CENTRAL CONTROL ROOMS AND PETROCHEMICAL PLANTS: COSTS AND BENEFITS

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Petrochemical plants are increasingly faced with the need to upgrade their control centers to support the installation of more advanced control systems and to better protect operations personnel in the event of catastrophe. Plants often take advantage of this opportunity to consolidate existing control rooms into a central facility, in hopes of improving plant-wide communications, increasing operating efficiency, and reducing construction costs.

However, there are a variety of factors which may negate these advantages, and in fact initial experiences with centralized control rooms have been decidedly mixed. In fact, aside from green field plants, fully successful central control room projects are rare.

In retrospect, this should not be surprising. The operations culture of the plant is profoundly changed by control room consolidation, and the duration and extent of the resulting disruption can be significant. Some plants have in fact determined through intensive study that upgrading and maintaining a number of smaller control centers is more cost-effective in the long run despite higher initial costs.

In this paper, we describe some of the key issues that must be considered in analyzing the benefits and costs of a central control facility, using operational experiences and case histories from a variety of plants.

PERCEIVED BENEFITS OF CENTRAL CONTROL ROOMS

Central control rooms are often part of a larger strategy to rationalize plant operations and to upgrade control equipment. As plants evolve and grow over the decades, they may end up accumulating large numbers of control rooms located adjacent to the units they control. This puts control room personnel at risk in the event of a serious incident, and it increases the costs associated with maintaining redundant equipment distributed around the plant.

Well-designed central control rooms have the obvious benefit of providing better protection for control room personnel. In addition, they are often thought to enhance communication between units, enabling better coordination of refinery-wide operations and more effective responses to upsets.

Central control rooms are perceived to provide a cleaner, distraction free work environment. Locating a central control room away from the center of field operations is perceived as an opportunity to separate console operators from the day-to-day interactions with field operations and maintenance. A perceived benefit is a more focused console operator free of the distractions stemming from the traffic and congregation of field operators and maintenance staff in the control house.

Central control rooms are also believed to enable both reductions in operations staffing and a move to more highly trained and knowledgeable console operators.

OBSERVED IMPACTS OF CENTRAL CONTROL ROOMS

While the perceived benefits of central control rooms are readily apparent, our experience indicates that they are easily overstated. Worse, there are significant adverse impacts associated with introducing central control rooms into existing plants, and the effects of these issues often comes as a surprise.

The majority of the issues associated with central control room projects arise not from technological or engineering problems but from unanticipated interactions of the new control room with the plant's preexisting operations practices. The issues are organizational, cultural, and psychological. Some of these are different from plant to plant, but many are common, and we focus on these in this paper.

Disruption of existing refinery operating culture

Operating teams in plants with distributed control rooms often evolve into close-knit teams with individual cultures. Members of these teams learn to appreciate each other's strengths and weaknesses, and they develop predictable responses to problems and unexpected operating events. While it is not always the case that these responses are optimal, they are almost always better than the responses of newly formed teams. The introduction of a central control room often results in the dismemberment of existing operating teams leading to a loss of teamwork and a reduction of understanding of individual strengths and weaknesses. This can lead to teams which run the plant "by the book," which may or may not be a good thing depending on how well developed "the book" is. It may also lead to team running the plant by the seat of their pants.

Loss of teamwork is further compounded by the fact that console operators in central control rooms are often running unfamiliar units. Depending on the extent of consolidation and the presence of union seniority rules, the units may also be staffed by fewer field operators, and the field operators may also be new to the units.

Reduced communication within units

Central control rooms are designed to increase interaction between the console operators of different units. But an under-appreciated side effect is that communication within the unit is reduced, especially between console operators and field operators.

Part of the reason is that voice communication (via radio or phone) is substituted for face-to-face communication, and the latter is far more efficient. Also, console operators are typically running more units, so there is less time available to communicate with all of them. Finally, since the field operators typically see much more of each other than the console operator, they set up informal communication methods in the field—such as blind lists and out of service logs—which are not accessible to the console operators.

