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Industrial Electrical Engineering and Automation

Design of a Process Overview Display in a Human-Machine Interface

Emil Lavin

Division of Industrial Electrical Engineering and Automation
Faculty of Engineering, Lund University

Design of a process overview display in a Human-Machine Interface

Master Thesis
by **Emil Lavin**

at the Division of Industrial Electrical Engineering and Automation

and Perstorp Specialty Chemicals AB

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Supervisor: *Associate Professor*, **Gunnar Lindstedt**

Supervisor Perstorp Specialty Chemicals AB: *Engineer Instrument*, **Tommy Rydén**

Examiner: *Associate Professor*, **Ulf Jeppsson**

Preface

This master thesis has been carried out at Perstorp Specialty Chemicals AB in the spring of 2014. I graduated from Perstorp Gymnasium in 2009 and have since then had a summer job at Perstorp Specialty Chemicals AB in between my studies at LTH. The fourth summer I got in contact with Site Manager Anders Hansson who then put me in contact with E&I Group Manager Jörgen Annell to plan my master thesis. We settled on the idea of an overview process display and that became my master thesis.

I would like to thank:

Tommy Rydén for being my supervisor and helping me with difficulties I encountered on the way.

Jörgen Annell for the opportunity to conduct my master thesis at Perstorp Specialty Chemicals AB and providing me with important contacts, ideas and resources.

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Abstract

The aim of this master thesis is to present new and well proven methods about how to best design an overview display. Since designing is a creative process and there can be many alternative designs that fulfill the same requirements, this master thesis will focus on presenting guidelines and principles that will aid in the design process.

How to design an effective interface display will be discussed in the context of Endsley's Situation Awareness model. This master thesis will cover ideas such as Information Rich display Design (IRD), High Performance Human Machine Interface (HPHMI), as well as briefly discuss alarm system design. The psychological aspect of implementing a change and making it a successful one is discussed in the light of the ADKAR model. This includes creating awareness, desire, knowledge, ability and reinforcement to the change. The two main types of overview displays, functional overview display and schematic overview display, will be compared by bringing forth pros and cons for both types. A practice oriented design process for overview displays is presented. The three main steps of this process are (1) identify the critical variables, (2) identify the critical interactions and (3) identify appropriate visualizations.

An overview display will be presented for a chemical process plant that produces Trimethylolpropane (TMP) in Perstorp. This master thesis will include interviews with an operator and a subject matter expert to identify the information needs according to the practice oriented design process. The overview display is presented in the software DeltaV.

Sammanfattning

Målet med detta examensarbete är att presentera nya och beprövade metoder för att bäst designa en processöversiktsbild. Eftersom design är en kreativ process och det kan finnas många olika designalternativ som uppfyller de ställda designkraven kommer detta examensarbete att fokusera på riktlinjer och principer som är till hjälp i designprocessen.

Hur man designar en effektiv gränssnitts-display kommer diskuteras med hänsyn till Endsleys Situation Awareness modell. Examensarbetet kommer beröra idéer så som Information Rich display Design (IRD), High Performance Human Machine Interface (HPHMI), samt kort diskutera hur man bäst designar larmsystem. Den psykologiska aspekten av att genomföra en förändring och hur man gör den framgångsrik kommer att diskuteras genom ADKAR-modellen. Denna inkluderar att man skapar kännedom, begär, kunskap, skicklighet och påminnelse om förändringen. Två huvudtyper av processöversiktsbilder och deras för- och nackdelar kommer att diskuteras. De två typerna är funktionella processöversiktsbilder och schematiska processöversiktsbilder. En praktisk designprocess för en processöversiktsbild presenteras. De tre huvudstegen i denna process är (1) identifiera de kritiska parametrarna, (2) identifiera de kritiska interaktionerna och (3) identifiera de mest lämpliga visualiseringarna.

En processöversiktsbild kommer att framställas för en kemisk fabrik som producerar trimetylolpropan (TMP), belägen i Perstorp. Examensarbetet kommer att involvera intervjuer med en operatör från fabriken och en ämnesexpert för att identifiera informationsbehovet enligt den praktiska designprocessen. Processöversiktsbilden framställs i programmet DeltaV.

1 Introduction

Perstorp Specialty Chemicals AB was founded in 1881, pioneered in plastic and formalin chemistry and is now the world leading company in several sectors in the specialty chemicals industry. One of the many manufactured specialty chemicals is Trimethylolpropane (TMP). To name a few applications, TMP is used in alkyds for paints, in saturated polyesters and polyurethanes for various coatings, and for surface treatment of pigments. The manufacturing of TMP in Perstorp, Sweden takes place in a large scale chemical process plant where around 30 operators and personnel work.

As of 2014, the current distributed control system (DCS) of the TMP process, RS3, is being replaced with DeltaV and management recognizes the need to explore the idea of implementing an efficient process overview display. The goal of this master thesis is to

1. Gather up-to-date and applicable practices of how to construct a process overview display, and
2. Follow these practices and implement a process overview display in DeltaV for the TMP process.

A limitation has been made concerning the scope of this master thesis. Alarm system design is a vast area in itself and would require a lot of time and resources to explore to its full extent. As a result of this and the consideration that it would be unwise to skip it entirely, alarm system design will only be discussed briefly in theory. Alarm system design will be implemented to some extent in the process overview display to show how it could be done based on the brief theory. Another reason not to explore too deep into the alarm system design is that such a system impacts all displays and pictures in a HMI. It should be designed to be consistent across all displays. From the author's point of view, the recommended practice would be to design an alarm system for the standard displays and then apply it to the process overview display.

Abbreviations used in this master thesis

HMI – Human Machine Interface

GPWS – Ground Proximity Warning System

SA – Situation Awareness

Sass – Situation Assessment

PV – Process Value

SP – Set Point

IRD – Information Rich display Design

HPHMI – High Performance HMI

2 Interface Display in Theory

This chapter will present information relevant to creating an efficient interface display in theory.

2.1 Basic Terminology and Definitions

Before introducing the concept of an overview display it is important to lay down the basic necessary definitions that are the **industrial process plant**, the **operator** and the **Human Machine Interface** (**HMI**).

2.1.1 Industrial Process plant

A plant is an industrial facility that manufactures chemicals by converting raw material into finished products. A plant consists of a set of equipment that produces the product in either continuous or batch operation. The equipment can involve pumps, reactors, pipes, tanks and pressurized vessels that together form different sub processes. The sub processes each bring a physical change to the product and can for example be distillation, separation, crystallization, filtration and evaporation. When the raw material has gone through all sub processes it is considered a finished product and enters the market. Workers in a typical plant usually consist of process operators, engineers, chemists, maintenance/repair workers, management and office workers.

2.1.2 Operator

The process operator is a person that is responsible for a certain unit or section in the process plant. The operator's job is to supervise the process plant and make sure the production is running in an efficient and safe manner. This is usually done from a central control room where several operators monitor the plant. In the control room, computers and control panels are located that give necessary information about the facility's status. It is common practice that the operator's service is available 24 hours a day, 7 days a week, and 365 days a year. This is because the production is very costly to interrupt and must be up and running at all times.

2.1.3 Human Machine Interface

The HMI is a tool that lets users communicate with a machine or automation system. The HMI transmits the users' commands to machines through an interface and translates complex data from the machines back into useful information to the user. The HMI acts as a connection between the user and the process controlled by providing important information, alarms and other features. In modern HMI-systems, several electronic displays with graphical representations are used to portray the process being controlled. Often one display is used for each process area. The operator interacts with the different graphical objects in the interface to adjust and monitor levels, temperature, pressure and other process variables. Often a process consists of multiple sub processes and this is where an **overview display** becomes useful.

2.1.4 Overview Display

The aim of the overview display is to provide a summary of information for all sub processes to the operator in one display. In that way, the process operator does not need to sequentially scan multiple displays to know what is happening in the plant. Instead, the operator examines the overview display and gathers a direct view of the operating state of the plant. In other words, the overview display is a tool that helps operators in maintaining awareness of the plant's status. Describing the plant's status can be done, for example, by showing key variables from the process and their respective deviations. As disturbances impact the key process variables, the overview display enables fast identification of potential undesirable situations.

2.2 Interface Display Hierarchy

When designing an interface display for an industrial process plant, the amount of information is often overwhelming and there is a need to present the information in an organized way. Using a multilevel display hierarchy to present information has become a recognized philosophy in effective HMIs. The hierarchy starts with an overview display at the top, where the operator monitors process deviations and the general direction of the process. When process deviations are detected, the underlying display levels provide increasing details where the operator can troubleshoot and carry out actions regarding the deviation. There exist four main levels in the hierarchy (Bullermer & Resing, 2009) but it should be noted that it is not a strict design and that the hierarchy structure can be tailored based on a specific process plant. The hierarchy can be seen in Figure 2.1.

- **Level 1 – Process Area Overview** or **Span of Control Overview Display**. This display type provides information about the entire responsibility of an operator, which in most cases is the same as the whole process. This type of display is usually a read only display and offers qualitative information with high information density.

- **Level 2 – Process Unit Control** or **Area-level Summary.** This type of display presents information as well as some interaction support for the main process areas in a process plant. For example, three area-level summary displays could be reactor summary, furnaces summary and distillation summary.

- **Level 3 – Process Unit Detail** or **Equipment-level Detail**. This kind of display provides thorough information about specific process equipment, for example a distillation tower. This display type is detailed and provides interaction support for relevant control equipment such as pumps and valves. Troubleshooting and diagnostic activities are generally performed on this display level.

- **Level 4 – Process Unit Support and Diagnostic Displays** or **Point Detail Display**. This level of display is the most detailed one and is used for manipulation of point values such as set points and alarm limits. This display type can be displayed as a whole display or just a faceplate or pop-up on screen.

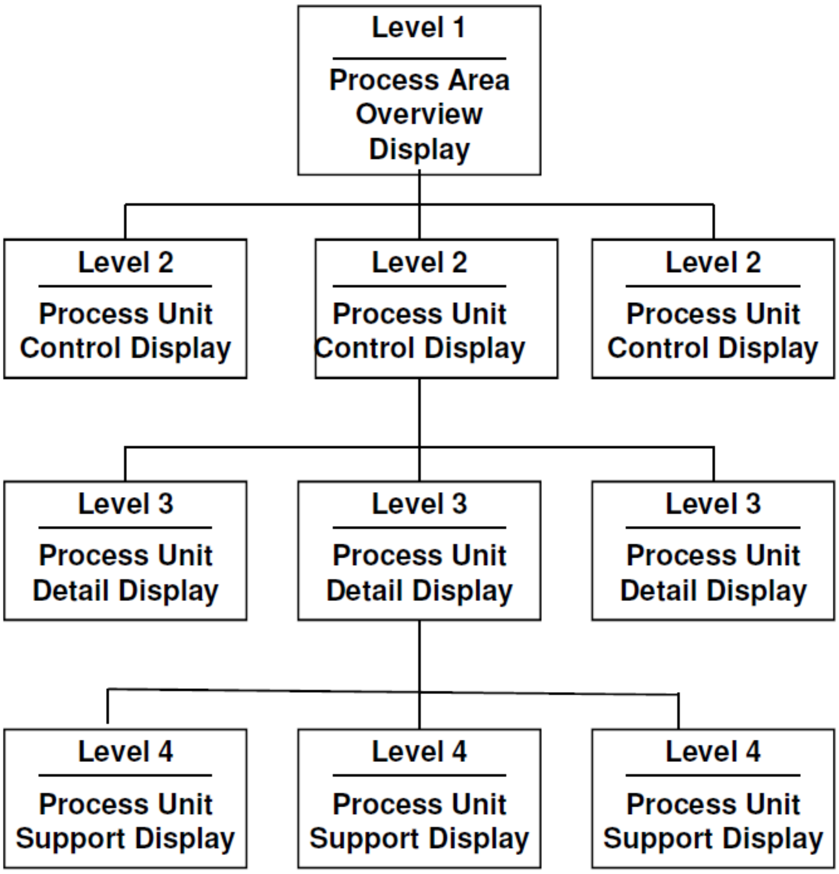

Figure 2.1 Schematic overview of the interface hierarchy. From Rockwell Automation presentation "The High Performance HMI".

2.3 Designing for Situation Awareness

Situation Awareness (SA) can be described as knowing what is going on so you can figure out what to do. The formal definition of SA, according to Mica R. Endsley, is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley & Jones, 2011). The term SA can be applied to many different sets of environments, from driving a car to operating a complex process plant. SA lies at the heart of human decision making and by enhancing operator's SA the amount of human errors can be decreased. Better awareness of the situation leads to better decisions, fewer errors and reduced costs. In many situations consequences of error can be severe, leading to property and human damage. For example, 80-85% of aviation accidents are attributed to human error, in which failure in decision making is attributed as a casual factor in 51.6 % of all fatal accidents and 35.1 % of all non-fatal accidents (Endsley, 1999). Therefore it is crucial to achieve a high level of SA. However, it is also very challenging. The reason why high level SA is hard to achieve is associated with both shortcomings of the human processing system and the difficulty to present complex systems in a good way. Designing for SA is all about ensuring that necessary information is obtained and presented in an easily processed way to the users, who can have a lot of competing information fighting for their attention. Guidelines on designing for SA can be found in 2.4.1.

2.3.1 Three Levels of Situation Awareness

SA can be divided into three levels (Endsley & Jones, 2011). Level 1 is the perception of key information in the current situation. Level 2 is the comprehension of that information in correspondence to operational goals. Level 3 is the projection of the situation in a near future.

Perception

The first level of SA is to perceive and gather information about the status, attributes and dynamics of relevant elements in the situation. The information needed varies between work domains and between different tasks and goals in the same work domain, depending on the SA requirements. For instance, a car driver driving along a road needs to perceive important information such as other cars, car velocity and engine rpm, pedestrians and so on. But, when standing still at a red light the current goals change so that the driver now only needs to perceive the color of the light and possible indications to upcoming accidents. Information such as car velocity is not relevant to this task. Importantly, Level 1 SA does not include the understanding of said information, only the perception.

Gathering of information comes from visual, auditory, tactile, taste and olfactory perception. This means that information in a process plant may not only come from looking at electronic displays, but also through subtle cues like feeling the vibration or hearing a machine stop or start.

Generally, problems with SA tend to occur at this level. A study showed that about 76% of errors made by pilots were related to not perceiving the information needed (Endsley & Jones, 2011).

Comprehension

This level of SA is about understanding the perceived information in relation to the work domain and current task and goals, so that the information perceived can be translated into decisions and actions. For instance, a driver approaching a red light intersection perceives visually that the light is currently yellow. The driver also visually detects the remaining distance to the intersection. The drivers' goal is now to slow down in case of the light not changing to green so the driver starts to break. The driver perceives the deceleration of the car and adjusts the braking power to be able to stop at the intersection. When the auditory cue of the engine being loaded with high torque at low rpm, the driver understands to gear down and then comes to a complete stop if the light turned red.

