delivery project mill standards bind departments into unified data management.

Better controlled data exchange means two challenges in practice. The systems must be ready to export and import data in an agreed format. This is normally the feature that is seen by the designers or design department managers as the data transfer is discussed. However, data transfer between systems has already existed for as long as there has been computer aided design. Traditionally design data has been transferred from one system to another case by case, because all the cases have been different. What makes this kind of data transfer work unwanted is the fact that it has to be redefined every time there is a new case. The key factor to this discussion and the second challenge is the data structure. With a suitable fixed data structure it is possible to minimize the rework in system adapters each time a new transfer case is started.

As the pipework design content and target of data usage are very similar within Andritz Oy departments involved in this development project there is a good background for finding a common data structure for the whole company's pulp and paper delivery. Pipework design is a wide field of expertise to be covered in one thesis work. There are many viewpoints to pipework data or what should be considered when designing a pipeline. The issue must be limited better. The leading factor to define this is the purpose of the pipe. The given challenge of common data transfer should be started by defining the pipeline purposes. Pipework design has numerous links to other design and engineering disciplines and business processes. This sets a challenge when defining the limits and targets for this thesis work.

Answering the business set challenges thesis work should follow a few basic principles. First of all, there must be a strict limitation what is considered to be pipework design relevant data. This is to be defined by the internal project customers, a.k.a. design departments before the actual study work is started. Only that way the thesis work can return a set of truly usable results. This working method carries a small risk too: the internal customer in this case is partly the same group as the study group. The definition of subject may influence the results by directing the discussion into issues that it sees important before the actual study.

To support the study and to get a bigger picture of research area, it should be studied if opinions should be gathered from purchasing department, project management and engineering development. This task could mitigate the risk of having too close relation between project definition and study group. Combining different views into one common approach could be a more reliant way to get trustworthy results about design requirements. So put together, this thesis work is supposed to offer a strict limited view to pipework data created by a wider group of participants. It is predicted that there will be a number of other requirements to widen the focus of this study, but these requirements must be studied separately in future projects.

Secondly it is seen important by design department managers to get a better view of pipework design relations outside Andritz Oy company limits. Two paths were discussed: subcontracting engineering office work practices and standardization between companies. As mentioned before Andritz Oy business concept on pipework design is heavily based on subcontracting engineering offices completing the pipework detail engineering. These connections must work fluently and new developments must not interfere with the everyday workflow. As starting point common design operation rules and pipework standardizations must be considered and followed. Current operations are based on them.

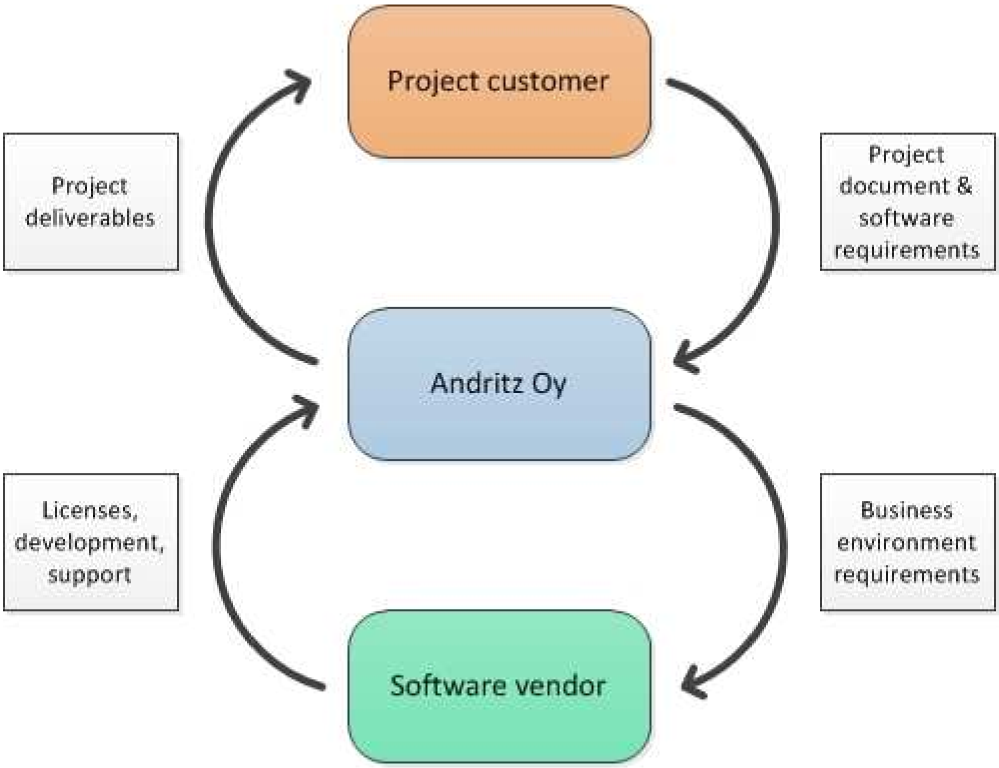

Diagram 2. Customer – deliverer – software vendor process. Payment runs down the right arrows, deliverables up the left arrows.

Third issue in discussion was setting targets considering the relation between software vendors, design tool users (Andritz Oy) and customers (the mill owners). In principle this link is a two-way loop that is powered by the design work completed by Andritz Oy to the customer. Although Andritz Oy is a major operator in pulp and paper business area, this business area is a small one compared other income sources for many big design tool companies. For example PDMS vendor AVEVA gets only some 2 per cent of income from pulp and paper. (AVEVA 2012) This leaves Andritz Oy only few possibilities to genuinely affect the development or data structure of the design systems.

Internal company experiences tell that there are two ways to develop the design software to better fit Andritz Oy needs: to make the modifications by ourselves or to find a good way to influence the vendor, who will then do the actual development work. The latter one is possible either by finding a good co-operation relation with the vendor or by combining forces with other companies with similar requirements. The goal, however, is very clear. If the software structure and solutions fit Andritz Oy requirements and working methods better, there is less tailoring needed, less ad-hoc work in project phase, less waiting time for designers and it will result in less man hours and errors in design.

Discussions with design department managers set a clear demand for better managed pipework data exchange. In practice the design departments require a reliable list of data elements that could be used as a ground rule for data exchange between main pipework design tools, process and layout design. Neither the content nor the usage possibilities of this list were clear in the beginning of the project, but the project work was defined to clarify these issues.

These notions have been used as starting point for the following practicum – the case studies.

2.4. Research problems

Thesis work is built around the main research problem

“How should pipework data structure be defined in engineering system integration?”

Background in company and its business environment sets two main viewpoints for this research problem. Issue is studied from data element and data structure user point of view. Both elements together define the data structure required in presented user case. Clarifying sub problems are set as follows:

“Which data elements are needed for pipework design?”,

“Which disciplines of design should be involved in integration work?” and

“How should Andritz Oy involve subcontracting engineering companies in integration?”

Fist sub question is a technical quest to define the required data element list according to company requirements. Based on field study and backed up with knowledge of today’s available design data models, answer to this question is the practical result this thesis work seeks.

Second and third sub question are closely related as subcontracting engineering companies are heavily involved in design disciplines. The study of involved participants draws the limits for data element list and directs the main problem.

3. Business environment megatrends

To be able to better understand the field of global design environment and business requirements it is important to acknowledge the change powers behind global engineering.

In 2006 Copenhagen Institute for Futures Studies released an article on business megatrends for next 15-20 years. According to author Gitte Larsen “Megatrends can be used as a methodology when you or your company works strategically with the future. You can, for example, use them as a base in development and innovation processes, and use them in combination with other trends in a more specific area.” (Larsen 2006)

Megatrends are interpreted as most probable trend lines for the future. Today the changes of the world affect business environment faster and more directly than ever. Out of ten top megatrends Larsen lists there are three that affect Andritz Oy operations directly. These are Globalization, Technological Development and Network Organizing.

Globalization makes it easier and quicker to reach any part of the world. It also brings the developing countries more possibilities to reach the information and opportunities that once were available for developed countries only. Technological development during the last decades has been outstandingly fast and human interaction has adapted new ways of using networks for every-day life, business and leisure. (Larsen 2006)

These three megatrends have big effect on manufacturing industry as developing economies can now provide services that were not available decades ago. Manufacturing industry has been reacting to the change by transferring design and production to low-cost countries. As design data is produced and managed in more locations new better ways for data management are needed. Design business will continue searching for more efficient ways to complete the given design tasks. This is not only dependent on the hour price of the designer. The total cost of engineering is the key factor which drives companies into making decisions of design locations.

