What Does "Good" Control Room Design Look Like?

Champion a process that ensures good control room design for both new construction or renovation projects.

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"Of course I know what good control room design looks like."

Anyone who has ever spent time in an operations center for a large refinery or chemical plant knows a good control room when they see one. Or do they?

In our experience, having been in many 24/7 mission critical control rooms in continuous process industries, finding examples of 'good control room design' is not easy. Think about your own experience. How many control rooms have you actually been in where the spaces were crowded, messy, disorganized, even perhaps mildly depressing? Did the room feel something akin to a dark, subterranean dungeon?

Perhaps the image below recalls your own experience with control rooms.

However, there have been vast improvements over the past decades in control room design, along with our understanding of the role design plays in the ultimate efficiency and safety of these mission critical spaces. There is an international awareness of safety in control room design spreading across the globe, in large part due to control room standards originally published in the year 2000 by the International Organization for Standardization (ISO). In particular, ISO 11064 spells out in detail the standards for ergonomics in the design of control centers, and the layout and dimensions of workstations to achieve maximum efficiency and safety. Adherence to these best-practices guidelines is strongly recommended in all industries where control rooms are present. Indeed, compliance with ISO 11064 standards can act in a company's defense and mitigate legal liability in the event of

an accident, incident or personal injury case; in the UK ISO 11064 is cited within the guidance to the legislation as best practice, so companies are advised to use it. With safety and efficiency as the drivers, facility siting and the design of a building from the operator-out, good control room design can be measured against the mandates of ISO 11064. The result is a building that offers return on investment for the owner that has maximized efficiency and minimized abnormal events.

Unfortunately, many control rooms have been built without adherence to ISO 11064 guidelines, and operators and owners have suffered the consequences with injuries, eye strain, repetitive motion impairment and slow response time to abnormal events.

Fortunately, a control room audit can identify steps to improving an existing control room and bring it up to the ISO standards (see page 8). Or for a new build, let's break down good control room design standards one-by-one.

» ISO 11064 helps establish good design standards with measurable results to avoid control rooms like many of us have experienced

Steps to Good Control Room Design

(1) **Facility siting** identifies the optimal location of the control room within the operational plant

(2) **Operator-centric design** looks at the building from the operator-out, not the architecture-in

(3) **Interior selections** based on ISO 11064 standards (interior finishes, furniture, lighting and acoustics)

Good Control Room Design Begins with Safety

(1) **The first critical step is facility siting**—hiring an experienced control room architect can assist with planning the best location of the building in proximity to the process plant. Will it be in a blast zone or located outside the process plant fence? Since the BP Texas City explosion in 2005, the American Petroleum Institute (API) and regulatory agencies (OSHA and U.S. Chemical Safety Board) have focused on developing new and revised recommended practices for risk assessment and mitigation requirements for temporary and permanent buildings located in or around processing units (e.g. API RP-752 Management of Hazards Associated with Location of Process Plant Buildings and API RP-753 Management of Hazards Associated with the Location of Process Plant Portable Buildings provide guidance for managing risk from explosions, fires and toxic material release. Recommendations include applications that will improve occupant safety and reduce building vulnerabilities.)

OSHA is in the process of conducting detailed site inspections, and has included facility-siting compliance as one of their top four focus items of these National Emphasis Program (NEP) inspections. The other three areas of focus are the integration of human factors, employee participation and operator training.

In addition to the regulatory compliance and legal liability protection benefits inherent in developing a facility siting risk-mitigation plan, developing a master facility plan is critical to the long term planning for a site. It not only addresses the immediate risk assessment requirements, but also addresses long-term (5 yr/10yr/15yr) facility infrastructure improvements and asset optimization, addressing security, IT infrastructure, site circulation, and workforce optimization.

Control Room as the "Brain" of the Process Plant

(2) Once the control building is sited properly, **the next step is to focus on the control room.**

Control rooms are the center of the operation, where production is controlled. It is where a business can make or lose money for the company. It is where catastrophic incidents are made or prevented. Control rooms can be found in many industries, from oil & gas, power & utilities, chemicals, and transportation to name a few. These control rooms house the people that are responsible for operating the system, whether that system is a refinery, an electrical grid or a city's train and subway system. Control room operators monitor and control technology and automation to manage the system remotely from a single room. Often the operators work long shifts in front of computer screens to ensure 24-7 coverage of the operation. And in many companies, the control room is where incidents are identified early and mitigated by operators, preventing catastrophic consequences.