Projection

Level 3 SA is the prediction of what the current situations' elements will do in a short term future. A driver approaching and proceeding through a busy intersection knows that an accident is likely to happen if the driver keeps on going. Consequently, this allows the driver to make pro-active decisions, like braking in time. To form projections from the use of current situation understanding can be mentally challenging and requires a good understanding of the work domain. Work domain experts often make several projections and develop a set of strategies and responses ahead in case of different kind of events happening. This allows for fast response time when events do occur and therefore avoiding undesirable situations.

2.3.2 Eight Failure Modes of Situation Awareness

In this part it will be discussed why it is difficult to form a good SA. By shedding light on eight different failure modes (Endsley & Jones, 2011) associated with SA, the aim is to be aware and take these into account when designing for SA. A good design solution knows about the human limitations and avoids problems related to human cognitive processing.

Attentional tunneling

When performing tasks people often interpret multiple pieces of information simultaneously, making it mentally demanding. They have to share their attention across a varying span of information sources. However, humans have bottlenecks in attention sharing, limiting the capability of processing a lot of data. In particular, people have a bottleneck in processing information within a single sense. Take hearing for example. It is quite difficult to listen and understand two people talking to you at the same time. To compensate for this, people tend to periodically scan the information they need to monitor. This scan can be done in a matter of seconds, minutes or hours, depending on the system. When switching attention between different information people can succumb to attentional tunneling, meaning they will lock in on certain information that they are trying to process. Consequently, this will exclude some information and therefore lowering their SA of the information they stopped attending to. One can argue that it is justified to only focus on information that is currently important but a major counter argument is that you need a full understanding across the board at all times to even know what information is currently the most important. Consequences may not always be critical due to this error but it is a common one. In aircraft and air traffic control accidents, 35% of all SA errors belong in this category, where the needed information is present but not attended to, due to attending other tasks.

Working memory capacity

The human memory is the central tool for maintaining SA, especially referring to the short-term or working memory. As a person scans different information in a situation, previously scanned information is remembered and combined with the new information. The working memory can be interpreted as a temporary cache where current information gets processed and combined to form a picture of the situation. However, this cache is limited to around seven plus or minus two chunks of information (Miller, 1956). A chunk can consist of several pieces of information itself. For example, the number 2000 can be seen as four individual information pieces or just a chunk that says two thousand. The working memory limit introduces a noteworthy SA bottleneck. Insufficient space and natural decay of information in the cache can result in poor SA. The decay of information in the working memory can occur as soon as after 30 seconds, unless the information is not repeated or revisited. Systems that rely heavily on a persons' working memory have limited reliability because memory failure is bound to occur. An example is a major aircraft accident that happened at Los Angeles International Airport when an air traffic controller forgot that an aircraft had been moved to a runway and assigned another plane to land on the same runway (National Transportation Safety Board, 1991).

Workload, anxiety, fatigue and other stressors

Stressors, or stress factors, are factors that will lower SA by making the process of gathering information less systematic and more exposed to errors. Psychological stress factors include mental workload, time pressure, stress, anxiety and uncertainty. Physical stressors can be vibration, noise, poor lighting and immoderate temperature. Also, physical fatigue due to lack of sleep or going against the circadian rhythm is common for night shifts. These stressors can weaken SA by occupying a portion of the working memory. They make people gather information less efficient and jump to conclusions prematurely. It is not always possible to eliminate all kinds of stressors but when possible the system should be designed to reduce them.

Data overload

When the rate of new information or the change of information surpasses the limit of our cognitive processing power, gaps and lapses in SA becomes present, making a person's SA outdated. By designing the way information is presented in the system, data overload can be reduced. Think of it as bandwidth; cognitive bandwidth in which information is flowing to the brain. Not much can be done to increase the size of the pipeline but by organizing and packaging the information, more information can flow through the pipeline.

Misplaced salience

Salience can be describes as how compelling a certain set of information is. Some aspects of information are more likely to attract ones attention. Aspects like that include for instance the color red, movement, flashing lights, noise, larger objects and things that are physically closer to you. This perceptual property has been evolved from an evolutionary standpoint and systems today make use of features like red color to indicate alarming situations. When used properly, salience can guide you to important information and improve SA. However, these features can be overused or used improperly. That is, when less important information is drawing the user's attention from the real important information. False alarms also belong to this area, where highly salient cues, like flashing lights, acts as unnecessary distractions and undermine SA.

Complexity creep

Complexity creep is a similar concept as data overload, in a way that systems may have so many features and rules that it is difficult for people to form a clear mental model of the system. The problem is that increasing complexity makes it harder for people to develop sufficient mental models, and therefore lack in SA. This is especially true concerning Level 2 and 3 SA, where they lack the understanding of the situation and consequently the projection of the situation. The complexity itself is a function of the system's number of components, the degree of interaction between components, the system dynamics and the predictability of the dynamics.

Incorrect mental models

Mental models are internal representations of a system and provide an understanding about how different parts in the system are linked together. They tell a person how to interpret the meaning of information they hear or see from the system. This is a key part to high level SA but will act as a hindrance when incorrect or inaccurate mental models are used. It is common that systems have several working modes and one frequent error is that people believe that the system is in one mode when it is in another. As a result people misinterpret new information and make wrong decisions based on the wrong model. When working with an incorrect mental model people also tend to explain away conflicting information to make their current mental model fit, even though the explanation is far-fetched. This results in slow detection of problems, if they are ever discovered.

Out-of-the-loop syndrome

With the increase of automation and automated systems, there is a need for appropriate design to avoid out-of-the-loop syndrome. Out-of-the-loop means that a person is unaware and does not fully understand how the automated system works. There is no problem when the automation is performing as it should but when failure occurs, the person in charge of monitoring are often unable to detect or properly correct the failure in time. Addressing this issue is often done by standardization and by reducing the number of different automation modes.

2.4 Guidelines and Principles for Designing an Interface

This section will cover principles, guidelines and inspiration for designing an interface. However, the truth is that designing is a creative process and there may exist multiple design alternatives that meet the design requirements. It is not possible to test and evaluate all potential design alternatives and identify their advantages and disadvantages. That would be very time consuming and cost inefficient. The next best thing is therefore to follow certain design guidelines and try to avoid as many pitfalls as possible.

2.4.1 Principles for Designing for Situation Awareness

This part will cover a summary of some principles of the designing for SA. More principles can be found in (Endsley & Jones, 2011).

Principle 1: Organize information around goals

Information should be displayed with regards to the operator's goals instead of in a technology oriented way, where information is organized based on sensors and equipment. Relevant and necessary information associated with a specific goal should be organized closely and support the decision making of the operator.

Principle 2: Support comprehension by presenting Level 2 information directly

Since the working memory is limited the information displayed should support Level 2 SA as much as possible. Instead of having the operator compare and calculate values manually in the working memory, it is better to display this information directly if possible. If the required mental process for each information source is lowered, the operator can handle more information sources simultaneously.

Principle 3: Provide assistance for Level 3 SA

Helping the operator project the future state of a situation improves the third level of SA and should be done when possible. However, it is often difficult for a system to completely show the future state of a situation. It requires an operator to distinguish and combine relevant information to form a mental model. Supporting the mental model can be done with trends, where the change of a variable over time is shown. Trends help the operator to predict future changes in variables.

Principle 4: Support global SA

Support global SA by providing the operator with an overview display. By doing this, the operator is aware of goals with the highest priority at all times, and consequently lowers the risk for attentional tunneling. In systems where attentional tunneling is a major problem, the overview display should have a dedicated place and always be available and visible to the operator.

Principle 5: Take advantage of parallel processing power

The amount of visual information an operator can handle at a given time is limited. However, when taking advantage of both auditory and visual information simultaneously, the information capacity can be increased. That is because the intake of auditory and visual information relies on different mental resources. The same goes for information received through touching or feeling something with the skin. For example, in visual information dense situations, information can be transmitted by electrically or mechanically stimulating the skin to further increase the operator's SA.

2.4.2 Principles for Designing Alarm Systems

Alarms are used to redirect attention to important information. In theory, alarms help operators maintain good SA by calling for the operator's attention to deviations that they may not be aware of. This is however not always the case. For example, in a major accident at a nuclear power plant about 50 to 300 alarms per minute can present themselves (Stanton, et al., 2000). This amount of alarms is overwhelming and almost always makes it impossible for any operator to identify the underlying problems. In addition to this many systems are plagued with high false alarm rates. Operators tend to have slow response or no response at all when dealing with alarms that they believe have low reliability; alarms that occur often but rarely indicate a dangerous situation. This phenomena is called the cry wolf syndrome (Breznitz, 1984), because people tune out alarms that they do not believe in. There are many examples of this. At a workshop for safety professionals, only 3 out of 300 people left the room when the hotel fire alarm broke out (Endsley & Jones, 2011). If this was the response rate for people focused on safety, then we can imagine the overall response rate dropping even further. This becomes very problematic when the time comes and the alarm is in fact true. Alarm systems are also designed with the assumption that people will react immediately to each alarm to correct the underlying problem. A study of commercial airlines in controlled flight into terrain (CFIT) accidents over a 17-year period showed that 26% of the cases involved no response, a slow response, or an incorrect response by the pilot to the ground proximity warning system (GPWS).

It is no secret that people respond to alarms in different ways and for a variety of reasons. The complex mental process involved in responding to an alarm can be seen in Figure 2.2. An incoming alarm signal is integrated with additional situation information. The understanding of the alarm and the underlying problem (Level 2 SA) is based on the operator's mental model, the operator's past history with the alarm, and their expectancies. Based on this interpretation of the alarm the operator will choose a response. Their response may consist of performing a corrective action to the problem, muting the alarm without performing an action or ignoring it in belief that it is not an indicator to a real problem, but an appendage from another situation that the alarm system does not take into account. There are several factors that dictate the resulting response from the operator (Endsley & Jones, 2011). Some of them will be discussed here.

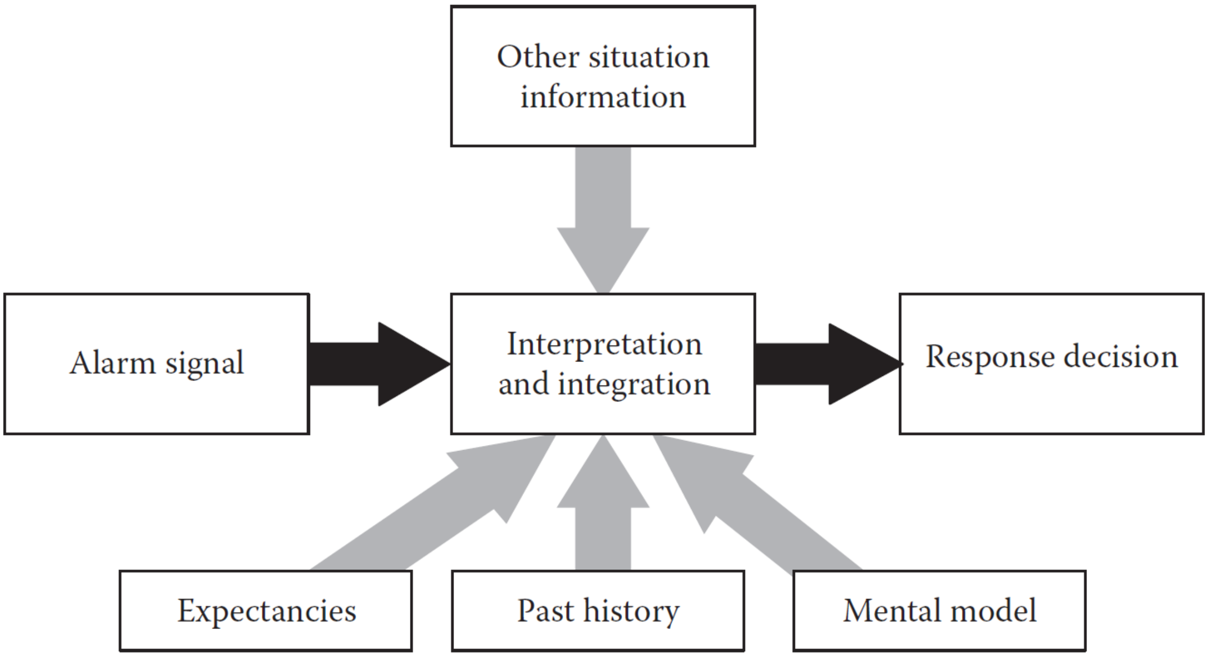

Figure 2.2 Mental process when responding to an alarm. Many things are taken into consideration. From Endsley & Jones (2011), page 149.

Alarm reliability

The operator's past history with an alarm and the amount of reliability associated with the alarm is a big contributing factor to how the operator will choose to respond to it. As discussed earlier, the cry wolf syndrome will make the operators have less confidence in the alarm. The confidence in the alarm has been shown to be a function of their past experience with false alarms for the system and the presence of other concurrent alarms. Concurrent alarms acts as confirming or opposing evidence to the original alarm. Since false alarms degrade the overall response rate, they should be reduced as much as possible. However, that introduces another conflict. When an alarm goes off there can be either of two error situations happening. Either the alarm is false, or there exists a real problem but no alarm is appearing (missed alarm). When designing an alarm system there is a trade-off between the probability that a false alarm will occur and the probability that a real problem will be missed. Consequently, by reducing false alarms you are also increasing the risk for missed alarms. The difficulty here is to find the desired equilibrium. Often missed alarms are considered as a major hazard, resulting in the decision to have a high false alarm rate instead. A way to solve this trade-off is to increase the sensitivity of the sensors in the system and therefore enhancing the ability to distinguish between true problems and nonevents. Technically, this translates to reducing the overlap of the signal and the noise. However, this will not reduce all false alarms. The cause of false alarms may not always depend on the sensitivity of the sensors or the algorithms themselves. Instead, it can depend on the situation conditions and various factors that the alarm system is unable to detect or interpret. An example of this is when GPWS produce alarms at particular airports where the in-flight involves approaching near mountains. The pilot is on the correct flight path and will avoid the mountains without problem, but the alarm system does not consider this and produces an alarm anyway. The alarm is correct to the system but false to the pilot in terms of warning for an actual hazard. Situations like this make operators accustomed to false alarms, desensitizing them to the alarms.

Confirmation

When people do not immediately respond to alarms, what they do is to search for additional evidence to confirm if the alarm is an indication of a real problem. Even though pilot training stresses an immediate response and the algorithms in the GPWS system assume such a response, it has been shown that pilots delay their response 73% of the time (DeCelles, 1991). The alarm signal can be seen as one element in addition to all other information that is available in a possible situation. From one point of view this is beneficial because people can take situational information into account that the system is unable to do, making the human a good final decision maker. From other point of views confirmation has its downsides. It requires extra time to look into further information and in critical situations time is very limited. There is also the possibility that people will make errors when determining whether to follow the alarm or not. Conclusively, designers of alarm systems need to take into account people's need to confirm alarms and not expect that they will follow them blindly. Supporting people's need to gather additional situation information when an alarm occurs can greatly improve alarm response behavior.

