Operations:
A control room is only a component in a complex system

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1. INTRODUCTION

The design of modern control rooms has benefited a great deal from ergonomics and resulted in working environment, furniture and human-machine interfaces that are more consistent with the needs of the people who work in them. However, I feel that many people involved in the design of control rooms assume that using the latest technology and following the most up to date standards will result in a successful outcome. They are reassured that what they have developed looks like a control should, but fail to understand that they are not simple objects that can be defined by their physical arrangements. A control room is actually a component of a complex system where people and equipment come together to control that system.

This paper explores the fact that any project developing a new or upgraded control room can have a significant impact on a wide range of human factors. It considers the role of the operator, taking into account the reality of what actually happens in the control room. It identifies how these activities can cause harm, both to the health and safety of the operator; and through the failure to control major hazards and process risks.

Control room operations have changed over recent years, and this has affected the risks that need to be managed. For example, in the process industry, technological advancements during the nineteen sixties and seventies allowed plant sizes and throughputs to increase significantly, and risk management was focussed on the magnitude of potential accident hazards. More recently the industry has become far more mature. There is less technical innovation and more focus on cost. This has resulted in increased automation and reduced staffing levels. Therefore, although the magnitude of hazard for a plant may not have increased, the magnitude per operator has, and this is why the focus for risk management needs to change.

2. WHAT IS A CONTROL ROOM?

Images on television of space mission ground control, emergency services, air traffic control, ship bridges and even The Simpsons mean that even people who have never set foot in a control room have a pretty good idea of what one looks like. They expect to see multiple computer screens, maybe a few gauges and charts; and people sat or stood around being 'in control.'

The fact that someone can recognise a control room when they see one does not mean they understand what it does or how it works. They can be impressive places, full of high tech equipment and a hive of activity. But a control room is defined by what it does and not by what it looks like. And it is not just the general public that make this mistake, with people involved in the design and management of control rooms sometime failing to view the 'bigger picture.'

2.1. A simple definition

Whilst we may recognise a control room by what it looks like, the equipment it contains and other physical characteristics; this does not give us a satisfactory definition. What we need instead is a definition that addresses its function. The following may fulfil this requirement

"A control room is a place where a facility or service can be monitored and controlled."

An important factor to recognise is that it is people that do the monitoring and control; and not the control room itself. Obviously the equipment provided in the control room is essential, but to be effective it has to support the requirements of the operator.

2.2. An analogy

The U.S. Department of Transport Pipeline and Hazardous Material Safety Administration (PHMSA) have said[1] that "Control rooms often serve as the hub or command centre for decisions….. The control room is the central location where humans or computers receive data from field sensors. Commands from the control room may be transmitted back to remotely controlled equipment. Field personnel also receive significant information from the control room."

The PHSMA say that "In essence, the control room is the ''brain'' of many pipeline systems."

This seems to be a useful analogy. We can describe a human brain as being a soft, shiny, greyish-white, mushroom-shaped structure. We talk about its size and where it is located, but none of this information gives a clue to its importance. It only makes sense when we look at the functions performed by the brain. These types of definition tell us that the brain is:

- The primary receiver, organiser and distributor of information for the body[2];
- The primary centre for the regulation and control of bodily activities, receiving and interpreting sensory impulses, and transmitting information to the

[1] PHSA - Pipeline Safety: Control Room Management/Human Factors. Rule update described at https://primis.phmsa.dot.gov/meetings/FilGet.mtg?fil=218

[2] http://www.thefreedictionary.com/brain

muscles and body organs. It is also the seat of consciousness, thought, memory, and emotion.[3]

2.3. The human perspective

The definition and brain analogy described above help us understand the role of the control room, but mean nothing if we fail to address the human perspective.

A key feature of all control rooms is that they are, to a greater or lesser degree, remote from the function or service being monitored and controlled. The impact on the person in the control room is that their ability to use their senses is diminished. In other words, their ability to see, hear, feel (e.g. temperature, vibration) or smell what is happening may be partially or completely lost. To overcome this, control room operators are required to rely on technology and other people to relay information about the system they are controlling. They then interpret that information to determine what is happening and whether action is required. Technology and other people are then used to carry out those actions.

New technology has had a big impact on control rooms. In the past there were physical limitations that affected how far a control room could be from the system being controlled. Digital systems do not have these limitations, whilst also allowing higher degrees of automation. This has had a significant impact on the control room operators' job and their relationship with their colleagues and the systems they control. Unfortunately, the introduction of technology has tended to be focussed on what is technically possible, without fully considering what is desirable for the people involved.

2.4. Examples where human senses have been neglected

2.4.1. VISIBILITY

A control room with a useful, direct view of the system is something of a rarity. In many cases the system is simply too large to view from a single location, so even if there is a window it is of limited value. Where the system is hazardous, control rooms are either windowless (with older buildings having had windows blocked in over the years) or they are located at some distance away.

