THESIS - **BACHELOR'S DEGREE PROGRAMME**
TECHNOLOGY, COMMUNICATION AND TRANSPORT

GLOBAL MECHANICAL DRAWING INSTRUCTIONS

Normet Oy

Author: Mikko Markkinen

SAVONIA UNIVERSITY OF APPLIED SCIENCES

THESIS
Abstract

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Abstract

The client for this thesis was Normet Oy, which is a manufacturer and a service-provider for a heavy mining and tunneling machinery. The objective of this project was to create new drawing instructions for Equipment Business Line while considering the global design and manufacturing environment. In addition, the scope was to develop administration, notation and consideration of different languages.

The work was started with a search of information and material from web sources, books and international standards. Furthermore, the employees of the client were consulted to find out more of the possible problems in the system. When enough information was collected, the structure for the new drawing instructions and a template was formed. In addition, a few ideas sprouted were refined for future implementation, yet many of the ideas that came out during the project were left to a concept phase to be dealt with later. Finally, when the instructions were ready, they were commented by specialists working at Normet. The instructions were edited according to their feedback followed by an approval for implementation.

The project reached its goals and the new drawing instructions were included in the new mechanical design instructions, which clarifies and standardizes mechanical drawings and design in Normet and facilitates translations to many languages. The work continues with an implementation phase, which includes training of engineers and insertion of new features to the system.

Keywords
technical drawing, instructions, development Project

SAVONIA-AMMATTIKORKEAKOULU

OPINNÄYTETYÖ
Tiivistelmä

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Toimeksiantaja/Yhteistyökumppani(t) Normet Oy	

Tiivistelmä

Työn tilaajana toimi Normet Oy, joka on Iisalmelta maailmalle ponnistanut kaivoskoneita ja palveluita tuottava yritys. Työn tavoite oli laatia piirustusohje laiteliiketoiminnan yksikölle ottaen huomioon globaali suunnittelu ja tuotantoympäristö ja lisäksi kehittää nimikeattribuuttien hallintaa, näkyvyyttä ja eri kielien huomioon ottamista.

Työ aloitettiin tiedon ja aineiston etsimisellä verkkolähteistä, kirjoista ja standardeista. Lisäksi Normetin työntekijöiden kanssa keskusteltiin piirustusohjeen sisällöstä. Kun tietoa oli saatu kerättyä tarpeeksi, alettiin tietoa jäsennellä piirustusohjeiden ja piirustuspohjan muodostamiseksi. Lisäksi joitakin tiedonhankinnan aikana saatuja ideoita jalostettiin käyttöönotettavaksi, mutta useita ideoita päätettiin jättää konseptitasolle myöhäisempää käsittelyä varten. Sen jälkeen, kun ohje oli valmis, sitä kierrätettiin Normetin asiantuntijoilla ja ohjeeseen tehtiin korjauksia heiltä saadun palautteen mukaan, jonka jälkeen työ voitiin hyväksyä käyttöön.

Projektissa päästiin tavoitteeseen ja piirustusohje laadittiin uuden suunnitteluohjeen yhteyteen, joka selkiyttää ja yhdenmukaistaa Normetin teknisiä piirustuksia ja helpottaa niiden kääntämistä eri kielille. Työ jatkuu ohjeen käyttöönotolla, johon sisältyy henkilöstön kouluttamista ja uusien ominaisuuksien lisäämistä järjestelmään.

Avainsanat
tekninen piirtäminen, ohjeet, kehitysprojekti

PREFACE

This thesis has been produced for Normet Oy, Equipment Business Line, R&D Department.

I want to thank the personnel of Normet Oy for great collaboration and for offering a fantastic subject for my thesis. This work will give me great tools and knowledge for future challenges. Special thanks to Project Manager Tero Kaatrasalo from Normet Oy for acting as a mentor in this thesis project.

In addition, I want to thank the representative of Savonia University of Applied Sciences and th thesis instructor Lecturer Anssi Suhonen.

Sincerely yours,

In Kuopio 7 April 2020

Mikko Markkinen

CONTENTS

TERMS AND ABBREVIATIONS

CAD	Computer Aided Design
CEN	European Committee for Standardization (EN)
Client	Refers to Normet Oy
DFMA	Design For Manufacturing and Assembly
DIN	Deutsches Institut für Normung, German Standardizing Institute
Drawing	Refers to technical drawings made from mechanical elements. Mechanical drawings.
GPS	Geometrical product specification
GCCT	Ground Control & Construction Technology
HSQE	Health, Safety, Quality, Environment
ISO	International Organization for Standardization
MBD	Model Based Definition 3.1
MDI	Mechanical Design Instructions
NPD	New Product Development
PDM	Product Data Management
PLM	Product Lifecycle Management
PMI	Product and Manufacturing Information
R&D	Research and Development
SFS	Suomen Standardisoimisliitto SFS ry, Finnish Standards Association
TBM	Tunnel Boring Machine
TPD	Technical Product Documentation

1 BACKGROUND AND PURPOSE

The purpose and objective of this thesis was to update the drawing instructions and templates of Normet Oy in order to meet the global development and manufacturing standards.

The client of this thesis was Normet Oy, Equipment Business Line, R&D Department. Normet is a fast-growing global company which is based in Iisalmi, Finland. Client has started to distribute development and manufacturing processes abroad and differences between Finnish and global drawing methods have started to cause issues such as unclarities with notes, dimensioning and manufacturing requirements. A more specific description of Normet's current drawing instructions and development can be read in the theory section of this document. The client is updating its design system during 2020 and upgrades brought by the system development will be taken into account in this thesis project and vice versa.

Unclarities with drawings take a significant amount of resources from manufacturing and design departments in Normet and subcontractors. In order to solve an unclarity, communication between Normet and subcontractor is required and time for the design engineer to orient on the problem and solve it. Communication can be tedious due to different time zones and languages. Therefore, it is important to standardize drawing production to minimize the number of flaws in drawings and ensure the same end-product quality regardless of where the drawing is produced and where it is used.

To make clients drawings more suitable for the global environment, drawing instructions must be created according to ISO TPD and GPS standards.

2 INTRODUCTION OF COMPANY

As mentioned earlier, Normet's first and largest unit is located in Iisalmi, where the majority of the equipment is designed and manufactured. In the same location, Peltosalmen Konepaja was founded in 1962. Through the variable years of growth and advancement, Normet has developed from a small workshop into a modern and a global company it is today. (1)

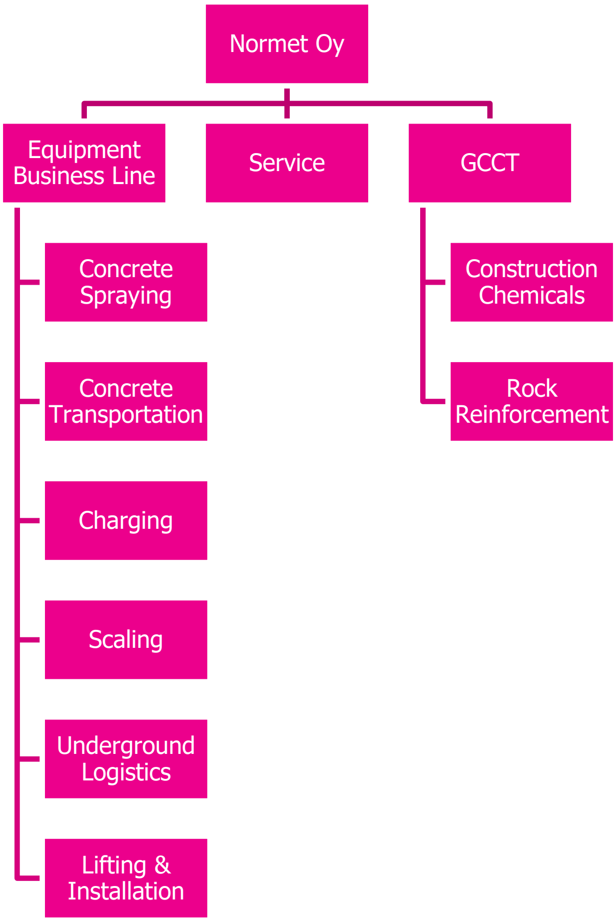


Figure 1 Normet Oy business lines & offering

Normet business lines consist of three different fields, all related to underground processes and machinery, which are demonstrated in Figure 1. Equipment Business contains all company fields related to mining and tunneling machinery. Service consists of spare parts supply, legacy upgrades, service agreements and machine rental operations. GCCT for example, focuses to concrete additives, ground water control, TBM additives and rock reinforcement. (1)

The safety and health are important values in Normet. Normet has committed to continuous development of HSQE and its principles.

As previously described, Normet is an international company and Normet offices have spread to over 30 countries and even more locations which are visualized in Figure 2**.** Business expansion to many sites enables close collaboration with customers and subcontractors. This project benefits greatly client's internationality since the information of different drawing procedures and standards is easily accessible inside the company.

Figure 2 Global presence of Normet Group Oy (2)

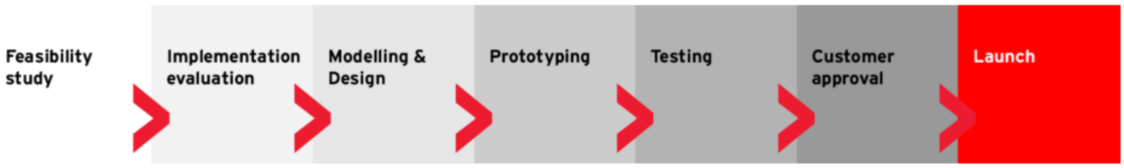


Figure 3 Flow chart of clients' research and development process of new product (3)

Normet has implemented a consistent new product development process called the Stage-Gate process. As pictured in Figure 3, it consists of seven stages which all must be approved before moving to the next one. This thesis focuses on the development of the Modelling & Design phase but the results achieved in this thesis affect practically to all stages of NPD touching the mechanical design and the manufacturing data, which is for example maintained by the maintenance design team. (3)

3 THEORY

3.1 Current CAD-system

Normet uses Autodesk Inventor 2017 as a main CAD-platform. It is integrated to Sovelia PLM-system through Autodesk Vault. Attributes for items are input into Sovelia-integration inside Inventor. The main workflow in Figure 4 remained untouched in this project, but it was necessary to add some new attributes in order to achieve the wanted outcome.