Expectancy

People's expectancies about the alarm play a part in their interpretation of its cause and significance. Operators expect certain alarms as consequences due to their actions. If a tank is manually being emptied they will expect the low alarm limit to appear. Alarms that appear in expected situation will be an annoyance. A problem arises however when the alarm is due to some other factor than the expected, resulting in an interpretation error and the underlying factor is disregarded. An example is an aircraft accident where the wheels were up when landing, causing significant damage to the aircraft (National Transportation Safety Board, 1997). The GPWS alarm that sounded in the accident was expected by the captain. The captain stated that he had interpreted the GPWS alerts as a high sink rate warning when in fact the alarm was due to the wheels not being down. The problem here lies at the ambiguity of the alarm. In this aircraft accident for example, the GPWS generates an aural warning and illuminates a red light labeled "PULL UP" on the instrument panel when any of 7 specific conditions are detected, 2 of them being (1) when descent rate is too high and (2) below 500 feet above ground level and wheels not down. This kind of problem can be prevented by increasing the level of detail in the alarm information.

The following part will cover some of the alarm principles and more can be found in (Endsley & Jones, 2011).

Alarm principle 1: Don't make people reliant on alarms – provide projection support

When an alarm appears, operators develop an understanding of why it alarmed and what they should do to correct it. This puts people in the position of being reactive to alarming situations. Instead of relying on the operators to make the right decisions in such situations, a better strategy would be to provide information needed to be proactive. Trend information can be effective by allowing the operator to recognize approaching problems. Instead of being alerted with a sudden low blood pressure, a better alternative would be to show the patient's blood pressure over time. This also helps the operator to understand the problem easier. Did the pressure suddenly drop or did it happen over time? Did the pressure drop simultaneously with another physiological parameter? Alarms should be used to back up this process of proactive trend analysis.

Alarm principle 2: Support alarm confirmation activities
As discussed earlier, people tend to seek out additional confirming information when an alarm triggers. To best support this process, regarding response time and accuracy of response, information should be displayed that allows them to quickly evaluate the validity of the alarm. A trend display is one way of confirming the validity. This answers if the alarm was truly out of limits or if it was just an irregular spike in the reading. Related parameters should be displayed together if one or the other are alarming. If for example the pressure increases in a closed vessel, the temperature is also expected to increase, thus confirming each other.

Alarm principle 3: Make alarms unambiguous
If an alarm can be misinterpreted, due to the operator's expectation or other factors, it is not really an effective alarm. Avoid the potential misinterpretation by clearly displaying the origin and cause for the alarm.

Alarm principle 4: Reduce false alarms
One way of reducing false alarms is by increasing the ability of sensors and alarm algorithms to detect when an actual alarming situation is occurring. This improvement of equipment is from a technical and engineering standpoint, and must therefore be considered with cost efficiency in mind. Another way of reducing false alarms is allowing the operators to modify the alarm limits regarding the current situation. This may however only be an option in some areas. For example, a medical doctor can set the alarm limit for heart rate to 100 for one patient and 150 for another, based on the patient's weight, age and physical condition. Such modification of alarm limits to current situations reduces the amount of false alarms.

2.4.3 Information Rich Display Design
Each process display tend to only contain a small fraction of the whole process, resulting in what is referred to as the keyhole effect; when looking at a single display you are not able to gather information from the other displays. The main objective of Information Rich display Design (IRD) is to increase the density of information in process displays and also improve the quality of that information (Braseth, et al., 2004). The result is a reduced number of displays with more relevant information in them, acting as a counter to the keyhole effect. IRD aims to reduce navigation between process displays by allowing the operator to monitor a larger part of the process on each display. This display design suits well in relation to the general idea of an overview display, where the operator can quickly scan the display and gather information from the whole process. The approach to designing an information rich display is to first map the different roles and mental capabilities the operator has while performing his or her work. The next step is to visualize the needed information in a way that helps the operator in the different situations. The Skill, Rule and Knowledge (SRK) model describes what kind of mental activities people use in different situations and can be applied to operators.

Skill based behavior
This is the lowest level of activities that the operator performs, for example positioning and clicking the mouse cursor at the right places. Skill based behavior is learned once and requires little to no mental effort when performing it later. The parallel capacity of such tasks is great and it can basically be done without paying attention to it, like riding the bike.

Rule based behavior
The rule based behavior is a natural response to a familiar situation. A cue from the environment acts as a trigger to perform an automated response activity. For example, stopping at an intersection if a car comes from the right or braking the car if the braking light on the car in front turns on. It requires experience with the situation to perform a rule based behavior since it is based on recognizing cues and patterns. The parallel capacity for rule based behavior is slightly less than skill based behavior.

Knowledge based behavior
The last level of activities is mentally demanding, requires full attention and the parallel capacity is weak. The knowledge based behavior consists of gathering information, interpreting the information, understanding what is going on, and figuring out and performing an appropriate response.

Operators often use knowledge based behavior when they memorize, compare and calculate different information while looking at displays. The interface rarely presents cues for rule based behavior because the appearance of the display basically remains the same regardless of situation. In addition to this, displays often use numerical values that does not support the operator’s rule based behavior. IRD try to make use of the skill and rule based behavior of the operator by translating information into visual objects that can be interpreted directly. IRD relies very much on pattern recognition on different levels and to demonstrate that statement, a typical IRD building block can be found in Figure 2.3. In this case it represents a separator process unit. So instead of a traditional schematic representation of the separator, IRD uses a functional trend-like object in the display. The green line is a trend, 21 and 23 is high warning limit and high critical limit, 18 and 11 is low warning limit and low critical limit. The process variable is shown as both a trend and the numerical value, which supports both rule based behavior with respect to the trend, and knowledge based behavior with respect to the value.

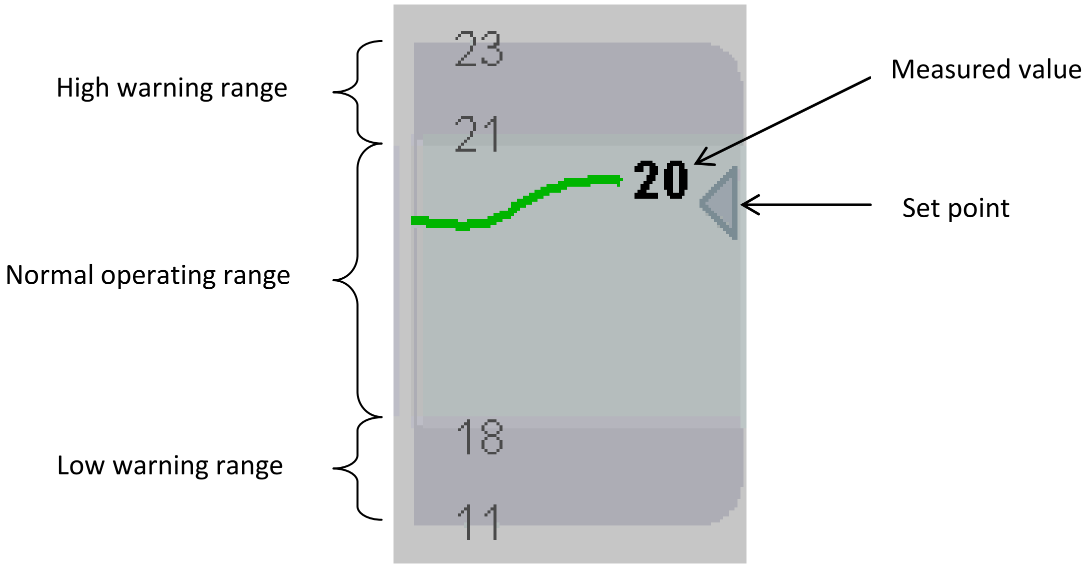

Figure 2.3 IRD building block of a separator. From Braseth et al. (2004), page 9.

Pattern recognition on a higher level can be seen in Figure 2.4, where the building blocks are presented together. The normal operating ranges of all building blocks are normalized to support pattern recognition. In other words, the operating range is scaled so that all trends are at the same level when in either normal or warning range. It is then easy to assess the overall status of the process at a glance by checking if the trends are vertically in the middle and approximately at the same height. The blue line represents water, the black line represents oil and the green line represents gas, making it easy to identify the different mediums in trends.

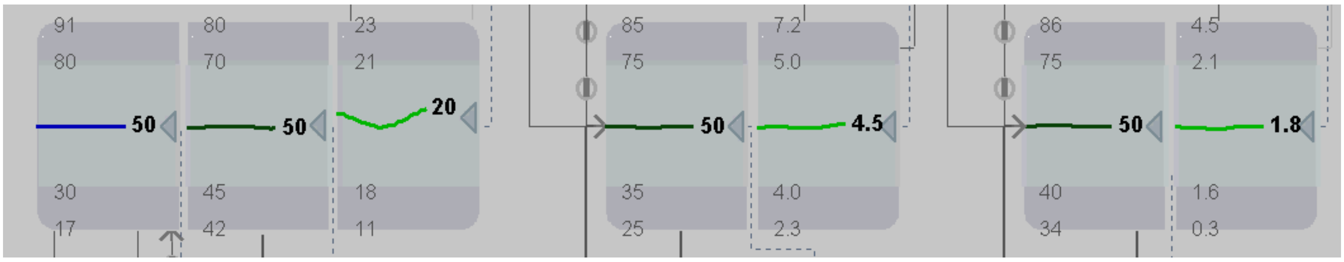

Figure 2.4 Multiple IRD building blocks to support a higher level of pattern recognition. From Braseth et al. (2004), page 10.

Furthermore, if a value enters the low or high warning range, the measured value is now highlighted with a colorful and salient background. This type of display setup uses the Dull Screen principle, where bright and salient colors are reserved for warnings and alarms. The remaining static information is presented in different gray tones to avoid interference with the essential information. Since the display has a high density of information, this display principle reduces the overall visual complexity and makes it easier to detect important information. An entire IRD display can be found in Appendix 3.

2.4.4 High Performance HMI

The High Performance HMI (HPHMI) philosophy is a collection of practice oriented design principles that are based on academic research, technology advancement in modern HMIs, benchmarking of other industries such as aviation, and lastly information learned from analyzing accidents and mishaps caused by inefficient HMI systems. Some of the principles will be covered in this thesis and the rest can be found in Hollifield et al. (2008). The principles can be divided into three primary areas; clarity, consistency and feedback. Clarity means for example that graphics should be easy to read and that the process conditions are displayed clearly. Graphics should present important information, not just raw data. Graphics should also not contain excessive detail and clutter. Consistency is about using standardized and logical graphic functions across all displays. The associated key strokes and required effort to interact with the interface should be kept at a minimum. The navigation between displays should be consistent and follow a hierarchical arrangement. Feedback means that significant actions should be accompanied by a confirmation mechanism so that unintentional events are avoided.

Analog is often better

Analog illustrations of data are often very powerful because humans have a great ability to recognize and interpret analog values. Even though the digital watch can give a more exact value of the current time, it is in most cases more useful to quickly see how much time we have left until another specific time. This can be done in a quicker way with an analog watch, where you can see that you for example have about 20 minutes until a meeting in just a glance at the watch. With that said, both digital and analog depictions have their area of application. When we want to get a sense of how big the margin is to an alarming situation, it is faster done with analog representations, rather than having to calculate the exact margin from two numerical values. On the other hand, a numerical value can be useful when used in further calculations that has to be precise.

Moving analog indicators

The purpose of moving analog indicators in a HPHMI environment is to make the status of the process visible and interpretable in just a few seconds. A common analog depiction is using bar graphs for values. However, this comes with the disadvantage that a bar is barely visible when the value is low. Therefore, the preferred method is to use a moving indicator in the same style as in Figure 2.5.

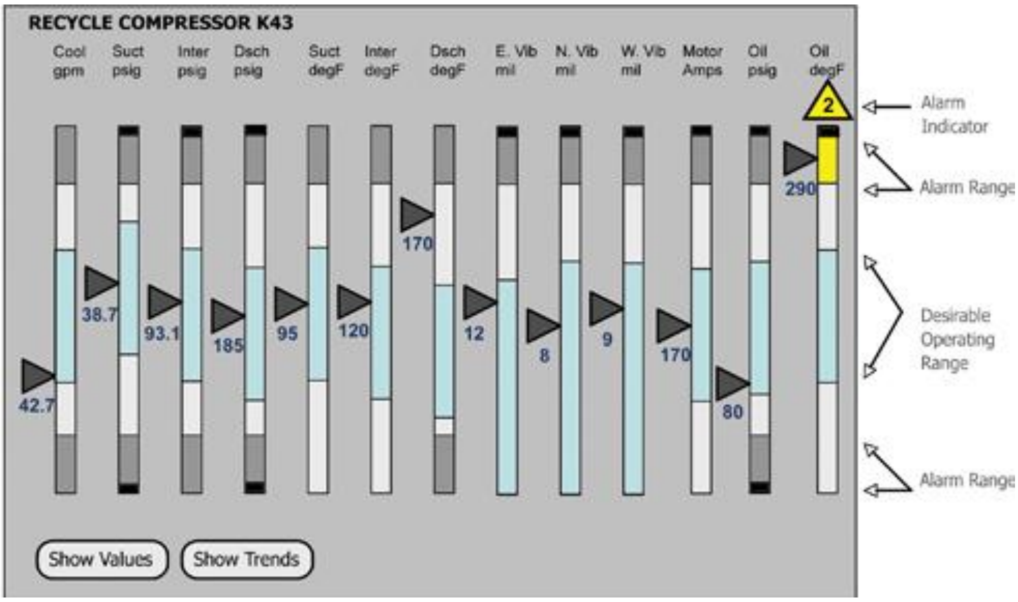

Figure 2.5 Presentation of process status with bars and moving analog indicators that shows the current level. From Hollifield et al. (2008), page 59.

Use of color

Usage of color should be used with consistency and direct operators' attention to important situations. In other words, the use of color must be used in the same manner across all interface displays to reduce possible misunderstanding and uncertainty. The key to a good operator interface is to provide effortless visibility of elements, but to reserve emphasis for alarming situations.

Background color

For many years, the majority of interface graphics has been either accompanied by a light or a dark background. This is mainly the result of limitations in the early display hardware and is also a great solution in some aspects. However, high contrast displays like black background with bright figures are fatiguing to the eye in the long run. A solution that appeals to both contrast and fatigue issues as well as glare problems and color interference, is the usage of light gray backgrounds. In addition it is recommended to have well lit control rooms to reduce the contrast between displays and the control room. The use of gray background will be further discussed in Section 3.3.

Foreground color

As opposed to entertaining websites, objects and figures in an operator display should have a very limited number of different colors. Operator displays do not have to compete for the operator's attention like a website has to compete with millions of other websites. Often a web page consists of information of equal importance and there is close to no consequences if you overlook a piece of information. The opposite is true for an operator interface. Static information such as vessels and process lines are less important than an alarming situation that can have significant consequences if overlooked. As a result, the advice is having vessels and process lines in dark gray or black. Instead of color, difference in line thickness can be made to distinguish between different vessels and process lines if necessary. Bright and intense colors such as yellow and red should be reserved to indicate alarming situations. If the control room uses multiple monitors, it is recommended to use blinking behavior in addition to colors to indicate alarming situations. The reasoning is that blinking objects are highly detectable by the peripheral vision.

Depicting text and values

Generally the amount of text should be minimized, but not entirely skipped. It should only be used when it is needed to explain or identify something on the screen that could not otherwise be expressed solely with graphics. Because of the usually lower resolution of CRT and LCD displays in comparison to books, the text should be in a sans-serif font to make it as readable as possible. It is important to use abbreviations consistent throughout all displays to avoid misinterpretation.

