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Information ergonomics improvement for preventive maintenance.

Wedge as a maintenance tool.

MASTER'S DEGREE PROGRAMME IN WELLFARE TECHNOLOGY
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Abstract

Objective of this study was to improve information ergonomics of preventive maintenance by using Wedge software. The plan was to make simple as possible platform inside Wedge to give maintenance supervisors a maintenance related platform regarding process pump data. Pump process data collected to platform was pumps electrical current and pumped material flow. The platform was made and introduced to maintenance partner's supervisors. Maintenance supervisors started to use this platform on daily basis for 2 week trial period. During that trial period 3 surveys were sent for them to get answers to research questions. First survey was to get the basic level of present system (DNA process operating system) information ergonomics. Second survey was to get information ergonomics improvement from the usage of Wedge. Final survey was to get answers to Wedge's total usability and information ergonomics improvement for preventive maintenance. Total potential of Wedge was then evaluated.

Results from surveys were hard to interpret as only 7 out of 10 participant answered. Wedge brought slightly positive change to information ergonomics in general, but more negative regarding to preventive maintenance. Usability was seen mostly as neutral all answers considered. As conclusion Wedge was hard to use for beginner user. A longer introduction would have been needed to ensure better learnability. For future research different process devices could be included to the platform. Even simpler platforms should be made for maintenance.

Key words
Wedge, Information Ergonomics, Usability, Preventive Maintenance

CONTENTS

1 INTRODUCTION

The aim of this study was to improve information ergonomics of preventive maintenance by using Trimble’s Process Diagnostics System Wedge software (from here on Wedge). Wedge is a software that is mainly used for industrial process data analyses. Some of Wedge’s key features are visualization of process, data analyses, root cause and dependencies diagnostics. (Website of Trimble Wedge 2020.) The Wedge software was already in use as a process data monitoring and analysis purposes at Nornickel Harjavalta Oy (from here on NNH). On behalf of NNH maintenance partner Quant Finland Oy (from here on Quant) the usage was low due to Wedge’s lack of content especially done for maintenance purposes. There was a known problem consisting of difficulties in finding and understanding specific process related information by Quant personnel. Information intensive work life makes it harder to control the massive information load and therefore it was decided to study Wedge in order to support preventive maintenance.

Plan was to study if there was potential to improve information ergonomics of preventive maintenance with Wedge and therefore, for example, lowering costs in maintenance. Usability is major part of information ergonomics as it is involved how much mental workload and decision-making something requires. If human-computer interaction is considered to be good in terms of usability then, for example, mental workload should degrease and improved productivity or employee engagement can be achieved. By investing in information ergonomics of maintenance large industrial companies could achieve a lot of savings per year with little effort. By making information more achievable, easy to read and comprehend maintenance companies like Quant could save in overall maintenance costs. By collecting the massive data flow coming from different systems and software’s and then compiling the most necessary data in one place could improve information ergonomics of maintenance personnel. The key indicators selected for closer examination were related to pump malfunction, more specifically pumps electrical current converted to percent [%] and pump produced flow of the pumped liquid cubic meter per hour [m^3/h]. (Website of ErgoPlus, 2021.)

This study consisted of constructing a data collection platform for maintenance. This platform was then used to make observations of some process pumps by Quant personnel. The data collecting platform was constructed keeping in mind the fact that Quant personnel weren't familiar with using the Wedge software. Platform was planned based on principles of information ergonomics to be easy and have as much as visual aids as necessary, such as Green-Red light model. The green light was to indicate pumps state as normal operating range. The Red light was to indicate pump malfunction state below or above normal operating range. Green-Yellow light was used to give the user the knowledge of pumps state “Running” or “Stop”. This aimed to keep the user from looking at the pump data that is in “Stop” state. Wedge's potential as data collecting platform was studies via 3 surveys to get the data if Wedge improved the information ergonomics and thereby preventive maintenance in some way. Wedge platform was introduced to some NNH workers to get confirmation that Wedge platform was in usable state.

This thesis was all about giving a usable platform for specific pumps condition evaluation for maintenance partner Quant. At the time of the study, main users were Quant's supervisors. Potential users in the future are also maintenance workers. Platform was designed to give instant feedback to user with one glance to indicate errors in the pumps. This fully tailored maintenance focused platform was to give information about Wedges potential in information ergonomics improvement of preventive maintenance. The pumps were easy targets to find out if Wedge software bends to the needs of maintenance.

Based on the above mentioned information ergonomic challenges related to preventive maintenance, the research questions of this study were as follows:

1) How and to what extend does Wedge effect on information ergonomics of preventive maintenance?
2) How maintenance supervisors experience the usability on Wedge?

3) What are the pros, cons and improvement possibilities of using Wedge from maintenance supervisors' perspective?

2 CONTEXTS OF THE STUDY

2.1 Harjavalta Oy

NNH is one of the world leading nickel manufacturer. Harjavalta factory was founded by Outokumpu Oyj in year 1960 and later on sold the nickel refining factory to OMG (OM Group). In 2007 PJSC MMC Norilsk Nickel group (Public Joint Stock Company Mining and metallurgical Company "Norilsk Nickel") bought the refining factory. PJSC MMC Norilsk Nickel is biggest metal and mining company and world largest nickel and palladium manufacturer, being also significant platinum and copper manufacturer. PJSC MMC Norilsk Nickel head office is located in Moscow Russia. (NNH Toimintakäsikirja, 2018.)

NNH functions as a part of Norilsk Nickel mining and metallurgical (MMC) branch. NNH manufacturing line starting from raw material handling to leaching and purification ends in cathode, bricket and chemical production lines. NNH produces metallic nickel for stainless steel and plating production. NNH also produces non-organic nickel salts such as nickel sulphates, nickel hydroxides and nickel hydroxide carbonates that is used for battery chemicals and other electronics production. NNH also produces ammonium sulphate and cobalt sulphate. NNH produced 62400 t of nickel products and turnover was 1 billion euros in 2019. NNH employs 300 own employees, but total employment effect in Harjavalta Industrial park is 500 persons. (NNH Toimintakäsikirja, 2018.)

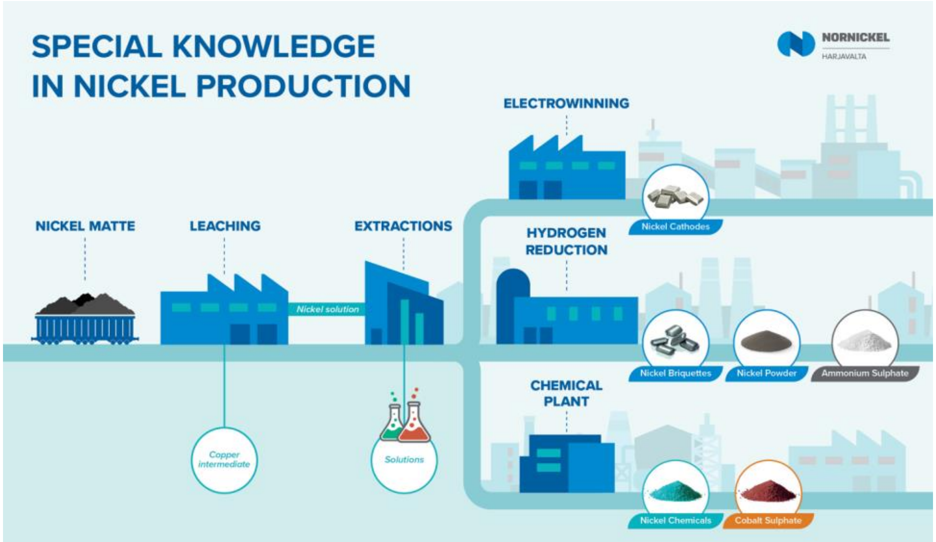

Figure 1. Simplified production line (NNH Yritysesittely, p. 10, 2021.)

2.2 Quant Finland Oyj

History of Quant as maintenance partner starts from year 1999 when Outokumpu Harjavalta Metals Oy outsourced maintenance to ABB Full Service. ABB Full Service was in maintenance partnership with both OMG and Norilsk Nickel to the year 2014. In 2014 ABB Group sold the Full Service business model to Nordic Capital which later on founded Quant Finland Oy. Quant maintenance model changed in 2016. The full service model was degraded so that condition based maintenance and lubrication was done by SKF and LVI was done by Tech Salmi Oy. Quant has been a global market leader in maintenance for over 30 years. In Harjavalta industrial park Quant has about 120 employees. (Quant Presentation, 2020.)

2.3 Wedge in a nutshell

Wedge was marketed as the best data-analytics tool on the market. Wedge was said to be easy and super-fast. Finding root causes and preventing imminent problems was also mentioned. Wedge could be used for improving industrial plant efficiency by anticipating coming problems and finding the root causes for that. Wedge was mentioned to be a perfect tool for process industry and also maintenance was mentioned for field of work. Wedge’s pros mentioned were visualize, cleanse, analyze and diagnose. Visualizing of the data in one platform made Wedge quick to operate and the experience user friendly. Wedge had powerful diagram tools that were customizable to user's needs. Cleansing of that data from raw unfocused data could be done, meaning, for example, filtering unwanted points. Analyzing tools such as statistics, correlation matrices X-Y plots, histograms etc. could be used in Wedge platform. Diagnostic tools meaning cause-effect relationships could be calculated in Wedge. Diagnostic tools could also be used for predicting and avoiding disturbances. (Website of Trimble Wedge 2020.)

3 IMPROVING PREVENTIVE MAINTENANCE

3.1 Information ergonomics

Information ergonomics can be defined as an evolving area of ergonomics focusing on the management of workload in information-intensive tasks (Franssila et al., 2016, p 1). Majority of workers nowadays belong to a group that can be called knowledge workers. Knowledge worker is challenged by the information rich work-life. According to Kirsh (2000) cognitive load increases if worker doesn't know how fast information needs to be processed or does it need to be totally ignored. The amount of information is so massive that workers can be overwhelmed by it. (Brinkley et al., 2009, p. 12-13; Kirsh, 2000, p. 19-22.)

Fragmentation of information creates a big problem as information that is found in multiple software or platform is hard to comprise to simple easy to use information. The problem comes when creating, seeking, using, sharing and organizing information. For example, workers use too much time to seek information, then filter the massive amount of information to usable form, and finally use this good quality information to gain something. Workers' efficiency suffers from growing information load, work pace, multitasking and interruptions. Constant interruptions cause strain in work load and deteriorate workers' well-being. Thus, improving information ergonomics makes workers’ life more efficient and less stressful. Also, the control worker has for his/her own work field improves and productivity increases from better information ergonomics. (Okkonen et al., 2017, p. 1-12.)