So imagine that control room again: it is among the most important physical spaces in the plant. Yet chances are the furniture in that control room is not nearly as comfortable or up to date as the furniture in the conference room. More often than not, it is the space that businesses invest in the least. Many control rooms around the world today were designed in the 80's or 90's. Since

» Facility siting analysis: green indicates new building locations within the plant

then, technological upgrades have been crammed into these poorly designed spaces without taking a step back to consider the true importance of the technology or the spaces. Operators forced to work in these crowded rooms are the unfortunate victims of this lack of foresight and investment in the operations. Understanding the operator's needs and how they interface with complex systems within a high-pressure environment is the first step. Subsequent design decisions emanate from this including:

- Proximity to other operators to enhance communication, collaboration and efficient work flow
- Access to other resource areas: testing, exercise, kitchen, restrooms
- Operator tasks and functional requirements drive the number of screens and size of workstations
- Ergonomic requirements may require a special modification to a workstation, such as providing a footstool for a shorter operator
- To customize workstations even further for operators, some manufacturers offer individual radiant heat panels, sound showers for sound masking, overhead task lighting, sit/stand capability, ergonomic seating with headrests

The risk of an abnormal situation escalation is always present in a control room. A state-of-the-art control facility gives the operators the ability to return the situation to normal in the shortest amount of time possible. Dozens of factors are taken into account, such as the orientation of workstations, screen information, noise reduction, arc of reach, line of sight, clutter mitigation, manual placement— all of these have the potential to improve or degrade the operator's reaction time and ability to communicate.

Design from the Operator Out

A human-centered approach to the design considers the needs of the operators first and foremost. Instead of designing from the outside-in by creating the architecture first, the building unfolds from within, the starting point being the operator, and is based on the programmatic functional and physical needs of that operator. As the demands for human-machine interface (HMI) have increased, so have the consequences resulting from inappropriate operator actions. We are all familiar with the technology and automation advances that have improved the software on the workstation, similarly, ISO 11064 lays out measurable guidelines for ergonomics, also called human factors engineering, which play a primary role in the selection of the interior finishes, furniture, lighting and acoustics.
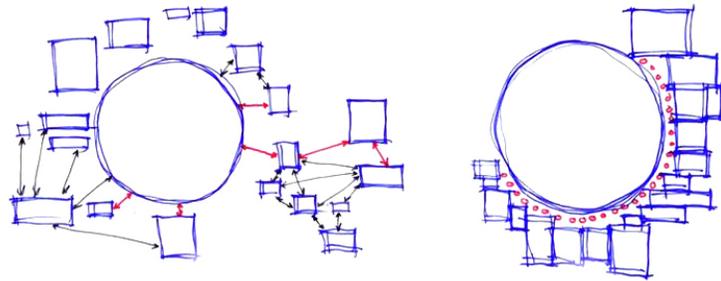
» Birth of a Building: Room block adjacency and circulation study
Left: Starting with the control room, adjacencies are shown in red for required and black for non-required
Right: The circulation corridor is shown in red dots

Measurable Elements to Good Control Room Design— According to ISO 11064

③ The last step is the selection of the interior finishes, lighting and acoustics, and furniture guided by ISO 11064 which lays out measurable guidelines for ergonomics that are proven to reduce inappropriate operator actions.

FINISHES
Selecting finishes according to the ISO 11064 guidelines creates a comprehensive list of measurable criteria. The hierarchy of value goes from dark to light, floor to ceiling. For example, floor finishes should have a light reflectance value (LRV) of between 0.2 and 0.3, walls 0.5 to 0.6 and ceilings 0.8 and have a matte finish. A few manufacturers for flooring, paint and ceiling product provide LRV data for their products which is helpful. In addition to the ISO requirements, the design must adhere to local building codes for flammability and slip resistance. The client's standards also must be followed as well. Above all else, the finishes must meet functional and durability needs. Often, these control rooms are in close proximity to the refinery and operators go from the refinery into the control building potentially tracking in residue such as tar, dirt and gravel. For example, floor finishes that provide

camouflage and easy maintainability for what is tracked in is a given. And with the reality that these control rooms have to last upwards of 30 years, durability is critical.

» Floor finishes camouflage dirt

Some finishes can provide multiple uses. Acoustically absorptive wall panels can double as tackable panels to pin up printed information, or triple as a visual break in a large wall plane if ceilings are high, or even as a decorative element which reflects regional identity while mitigating sound.