Values of variables should stand out in comparison to static text. An appropriate choice for depicting values is in a bold dark blue manner, which works well together with a gray background. If needed, the units of measurement should be displayed in a lower contrast text next to the value. Leading zeros should not be displayed and the number of decimals should match the operator's precision need.

2.5 How to Successfully Implement a Change

It is safe to say that everyone has gone through some sort of change in our personal lives or in our professional careers. It is also safe to say that some changes succeed with no problems while some changes struggle and may never be implemented. Designing and implementing a new interface design is in fact a change and has to be treated with respect. The question is - how come some changes fail while others succeed? Jeffrey M. Hiatt (Hiatt, 2006) explains the basic model of how a successful change can be implemented and gives an understanding of how change works both on the individual level as well as in business and management. The five building blocks for change are awareness, desire, knowledge, ability and reinforcement.

2.5.1 Awareness

The first step to a successful change is to create awareness of the change. This includes answering questions like "*why is the change necessary*" and "*what happens if the change isn't carried out*". Several factors affect the ability of people to become aware of a change and those are:

1. A person's view of the current state

If a person heavily favors the current state it is difficult to create the awareness of the change. The person may argue that "we have been doing it this way for as long as I remember and why change now?" On the contrary, if a person is unhappy with the current situation they may be more eager to change, independently of what the change really involves.

2. How a person perceives problems

How people process information and make decisions can vary from one person to another. Some people might catch on directly while others need more time to process the change, making this a factor to take into account.

3. Credibility of the sender

The person who communicates the awareness should be someone that the target group has respect for and trust in. The credibility directly influences the way a person acknowledges the awareness.

4. Circulation and misinformation or rumors

It is important to communicate the right information and reduce possible confusion and the spread of false information. For example, there is a chance that rumors may fill the gaps when information is being withheld from managers. This leads to wasted time spent on correcting the false information.

5. Contestability on the reasons for change

If the reasons for change are debatable, the time it takes to acquire awareness is going to be longer. Some reasons on the other hand may strictly be non-debatable. For instance, a change that is being made because of a new emission regulation is hard to debate because the consequences for not changing can include breaking the law and receiving fines.

Building Awareness

Building awareness is a process that requires time. It cannot be conveyed through a single message and expect the response to be positive and identical from all employees. According to Hiatt, the awareness process should consist of **effective communications**, **executive sponsorship**, c**oaching by managers and supervisors** and lastly **ready access to business information**. Communications can include channels such as face-to-face meetings, email, executive and project team presentations, memos and so on. It is common that several communication channels are used in parallel for higher effectiveness. An executive sponsor is the most suitable person to communicate why the change is needed. Often this is a person in charge that employees will respect and listen to. It is important for the sponsor to actively engage and participate throughout the whole change process. Managers and supervisors should take part in both group meetings and individual meetings with the employees to further build awareness. This helps clear up confusion and helps correct misinformation that may circulate in background conversations. Ready access information such as company performance, market conditions and competitive threats should be accessible to the employees. This builds a continuous awareness where the employees instead of getting surprised by changes, anticipates them.

2.5.2 Desire

The next step to a successful change is to invoke a desire for people to support and participate in a change. It is impossible to force somebody to feel a desire to do something. Additionally, even if significant advantageous information is presented about a change, there is no way of telling if the receiving person will develop a desire. As an example, I may be aware that there exist cars that produce a very low amount of emission (obviously environmentally friendly) but that does not mean I have the desire to rush out and purchase one of those cars. Furthermore, the decisions people make can appear to defy logic and seem unreasonable from an outsider perspective. It is therefore important to know the factors that determine a person's desire to change and those are:

1. The nature of the change

What impact will the change have on a person or a group and ultimately "What's in it for me?". Basically, after a person is made aware of a change the person will decide if the change is an opportunity or a threat. Often there exists some kind of sacrifice a person has to make in order to make a change. The desire exists if the resulting reward is worth the sacrifice. It is important to create awareness of the change in a way that is attractive to a person or a group.

2. Organizational or environmental context
A company's history and culture plays a major part in creating a desire to participate in a change. The person or group that is subject to a change will consider a number of factors such as the success of past changes, the amount of change that is already going on and the rewards and reinforcements from past changes. As an example, if a company often starts changes and does not follow through, that can negatively affect the employees' desire to participate in a change.

3. An individual's personal situation
Another factor that plays a role is the life situation of the individual in subject to a change. That includes family status, financial security, age, health, career ambitions, educational background and relationships at work and at home.

4. Personal motivation
The last factor is the underlying motivation that makes up an individual. Some people tend to have a desire to help others while others can have motivations like making a difference in the world, avoiding negative consequences or avoiding conflicts. Some people are more willing to take risks, some desire higher positions and strive for financial security. Every individual is unique and composed of different driving forces.

Creating desire
A fundamental strategy in creating desire is to work proactively. It is not recommended to introduce a change and then react to the individuals that show resistance because this only leads to damage control. Instead, focus on the creating energy and engagement around the change that inspires all levels in the organization. Anticipate and address possible resistance ahead of time and that can lead to less resistance. It is also recommended to engage the employees in the change process as much as possible, resulting in a greater desire to support the change.

2.5.3 Knowledge
When a person is aware and has the desire to change, the next step is the knowledge of how to change. The knowledge learning is determined by the following factors:

1. A person's current knowledge base
The current knowledge of a person and the gap between the required knowledge determines the probability of success. In some case the person may already have the required knowledge but in some cases the gap can be substantial. The current knowledge is a combination of former education and work experiences.

2. Capability of the person to learn
Together with the knowledge gap, the person's capability to learn also determines the probability of success. In addition to this, the capability affects the time it takes to implement the change. Some people learn quickly while others struggle with seemingly easy information. Just by examining a school class we can understand the varying range of peoples' capability to learn.

3. Resources available to provide education and training

Resources available vary from a company to another and can include things such as instructors, available classroom locations, financial resources and other equipment.

4. The access to, or existence of, the required knowledge
The accessible knowledge may vary from one organization to another depending for example on the geographic location. Some areas in the world simply have very little access to educational institutions, internet and other knowledge sources. Furthermore, advances in scientific fields often act as enablers for changes to be made.

Developing knowledge
Developing knowledge is often seen as the central component to change and some project team leaders may even begin the change process with this step. However, skipping the previous steps may negatively impact the probability of success. Tactics and strategies used in developing knowledge are **effective training and education programs**, **job aids**, **one-on-one coaching** and **user groups and forums**. The training program should be effectively designed and executed. Assess what the employees know today and find out what they will need to know when the change is implemented. It is recommended to deliver the training as near as possible to the implementation. The learned information will drop quickly if is not applied directly. Job aids can refer to checklists and templates that help the employees to remember and follow procedures. The aids can be online trouble shooting help files, paper documentation or manuals. One-on-one coaching is an extended part of the training program where each employee has the opportunity to a customized education based on this individual's learning pace. Furthermore, forums and other group channels are powerful ways for employees to learn from each other.

2.5.4 Ability
Ability is the translation of knowledge into performing the required change. Knowledge by itself is insufficient in performing a specific task. For example, a person that just completed lessons with a golf professional does not go on to make par on every hole. Ability is the final step to make the change a reality and there are multiple factors that impact a person's ability:

1. Psychological barriers
An example of a psychological barrier that can affect a person's ability to perform change in the workplace is the fear for public speaking. It can also be a more specific barrier; for example, paralysis at the sight of blood can be a devastating trait for a paramedic or a firefighter, as the barrier may prevent the person from doing their job.

2. Physical abilities
Every individual has a physical limit to what their body can perform. Football, for example, is a sport that many have the knowledge of but only a very few may play it professionally. In a typical workplace, physical limitations refer to strength, dexterity, physical size and hand-eye coordination.

3. Intellectual capability
A person's intellectual capability is put to the test to some degree when developing a new ability. Some people are naturally innovative and creative while others are good with math and numbers.

Depending on the nature of the change, the mental capability will act as a limitation for some individuals.

4. The time available to develop the needed skills
Another constraint is the time available to develop a certain ability. If an individual has the potential to learn the required ability but is unable to acquire it in a given time frame, the change might fail.

5. The availability of resources to support the development of new abilities
Supporting a person through the development of new skills can be done by having access to mentors, subject matter experts, proper tools and materials and personal coaching. The availability of such supports will dictate the development rate of the ability.

Fostering Ability
As stated before, knowledge does not automatically lead to ability. For that reason, it is important for the management to support the employees in developing the new ability. Four tactics that can be used are **day-to-day involvement of supervisors**, **access to subject matter experts**, **performance monitoring** and **hands-on exercise during training**. The development of new abilities requires both time and practice and the involvement of supervisors in this process is highly recommended. Mistakes and errors are a natural part of the learning process and there should be an open channel of communication between the supervisor and the employees for this reason. Employees should feel safe to seek out help and give feedback concerning the change. Provide the employees with access to subject matter experts and any remaining knowledge gaps should be taken care of. Some companies use help desks where employees can call and ask questions. To ensure that the change is being implemented as intended, it is recommended to monitor the change and perform measurements. By doing this, the management can identify where the employees are doing well and in what areas they need improvement. Hands-on exercises like role plays, simulations and similar techniques allow the employees to learn new abilities in a safe and controlled environment.

2.5.5 Reinforcement

Reinforcing a change is about acknowledging and rewarding the progress an organization or individual has made. Reinforcement can include public recognition, celebration or personal acknowledgement. The focus is on telling the involving people that they matter and that their progress and contributions are valued. The effectiveness of the reinforcement is determined by multiple factors:

1. The degree to which the reinforcement is meaningful to the person impacted by the change
From the receiving individual's perspective, reinforcement is considered meaningful if it is delivered by a person that the individual respects and if the reward is valuable to the individual.

2. The association of the reinforcement with actual demonstrated progress or accomplishment
Showing appreciation and recognition is important when an individual has succeeded with a change. It lets them know that people still care and that the change was important. On the other hand, rewarding when no accomplishment has been made can undermine the value of future rewards, because people like to be acknowledged when they feel they have made a meaningful contribution.

3. The absence of negative consequences

If a person is experiencing negative consequences when they perform the intended change, it can degrade the overall performance of the change. One example is peer pressure; the rest of the group insists of doing things the old way and will apply social pressure on the people that conform to the change, which in turn acts as a negative consequence to the people actually doing the right thing.

4. Accountability systems to reinforce the change

Some people are more likely to maintain a change if they have some kind of accountability system available. To a person that works out in a gym and wants to become stronger, this system can be a personal trainer who monitors and tracks the person's progress. Accountability systems in a work place can be job performance measurements, where the results of change are visible on a continuing basis. Objectives and goals can be set up and when they are eventually achieved, rewards and recognition follow to further reinforce the change.

Reinforcing change

With effective reinforcement you can avoid the employees to go back to the old way of doing things and increase the probability to reach the intended change. Tactics that are used to reinforce change can be **celebrations and recognition**, **rewards** and **feedback from employees**. The most effective way of recognizing an employee's work is by having one-on-one informal conversations where the supervisor acknowledges the employee for their work in a genuine way. Celebrations are another possible tactic. Celebrations consist of fun activities where the whole group involved with the change, for example, goes bowling together. Additionally, rewards can be used to acknowledge the employees for their contributions when certain objectives are met. Lastly, receiving feedback from the employees is a part of the reinforcement. Simply ask how they are doing after the change is put into practice and what they think about the change.

3 Designing an Overview Display

3.1 Relation between Overview Display and Situation Awareness

Problems with SA have been found to be a leading casual factor in several industrial and aviation accidents (Durso, et al., 2007). Also, the lack of overview display has been found to be a factor in a couple of significant hydrocarbon processing industry accidents (Health and Safety Executive, 1997). Therefore it is important to design an overview display that can help operators to maintain good SA.

One question to ask is if SA improves with an overview display. In a study, people were asked to monitor four high level variables related to a city and report any deviations from certain goals (Rivera, et al., 1998). This was done with both an overview display present, and not present. The study was set up to measure SA and Situation Assessment (Sass), where the latter can be described as the process of collecting information needed to maintain SA. The number of verbalizations for the Sass was measured and was greater with the overview display present, translating to more situation assessment behavior with an overview display. Subjects in the overview display condition also showed better awareness of the state of the city. Overview displays tended to reduce the time between perceiving a deviation and performing a corrective action. This is helpful in alarming situations where quick action is critical.

Designing for situation awareness is the basis for effective overview display design. A graphical interpretation of the relationship between overview display and SA can be seen in Figure 3.1. **Orienting** is where the operator scans the Level 1 overview display and other possible displays in the hierarchy, picking up on salient information and discarding non important information. At any given time, the operator identifies a process deviation. **Evaluating** is when the operator reaches a conclusion about the process deviation, either by simple understanding or by further looking into Level 2-3 displays for more detail and confirmation. The detailed displays are used to troubleshoot the deviation and form a hypothesis of the cause. **Acting** is when the operator makes control actions to manage the process deviation based on the hypothesis. **Assessing** is when the operator continues to scan the Level 1-3 displays to determine if the actions had desirable effects.

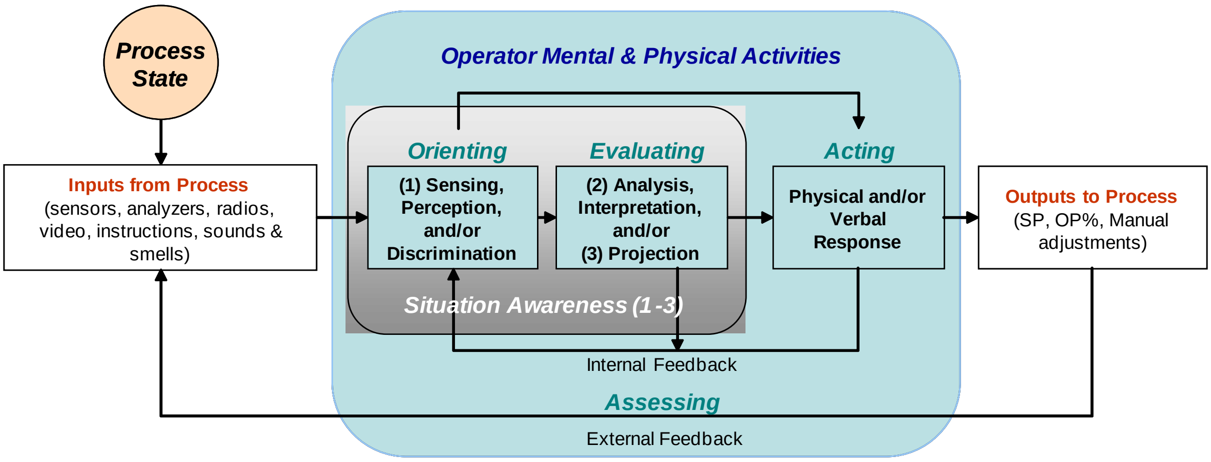

Figure 3.1 The mental process when gathering information about process state and then translating it into action and output to the process. From Abnormal Situation Management (ASM) Visual Thesaurus Webinar "Using Qualitative Display Shapes for Improving Operator Situation Awareness" (December 10, 2010), page 10. SP = set point. OP = output.