Kalakoski (2020) conducted a study about effects of a cognitive ergonomics to cognitive strain and well-being at workplace. The study was conducted as a cluster randomized controlled trial. Recognized problem was information overload that cause impaired performance in tasks and therefore lowers well-being in work. It was mentioned by Kalakoski (2020) that modern digitalized work environments are relying heavily on cognitive information processing. Cognitive strain in work brings a notable risks concerning work performance. Fragmentation of work, multitasking and information load strains the knowledge worker. The study suggested expanding the research of cognitive strain causing work performance risks in order to avoid the decrease of well-being at workplace. (Kalakoski, 2020, p. 2-16.)

Fista (2019) conducted a study concerning cognitive ergonomics measurement tools. The study consisted of measuring such areas as mental workload, decision-making, skilled performance and human reliability in human-system. These areas were tested and measured with objective measurement tools, for example, heart rate variability, galvanic skin response and eye blink rate. For objective measurement the advantage is that it can be used continuously and it detects mental workload changes. Disadvantages for objective measurement is the need for special equipment. Subjective measurement tools, such as, NASA task load index, root mean square deviation and subjective workload assessment technique were used in Fista’s study. Subjective measurements have a high degree of acceptance by user, but they can also have negative impact. Because the assessment in Fista’s study was done after work day, the user could easily forget things from work day. There is also the risk that user does not tell the real answer thus s/he produces false information. The result of the study was that both objective and subjective measurements can be used to provide contribution to mapping of cognitive measurement research. (Fista, 2019, p.1-10.)

Fiserova (2013) conducted a study related to method of cognitive ergonomics in assessment of psychosocial risks in work. The study focuses on human psychic workload, mental performance and reliability in work systems. In addition, it concentrates on evaluation and optimization of above mentioned areas. In study was noticed that growing information intensive workload increases the stress level of workers and it can impact on their health and safety. Evaluation was done with physiological measurements, subjective measurements, performance evaluation and work and task analyses. (Fiserova 2013.)

3.2 Usability

Usability is a modern way of thinking and it is a part of feasibility. Usability is said to be an attribute of quality that assesses user interfaces ease-of-use, as in how easy it is to use. Usability can be divided into 5 main areas that are learnability, efficiency, memorability, errors and satisfaction. (Nielsen 2012.)

Learnability describes how easy user can accomplish basic tasks in first encounter. Learnability could be defined as the most important area of usability. Consistency is an important part of learnability and learning process. Consistency guarantees that user can learn the use of software. Efficiency indicates how quickly can tasks be performed. Efficiency is often measured with users that are acquainted with the software as achieving perfect user efficiency can take years of usage. Memorability describes how easily user can remember how to use the software. If the software is easy to come back to then the memorability is good. Memorability is best tested with people that use software occasionally. (Nielsen, 1993, p. 26-32.)

Errors defines as how many errors do users make and how can they recover from them. Leading the user do right things with help of error warnings could improve usability. Also it is important to give feedback, if function is succeeded then a sound or visual information about it assist user. Totally obstructing error making leads less frustrated user. If user has to correct his/her own small error, it mainly leads to lack of efficiency. Errors could be measured statistically by how many errors does user make. Satisfaction means that software is pleasant to use. Visually and esthetically engineered software is pleasant to use and it brings satisfaction. If software is made to perform tasks only without visualization satisfaction would decrease. For example, visualization of statistic in pie chart could bring satisfaction to user because of its visual appearance. (Nielsen, 1993, p. 26-32.)

Shults (2012) conducted a study for improving the usability of Wedge program to specific user group. Study was made to boost up software rate of use and improve usability. Questionnaire and interviews were made and from those results custom process model “site” was made. After the “site” was ready to use, user comments were acquired and final process chart was made. Conclusions in this study were that software was easy to use, clear and simple. However, no one was using it after it was done. (Shults, 2012.) In the study it was said that users were not involved enough in the process of implementing the study. (Shults, 2012, p. 5-26.)

3.3 Preventive and predictive maintenance

Mobley (2004) stated that preventive maintenance can be defined as well scheduled maintenance operation, not too early as in putting normally working equipment under maintenance but not too late as in fixing a broken equipment. Preventive maintenance is time driven, meaning how long does it take to equipment to stop by failure. The opposite of preventive maintenance is run-to-fail type of management. Run-to-fail type of maintenance does not use any money to fix equipment until it is in nonfunctional state. In this type of reactive maintenance management everything must be immediately in order for it to work such as spare parts and maintenance workers etc. Reactive maintenance also increases equipment down time. (Mobley, 2004, p. 1-6.)

In preventive maintenance it’s always assumed that equipment degrades in time. Preventive maintenance measures enable the possibility that equipment can work the statistical operation time. This prevention is done by using some statistic knowledge of “typical” degrading time of specific pump or other equipment. To ensure that equipment doesn’t break in the middle of normal operation time, preventive measures are needed. Such measures are, for example, lubrication to pump and motor bearings and adjustment alignments for pump and motor. Measures such as vibration monitoring could also be used to prevent catastrophic equipment break down. In preventive maintenance spare parts aren’t always in stock. Preventive maintenance ensures that spare parts can be ordered before the equipment fails. Then there’s no need to keep expensive spare parts in stock to raise plants spare part inventory. Money is saved by keeping plant spare part inventory in minimum. (Mobley, 2004, p. 1-6.)

Predictive maintenance can be defined as an attempt to detect break downs before they occur by using, for example, vibration monitoring. According to Mobley (2004) predictive maintenance can also be defined as a philosophy or attitude which needs help of monitoring systems to gain better maintenance results and avoiding sudden break downs. Productivity, product quality and overall effectiveness of a production plant is improved when predictive maintenance is in order. Predictive maintenance can minimize unscheduled breakdowns. A good predictive maintenance is cost-effective and produces better result for production and maintenance unit. (Mobley, 2004, p. 1-6.)

Higham and Perovic (2001) conducted a study for maintenance of process pumps. In the study the main differentials were pressure and flow measurements. Key aspects in this study were fault detection and identification, predictive maintenance, pumps and signal analysis. The study was very informative and the results verified author’s argument that fault can be detected by comparing pressure and flow measurements. (Higham & Perovic, 2001, p. 226-248.)

4 RESEARCH DESIGN AND METHODS

A work-life related investigative research and development approach was used in this study. From that perspective the research produces knowledge that can be applied to practice. Investigative research and development approach unites concrete development and research approaches. Knowledge for research was collected from real work-life environment. The research and the gathered data will serve the Wedge’s improvement process in the future. This kind of research is not committed to a specific type of theoretical assumptions or methods. (Toikko & Rantanen, 2009.) In this study surveys were planned for data collection for possible improvements in information ergonomics and therefore preventive maintenance improvement.

In this study, the Wedge platform was made for pumps from four manufacturing departments of NNH, leaching plant, extraction/reduction plant, electrowinning and chemical plant. Wedge basics were briefly introduced to the participant group. All members didn’t participate to this introduction. Introduction included login to Wedge, how to use it in basic level, movement in platform and what is in platform. The cover letter APPENDIX 5 was sent via email to all participants and for clarity it was sent in finish. With cover letter also brief manual APPENDIX 6 was sent to participants. Survey forms were constructed to get answers to information ergonomics improvement from Wedge usage and to get answer if Wedge’s total usability good enough to be used as a maintenance tool. Surveys APPENDICES 7 and 8 are the first and the second surveys, that were sent to get the answers to information ergonomics improvement compared to older software DNA. These survey statements were information ergonomics through usability type of statements. APPENDIX 9 was the final survey that was sent to get answer to Wedge’s total usability. Those statements were more for the usability theory of Nielsen (2012), also statements were included for specific information ergonomics of preventive maintenance to get answers to research question 1.

Survey forms were made to get answers to research question. Surveys were done in 3 different phases. First and second survey will have the same questions (Form 1A/1B). Survey form 1 focused on information ergonomics of process data (pumps) in general. Survey form 1 was answered 2 times, once before the Wedge was presented to Quant and once after 2 weeks of using Wedge. The first survey (Form 1A) gave a starting level of information ergonomics Quant had concerning pump process data with old software. The second survey (Form 1B) gave the improved result after 2 weeks of using Wedge. Survey form 2 (Form 2) focused on Wedges usability and information ergonomics improvement that Wedge had possibly brought concerning pump process data. All survey forms had open feedback part to give pros and cons of Wedge freely. Survey respondent opinions were thought to be a valuable part of this study in further development.

The data of survey answers from forms 1A and 1B were compared if there were improvement in information ergonomics and if it had affected preventive maintenance for pumps. Survey Form 2 gave information ergonomics improvement on daily work life, for example, how was Wedge's total usability, was the green-red light model informative and if Wedge gave a better view of pump process data. Survey Form 2 also gave information if Wedge usage brought benefits to information ergonomics regarding preventive maintenance of pumps thus improved preventive maintenance and also did pump maintenance actions improve based on Wedge usage.

Surveys all together gave the data about information ergonomics improvement and Wedges total potential. Surveys gave data if the right information was easier to find thus improving preventive maintenance for pumps. Surveys had the open feedback part that gave pros and cons from how Quant personnel experienced the usability of Wedge. With constructive open feedback Wedge was to be developed further to help with needs of maintenance.

Survey forms with cover letter were sent to 10 persons from Quant. These recipients were reached via email, due to remote working. No names were used in surveys to protect the anonymity and ethical rights of participants. Only the conductor of the study saw the specific participant answers. All participants were expected to answer truthfully. To ensure reliability, survey forms were pre-tested by a co-worker.

4.1 Building the platform

4.1.1 Basic platform setup

Building the Wedge platform started by consulting different NNH production plant personnel about the pumps they wanted to be taken part of this study. After the pumps were carefully chosen a table for pumps was created (Pump information table APPENDIX 2). To pump information table, certain process data was gathered to be later used on building the platform. The gathered data was location, name, motor

DNA-position, Flow DNA-positon, Pressure DNA-position, Tank Level DNA-position of the pump. This data table was used as help in building the platform as it was needed to use these DNA-positions to find the related measurements. Pump information table also included low, target and high limits for current and flow. These were later on used to build the pumping information and limits.

As the basic information was gathered the platform designing was taken into action keeping focus in usability and information ergonomics. The plan was to make the platform as simple as possible. Simple process flow chart was made to give a perspective to user of what was being measured. Measurements were implanted to the platform from database which held over 75000 DNA-positions, other process sample measurements or information from all of NNH manufacturing plants. The positions were implanted with drag and drop method and then set up for the measurements were made. After all of the pumps were created to the platform some DNA-position measurements were shown and some green-red lights were adjusted to get some visualization effect. From figure 2 user can see pump SA13 P1 as a pump picture and its current. Flow indicator to the next vessel is located in the line and its flow measurement is below the picture. This kind of setup was done for 10 pieces of pumps. Some of the pumps were duplicates as reserve pump to the same process as, for example, SA13 P1 and SA13 P2 were duplicates, only one of them was running at a time.