Risto Kuivanen from Technical Research Centre of Finland (VTT) has studied the issue of manufacturing industry in Europe and writes in his 2008 article The future of manufacturing industry in Europe. **“**To maintain and enhance the competitiveness of manufacturing industry, new innovative approaches and methods should be developed and implemented. The work in this area is underway and both international and national efforts have to be made. Especially new approaches, such as network manufacturing and broad implementation of ICT, have been under investigation and development. The implementation of ICT tools needs both technological and procedural development”. (Kuivanen 2008)

As Kuivanen (2008) states in his article, businesses who are best capable of adapting the new business environment and bringing their operations to match the new era are the ones to survive. Building a new line of abroad operations and attaching it to company’s current way of working may not be the right way to go forward.

More important than the actual change is to recognize what exactly is the benefit of using low cost resources. “The best way of keeping a manufacturing industry in at least a major part of Europe is to specialize, mainly in production, where there are needs for special skills, and where the price of the workforce is not a key factor. This is easiest with products that are highly innovative.” (Kuivanen 2008) According to Kari Asikainen, Engineering Manager at Foster Wheeler Finland, total engineering cost evaluation should be completed with care when selecting the tasks that are outsourced. “For us (Foster Wheeler Finland) the most cost efficient engineering resource is a local Finnish small engineering office specialized in one limited task”. (Asikainen 2012)

Asikainen’s employer Foster Wheeler has a common product environment and a shared history with Andritz Oy. Both companies design and manufacture power boilers for steam and electric generation and were part of Ahlström until the 1990’s. With the technological solutions design software vendors provide today it is made easy for us to think, that taking a design operation over to a low-cost country would be easily managed task since the technology supports the exchange. As Kuivanen (2008) points out, there is a need or a wider viewpoint.

Decision making in design work outsourcing should only be made after a thorough study of processes. And to know the future, the first step is to get to know the present. In big picture calculating the total savings is essential. As a result of their studies for ABB Corporate Research Karandikar & Nidamarthi (2005) listed the most essential areas for success in building a sustainable global engineering network. Setting the goals is important along with communicational and organizational skills. And to keep it together a solid series of management procedure and product standards must be validated and followed.

"…the development of common and shared work processes including common engineering analysis, design calculation and product data management tools. Such standardization reduces the chances of miscommunication and also unnecessary design effort thus improving the efficiency of the engineering process. Engineering can be both optimized and globalized by means of standard solutions that can be repeatedly used or easily scaled in customer projects. That is, a system is delivered by using as many standard solutions that are common across countries. All work processes within the business – sales, engineering and supply – need to be re-defined based on standards, and should be globally optimized. For example, cost effective suppliers from ECs can be developed for supplying complete standards to all global engineering locations." (Karandikar & Nidamarthi 2005)

Andritz Oy has been operating in this field for many years now. The work design departments have completed to outsource design work have followed the basics of known recommendations. However, with design system driven operations, there is unfortunately too little initial information to base one's decisions on. In this ever changing world of design, testing-analysing-modifying is a key operation in system development work and many times the hands-on testing of new operating models can result in better and faster results for business management to base their decisions on. Best way to proceed is to study and analyze the working operation processes and define what exactly is required to fulfill the needed tasks. Dividing the workload between two offices always leads to data exchange challenges. This is natural in an environment where the designers are not close to each other and do not always speak the same language. Development in this field is an long process as Kari Asikainen (2012) sums up in his presentation: “Technological solutions should only follow the direct requests from the business operations”. The best practices are usually found with time.

4. Pipework data and standardization

Data management in engineering is a business driven field of excellence with not too many released academic studies. As it is essential factor in all business core competence, companies are willing to share only general information and case stories of their experiences in this area. Business environment, however, is the same for all companies: plant delivery time has become a competition factor as is quality of deliverables – better ways to manage design data are required.

Reaching and maintaining a common understanding over technical data is surprisingly difficult. We all share a number of incidences where the idea we have presented is interpreted differently by the receiver. Bad communication is a common problem and it can happen both human-to-human and system-to-system. In the end it is always a man defining the data structure and rules. It is very common for us all to interpret the given data according to our habits, previous experiences or prejudices.

Barley et. al (2012) studied the use of objects, i.e. pictures, charts etc., in conveying ideas between engineering groups and found that idea transfer is commonly affected by other intentions. What we use as supporting material for a task is often selected in a way, that it supports our vision of next tasks and thus is not uninfluenced. “When creating objects, engineers considered their own strategic intent as well as their expectations of group dynamics. To these ends, engineers drew on their peers and colleagues in their group for advice and to access the resources (e.g., data and materials) necessary to build objects that would fit their motives when preparing to interact with engineers from other groups.”

Efficient way to exchange data requires rules and methods, which are not influenced by interpretation. This requirement is important especially when it comes down to data exchange between groups of different cultural background. Naturally there is a request for tacit knowledge when transferring experience information, but when it comes down to simplified data exchange there should not be possibilities to interpret the data in a wrong way. Pipework data exchange can be divided into two separate tasks: data exchange and experience exchange. It is important for any design operation that the data exchange is defined clearly and leaves no room for interpretation.

Design data exchange is always affected by its surrounding environment and connecting disciplines from engineering, project delivery and other operations. Defining the factors that affect the data is important, because the data presentation format should be always selected according to the use case. In many cases the dependencies are very difficult to define. Bartolomei studied the design systems data management in large scale complexity projects and noticed, that engineering data relations in large scale projects such as military airplane development is too complex to be comprehended by normal project management tools. Complex engineering data requires better system modeling and new ways to present the dependencies. (Bartolomei 2010)

Andritz Oy has completed a project to model the top level of design processes within pulp and paper divisions, but this work has been completed only in the top level and from the designer point of view. Pulp mill data management is large issue to be modeled and even pipework design procedures and data element dependencies are very hard to model. This is so mainly because the design process is not fixed from one project to another and partly because the design processes are not unified within company. Design data structures can be defined even when the operations and processes are not completely known. As long as the data structure is used in limited operations, such as process design and pipework detail design, the data dependencies are relatively simple to define.

Much of the design data structure and usage complexity can be explained by the nature of the projects. There are normally many different companies and user groups who require, modify and produce new data in their systems. Cai (2006) states, that companies generally recognize the need for better control over common data, but the knowledge management routines and responsibilities are commonly failing. This is because companies are not using enough resources to study the co-operation in projects and therefor the key elements for successful knowledge management are missed.

Both Cai (2006) and Bartolomei (2010) state, that the key factor for creating a good design data management is knowing the design processes and use cases behind the operations. Although the approach for data management systems is many times software based, IT is only one of the key factors. Defining pipework data elements requires knowing who uses the data and where. Companies craving for better structured data should use time to define this better.

Creating a new data structure and implementing it into existing system landscape should be completed with care and time. The newly defined data structure may have impact on working procedures and therefor changes should be evaluated. Target organization IT landscape is always a product of company history and the design tool procedures are usually not easy to change. “The challenge for data management is to support each tools with its appropriate data format, ensure the seamless flow between tools and enable an integrated view upon all relevant data, if required.” (Steiert 2005)

The data structure change has to consider the company design operations both in-house and outside. Internal changes in company data management may affect the design co-operation with subcontracting engineering company. If the change is to be completed, all connecting participants and their key procedures should be evaluated. Steiert also presents, that the agility of systems should be taken in notice. Too strict data structure definition leaves out the possibility of adapting new requirements later on. Pipework design development demands clear and usable definition of data elements.

Design data definition and connecting process management should be the key task in design system integration development. Knowledge of connecting processes is essential, because the data structure and elements cannot be defined before the connecting operators are known. Data elements themselves must be defined so, that their content and use is recognized by all data transfer participants

5. Standardization in inter-company co-operation

Efficient design operations in global engineering network are dependent on finding the best ways for inter-company co-operation. When operating in a multi-company project the timing of common rule setting and agreement is crucial. The sooner the operations and data management issues are in line within the whole delivery project the better the outcome is quality-wise. Sheremetov (2008) studied the overall targets and revealed that for petroleum industry plant projects the well selected data model is highly important. When data is better managed, project relevant decisions can be made earlier in timeline and thus better managed operations come down to lower final costs and better manufacturability of products. Better structured data means fewer input errors for design input data and better reliability for the data reporting. Concurrent and collaborative engineering (CCE) requires also scalability of the data models. New possibilities for integrating new platforms and tools with existing ones will appear. (Sheremetov 2008)

Advanced data management co-operation between engineering companies is required, because of the surrounding business environment challenges companies to think differently and develop new ways for co-operation. As mentioned by Karandikar (2006) there is a need for better defined development work to achieve the benefits of global engineering network. This is especially needed when operating with emerging countries where also Andritz Oy has own operations and subcontracting engineering companies. The challenge is not in subcontracting companies being able to adapt the new ways of working but in customer companies' lack in process and structure knowledge of their own products and operations. This sets a challenge for defining the level and means of co-operation.