3.1.1 Three Levels of Situation Awareness with Respect to Overview Display

This section will reintroduce the concept of the three levels of SA in context to the process operator position and the overview display (Bullemer & Reising, 2008).

Perception

The term perception refers to noticing process information and the changes to that information. The operator perceives and notices changes/patterns in trend displays. For example, if a variable is continuously increasing or decreasing, or if there is a sudden drop or spike in the data. Furthermore, reading a variable's set point (SP) and process value (PV), noticing alarms and reading the alarm description, hearing auditory information such as communication with other operators and audible alarms.

Comprehension

Comprehension refers to the understanding of the process state. The comprehension also includes understanding how optimal the process is running, how impactful potential deviations are and how close to current operating limits the process is.

Projection

Projection refers to the operator predicting where the process is heading. Furthermore, predicting how well the process will respond to certain control actions, extrapolate information from trend displays into the future, predicting if the process state will remain stable and predicting how fast the process will stabilize after deviations.

3.1.2 Failure Modes with Respect to Overview Display

There are many problems and failure modes that can potentially arise with a finished overview display. If operators have an overview displays, they report rarely using them (Bullemer & Reising, 2008). In some cases operators report that they would rather have another, more informative display in its place, and if they do look at the overview display, they tend to only look at a few variables. The reasons to said problems can be for example that (i) they do not have the correct information in them, (ii) they have too much information in them, or (iii) they have the correct information but it is displayed poorly because of (a) poor visualization techniques, or (b) visualizations incompatible with the operator's decision making.

The following part will discuss some of the SA failure modes discussed earlier in 2.3.2, but this time in the light of the process operator and the overview display.

Incorrect mental models
Each operator develops their own mental model of the process. The operator's mental model is a product of their training and operating experience, which can differ from one operator to another. One operator may understand the process in one manner and solve problems accordingly whearas the next operator may look at the process in a slightly different way, introducing some variability to the control of the system. In worst case scenarios their mental models can differ so much that some of them lack critical relations between process variables which will result in unnecessary errors. By using an overview display, the goal is to create a common mental model for all operators and ensure that everyone is on the same page, decreasing the variability among the operators.

Attentional tunneling
It is easy for operators to lose the big picture when they direct their attention to a single problem. They get focused on the "fire they are fighting" and do not take a step back to evaluate the entire process state, because doing so would require scanning through several displays and most likely actually replacing the display used to "fight the fire". This effort-requiring problem may keep operators from doing so. By using an overview display, however, the big picture can be maintained with little to no effort from the operators because the entire process state fits in a single display. The overview display also acts as a reminder to keep the big picture.

Data overload
It is no secret that people process information at a very slow rate compared to modern computer processing power. Without an overview display, it may be unreasonably demanding to repeatedly scan multiple displays, find and remember important PVs on different displays then compare them to the mental model and finally carry out appropriate actions. By using an overview display, the volume of data that needs to be monitored and remembered can be reduced and fitted into one display. Deviations on critical variables act as indications to further look into details on additional Level 2-3 displays.

Misplaced salience
Color-coding, audible alarms and blinking animations are examples of salient factors that are used to direct the operator's attention. When they are overused or misused, the operator may fail to discover critical information, either because of the information being way less salient or other less important information being too salient.

3.2 Functional vs. Schematic Overview Display

This section will compare and evaluate two different formats of overview displays, the first one being a schematic design and the second being a functional design. The main design difference between these two is the way process parameters are visualized. The schematic display is a traditional design technique where process information is presented together with graphical objects corresponding to the actual process. In other words, the schematic display is mimicking the real world design by representing process equipment with various graphical shapes. This includes equipment and connection lines such as tanks, pipes, pumps and vessels. Information about the process is displayed in a quantitative way, which means process variables are shown as numerical values.

On the contrary, a functional display presents process information in a qualitative way, which means process variables are shown relative to their limits in so called qualitative indicators. Such indicators can be analog gauges or other dynamical representations. Displaying the numerical process variable in addition to the indicator is optional.

In a recent study, the performance of functional and schematic displays were evaluated and the question was if functional overview displays were more effective in supporting operator's SA (Tharanathan, et al., 2012). The experiment was set up so that an operator monitored either a simulated low complexity or high complexity upset scenario, with either a functional display or a schematic display. Both display formats were designed with the same key process parameters and the only difference was the display design; functional = qualitative design, schematic = quantitative design. There were in total eighteen operators in the experiment and they were all professional operators with a mean value of around 10 years of experience on the current process unit. The number of process deviations during an upset scenario was 15-33 for low complexity and 146-169 for high complexity. In addition to the monitoring task the operator were asked to perform a secondary task simultaneously, to simulate a more realistic situation. The measured result consisted of four values. The first one was the amount of Level 1 SA. The second value was Level 2 SA. The third was a performance measure on the secondary task and the fourth was the operator's subjective workload experienced when monitoring the process. The results from the study showed that operators detected more changes when monitoring the functional display as compared with the schematic display. This translates to a higher Level 1 SA. The interesting thing to notice is that the operators who participated in the study were all used to traditional schematic displays and still got a higher overall accuracy percentage with functional displays. The operators also showed a higher Level 2 SA with functional displays because they were able to better comprehend the status of the process in different scenarios. The result of the secondary task showed no difference between the functional and schematic scenarios. This shows that the operators had the same performance on the secondary task but displayed a higher overall SA with functional displays. The operator's workload tended to be higher with functional displays. The reason for this can be explained by the operators detecting more deviations with functional displays and therefore experiencing a higher mental workload to keep up with the changing process.

One suggested effect of using the functional display design is that it requires less memory resources, which in turn becomes advantageous when operators have to multitask, similar to a typical control room situation.

3.3 Why Gray Background for Overview Display?

Traditional display interfaces often use black backgrounds with a low amount of color options because of limited technological capabilities when the systems were built. As a result of the color limitation, the same color is used to visually represent several features with different meaning. The highly salient color red, for example, might be used to indicate that a critical process alarm is active, a pump has stopped and at the same time be the main color for pipes containing hot water and steam. In such an environment, the operator has to perform additional mental efforts to identify and evaluate what each red object on the display means in order to not miss critical red alarms. The black background in combination with a bright control room forces the eye to make an adaption to different light levels every time the operator shifts view from the display to the control room and back. Over the span of an 8 hour shift where the operator repeatedly shifts attention between the display and the control room, the operator may experience some degree of eye strain.

It is important to notice that the aim for the color scheme is not to look attractive and fun to look at. The aim is to enhance the operator's performance and situation awareness in the control room. Over the course of a shift, the operator has to stay alert and monitor less frequent events that take place at unknown times. Therefore it is important to design a display that captures the operator's attention when critical data is changing and the color scheme plays an important role in this context. The design guideline of using a gray background (Bullemer, et al., 2011) is a result of a few important design objectives. The color scheme should support the objective of:

- directing the operator's attention to critical information in the least amount of time and with the least chance for misinterpretation and error;
- aiding people with color vision deficiencies;
- reducing glare from the display so that the control room light level can be sufficiently high to support the alertness on night shifts and to support tasks besides the display (for example, reading a paper);
- reducing eye strain and fatigue.

With a **gray** background, it is easy to manipulate the amount of salience that is displayed for different objects. The reason is that a gray background is very discreet and less salient in itself. From a color contrast perspective, another reason is because there exists a wider range of foreground colors to use in combination with the gray background. This is especially true for people with color vision deficiencies where it is harder to differentiate between colors.

Static information such as vessels and other currently less important data should blend in with the background. For instance, the color of less important data could be in slightly darker tones of gray compared to the background. Critical alarm state could be made salient with the color red. However, red should then only be used to indicate this specific meaning. Furthermore, to indicate that a pump is stopped, the color purple could be used.

It is reasonable to have a well-lit control room to improve the alertness level, especially during night shifts. Gray background is therefore a good option because then the difference in lighting between the control room and the display is kept to a minimum. As a result, the operator's eyes have to adjust less between the screen and the surrounding control room, resulting in a reduced risk of eye strain.

In conclusion, the recommendation is to use a gray background in combination with grayscale colors for static and less important information. Important information should be made salient and unambiguous with colors such as red for critical alarms.

3.4 The Practice Oriented Design Process Associated with Overview Display

Identifying the information needs of an operator to make decisions and perform specific tasks is a key part in the design process. The problem is that traditional information gathering through task and work analysis can be very time and resource demanding. Companies have an interest in profit and therefore it is of great importance that time should be used effectively. The following part will present a practice oriented procedure for designing an overview display (Reising & Bullemer, 2008).

Identify the operator's information needs:

1. Identify the critical variables;
2. Identify the critical interactions;
3. Identify the appropriate visualizations.

3.4.1 Identify the Critical Variables

The critical process variables that define the plant's status are the basis for the overview display. Identifying the variables is ideally done by interviewing both experienced operators and process engineers, alternatively subject matter experts. The operators help to identify variables or features that provide an early indication of process deviations based on past experience. If the operators know the value and status of these variables they have a good understanding of the health of the plant. The engineers help to identify underlying mental models and process functions based on designed intent. Examples may include mass balances, energy balances, pressure profiles, temperature profiles and so on. Engineers also provide calculated process conditions and critical business information such as recycle percentages, monthly emission totals, remaining hours to full/empty cistern, energy consumption, operating productivity based on production targets and so on. One thing to note is that some of this information, especially the business information, may not be found on the local control network so additional efforts may have to be carried out to get that information.

3.4.2 Identify the Critical Interactions

The interactions refer to the mental activities and the decision making of the operator when viewing a particular variable. Is the variable supposed to be within two levels? Is the variable's historical data interesting? Is the variable used in comparison to another variable? Do further calculations have to be made with the variable? Those are examples of questions that need to be answered by operators and experts in this section.

3.4.3 Identify the Appropriate Visualizations

What are the best ways to represent the critical variables to aid the mental activities and decision making of the operators? Identifying the appropriate visualization is based on the previous definition of the interactions. By using suitable graphical objects that support operator SA, it eliminates the need for mental calculations and comparisons. The goal is to transform cognitive tasks into perceptual tasks and consequently reducing the likelihood of mental errors. When designing the graphical objects one should have the interaction requirements in mind and follow the guidelines presented in 2.4. The following illustrates an example; **showing the process variable's current value**

relative to a target range and appropriate alarm limits. A unique metaphorical shape is created for each type of process variable. For example, a speedometer in the case of the flow gauge and a thermometer in the case of the temperature gauge. The current value, target range and alarm limits are portrayed in the graphical object (see the speedometer in Figure 3.2).

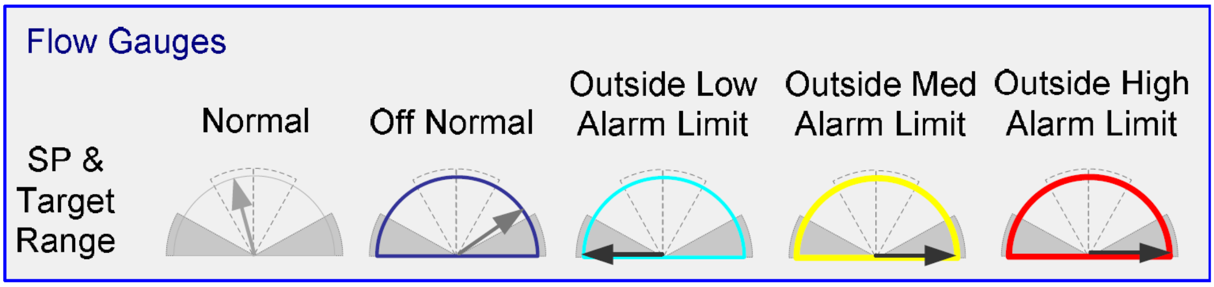

Figure 3.2 Appropriate visualization of a flow gauge in its different states. Arrow depicts the current value. Dotted lines shows target value range. From Bullemer & Reisin (2008), page 12.

3.4.4 The Interview

It is important to reflect on the fact that it can present a challenge to identify the operator's needs through interviewing. One reason is because there is no guarantee that the operator knows exactly what information he or she actually needs. For instance, if the operator has considerable experience with an existing system and is fully aware of its flaws, the operator might not think of them as flaws any longer because the operator has become used to them. Another reason along the same lines is that what the operator thinks works best might not always be equal to what actually works best. In addition to this there may exist multiple opinions on the same matter. Of course it is ideal to cater to every operator's needs, but what action is to be taken when there are different opinions on the same matter? There is the possibility to go along with what the majority of the operators think about a matter. However, to be sure of the majority, all operators have to be interviewed. The drawback is that it can be very time demanding to interview everyone. One compromise can be made so that the interviews are carried out in larger groups to reduce the interview time. This introduces, however, another drawback - it may be difficult to capture everyone's opinion when group thinking comes into play (Endsley, 1999). Ideally, operators will be interviewed individually to ensure that everyone has the opportunity to share their opinions. In the end, trade-offs has to be made and it is important for the interviewer to be aware and prepared for possible challenges.

Interview structure

The interviewer should review available material and information about the process before beginning the interviews. It is beneficial for the interviewer to have an understanding of the process and the nature of the operator's work before starting the interviews (Endsley, 1999). It is recommended to begin each interview with an introduction of the purpose of the information gathering. Then follow up with the aim of the overview display. The interview should be structured with room for elaborate responses and follow-up questions. Systematically go through all sub-processes to reduce the risk of missing critical variables. Consider the possibility to conduct the interviews in the context of a select set of operating scenarios to efficiently gather all the information requirements (Reising & Bullemer, 2008). The interview material used for the TMP process overview display can be seen in Appendix 1.

3.5 The High Performance HMI Process Overview Display

Figure 3.3 shows an example of a process overview display in the HPMI fashion. It includes bars with moving analog indicators and trends of important variables. The display consists of six main areas; Reactor 1, Reactor 2, Hydrog A, Hydrog B, Feed System and Aux Systems. Within these areas are multiple process variables presented in different visualizations. The lower left corner shows an alarm list of alarms that are currently active. The upper right corner shows two key performance indicators. The lower middle section is a navigation panel where the operator can click and navigate to other displays. The four circles in both Hydrog A and Hydrog B are so called Radar Plots. In brief, a Radar Plot is a chart displaying multivariate data. In this particular example, the Radar Plots presents 12 variables each, starting from the value 0 in the center and increases as the distance grows from the center. The point is to learn that a certain graphical appearance of the Radar Plot corresponds to a certain situation in the process. Radar Plots will not be discussed in detail and the reader may look into it even further if desired.