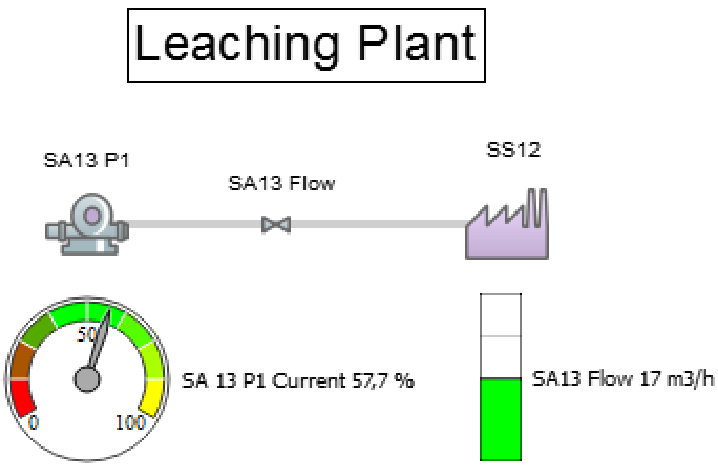

Figure 2. Basic pump setup in Wedge platform

4.1.2 Specific pump setup

Part of information ergonomics is the usability of technology and the possibilities to adjust the technology for user needs thus improving information ergonomics (Shults, 2012). Consequently, can be argued that usability is significant factor of information ergonomics. According to Franssila 2014 workers individual and working community's working habits are important factors of information ergonomics. (Franssila et al., 2014, p. 11-15.)

When pump specific setup was being made, the Pump information table APPENDIX 2 was taken into a deeper consideration. For example, from figure 3 below can be seen SA13 P1 DNA-position that was dragged into the platform. For example, M-32088.E1:av was the pumps current. Limits for pump current and flow were also the base knowledge used in the construction of the wanted data for green-red light model. By giving limits to pump specific current and flow a calculation series could be made. With these calculation series the green-red light model was created to give specific knowledge of pumps condition. Green light meaning good, OK and red meaning bad, error/malfunction.

Tag	Unit	Description
M-32088.E1:av	%	SA 13 P1
M-32088:cur	%	SAKEUTTIMEN 13 ALITTEEN KIERRÄTY
M-32088:ins	RUN	SAKEUTTIMEN 13 ALITTEEN KIERRÄTY
M-32088:ld	L/D	SA 13 P1
M-32088:ma	M/A	SA 13 P1
M-32088:s		SAKEUTTIMEN 13 ALITTEEN KIERRÄTY
M-32088BY	I/O	SA 13 P1

Figure 3. Example of DNA-position list from Wedge

Limits for the pump current and flow were constructed as follows. As current was measured in approximately from zero to hundred percent in process operating DNA-system, the calculated or setup limits were in between 0 % to 100 % percentage. As for pumps normal operating current was in between 40 % to 75 %, these were the current optimal target levels. Current low and high were then calculated from Wedges trend tools automatic average counter. Average values were adjusted to nearest even percentage from 30 % to 60 % as low limit and 65 % to 85 % as high limit. Each pump had their own specific limits except the ones with identical duplicate. As for flow each pumps flow indicator limits were constructed as currents were. So that every pump had own flow low and high limits and an optimal target. Duplicate pumps shared the flow indicator DNA-position. Separate pumps had their own flow indicator DNA-position Flow low limits varied from 5 m^3/h to 47 m^3/h and the flow high 10 m^3/h to 65 m^3/h. Normal flow target values were in between 8 m^3/h and 56 m^3/h. From figure 4 and 5 below the different limits can be seen in specific pump Wedge properties.

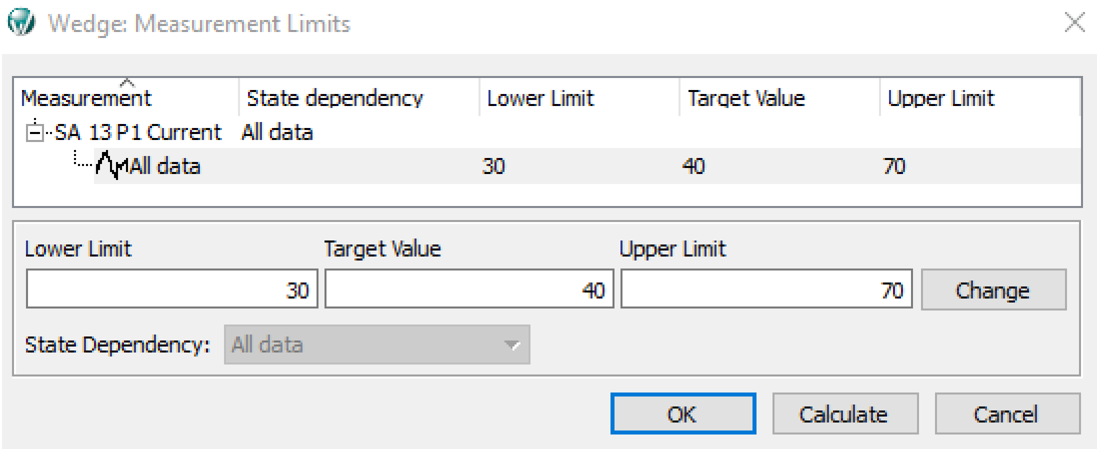

Figure 4. Measurement Limits for SA13 P1 current.

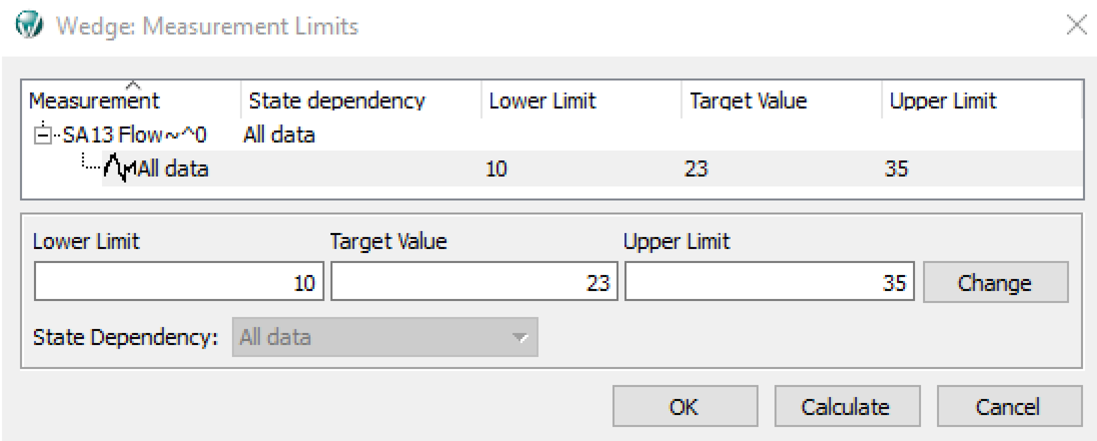

Figure 5. Measurement Limits for SA13 Flow.

4.1.3 Green-red light system

To get the green-red light system to show the specific light was done with calculation formulas inside Wedge platform. Basic assumption for current was made so that if current exceeds low or high current limit and the flow exceeds low or high flow limits, then error is shown as red light. Another assumption was made that if pump current exceeds low or high current limit or the flow was exceeding low or high flow limit the light would turn red as sign of error. And if current and flow was in between the low and high limits then it was OK and the light was green. Yellow light was made to tell if pump was running, if light is green pump is running and if light is yellow the pump is not running. Useful information was also made for pump data table. Pump starts per month and pump errors per month were done for extra information only.

Last Month

Pump data table

Plant	Leaching	Leaching	Reduction	Reduction	Chemical	Chemical	Electrowinning	Electrowinning
Pump	SA13 P1	SA13 P2	VS211 P1	VS221 P1	KT3251 P2	KT3951 P2	LS8 P1	LS8 P2
Pump or Flow error (green=OK, RED=error)	SA13 P1	SA13 P2	VS211 P1	VS221 P1	KT3251 P2	KT3951 P2	LS8 P1 LS8 P1 / HT1	LS8 P2 LS8 P2 / HT1
Pump and Flow error (green=OK, RED=error)	SA13 P1	SA13 P2	VS211 P1	VS221 P1	KT3251 P2	KT3951 P2	LS8 P1 LS8 P1 / HT1	LS8 P2 LS8 P2 / HT1
Pump running (green=run, yellow=stop)	SA13 P1	SA13 P2	VS211 P1	VS221 P1	KT3251 P2	KT3951 P2	LS8 P1	LS8 P2
Pump starts per month	Start 0 times	Start 1 times	Start 2 times	Start 5 times	Start 70 times	Start 57 times	Start 0 times	Start 1 times
Pump errors per month	Error 0 times	Error 65 times	Error 5 times	Error 2 times	Error 86 times	Error 80 times	Error 0 times	Error 2 times

Figure 6. Pump data table in Wedge.

4.1.4 Calculations for pump data table

The setup for calculations was done from Wedge platform for each pump. Example for the calculation sequence goes as follows. For these calculations SA13 P1 pump was used as an example. First the electrical current with setup low and high limits was changed to binary form. The flow with setup low and high limits was changed to binary form. When in binary form the electrical current or flow trend gave spikes when low or high limits were exceeded. From those spikes as flat zero line meaning the normal and the spike on trend meaning an error. Pump run/stop trend was also changed to binary form.

Equation 1. (x1>1high) | (x1<1low),

x1 being SA13 P1 current (M-32088.E1:av).

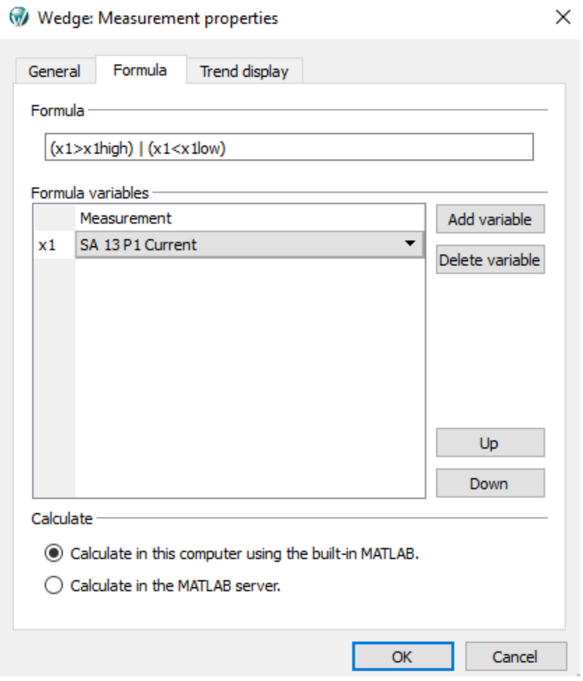

Figure 7. Equation formula 1, for SA13 P1 current change to binary form.