This lack of visibility can affect the relationship people have with the system they operate, with a concern that the 'Nintendo generation' may start to think that their process plant, nuclear power station or rail network is just another video game. When something goes wrong, the need for visual confirmation and feedback often means others are sent to investigate, which involves sending them to a potentially dangerous location and introduces the possibility of communication errors.

The problem is that providing a window is not always possible or effective in addressing these issues. Therefore the question is whether anything else can be done to overcome the restrictions to the operators' use of vision. CCTV is one option, and operators working in control rooms where CCTV is available tend to find it useful. . However, it is not always seen as a critical feature. I am aware of two recent examples where control room operators have been denied access to CCTV because it was seen as purely a security function. In the first, monitors were removed from the control room because it was feared that the ability to observe

[3] http://www.medterms.com/script/main/art.asp?articlekey=2516

activities beyond the site fence would breach human rights of the general public. In another, CCTV was not specified for a new control room because it may contravene policies designed to prevent unacceptable monitoring of employee activity. In neither case the impact on the operator of these decisions to deny them visibility of their system was considered.

2.4.2. BEING ABLE TO HEAR

There is no doubt that operators can detect or diagnose problems early if they are able to hear what is going on in the system. On more than one occasion I have been in a control room and an operator has said something has occurred on plant (a compressor tripping and relief valves lifting are two examples that I remember). What has happened is that they have detected a subtle change in background noise. In fact, it may not be the operator directly involved in that part of the system that makes this comment, because they will normally be informed by alarms or other indications on their control screens. But it is others in the vicinity who, with this knowledge, can offer their assistance.

The use of hearing was demonstrated to me recently when conducting a workshop in a room adjacent to the control room. The operator present detected a strange noise and was quite perplexed because he did not recognise it. This prompted him to investigate. It turned out to be a stunt plan practicing tricks nearby.

I have recently been involved in analysing a situation where a lack of hearing may have contributed to a potentially serious incident. The activity taking place was charging molten metal into a vessel. Whilst the crane driver handling the ladle had some visibility, the occurrence of ‘pops and bangs’ was an audible sign that something may be amiss. However, because the crane driver was sat in an insulated and air conditioned cab he could hear very little from outside. Therefore, the people who could hear the noises could do little to avoid the problem, whilst the person who was in control was denied these early warnings.

2.5. Key message

I am not saying that every control room should have a window, CCTV or listening devices. But it is important to recognise that operators working in a control room will inevitably be denied the use of some of their senses. The potential risks of this should be considered in order to identify if anything should be done to compensate.

3. CONTROL ROOM ACTIVITIES

If our control rooms are going to be an effective component in our system, we need to understand their function and how they are going to be used.

3.1. What do control room operators do (in reality)?

The obvious answer to this question is that control room operators 'operate'! However, this implies some level of action, which may not accurately reflect reality in many control rooms. Therefore, an alternative answer could be that they 'monitor.' This is probably more representative of what they do most of the time, but it is such a passive activity it is unlikely that anyone would find it stimulating enough to provide any level of job satisfaction or motivation. Given that in many industries the control room operator has the most critical role in ensuring safe and efficient operations, it is vital that we have a better idea of what they do if we are to understand the risks fully.

3.1.1. NORMAL OPERATIONS

The reality is that operators working in a modern control room are involved in a range of activities. Whilst some are clearly recognised as operations many in the past would have been a supervisor's responsibility. Also, organisational changes (e.g. introduction of 'self managed' and 'multi-skilled' teams) means that teams are smaller and the result is that some tasks performed by support staff in the past are now performed in the control room. The following is an illustrative list of what control room operators actually do, in addition to operating the plant:

- Communicate with other people inside the control room;
- Communicate with people in other locations;
- Answer telephones;
- Conduct shift handovers;
- Carry out administrative tasks;
- Eat meals;
- Coordinate non-routine activities (e.g. give permission for work to start, issue permits-to-work etc.);
- Read and send emails;
- Training (for themselves and others);
- Inputting maintenance requests;
- Etc.

3.1.2. ABNORMAL OPERATIONS

As well as the above tasks performed during 'normal' situations, the control room also acts as a 'hub' during emergencies. In addition to responding to the operational aspects of the emergency, the control room operator may be involved in:

- Raising the alarm;
- Notifying emergency services;

- Co-ordinating communications between the parties responding to the event;
- Keeping a log;
- Conducting the roll call.

3.2. Other users of the control room

Clearly the control room operator will be the main user of the control room, but there will be others who will use it to a greater or lesser extent. They include supervisors, field operators, maintenance personnel, managers and trainees. It is important to recognise who may be required to use the control room in order to provide the facilities they need. Equally, we need to strike the right balance between allowing easy access, without causing unnecessary distraction or confusion about who is actually in control.

The scenarios where other people may need or wish to use the control room include:

- Speak to the control room operator;
- Involve the control room operator in a group activity (e.g. team briefing);
- Access information about the system being controlled (i.e. read-only);
- Make control actions (e.g. to test part of the system that is undergoing maintenance).