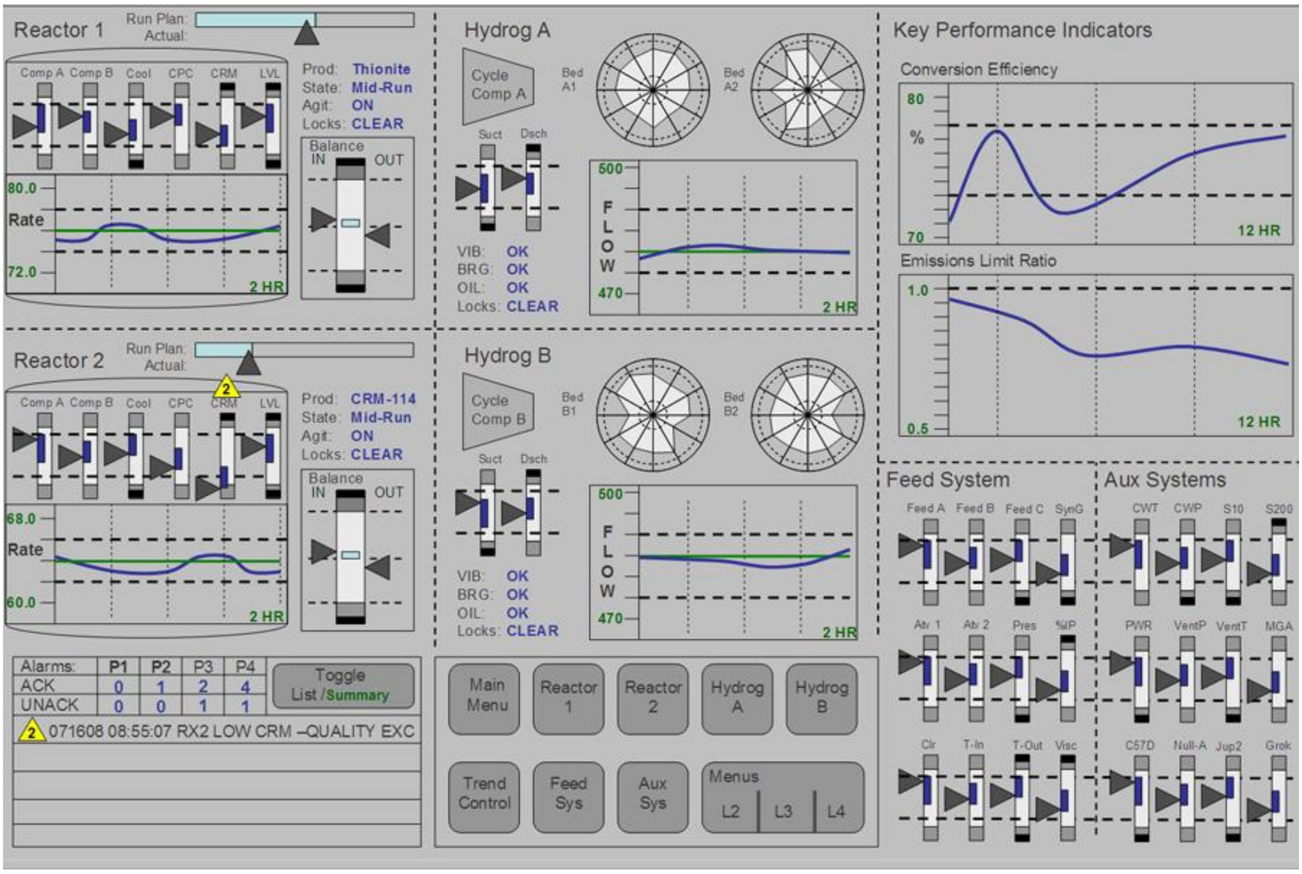

Figure 3.3 HPHMI process overview display with graphic elements representing important key variables. From Hollifield et al. (2008), page 101.

3.6 DeltaV

A process overview display will be designed in the DeltaV digital automation system. The DeltaV system consists of both hardware and software components. The main system hardware includes a control network for communication within the system, power supplies, DeltaV controllers that manage data and communication between the control network and I/O systems and at least one I/O system per controller that receives data from field devices . The DeltaV software applications that are relevant to this thesis are DeltaV Explorer and DeltaV Operate. DeltaV Explorer is similar to the Windows Explorer and lets you view and navigate the DeltaV system. The DeltaV Operate application has two modes, configure mode and run mode. Designing process graphics can be done in configure mode while run mode is used by the operators when they monitor the process. Basically, the making of the process overview display take place in configure mode and then run mode is utilized to test the functionality of the overview display.

To create process graphics in configure mode, the designer can make use of drawing tools such as boxes, circles and lines, drag-and-drop features, tool-box buttons and pull-down menus. The DeltaV Operate configure mode in Windows setting can be seen in Figure 3.4. The system tree to the left lets the user navigate through the picture hierarchy and the work area to the right is used to design pictures.

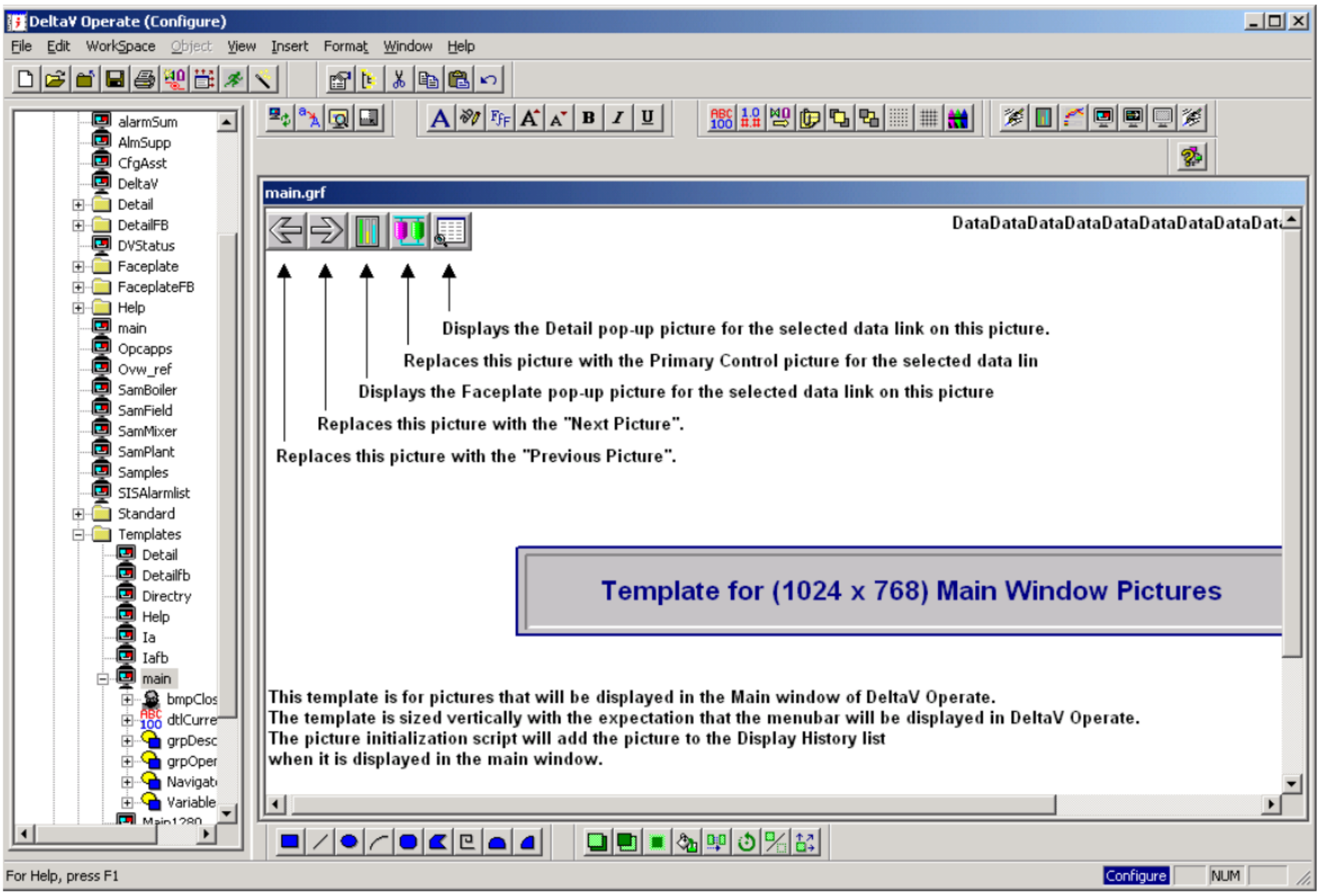

Figure 3.4 DeltaV Operate configure mode in Windows setting. System tree to the left and work area to the right. From the DeltaV manual "Getting Started With Your DeltaV Digital Automation System". Emerson Process Management (March, 2006).

4 Results

4.1 Interview Results

The complete interview result in Swedish can be found in Appendix 2. This section will provide a summary of the most important things.

A general comment about how to form a perception of what is happening in the process: “It takes a long time to gather a perception of the whole process. Especially when you come in after a free week, and in addition to this you do job rotations every day in some shifts. This means that you are at the same work position about 4 times in a month, which is a small amount.” To form a perception you look at several “trend groups” where multiple relating variables are shown in time. The trend time interval varies between 1h- 24h, in some cases even longer.

There are not many different process modes in the process. The production rate can differ sometimes but it is still the same values that the operators look at. More specific, it is the same variables that are interesting and important in all process modes. One process mode example: if there is a problem with the steam compressor, the evaporation sub process is run on live steam. This changes some aspects of the process but it only happens about once every four years. It is then common that the operators look at manuals and instructions when switching to live steam. Critical variables and interactions can be found in Appendix 2 (in Swedish).

4.2 Appropriate Visualizations

4.2.1 The Main Visualizations

Most of the critical variables can be divided into five main visualizations; (1) basic level indicator, (2) level indicator with set point, (3) temperature indicator, (4) value that must not exceed a certain limit and (5) level indicator with trend. Special visualizations have been created for a few critical variables.

Basic level indicator

This is the base for all indicators. It consists of a vertical bar with appropriate height. A moving analog indicator is placed to the left of the bar and changes its positions according to the linked value; starting at the bottom of the bar at 0 % and ends at the top of the bar at 100 %. The normal operating range is colored with a tone of light blue. High and low limits are represented with light gray sections. Critical high and low limits are represented with darker gray sections. When a limit is surpassed the respective alarm section is colored.

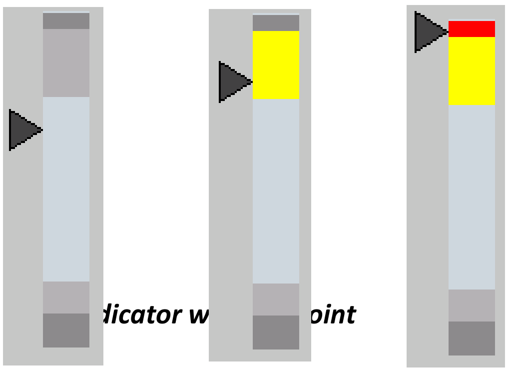

Figure 4.1 To the left: Basic level indicator without alarm active. Middle: First warning limit is surpassed. To the right: The critical limit is surpassed.

The style and the colors are the same as the basic level indicator. This indicator is used with variables that adjust to a set point with a PID controller. The set point is always vertically centered on the bar to support pattern recognition. The low and high limits are defined by how much the process value can oscillate around the set point.

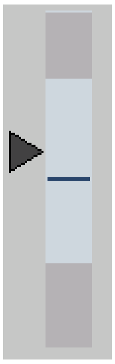

Figure 4.2 Level indicator with set point vertically centered. Alarms are presented according to the basic level indicator.

Temperature indicator

The style and the colors are the same as the basic level indicator. What separates it from the basic level indicator is the addition of a circle at the bottom of the bar. This is supposed to represent a thermometer. When a limit is surpassed, this circle is colored according to the alarm.

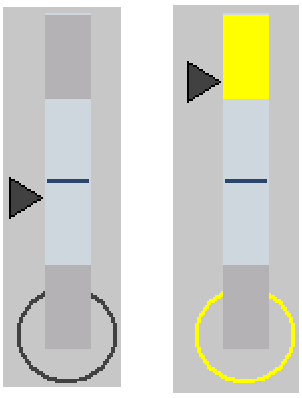

Figure 4.3 To the left: Temperature indicator without alarms active. To the right: First warning limit is surpassed. If there exists a critical limit it is presented in red.

Value that must not exceed a certain limit

The style and the colors are the same as the basic level indicator. This type of indicator is used for variables that only have a high limit and also have a significant impact on the process. Inspiration comes from the RPM gauge in cars, but instead of the red section at the end, this indicator uses a tone of gray.

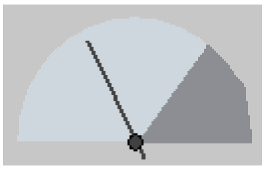

Figure 4.4 Visualization for values that must not exceed a certain limit. Alarms are presented according to the color scheme in the basic level indicator.

Level indicator with trend

The level indicator with trend is basically a horizontally extended version of the basic level indicator. Instead of the moving analog indicator, this indicator uses a blue line that represents the value over a certain time period.

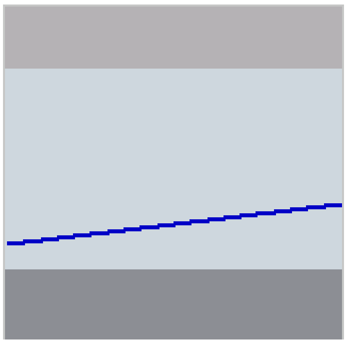

Figure 4.5 Level indicator with trend in blue.

4.2.2 Special Visualizations

This section will cover the visualizations that do not fit into the five main visualizations.

Reactor process visualization

This visualization is aimed at the reactor sub process. The process is cyclic and draws inspiration from the analog clock format. The cycle begins with the reactor empty. Formaldehyde dissolved in water gets poured in, followed by sodium hydroxide and butyraldehyde. Then a certain time is required for the reaction. Formic acid is then poured in and the last step is emptying the reactor. Then the cycle repeats itself.

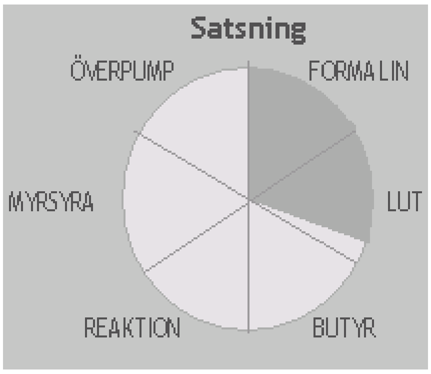

Figure 4.6 Visualization for the cyclic reactor process.

Centrifuge visualization

To convey which centrifuge is functioning and which is not, a table-like arrangement is made of all the centrifuges. Green dot means that the centrifuge is operating in automatic mode. Orange dot means that the centrifuge is operating in manual mode.

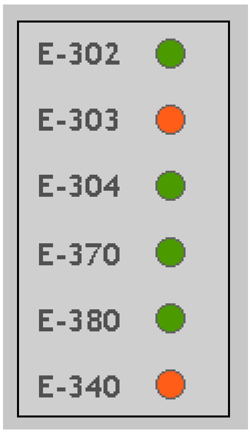

Figure 4.7 Table-like visualization of centrifuges operating mode. Green = automatic mode, orange = manual mode.

Trend object

There was a certain need for an easy overview of the levels in V850, V870 and V880. The visualization is simple and contains the three levels and a reference point going horizontally at 50 %.