The reduction in communication leads to unexpected difficulty with routine efforts such as maintenance coordination, permitting, and Lock Out/Tag Out. We have frequently observed field operators and console operators in remote control rooms working at cross-purposes. It is not uncommon to see mistakes by field operators that are not announced to console operators. These kinds of communication problems have led to serious incidents, such as the wrong drum being opened on a coker or the wrong line-up being completed for a product stream.

Perception of inequitable working environments

Both console operators and field operators perceive inequities in differentiation of their job tasks. Console operators decry the burden of responsibility they bear, relative to their more limited plant scope peers working outside. Dissatisfaction also flow from converting employees who signed up for a "walking around out of doors" job to "clerical" computer workers: long hours of sitting, visual fatigue, and reduced diversity in work location. Field operators recognize that they're now afforded less opportunity to enjoy the climate controlled cocoon, protected from the weather and the risks of the plant environment. In addition, they fear that their process knowledge and control expertise may deteriorate, due to reduced exposure, with possible negative implications for career advancement.

Failure to achieve plant-wide collaboration

Perhaps the most surprising observation we have made, at least to central control room advocates, is that central control rooms do not appear to succeed in promoting inter-unit communication in those plants in which inter-unit communication is a problem. We have seen central control rooms, introduced to address communications problems between units of a plant, in which the units are run from consoles that, although located in the same room, are as isolated as ever: Operators still do not work together. Moreover, they tend to communicate only via telephones rather than face-to-face. Especially in abnormal situations, the primary means of communication that we have observed is the telephone.

In hindsight, this should not be surprising: Communication issues are much more due to organizational issues than they are to physical location. Plants with distributed control rooms and a strong communications culture overcome the obstacles. Plants with a weak communications culture should not assume that the obstacles are physical—they rarely are.

Loss of field knowledge by console operators

Central control rooms often result in dedicated console operators. Unless specific actions are taken, the result is usually that the console operators gradually lose awareness of and knowledge about conditions in and the nature of the field operator's environment. We have observed several consequences of this. First, the console operators may begin to treat their job as a sort of video game, and lose sight of the fact that the indications on the screen represent physical processes with physical attributes. In one case we witnessed, a console operator forgot that two process drums were located quite far apart, even thought they were near each other on the schematic. In another case, an operator lost sight of the fact that the rate at which a tank filled on the schematic was a function of process hydraulics, not the processor speed of the display computer.

Second, the console operator may have a reduced understanding of the field operator's tasks. For example, the time to catch a sample depends on a variety of factors, including the kind of sample, the sampling equipment, the location of the sampling point, the location of the sample containers, and so on. Without continued exposure to these variables, console operators may not realize how much time is needed to do even this routine job. Over time, this lack of understanding can lead to different mental models of how operations are carried out, and it can also become a source of friction between the central control room and the field.

Different distractions affect operator attention

While it is true that the placement of a central control room away from the field minimizes distractions from the traffic and congregation of field operators and maintenance staff, other sources of distractions emerge in the "fishbowl" of central control rooms. When several consoles are located in a large common area, significant distraction can emerge from the noise and lighting configurations around other consoles.

Each console has an alarm system to alert operators to significant process events. We have observed configurations where operators are distracted by each other's alarm annunciations. In some cases, operators can even be confused as to whose alarm system is annunciating. The console operator can also be distracted by the consultations going on over another console.

The central access of console operators to engineers and managers provides more opportunity for face-to-face discussions. So while the console operators may be chatting less with field operators or maintenance personnel, they are still exposed to face to face conversations. The major distraction comes when the target of the conversation is with an adjacent console operator.

And finally, operators also have to contend with the music or lighting preferences of the neighboring console operator. It seems as though each individual operator has a slightly different preference for music loudness or lighting brightness. Unfortunately, console operators are often left to police this issue on their own and the most aggressive personalities tend to win. Although these same irritants can exist in field control centers, the interdependent, rotational nature of the field operator relationships encourage achieving an accommodation (I'll get my turn...). These interdependencies are slow to be recognized in newly centralized control facilities.