LIGHTING
Rather than an afterthought, good control room lighting should be as integrated into the design as the placement of the ceiling, walls and floor. The optimum lighting in a control room demands quality ambient, uniform illumination, which is a combination

» 80/20 suspended lighting—80% up, 20% down

of fixtures such as indirect, task and suspended lighting. If all lighting comes from the ceiling, intense glare makes screens unreadable (many operators will shut off all light and sit in the dark rather than deal with headaches and errors

caused by glare). Screens mounted to a sit-stand workstation required by ISO 11064 could also potentially bump into suspended fixtures. Therefore, an adequate ceiling height is required to accommodate the suspended fixtures.

Dimming pre-sets for the overall lighting are established to work with operator preferences and lighting requirements throughout the day. One approach is to provide low, medium and high level pre-sets to have the capability to adjust the lighting levels on ambient lighting, while keeping on a consistent low level indirect light source. Task lighting at the work surface can be integrated into workstations and aimed onto documents, including training manuals, OSHA documents, ship logs, permitting tags, etc., instead of bouncing off of screens. This eliminates eye strain and improves operator efficiency. ISO 11064 has guidelines that spell out lighting requirements throughout the control room: 47 foot candles (FC) at work surfaces, with an acceptable range of 18.5 - 46 FC.

ACOUSTICS
As important as the finishes and lighting, acoustics can make or break a control room. ISO 11064 dictates the ambient noise can range from 30 - 45 dB. Alarms, conversations, radios and computer noise create a distracting environment for the operators that can be mitigated by articulating the shapes of the ceiling and walls, and with the use of acoustic absorptive material for ceiling, wall and floor surfaces.

FURNITURE
A work environment informed by the science of ergonomics maximizes productivity and minimizes the risk of personal injury. Operator seating, sit/ stand workstations, screen display quantity and mounting heights, mobile files all positioned and designed according to ISO 11064 standards complete the good control room picture. The furniture

must not only be ergonomic and adjustable, but robust, especially if working in a remote location where parts are not easily available. The control rooms are occupied 24/7 so it must withstand the rigors of time and use.

Workstations are highly customized desks for the operators, the size and configuration of which is determined by management objectives, and limitations on the quantity of screens any one operator can monitor. ISO 11064 has ergonomic guidelines for reach and eyesight distances. Flat panel displays and touch screen technology take up less space, are more energy efficient and require less cooling within the workstation. The size and quantity of workstations dictate the size of the control room, rather than the other way around, with a set amount of square footage allowed per operator.

Exercise equipment such as exercise bikes, treadmills in close proximity to the workstations, or an exercise room with cardio and weight machines help aid in alertness and mitigate fatigue.
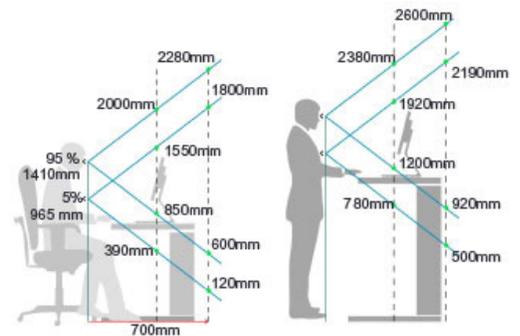
» ISO 11064 has ergonomic guidelines for reach and eyesight distances.

Sensory (Intangible) Elements Perceived from Good Control Room Design
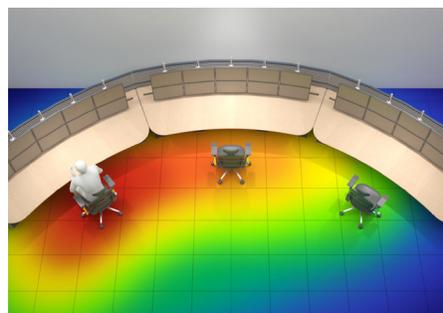
SIGHT

When you walk into a well-designed control room, what makes that space work? The first thing you might sense is a feeling of spatial openness because of the high ceilings, and unobstructed views due to lack of columns. Workstations are uncluttered, since there is adequate space per operator to do his or her job. The finishes are light and complement the geometry of the room and regional aspects of the location, and the lighting is pleasantly glare-free. The space is designed from the operator-out, so the principles and elements of design are human-centric and harmonious. There is the right amount of both variety and unity—a state of agreement or a feeling of rightness.