Standardization is commonly recognized way of ensuring everybody is following the same rules. It is fairly easy to use a recognized standard as the development and discussion backbone. Standards to be used in design data integration can generally be international or local as long as the definition is completed in smart way and it fits the needs of the target. Effective plant delivery project can only be based on good process knowledge and study of business environment. (Ma & Hadi 2012)

Design data integration is dependent on two subjects: the definition of the content and the overall system of data exchange. Between these two areas are the information integration standards that define the structure of data elements, their relations and the rules for the data exchange systems. Wiesner et. al. present interesting user case in his article *Information integration in chemical process engineering based on semantic technologies* (2010). Study reveals how XML based data transfer is used to gather together the distributed design data from many different source systems into one common data model. This procedure is very close to Andritz Oy operations with the exception that Andritz Oy combines the data and 3D models already in the design phase of the project. XML data transfer is flexible and suites the requirements of the study case. Baseline of Wiesner et. al. study applies to many known design data integration cases – a commonly known neutral data format is a good ground for creating data exchange procedure.

In general neutral data formats are not only for defining the structure of the data. Well defined neutral data model enables also more sophisticated way of using the data. When the relations and structure of data are defined and clarified it is possible to build relations and operational dependencies between data elements. Bronsvoort et. al. describe in their study *The Increasing Role of Semantics in Object Modeling* the possibilities of semantic data model applications in 3D worlds. By defining the structures of the data in hierarchical way it is possible to make elements follow their hierarchical rules and fulfill tasks defined by applications. Bronsvoort et. al. present an example of interior design CAD software where 3D elements are following rules when placing them in the layout. Chair element is dependent on the distance and placement angle of the table element. Data structure dependency makes general data model object behave in wanted way. When table is moved chairs follow and relocate themselves according to rules. (Bronsvoort et. el. 2010)

Usage of these sophisticated features of data model management is dependent on the use target application and the needs of the application customer. In Andritz Oy case the data element structure could be defined in a way that allows dependencies to be built in Bronsvoort et. al. described way. In pipework data elements this could mean setting data level rules to be used in design environments. For example certain combination of pressure, temperature and material could define the request for certain PED class to be checked and validated. Also value checking could be made easier with ruling that minimum operating temperature can never exceed maximum operating temperature. There are still many doubts in taking the data model development in this direction. For easier application and problem fixing these settings are commonly completed in software systems leaving data model dependencies untouched.

When discussing data transfer within a design project, some neutral data formats are normally mentioned. Mun & Yang (2009) compare three common neutral data models that are most used in plant delivery industry: Generic Product Model (GPM), ISO 10303 STEP and ISO 15926 Process plants. Target environment for the study is nuclear power plant where the amount of data to be handled exceeds pulp and paper projects clearly. In this demanding design environment Mun & Yang find GPM to be best solution since it is most flexible and has less fixed attributes. "…after translated into neutral model data in an integrated manner, various kinds of data created in the design phase, such as 2-D schematic diagrams and 3-D solid data, logical configuration information, and plant items' specification information, can be used for effective operation and maintenance in plants with a long-term lifecycle". (Mun & Yang 2009)

Selecting a data model must follow closely the requirements of the target environment. Studying the background and the actual usage environment and cases is very important, because along with the flexibility the structure of the data model is very important for defining and using the structure. This must be considered when selecting a suitable data model for Andritz Oy pipework data.

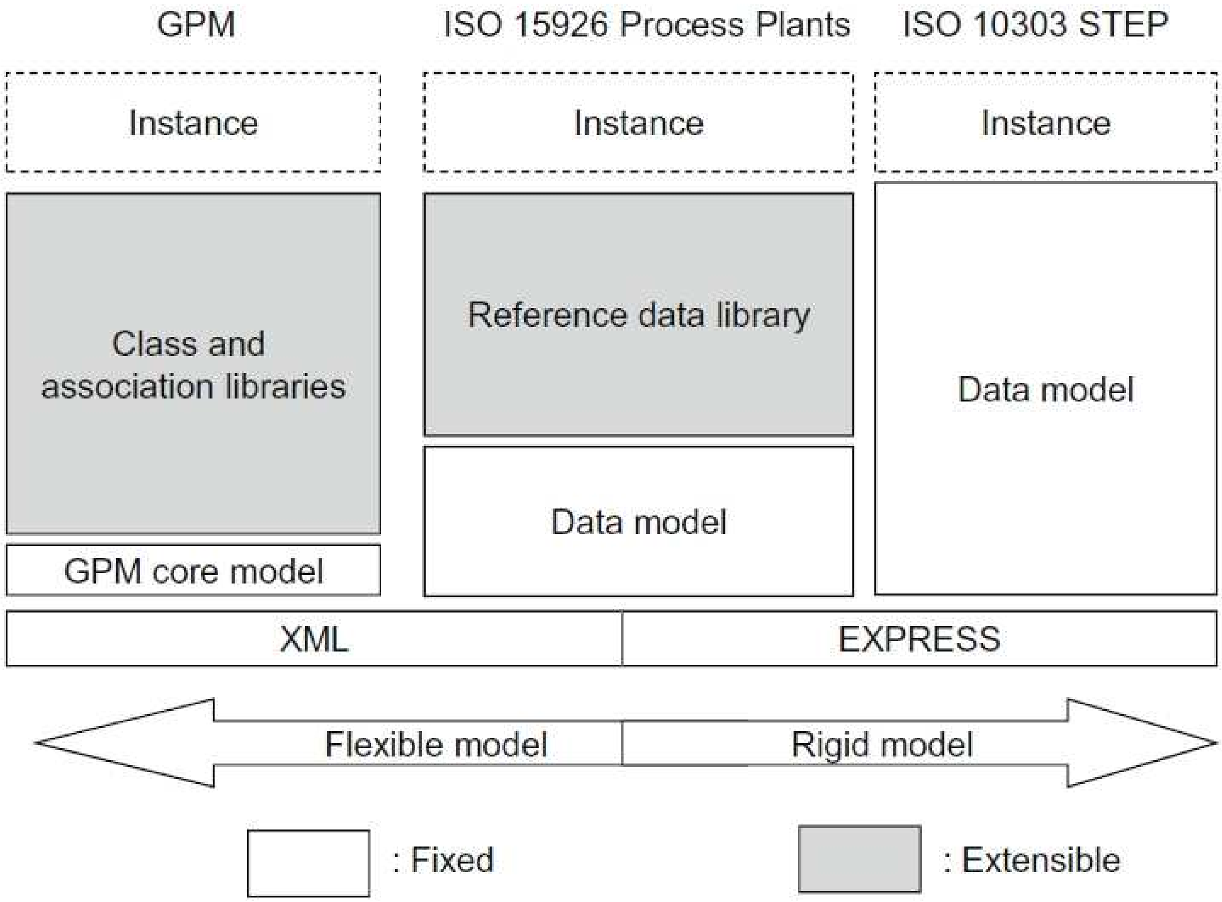

Fig. 2. Comparison of the GPM, ISO 15926 Process Plants, and ISO 10303 STEP.

Diagram 3. Structure comparison of three common neutral data models (Mun & Yang 2009).

Generic Product Model (GPM) was presented to enable better and more flexible understanding over products. GPM applies a conceptual model of the item, which is then represented by case relevant selection of classes and association libraries. (Koizumi et. al. 2004) "The idea is that product development develops product families with well-defined interfaces between subsystems and components of these families, in such a way that these subsystems and components are also developed as families. In a similar way, it is suggested that the supplying factories are organized in a way that mirrors the product family structure. In this way, product variety can be combined with learning and continuous improvement. This idea leads to intelligent product documentation in line with the (generic) product structure. The paper argues that such intelligent product documentation is helpful in all business processes in order to cope with variety.” (Erens & Wortman1996) What GPM is lacking is the structured view on the selected data. Too much definability is not always the easiest way to complete a data model.

