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Control room ergonomics with the operator in focus
for an attractive collaborative environment

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Control room ergonomics

Abstract

We are seeing a growing awareness of the importance of the operator and the control room environment. Within the global process industry, five percent of annual production is lost every year due to unscheduled downtime and poor quality.

The ARC Advisory Group estimates that almost 80 percent of these losses are preventable and that 40 percent are primarily the result of operator error. Another alarming fact is that many of today's operators are near retirement and it has been found difficult to find replacements among the younger generation. This issue is particularly worrying within the mining industry, where many of the production sites are located in very remote areas. Our challenge is to create an attractive, safe and effective environment where the operators are in focus. It is far more important to ask questions like "why do we need a control room, what tasks are to be executed, how can we implement an operator interface that works safely even in critical situations, and how can we secure a high knowledge level with a minimum turnover of new operators" instead of "how can we build the most impressive display wall for our visitors and how much money can we save by buying non-ergonomic furniture and skimping on good control room layout planning."

Keywords for a successful control room are: human factors, ergonomics, collaboration, good health and satisfaction. The latter can only be accomplished if we change our outlook from technology and cost-fixation to a complete focus on the operator and the total control room solution.

Introduction

In the early days of industrial automation, system designers attempted to automate everything and remove the human operator – whom they considered the weakest link in the process control loop – entirely. Today, it is clear that the human operator is an integral part of any automated control loop in almost all industrial applications of any size. Understanding and maximizing collaboration between the control system and the human operator is therefore essential. Furthermore, a systematic design approach to this task is crucial for reasons of safety and optimum system performance.

The global process industry loses $20 billion, or five percent of annual production, to unscheduled downtime and poor quality. The ARC Advisory Group estimates that almost 80 percent of these losses are preventable and that 40 percent are primarily the result of operator error.

As industrial plants become larger and more complex, an increasingly sophisticated alarm system is required to inform operators of potential malfunctions. The old way of thinking was to blame malfunctions on human error if an operator had overlooked an important alarm. In 1999, the Engineering Equipment and Materials Users Association (EEMUA) published a guide to the design, management and procurement of alarm systems, known as EEMUA 191. This document has since become the worldwide de facto standard for alarm management. EEMUA 191 makes it clear that if the plant's management has failed to reduce alarm rates to a reasonable level, then the operator cannot be held accountable.

We can easily understand that our increased demand for higher productivity and better quality has changed the situation for the operator over the last fifty years. More complex applications, more data to interpret and more alarms to process are some factors that affect the operator. With this increased responsibility for overall profitability and lack of continues training, it has become harder to find operators willing to accept this burden and devote their working life to the control room. It has been estimated, by the ARC Advisory Group, that most companies spend less then 2% of available hours on training. To make things even worse, operators are not always in focus when new control rooms are built. Lack of understanding of human factors, too much emphasis on technology and not enough involvement by operators in the planning phase of the control room all result in poor ergonomics and dissatisfied staff.

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If we examine the consequences of this attitude, we find a very high employee turnover rate among operators. What's more, the costs of hiring and training new personnel are considerable. It is estimated that the cost of training one plant control room operator is at least $100,000. Poor ergonomics is also a major reason for the large number of days lost to sickness and work-related injuries every year.

A growing problem is also the fact that many of today's operators are approaching retirement and it is difficult to recruit replacements among today's younger generation. This is particularly acute within the mining industry, where many of the production sites are located in very remote and unattractive areas. The ARC Advisory Group estimates that almost half of the operators retiring before 2030 can not be replaced.