SOUND

In a control room, noise and sound are two different things. Noise needs to be restrained, but sound defines the architecture. What is the sound of a control room? The hum of multiple computers, the quiet discussions among the operators as they collaborate to solve a problem, the clicking of a computer keyboard—acoustics can act in deep visceral ways not unlike music or the sense of smell. On some conscious level, there is a correlation between the function of a place and the sound we expect it to make. Consider how a solid door sounds better than an inexpensive hollow door, because its heavy "thunk" reassures us that the door is a true barrier, corresponding to the task it serves. The quiet buzz of activity in a control room tells us that the acoustic measures designed into the space are doing their job.

TOUCH

How does a space feel? Air quality and temperature play a huge role in keeping operators alert and awake. Lack of a consistent ambient temperature is a common complaint in a control room as you travel through the space, which are often cold in one corner, hot in another and no one seems happy. Sound familiar?

Per ISO 11064 "the control room should be supplied with outdoor air in sufficient quantities to dilute internally generated pollutants." In addition to fresh air, there should be the option for the operators to adjust the temperature or an automatic adjustment of temperature depending on the time of day to compensate for diurnal rhythms of body temperature. The room temperature should range from 70 to 72 degrees Fahrenheit/21 to 22 degrees Celsius, and air movement not to exceed 4" to 6" per second. The goal is to create the perfect temperature and just enough air movement to stay awake and comfortable.

» Control room that is obstruction free and spacious

» Acoustical study of sound levels from operators at workstations

What is ISO 11064?

The International Organization for Standardization (ISO) specifies the standard principles for the ergonomic design of control centers—including layout and dimensions of workstations. It's a tome of control room best practices, the purpose of which is to enhance human performance and promote safety best practice.

ISO 11064 is divided into 7 parts:

Part 1 – Principles for the design of control centers

Part 2 – Principles for the arrangement of control suites

Part 3 – Control room layout

Part 4 – Layout and dimensions of workstations

Part 5 – Displays and controls

Part 6 – Environmental requirements for control centers

Part 7 – Principles for the evaluation of control centers

For more detailed information on ISO 11064, visit www.BAWarchitecture.com/ISO11064

Economic Benefits of Good Control Room Design

ROI, EMPLOYEE ATTRACTION AND RETENTION

The return on investment in operator safety and efficiency is real and demonstrable. Abnormal situations and catastrophic events have a better chance of being avoided, which saves lives, money and the environment.

When control rooms are designed correctly the first time adhering to the ISO standards and incorporating HFE, there could be up to a 15% savings in capital expenditures according to a Shell study documented by Rensink in 2002. (see references). There is a reduction in engineering hours, project duration time and rework. The net benefits include an improvement in working conditions; commitment on the part of the end users, improvement of client "buy-in",

an improvement in functional aspects of the design, and efficiencies in communication and operation within the project team. Furthermore, including the operators and managers in decision making for the project gives them a stake in the project decisions and a sense of ownership.

There is a new generation reporting to the office today that is well aware of 21st century office trends, and this generation expects a work environment that includes ergonomic furniture and state-of-the-art technology. Control rooms that include great HFE elements are attractive to a new generation of prospective employees. And those new workers tend to want to stay for a while, leading to potentially huge savings in human resources and training.

Implications of Poor Control Room Design

YOU CANNOT AFFORD TO IGNORE HFE

When you invest in HFE upfront it will save you money in the end. Safe, productive, efficient operators make for safe, productive, efficient and profitable plants. And human performance is intrinsically linked to system performance. Why invest in ergonomics? Few would quibble with the need for investment in the high-tech hardware aspects of a control room system, but in fact the human-machine interface is key to a reliable design. Human factors need to be studied and implemented to get optimized performance from the operators. These key people are engaged in highly cognitive tasks, and are called upon to make split-second decisions with huge safety—and financial—implications. Supporting them in their tasks needs to be job number one. A state-of-the-art control room gives operators the ability to return the abnormal

situations to normal in the shortest amount of time possible, because the human-machine interface is approached holistically.

SAFETY AND THE BOTTOM LINE

Unsafe, unproductive work environments are in the end very costly on a number of different fronts. For example, if an offshore oil platform fails to integrate best practices to avoid an explosion, the result can be a spill. This costs money, but more importantly, it can cost lives and damage the environment. The risk of a catastrophic event, such as an oil spill, can be reduced by employing best practices in control building design. The integration of architectural, interior design and human factors elements is key to delivering the safest, most productive, and most durable workspaces.