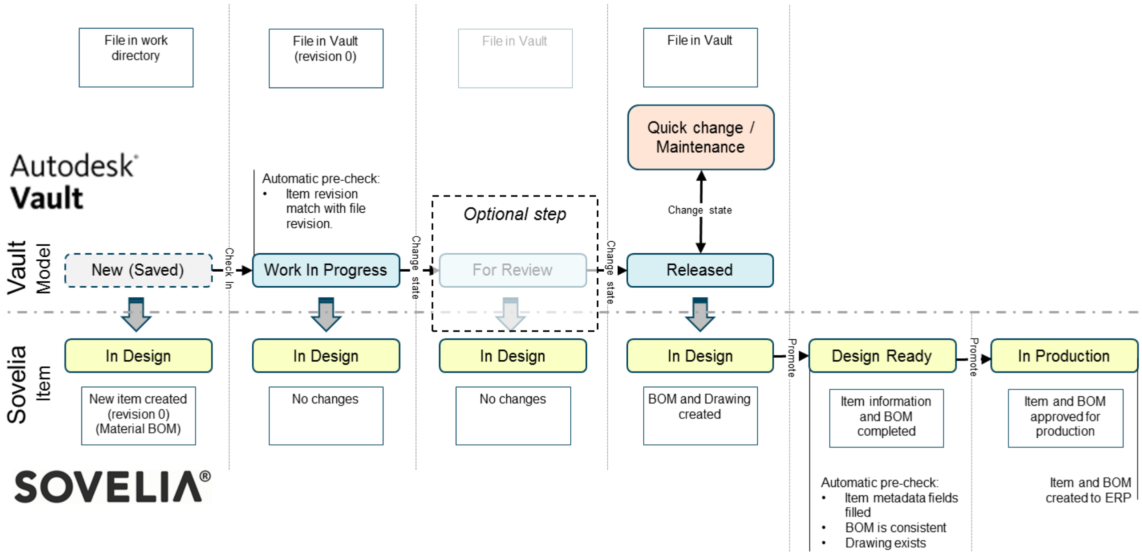


Figure 4 Workflow when creating new items

The system has a few drawbacks. The most important issue is the problem with item attributes included in the drawing. When the property value is changed in Sovelia it does not update to the drawing. Therefore, amount of data included in there must be kept as compact as possible in order to avoid inconsistencies in item attributes. Quite a lot of manual work is required to repair the incorrectly typed data. To edit a drawing, its state must be changed to quick-change to allow the update of the drawing to PDM. After that, the model and the drawing must be checked out. Then the correction can be done and after that the process goes the other way around. Check in must be done and then the file must be released. Sometimes drawing converter program does not work and drawing does not go to Sovelia. This should be checked individually because no prompt is sent to an engineer from a failed attempt. File state change operations can be usually done easily, but particularly with large assemblies, the operation can take time to complete. Therefore, all unnecessary state changes and drawing edits should be kept at minimum. This can be achieved with automation of item data input to the title block.

Although the current system is not ideal and has downsides, it enables a convenient way to mass-drive items to different states and replace them without going through every structure containing the item. That is a huge time-saver and makes Normet less susceptible to the problems of supplier chains. Items with identic connection interfaces can be easily replaced with an improved or cheaper product.

The client has created its own general tolerance standard NOR340 which summarizes the most common machine industry general tolerances into one document which is referred in the drawing to avoid selecting a list of standards for a particular item. Problem is that foreign subcontractors have accustomed to a model in which all the required data for manufacturing a part is included on a single drawing sheet. Normet uses a very simplified drawing template and recommends keeping drawings as simple as possible. Part lists and other instructions such as welding instructions come separately and those are not implied in drawings. The subcontractor might think that those are only informative appendices, not binding. The sufficiency of NOR340 according to global TPD and GPS standards is clarified in the chapter 5.2.

Developing markets and procedures must be always considered and therefore, drawing instructions follow the latest standards to be ahead of the game. By relying on international standards, drawings are more understandable around the globe.

Objective of this thesis is to search the best possible constraints and attributes for drawings. Other international companies have created their own policies and there might be some ideas which have not come into consideration at Normet. Subcontractors and Normet personnel were also consulted.

3.2 MBD

MBD is an alternate and more modern way to express the design intent. It uses 3d-objects which can be arbitrarily rotated and viewed from any angle on a computer screen and any wanted dimensions can be queried and obtained from model. The 3d-model can include PMI. For example, geometric tolerances, important dimension and datums. When specifications can be presented in the model, a traditional 2d-drawing loses its importance. It can be used alongside the model containing only a simplified notation or same specifications can be in the model and drawing and either can be used with the product data set to have fully constrained product specifications. Product specifications can be also defined only by the model like in Figure 5 (4)

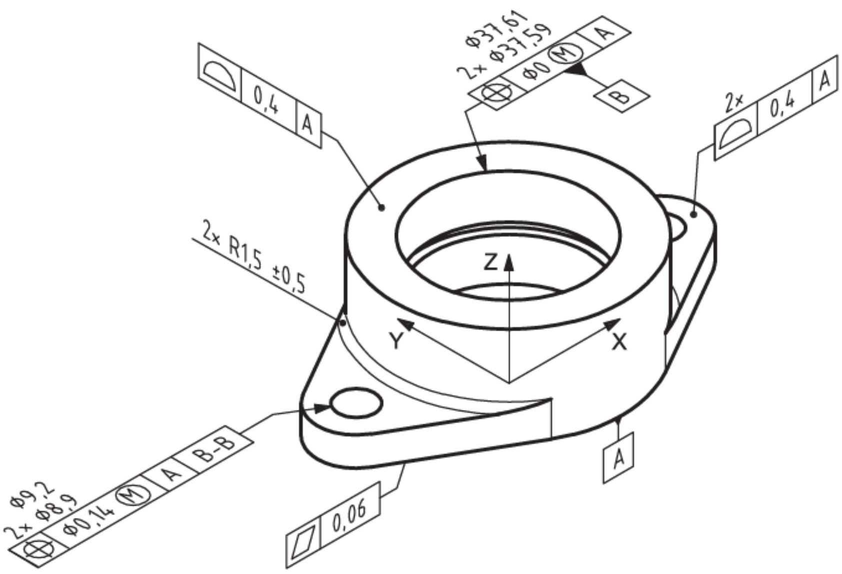


Figure 5 Example of MBD. This type of model does not need a drawing at all. (4)

Described method to define product specifications is specified in ISO 16792. There are many challenges to face before the client can start using this method. Tools used in MBD are built in CAD-system, but engineers are unfamiliar with methods and procedures adjoining MBD. Therefore, implementation requires lots of training. In addition, subcontractors are also unfamiliar with MBD and tools for sharing and viewing MBD-data requires a vast amount of development and research as well before this method can be even considered to be the main method of communicating design intent.

3.3 GPS

GPS is a unified method to define geometric properties of a product in a technical drawing. It is developed by ISO/TC 213-technical committee and contains over a hundred standards for different purposes. In some parts of the world, the term GD&T is more common but practically it refers to the same principles as GPS although it is based on a ASME Y 14.5 (5)

ISO 8015 is standard defining basic concepts and rules for GPS.

3.3.1 General & work-method-oriented tolerances

General tolerances are used to simplify drawings. If no general tolerances are in use, it practically signifies that all dimensions and shapes in the drawing must be toleranced by using standard deviation and geometric tolerances. When general tolerances are used, they can for example define deviations for all dimensions without tolerance, shape requirements for geometry and surface texture.

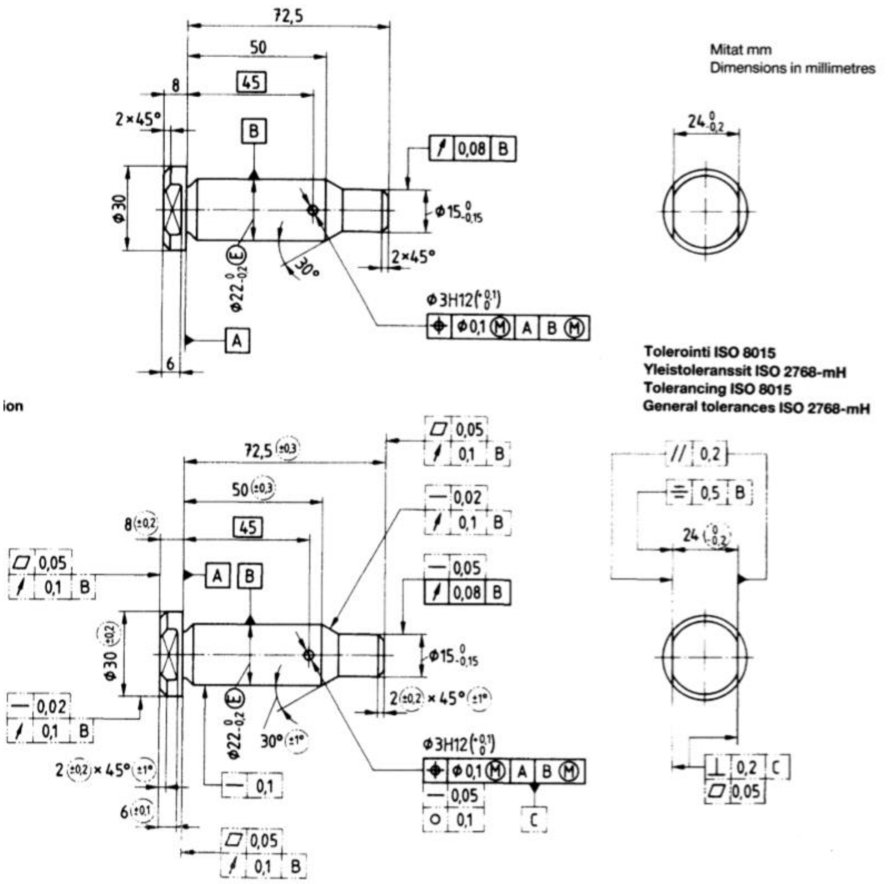


Figure 6 An example of possible simplification when ISO 2768 is applied. Properties marked with broken lines are defined with general tolerance e (6)