Equation 2. (x1<x1low) | (x1>x1high)

x1 being the SA13 flow (F-3902:me)

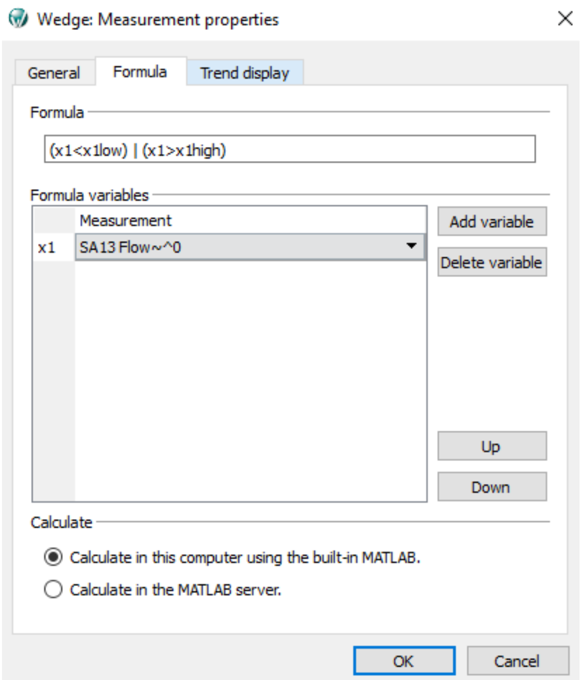

Figure 8. Equation formula 2, for SA13 flow change to binary form.

Equation 3. (x1==1) | (x2==1)

x1 being the SA13 P1 current high/low in binary form

x2 being the SA13 flow high/low in binary form.

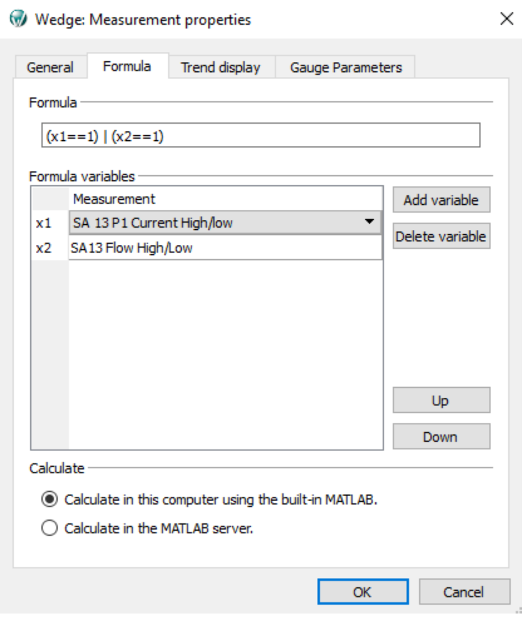

Figure 9. Equation formula 3, for pump or flow error.

Equation 4. (x1==1) & (x2==1)

x1 being the SA13 P1 current high/low in binary form

x2 SA13 flow high/low both in binary form.

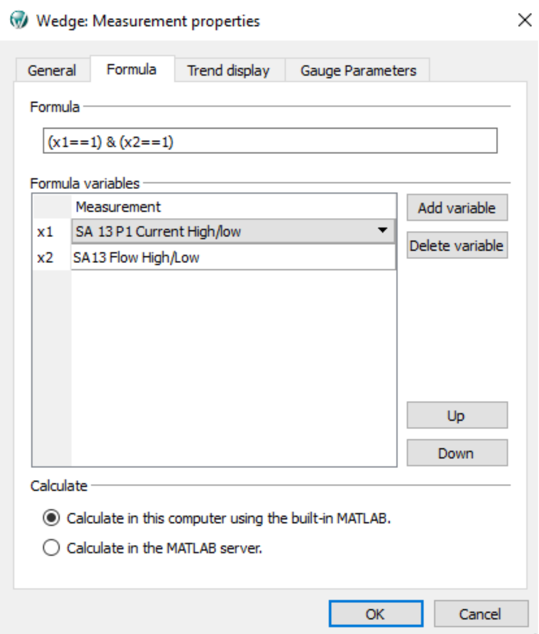

Figure 10. Equation formula 4, for pump and flow error.

Equation 5. x1==1

x1 is SA13 P1 (M-32088:ins) run state in binary form.

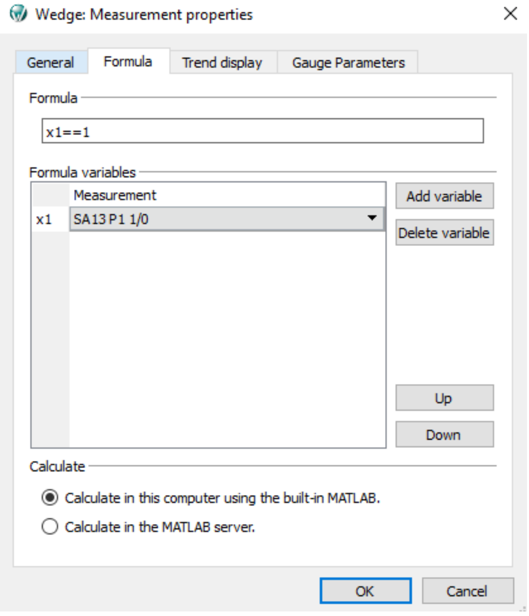

Figure 11. Equation formula 5 for SA13 P1 run state change to binary form.

Equation 6. wdiff(x1==1)>0

x1 is SA13 P1 run state in binary form

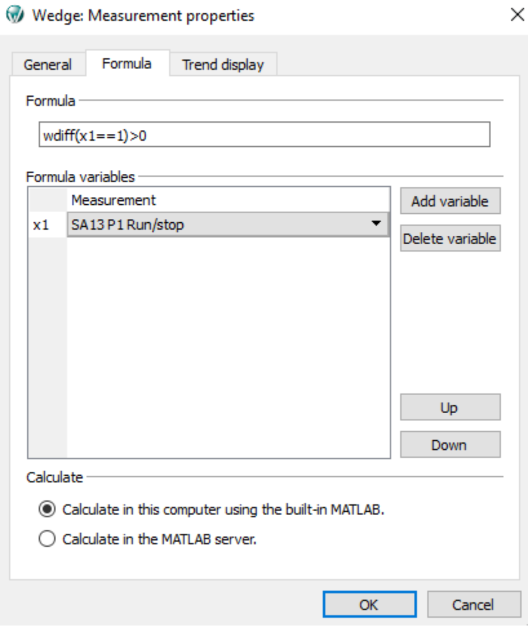

Figure 12. Equation formula 6, for sum countdown.

Equation 7. cumsum2(wdiff(x1==1)>0,wdiff(x2))

x1 is SA13 P1 run/stop, in binary form

x2 is month

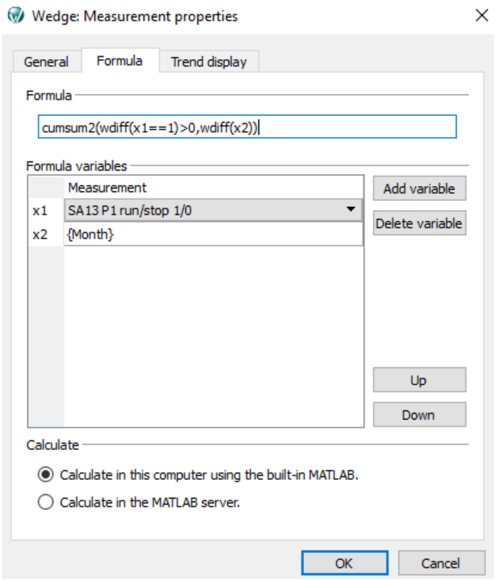

Figure 13. Cumulative sum from the last month pump starts.

Equation 8. wdiff(x1==1)>0

x1 is SA13 P1 pump or flow high/low, in binary form

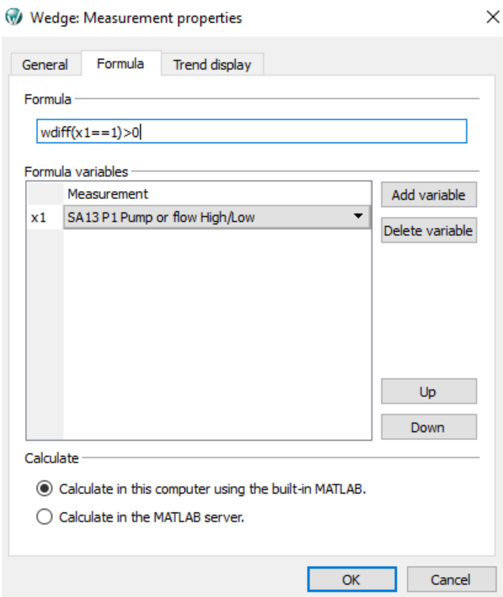

Figure 14. Error count, in binary form

Equation 9. cumsum2(wdiff(x1==1)>0,wdiff(x2))

x1 is SA13 P1 Error Count, in binary form.

x1 is month.

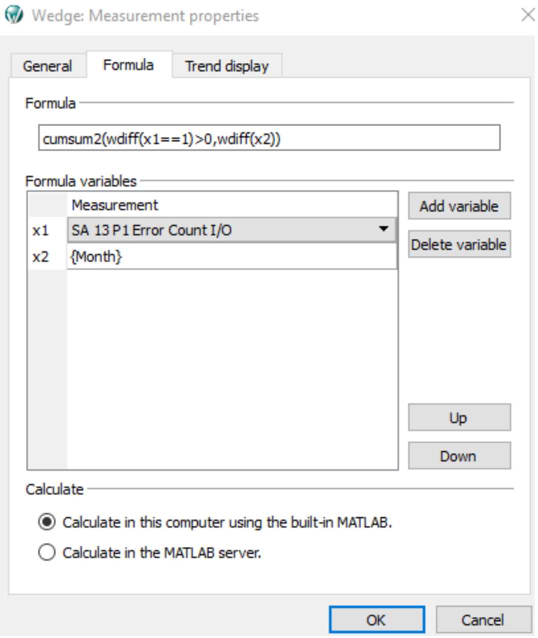

Figure 15. Cumulative sum from last month errors.

5 SURVEY RESULTS

Survey 1A was sent out to 10 participants at start of the Wedge 2 weeks' trial. Survey 1A was answered by 7 of the participants. Survey 1B was also sent to the same 10 participants after 2 weeks of Wedge usage. 7 of those participants answered the 1B survey. Surveys were sent to participants as scheduled via email, but getting answered surveys back from participants was challenging. The 2 weeks' trial period meant for the testing and survey answering stretched out to over a 5 weeks. As the surveys were gotten back from the participants, the surveys were examined carefully and thoroughly. A few participants gave comments and improvement proposals. Those comments are shown below later on. The researcher took a notice that those participants that didn't come to introduction meeting gave the most negative answers.