Some of these activities could be performed in another location. This can avoid distraction, but it is important to recognise that there are benefits from allowing control room operators to have personal interactions with others. Face to face communication is usually far more effective than using a telephone, email etc. Also, it is important to recognise that a lot of communication takes place at a very informal level, which is lost if people don't have the chance to spend time together.

In the past, high demand situations (e.g. non-routine activities and responding to events) required muscle power in the field. Now, the increased ability to monitor and control systems remotely means the control room operator is likely to require assistance. This needs to be considered in control room design, possibly with the inclusion of 'spare' workstations that will allow others to assist.

3.3. Examples where control room activities have not been properly understood

3.3.1. USE OF LARGE SCREEN DISPLAYS

Most modern control rooms will have some form of large screen display. However, they are often included without any real understanding of how they are going to be used.

On one project I worked on the control room specification for a new facility included three operator work stations with normal sized monitors and three larger screens. The initial assumption of the designer was that the large screens would be used by the control room operators, and so would need to be located in line with each work station. However, this would have been difficult to accommodate in the room, in a way that made them visible and information legible.

My question was 'who is likely to be the main user these large screens?' The answer from the operations team was the supervisors. The control room operators would only use them occasionally. Having this information not only made locating the screens easier, it ensured they would be more convenient for the intended user.

It seems to be a common assumption that control room operators will find large screen displays useful. But my experience is that most consider them to be no more than a 'nice to have.'

3.3.2. BASING THE SUPERVISOR IN THE CONTROL ROOM

In two recent projects it has been proposed that the supervisor should have a desk in the control room. Whilst I may accept this in a large control room housing a number of operators, these were small rooms and the only available location for the supervisor's desk was immediately behind the control consoles.

In both cases the proposal to locate the supervisors was based on historical arrangements, and no thought had been given to the potential impacts in a new control room. I had a number of concerns with the proposed arrangements, including:

- Supervisor causing a distraction in the control room when carrying out their day to day activities (e.g. routine meetings, phone calls);
- Control room operators perceiving that they are under continuous scrutiny;
- Confusion about who is responsible for diagnosing events, making decisions and directing actions;
- Lack of space and increased clutter.

In most cases, particularly for smaller control rooms, the best arrangement is to locate the supervisor in an adjacent office, with a window allowing visual monitoring and a door for immediate access when required. This was fully accepted for one of the projects I mentioned above, whilst the other proposed that the adjacent permit office could be used by the supervisor, but wished to retain a table in the control room for the supervisor to use if required.

3.3.3. RESTRICTING ACCESS TO THE CONTROL ROOM

I have come across a number of situations where over-zealous attempts to reduce distractions in control rooms have had the opposite effect. Often, the result is that the control room operator receives more phone calls. The problem is that someone making a phone call has no idea what is happening in the control room. If they are present they can see if the operator is busy or stressed and know to come back later. In one case, putting a lock on the door to restrict access caused more distractions because visitors continually knocked on the door, requiring the operator to get up to either let them in or direct them to someone else.

3.4. Key message

To get an optimal control room design we need to understand how it will be used. This means knowing what tasks will be performed by the control room operator and others.

4. CONTROL ROOM TECHNOLOGY

Referring back to our definition of a control room as “a place where a facility or service can be monitored and controlled,” we can see that they can only exist through the use of technology. Initially, this would have been mechanical devices linked directly to the system under control. Electro-mechanical and pneumatic systems followed, and now we are very much in the digital age. There is no doubt that the capability of the available technology has increased significantly, but the problem is that human capabilities have not.

4.1. Increasing Automation

As technology has developed, the ability to automate processes has increased. Initially, humans were involved in all operations because systems were fully manual. Early automation meant that the operator could set up individual controllers to maintain parts of the system within defined parameters. The extent of automation has increased so that operator inputs are significantly reduced, and the role has changed to supervisory with some systems able to operate almost completely autonomously, providing only limited information to the operator.

4.2. Other technology

Control systems are not the only technology found in control rooms. As with most work places, control room operators will be required to use personal computers and communication devices. Where information used to be recorded by hand onto paper, it is now entered directly into a computer. Now that phones, radios and email are readily available, there is less need for face to face communication, but this can be to the detriment of the quality of communication that occurs.

4.3. Impacts on people

Automation has had a significant impact on the people who operate our systems. Less operators are required and the job has become more passive and sedentary. It has increased areas of responsibility and the ability to achieve greater levels of control has meant that more hazardous operations can be carried out.

Experience has shown that installing new technology without adequate consideration of human factors has caused a number problems including:

- Operators overloaded with data and alarms;
- Non-intuitive interfaces requiring people to work harder to use the equipment;
- Replacing analogue panels with computer screens can reduce the amount of information visible to the operator at any one time and removes a degree of spatial awareness;
- Over-reliance on the technology because people assume a new machine is more sophisticated than it really is and so it cannot get things wrong.