ISO 2768 is a tolerance that is mainly applied to different modes of machining, but it can be used to other manufacturing methods as well if precision applied manufacturing process can fit inside the specified limits without special methods. (7) (6)

The standard includes two parts. The first part defines tolerances for linear and angular dimensions without tolerances. The second part gives requirements for geometry which is not dimensioned at all. Without application of these tolerances all features in a part must have several tolerance indications to fully define the specifications feature has to have to match the design criteria. As pictured in Figure 6, the use of general tolerance saves engineer’s time and therefore, increases the productivity when there is no need to determine additional tolerances. The reading fluency of a drawing is improved when only the essential data for a product functionality is visible. (7) (6)

4 DEFINING

During the research, multiple development ideas emerged. Due to a vast field of different development areas, it was decided that this thesis only concentrates on the creation of new mechanical design instructions and particularly to the development of drawing instructions included in mechanical design instructions. Some methods and defining made in instructions are not practical without system changes and enhancements. The needed updates are listed in Appendix 3: Identified fields of development

In order to compile new instructions, a few decisions needed to be made. What new system properties are needed and does the client have the intent and resources to implement them? Instructions are a tool for the design workflow definition and therefore defined specifications must be integrated seamlessly to the design system. The coming system update gives the possibility to implement certain updates and that chance should be utilized.

In the future, it is possible that 2d-technical drawings become obsolete and the machine industry will start to use MBD. When implemented properly and ensured that all subcontractors have the proper equipment and knowledge to utilize it, MBD is a far more cost-efficient and demonstrative way to represent design intent and manufacturing data. It enables a far better understanding of the object than traditional 2d-drawings. Instructions should be driving the design workflow towards MBD and that should be noted when defining attributes in a drawing, which should be decreased slowly as time passes until no drawing is needed. A more detailed description can be found in chapter 3.2

In addition, this thesis compiles the development concepts that appeared during the research and considers briefly different approaches to them and why those matters need development in the first place. These concepts are found in the Appendix 3: Identified fields of development

5 IMPLEMENTATION

5.1 New drawing template

A drawing template should be created according to the definition in ISO 7200. All mandatory fields currently used, optional fields and additional fields that were added are listed in the Table 1.

Field name	Description	Obl
Legal owner	Owner-company of document. Logotype can be used	M
Identification number	Unique number for each item. Client has 9-digit sequential number	M
Revision index	Unique number for each revision of item.	O
Date of issue	Date when item is first released to use	M
Sheet number	Number of the current sheet	M
Number of sheets	Number of sheets in drawing document	O
Title	Name of component in drawing from standard name library	M
Supplementary title	Additional information of product	O
Approval person	Name/names of inspector(s) of document	M
Creator	Creator or changer of document	M
Document type	Indicates the role of the documents' information and format	M
Paper size	A0, A1…	O
Scale		x
Mass		x
Units	inch or mm	x
Copying prohibited		x

Table 1 Data fields in the drawing title block. Red rows are missing fields or otherwise needing clarification. M = mandatory, O = Optional, x = Attributes from other standards (8)

As pictured in the chapter 3.1, drawing attributes can't be changed directly from the PDM. It limits the possible data fields that can be included in the title block. Design system update apparently does not improve the situation. Therefore, the drawing sheet shall contain only data which is not changed without revisioning.

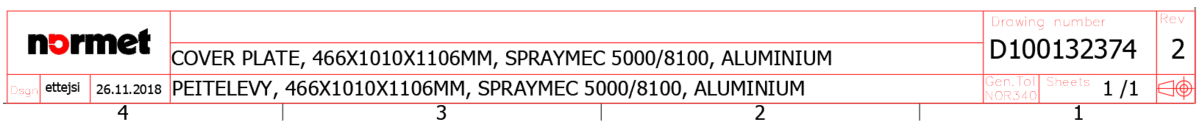


Figure 7 The current title block

The current drawing template in the Figure 7 is basic and contains duplicate information. More fields are required to make it sufficient according to ISO 7200

The new title block was produced by editing the existing title and adding necessary attributes which were requested by Indian colleagues. The basic design was kept similar to the current title block, but changes in fields were done to include all the required information as can be seen in the Figure 8.

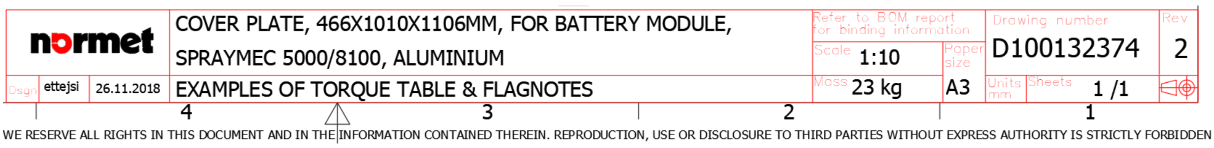


Figure 8 The preliminary title block produced in this thesis-project

The layout of the owner, the creator and date fields were kept same. According to ISO 7200, creator in the title block should be the one who has created the drawing itself. Currently, the field's name is "Dsgn" and it states by default the person-id of the founder of the model-file if it is not changed manually. Manual changing is necessary when making new items by copying the old. The copy process in Inventor exports the person-id of the original designer and therefore enables a possibility for human error.

ISO 7200 also states that the date shall be the release date of the first document. Currently, the date is determined by the creation date of the model-file by default and because the drawing is locked when it is approved to a production-state, the date can't be changed to be the release date. It was decided to address this problem later and leave it to be, because it hasn't caused any harm yet. More information is found in the Appendix 3: Identified fields of development. (8)

It is a publicly renowned fact that particularly people and organizations residing in eastern and southern Asia think rather differently about copyrights. The lack of any text prohibiting the reproduction or distribution of drawing in current title block enables local subcontractors blithely to do anything with valuable manufacturing data belonging to Normet. The client had such text in use at the schema template. It was directly copied from there since no reason was found why it can't be used also in mechanical drawings.

Textual information area went through some changes. The title is chosen from a library which has translations in multiple languages. As in the Figure 7 the drawing has a title in Finnish and English and in addition, has the same description. This consumes space from the title block which is already too small. Consequently, The Finnish name with the description was removed because the only approved language after utilization of MDI is English and space was needed for new attributes. The new template now has two shorter rows for title and description which is a more space than before and enough for almost all cases. At the bottom there is an optional field which is empty in Figure 7 and used to describe the contents of current drawing sheet in Figure 8. Any optional info can be included there. It was moved under the title because the block is read from top to bottom and title is a more important attribute than optional description.

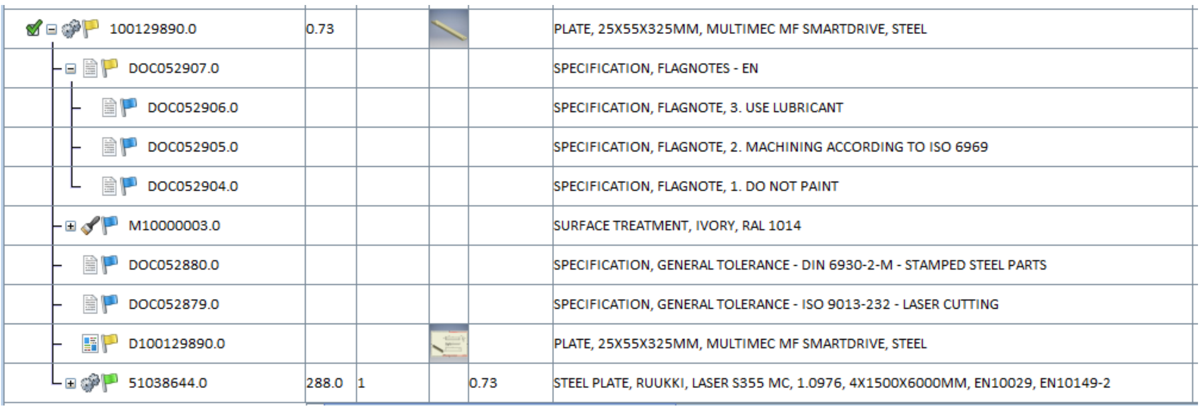
The fields requested were added after titles. A scale is needed to quickly visualize the size of the product. Inventor takes the scale from the first main view according to the research. Therefore, the possibility for error is minimized and the scale is visible for the ones wanting the scale to be available.

The mass is included for the same reasons as the scale. It gives information of the products size properties quickly with difference that it can already be found in Sovelia. Since all subcontractors do not have access to Sovelia, the mass data is important for logistics. The mass and the center of mass must be marked if the object weighs over 20 kg, but from a logistical standpoint, 50 grams and 19 kilograms have a huge difference and the data makes planning of logistics easier.

The sheet size is included to make drawing printing easier, because printers seldomly detect paper size automatically. In addition, reference to the BOM-report was added to notify the reader that more binding information exists on a separate sheet.

5.2 NOR340

According to SFS, the company needs a license to have direct quotes and elements from standards and share those to third parties (9). Nonetheless, NOR340 is completely produced by the client and merely corresponds to copyright general and work-method oriented tolerance standards it briefly presents.