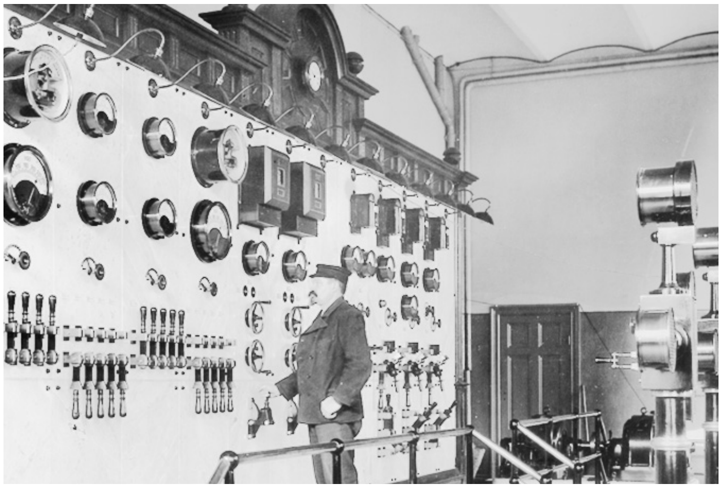
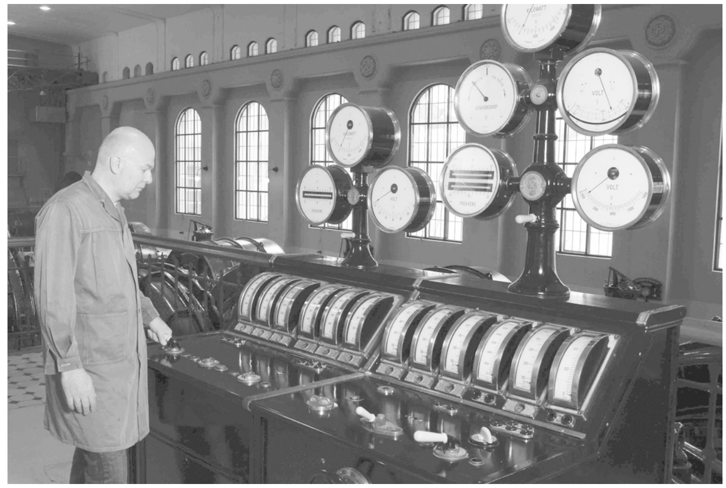
Our challenge is to create an attractive, safe and effective environment with operators in focus. Questions like "why do we need a control room, what tasks are to be executed, how can we implement an operator interface that works safely even in critical situations, and how can we secure a high knowledge level with a minimum turnover of new operators" must be asked. "How can we build the most impressive display wall for our visitors and how much money can we save by buying non-ergonomic furniture and skimping on good control room layout planning" are aspects that should never be raised.

Background

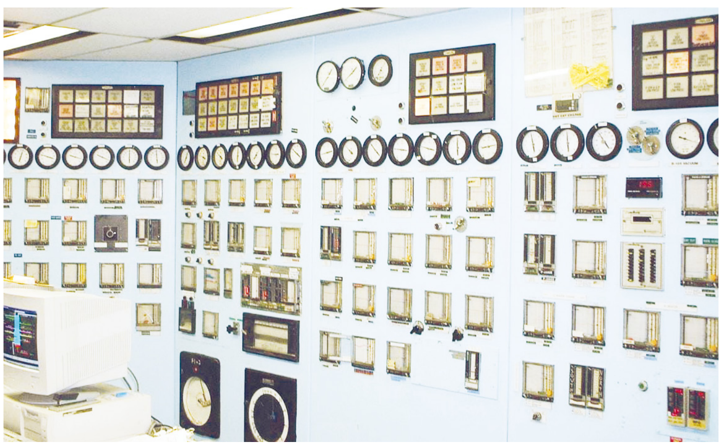
Existing Issues in Many Control Rooms

Many issues can be identified in existing control rooms. Some are listed here to give you a feeling for the magnitude of the problem (ideally, you should read opportunity).