5.1 Starting level and 2 weeks' trial survey analysis

From first survey 1A the point was to get a baseline to current situation when maintenance looks up process pump related data. Survey gave valuable information how maintenance partner saw the current situation from that angle. The answers from survey 1A divided heavily between participants as can be seen from the bars below. This survey proves that already with the software (DNA) in use is held up high concerning process pump related data.

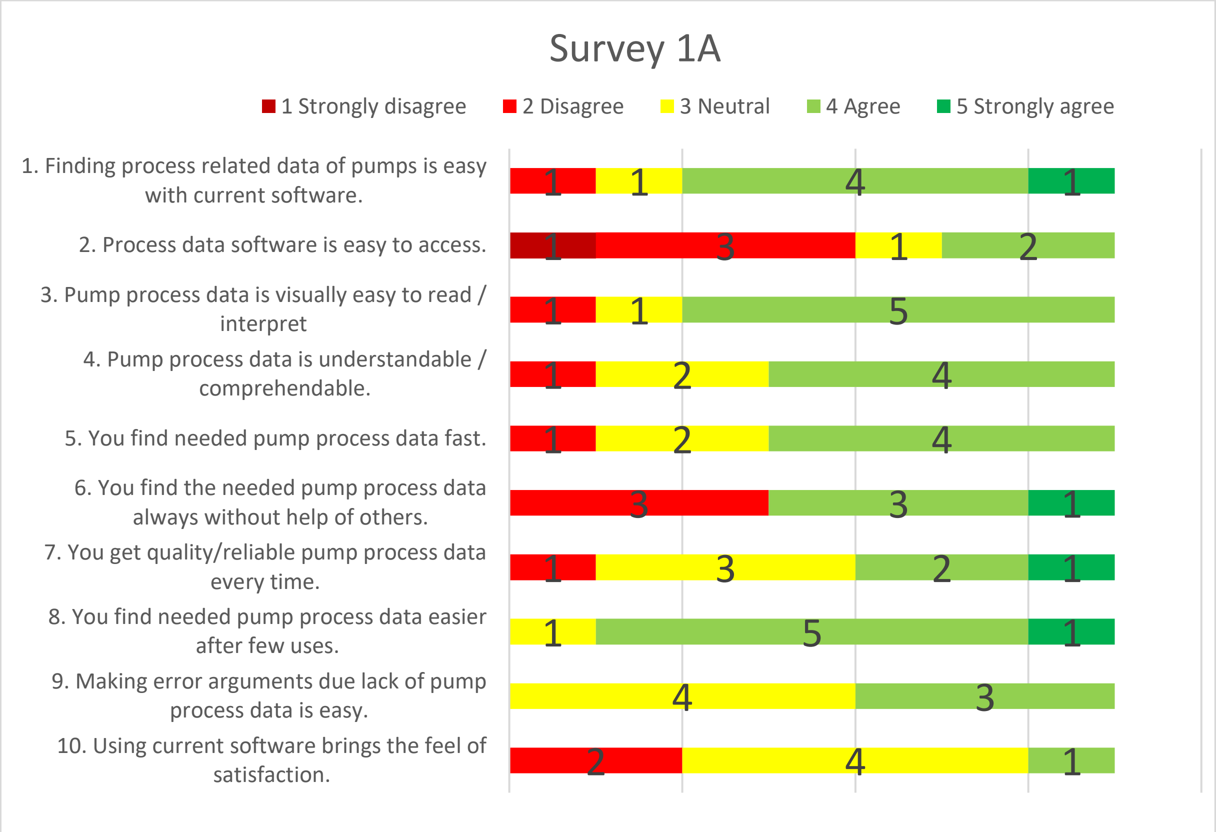

Figure 16. Survey 1A results.

Second survey 1B was done for getting comparable data in between old DNA software and Wedge. This survey was done after brief but daily usage of Wedge. With this survey answers also divided heavily and no major difference was noticed when comparing these first surveys in overall.

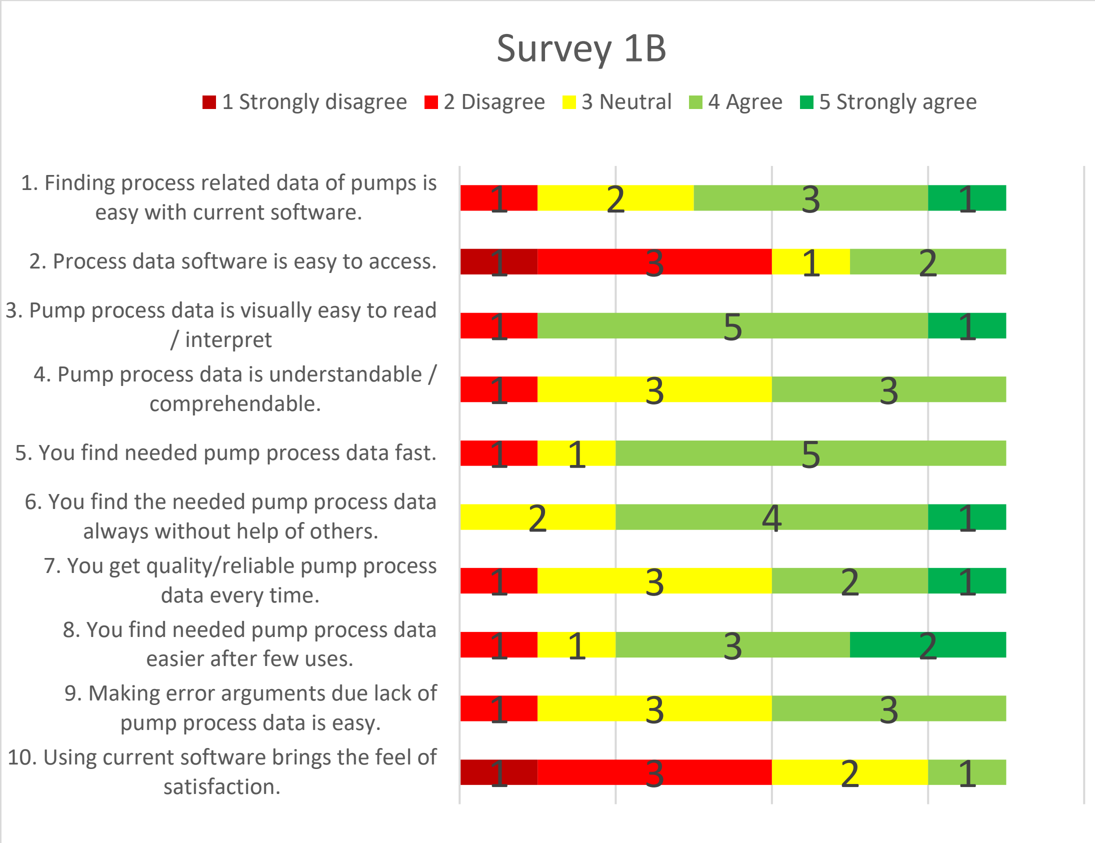

Figure 17. Survey 1B results.

Statement 1 "Finding process related data of pumps is easy with current software" in survey 1A was agreed by 4 and strongly agreed by 1 participant, which can be interpret that current DNA software is fairly easy to use as only 1 participant disagreed and 1 was neutral. If compared to surveys 1B 1 of the participants changed their answer to a positive and 2 to a negative direction. This change may be an after math of only 2 weeks of daily usage of Wedge. From researcher point of view more positive answers were expected even it was so short test period.

Statement 2 "Process data software is easy to access" in 1A was agreed by 2 participants and disagreed by 3 and strongly disagreed by 1 participant. Also 1 was neutral. It seems that concerning statement 2. the accessibility to DNA system was not too easy even after years of usage. This indicated the lack of "easy access". If software is not easily accessible from any desktop or laptop etc…, it decreases the total usability of the software. There was no difference when compared to survey 1B overall, but participant answers differed slightly as 1 answer changed to a positive and 1 to a negative direction.

Statement 3 “Pump process data is visually easy to read / interpret” was agreed by 5 and disagreed by 1 participant. Also 1 was neutral. Visually DNA software seems fairly easy to read. In survey 1B 3 participants changed answers to positive direction and 1 to a negative direction. As this study was to make visually easier to read pump process data, the answers leaning to positive change have to be taken into account as an accomplishment from researcher point of view.

Statement 4 “Pump process data is understandable/comprehendible” was agreed by 4 participants and disagreed by 1. 2 participants were neutral. As for statement 4 in 1B survey, one participant changed to positive and 2 changed to a negative direction.

Statement 5 “You find needed pump process data fast” 4 participants agreed and 1 disagreed. 2 participants were neutral. Statement 5 in survey 1B 2 participants changed to a positive and 1 to a negative direction.

Statement 6 “You find the needed pump process data always without help of others” was strongly agreed by 1 and agreed by 3. Statement 6. was also disagreed by 3 participants. At survey 1B this statement showed the most success when compared to survey 1A in overall figures 16 and 17. After more careful analysis 3 participant leaned to positive and only 1 to a negative direction.

Statement 7 “You get quality/reliable pump process data every time” was strongly agreed by 1 and agreed by 2 participants. 1 participant disagreed on this statement and 3 was neutral. Survey 1B gave identical answers in overall. Still there was 1 change to a positive and 1 change to a negative direction.

Statement 8 “You find needed pump process data easier after few uses” was strongly agreed by 1 and agreed by 5. 1 participant was neutral. Statement 8 divided participant answers more. As 2 participants changed to a positive and 3 to a negative direction.

Statement 9 “Making error arguments due lack of pump process data is easy” was agreed by 3 and 4 was neutral. In survey 1B one change to a negative direction.

Statement 10 “Using current software brings the feel of satisfaction” was agreed by only 1 and disagreed by 2. 4 participants were neutral. In survey 1B one participant that disagreed changed to strongly disagree. There were 2 changes to a positive and 2 changes to a negative direction.