100129890.0	0.73				PLATE, 25X55X325MM, MULTIMEC MF SMARTDRIVE, STEEL
DOC052907.0					SPECIFICATION, FLAGNOTES - EN
DOC052906.0					SPECIFICATION, FLAGNOTE, 3. USE LUBRICANT
DOC052905.0					SPECIFICATION, FLAGNOTE, 2. MACHINING ACCORDING TO ISO 6969
DOC052904.0					SPECIFICATION, FLAGNOTE, 1. DO NOT PAINT
M10000003.0					SURFACE TREATMENT, IVORY, RAL 1014
DOC052880.0					SPECIFICATION, GENERAL TOLERANCE - DIN 6930-2-M - STAMPED STEEL PARTS
DOC052879.0					SPECIFICATION, GENERAL TOLERANCE - ISO 9013-232 - LASER CUTTING
D100129890.0					PLATE, 25X55X325MM, MULTIMEC MF SMARTDRIVE, STEEL
51038644.0	288.0	1		0.73	STEEL PLATE, RUUKKI, LASER S355 MC, 1.0976, 4X1500X6000MM, EN10029, EN10149-2

Figure 9 Extract from Sovelia structure of a plate part with example standard blocks and flagnotes.

As explained in chapter 3.1, NOR 340 is a company general tolerance based on international standards. Although a separate document for the general tolerance definition is sufficient, NOR340 is outdated and in effect for all items which have a drawing. During the project, an idea came up to include the required general tolerances to the item structure. Hence, standard relations could be used to define working methods, which is currently largely delegated to suppliers resulting in occasional quality problems due to different manufacturing methods used by different manufacturers of the same part or the assembly

The idea is left to a concept phase in this thesis but will be developed and implemented in near future. Figure 9 contains an example of the future method of general tolerance definition. First is surface treatment which is already in use and has an intuitive way to add the desired treatment in CAD. More information about the surface treatment specification and optimization development can be found in the Appendix 3: Identified fields of development

The method of definition, as described above, should be applied also to the standard block's insertion to the item structure. By default, those could be driven according to the part or the assembly type. For instance, a plate part has automatically ISO 9013 with suitable quality tolerance for laser cutting and DIN 6930 with medium precision as relations if there is no need to change them to meet the design requirements. General tolerance principles and functions are described in the chapter 3.3.1

To ensure the practice of the given general tolerances, brief self-produced documents to sum up the contents of the standard shall be placed as a relation to standard blocks. Those documents will contain the required limits for the chosen quality class and a short description of the purpose and principles of the standard in a way that it is perfectly understandable also to the personnel who have little experience in general tolerances.

5.3 Compilation of new MDI

The client wanted to update the existing planning guide instead of creating separate instructions. As a result, no additional determinative documents were created in this project. It is beneficial to have all required information related to the product design and manufacturing documents in the same place. It enables easier sharing of the information and makes engineering management more efficient.

Instructions were produced according to the currently used planning guide and the research done in this project which is described in this chapter. With all the gathered information, it was possible to compile new mechanical design instructions. The new name represents the contents of the document better and leaves room for separate instructions for hydraulic, pneumatic and electric design guides which might be created in the future.

This chapter discloses some of the main details and justifications behind the instructions. The chapter's structure corresponds to Appendix 1. Drawing instructions to better confine reasoning to certain part of instruction.

5.3.1 Preface

Instructions were made according to basic document standards. Such decision was made to clarify to the reader that document at issue is authoritative and it determines how the mechanical design of Normet should be made for it to be sufficient quality and corresponding to procedures defined in internationally recognized standards.

The preface determines in what scope the produced instructions shall be applied. Since instructions touch the whole mechanical engineering branch of the product design, it was defined to be binding for all 3d-models and drawings created for Normet Oy unless separate instructions are given by a Normet manager or an item master. An item can't be approved to the design ready or the in production-state if it does not meet all the requirements specified in this standard. A possibility to disregard instructions with the express authority was included to avoid a situation where certain application is not considered in instructions or the application is against the given rules. In some cases, this is the only way to meet the design intent if no other way is available.

A list of the applied standards was also included in preface. At the start of the document list is visible and easy to notice by those who seek for more information. It was defined that all the listed standards will be applied if instructions don't have opinion on certain application. All the information to cover all possible design situations would not fit into a reasonably sized document. Therefore, the list was added. SFS Online was mainly used to figure out the most useful standards for the client (10).

Finally, it is stated that instructions are updated on a yearly basis and anyone can give feedback.

5.3.2 General rules for 2d-drawings

This chapter was written to define the fundamental rules for all the mechanical drawings of Normet.

5.3.2.1 General

This section compiles general definitions, most basic concepts and matters that were not wide enough to have a section of their own.

Manufacturability and clear and understandable drawings are main principles of a good mechanical design. That is why those are the first introduced matters. In addition, it is told that a new revision of item must always follow all current instructions. Currently, during a drawing update, common practice is to only add necessary changes to the drawing and existing objects are left unchanged although the drawing might be very unclear and against all present requirements. With this statement, the objective is to change that culture and require engineers to do drawing updates properly.

Normet values the safety of employees. It must be considered and striven to be developed in all work assignments and therefore lifting safety is taken into account better by directing the engineer to use more resources to design of the lifting points. When fastening points are designed properly it enables safer work environment for the mechanics.

Currently, drawings can include text in both English and Finnish. Because of the international working environment, a drawing should be understood in a default format as widely as possible. Therefore, only English is used in the drawing sheet itself. Since flagnotes enable a way to present notes in the PDM and easily have translations in all needed languages in the item structure, multiple languages in drawings are not needed.

The accepted paper sizes must also be defined. Normet has used only a horizontal layout for a long time. It has proven to be sufficient to only have horizontal drawings. Because of non-standard width of the current and the new drawing title block, A4 is too small to use. Therefore, approved paper sizes are from A3 to A0. In addition, it was defined that scale, mass and original paper size must be visible in all drawings for reasons described in the chapter 5.1 together with the statement that a drawing can only refer to an one item. (8)

5.3.2.2 Lines

Lines in mechanical drawings are defined in ISO 128-20 & -24 and principles introduced there are applied to Normet mechanical drawings. Line weights and the distance between parallel lines were defined and the update of line weights and styles were emphasized if those are outdated (11).

5.3.2.3 Projections

Projections are a way to express an item geometry in a drawing. They are needed to be specified to enable clarity of the drawing. Manufacturers will not understand the geometry specified in a drawing if it is not pictured by following common rules and standards.

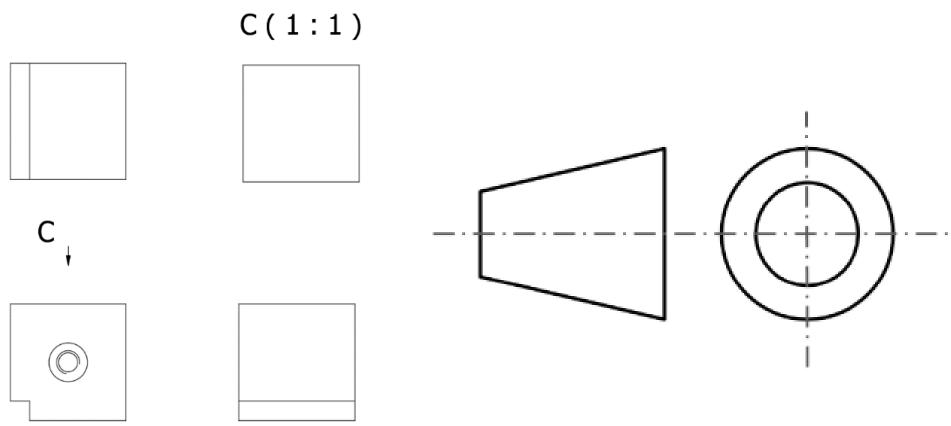


Figure 10 A first angle projection, a notation of exceptional location of view and symbol.

The client uses first angle projection method which is described in the Figure 10. It is an established way of notation at least in Europe. Another common projection method is a third angle projection method which is rarely used in Finland.

5.3.2.4 Title blocks, item attributes and notes

As mentioned in chapter 5.1, a drawing must stay as simple as possible to avoid inconsistencies between the item structure and the drawing. Therefore, in this chapter it is defined that only the necessary data is included in the drawing and textual data is in the item structure. That is achieved by using flag notes. Other attributes in the structure are specified in the chapter 5.2.

Flagnotes are icons in the drawing and according ISO 129-1 their shape is a hexagon with a number inside. A note corresponding to the number can be indicated in drawing or on an adjoining document (12). The idea is to have flagnotes in the structure. When located there, those can be easily translated to different languages as needed. The implementation should be done thus no additional workload is laid to engineers. It requires a consistent design of the system. The preliminarily planned implementation and workflow with design requirements are pictured in the Appendix 3: Identified fields of development.

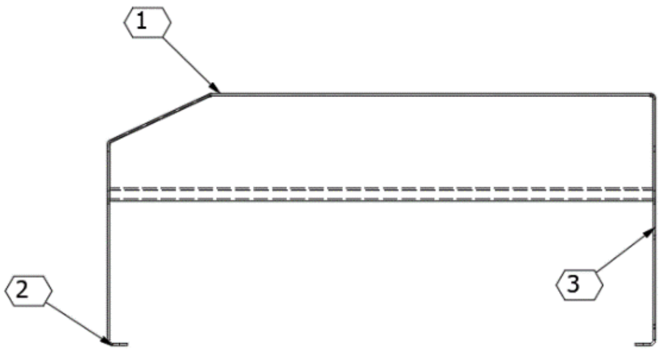


Figure 11 Flagnotes in drawing. Designations for flagnotes are specified in Figure 9

This chapter includes also the definition of surface treatments and gives example of the notation for features that are not treated in drawing, which previously had several ways of indication. Standardized notation ensures understandability and possibly reduces the number of complaints to subcontractors when items are painted correctly more often.

5.3.2.5 Dimensioning

Topics and principles of dimensioning are known to share opinions amongst engineers and technical drawers. Therefore, this section of the instructions was the hardest to be defined. In addition, dimensioning is an extensive field in mechanical engineering and a wide research was needed to determine the best possible procedures and constraints for mechanical drawings of Normet. Definition and examples of the surface texture, specification operators, slot dimensioning and surface indication are also given in this chapter.

The main principle of dimensioning is that a true existing product can’t perfectly correspond to a geometry defined in manufacturing documentation. As a result, some amount of error is always included in a physical part. Because all errors can’t be avoided and minimizing of errors will be very expensive, the engineer must define a suitable location in the product where the manufacturing run-out can be driven. Dimensioning is a tool for that and therefore, the knowledge and a proper definition enables better quality and cost-efficiency of products.