- Operator does not have a good overview of the complete process
  - Separate control rooms for different parts of the process
  - Individual operator does not have access to any large overview display
- Limited space on each operator HMI
  - Normally only one or two monitors per keyboard
  - No possibility to adapt the workspace to individual needs
- HMI is not optimized for operator tasks
  - No single, unified environment for presenting information to the operator i.e. documentation, maintenance records, live video, weather reports and other web- related services
  - No good way to present information in context
  - Difficult to navigate among displays and information windows
  - Information windows cannot be classified and configured to appear according to individual needs
  - No automatic adaptation of different display formats on different presentation media
- Large display walls are not implemented with the operator in focus
  - Wall is too far away from the operator
  - Normally no interaction supported, especially in critical situations
  - People can walk between the wall and the operator and visually block important information
  - Viewing angle is limited
  - Wall cannot be moved up and down for adapted working height
  - Valuable space is wasted that could be used for more important tasks
  - Wall defines the layout of the whole control room and limits possibilities for adapting to future changes
  - Wall affects the way people move around in the control room and how operators communicate with each other
- CCTV information is poorly integrated in the operator environment
  - TV monitors are often located in awkward positions, even behind the operator
  - Operator needs to spend time finding the actual camera instead of focusing on the video information
  - No connection from the camera screen to the actual process object that is represented by the video information, i.e. the operator cannot 'close the valve' from the TV monitor screen
  - Operator cannot easily look at recorded information with a view to support quick decisions
- Control room was built with limited focus on human factors and ergonomics
  - Operator consoles are normally not adjustable in working height for different individual operators
  - Not enough legroom
  - Not possible to adjust height or position of individual monitors
  - Large screens or display walls are mounted in fixed positions with no possibility to adjust for different working conditions
  - Screen colors and ambient lighting are not optimized for the human eye
  - Noise level too high due to fan-equipped computers, ventilation and other technical equipment
  - Meeting rooms, rest areas, office space, etc. are not integrated in the control room layout, even though this affects the operator's daily tasks
  - Position of doors and walkways generate traffic in the control room that can create disturbances
- Control room not built for collaboration Isolated 'islands' of operators
  - Difficult to communicate between different operators due to distance between consoles
  - Difficult to develop "knowledge workers" by not letting the operators work in teams with experience sharing

Figures 1-2 Early attempts to create a plant overview




Figures 3-4 Wall panels with chart recorders, alarm enunciators and single-loop controllers.

There Has Always Been a Need for an Overview

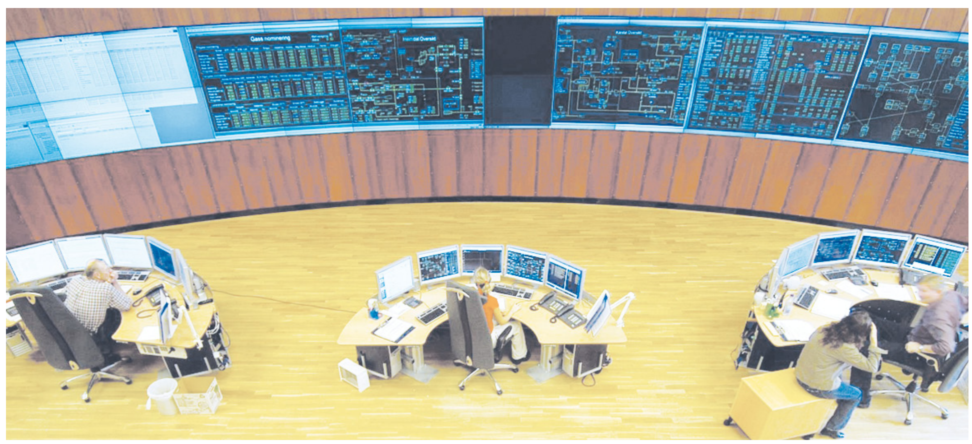
Let us take a look at some history. There has always been a need for an overview. Before the operator control room was available, the operator had to walk around the process and smell, feel and listen to the different parts of the plant. The first attempts to support the operator implied that all instruments, switches, etc. were gathered at one common location. See Figures 1-2. Information and interaction were combined in the same piece of hardware. A switch could, for instance, be moved in different positions with direct feedback on the current status.

The next step was the development of chart recorders, alarm enunciators and single-loop controllers mounted in large wall panels. It was now possible to get a very good overview of the process with recorded trends, differentiated alarms and loop status. Of course, all interaction could be carried out directly at the wall panels (see Figures 3-4).