ISO 10303 STEP and ISO15926 are commonly studied and used also in pulp and paper business area by many companies. ISO 10303 STEP (Standard for the Exchange of Product Model Data) is a product of mid 1990’s initiated standard work to define a data model which would not be system bound. In STEP the application protocols (APs) are parts of the standard that define data models for a certain application domain. “STEP APs capture object information as a snapshot in time and lack the ability to capture how the object changed through time. This was one of the motivations behind the development of ISO 15926.” (Bartes et. al. 2005)

ISO 15926 is described as more flexible and adaptable data model than ISO 10303 STEP. ISO 15926 is also supported by many software vendors and what is interesting to Andritz Oy both AVEVA and Siemens (Comos) have created export features from system design data to ISO 15926 compatible XML data. The standard is widely recognized in pulp and paper industry sector and there are applications in plant data management based on it. This makes ISO 15926 very interesting standard for Andritz Oy.

6. Case 1 – Pipework data in Andritz Oy

6.1. Background

Development work around pipework data elements was started already in 2008 when Andritz Oy implemented process and automation design system Comos. This Siemens software is a database based design tool, which allows designers from many design disciplines to use common engineering data elements instead of discipline specified data sets separate excel, process design tools and automation tools.

Working in a tool with one common database for process and automation raised soon a question of automated data transfer from Comos to 3D plant design tool PDMS. The data transfer has been completed so far with exporting CSV formatted Excel lists and reading them in in receiving system. This has been challenging since the data structures in systems are not fully compatible. Also the structures in PDMS tend to change during the design project because of customer needs and project working practices. So practically the starting point was project by project configurable tables in both ends of the transfer process. According to learning from Steiert (2005) this is not an efficient way to operate.

Already in the Comos software implementation phase the data exchange between these two systems was seen as complicated task; not because of the technology but because of the data structure. As mentioned before in this thesis work, the design disciplines use pipework data in a different way and it was unclear which design discipline (or system) would be the master of each data element. The working routines within Andritz Oy design departments were also changing.

PDMS is used mostly for pipework detail design and Comos gives the initial data for pipework designer. So when the development project for Comos-PDMS data transfer started in 2011 it became clear, that there would be a need for second development project – one that handles the pipework data structure. The relation between Comos-PDMS project and pipework data structure project was defined so, that pipework data structure would be completed first, since it defines the starting points for technical implementation.

Inter-company operations are important to Andritz Oy because of the nature of company's engineering operations. Detail design for pipework is mostly completed by sub-contracting engineering companies. To be able to complete piping design in such global environment Andritz Oy has to have a solid internal knowledge of these issues. Inter-company co-operation is very strong in Finnish pulp and paper business area. As stated earlier in co-operation theory chapter, there is benefit in studying common business problems and finding solutions that can be standardized or agreed other ways between operators.

For creating pipework data structure in design system integration following requirements were set:

- *Only data is transferred. Data elements must be simplified and defined so clearly, that there is no possibility for mistake by interpretation.*
- *Data elements must be unified within design systems and as well unified as possible with design supporting systems.*
- *It is preferred but not mandatory, that pipework data elements to be defined follow an existing pipework data standard.*

This defined the guideline for pipework data structure definition work.

6.2. Project description

In practice this thesis work was completed in a form of an Andritz Oy internal development project, which is to be completed in Andritz Oy by the end of 2012. The project was started in the October 2011 which makes the project operation period roughly 14 months. Completion of project requires some 30 per cent of monthly working hours from one person, the author. Project team and related co-workers were utilized as they were needed. Design system administrators' and design department managers' role was not budgeted since the work was mostly responding to questions and filling definitions ad-hoc. Project was completed in four main parts and it follows an applied software development project structure. (Haikala & Märijärvi 2006)

Work was initiated with a definition of requirements. Requirements for pipework data structure management were gathered from Andritz Oy business units and processed into one updateable list. Requirements were divided into two main sections: business requirements and technical requirements. Restrictions and turned down requirements were gathered too as they can be used later on to define the operating environment. Project requirements are presented in *APPENDIX I*.

Definition of project targets followed the requirement gathering. Research problems of this thesis work (see ***2.4 Research problems***) were prepared, discussed and declared according to requirements. Project targets were defined in project plan document and their completion is studied as the project is finished. Schedule of project plan is presented in *APPENDIX II*.

Study was completed according to project definition and requirements. Work was to be completed mostly during working hours in Andritz Oy with the exception of theoretical studies in Lappeenranta University of Technology. The subject of the thesis work also requires co-operation with other engineering companies, standardization associations and other operators. However, the notes and results in this thesis work are solely of Andritz Oy point of view. If any of the solutions apply for larger group of companies, it is to be noted in text.

Fourth part was the result analysis. Study was set to give answers to all main and sub research problems (defined in ***2.4 Research problems***). Results from analysis can be used in both inside Andritz Oy's own processes and in inter-company operations.

Target completion is followed normally by a steering team, but this project does not have a defined steering team. Work was followed, commented and directed by Engineering Director Timo Juvonen, also listed as supervisor of this thesis work.

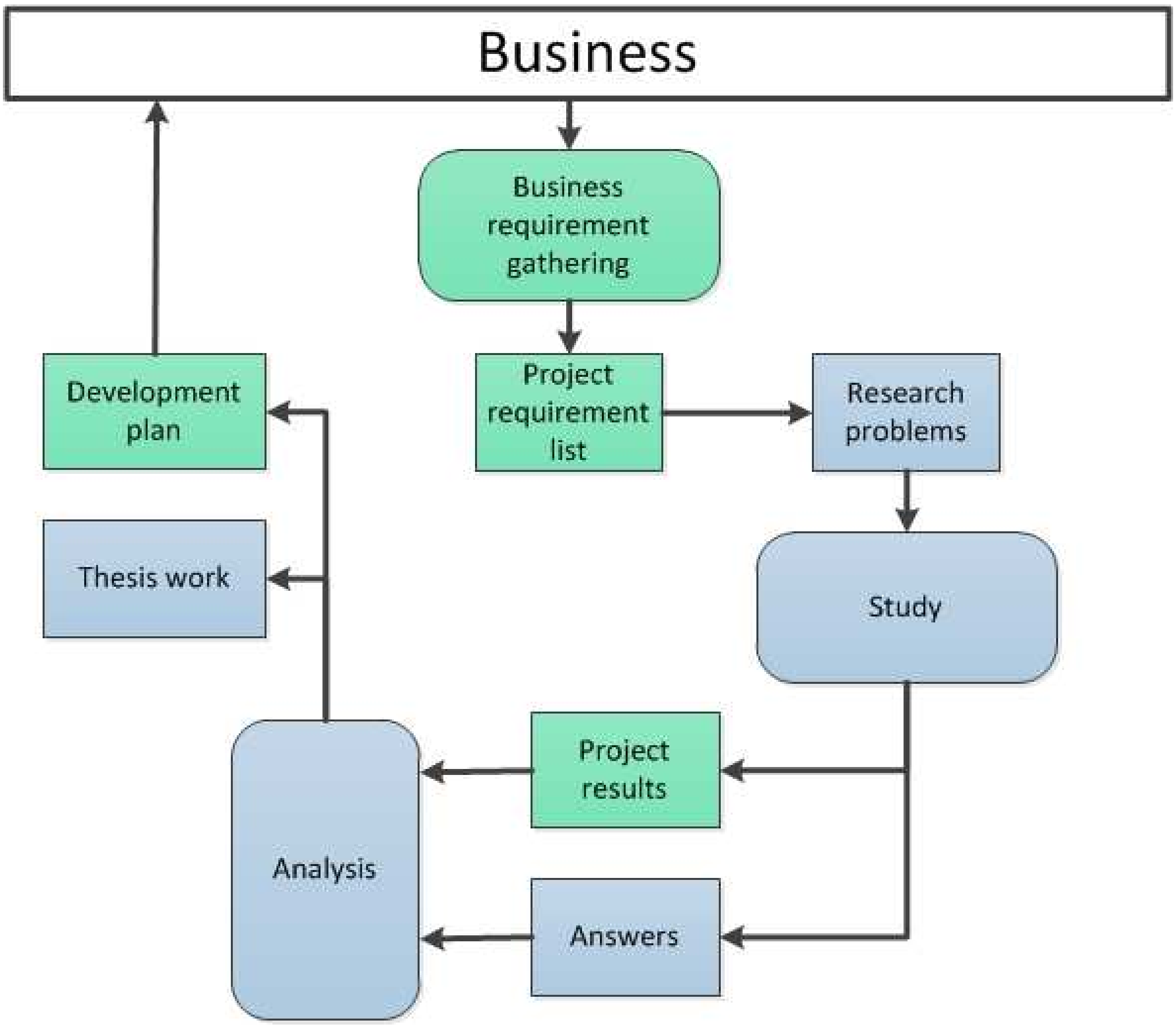

Diagram 4. Project completion process

6.3. Project completion

Before the data structure or project content could be studied there was a need to clarify the internal customers of this project. See Diagram 5 for involved participant list. Design departments for plant design were naturally involved from the beginning of discussions as they are the internal customers of the project. Automation department was also contacted and invited to discussion, but as their involvement could be covered by other participants, their presence was not required in this project. System administration specialists were added to project group only after the requirements were already collected from design departments.