The main dimensions define outer dimensions of the product. They are seldom used as determinative dimensions, because outside dimensions have rarely any purpose in a functional definition of a product. Consequently, those are reference dimensions which are in parenthesis. All parts in assemblies are not always necessarily fixed in place, for example hoses and other flexible components. Therefore, outside dimensions are placed to fixed parts only.

Due to reasons described above, features should not be over-constrained. For example, closed chain dimensioning, which is pictured in Figure 12, causes a manufacturing run-out to divide unpredictably between features and probably induces that the part does not fit in place.

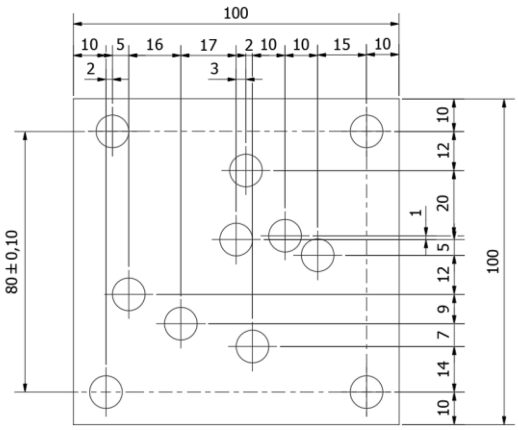


Figure 12 Example of closed chain dimensioning

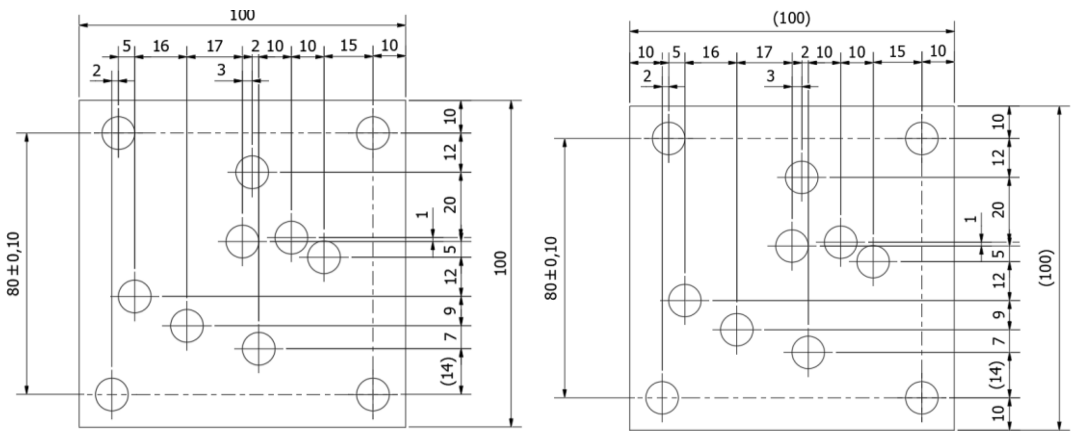


Figure 13 Examples of open chain dimensioning

Open chain dimensioning is slightly better. Location of the manufacturing run-out can be controlled by removing dimensions or using reference dimensions. Where the run-out should go is dependent on design intent and should be considered by a design engineer as mentioned above. This method can be used when there are only a few dimensioned features.

However, with a long dimension chain run out will start to stack and the last feature is nowhere near it needs to be. This method should be avoided if possible, particularly with more complex items which have a large number of features to be dimensioned.

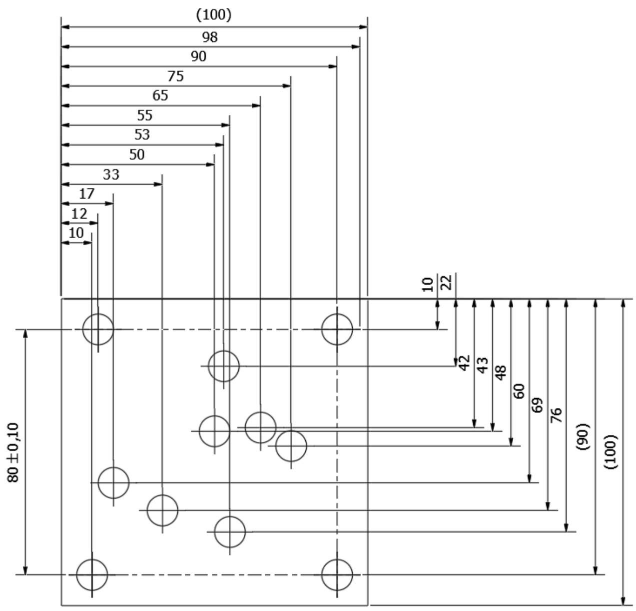


Figure 14 An example of parallel baseline dimensioning

Parallel baseline dimensioning defines features location far better and run-out stacking does not happen. This method is preferred when only a maximum of 4-5 dimensions are needed. In other words, this method is not suitable for complex items either. Practice defined in Figure 14 takes too much place and is unclear. Therefore, when more dimensions are needed, in Figure 15 there are examples of dimensioning principle which can be used as an alternative.

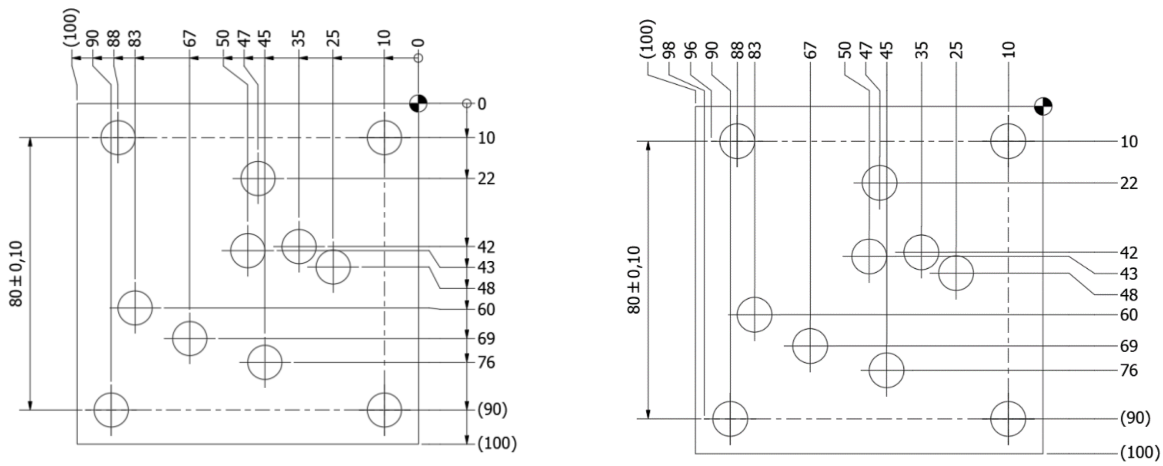


Figure 15 Examples of continuous baseline dimensioning

Continuous baseline dimensioning (Ordinate dimension set), described in Figure 15, combines the best features of all principles represented. The method in the picture on the left should be preferred when a view contains many objects to be dimensioned. Broken lines enable dimensioning objects which are close together. On the right is another type of continuous baseline dimensioning. This shall not be used as it is not as clear than the earlier method.

These examples actively illustrate that certain dimensioning styles are more informative and compact than others. Normet drawings should be presented as clearly as possible. Consequently, continuous baseline dimensioning was recommended to be used mostly, without forgetting functional dimensions, which are, in many instances, best to be noted separately.

Simplification of a hole and a pattern feature was instructed to be carried as defined in ISO 129-1. It is not effective to dimension frequent objects in drawing. Those can be indicated by noting only a one feature and by placing the quantity of it to callout as has been done in Figure 16. (12)

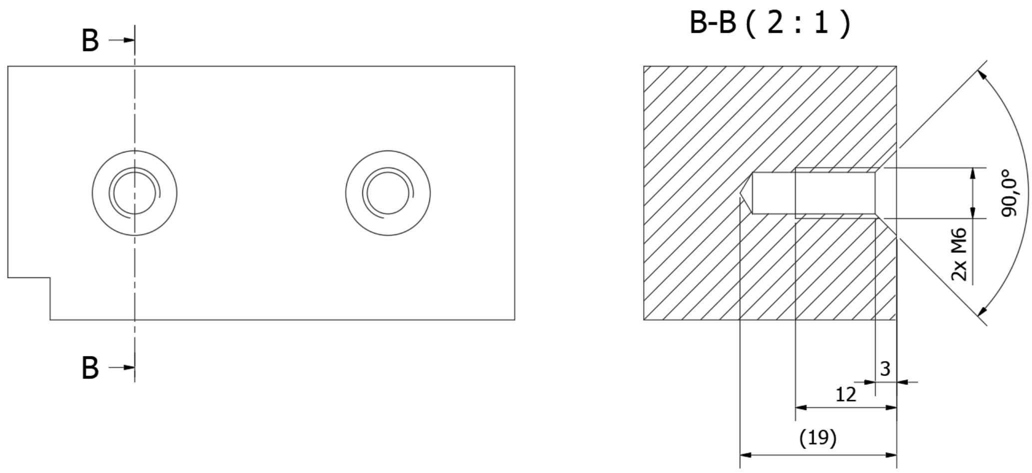


Figure 16 An example of dimensioning countersunk hole.