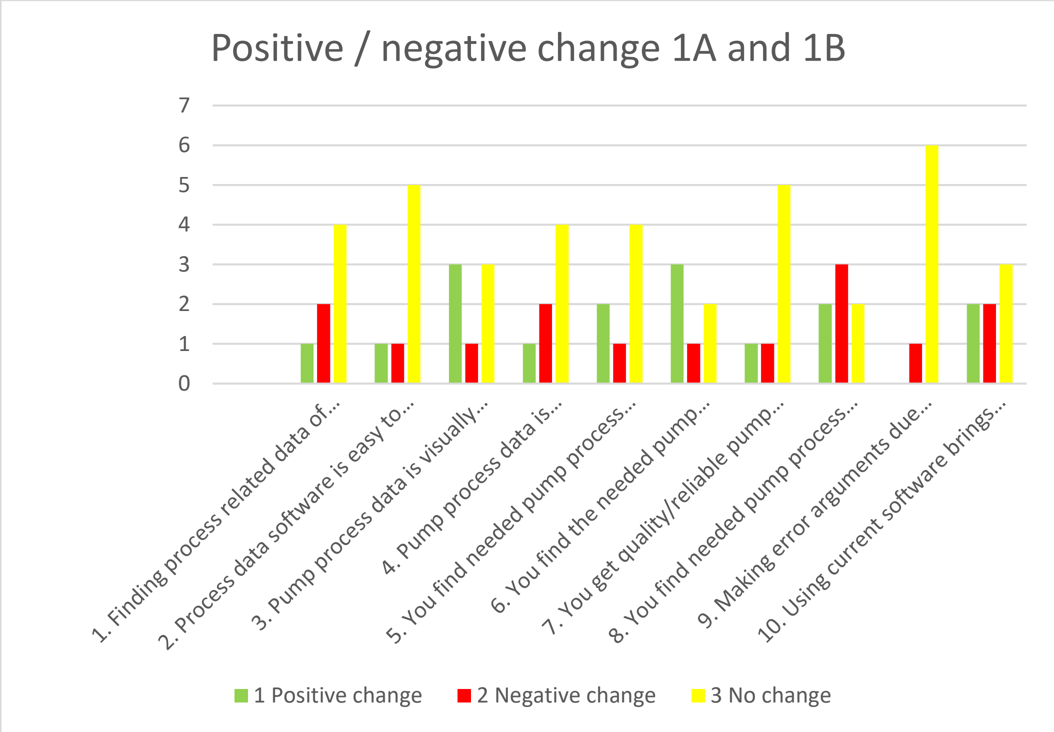

Figure 18. Positive / negative change comparison.

All in together there were 16 positive changes and 15 negative changes to participant answers. This tells that some seemingly thought that Wedge had some positive effects on areas such as visual readability, easier and faster access of specific pump data. But also pump data was harder to find with Wedge software, also the data was not as understandable/comprehendible and seemingly the pump data was harder to find after few uses. Figure 18 also tells the answers that didn’t change at all.

Free feedback was given by few participants, but quality of the feedback compensated the amount. There were few issues concerning login through Citrix portal to the Wedge software. Firstly, Citrix portal that Quant personnel use to get into NNH DNA software and Wedge etc. is slow to use and kicks user out after 1 hour of usage. “Citrix login is tricky as user get logged out due timeout”. When using Wedge through the Citrix portal, the software becomes very slow to use and even slightest timeline, other parameter changes crashes the Wedge software very easily as pointed out in two following extracts: “Operating system in wedge is very slow and platform site updates very slowly”, “Wedge crashes/gets stuck have to restart”. Also “moving” in the platform was experienced to be tricky. One of the participants explicated this problem by stating that “Can’t move in the platform, keep getting stuck. If this was different probably would be a good software”. It became clear that using the platform basics moving etc. needed time to getting used to.

Not participating in the brief introduction meeting generated the following issue: “Had troubles getting Wedge to work properly, didn’t have the time to participate in earlier meetings, so opportunity to look at data in DNA is easier to approach”. As can be stated that using totally new platform independently as work related tool is not easy without basic introduction and even with introduction it was still considered fairly hard to use.

The lack of understanding the process behind the logic, calculations and brief introduction caused the following questions: “How to react to errors and why? Background should be opened more”, “What different alarms were calculated to error counts, what should be concluded? and “Were the limits set out right or should they be changed?”. Without further knowledge of specific pumps process data, it was seen as a difficult to understand the error and how it came to be. Knowledge of how the platform was built made it clearly easier to use from researcher’s perspective.

5.2 Usability analysis

Survey 2 was supposed to give answers for total usability for Wedge in this application. The participants answered the statements and they differed a lot. Many participants experienced Wedge in a positive way in overall. But there was few that experienced Wedge very negatively. Based on neutral answers, most participants were unsure whether Wedge gave anything to information ergonomics of preventive maintenance. Under the Figure 18 some of the most interesting results are highlighted.

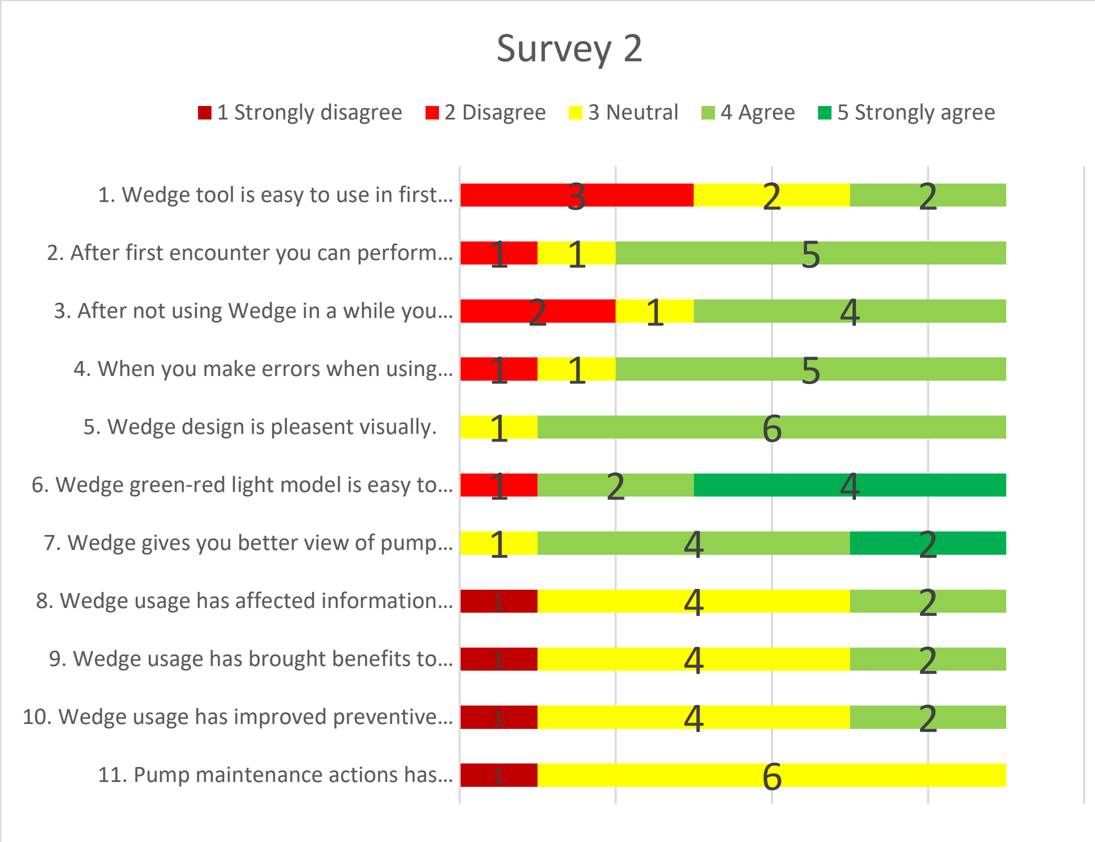

Figure 18. Survey 2 results.

These following comments are from survey 2 free comment section. “When you take break using Wedge it isn’t easy to use again” gives solid proof that Wedge is not easy to use, when used irregularly. Participants were instructed for daily use, but it seems that it wasn’t enough to maintain reasonable level. “Wedge is not very accessible” comment was given by one participant. Quant used Wedge through Citrix portal, it gave a lot of trouble in basic use.

“Wedge’s Green-Red light model is very easy to read” positive feedback came up few times. This proofed the point that some participants experienced Wedges light model positively (agreed or strongly agreed). But there was the fact that one participant experienced this negatively (disagreed). The green-red light model was supposed to be visual aid for easier use. Seems that this light system failed with one participant. Following statement proves that Wedges readability is a bit better when compared to DNA software “Wedge gives better readability to pump process data”. Thought this statement was in conflict with at least 4 participants answer.

Comment “Wedge has slightly brought better information ergonomics concerning pumps” was given by one participant. As answers were mostly in neutral range, this comment was the only one that gave any indications about information ergonomics improvement made by Wedge. As there was only one positive feedback on information ergonomics on the other hand was some major negative feedbacks concerning same subject.

Wedges usage for preventive maintenance information ergonomics improvement was a failure when analyzing these 4 comments below. Expectations of success were still high as most participants answered positively in survey 2. Few participants gave very negative feedback regarding to information ergonomics: “Wedge does not affect positively on information ergonomics of preventive maintenance”, “Usage of Wedge does not bring any benefits for preventive maintenance”, “Wedge does not affect positively on preventive maintenance” and “Wedge usage has not brought beneficial preventive maintenance actions”. When thought about what these comments were based on, there was a change that daily usage and checking the pump data was not achieved. Also the introduction could have failed with these particular participants.

One participant felt strongly that Wedge didn’t give satisfaction when using: “Using of Wedge does not give the feel of satisfaction”. When analyzing this comment, Survey 1B concluded that only one participant felt satisfaction after using Wedge and 4 answers were negative.

6 DISCUSSION

From Wedge’s green-red light model Quant was supposed to react independently for pump malfunctions via Maximo service request. These independent reactions for malfunctions was supposed to decrease downtime thus improve preventive maintenance. Zero Maximo service request was made regarding this Wedge usage. Surveys all in all gave an important insight on Wedges total ability to be used as an extension of process operating system such as DNA. How to draw conclusions from so variety of answers was found to be difficult. But when starting from Nielsen's usability theory to get the baseline for the research questions 1 and 2.

1) How and to what extend does Wedge effect on information ergonomics of preventive maintenance?
2) How maintenance supervisors experience the usability on Wedge?
3) What are the pros, cons and improvement possibilities of using Wedge from maintenance supervisors' perspective?

When analyzing usability of Wedge in this application it seemed that the learnability became an issue in some participant's experience. First encounter with Wedge was crucial to the success of the study and from researcher's point of view the result wasn't satisfying. As the introduction for Wedge was brief and the number of the participants was low. This brief introduction was enough for some participants as they were able to use Wedge without major issues. Those who missed the introduction the problems started as soon as the first day of the 2 week testing period. The baseline for learnability was according to Nielsen (1993) that user can accomplish basic tasks easily first time they encounter the design. This baseline defined the Wedge platform's learnability to more negative than positive, as can be seen from Figure 18 first question. As consistency is as important part of learnability, this wasn't measured in any way during the study, as participants were alleged to use the Wedge platform on daily basis. According to Nielsen (2012) consistency guarantees that user can learn the use of software, but as researcher I found this to be a dangerous assumption, as it could be impossible for everyone to learn the use even usage was consistent.

Efficiency was rendered mostly as a positive way, though efficiency wasn't measured with objective tools but participants own opinion how Wedge was to use. As one participant had a negative answer, the following factors led to that. The lack of participation to introduction, caused many problems to participants. The focus of the study was clear to most of the participants, but few had starting problems, they saw the Wedge platform on their own and didn't know what was supposed to check etc. Clearly those who participated to introduction had more positive answers. This study's main point was to give a platform that can be used in one glance, but couldn't be done if participant didn't know what to look for and check out. Learning leads to efficient use and the more participant uses the more efficient person will become. Efficiency Nielsen (1993) growths little by little of usage, it could take years to achieve perfect user efficiency.