Department	Participant	Responsibility
---	Project manager	Project management, connections outside Andritz.
KR Plant design	Engineering Manager	Department requirements & processes
KF Plant design	Engineering Manager	Department requirements & processes
~~Automation~~	~~AEI Engineer~~	~~AEI connections~~
Comos	Administrator	Comos data structure
PDMS	Administrator	PDMS data structure

Diagram 5. Project involved persons.

After the internal work group was gathered there was a need to solve the connection links outside Andritz Oy company bounders. As described in previous chapters Andritz Oy operations are dependent on surrounding business environment and co-operation with customers, engineering offices, consultants, standardization organizations and development groups is necessary and a preferred starting point in data structure definition (Cai 2006). Before the right partners for the development work could be selected, a deeper definition on development project target had to be completed. As the most acute case required by design departments where this data exchange was to be completed was a case of the pipework data transfer from process designer to detail piping engineering. Technically in Andritz Oy environment this meant exporting pipe line list out of Comos and importing it into PDMS for 3D piping routing and detail design.

In delivery projects most of the pipeline detail design is completed by Andritz Oy subcontracting engineering companies. Most commonly used engineering offices from recent years KF and KR operations point of view were selected. Nine engineering companies were listed, seven of them in Finland, two in South America. At first stage it was planned that all of these companies would be contacted and information on pipework data structures would be discussed, but knowing from the delivery projects how reluctant companies are to discuss their systems or modify them, it was seen best to take a different kind of approach. As all of the companies involved are also bound to use of piping standards it was assumed that by creating an pulp and paper industry suitable standard for pipework data structure there would be less objection to change. Chapter 7 ***Case 2 - PSK 59/9 Pipework data elements*** describes the case of inter-company development work. At this point it was also decided, that South American engineering companies were not to be included in the development work because of the practical issues. Rules defined in Andritz Oy projects are transferred to engineering companies regardless their location.

Knowing the participants for the project next step was to gather the requirements from the key players. As pipework design has many links both backwards (standardization, material management), sideways (project organizations, subcontractors) and forwards (procurement, manufacturing, installation) next task was to define if requirements from design departments was enough. The internal pipework design process data flow gave an answer to that question. Studying the process of data flow to and from design departments showed that pipework data is mainly passing the project phase through one link – the link between process and pipework designer, forth and back.

Pipework in this thesis work is defined as process relevant pipework. To be able to define pipework related data you first need to define and categorize the pipe items. Andritz Oy manages many different sorts of pipework in plant delivery projects. Each pipeline belongs to a specified mill standard category and is to be designed according to a known and calculated standard. Each category carries different requirements for pipework and is normally specified for a certain use in mill. The use of pipe defines the physical and material requirements. As an example high pressure piping carries more testing and proofing requirements than process piping (63 bar and under) and therefor it is often handled in different lists and with different procedures than process piping.

Along with standardization and mill areas the pipes covered in this definition can be categorized according to following features:

- *Size and other significant physical features.*
- *Owner of scope, i.e. who designs, delivers and installs the pipeline.*
- *Pipe material purchasing issues, for ex. material delivery time.*
- *Mill / project specific requirements, for ex. installation order.*
- *Difficulty of design or installation.*
- *Hazardous media requirements.*
- *Special information requirements.*

Usage and requirements of a pipeline are basis for pipe standardization. Traditionally different industries have created their own pipework standards, which have been developed according to industry needs. There is also a great number of national, international and vendor specific pipework standards, which are commonly used in pulp and paper industry. These are the starting information for creating design system libraries and specifications for pipework.

The initial pipework data structure discussion was started in March 2012 with two main design departments KF in Kotka and KR in Varkaus. Definition work was completed in a series of engineering manager interviews. For both department managers there was an initial email question list to fill in own data elements required and then a unified list was set for comments. Modifications were made according to discussions and initial requirement list is shown in *APPENDIX III*. As KR and KF design department managers were interviewed on data element requirements, project relevant background information about department business requirements was gathered. The target was defined as:

"…a more flexible data transfer between design systems. We need to have tested and proofed procedures especially when a proposal project becomes a delivery project. It is essential to think about subcontractor engineering offices too when it comes to data exchange between systems. Also, there can be different project structures within the delivery project: one department may want to use different data structure even when the project is a common one between all departments. You have to be careful which data elements to integrate." (Nisula 2012)

Design environment in Andritz Oy today has both internal and external requirements that need to be considered when starting an integration definition work. Interviews with design department managers were formatted to cover these requirements as good as possible. The list of data elements required is stressing on process values to be transferred to pipework design as the task was initialized. Also some values from calculation were seen important too: pipe area, calculation temperature and pressure were added to list.

6.4. Moving forward

Project results are presented to engineering department management in two parts. Technical data of pipework data element list is taken in use in inter-company data exchange as soon as it is validated by PSK and tested in suitable project. This requires co-operation with one or many subcontracting engineering offices. Luckily many of Andritz Oy’s most commonly used pipework detail engineering subcontractors are involved in PSK 59/9 project. It is also anticipated, that the data element list requires more testing and updates than can be completed during the period of this thesis work. Secondly, this thesis work is given to Andritz Oy use as it is released. It can be used as development project supporting documentation.

As the focus of development work was set on the co-operation with pipework detail design involved companies, the discussion was taken over to THTH Tools work group which was seen as suitable forum to raise a question of co-operation in this field.

7. Case 2 - PSK 59/9 Pipework data elements

7.1. Background

There are some basic notions what comes to usability of a pipework data standard. As always each standard is created according to the standardization group requirements and there is no theoretical possibility to create a data definition to suite all needs and software requirements. The approach to pipework design differs from one design discipline to another. In addition other business systems (sales configurators, ERP, material management, CRM, purchasing tools etc.) store some pipework data. When integrating data between systems one should always know the working procedure and data master location for each data element. Otherwise integration runs into duplicate data problems and if the working procedures are not clear there is a risk of running initial data over changed values.

When creating a standard for pipework data structure one must also keep in mind that the data elements may need some updating. It is not a rare case that new elements need to be added to standard making the implementation a non-standard one. Any usable pipework data model should be defined in a way, that adding new elements is possible. And like Bronsvoort et. al. (2010) noted there are more possibilities to use data models than Andritz Oy is primarily aiming at.

Considering the connections Andritz Oy has to global design community and project delivery possibilities of commonly recognized data exchange and definition standards must be studied. There are many standards to describe pipework data structure and data exchange between design, engineering and data management systems. These standards normally define two areas: structure of the design data or rules for data transfer methods.

Andritz Oy has also a long history in participating in standardization work (SFS) and development organizations (for ex. THTH ry). Comparing the pipework data structure work requirements and Andritz Oy current project environment to this background it seems obvious this is a development work that cannot be completed without strong connection to other companies and organizations. It was a lucky co-incidence for this development project there was an active discussion forum available in THTH Tools work group to start the co-operation discussion with key partners.

In the current global business world the design of a pulp mill would be impossible without the influence of many international standards and regulations. There are a number of local and international piping standards and requirements to be followed. The standardization work brings the engineering offices and plant delivering companies together. It is without a doubt the basis of co-operation discussion when starting a data structure discussion. From Andritz Oy point of view, company business model is dependent on international operation. Standardization dependency is partially driven by the customer but it is also enhanced by company itself as an internal procedure. Commonly recognized pipework standards make a solid starting point in discussion with customers and co-operative companies. As Karandikar and Nidamarthi (2005) state in their study for ABB, unifying the standards within the company operation is essential for global engineering network success.

In business in general the main question in standardization versus design operations is how thoroughly each company should follow the standardizations and to which state one should develop own rules of operations. As an example the data structure for pipework described by ISO 15926 is a good starting point for pipework data structure work as it is a widely recognized standard. The backside of a global standard is the usability in real life. No pipework data element definition can cover all the tricks of a trade for all industries. It is fairly safe to say it cannot do that for any single company alone. Localization is needed since the requirements both between and within companies varies a lot. Different industries want to manage different data. For example one could assume comparing pharmaceutical industry piping with power boiler piping would bring out totally different requirements for pipework data. Some basic pipework data elements will be the same, naturally.