As computers were developed, it became possible to move the wall panels onto several process graphics with full interaction. However, the new problem created was that the total overview was now lost. Each operator screen became merely a keyhole into the process (see Figures 5-6). Navigation was another subject for improvement. With only one screen (or possibly two), it was difficult to find the required information and act in a timely fashion. In many installations, this was solved by adding absolutely everything possible to one single screen, thus avoiding the need for display navigation. The problem with this solution is obvious. If something critical happens on this screen, it is difficult to interpret the information in a secure way.

The solution to this shortcoming with computer screens and HMI software was large display walls. Finally, here was a way to replace the wall panel with an electronic version that could display the total process overview with support for modifications. It was even possible to use part of the large display wall as a CCTV monitor. Large display walls like these are still commonly found, particularly in control rooms in sectors like Oil & Gas and


Figures 5-6 Each operator screen is acting as a keyhole into the process

Figures 7-8 Large display walls define the layout of the complete control room.

Utilities (see Figures 7-8). Unfortunately, these large screens are not implemented with the individual operator in focus. The main purpose of a large screen is to present an overview of the total process for everyone in the control room, with the emphasis on deviation from the normal process state. As soon as such a deviation is identified, the operator has to move his/her focus to the normal screens and translate the relative deviation to something measurable in real numbers. This can be very stressful, especially with many other people in the control room hanging over their shoulder.

Yet another problem is the way the display wall affects control room layout. The wall ends up defining the layout of the complete control room, and it thus limits possibilities for future changes. Valuable floor space is wasted on both sides of the wall. Space behind the wall is needed for maintenance access, but there is also a recommended minimum distance between the wall and the operator consoles. This latter space is normally used as a walkway that generates disturbing traffic in the control room. The fact that the display wall is fixed in position also makes it difficult to have adjustable consoles. For example, a large display wall mounted to allow consoles to be adjusted for standing operation would be too high for operators who prefer to sit.

The latest solution to all of the above shortcomings is the interactive personal large display integrated with the operator console. An example of this new type of operator console is the Extended Operator Workplace (EOW) from ABB (see Figures 9-10). A large curved seamless display with almost unlimited viewing angle is mounted behind the normal monitors. All parts of the console, including the large screen, are motorized for optimum working conditions. The large screen is completely interactive for safe, fast and correct decision-making. This means that faceplates, trend displays, documentation, maintenance records and any other object-related information can be accessed on the large screen, in the actual context, without any delay or need for separate browsing.

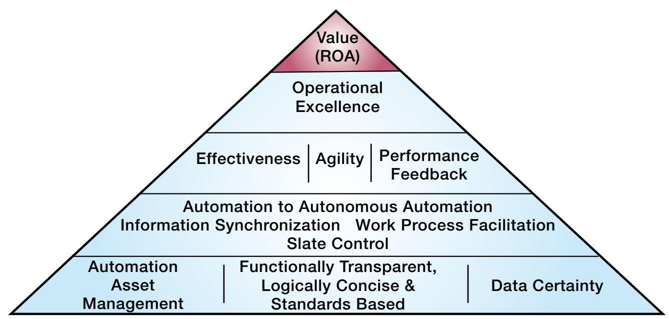
Figures 9-10 Extended Operator Workplaces from ABB with interactive personal large displays.

Live video is another good example of how this large EOW screen can be used. Instead of changing the focus to a separate console or separate CCTV monitor, the operator can instantly display the live video aspects of the actual process objects directly on the large screen. As this screen is integrated with the console, there is no wasted space on either side of it. Disturbing traffic is eliminated and the consoles can be moved around as conditions change. Furthermore, as the consoles are ergonomically designed they can be adjusted for individual operators. Adjustable arm-rests are integrated and there is plenty of legroom. All computers are normally removed from the control room and placed in a separate computer room with a controlled environment. In this way, the noise level can be kept to a minimum, and it is much easier to keep the control room floor clean. All of these factors work in favor of attracting new and hopefully younger operators into the control room.