However, even when new technology is implemented well, it can have a significant impact on the people operating the system. This can be positive, by using automation to relieve people from boring, unpleasant and potentially hazardous

tasks. Also, achieving more consistent operation and more reliable response to events and abnormal situations. However, these can come at a cost, including:

- People end up working in smaller teams, and are more likely to feel isolated;
- The absence of one team member has a proportionally greater effect on either the team's ability to deal with high work-load events or other team members work extra hours to cover the gaps;
- People have less autonomy because they are driven by what the equipment is doing;
- People have less opportunity to make positive contributions to the job;
- Operators have less opportunity to experience abnormal situations, and those situations can be more complex than is the case for manual operation;
- Managers reduce their interaction with their staff because they can access the data they need from their desk without having to visit the control room.

4.4. Unreasonable expectations

Problems seem to occur with control rooms because people assume that using the latest technology will inevitably be beneficial. This means they can have unreasonable expectations of what the technology can do, or fail to recognise the potential negative impacts. Often this is because the role of the control room operator is not considered adequately and so not enough account is taken for their needs and capabilities.

4.5. Examples where new technology has been used without a full understanding of the potential impacts.

4.5.1. PROCESS ALARMS

Rather than referring to a specific example where process alarms have caused problems for operators, it is an unfortunately the case that virtually every control room with a digital control system has problems with alarms. They include:

- Operators receiving nuisance and 'non-alarms' during normal operations;
- Operators are overloaded with alarms when things start to go wrong;
- Operators receive alarms they do not understand or know what they need to do to respond;
- Alarms not giving operators sufficient warning to perform necessary actions.

Alarms have not always been such a problem in control rooms. When they had to be 'hard wired' they had a cost that was sufficient to ensure only those that were considered essential were provided. When digital control systems were introduced an alarm only required a line of code at minimal cost. People felt that more alarms must be better, and so many more were provided. The result of this was very evident at a control room I visited, which contained a mixture of control technology. The most recent control system, installed in 2004 using computers running Windows XP

was considered to be the worst performing whilst the oldest, a 1992 Vax based system was considered to be the best.

There is no particular reason why a digital control system cannot have a good set of alarms. However, it does require some substantial effort to achieve a system that is consistent with human capabilities and requirements. The guidance exists on what has to be done, but to date there is little evidence to show that it is being used effectively. I have noticed that alarms are added to systems from very early in the design process, often before any form of philosophy has been developed. Once they exist, the management of change systems companies' have in place often make it very difficult to remove or modify them.

4.5.2. PROTECTIVE DEVICES

As well as alarms to warn operators of problems, most modern systems are provided with protective devices ('trips') that intervene when a hazardous situation occurs. As with alarms, these devices have become cheaper and easier to install, and as result are being used more frequently.

Whilst protective devices have an important role in hazardous systems, they are not always implemented effectively. One consequence can be operating difficulties, requiring the operator to circumvent or override the devices, which can actually increase risks. One plant I worked at was considered to be particularly hazardous, and so multiple levels of protection were provided with the intention of preventing major accidents. Unfortunately the complexity of the process was not fully understood when the protective devices were designed, and the result was that it was almost impossible to start-up the plant without using certain inhibits and overrides. The problem was that the operating team had to use a great deal of their own discretion to decide when inhibits and overrides could be used safely.

The other problem with complex protective devices is that they can give the operator too many options when they are deciding on how to respond to a situation. Designers feel that this will give flexibility. In reality, operators will tend to choose the most wide ranging trip available because they fear any other may not have the effect they want. Often the information given to the operators about protective devices is focussed on what the device will do, rather than on which should be used in different scenarios. This is another example where problems can result because of a focus on the technology rather than the user.

4.5.3. REMOTE ACCESS

A feature of digital control systems is that they can be accessed from anywhere with the appropriate network connections. This can be very useful, but there is a danger that engineers and managers start to rely too much on this capability, and so visit the control room less often. And I have certainly heard complaints from control room operators where they feel decisions are being made and instructions issued without, what they consider to be, adequate discussion or explanation.

The ability for remote access to the control system may not always be healthy for the engineer or manager. It can mean they never quite leave the job behind, always checking in from home to make sure everything is running OK. At one plant I was told the manager would take his laptop on holiday and use it several times a day to check operations. This can also affect the attitude of operators who start to feel they are either not trusted or not given responsibility to run the system without interference.

4.5.4. CORDLESS PHONES

Control room operators always need access to phones. Given that some consoles can be large, it can be difficult to locate a wired handset and so cordless phones are being used. The difference is that they require a power supply to operate

One control room I visited had replaced all their wired handsets with cordless. When I asked what would happen if there was a power failure the answer was 'we hadn't thought about that.' It was relatively simple to provide them with an Uninterruptible Power Supply (UPS), but the potential impacts of changing technology had not been thought through properly.