One way to make inter-company co-operation in data element level better is to bind the common software vendors to follow the rules and regulation better. Today each software vendor manages the data in their own way. ISO 15926 compatibility is a term often heard from software vendors, but so far the results of this development have been more or less adapters exporting pipework data into ISO 15926 compatible XML format. As this thesis work is written no software vendor is actually known to implement ISO 15926 or any other defined structure inside their system as the basic pipework data structure. This may be a far cry in future too as many design systems are moving into format which allows more tailoring. Better adaptable systems are easier to sell and tailoring them is faster for new customers.

Pipework data structure is formed as a mixture of many outside and company-bound requirements. There is a lot of influence from business environment as no company is an island in the sea of global plant delivery. What comes to designing a pipework data structure for Andritz Oy, an optimum mixture of standardized and self-defined data elements is set to be found in the development project described in this thesis work. This is the basis of efficient plant delivery. (Ma & Hadi 2012)

Inter-company co-operation sets some boundaries for this development project. Project operations and results needs to be in line with the Andritz Oy co-operation requirements. Global aspect has to be acknowledged and key partners must be involved. On the other hand it gives good starting point to begin the discussion with the key partners: pulp and paper industry is relatively small circles in Finland. To ensure that the new development work is implemented the software vendors must be contacted (see *Diagram 2*).

7.2. Collaboration

Group study of the thesis work was completed in a form of inter-company co-operation project between Andritz Oy and engineering companies. Co-operation was initiated by THTH ry (Teollisuuden hajautetun tiedonhallinnan yhdistys THTH ry) where author operates as a chairman of Tools work group. (THTH ry 2012) This group aims to exchange experiences and knowledge on design tools and to find possibilities for co-operative development. Pipework data structure definition was the first common development project started by THTH Tools work group.

THTH Tools work group is an information exchange and development group target of which is to create knowledge for participants from the software point of view. This differs much from the basics of many other co-operation formats as many groups include software vendors or are directly software company related task forces, for example user groups. THTH Tools work group participants in 2012 meetings have been following companies: Andritz, Foster Wheeler Energia, Metso Power, Neste Jacobs, Pöyry, SWECO, YIT, CTS, UPM, and Outotec. All of which are recognized engineering companies with system development operations.

As stated in previous chapter, the link between pipework data structure development project and THTH Tools work group was a matter of good timing. In early 2012 the work group was discussing possible development ideas. The issue of unified pipework data model had been a talking topic for some time. Mostly this was a discussion of pulp and paper sector companies. In the beginning of discussion it was seen, that this development should also include other industries.

Practical approach for this work was discussed within the group and co-operation with PSK Standards Association (Prosessiteollisuuden StandardoimisKeskus) was seen as good option to study. PSK was contacted and workgroup PSK 59/9 founded in February 9th in the first standardization work group meeting. Participants were more or less the same companies, who had ignited the development project for common pipework data structure. Target was set to study the earlier pipework standards by PSK, search what is available globally (especially ISO) and define the approach or the new development work. Andritz Oy has a long history with this standards organization and work has resulted many new standards and instructions during the years. In the field of piping PSK has completed a good and recognized set of EN (Euro Norm) pipe specifications that are widely used in pulp and paper industry in Finland and globally.

As the field of known standards was studied the standardization work group (later 59/9 group) noticed there was usable pipe data model standards available (ISO 15926 and PSK 5967), but they did not completely match the need of the 59/9 participant companies. As described in Mun & Yang's (2009) article ISO 15926 is a globally recognized approach to define the plant data and it sets a good background for a line of rule sets, but 59/9 group did not find it complete. Many practical attributes were found missing. However, it is a good starting point for further development and it was considered as best way to link the new development work to any known standard or data element list.

PSK 5967 is standard that defines the classes, sub-classes and their relations for piping information structure used in XML data transfer. It belongs to a series of standards that defines the system independent XML interface. Comparing to other data formats (Wiesner et.al. 2010) XML is practically perhaps the best way to present the transferred data, but the 59/9 group found it difficult to match the PSK 5967 standard with uprising everyday needs. Main issue in this was the fact, that PSK 5967 combines the data elements definition with the data presentation definition. Analyzing the initial request of 59/9 involved companies main focus was on defining the common data element list and not limiting it to a certain data presentation format (XML).

As the project got along and basics of known standards were studied 59/9 group defined more precise goals for the work. Standard PSK 5981 is defined for the transmission of equipment data related to engineering, construction, operation and maintenance of a production plant. This standard had been created for the needs of plant equipment data transfer. 59/9 group decided to update the data element list with pipework data elements and that way the same standard could be widened to match new usage instead of creating a new one. Standard PSK 5968 was completed to define the newly created data element list from pipework point of view. It was also seen important to include an instruction of usage for anyone using the standard. This was especially aimed for software vendors so they could better prepare the needed data adapters for pipework data transfer.

Each 59/9 participating company gathered their own pipework data element requirement list and came back with a suggestion list for new data elements for renewed 5981. A common work list was discussed, evaluated and too into comment round. As this thesis work is written, the common data element list standard PSK 5981 is about to be sent to PSK participant companies for comments and proofing.

7.3. Data element list

Appendix IV describes the data element list as it was written after the PSK 59/9 group discussion. Data element list in Appendix IV is presented from Andritz Oy point of view. The original required elements are on the left side of sheet. Data elements marked green were found in PSK 5981. Yellow ones were not found but added to the list as new data elements. A discussion was held for each new element and their format and description was discussed. Orange elements mark a compatibility issue between Andritz Oy initial requirement and the resulting data element. In case of Design temperature the further study clarified, that the needed element was actually Upper limit design temperature or Maximum design temperature. Big part of the 59/9 group work was clarifying and defining what exactly is meant by the data elements.

SUUNNITTELU-LÄMPÖTILA	Design temperature		7005	Suunnittelulämpötila max	Upper limit design temperature
SUUNNITTELUPAINE	Design pressure		5778	Suunnittelupaine	Design pressure
SUUNNITTELU-VIRTAUS	Design flow		-	Suunnitteluvirtaus	Design flow

Diagram 6. Examples of pipework of data element list markings.

Majority of existing data elements were found in ISO 15926 and the ISO 15926 element number was added to list. Only two of eleven new elements were found in ISO 15926 which indicates that there was a need for a new list. If there was no link to ISO 15926, field was marked with minus. This way it was known, that the link connection was checked.

Many of the Andritz Oy requirements were recognized by other companies too, but some were not seen fit to be included in a common standard. For example calculation temperature and calculation pressure were seen to be of Andritz Oy own origin. Those are used commonly within Andritz Oy, but that data seldom leaves the company. For 59/9 work group the standardization work was good practice in understanding the procedures of rivaling and co-operative companies. This kind of data element level benchmarking was seen very interesting and raised many new questions about other design area data element.

Defining the data elements was very challenging task. In a field of pipework design there still is a number of different interpretations about the common data elements. This problem also presented by Barley et.al. (2011) was exactly what the group wanted to mitigate by using a lot of time for defining data elements. In many cases the goal was found by finding the lowest common denominator in data element definition. This way each company could ensure that the core value of the data element is transferred and the local usage can internally be combined to another use. For example System code is data element that could be used locally in describing any group the pipeline belongs to. Instead of defining system codes for process group, scope of delivery group and hazardous media group there is one system code element that can be used to any of these cases.

Definition of pipework insulation also raised a lot of discussion. In pipeline lists the insulation thickness has always been a significant attribute. But with data element list the thickness is not always available. Pipes can be insulted for many purposes. There can be thermal insulation because of possibility of pipe media being frozen, there can be safety insulation preventing plant operators from burning themselves in hot pipes and a number of other insulation reasons. Not all of them carry the thickness information. For this reason the 59/9 group decided to mark the insulation with Insulation purpose, which would tell the type of insulation and Insulation specification, which would specify the technical details of the insulation, for example the thickness. Internally each company will most likely continue using insulation thickness as defined attribute in their own lists, but for inter-company data exchange it could not be defined as clearly as was wanted.

The link between the new standard 5968 and software vendors was seen very important, because the otherwise the new standard could end up as only a new requirement list, which would have no practical value. PSK 59/9 group decided to create an instruction for standard usage. A great number of plant design software vendors were contacted. These include AVEVA, Bentley, Siemens, Intergraph, Cadmatic and CAD-Q. Each company was given the description of the work done and a question what information is needed to be able to create an adapter that would import and export this data.