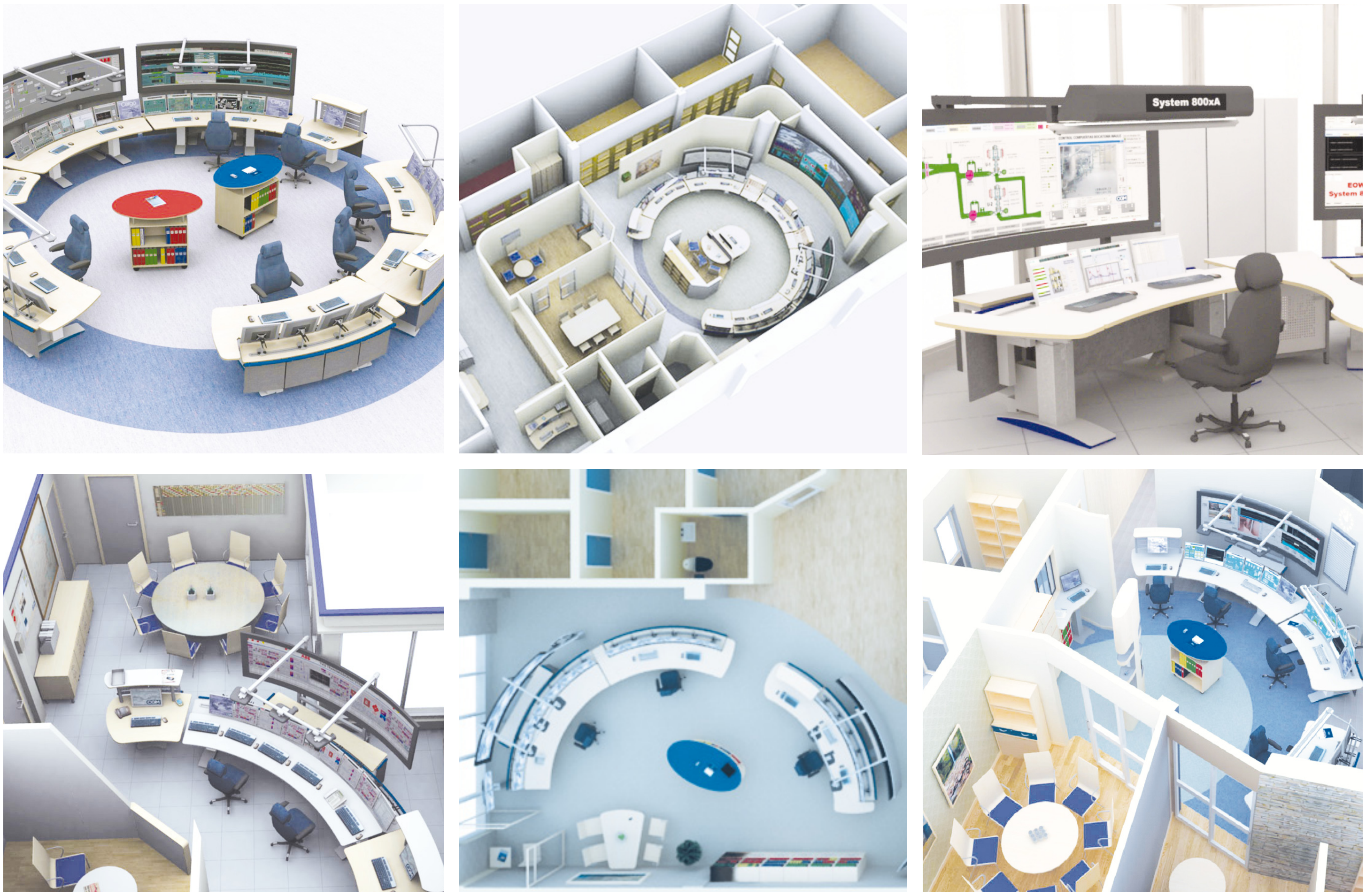
CPAS and Operational Excellence

The ARC Advisory Group introduced a new vision for Collaborative Process Automation Systems (CPAS) already in 2002. The intention was to create an environment where everyone could access all relevant data in context in a secure way. The HMI part of this vision is included in the section called Operational Excellence. According to the group, the definition of Operational Excellence is “A single unified environment for the presentation of information to the operators as well as the ability to present information in context to the right people at the right time from any point within the system”.