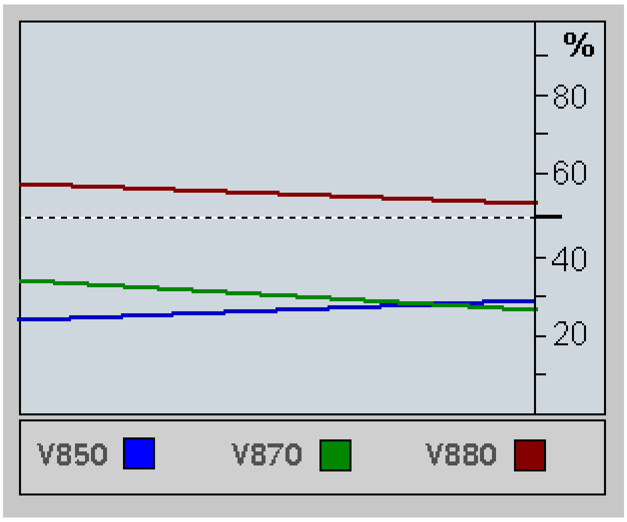

Figure 4.8 Trend object showing the values of V850, V870 and V880 over time.

Just the value

Due to the limited space, several levels and values are displayed as just the value with a description on the left side. These variables were selected because they are either less important or the operators have a past history with the numerical value of the variable. When the value's limit is surpassed, a box of appropriate color appears around the name of the variable (yellow = first limit or red = critical limit). The color of the value is in a tone of blue and was chosen because of the comfortable and neutral contrast with the gray background.

Figure 4.9 To the left: Visualization of just the value of a parameter. To the right: Alarm limit is surpassed and value is surrounded by a yellow box.

4.2.3 The process overview display without alarms active

The finished process overview display can be found in Figure 4.10. The figure is a screen capture of the display in DeltaV. The variables are displayed according to the process flow, starting with the reactor in the upper left corner. The process flow can then be read as how one would read a book; from left to right and from the top to the bottom.

4.2.4 The process overview display with some alarms active

Figure 4.11 shows how the overview display looks when some alarms are active. Some have reached their warning limit (yellow) and some have reached their critical limit (red).

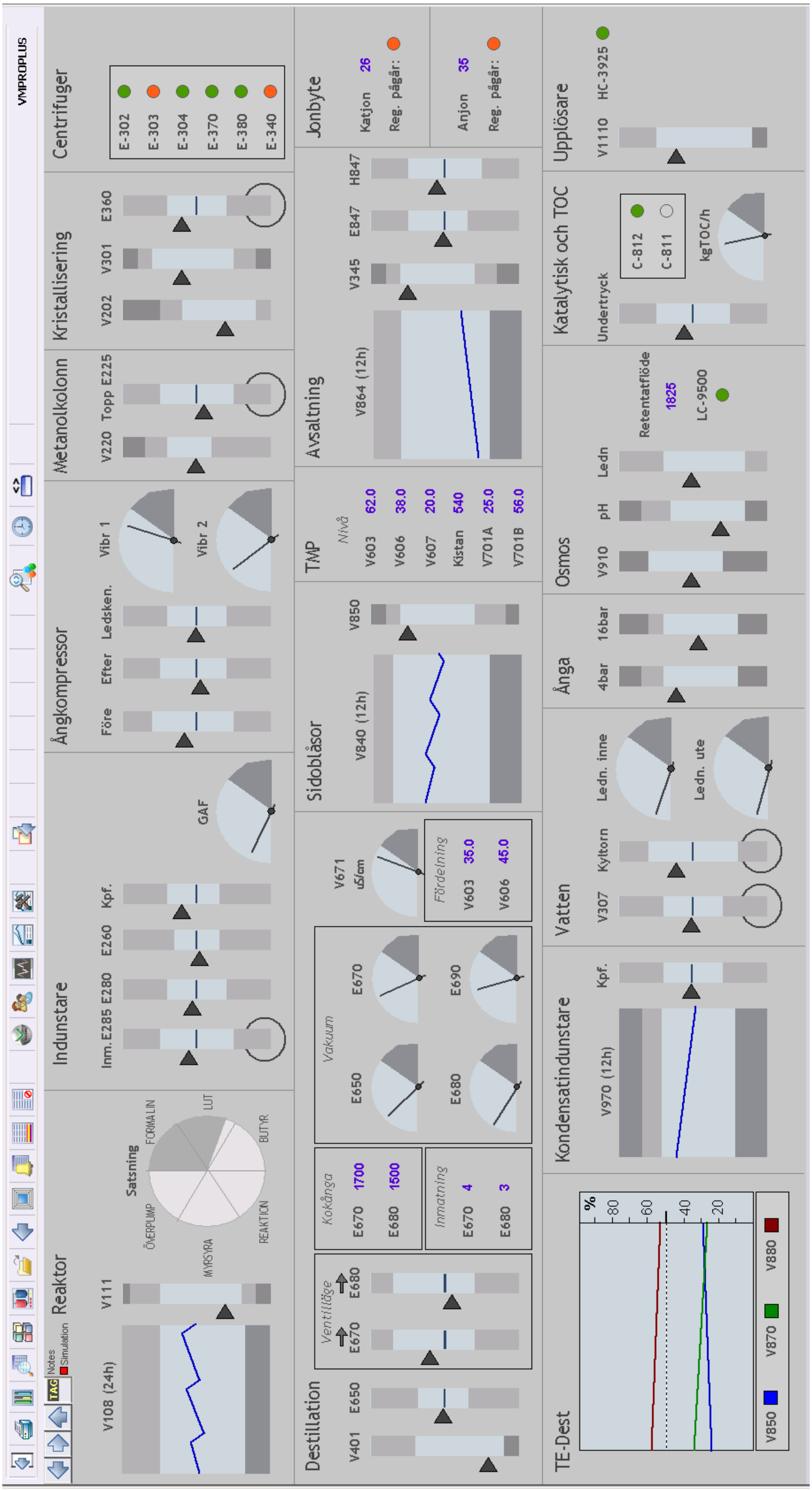

Figure 4.10 The finished process overview without any alarms active.

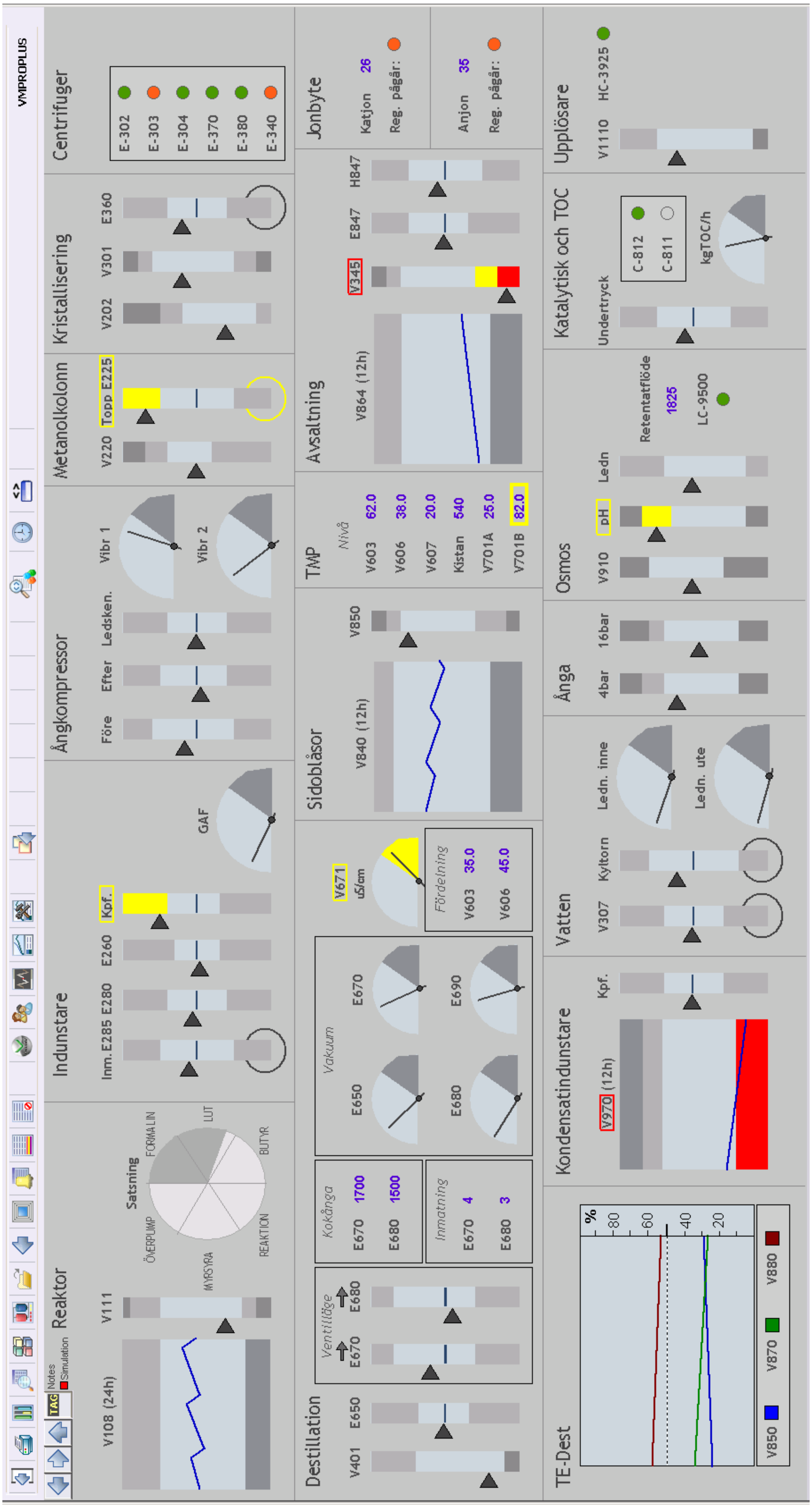

Figure 4.11 Process overview display where some variables have reached their warning limit or critical limit.

5 Discussion

The author would like to add his personal thought on the whole schematic overview display versus functional overview display. Schematic is better in the case of learning purpose. It would be easier for a new operator to learn the process if the whole process was being displayed in one picture with all the vessels and connections. On the other hand, the functional is better when the operator knows the whole process by heart and can extract valuable information from just seeing the level of a tank without physically seeing its place and connections in the process.

One important part in the making of a process overview display (in any design process really) is to do a follow up and evaluate the initial result. It would be highly desirable, but due to lack of time and resources this could not be executed in the scope of this master thesis. In the evaluation, one would ask the operators to answer questions like:

- Is the something missing? For example missing variables.
- Is there something in the display that does not need to be there? For example redundant variables.
- Are the visualizations appropriate? If not, why?
- Are there trends to the variables that need trends?
- Is the text clear and can it be easily read?
- Are the abbreviations correct?
- Other opinions, aspects and thoughts?

Perhaps to some people the process overview display may seem very information dense and overwhelming. But keep in mind that it is not meant to fully grasp and interpret the display after seeing it for the first time. The idea is to learn and become accustomed to the display so that after a while, maybe a couple of days or weeks, an operator can take a glance of two seconds and immediately understand where and what problems there are in the plant.

In the interviews, the discussions easily wandered on to other topics and less relevant talk, just like a normal conversation does. It was common that we started to discuss how things in the plant worked instead of just the interaction the operator had with the variable. This thought came up when the author went through the interview answers and found that some answers had little meaning of the actual interaction, and more information about how the variable and the associating process worked. In future interviews, the author would have pushed more to get the concise and concrete interaction with all variables. Conducting interviews are not an easy task and requires some training. The skill is to lead the conversation and get to all the important things in a natural manner without losing track of the objective. This would ideally also be done without being too repetitive and boring.

6 Future Work

The author would like to recommend some future work that would complement this master thesis. First of all, the amount of interviewees used in the research for the operator's information needs will directly have an impact on the quality of the result. The more interviewees, the more data and information can be collected and will consequently take more opinions into consideration. Ultimately, this will make the result more scientific and conclusive. Therefore, if possible, expand the number of interviewees in future design processes.

Color vision deficiency is a topic that is mentioned in this master thesis, but not fully explored. Before a final implementation and as a general future recommendation, this topic needs to be carefully investigated. Are all colors in the interface visible and distinguishable for people with color vision deficiency? If not, change the color to a more appropriate one. On a side note, if none of the operators have color vision deficiencies it is possible for the management to make the decision not to aid people with color vision deficiencies. Just beware of a future scenario where new operators have to be hired. Some of them might have color vision deficiencies.

As mentioned in the Discussion section, it is recommended to do a follow up on the implementation of a process overview display. See the Discussion section for further information.

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Appendix 1 Interview Guide for the TMP Process

The purpose of the information gathering is to identify the most important variables for the TMP process. These variables are then to be presented in an appropriate way in a process overview display. **The aim** of the overview display is that an operator will get a quick overall perception of the whole process by looking at one display only. For example, an operator has been outside the control room on an errand and returns to the control room. Then the operator proceeds to skim through the overview display to gather a view of what is happening in the process. The operator detects unwanted situations or if the process is about to enter unwanted situations. The operator then navigates to more detailed displays to troubleshoot and fix the problem.

First identify if the process has different process modes and if the information requirement then changes. Most processes have several operating modes. For example, live steam mode, normal operating mode, starting up and shutting down mode, alternative products mode, partial rate mode and various expected abnormal situations. An example where information requirements change with production rate: the level in a tank can be more important to know when the production rate is higher, because it will fill up much faster and must be detected sooner.

1. Identify the critical variables

All sub processes included, which variables are sufficiently critical to be shown on the overview display? In other words, which variables

(i) gives an early indication to process deviations and has to be tended to as quickly as possible?
(ii) have a significant impact on the process operations from a historical perspective?

2. Identify the critical interactions

For all variables, how does an operator interact with that variable?
What decision does the operator make when aware of the state of the variable?
Some examples:

- Is the variable supposed to be within two levels?
- Is the variable's historical data interesting?
- Is the variable's rate of change important?
- Is the variable used in comparison to other variables?
- Other calculations or work related to the variable?

Process areas (in Swedish):

- Råvaror/Reaktor
  - Råvaror
  - Formalinblandning
  - Formalinkylning
  - Reaktor
- Indunstning
  - Förvärmning
  - Indunstare
  - Ångkompressor
  - Metanolkolonn
- Kristallisering/Formiat
  - Kristallisering
  - Centrifuger
  - Formiatupplösare
- Destillation
  - E650, E670, E680, E690
  - Sidoblåsor nivå och vacuum
- TMP
  - Lagertankar
  - Flingvalsar
  - Flingvalskylning
  - TMP säckning
- Nödduschar
- Ammoniaklarm
- Jonbyte/Rening
  - Avsaltning, E340
  - Katjon
  - Anjon
  - TE-destillation
  - Osmos
  - Kondensatindunstare
  - Katalytisk förbränning
- Ånga/Vatten
  - Ånga 4 bar
  - Ånga 16 bar
  - Varmvatten
  - Processvatten
  - Kyltorn
  - TOC, avlopp

Appendix 2 Interview Results (in Swedish)

Generell kommentar till hur man bildar sig en uppfattning som operatör:

”Det tar lång tid att bilda sig en uppfattning om hela processen. Speciellt efter att man har varit på frivecka och plus att man roterar arbetsposition varje dag i vissa skift. Det leder till att man är på samma position ca 4 ggr. i månaden.” Att bilda sig en uppfattning innebär att titta igenom flera trendgrupper där 3-5 viktiga parametrar visas i förhållande till tiden. Intressant tid kan vara mellan 1h-24h bak i tiden, i vissa fall ännu längre bak.