4.6. Key message

Using the latest technology does not guarantee improvement and can actually lead to problems. Also, it can affect the culture of the organisation.

5. CONTROL ROOM DESIGN

Most problems with control rooms have their root in poor design and management of change. This is for both new and modifications of existing control rooms.

5.1. New control rooms

Control rooms are expensive, and creating a new one is rarely undertaken lightly. Obviously, it is required for a new facility but there are a number of reasons why an existing facility may require a new control room. They include equipment obsolescence, perceived benefits of new technology and/or potential cost savings, or improved safety by introducing greater safeguards or moving the control room away from a hazard.

There seems to be two schools of thought that are adopted by project teams that result in poor control room design for different reasons. The first is that all control rooms look the same, and so there is little to be considered in the design. The second is that a control room requires specialist designers, and that they can be left alone to create something that is state of the art with minimal input from others.

5.2. Modifying existing control rooms

Changes to control rooms often occur with little thought or control. Whilst individual changes may only have minimal impact, over time they can significantly change the way the control room functions.

5.3. Managing change

Whether a new control room or a modification, it is important to recognise that the result is a potentially significant change that needs to be managed. Often there is more than one driver and/or other changes occur at the same time. This makes managing the changes difficult. To some companies a new control room is seen as a re-instrumentation project, and so run by instrument engineers. Others see it as a process improvement, and the project team includes more people with operations experience. Others recognise it as being, or at least including elements of organisational change, and so include more business management personnel. The reality is that implementing a new or upgraded control room is a complex project that involves the use of technology, but will impact greatly on people at multiple levels in an organisation.

Many companies fail to recognise the potential impact of a new or upgraded control room and so fail to adequately control the risks. Examples of problems experienced by companies include:

- Creating resistance to changes because people do not understand what is happening, cannot see the benefits or suspect ulterior motives that may impact on their employment and/or terms and conditions;
- Creating a high training load by simultaneously introducing new processes, control systems and ways of working;
- Failing to recognise the informal arrangements that make a positive contribution to operations, which are no longer possible because of the way system changes have been implemented;

- Limiting the options for covering sickness and holidays because teams have become smaller and individuals more specialised in their roles;
- Creating a system that requires a higher degree of skill than is available within the existing workforce.

5.4. Examples where the design process has failed

5.4.1. FURNITURE CHOICE DRIVING DESIGN

I joined one project where a control room was in the early stages of design. The operating team had already specified that they wanted a certain console design provided by a well-known control systems vendor. I felt it was rather early to be making such decisions and asked how it had been made. It transpired that they had seen these consoles at another facility and liked the look of them. They seemed to be particularly impressed by the fact that you could turn a wheel and they would move up and down. The project team felt compelled to give the operators what they want, without any real consideration of whether it was appropriate or good value for money.

The operating team had also asked for a rather large plasma screen, and had specified that if made up of more than one screen there should only be no (or minimal) visible join. Again, this did not seem to be based on any specific requirement and was a case of where bigger was assumed to always be better.

Having been told about the above items already specified I looked for some form of basis of design. I found that the foundations for the building had already been created, but little other information seemed to be available. When I asked how many operators would be working from the control room I was told by the project manager that they were providing the number of workstations that could be bought for the available budget and would fit in the room. This was a big company working with a major hazard, that had clearly given little or no consideration to the importance of control room design.

5.4.2. PLAUSIBLE DESIGNS ON PAPER

Part of the problem with new projects is that building and room sizes are specified very early, but internals are designed much later. There is a danger that insufficient space is made available, and I have visited a number of control rooms that provide a poor working environment because they are simply too small.

I have worked on two projects where there have been attempts to avoid these problems by generating an outline design early on in the design process, but where the results were deceiving.

In the first a drawing had been produced showing a console desk and chair, indicating that plenty of space was being provided. It However, when I took a ruler out I realised that the desk width was far less than acceptable. It would have been easy to have accepted the drawing at face value, assuming there would be plenty of space.

On the second project, as well as drawings, a 3D model had been produced. The project team felt this would prove, beyond doubt that there was plenty of space to accommodate everything that was required. It certainly looked impressive until I did some simple calculations of the furniture and equipment dimensions. Whilst it would

fit, there would be insufficient space for walkways, and it would have felt very cramped.

To the credit of the two project teams they understood my concerns and made significant changes to the early plans to ensure sufficient room would be available. But it was quite possible that decisions could have been made, based on the drawings and 3D models, that could not have been changed at a later date.

5.4.3. CONTINUAL ADDITIONS

I have visited a number of control rooms where the operators have far too many screens to monitor because of multiple changes occurring over time. In one case we counted 27 screens linked to 10 distinct systems in a control room that was often manned by a lone operator. It was clearly impossible for one person to monitor all the screens at the same time, especially as they were arranged around the room so that some would always be behind him/her. The different systems had different user interfaces, which caused confusion. Also, all had their own alarms, which meant operators were often overloaded and it was difficult to identify the priorities for their attention.