Improve an Existing Control Room

Identifying the problem areas of an existing control room can be accomplished with a control room audit. The list of practical fixes can be addressed in a renovation that can transform an existing control room into an up-to-date facility of focus, accomplishment and collaboration. Retaining key staff, attracting new talent and ensuring safety and peak performance in a 24/7 mission-critical environment are all good justifications for an audit.

PEOPLE
Do you worry about the "human" element? Retaining key staff, attracting new talent, and ensuring safety and peak performance in a 24/7 mission-critical environment are all important reasons to audit your control room.

TECHNOLOGY
Upgrading your technology? Placing new technology in a control room that was designed more than 10 years ago is not going to be easy. But there are improvements to lighting, furniture and acoustics that just may help you get the most of your investment.

ISO COMPLIANCE
Is your facility in compliance? ISO 11064 set international standards for control room ergonomic best practices in the year 2000. Following ISO 11064 recommendations is one of several tools we use to design operator-centric control rooms.

AN AUDIT CAN IDENTIFY SEVEN COMMON CONTROL ROOM INEFFICIENCIES:

LIGHTING
Glare, non-dimmable fixtures or lack of proper lighting can lead to misinformation or fatigue, with critical consequences.

ACOUSTICS
Noise can be distracting, or even disruptive, increasing response time.

WORK FLOW
Obstacles, inefficient pathways, limited access to meeting and break rooms, proximity to distractions—all compromise efficiency and safety.

SCREEN SIZE
Small, dated screens often don't allow for all modern data to be displayed.

HUMAN-MACHINE INTERFACE
Line of sight and arc of reach must be optimized such that mission-critical reaction time is minimized in the event of an abnormal situation. Basic considerations for comfort can change dramatically across different operators using the same equipment over several shifts.

WORKSTATION CONFIGURATION
Poorly configured seating arrangements or poor operator adjacency can thwart collaboration and optimum communication.

ADJUSTABLE WORKSTATIONS AND SEATING
Stationary or minimally adjustable furniture can cause fatigue and even lead to chronic health issues over time.

Take our quick 5-minute, online survey to see how your control room measures up: www.BAWarchitecture.com/survey

Beyond the Control Room

With the rapid emergence of mobile technologies and adoption of cloud computing, control rooms are no longer the only "control" for the process. Field operators, operations managers, and engineers all have greater access and ability to provide input to "controlling" the process. The impact of these technology changes in control room design leads to better control decision if there is appropriate collaboration and communication between and across the team. Control room design must reflect these needs with appropriate space and access to facilitate collaboration with many resources that may not be physically present. Large screen collaboration boards or tables, along with video conferencing becomes a minimum requirement. Access to physical space and technology for training, simulation and virtualization of process changes will become more important affecting the work flow of the control room itself.

Consolidation of control rooms and more remotely located control rooms are expected with continued advances in technology. The proliferations of sensors along with mobile access is expected to increase the "intelligence" of the control room to help make the plant safer in the long run; allowing maintenance to be more dynamic and predictive, facilitating automated procedure for complex tasks like shut-downs and start-ups, providing access to real-time weather forecasts and more easily monitoring environmental regulatory activities.

For more information on how technology is shaping the future of control buildings and the Industrial Internet of Things, visit www.BAWarchitecture.com/IIoT

Conclusion

Use of ISO 11064 can guide control room design decision making. With the assistance of an experienced control room architectural and interior design firm the elements of good control room design can be integrated into a building that is not only safe for the operator but improves the owner's bottom line.

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About BAW Architecture's Research + Education Whitepaper Series

As a thought leader in control building architecture for the past quarter century, BAW Architecture has been actively engaged with others in the industry, and is committed to staying educated, and to educating others about best practices in control room architecture, interior design and human factors. To that end we began this 'Research + Education Whitepaper' series to share our knowledge in the hopes that better control rooms leads to better business resulting in minimized risk and optimized safety.

BAW has built more control room projects than any other company in the industry—more than 100 over 25 years for Chevron, ExxonMobil, Shell, Fluor, Honeywell, and many more. That's more hands-on, earned control room expertise than any other company in the world.

We are a tight-knit, nimble group of architects, interior designers and ergonomics experts who create intelligent, innovative solutions to our clients' control room and control building challenges. We often lead groups of 350 or more people on projects around the globe.

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References and Recommended Reading

ISO 11064.1-7 Ergonomic Design of Control Centres

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About the Authors

BAW Architecture designs control rooms, control buildings and operation camps that feature a user-driven approach, and integrate architectural, interior design and human factors elements to optimize performance. Our buildings for Fortune 100 companies can be found throughout the world.

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