Dimensioning of complex holes containing countersinks or bores is done best by taking a section view and dimension the properties of a hole to avoid misunderstandings. Another option is to use a callout, but interpretation errors are possible, if the manufacturer is not familiar with rules defined in ISO 129-1. Therefore, dimensioning of the hole is mandatory if it has any other properties than thread.

c	
e d	a b
b	Secondary surface parameter
c	Manufacturing method
e	Minimum material removal
Material removal not allowed	Material removal required

d	Lay
=	Parallel
⊥	Perpendicular
X	Cross-hatch
M	Multi-directional
C	Circular
R	Radial
P	Particulate

a	Surface parameter
	D F S-L / Rz N C V
D	Tolerance direction, upper (U) or lower (L)
F	Filter type, for example "2RC"
S	Short filter cutoff, for removing noise
L	Long filter cutoff, for removing waviness
R	Profile type, primary (P), waviness (W), or roughness (R)
z	Parameter type, for example "a" for Ra or "3z" for R3z
N	Assesment length; multiple of sampling length, usually 5
C	Comparison rule, "max" for 100%, "16%" for 116%
V	Specified value in micrometers

Table 2 Basic principles of surface texture notation defined in ISO 1302. Equivalency checked by author. (13) (14)

It was defined to mark surface roughness according to ISO 1302. Contents of the standard are briefly reviewed in Table 2.

Fit or deviation dimensions alone are not specific enough to define specifications for the product in most cases. Specification modifiers and geometric tolerances should be added to ensure correct shape properties as has been done in Figure 17. Only the diameter tolerance specified there does not limit the straightness or the circularity of the axle and therefore it can be stated that the work-piece is compliant although it is warped. With envelope requirement Ⓔ axle geometry can be limited to fit in a perfect cylinder and the smallest measure to the given lower limit.

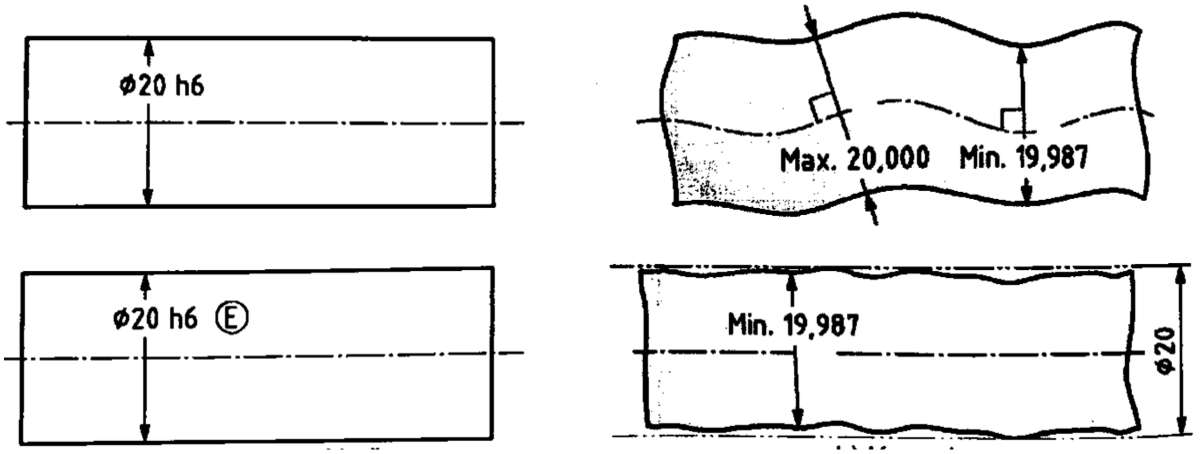


Figure 17 Envelope requirement application example. (11)

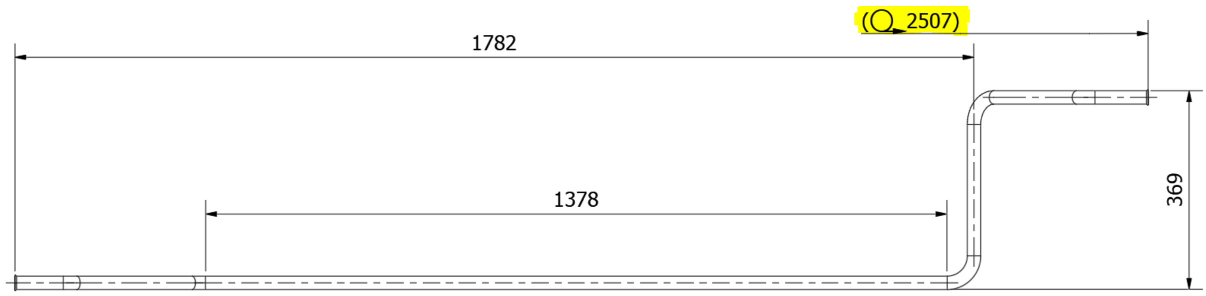


Figure 18 Correct notation for straightened length of bent part.

It was defined to indicate the straight length with a dimension containing symbol for developed length as pictured in the Figure 18. The symbol for developed length seems to be rarely used and unknown for engineers. Definition of this symbol is simple and with the use of it, the amount of text can be reduced in drawings and with international notation, no problems with language should be encountered. This notation is not allowed in sheet metal parts because those require a separate flattened view to be placed in drawing.

For dimensioning of semicircle features or so-called slots, multiple options exist. To avoid inconsistencies only a few of them should be used. A definition was given to use modified ISO 129-1 method where slots can be dimensioned to view, or callout can be used. ISO 129-1 also defines the marking of radius, although width of the slot is dimensioned. This notation was considered to be useless and therefore it was not utilized. The accepted methods are in Figure 19. (12)

The majority of clients' items are plate parts. Clarity of dimensions, particularly in a thin, but large bent plates, is a problem because the reader of the drawing can't be sure on what geometry the dimension line is attached. In the worst-case scenario, interpretation error will cause an error as large as two times the plate thickness, which will result in scrapping of component in most cases because it does not fit into place. Therefore, if a risk for misconception with dimension lines place exist, surface indication must be used as described in the Figure 20.

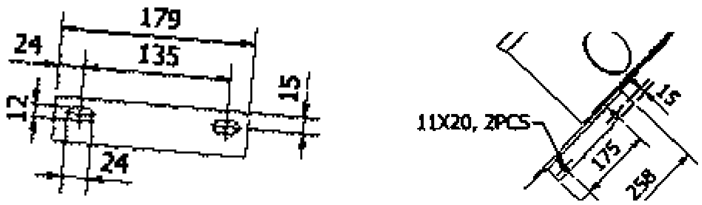


Figure 19 A recommended style for slot dimensioning should be done like in the view B. Other option is shown in the view A.

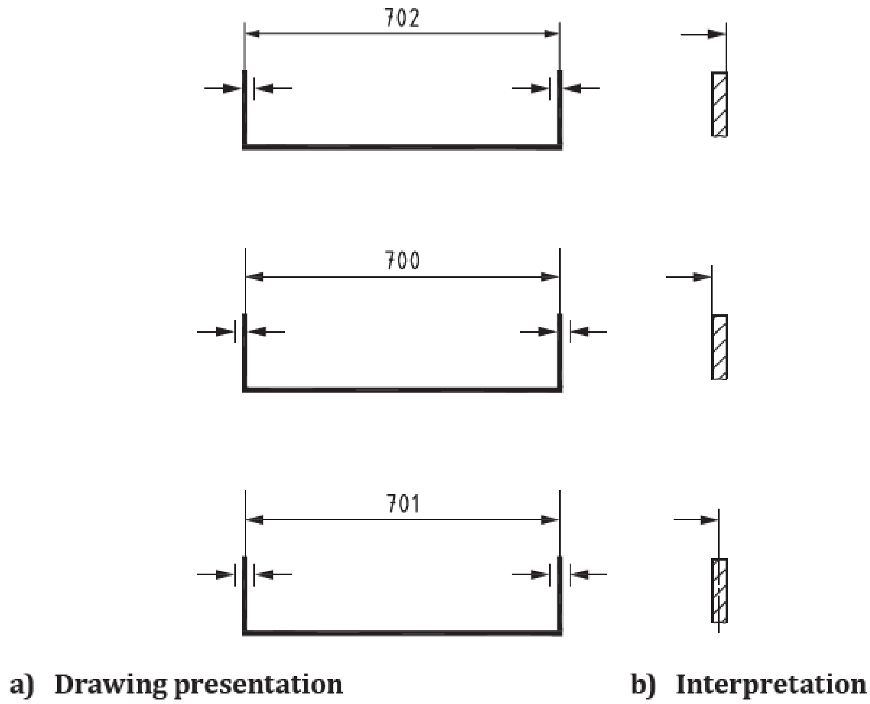


Figure 20. A surface indication of a thin component. (12)

5.3.2.6 Threads

It was defined to mark thread markings as simply as possible. A pitch and a tolerance class are not marked if those are standard. This was done to simplify the notation. Correct notation for M12X1,75-6H- thread is described in the Figure 16.

5.3.2.7 Welds

Welding section defines the used standards and the notation in drawings. Due to a vast number of different weld types, the instruction recommends referring to ISO 2553, which defines standard welding symbols. Commonly used welding methods are given in the table as a reference for the engineer. Normet has defined a standard welding process, which shall be used if no other method is defined in the drawing. Therefore, the welding section does not have to be very specific, because a very basic notation is mainly used, and process or welding class definition is rarely needed.

5.3.2.8 Applied work-method-oriented tolerances

General tolerances were mainly selected from ISO standards. ISO has general tolerances for thermal cutting, welding, casting and machining. Plastics moulded parts and sheet metal general tolerances were to be selected from DIN standards, because no international or European standards were not available.

More information about the benefits and principles of general tolerances are given in chapter 3.3.1. Designed notation for general tolerances is described in chapter 5.2.

5.3.3 Specific 3d-modeling and 2d-drawing rules for mechanical item types

Since different item types have requirements to be fulfilled that can’t be applied to other types of items, it was decided that instructions should contain a chapter, where these rules are specified, and example drawings presented to clarify given instructions.