Driftlägen:

- Färskångadrift, men det händer väldigt sällan, ca 1 gång på 4 år. Då tittar man i instruktion hur man ändrar till färskånga och sedan är det ungefär samma information man behöver. Undantag är kompressorinformationen som man nu inte behöver.
- Olika hastigheter, men det är samma värden man tittar på, samma behov.

<u>Kritiska parametrar och interaktioner</u>

Område	Tagg	Beskrivning	Interaktion och övriga kommentarer
Formalinblandning	LI-1080	Nivå V108	Tittar på trend ca 24h bak. Man vill se om topparna är på väg upp eller ner. Trög i reglering. Man vill även jämföra med var man är i satsningen.
	DC-1104	Konc. blandad formalin	Man vill se om den blandade koncentrationen är rimlig med avseende på hur mycket starkformalin som kommer in.
	FC-1011	Flöde starkformalin	Är flödet rimligt? Man jämför FC-1102 (utmatning V110), FC1011 (flöde starkformalin), ventilläge och blandad formalinhalt.
	DTI-1106	Difftemperatur	Ur en kostnadseffektiv synpunkt ska den vara så låg som möjligt. Under 4-5 grader Celsius.
Reaktor		Var man är i satsningen	6 olika lägen i en cyklisk satsning. Formalin --> lut --> butyr --> reaktion --> myrsyra --> överpumpning . Intressant tillsammans med nivå i V108 och V111.
	LI-1080	Nivå V108	Man vill hålla koll på formalin-nivån så att den inte är för hög eller för låg med avseende på satsningen. Trend är viktig här, stiger eller sjunker nivån?
	LI-1110	Nivå V111	Man vill ha nivån runt 38% för överpumpning till V111 och då ska nivån i V108 vara någorlunda redo att ta formalin ifrån.
Förvärmning	TI-1112	Temperatur total	Man tittar så att den totala temperaturen ligger runt ett visst värde. Just nu körs inmatningen på max så då får värdet bli lite vad det vill och man justerar bakifrån.
		Temperatur sammanlagd	Ska ligga runt ett börvärde.

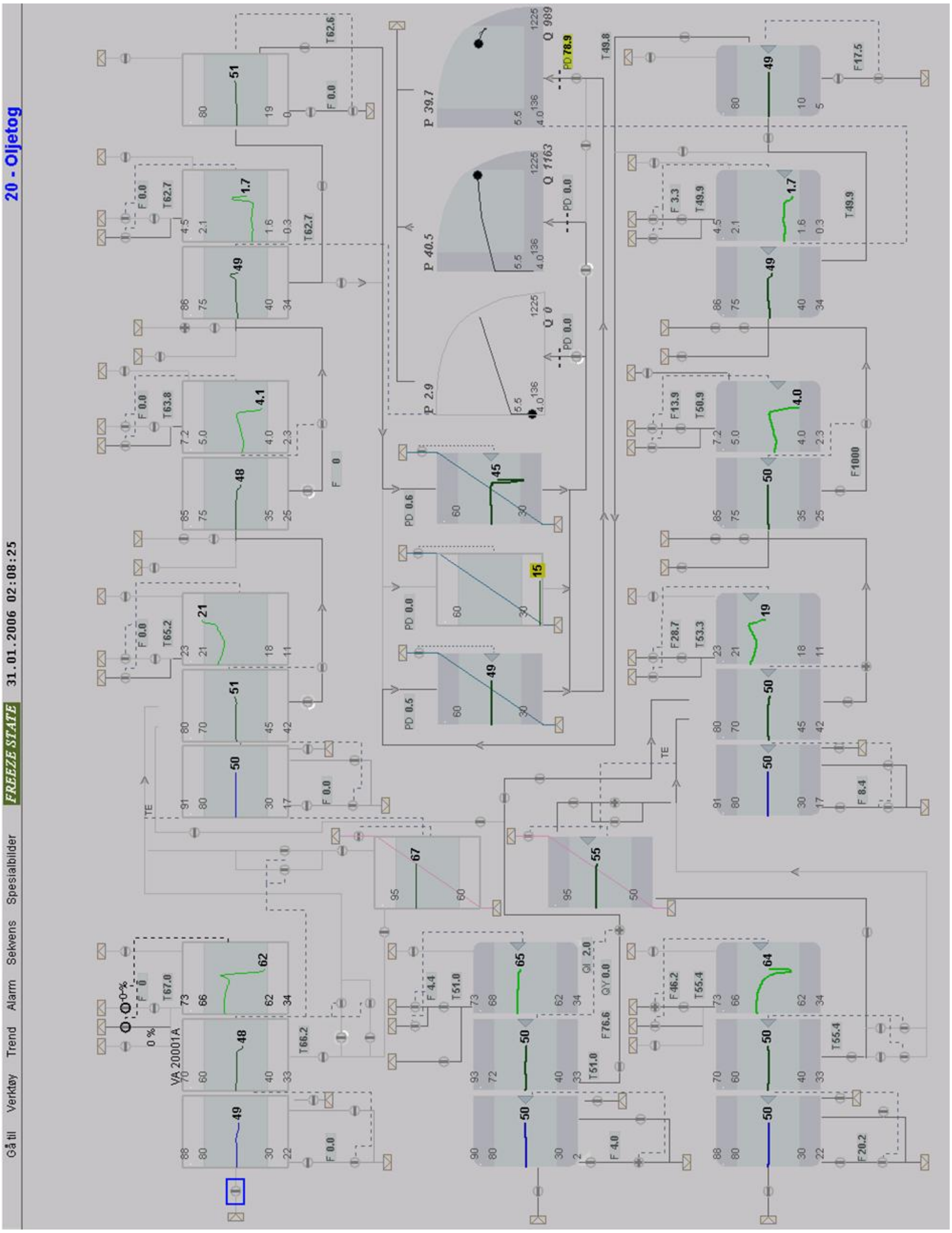
Indunstare	LC-2801	Nivå E280	Ska ligga runt sitt börvärde.
	LC-2601	Nivå E260	Ska ligga runt sitt börvärde.
	PI-1116A	Difftryck, filterbyte	Trycket stiger sakta men säkert vid normal inmatning. Trycket får inte överstiga för mycket och filter ska bytas med jämna mellanrum för att hålla ner trycket.
	DTC-2602A	Kokpunktsförhöjning	Hänger ihop med inmatningstemperatur till E285 (TI-1112). Man jämför värdena. Om inmatningstemperaturen sjunker får man kompensera upp med ånga för att fånga upp kokpunktsförhöjningen.
Ångkompressor	PC-2603	Tryck före	Ska ligga runt ett börvärde.
	PI-2313	Tryck efter	Jämförs med trycket före, ska vara rimlig.
	SI-2301	Vibrationer steg 1	Vibrationerna får absolut inte överstiga en viss gräns i ett antal sekunder.
	SI-2311	Vibrationer steg 2	Vibrationerna får absolut inte överstiga en viss gräns i ett antal sekunder.
	GI-2603	Ledskeneläge	Ska ligga runt ett börvärde.
Metanolkolonn	LC-2201	Nivå V220	Ska ligga runt ett börvärde.
	TC-2254	Temp topp E225	Ska ligga runt ett börvärde.
Kristallisering	LI-2021	Nivå V202	Bufferttank. Ska inte vara för hög eller låg. Stor tank. Finns trend över denna + V301 + V401. I början av varje skift skrivs det ner nivåerna på dessa.
	LI-3010	Nivå V301	Samma som för V202. Ska finnas buffert om det uppstår problem i processen före eller efter.
	FC-3504	Ventilläge E350 --> E360	Ventilläget jämförs med flödet mellan E350 och E360.
	TI-3607	Temp. i E360	Ska ligga runt ett börvärde.
Centrifuger		Vilken centrifug som går	Man vill ha reda på vilka centrifuger som går. Det vill säga om en centrifug är i hand eller auto, stopp efter cykel eller stopp efter steg. Grön= auto, orange = hand.
Formiatupplösare	HC-3925	Igång eller ej	Man vill veta om man kör till upplösaren eller inte, vilket kan ses på spjällets läge.
	LI-11100_N	Nivå V1110	Det finns en maxnivå som man ska ligga under. Maxnivån kan ändras på behov av en annan fabrik.
Destillation	LI-4010	Nivå V401	Samma som med V202. Plus ska helst ligga lågt än högt.

	LC-6501	Ventilläge E650 --> E670	Ska ligga runt ett börvärde. Beror på och jämförs med nivå i E650.
	FC-6604	Ventilläge E650 --> E680	Ska ligga runt ett börvärde. Beror på och jämförs med nivå i E650.
	PI-6502	Vakuum E650	Ska ligga under ett börvärde.
	PI-6702	Vakuum E670	Ska ligga under ett börvärde.
	CI-6715	Ledningsförmåga E671	Ska ligga under ett bestämt börvärde för att få ut godkänd TMP. Om ledningsförmågan blir för hög stängs ventlilerna ut till lagertankarna.
	HC-6721B	Fördelning till V603	Man vill veta hur mycket av utgående TMP fördelas till V603 i %. Denna plus V606 blir dock inte 100%.
	HC-6721C	Fördelning till V606	Man vill veta hur mycket av utgående TMP fördelas till V606 i %. Denna plus V603 blir dock inte 100%.
	FC-6704	Kokånga till E670	Ska ligga runt ett värde enligt lista som beror på inmatning i E670.
	PI-6806	Vakuum E680 packad	Ska ligga under ett börvärde.
	PI-6802	Vakuum E680 botten	Ska ligga under ett börvärde.
	FC-6811	Kokånga till E680	Ska ligga runt ett värde enligt lista som beror på inmatning i E680.
	PI-6902	Vakuum E690	Ska ligga under ett börvärde.
Sidoblåsor	LI-8400	Nivå V840	Man vill veta hur nivån har sett ut de senaste 12 h för att se om den är sjunkande eller stigande.
	LI-8500	Nivå V850	I samband med katjon regenerering vill man veta om nivån är låg (30%).
TMP	LI-6030	Nivå V603	Man vill ha en överblick på nivån i lagertanken.
	LI-6060	Nivå V606	Man vill ha en överblick på nivån i lagertanken.
	LI-6071	Nivå V607	Man vill ha en överblick på nivån i lagertanken.
	WI-3200	Nivå kistan	Man vill hålla koll på så att nivån inte blir för hög. Personen ansvarig för nivån ska egentligen ha full koll men om det har hänt något och nivån blir för hög får det stora negativa konsekvenser.
	LI-7010	Nivå V701A	Man vill veta nivån. Personen ansvarig för nivån ska hålla koll på den men ser man att denna nivån är för hög vet man att det är problem nere i säckningen.
	LI-7011	Nivå V701B	Man vill veta nivån. Personen ansvarig för nivån ska hålla koll på den men ser man att denna nivån är för hög vet man att det är problem nere i säckningen.
Avsaltning	LI-8640	Nivå V864	Man vill ha en trend så att man ser hur nivån artar sig. Trenden tittas på i samband med hur stor inmatningen till V864 är. Om det är hög nivå i V850 så får man sakta ner inmatning till V864.

	FC-8644	Inmatning E847	
	PC-8476	Ångtryck H847	Ska ligga runt ett börvärde.
	LI-3450	Nivå V345	Man jämför nivån i V345 med nivån i V850 och hur många kubik som katjon har gått.
Katjon	FQ-8502-DRIFT	Hur många kubik har gått	Hur många kubik har katjon kvar? I en excel-fil skriver man upp hur många kubik katjon har gått föregående gånger. Sedan görs en uppskattning på hur många kubik som går denna gång.
Anjon	FQ-8702-DRIFT	Hur många kubik har gått	Hur många kubik har anjon kvar? I en excel-fil skriver man upp hur många kubik anjon har gått föregående gånger. Sedan görs en uppskattning på hur många kubik som den går denna gång.
TE-dest	LI-8800	Nivå V880	Bufferttank. Ska inte vara för hög. Nivån jämförs med nivå för V850 och V870 i trend. Jämförs även med hur långt anjon och katjon har gått.
	LI-8500	Nivå V850	Samma som för V880.
	LI-8700	Nivå V870	Samma som för V880.
Osmos	FC-9281	Retentatflöde	Man vill veta värdet, det vill säga hur snabbt körs det? Flödet har återkoppling till V108. Flödet jämförs med topparna i V108 trend.
	LI-9100	Nivå V910	Man vill ha koll på värdet.
	LC-9500	LC-9500 öppen eller stängd	Om den är stängd så rinner det till V940 och vidare till V860.
	PHI-9126	pH	När man kör till formalinfabriken vill man ha en koll på hur pH ser ut. (kvalitetsperspektiv)
	CI-9125	Ledningsförmåga	När man kör till formalinfabriken vill man ha en koll på hur ledningsförmågan ser ut. (kvalitetsperspektiv)
Kondensatindunstare	LI-9700	Nivå V970	Ska ligga mellan hög- och lågnivå. Dessutom ska den vara sjunkande hela tiden. Trend.
	DTC-9753	Kokpunktsförhöjning	Har tendens att svänga. Komplex styrning. Ska ligga runt börvärde och inte svaja för mycket.
Katalytisk förbränning	C-812 el C-811	Vilken fläkt går	Man vill veta att rätt fläkt går. Går C-812 eller C-811? Rätt fläkt är i 99% av fallen C-812 för C-811 går rakt ut i luften utan förbränning.
	PC-8111	Undertryck	Ska ligga runt ett börvärde.
Ånga 4 bar	FQ-9002	Ångtryck	Tryck från ångcentral. Ska ligga rätt.

Ånga 16 bar	FQ-9001	Ångtryck	Ska ligga på ett rimligt värde.
Varmvatten	TI-3073	Temp. V307	Ska vara ca. 90 grader, dvs. runt ett börvärde.
Processvatten	CI-2505	Ledningsförmåga tätningsvatten inne	Ska ligga under ett visst värde. Om den larmar så vet man att en pump läcker. Vidare utförs uteslutningsmetoden för att lokalisera vilken pump.
	CI-8205	Ledningsförmåga tätningsvatten ute	Ska ligga under ett visst värde. Om den larmar så vet man att en pump läcker. Vidare utförs uteslutningsmetoden för att lokalisera vilken pump.
Kyltorn		Vattentemp. från kyltorn	Ska ligga rätt.
TOC, avlopp	FI-6005-TOC	Mängd kgTOC/h	Om inte anjon eller katjon regenereras ska den inte visa utslag.

Appendix 3 Example of an Information Rich Display Design



Source:

http://www.ife.no/en/ife/departments/software-engineering/products/procsee/screenshots/ifehsi