Memorability according to Nielsen (1993) was described as how easily user can remember the use of software in this case. To a surprise memorability had some negative answers, as Wedge platform was done in a way that it didn’t need any actions beside the “last month” refresh button. But at least four participant answered in a positive way as expected. Memorability in this case wasn’t tested in any way, the result came from participants own opinion on the matter.

When errors are made can user recover from them in reasonable time is a way to measure one part of usability according to Nielsen (1993). This study proved that when encountering an error while using Wedge participants could recover quite well, only one participant had problems recovering from errors. As the Wedge platform was made to be as simplistic as possible, avoiding errors was easy. User didn’t need to “touch” anything just open and look at the platforms green-red lights.

Satisfaction brought by Wedge had the most positive score when comparing all survey data. After 2 weeks of using Wedge the satisfaction what according to Nielsen (1993) can be defined as visually and esthetically pleasant was achieved very positively. Visualization of the pump process data was a success at this according to survey 2. As the feedback was that the green-red light system was easy to read and comprehend. Just by entering data in numbers etc. would probably make this kind of platform very heavy to use for the eye.

Wedges information ergonomics factors were complicated to interpret from survey answers. Most positive statement told that Wedge gives a better view of pump process data. This was a good statement as it gives the study overall fact that Wedge was better visually and the data was pre collected to the platform table when comparing to DNA system where user needs to extract data by itself. As improving information ergonomics means making workload management easier for worker according to Franssila (2016). Easier access to data and when data is somehow filtered to an easy to read form, helps the knowledge worker information intensive tasks. Wedges usage had affected information ergonomics of preventive maintenance, but how is the question. By giving easier to read and interpret data brought faster, easier to find and clearer data about pumps current situation. It had also affected negatively, that apparently pump process data was harder to find and not so clear to see with the green-red light system.

To what extent Wedge brought benefits to information ergonomics for preventive maintenance. According to survey 2 the pump maintenance actions did not improve thus Wedge didn’t improve preventive maintenance in this specific matter as much as expected. As Mobley (2004) stated that preventive maintenance could be defined as scheduled maintenance action, these kind of actions weren’t done during the trial. As if run-to-fail type of maintenance management was in play. If trial time would have been longer, let’s say 2 months, there might have been preventive maintenance actions.

Surveys positive answers were supposed statements that “If usage stabilizes, could get more out of Wedge”. Much room to improve according to few participants, as platform was too confusing and formulas were confusing to new participants they didn’t know what the calculations and the green-red lights were based on. The Wedge platform access would have to be changed to a single login type of solution. So that the workers in future could use Wedge more freely without Citrix portal. That would bring easier and faster basic usage for the software. The nice to know pump start and error count, in some cases caused a lot of astonishment. The amount of pump starts, for example, was close to 70 times per month and this was considered a “red flag” as why was this so many, “something is definitely wrong, wrong pumps or error in calculation” when checked these calculations were correct. Different kind of processes have different kind of run patterns, some pumps are on 24/7 and some pumps are meant to start 5 times per day because of batch process. This kind of indication could have been reported to Maximo as preventive maintenance work order. Unusual behavior of the pump was noted like in Higham and Perovic (2001) study focusing on fault detection and identification of pumps.

7 CONCLUSION

When summing up some thoughts came up. Wedge although being hard to use at first touch, brought users satisfaction and could be said that usability in total was positive. User would need a lot of usage before perfect usability can be achieved. Learnability was thought to be a stumbling block for good total experience. Lack of larger scale introduction for Wedge usage was considered to be the major factor leading to failing of some participant experience with the platform. Importance of introduction for smooth practical usage of Wedge was considered an important finding in the study. It was thought that investing in better introduction and orientation period would have paid off in the end. From practical perspective the time scale of the study could have been bigger than 2 weeks. Developing the platform based on user comments would have been an ideal situation. By modifying the platform, the usability and information ergonomics improvement could have been seen in more positive way. Information ergonomics improvement together with usability both support each other forming possibly a good result.

Limitations for study were considered to be the small selected group for this Wedge study. Optimistic plan for the specifically selected groups participation backfired and 3 out of 10 participants didn’t participate to the study at all. And 2 of the participated didn’t participate in introduction. The small participant group for this study was a known risk from the start, yet it wasn’t seen as a major issue. As for the participants that participated for the Wedge trial period and answered surveys gave good feedback concerning total usability and information ergonomics.

Future possibilities are to expand the usage of Wedge to a larger user group. Larger user groups such as including maintenance workers to user group could bring benefits to their understanding of different process pumps or other devices. But on the other hand their work is related more to the actual maintenance performance and not so much in computer work. By adding more pumps to the platform and possibly separating different manufacturing departments from each other would give user a clearer design. Possibly constructing larger sub-processes to the platform would give the user more information about surrounding process. Also, whole devices could be introduced to the Wedge platform, such as mills, filters or autoclaves for example. This should be researched in the future if whole devices or sub-processes could be done reliably to the platform for use of maintenance. Most of all a research for different kind of these tools such as Wedge should be investigated if more suitable ones exist.

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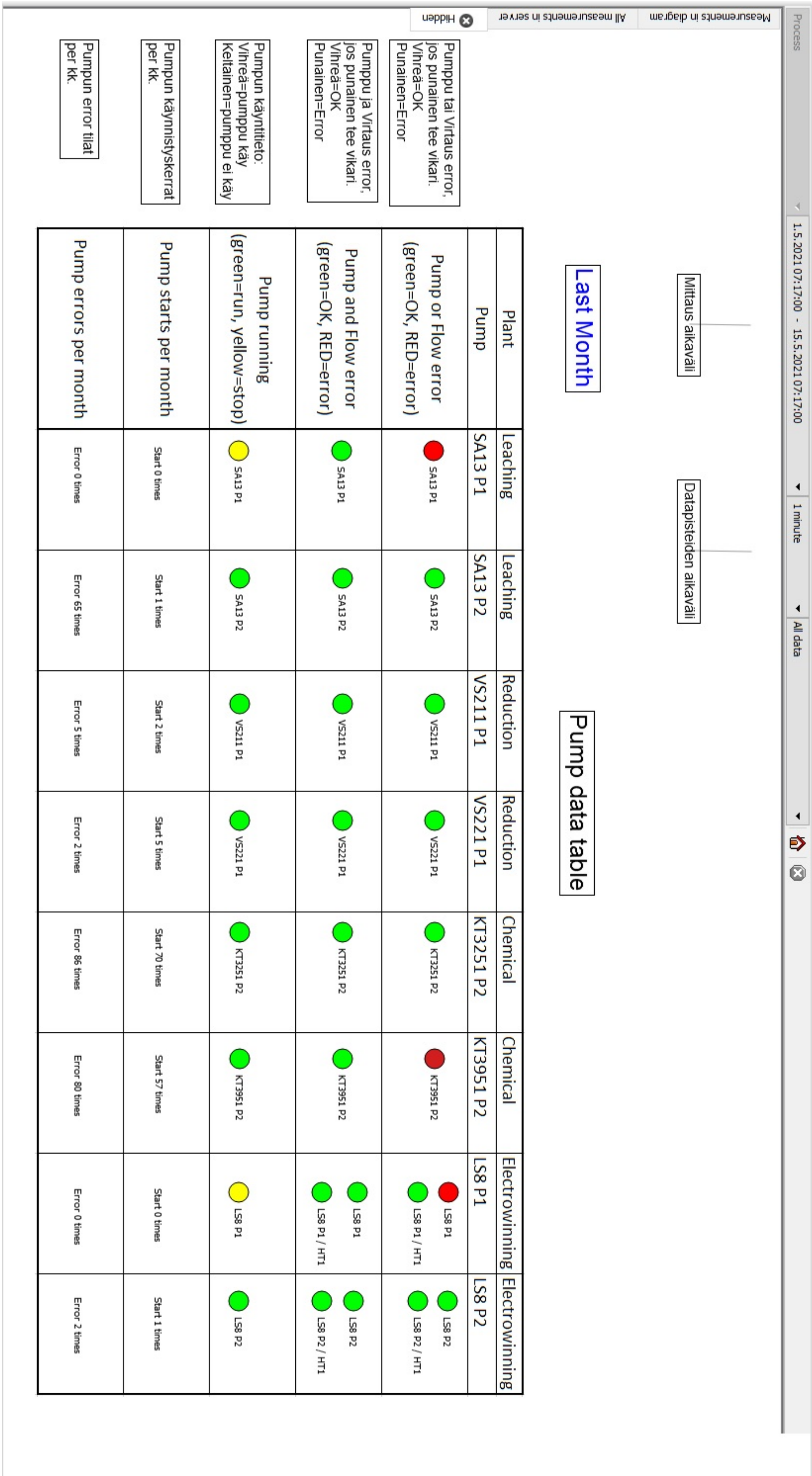
APPENDIX 1



Plant	Leaching	Leaching	Reduction	Reduction	Chemical	Chemical	Electrowinning	Electrowinning
Pump	SA13 P1	SA13 P2	VS211 P1	VS221 P1	KT3251 P2	KT3951 P2	LS8 P1	LS8 P2
Pump or Flow error (green=OK, RED=error)	SA13 P1	SA13 P2	VS211 P1	VS221 P1	KT3251 P2	KT3951 P2	LS8 P1 LS8 P1 / HT1	LS8 P2 LS8 P2 / HT1
Pump and Flow error (green=OK, RED=error)	SA13 P1	SA13 P2	VS211 P1	VS221 P1	KT3251 P2	KT3951 P2	LS8 P1 LS8 P1 / HT1	LS8 P2 LS8 P2 / HT1
Pump running (green=run, yellow=stop)	SA13 P1	SA13 P2	VS211 P1	VS221 P1	KT3251 P2	KT3951 P2	LS8 P1	LS8 P2
Pump starts per month	Start 0 times	Start 1 times	Start 2 times	Start 5 times	Start 70 times	Start 57 times	Start 0 times	Start 1 times
Pump errors per month	Error 0 times	Error 65 times	Error 5 times	Error 2 times	Error 86 times	Error 80 times	Error 0 times	Error 2 times