Shortage of operators wanting to work the console

A number of sites we have visited have been surprised that the central control room job is perceived to be undesirable, even when a pay differential is present. The central control room may be perceived as a stressful place to work, in which everyone is always on duty. It may be perceived as a cave. People may feel that they are under a microscope, and that every mistake will be identified as a cause for discipline. Alienation from historical field crew relationships, closer working relationships with unfamiliar technical and management personnel, and the risk of being perceived as an overachiever by their coworkers dissuades some otherwise exemplary console operator candidates.

FACTORS TO CONSIDER WHEN CHOOSING BETWEEN A CENTRAL CONTROL ROOM AND A DISTRIBUTED CONTROL ROOM

We do not mean to imply that central control rooms should not be built, nor that good success is not possible. We believe that the reason that it has been relatively rare to date is that central control room projects have not been broad enough; that is, the requirements of the central control room project have excluded organizational issues. Some of the issues that we believe must be considered in any central control room decision are listed below.

Shared understanding of goals

By far the most common error in our experience is that the central control room is authorized in the absence of a broad understanding of what the alternatives are. The experiences cited above indicate that a central control room is not a quick fix for cultural issues, communication problems, or reliability concerns. Plants with cultural or communications issues need to understand the source of those and deal directly with that source—it is rarely a problem with distance. Plants that have problems controlling refinery-wide upsets may benefit much more from a concerted effort to address how upsets get started in the first place. Plants with reliability issues might benefit from *increased* staffing levels or an enhanced preventive maintenance program much more than from a central control room.

Full accounting of costs and benefits

It is important to make careful allocations of benefits among the various features of a central control room project Anticipated savings need to be analyzed and appropriately distributed to the central control room itself, versus the effects of any staffing consolidation, enhanced procedures, control system upgrades, process upgrades, organizational development, better training, and so on. These solutions are potentially independent, and their cost benefit ratios may vary widely.

Plants also need to fully anticipate and plan for the downside of a central control room. Change causes problems, and big changes cause big problems. The change may nevertheless be justified, but central control room planners need to resist optimism in predicting when benefits will start accruing. In our experience, there are several factors that are often missed in assessing the impact of a central control room.

Existing operations culture. Established operations cultures often provide value that is under-appreciated. It is not uncommon for different units in a plant to have separate reputations, and even to have different ways of doing things. These differences tend to become amplified over time, leading to nicknames., logos, mascots, and internal competition. The costs of this kind of divergence are almost always more visible than the benefits.

One reason is that the costs are misrepresented. For example, consider a situation in which internal competition that leads one unit to develop better ways of doing something that are not shared with other units. Many plants would consider the competition to be a problem, and cite the lack of sharing as a cost. We would rather conclude that, although the competition has undesirable elements, it has in fact produced the benefits that the organization wants to share.

Size of Operation/subdivision of units. Effective operating teams tend to be composed of five to ten people. Larger teams tend to form subcultures, and smaller teams are less able to include the knowledge and other resources that are needed.

In developing plans for central control rooms, it is often the case that a project team assigns console operators to process units based solely on the characteristics of the process units—their complexity, the number of control loops, and so on. However, a console operator is not just an operator of the process, but a coordinator of an operations team. If that team is too big or too small, the console operator's workload will increase, and the assumption used to allocate units may become invalid.

Physical layout of plant. The issues associated with locating a central control room in a relatively small, compact plant are very different than those associated with a large plant, particularly if there are barriers to movement to contend with such as terrain, railroads, waterfronts, or highways. Long distances (greater than about three minutes transit time) between central control room and units causes problems for which we do not yet have case studies of success. In these cases, a central control room must also be a *remote* control room, and it is not clear that information technology has yet advanced far enough to ensure success for large process plants.

ENSURING THE SUCCESS OF A CENTRAL CONTROL ROOM PROJECT

Assuming a central control room is appropriate, there are implementation issues that must be considered, but which are often overlooked.