5.3.3.1 Assembly

This chapter was written to define acceptable methods and procedures for different assembly types in addition to requirements specified in the chapter 3 of Appendix 1. Drawing instructions **CONFIDENTIAL**. The design workflow described in this chapter will be updated in the future. Specifications for new workflow are in the Appendix 3: Identified fields of development

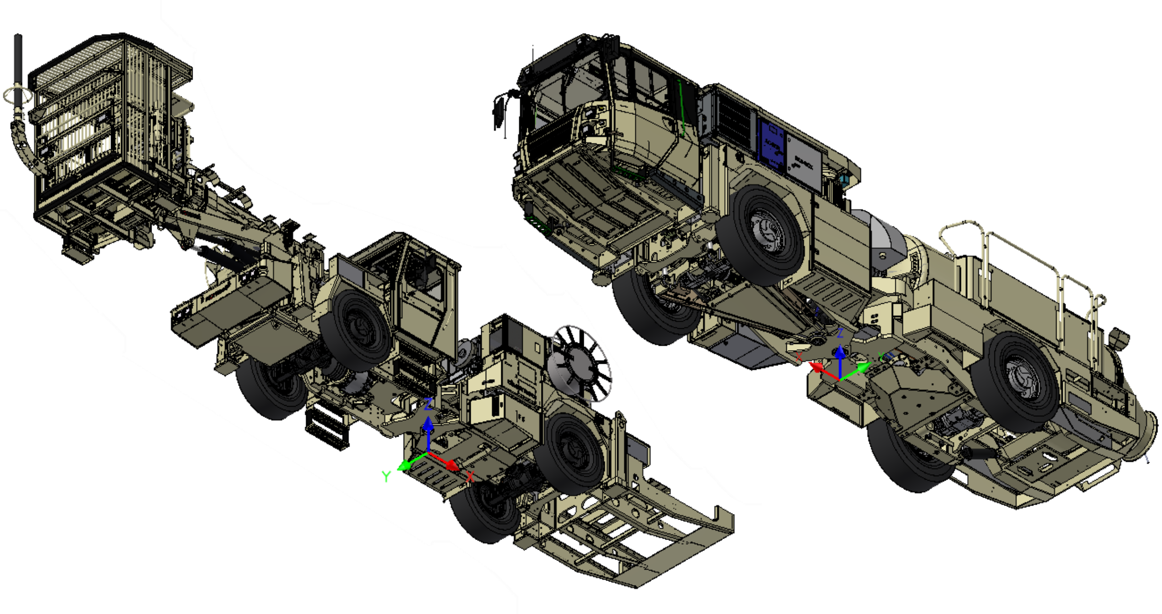


Figure 21 Picture used in instructions to describe location of origin and direction of coordinate axes

At first, general instructions for all assembly types were given concerning the origin location, which can be seen in Figure 21. In addition, certain modeling methods were introduced which are described in respective chapter in Appendix 1. Drawing instructions **CONFIDENTIAL**.

Part numbering (position numbering) needed clarification. Previously, there was a minimal number of instructions, that didn't state whether the same part number can be shown only once in the drawing or can same part number be displayed many times to avoid misconceptions. Therefore, instructions now state as defined in ISO 6433: Parts are referenced only once if there is no chance for misunderstanding. (15)

Part selection process was directed to a more efficient workflow. Previously, standard components needed to be searched according to their attributes and those were not included in an any consistent library. Such method results in several problems. Firstly, a duplicate item can be established since an already existing item could not be found. Duplicates affect to system's cost-efficiency and locating and replacing them with correct items takes an excessive amount of time. Secondly, the use of multiple interchangeable component causes a rise of costs, due to inability to utilize mass-discounts and efficient logistics. Lastly, finding the correct item among tens of thousands of structures can take a huge amount of time if engineer does not know where to look. Those problems are easily solved by implementation of a part library. (16)

Recently, a consistent standard component library was founded, and it includes recommended components for use. Instructions recommend the use of it since it is a new platform and proper utilization still requires more attention amongst engineers. (16)

Examples were presented from mechanical, hydraulic, pneumatic and electrical assemblies. Examples can be seen in Appendix 1. Drawing instructions **CONFIDENTIAL**, chapters 4.1.1-4

5.3.3.2 Weldment & Welded and machined assembly

Under assembly type is also Weldments and Welded and machined assemblies. They need their own separate rules because of the difference between assembly methods.

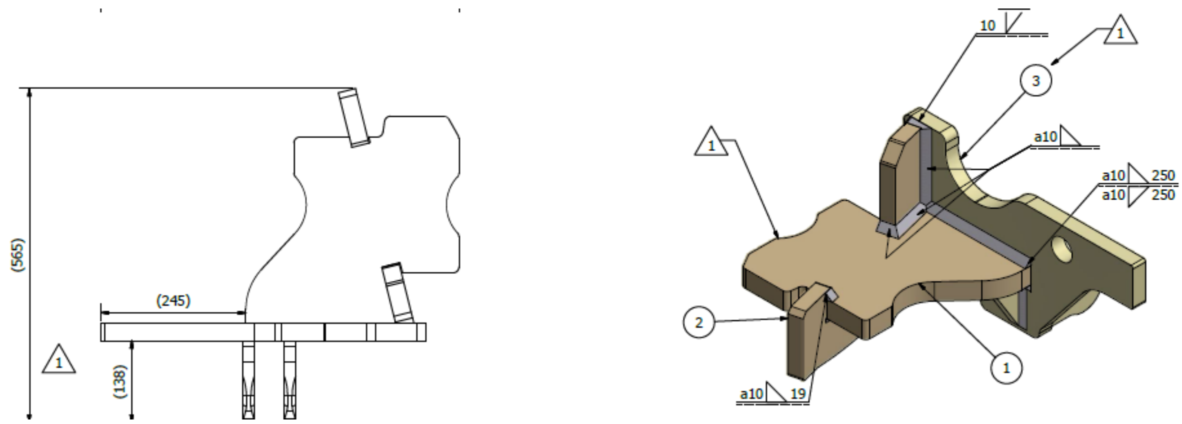


Figure 22. Welding sheet of drawing. One weld is visible in orthographic view and should be hidden.

Previously welds were not modeled anywhere. Although, at first hearing it seems not a problem at all but without visual feedback on a computer screen, perceiving the space taken by weld is hard in many cases. It causes that parts can't be fitted in an intended place because it has an impact on the weld. In such a situation, costly modifications must be made and those might have impact even to the quality of the product among the other downsides. When welds are modeled in the design phase, all previously described defects can be avoided with a relatively minor amount of work, due to developed tools inside Autodesk Inventor that can be utilized for efficient weld modeling. Therefore, instructions define that welds should be modeled and be visible in axonometric views and hidden in orthographic views. If welds are visible in orthographic views, where the locations of parts are dimensioned, interpretation of the correct position might be unclear.

Another matter worth mentioning concerns document structure of welded and machined assemblies. At the moment all welding and machining specifications are done on separate sheets under same item. If those were done on a same drawing sheet, it is possible for example, dimension welded part position from a machined feature which does not exist at the welding phase. Therefore, it is very important to avoid such a situation to ensure a smooth manufacturing chain.

It was also considered to create separate items for the welded and machined assembly mainly due to warehousing. A certain item that has two configurations which have different values, because machined assembly is more refined product, and weldment and machined configuration can't be distinguished from each other in the system. In that case, the warehouse value can't be calculated. Another problem with the present practice is the possibility of using multiple subcontractors for different phases of product manufacturing. If welding and machining are in the same item, how partition is defined? Currently no such scenario has occurred. Therefore, the design was not limited by purchasing and warehousing and it is fully acceptable to act as earlier. Even though, one item method is fast and saves some of the engineers' time, it was recommended in instructions to create separate items, if there is a chance that the weldment can be modular and used to multiple machining configurations.

5.3.3.3 Part

Separate instructions for different part types were created correspondingly to assemblies. In other words, instructions were given for different part types respectively. Different categories specified in PDM are a plate part, a bar part, a tube part, a profile bar part, a change of purchased component and commercial items, which do not directly belong to this category, but some restrictions needed to be given concerning content center and its applications.

The plate part was a type needing definition most due to a wide variety of rules and procedures already defined. In addition, the plate part is the most common in-house design item. Therefore, a proper and a right design definition will give the most benefit to the client.

In contrast to a widely used method of notation for bent sheet metal parts, Normet does not use a bend callout to define bends but uses dimensioning bends to views instead. This practice dates back to a time when CAD-programs did not automatically create such notes and those were needed to be written manually. Due to a human error, such method could easily leave typos in bending notes resulting in an invalid component at the worst case. Bending notes are not allowed in new instructions because engineers and subcontractors are used to the current practice and one objective for new drawing instructions was to reduce the amount of the information in the drawing.

Because of the prohibition of bending texts in drawings, a flat pattern view is very simple containing only the main dimensions and distance of bending lines from their respective edges. That is efficient because at the production programming phase cut machine operator must extract geometry from the drawing and remove any dimensions or notes from the flat pattern view to obtain geometry for the machine. Time is saved, when the view is simple and therefore no other dimensions than specified above are allowed in the flat pattern view. Furthermore, the flat pattern view can't have features visible which are done after bending for example threaded holes.

The holes which can deform in press brake, should be marked with a flagnote to avoid misinterpretation.

Other types were simple and did not need as detailed definitions as plates. For bent parts with a constant cross-section, it was defined that the straight length should be presented as described in Figure 18. If the cross-section is not self-explanatory, section view to describe internal properties must be inserted to the drawing.

Founding of commercial items were needed to be clarified, since a new content center was founded recently. If new fasteners or other simple configurable parts must be brought to use, those are added to the content center rather than Sovelia. The content center enables an easy and intuitive way to insert components to assemblies and to administrate parts. Therefore, it is far superior compared to an old method and was therefore it was instructed to be the correct procedure.

Change of purchased component is, as can be guessed from name, commercial items, which must be modified in the factory to meet the design intent. Previously, the definition was unclear, and it resulted in incidents where no modifications were made due to an inadequate notation for change. For that reason, clear instructions were given to document change to both the part and assembly.

5.3.3.4 Revision

Revision or in other words, product change management is a wide subject which does not belong to drawing instructions and therefore it has instructions of its own. Drawing instructions only consider about the change documentation in drawings or so-called revision marking and defines its principles.