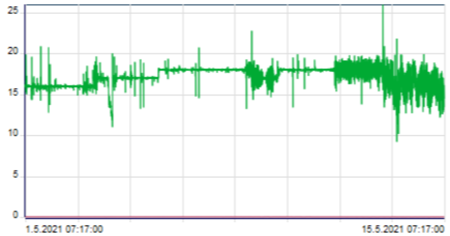
APPENDIX 2

Plant	Pump	Motor DNA-position (E.1)	Flow DNA-position	Pressure DNA-position	Tank Level DNA-positon	Current Low [%]	Current Target [%]	Current High [%]	Flow Low [m3/h]	Flow Target [m3/h]	Flow High [m3/h]
Leaching	SA13 P1	M-32088.E1:av	F-3902:me			30	40	70	10	23	35
Leaching	SA13 P2	M-32087.E1:av	F-3902:me			30	40	70	10	23	35
Reduction	VS211 P1	M-36090.E1:av	F-36168:av, F-36443:av	P-36242, P-36257	L-36219	60	75	85	47	56	65
Reduction	VS221 P1	M-36362.E1:av	F-36169:av, F-36444:av	P-36243, P-36258	L-36220	60	75	85	47	56	65
Chemical	KT3251 P2	M-88073.E1:av	F-88006:me			45	60	75	5	8	10
Chemical	KT3951 P2	M-88402.E1:av	F-88099:me			45	60	75	8	12	16
Electrowinning	LS8 P1	LS8P1:cur	F-3401:av, F-3404:av		L-3407 HT1	30	45	65	25	37	50
Electrowinning	LS8 P2	LS8P2:cur	F-3401:av, F-3404:av		L-3407 HT1	30	45	65	25	37	50

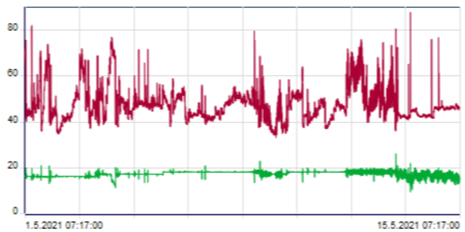
APPENDIX 3

Trendiviivojen värit:
Punainen=Pumpun virta
Vihreä=Virtaus

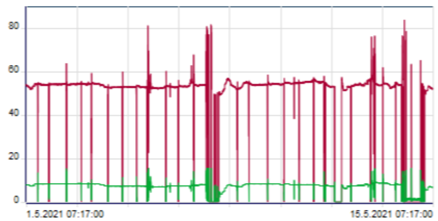
SA13 P1 Current and Flow



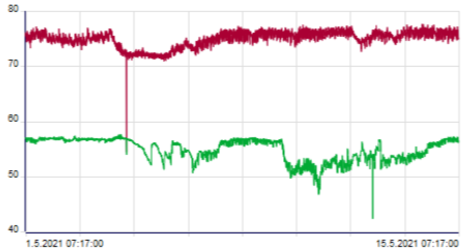
SA13 P2 Current and Flow



KT3251 P2 Current and Flow

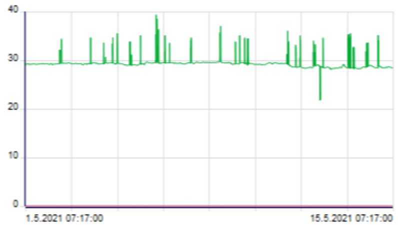


VS211 P1 Current and Flow



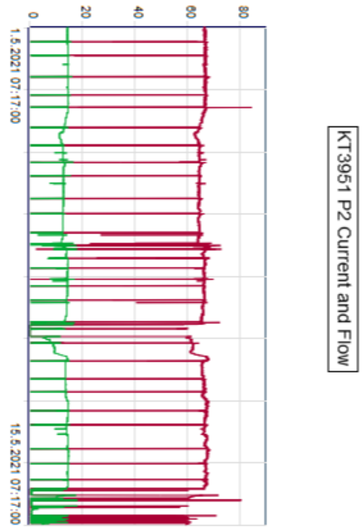
VS221 P1 Current and Flow

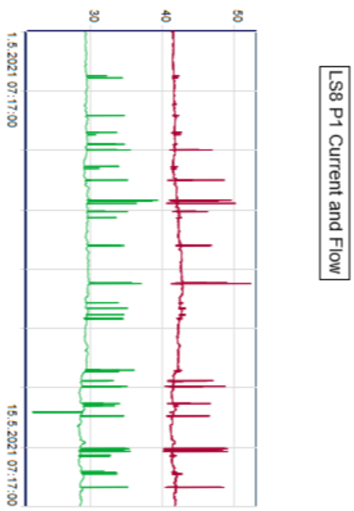
LS8 P1 Current and Flow



Measurement	Unit	Average
SA 13 P2 Current	%	47,29
SA13 Flow	m3/h	17,15
SA 13 P1 Current	%	0,02
VS211 P1 Current	%	74,91
VS211 Flow sum	m3/h	54,79
VS221 P1 Current	%	70,63
VS221 Flow sum	m3/h	56,59
KT3251 P2 Current	%	48,34
KT3251 Flow	m3/h	7
KT3951 P2 Current	%	59,54
KT3951 Flow	m3/h	12,17
LS8 P1 Current	%	0
LS8 P1 Flow sum	m3/h	29,13
LS8 P2 Current	%	41,79

APPENDIX 4


KT3951 P2 Current and Flow
0
20
40
60
80
1.5.2021 07:17:00
15.5.2021 07:17:00


LS8 P1 Current and Flow
30
40
50
1.5.2021 07:17:00
15.5.2021 07:17:00

APPENDIX 5

Moi,

Aiemmin keskustelimme teidän osallistumisesta minun opinnäytetyöhöni liittyen Wedge:n prosessipumppudatan seurannasta.

Tulen lähettämään teille kyselyitä (1A) nyt tämän viestin liitteenä, jonka tarkoituksena on kartoittaa lähtötilannetta informaatioergonomiasta prosessipumppujen datan saatavuuden ja nykyisen DNA:n ohjelman kautta.

Kysely (1B) lähetän 2 viikon testijakson jälkeen yhdessä kyselyn 2 kanssa. 1B kysely antaa Wedgen pohjalta tehdyn seurannan antamaa mahdollista informaatioergonomian parannusta/vaikutusta.

Kysely 2 antaa vastausta Wedgen käytettävyyteen.

Vastaamalla kyselyihin annatte luvan käyttää saatua dataa opinnäytetyössäni. Työ tehdään tietenkin teidän anonymiteettiä suojellen, ainoastaan minä tutkimuksen tekijänä tiedän keneltä saan vastaukset. Vastauksista saatu data on täysin anonyymiä.

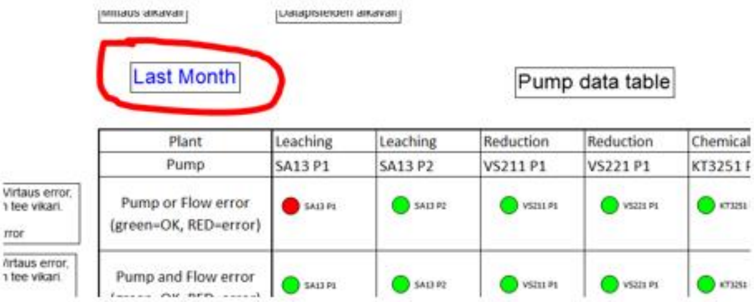
Aleksi Poikkimäki

Wedgen Pump maintenance tool sivun käyttämisen perusteet.

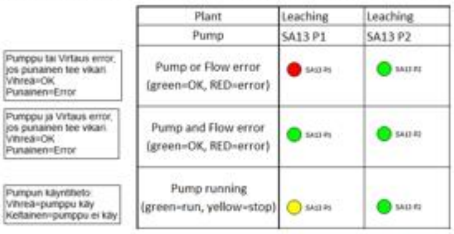
1. Käynnistä Wedge Citrix terminalin kautta.
    a. https://terminal.nornickel.fi/vpn/index.html

2. Valitse Kunnossapito.
3. Valitse Wedge Pump data sivu.

4. Paina "Last Month" Macronappulaa.(pakottaa viimeisen kuukauden aikaväliksi)



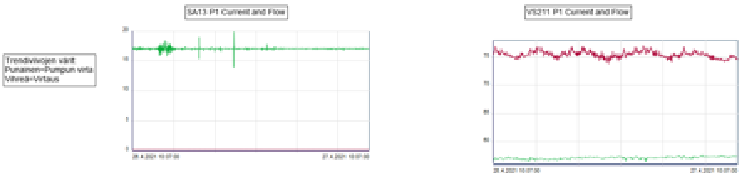
5. Katso onko taulukossa punaisia palloja(tarkista myös käyntitieto, jos käyntitieto keltainen pallo→pumpun pallo punaisella, koska pumppu seis).



6. Tee punaisista palloista kirjaus ylös ja laita viestiä Aleksille onko olennainen vika päällä.
7. **Tee punaisista palloista vikailmoitus** Maximoon alkutunnuksella ”Wedge”. Kirjaa vikailmoitukseen päivämäärä ja kellonaika. Esim. ”Wedge SA13P2 punaisella 26.4 9:30”.
8. Voit katsoa pumppujen käynistys- ja error määrät taulukon alimmilta riveiltä.

Pumpun käynnistyskerrat per kk.	Pump starts per month	Start 0 times	Start 11 times
Pumpun error tilat per kk.	Pump errors per month	Error 0 times	Error 105 times

9. Voit tutkia pumppujen trendejä Virran ja Virtauksen suhteen.



Survey Form 1A Information ergonomics	1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree
1. Finding process related data of pumps is easy with current software.					
2. Process data software is easy to access.					
3. Pump process data is visually easy to read / interpret					
4. Pump process data is understandable / comprehendable.					
5. You find needed pump process data fast.					
6. You find the needed pump process data always without help of others.					
7. You get quality/reliable pump process data every time.					
8. You find needed pump process data easier after few uses.					
9. Making error arguments due lack of pump process data is easy.					
10. Using current software brings the feel of satisfaction.					

Write free comments and improvement proposals below:

Survey Form 1B Information ergonomics	1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree
1. Finding process related data of pumps is easy with current software.					
2. Process data software is easy to access.					
3. Pump process data is visually easy to read / interpret					
4. Pump process data is understandable / comprehendable.					
5. You find needed pump process data fast.					
6. You find the needed pump process data always without help of others.					
7. You get quality/reliable pump process data every time.					
8. You find needed pump process data easier after few uses.					
9. Making error arguments due lack of pump process data is easy.					
10. Using current software brings the feel of satisfaction.					
Write free comments and improvement proposals below:					

Survey Form 2 Wedges usability	1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree
1. Wedge tool is easy to use in first encounter.					
2. After first encounter you can perform needed tasks in reasonable time.					
3. After not using Wedge in a while you can re-establish profiency easily.					
4. When you make errors when using Wedge you can recover from them in reasonable time.					
5. Wedge design is pleasent visually.					
6. Wedge green-red light model is easy to "read".					
7. Wedge gives you better view of pump process data.					
8. Wedge usage has affected information ergonomics of preventive maintenance.					
9. Wedge usage has brought benefits to information ergonomics regarding preventive maintenance.					
10. Wedge usage has improved preventive maintenance.					
11. Pump maintenance actions has improved based on Wedge usage.					
Write free comments and improvement proposals below:					