5.4.4. NEW SYSTEM IN AN OLD CONTROL ROOM

Older control systems were often large and, once in place, difficult and expensive to move. I have visited a number of control rooms where a new system has been made to fit in an existing control room without removing the old system. The result is rarely impressive.

In one case, a whole new control system was forced into the corner of an existing control room. The resulting work space was very poor with almost zero leg space because an equipment cabinet was in the way. The view was that this was a temporary situation because a new control room was going to be built as part of another project. However, it was expected to be in place for at least two years. I was particularly surprised to hear that the new arrangement had been assessed and considered to be compliant with Display Screen Equipment (DSE) requirements. This was clearly not the case, and showed me how little thought is sometimes given to significant modifications to control rooms that are manned 24 hours per day.

5.5. Key message

Designing a new control room or planning modifications is a major, human factors undertaking. However, it is not what they look like that is most important, but how they support the people who are going to work in them.

6. MANAGING CONTROL ROOM RISKS

There are two main sources of risk associated with control rooms. The first is the potential to harm personnel working the control room. The occupational health and safety risks are relatively easy to assess and control. The second risk is the potential to cause harm as a result of the action or inaction of the control room operator. These process safety risks are potentially much more significant, but can be difficult to assess and control.

6.1. Risks for the control room operator

A control room is generally considered to be a reasonably safe place to work, similar to an office. This means the main concern would be slips, trips and falls. In addition, control rooms are likely to house some electrical equipment and maintenance within the building will inevitably involve some working at height. Clearly, most of these hazards should be avoided through good design, construction and maintenance of the building and equipment.

The second consideration is what does the person do that can cause them harm? For the control room operator excess physical exertion or exposure to hazardous agents is unlikely to be an issue. In fact the lack of physical activity may be more of a problem with the potential for back pain, repetitive strain injury and weight gain. More importantly, mental exertion may be an issue, with long periods of monotony and occasionally high demands resulting in stress and fatigue (with shift work likely to exacerbate this).

The third consideration is the hazards surrounding the control room that may affect its occupants. These would include flammable, explosive and toxic materials that may be in other parts of the building or outside.

6.2. Issues requiring particular attention

Although control rooms and the systems they control vary a great deal, experience of assessing existing and new control rooms shows a number of recurring problems. Many of these have arisen because technological advances have been implemented without fully considering the impact. This is often because the human factors are not adequately considered. In each case, whilst the design of the control room can contribute to the risk, the solutions go far beyond physical design and enter the realms of management and organisation.

6.2.1. STRESS MANAGEMENT

Stress is a real hazard of control room operations, and as well as affecting the health of the individual, it can result in higher rates of error with potentially serious consequences. For many control room operators the greatest problems are due to boredom and frustration, which are often closely related to motivation. To avoid these problems people need to perceive that their work is meaningful and satisfying, which generally requires[4]:

- Skill variety - the opportunity to use skills
- Task significance - a feeling that the work is worthwhile

[4] Hackman and Oldman

- Task identity - having well defined tasks with specific objectives
- Autonomy - being able to control how work is performed
- Task feedback - receiving information that confirms work has been successful

Unfortunately the modern control room does not automatically fulfil these needs. For example, most of the control room operator's job is to monitor automated systems, which gives little variety or autonomy. Also, the task is never ending, especially with continuous operations. This means individuals receive little direct feedback of how successful they have been and hence there is little identity with the outcomes. To some people this issue may be considered a trivial matter of job satisfaction. But if people are stressed it can have serious health consequences and, if it results in making more errors, then major accidents become more likely.

There is also the possibility of stress caused by high demand situations. Clearly, the best strategy is to avoid those situations in the first place. However, the design of the control room, human-machine interfaces and the supporting organisation can have a significant impact on how well a control room operator can cope with events. Also, it is important to train people in emergency response, to assess their ability to cope, and to have systems in place to deal with stress after the event.

6.2.2. FATIGUE MANAGEMENT

Many control room operators will work shifts, which will undoubtedly raise concerns regarding fatigue. The working environment and nature of the tasks can increase the level of fatigue, which then increases the likelihood of error. Clearly the room needs to be designed to minimise the likelihood of fatigue through lighting and ventilation. Control room operators need the opportunity to take breaks away from their consoles, both on a regular basis and if they are feeling tired. However, as control rooms become more technical there is a tendency for people to become more specialised in their roles. Combined with the continual pressure to downsize teams, the ability for operators to take quality breaks is reducing. Also, it is important that the hours worked by operators are controlled. This is often not the case, with operators being able to work overtime and swap shifts without control or review.

6.2.3. COMMUNICATION

Communication has a key role in operators maintaining an up-to-date view of how their systems are functioning, and in the execution of tasks. Also, it will affect how well control room operators are able to detect, diagnose and coordinate the response to events.