8. Results

8.1. Conclusions

Data structure definition for pipework was a demanding task. The field of pipework data is not unified even within one industry sector and companies can have very different views to technically same issues. Driving force for this kind of development is the benefit of co-operation in the same geological area or business sector. Many operators are attached to each other in global engineering environment. To be able to define the requirements of pipework data structure or the data elements it is very important to limit the scope as clearly as possible. The old saying applies in this case too: one should not try eating an elephant in one piece.

Separating the pipework data structure definition as internal development project away from technical design tool integration project was a good call. The challenge with many design systems today is the oversized emphasis on developing better and faster tools whereas the structure of data is either too strongly defined or left clearly undefined. On the other hand as long as there is no commonly recognized set of pipework data elements there cannot be a common set of attributes for pipework. As software vendors keep close look on the possibilities to sell more tailoring of their products, personally I do not see this kind of common data structure development happening in near future either. Key for integration is to set the rules between design system user companies.

I found 59/9 group work very efficient and interesting way to co-operate. As the standardization work is yet to be finished, it is impossible to state all the benefits of the newly created standard. But starting from the known ones, the primary goal of THTH Tools work group was already reached as the involved companies created a list of commonly recognized data elements to be transferred between participants. This means that in practice an engineering office can expect the pipeline data from Andritz Oy or Metso to follow the same format and notions each time. Full compatibility cannot be reached ever, but if 90 per cent of data elements would be unified there would be a lot less adapter customization work and a smaller risk of errors.

There are still some expectations what comes to co-operation with software vendors. From history it is known that big software companies like Autodesk or Siemens are a bit reluctant to approve any changes from minor industry sectors. Strength in PSK standardization work in this case is the common front of all companies sending the message to vendors. If the internal data structure of each pipework design system is not to be changed, a good co-operation in creating the needed adapter for data transfer could be as good. Pressuring vendors in discussion with users and other vendors will drive this work forward.

8.2. Essential results

It can be said, that in the beginning of this thesis work the research problems were set to guide the study into too wide approach towards the subject. As the work went along the problems needed to be addressed more tightly and defined more clearly. Pipework design is a wide field of expertise where each design discipline and connected operations require a different but partly overlapping set of attributes for their own use. Data structure should always be defined according to the requirement of each discipline. For process design to 3D pipework detail design the required data elements are defined in Appendix IV.

Qualitative study of internal data elements among design departments returned a list of data elements that could be trusted to be departments' actual needs in the given case of pipework data transfer. Combined list represented the knowledge of the data gathering moment. Group study, however, pointed out many data elements in the internal list were not fully supported or understood by the co-operative engineering companies. As Appendix IV shows most of the data elements initially required by Andrtiz Oy needed more clarification and for example insulation representation in data element list was completely modified compared to initial list. This indicates that the design departments have the practical knowledge of managing the data needed in 3D plant design, but the representation format is not completely clear between companies. This was initially seen as one of the biggest challenges between companies when starting this thesis work and as results of the study fix some of these problems the study itself can be held successful.

It was noted in work, that a study of disciplines involved should be completed before the data structure definition is started. This requires clarifying the data flow process to at least the basics level and finding the master location for each data element. For the studied environment the design departments carry most of the responsibility for managing pipework data. From Andritz Oy point of view subcontracting engineering offices are in key position too, as the majority of detail pipework design is completed outside Andritz Oy offices. Subcontracting offices should be involved closely in system integration for this reason. In the current field of design systems there is not much the software vendors initially can or will give to co-operation. Therefor more resources should be focused on inter-company co-operation of defining clearer data structures and procedures. There is still a lot to do in the field of design data structures in pipework design and other design areas.

"How should pipework data structure be defined in engineering system integration?"

This thesis work brings out the following three facts on the main research problem:

1. Pipework data structure must be as clear as possible. There should be no room for any interpretation in data. Common understanding is reached by discussion of target industry area co-operators and by defining data elements as usable as possible for their needs. Data must not be defined only by the use purpose, because use cases differ. Usability of defined data elements is ensured when data element is either so simply described it cannot be mistaken for another element or so general it can be used in many cases, for example System code.

2. There must be a simplified list of data elements, which are validated in your design environment to be used both inside internal company operations and (global) design environment. Data element list main focus is on the data transfer and there can be design system internal modifications and additions to list as long as the exported format is unified. This must be noted when creating adapters.

3. Selected data structure should be as compatible as possible towards the industry data management standards and possible de facto practices. If creating a new data element model links to existing ones is a big benefit when seeking for a wider approval for the data structure.

8.3. Practical implications

In general the development project and this thesis work found the answers to questions set by the business. The practical result, data element list, was found suitable for the Andritz Oy business environment and need to unify the operation with key co-operative engineering companies was met. Even with the lack of knowledge how connection to software vendors will turn out, the work completed in 59/9 work group can be categorized as a success.

In general given results of thesis work were not surprising. The development project and thesis work study were completed with few new revelations of business area or co-operation between companies. On the other hand the target of the study was not to find new forms of operation but to clarify and define better rules for existing ones. This goal was reached with common data element standard.

The data element list is usable in Andritz Oy, but the there are differences between design departments. Pipework data element list is compatible with KF division where Fiberline, Caustization and Wood handling departments operate mostly in low pressured process piping environment. Requirements from KR boiler area have some fields of pipework data still uncovered due to higher demands in validating and calculating the pipes, but on the other hand those pipework data elements are more commonly used within the company and direct transfer outside Andritz Oy borders is not common. Internally in Andritz Oy the data transfer is not as big of a challenge as it is between companies. Design culture and operation rules travel easier within the company than between two companies. For special internal transfer cases there are normally transfer tools, with specialized tailored data structure. Need for a common data structure in these cases is small.

Development project for pipework data elements was carried out in a small but active group within Andritz Oy and a competent task force at 59/9 work group. The voice of Andrtiz Oy was heard in decision making, there was active co-operation and practical results for the work are usable. The only operator missing from any of the project teams was an external data expert, who could have given a more academic approach to data management. This could have speeded up the definition work. Co-operation with universities of this field is to be considered in future projects.

Pipework data structure development will be continued within Andritz Oy. In this project the user case was link between process and 3D plant design, but piping data requirements for data transfer to calculation, manufacturing and purchasing could bring out new element requires. The data element list will be updated eventually as these requirements surface. Co-operation with 59/9 work group companies and other participants must be re-evaluated then. In-house the list of pipework data elements can be extended with internal data elements if required.

PSK 5968 standard for pipework data structure is on comment round as this is written. Wider use of the standard depends next on how well it fits the need of companies. It is good idea to keep also eye on the development of ISO 15926 and other suitable connecting standards. Their development has more influence in software vendors and international agreements than local PSK standard, but meanwhile the PSK 5968 is more suitable for 59/9 companies’ needs.

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APPENDIX I, Project Requirements

Business requirements

Num	Date	By	Name	Description	Notes
1	17.11.2011	MWE	Complexity	Structure must be simple and understandable.	
2	17.11.2011	MWE	Standards	All commonly used pipework standards must be considered. Data structure must be same for all standards.	EN, ASME, SFS, SSG, JIS etc.
3	14.12.2011	HLÄ	High pressure pipes	High pressure piping requirements must be covered.	
4	19.11.2011	SNI	Scope of pipework	Data structure must cover the whole Andritz pipework scope of delivery.	
5	10.1.2012	SNI	Subcontractors	Pipework data element list must be open for engineering offices and it must be usable in subcontracting offices too.	

Technical requirements

Num	Date	By	Name	Description	Notes
1	17.11.2011	MWE	Softwares	Data structure must be usable with tool versions Comos 9.1 and PDMS 12.1.SP2.	
2	14.12.2011	HLÄ	Disciplines	Elements must be found in both process and 3D plant design environment.	
3	10.1.2012	MWE	Compatibility	ISO 15926 compatibility or equivalent.	Can be according to some other wee known standard too.
4	10.1.2012	MWE	Hierarchies	Data elements must apply to PIPEs, not pipe branch or components.	