What the advisory group means is that the operator environment has to be in focus if maximum Return on Assets (ROA) is to be achieved. The operator must have access to all relevant data and tools that help him/her make decisions and act quickly in relation to a situation in the process. All data must be synchronized and presented in a unified way, in context, and without the need to login and browse in separate systems. Navigation must be quick and intuitive to avoid delays when searching for data. Once again, we need to think about how we use a mixture of large screens and normal monitors. The large screen has to be interactive to allow for immediate display of critical information with tools to act. It is also important that all screens support transfer of information. If, for instance, an operator finds something important that he/she must share with others, there must be a way to send this information (duplicate) to any other screen (workplace) in the system. It could be a trend display that must be shown on someone’s large display for further investigation, or a live video window that must be possible to see on multiple screens, even over a long distance. (It can be very limiting for operators if a video window is presented in the corner of a display wall without being able to move it or duplicate it to any other location on any other screen.)



Return on assets: Collaborative Process Automation System (CPAS) Guiding Principles



Figures 11-16 Examples of control room layouts with the operator in focus.

The ARC Advisory Group also emphasizes the importance of ergonomics in the control room. In a report written in July 2007, it recommends that “Design and implementation of control room and HMI, should include ergonomics and change management”. It is further recommended that “Technology providers should … propose solutions and implementation approaches that include ergonomics and change management skills”.

Operational Excellence means a lot more then just functionality in the DCS system. Ergonomics and focus on human factors are equally important to keep the operator alert and healthy and ready to act in a situation. So what do we mean with ergonomics and human factors? Let us repeat some of the most important factors that affect the operator in the control room:

- Operator does not have a good overview of the complete process
- Working height
- Viewing angle
- Sitting comfort
- Legroom
- Ambient lighting
- Noise level
- Traffic
- Access to other functions or rooms (rest room, kitchen, toilet, meeting room, offices, computer room, library, exercise room, emergency room etc.)
- Console proximity (communication and collaboration)

Results and Discussion

The fact that we need to change the way we plan control rooms and move from a technology-driven approach to one that is operator-focused is quite obvious. We need to create a safer and securer environment that will attract new operators into the control room. To do this, we need to challenge ourselves. Are there other new ways to plan the control room? Are there other new technologies that allow us to think differently than before? Can it be that the younger generation has different demands and requirements?

Let us look at an example. In a typical bid specification, all operator seats are specified as two-monitor seats with no information about any human factors or how these seats are supposed to fit into the control room layout. Sometimes we see a specification for a large display wall with a number of projection cubes and an overall size. What are missing in these specifications are the reasons behind these numbers. Why only two monitors per operator seat? Why should the display wall have a certain size? What is the purpose of the large display wall? What information will be presented on the monitors and what on the wall? How should information be presented and how should the different screens and monitors interact with each other?

This bid specification typically illustrates a technology-driven approach. We start with the known hardware facts without any thoughts about the operators and soft factors. If end-users don’t know that it is possible to have three or four monitors on each operator seat, plus supporting software that always makes sure that any given data are presented in a controlled way with minimum mouse movements or window re-sizing, they will naturally specify two monitors per seat. This is the way it has always been done before. The same applies to the large display wall. It is better to focus on why, when and by whom before deciding on the physical size. If end-users don’t know that there are personal large displays that can be adjusted for correct working conditions with full interaction, they will naturally specify a large display wall that not only provides a process overview, but also makes a great impression on visitors.

For the next control room project, therefore, we should change our focus from technology and cost-fixation to a complete focus on the operator and the total control room solution. With this approach, we will find that it is possible to combine higher productivity with better quality and safer operation. Operators will be more satisfied and we will lower the turnover of new workers.

Nomenclature

CCTV	Closed Circuit TeleVision
CPAS	Collaborative Process Automation Systems
DCS	Distributed Control System
EOW	Extended Operator Workplace from ABB
HMI	Human Machine Interface
ROA	Return On Assets

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