As control rooms become more remote, there is less opportunity to communicate face-to-face and greater reliance on other means. Radios and phones are used more often, along with email and other less immediate forms of communication. As well as generally being less effective that face to face, there can be significant problems with reliability, and often there is no suitable backup available.

6.2.4. PROCEDURES

Procedures describe how tasks are (or should be) performed. In theory control room arrangements should not influence procedures directly. In practice the use of technology and automation does affect how tasks are performed, and potentially the frequency that someone performs a task. Also, there can be different modes of operation (e.g. automated and manual control) that will affect the role played by the

human. Unfortunately many companies do not have good procedures and there can be cultural problems that affect their use. This can mean that procedures that may have been adequate in the past are no longer suitable for current ways of working. Development of procedures should be an important part of any control room project, but the procedures needed in the future may be quite different to those that have been used in the past.

6.2.5. TRAINING AND COMPETENCE

Even with the best procedures, control room operators need to be highly skilled and knowledgeable of the systems they operate. At present there is an over-reliance on on-the-job training, with insufficient structure. The result can be the passing on of poor practices and bad habits. Also, with highly automated and reliable systems, on-the-job training does not provide the opportunity to learn about the response to abnormal events. On-the-job training will always be a key part of learning a control room operator job but it is necessary to provide structure to ensure the correct skills and knowledge are achieved, to supplement it with various forms of simulation and to assess that appropriate competencies have been achieved.

The methods that people will become competent in control room operations needs to be considered as part of any control room project. This should cover both the immediate needs prior to commissioning the project and in the longer term. New technology may mean that some tasks will be performed differently and possibly much less often than in the past, which means training and methods of maintaining competence will need to change. Also, providing space and facilities to train people needs to be considered in the design.

6.2.6. SUPERVISION

Although control room arrangements do not directly affect supervision, they have resulted in smaller teams and hence a perception that less supervisors are required. In fact, as control room operators have required higher level skills they have tended to take on roles previously performed by supervisors, whilst all individuals on teams are tending to manage themselves to a greater extent.

The location of a control room can affect how a supervisor is able to perform their role. For example, if they have an office in the control room they may be more able to supervise the control room operator, but may be less able to monitor the activities of people working outside of the control room. Also, as control rooms have become more technical the operator job has become more specialised. This means it is now quite frequent for a supervisor to be in the position of supervising people in a job they cannot do themselves, which also limits the amount of support they can provide.

6.3. Process safety risks

PHMSA has identified a number of serious incidents involving control room operations.[5] "When a controller failed to recognize a pipeline rupture and subsequently restarted pumps, the larger amount of product released resulted in fatalities. When controllers failed to provide complete information during change in shifts, the result was an overflowed tank, fire and explosion. When a controller failed

[5] Pipeline Briefing Sheet - Control Room Management/Human Factors. Available at http://www.phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/Control%20Room%20Management%20Human%20Factors.pdf

to recognize the presence of contaminants in gas removed from storage, the resulting pipeline failure led to a loss of service to several towns. When controllers have failed to react to emergency calls, there have been delays in identifying and correcting critical pipeline safety problems."

The issue here is that the errors of the control room operator can affect many people including staff, neighbours and the general public. Although the risks to the control room operators may be modest, their actions and errors may create very great risks for others.

People often find it difficult to understand the process safety risks of control room operations, and struggle to assess them in an effective manner. This is because many are quite intangible. However, there are a number of freely available techniques that can assist by providing some structure to carrying out assessments in an objective manner. The following three methods have resulted from work carried out on behalf of the UK's Health and Safety Executive (HSE).

6.3.1. HUMAN FACTORS ASPECTS OF REMOTE OPERATIONS OF PROCESS PLANT

This was published in 2002 as Contract Research Report CRR432. Although it does not describe an assessment methodology, it lists a number of issues to consider when evaluating a control room. These include

- Location – things to consider as control rooms are moved further from the system being operated;
- Communications – the impact of communication methods that do not include face-to-face interaction (e.g. radio, telephone, written);
- Interface – the differences between older panels and modern VDU displays;
- Automation – the benefits and risks of increased levels of automation;
- Team – the potential impacts of smaller teams and different organisations (e.g. self-managed teams);

The publication includes some checklists that are useful for evaluating existing control rooms, and when considering changes to arrangements. They can help by providing focus for 'brain storming' storming sessions and structuring risk assessments.

6.3.2. ASSESSING THE SAFETY OF STAFFING ARRANGEMENTS FOR PROCESS OPERATIONS IN THE CHEMICAL AND ALLIED INDUSTRIES

This was published in 2001 as Contract Research Report CRR348. It followed concerns from HSE that companies were reducing staffing levels and making other changes to staffing arrangements without adequate assessment of the risks. The HSE were concerned that these changes could impact on the ability to control abnormal and emergency conditions; and may also have a negative effect on staff performance through an impact on workload, fatigue, etc.