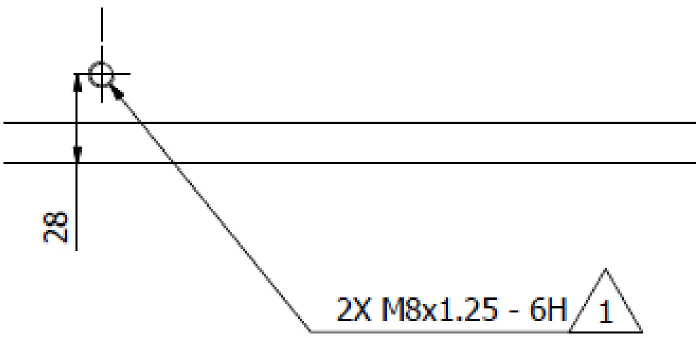


Figure 23 Example of revision tag. Revision text states that two M8 holes are added.

Before an appropriate definition, it was instructed that all change must be shown with revision tags. This leaves room for an open interpretation and matters of taste directed what objects should have revision tags and what not. The main problem occurred in multi-sheet drawing where the same component is used in multiple places in the assembly. Its quantity is changed, and it is tedious to mark all part references with a revision mark, because Inventor does not have a built-in tool for finding balloons. More about possible approach to this problem is in Appendix 3: Identified fields of development. For now, only location where the quantity change occurs should be marked. However, if the majority of the product is changed, then revision mark near the title block is sufficient.

5.3.4 DFMA

This chapter was not actually a part of this project, but due to a decision to create only one instruction document, DFMA instructions and recommendations had to be included in the instructions. This section was largely copied from the previous planning guide, with a brief analysis, an upgrade of the obsolete data and minor refinements.

5.3.5 Needed system enhancements

Some specific enhancements are needed to utilize the new instructions completely. A few new symbols must be added to the symbol library and new features to the product management system should be considered further. Specific list of needed enhancements is in Appendix 3: Identified fields of development

6 RESULTS

Objectives set in the thesis plan were met and new drawing instructions were created and merged to new mechanical design instructions. Many of the fields of development identified were solved and the implementation planned to the near future.

Because of the character of this project, the main scope of the thesis stayed the same, yet matters around it changed when the amount of knowledge of the field increased. Therefore, all aspects planned were not included in this thesis but left to be considered later and other ideas that came-up later were prioritized more urgent as the original.

6.1 Fulfillment of implementation plan

The project was carried out as planned and pictured in the Figure 24. Personal research continued through most of the project. The objective of the phase was to find materials and examples which can be used as a base for the discussion phase and as a source in thesis and drawing instructions. (17)

Figure 24 Phases of the thesis project. (17)

The discussion gave the information and the experience to merge the benefits of above-mentioned materials into a tailored drawing instruction body. In this phase, informal and short discussions were done mainly with Normet employees to gain knowledge what improvement ideas employees working with mechanical drawings have and how drawing production is implemented in other businesses. The plan was to have wide and formal interviews with subcontractors and representatives of other companies working in a similar field, but those would have taken lots of time and probably the same results would have been achieved. Many Normet employees have a long career and have worked in many leading machine industry companies around the globe. With their knowledge a wide picture of correct drawing procedures could be created.

With facts and knowledge gained from materials and interviews, preliminary drawing instructions and templates were produced. Production of them was kept collaborative and required adjustments were made according to feedback given by managers and other employees.

Final stage of this project is approval. Instruction went through client's approval process and were added to PLM system.

6.1.1 Schedule and resources

6.1.1.1 Schedule

Goal was to have the thesis ready for review in the middle of March. It was planned to have the thesis-related documents such as the drawing standard and the template ready at the beginning of February before finishing part of the thesis starts. Objective was not met due to other non-thesis-related responsibilities which needed attention in January and February. Therefore, schedule was delayed. According to the plan the thesis should be ready by May.

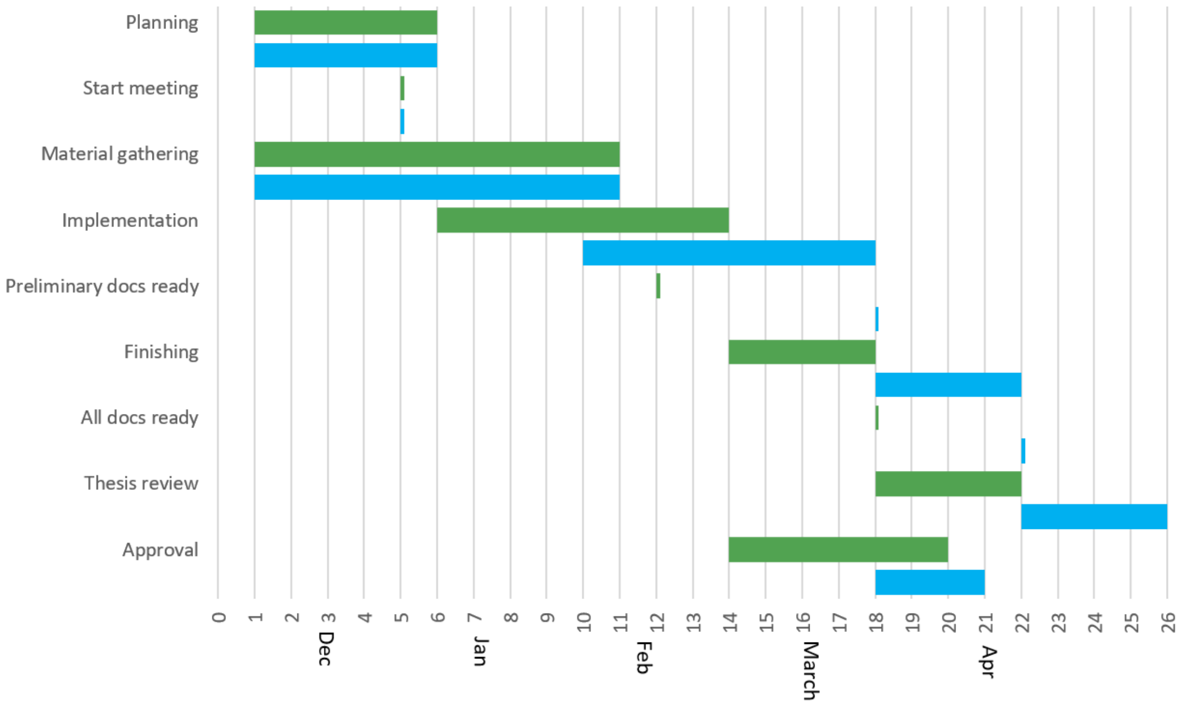


Figure 25 Thesis planned and realized schedule. Week 1 is start week 46. (17)

It can be seen in Figure 25 that the implementation contained the discussion, the preliminary instructions, the preliminary template, feedback and adjusting phases. Finishing consisted of final adjustments to thesis, presenting results and other matters relating to graduation. (17)

6.1.1.2 Resources and Time

One employee was loaded to this thesis project. Additional resources required for interviews and meetings were minor and were not considered to be expense items. 475 hours was the planned duration to accomplish the set objectives. The true working hours consumed in this project are 312 hours (6.4.2020). An approximate accumulation will be additional 30 hours for the finalizing and preparation of thesis-seminar. Therefore, total time taken to complete the project is 342 hours which is 133 hours less than anticipated. (17)

6.1.2 Risks

As pictured in the Appendix 2: Risk analysis, , gravest risks were in finding a solution and schedule, which is tight. Those matters were paid attention to and were considered often in order to avoid realization of risks. Nevertheless, schedule was delayed. It was a planned action and therefore, the realization of risk did not happen.

6.1.3 Ethicality and reliability

Normet Oy is a limited company possessing a large amount of intellectual data disclosure of which could a cause significant harm to the company. It is was uttermost important to keep the any kind of trade secrets outside of the thesis report. The revisions of thesis were reviewed by a supervisor before release and required confidential data to understand all the points in this thesis are included as appendices.

6.1.4 Relevancy

This thesis, if it manages to reach its objectives, will make designers and manufacturers work easier and more effective due to fewer unclarities concerning drawings. More effective work effort will increase productivity bringing added value to the client. The achieved results will come visible in the future since documents produced in this thesis are not yet brought to use.

From a personal perspective, this thesis was an excellent possibility to advance knowledge in drawing standards, which act a great role in mechanical engineering and the CAD-system development.

6.1.5 Identified fields of development

The project resulted in multiple ideas which could be used to make Equipment Business Line functions more streamlined. Although, fields of development were found, all could not be considered in this thesis. The developed topics in this thesis were selected to be solved first from a huge list gathered from colleagues and author's own ideas. All ideas which seem to have a true benefit to the client are listed and shortly described in Appendix 3: Identified fields of development

6.2 Recommendations

Firstly, the training for an application of new mechanical design instructions should be arranged to improve flow of information and to orient engineers for use of the new instructions and what all the statements actually mean. Secondly, the described system and procedure updates should be implemented to enable proper application of new instructions. And finally, other development ideas should be considered whether those should be refined or not. More information of the continuation of the project in Appendix 3: Identified fields of development

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Appendix 1. Drawing instructions **CONFIDENTIAL**

Appendix 2: Risk analysis

	Risk						
Schedule	Probability	Extent of the effect	Effect to the project at worst	Importance of risk	Risk management class	Measures to minimize the risk	Risk factor
Time runs out	2	4	delay	3	2	Planning	11
External lag	2	2	delay	4	2	scheduling	10
Organization							
Changes in organization	1	3	fall	2	3	Construct a new organization	9
Absence	2	2	delay	4	2	scheduling	10
Problems in teamwork	1	3	delay	3	2	Try to understand and respect others	9
Achievement							
Project management fails	1	3	delay	3	3	Partition	10
Lack of needed tools	1	2	delay	2	1	planning	6
Data of the project disappear	1	4	delay	3	1	Backups + IT-skills	9
Problem in communication	2	3	uncertainty/delay	2	2	good language skills and collaboration	9
Working solution can't be found	1	5	fall/delay	5	2	Design	13
	1=small 2=med. 3=large	1=small 2=medium 3=important 4=large 5=very large			1=removing 2=minimizing 3=prevention 4=collection		

Appendix 3: Identified fields of development and updates **CONFIDENTIAL**