Rotation of personnel among operating positions

In our experience, the dedicated console operator model is difficult to do well (unless units are highly automated and field positions are deliberately de-skilled). Good success stories in case studies are rare.

Sites that rotate operators among operating positions have had more success. Not only does this support the maintenance of skills among the operators, but also the transfer of knowledge as they take turns operating in the same areas and discuss the problems they encounter. Rotation is especially effective (but more difficult to implement) when consolidation is a goal, because operators need to learn new units quickly. However, rotation need not be homogeneous: The console operator duties can rotate among a subset of a crew, with that subset changing over longer periods of time. Although rotation is not a substitute for training, it is an excellent supplement

Need to support operations changes with systematic effort

The change that will ensue from a control room consolidation is difficult to overstate. Sites that have had success have focused on systematically supporting the change process with a wide range of ancillary efforts.

Procedures. The plant's procedure system usually requires comprehensive review, especially if consolidation of operating positions is contemplated. It is often the case that existing operations team have developed informal supplementary procedures, workarounds, or short cuts that need to be identified and either integrated into the formal procedures or consciously abandoned. Procedures that involve the interaction of different operators must be carefully audited. This is also the time to survey procedures to identify those that involve multiple units, and to determine if the coordination mechanisms within those procedures will still be appropriate in a central control room.

Incident and near miss reporting. The change to a new operating paradigm will require significant learning, and the incident and near miss reporting system is a key tool in that regard. Deficiencies in the system should be identified and eliminated very early in the central control room project. If a punitive culture exists, significant effort may be required to ensure that operating issues are in fact identified. Change in such cultures is usually very difficult, and organizational change efforts may be beneficial prior to starting a central control room implementation project.

Training. A systematic effort to identify training needs for the new organization should be an early action. Design and implementation of a training program is needed prior to the transition to the new organization.

The training program needs to include the definition of roles and responsibilities. Specifically, roles and responsibilities need to be defined in the areas of decision making, collaborative interactions, and new work practices and tools. In the area of decision making, operators need to know the scope and context of individual decisions and team decisions. For example, the final authority on decisions to reduce throughput needs to be clear. Similarly, one person needs to be designated as responsible for coordinating the activity of other operators in the field during an abnormal situation. When communicating problems, the console operators need to know whom to interact with, how their process can impact other areas, and what they need to communicate in collaborative interactions.

Cultural change. Most importantly, change agents need to be aware that cultural change does not necessarily come about through traditional training approaches or alterations of the physical space. Cultural changes require considerable effort to alter the values and beliefs engrained in each individual. Changes to values and beliefs require the implementation of programs that address individual employee motivations such a performance recognition, pay incentives, peer approval, pride in contribution to the larger effort, or avoidance of harm.

Workload factors. Central control rooms almost always result in increased workload even when consolidation of operating positions is not part of the program. A variety of measures, such as more formalized shift changes, better logging, alarm system enhancements, and better communications protocols, can minimize the impact. In addition, comprehensive upgrades in *field* ergonomics may be warranted, in order to increase efficiency in the field, and to ease coordination between console operator and field operator.

Communications technology. Moving console operators to a central control room requires more communications technology than better radios. Systematic measures must be taken to combat the inevitable loss of information that occurs when face-to-face communication is eliminated, and to ensure that information is widely shared within the plant. On-line procedures, remote video, field access to process information, and improved on-line access to a wide variety of plant information may be required.

Opportunity to supplement operations changes with changes in other areas

It is often the case that the full benefit of changes in one area are not realized as expected because of unanticipated bottlenecks that arise in other areas. Although a full analysis of this problem is outside the scope of this paper, three areas in particular deserve mention.

Maintenance system. As the new operational paradigm takes hold, maintenance issues may become a new bottleneck to more efficient operations. For example, a plant that has become operationally capable of more flexible operations (e.g., rapid changes in product slate) may be unable to take advantage of that capability if the necessary process or control equipment is out of service a large proportion of the time.