The publication presents a practical methodology that has been widely used. It has proved most effective at assessing control room arrangements. Subsequent guidance has recent been published by the Energy Institute.

Assessments are carried out during facilitated workshops, similar to HAZOP. The first part of the methodology assesses the likelihood that hazardous situations will be correctly detected and diagnosed by the control room operator, and that the appropriate response will be made. The second part assesses whether the organisation is place to ensure the arrangements are sustainable.

The methodology considers a wide range of issues, including staffing levels. However, it is emphasised that it does no calculate a minimum or optimum number of staff. Rather, it takes into account all relevant arrangements to conclude whether staffing, technical and/or organisational issues need to be improved. The methodology is particularly useful where arrangements are being changed.

The benefits of the using the method have been shown to include:

- It brings staffing issues into the open;
- It is practical, useable and intelligible;
- It is robust and resistant to manipulation and massaging of its output;
- Results in practical and effective improvements.

6.3.3. DIFFERENT TYPES OF SUPERVISION AND ITS IMPACT ON SAFETY IN THE CHEMICAL AND ALLIED INDUSTRY

This was published in 2004 as Research Report 292. It presents a thorough definition of what constitutes supervision as a management function and its impact on health and safety; and a method of assessing how supervision is delivered so that areas for improvement can be identified.

Although the method is not specifically related to control room operations, it is clear that in modern organisations the control room operator often fulfils some significant aspects of the supervision function. Also, the way a team functions has a significant impact on how well the system operates and the hazards are controlled. Therefore, supervision should be an important part of any assessment of control room risks.

6.4. Putting risk controls into practice

Control rooms do not just appear within our systems but occur as the result of significant projects. In many case these projects start with the aim of using the best available technology and following the latest design standards. Often, it is assumed that this approach will guarantee success. However, the failure to consider the impacts on the people that must operate from the control room combined with the inevitable constraints placed on projects by budgets and time can cause human factors problems.

Involving end users in the design process is an important step in managing the risks of control room operations. It provides the opportunity for the people who will operate from the control room to tell the designers what they need and want. It should definitely be considered as being a minimum requirement but does not, on its own address all the issues.

The techniques described above assist in assessing risks and suggesting controls by challenging experience and assumptions. They can be used to assess how well existing control rooms contribute to the management of process risks and encourage designers to consider systems beyond the control room. Also, they can encourage the end users to move beyond asking for the recreation of systems similar to those they have experience of and to accept changes that will result in reduced risks.

7. CONCLUSIONS

Control rooms perform many roles. They are a workplace, with all the hazards related to 'normal' jobs. They can act as a refuge providing protection against hazardous events. And they are a component in a complex system where people and equipment come together to control that system.

The important things to realise are that controls rooms are not defined by their appearance or physical arrangements. Also, they are only a component and not a system in their own right. It is easy to become focussed on the physical arrangements and technology and forget that they are essentially a tool for the operators to help them do their job. Like any tool, they have to fulfil the needs of the user and the business. It is easy to assume that using the latest technology and following the latest design standard will generate a successful outcome, but this is rarely the case.

The construction of a new or significant modifcation of an existing control room is invariably accompanied by other changes such as centralisation, de-manning, use of new technology and increased automation. Whilst the operator is often trained in detail about how the control system works, which is likely to be new to him/her, the other aspects of change are often treated in much less detail or even completely over looked. This is usually because the fact that new control rooms can fundamentally change the way people communicate, teams function and the system is operated is often not appreciated or analysed in any detail. The reality is that in modern control rooms the operators have less opportunity to communicate face to face, they work in smaller teams with less supervision and their window on the system provided by computer monitors is significantly less than was provided in the past where analogue and schematic displays were the norm.

Involving end users in the design of a new control room or major modification can undoubtedly remind the design team that there is a human element to the control room. However, without any structured prompts this involvement can result in demands for a system that recreates many of the features of control rooms encountered in the past. Techniques are available that encourage challenge of past experiences; highlighting weaknesses that may have been overlooked or accepted because there had not been any major failures or accidents. They allow control room projects to become a process of improving risk management by addressing all technical and human aspects of a control room.

8. REFERENCES

Energy Institute 2002. Report of Workshop on Human Factors in the Petroleum Industry.

Energy Institute 2004. Safe Staffing Arrangements - Use Guide for CRR348/2001 Methodology

Hackman, JR and Oldman, GR 1980. Work Redesign.

HSE 2001. Assessing the safety of staffing arrangements for process operations in the chemical and allied industries. Contract Research Report 348/2001

HSE 2002. Human Factors aspects of remote operation in process plants. Contract Research Report 432/2002

HSE 2004. Different types of supervision and the impact on health and safety in the chemical and allied industries. Research Report 292

PHSA 2010. Pipeline Safety: Control Room Management/Human Factors. Rule update described at https://primis.phmsa.dot.gov/meetings/FilGet.mtg?fil=218