APPENDIX II, Schedule of project plan

Num	Name	Desc	Resp.	Due date	Compl	Notes
1	Project team	Define project team	MWE	11/2011	100 %	
2	Requirement gathering	Gather requirements from customers.	MWE	11/2011	100 %	
3	Project definition	Define project targets and schedule	MWE	11/2011	100 %	
4	Initial internal discussion	Discussion with Nisula and Lähdeniemi – targets for the work.	MWE	12/2011	100 %	
5	Internal data elements query	Data element lists gathered.	MWE	01/2012	100 %	
6	Internal result formatting and analysis	Data element lists combined, overlapping items processed.	MWE	01/2012	100 %	
7	Discussion	Combined list presented and comments gathered.	MWE	01/2012	100 %	
8	Internal list completion	Internal list completed.	MWE	01/2012	100 %	
9	Co-operation definition	Co-operation companies selected and contacted.	MWE	01/2012	100 %	
10	Company discussion and comments	Discussion and comments to internal list. Company specific results gathered.	MWE	01/2012	100 %	
11	Result analysis	Results gathered together and processed to comment list.	MWE	02/2012	100 %	
12	Company comments	Comments gathered from participating companies.	MWE	02/2012	50 %	
13	Initial co-operation list	Completed and commented list completed.	MWE	02/2012	30 %	
14	Internal validation and comments	Co-operation list comments from Nisula and Lähdeniemi.	MWE	08/2012	0 %	Commenting requires time.
15	Complete list	List completed for Andritz use.	MWE	09/2012	0 %	Continued with co-operation work –> New elements?
16	Implementation	Data element list taken in use in Comos-PDMS data transfer tools.	MWE	02/2013		

Appendix III, Initial pipework data element list

Requirements	
Attribuutti	**Translation**
ERISTYS	Insulation
ERISTYSPAKSUUS	Insulation thickness
ERISTYSTYYPPI	Insulation type
HALKAISIJA	Diameter
JÄRJESTELMÄKOODI	System code
KOEPAINE	Test pressure
KÄYTTÖLÄMPÖTILA	Operation temperature
KÄYTTÖLÄMPÖTILA MAX	Upper limit operation temperature
KÄYTTÖPAINE	Operation pressure
KÄYTTÖPAINE MAX	Upper limit operation pressure
KÄYTTÖTARKOITUS	Purpose Description
KÄYTTÖVIRTAUS	Operation flow
LASKENTALÄMPÖTILA	Calculation temparature
LASKENTAPAINE	Calculation pressure
LÄHTÖREFERENSSI	From
MATERIAALI	Material
NIMELLISKOKO DN	Nominal size
PAINELUOKKA	NP
PED-LUOKKA	PED class
PINTA-ALA	Area
PITOISUUS	Density
PROSESSIAINE	Media / Fluid??
PUTKILUOKKA	Spec
PUTKIPOSITIO	Pipe position
PÄÄTEREFERENSSI	To
SAATTOTYYPPI	Tracing
SAKEUS	Consistency
SEINÄMÄN PAKSUUS	Wall thickness
SISÄHALKAISIJA	Inside diameter
STANDARDI	Standard
SUUNNITTELULÄMPÖTILA	Design temperature
SUUNNITTELUPAINE	Design pressure
SUUNNITTELUVIRTAUS	Design flow
TOIMITTAJA	Supplier
ULKOHALKAISIJA	Outside diameter
VIRTAUS	Flow
VIRTAUSNOPEUS	Flow rate

Appendix IV, Completed pipework data element list

Requirements			**PSK 5981 equivalency**				
Attribuutti	**Translation**		**ISO 15926-4**	**Tietoelementin nimi**	**Data element name**	**Kuvaus tai esimerkkitäyttö**	**Description in ISO 15926-4 or example fulfilling**
ERISTYS	Insulation		-	Eristystarkoitus	Insulation purpose	Lämpö-, kylmä-, kondenssi-, suoja- tai paloeristys	Heat-, cold-, condensate-, safety- or fireinsulation
ERISTYSPAKSUUS	Insulation thickness						
ERISTYSTYYPPI	Insulation type		-	Eristysspesifikaatio	Insulation specification	SFS 3977 eristyspaksuustaulukko B.2	SFS 3977 insulation thickness table B.2
HALKAISIJA	Diameter		5789	Halkaisija	Diameter	-	Intercept made by the circumference on a straight line through the centre of a circle.
JÄRJESTELMÄKOODI	System code		-	Osaprosessi	Sub-process	Tiedonsiirrossa tarvittava vapaasti valittava koodi, joka yksilöi tietyn prosessin osan. Esimerkiksi höyryputkisto, jonka koodi on H251.	Freely selectable code which describes and defines certain part of the process in the datatransfer. For example steam piping (code H251)
KOEPAINE	Test pressure		6887	Koepaine	Test pressure		A pressure to which an object should be subjected to test for leakage and structural integrity.
KÄYTTÖLÄMPÖTILA	Operation temperature		6423	Käyttölämpötila	Operating temperature	Lämpötila, jossa kohteen odotetaan toimivan	A temperature under which an object is supposed to work.
KÄYTTÖLÄMPÖTILA MAX	Upper limit operation temperature		7034	Käyttölämpötila max	Upper limit operating temperature		
KÄYTTÖPAINE	Operation pressure		6421	Käyttöpaine	Operating pressure		A pressure under which an object is supposed to work.
KÄYTTÖPAINE MAX	Upper limit operation pressure		7033	Käyttöpaine max	Upper limit operating pressure		
KÄYTTÖTARKOITUS	Purpose Description		4133	Käyttötarkoitus	Purpose description		

KÄYTTÖVIRTAUS	Operation flow		-	Virtaus norm	Normal flow	Käyttötilanteessa oleva virtaus	
LASKENTALÄMPÖ-TILA	Calculation temperature						
LASKENTAPAINE	Calculation pressure						
LÄHTÖREFERENSSI	From		-	Mistä	From	Putkilinjan alkamiskohta	The start of the pipeline
MATERIAALI	Material		-	Materiaali	Material		
NIMELLISKOKO DN	Nominal size		6359	Nimelliskoko	Nominal diameter	Esimerkiksi DN 250	A diameter which is an expected (theoretical/as designed) diameter.
PAINELUOKKA	NP		-	Paineluokka	Pressure rating		
PED-LUOKKA	PED class		-	PED -luokka	PED class		
PINTA-ALA	Area		5577	Pinta-ala	Area	-	A = double integral (dx.dy) where x and y are cartesian coordinates
PITOISUUS	Density		5696	Pitoisuus	Concentration	Esimerkiksi 10 % rikkihappo	For instance 10 % sulfuric acic
PROSESSIAINE	Media / Fluid??		1829	Prosessiaine	Fluid	Aine, joka voi virrata	A compound which is able to flow.
PUTKILUOKKA	Spec		-	Putkiluokka	Pipe class	Putkiluokalla tarkoitetaan samaan putkilinjaan soveltuvien putkien ja putkenosien valikoimaa, jossa mitat ja materiaalit on määritetty.	A pipe class denotes the selection of such pipes and fittings as may be used for one and the same pipeline, in which selection their dimensions and materials have been defined.
PUTKIPOSITIO	Pipe position		4031	Putkilinjatunnus	Line label	Putkilinjan koko koodi, katso PSK 3603	A tag name that is intended to reference to pipeline
PÄÄTEREFERENSSI	To		-	Mihin	To	Putkilinjan päättymiskohta	The end of the pipeline
SAATTOTYYPPI	Tracing		-	Saattotyyppi	Tracing type	Esimerkiksi kuumaöljy, sähkö tai höyry	
			-	Saattolämpötila	Tracing temperature		
SAKEUS	Consistency		-	Sakeus	Consistency	Veteen sekoitetun selluloosamassan massaprosenttinen pitoisuus.	

SEINÄMÄN PAKSUUS	Wall thickness		7141	Seinämän paksuus	Wall thickness		A thickness which is the thickness of the part of an object normally called wall: - Wall thickness of a pipe, - thickness of a building wall, etc.
SISÄHALKAISIJA	Inside diameter			Sisähalkaisija	Inner diameter		
STANDARDI	Standard		4165	Standardi	Standard	-	An information that contains prescriptive rules, guidelines or characteristics of activities or their result
SUUNNITTELU-LÄMPÖTILA	Design temperature		7005	Suunnittelulämpötila max	Upper limit design temperature		A temperature that an object is designed to withstand.
SUUNNITTELUPAINE	Design pressure		5778	Suunnittelupaine	Design pressure		A pressure that an object is designed to withstand.
SUUNNITTELU-VIRTAUS	Design flow		-	Suunnitteluvirtaus	Design flow	Putken mitoitusvirtaus.	Dimensioning flow of a pipe
TOIMITTAJA	Supplier		4186	Toimittaja	Supplier name	Kohteen toimittaja	A name of a person or organisation that had or has or is intended to have the role of supplier in a transaction.
ULKOHALKAISIJA	Outside diameter		-	Ulkohalkaisija	Outer diameter		
VIRTAUS	Flow						
VIRTAUSNOPEUS	Flow rate		5926	Virtausnopeus	Flow rate		

(PSK 59/9, referenced 18.10.2012)