Increased instrumentation/automation The introduction of more efficient operations may change the relative benefits of instrumentation upgrades. If a plant can eliminate operations disruptions and spend a larger proportion of time running near capacity, optimization systems may be warranted even if they hadn't seemed cost-effective in the past.

Plant improvements. The potential benefits of a central control room may be easier to achieve if certain changes to the physical plant are made. For example, efforts to reduce inventory for economic reasons notwithstanding, the addition of intermediate storage between units may provide even greater benefits by helping to isolate process upsets. Alternatively, tighter integration may require providing operators with advanced automation tools to compensate.

The consolidation of multiple redundant functions (e.g., multiple vapor recovery units) may not be economically justified, but the addition of additional linkages between such similar units may enable a plant to respond with more flexibility to unplanned outages or changes in the economic climate.

Finally, increased sparing of critical equipment may also reduce stress on operators that is often caused when the plant is run in unusual configurations due to outages. Similarly, abnormal situation management tools can increase operator comfort with such operating modes.

METRICS

The current enthusiasm for the central control room "solution" is in part because the benefits are immediate *using existing measures*. For example, since well-known benchmarking services report console operator staffing levels, a central control room has a very predictable and immediate impact. Overall operational effectiveness, however, is less well measured.

A central control room is a very visible change, much flashier than, for example, sustained effort at improving procedures. Embarking on a central control room project clearly signals that action is being taken to solve a problem. It is a solution that is easy to make intuitive arguments for, and the benefits arguments can be intuitively persuasive.

Unfortunately, intuition is not always correct in large organizations. For example, we have observed people conclude that workers' failure to act appropriately in conducting routine pump preventive maintenance required improvements to the training program. However, it turned out that the failure had more to do with the failure of the plant to provide sufficient support for the practice than it did with workers' not knowing what to do. The workers did not have time to conduct the procedures given the design of the work environment, availability of tools, resources to execute the existing procedures and the priority given to preventive maintenance tasks. Plants need to focus on understanding the essence of problems and potential for real benefits.

In many cases, plants may need to create a metrics system in order to carry out a principled cost/benefit analysis before embarking on a central control room project. When this is true, it is also evidence of why change in that plant is difficult: If measures are lacking, it is nearly impossible for a large organization to be aligned enough to successfully carry out a systematic improvement program.

CONCLUSIONS

Process plants such as oil refineries are among the most complex systems on the planet, rivaling weapons systems, airliners, and manned spacecraft. Unlike those systems, however, process plants are sometimes not as well controlled. A primary reason for this is because they are operated by large organizations of people.

In airliners, pilots have the span of control and the tools to permit one individual to be truly "in control." In military systems, commanders have military discipline and the chain of command to permit one person to be truly "in control," or at least "in charge." In space operations, budgets permit extensive planning, significant redundancy, a large organization, and clear lines of authority, so again, the system as a whole is usually very well controlled.

Nevertheless, significant operational problems and occasional disasters occur in all of these systems. Airliners crash; aircraft carriers collide with their escorts; satellites are lost due to operational errors; spacecraft collide with space stations. By far the largest source of these incidents is this*: People are not perfect.* They are not perfect in carrying out routine operations; they are not perfect in responding to unexpected events; they are not perfect in handling major crises.

Organizations devote considerable effort to making sure that their systems are engineered insofar as practical to avoid the simple consequences of that fact. In process plants, there are multiple engineering solutions to the problem, including protective devices, shutdown systems, procedures, training, and organizational initiatives. There are also informal solutions, such as the operational experience and unit cultures that evolve of years of plant operation. By and large, these approaches are very successful, in that plants continue to improve.

The jury is still out on how a central control room can become yet another tool for improving operations. Intuitively, the advantages are obvious. However, the early experiences of the industry appear to us to indicate that this tool needs to be used with caution: The introduction of a central control room by definition disrupts many of the organizational systems that are in place to efficiently operate process plants. The significance of the disruption has been surprising, but plants are now in a position to anticipate most of the negative effects and plan to minimize their impact.