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Human-Machine Interfaces for Plant Automation

Samuel M. Herb, Author

- **Humans in Control**
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- **Video Monitor Hardware**
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Taken from the book: ***Understanding Distributed Processor Systems for Control***

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Humans in Control 8

Just as our present-day architecture grew out of simple controllers then to control systems and now to open control networks, our techniques for interfacing with the control process itself have been evolving as well. Since the beginning of mankind, humans have been making "stuff." The trick is to make the "stuff" the same way every time it is made. The intricacies of converting how you make the stuff consistently and repeatable is parallel to the way mankind has always interacted with the inanimate. It is imperative to understand this human process before any progress can be made in developing useful operator interfaces (and any other user interfaces) to make a plant *PRODUCTIVE* (remember that goal?).

The Process of Control

Much as in the act of cooking, ingredients are mixed for a length of time, and perhaps heated for a period of time until they are "just right," whatever "just right" is. If this person had an apprentice, he had to literally live with him. That's why apprentice programs lasted long periods of time, like seven years or so. The apprentice had to learn what it was that the master did when he made the stuff. How long did he do it, how much did he do it, what were the ingredients, and what changed when conditions changed, (e.g., if it was winter or summer, day or night, or if different kinds of wood were used on the fire, etc.).

And at one point the master would turn to this apprentice and say, "Charlie, come over here, look into this cauldron. This stuff is just right." Charlie would come over and look in the cauldron and see what "just right" looked like. Now he didn't always know whether he was looking at a texture or a consistency or a color or whether he was smelling it or feeling it or getting close enough to it to feel the temperature. It was actually a combination of all of these, and somehow Charlie had to understand what "just right" was every time it was "just right."

Figure 8-1. Process Control is the Art of Making "Stuff" the Same Way… Every Time You Make It!

If you tried to convey all of that experience through a sensing device, a measuring device, or some kind of display, you have the problem of sharing the sense of "just right" in the same way to everyone who observed the process. Unlike Charlie, who has seven years or more to learn what it's like, a control room operator of today will be a different person from one shift to the other, from one day to the next, or after many emotional strains. So somehow vendors must make existing technology convert all of those indicators of "just right" into whatever each individual can sense understand, and respond to.

Brown's Instrument for Repeatability

As time went on, the master might find a method for helping the operator understand this. For example one Eddie Brown in Philadelphia in the 1850s was managing a salt bath to temper steel. He wanted to assure that apprentice followed the exact same procedures as he. He capped one end of a pipe and inserted the closed end inward through the wall of the salt bath, which had had a metal rod of a different material welded on its inside end. The dissimilar materials changed lengths differently as the temperature changed. The rod would protrude from the open end of the pipe by different amounts as the temperature changed.

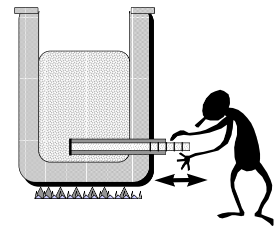

Figure 8-2. Eddie Brown's Instrument to Measure Temperature

When the temperature was just right, the master etched a mark on the rod, and he could say to his apprentice, "When that mark gets to the edge of the rod, the temperature is just right." That became both the sensor and the indicating device. In fact, as time went on it was part of a control system. The person doing this, Eddie Brown, repeated this in other vessels, and eventually began selling the device, forming the Brown Instrument Company, which later (in 1934) became part of Honeywell. This was the beginning of a series of many different temperature measuring devices using different forms and shapes. The point is that on this device, the user didn't know the precise temperature of the vessel. He did know, however, that the vessel was the identical temperature that it was last month or even last year. The whole key to industrial process control is *repeatability*, which is more necessary than the accuracy of absolute measurement. Oh yes, accuracy is involved, but it is not accuracy in the sense of an absolute temperature or measurement, but rather the accuracy of a measurement's repeatability.

Touring the Plant with All the Senses

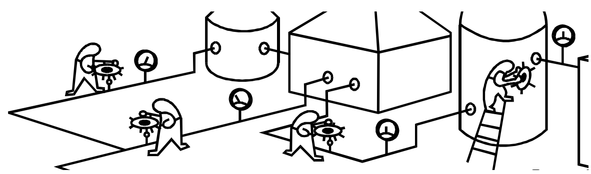

Figure 8-3. All of the Senses Were Used When "Touring the Plant"

Now this challenge of using the senses to determine the progress of any industrial process often required someone whom was the expert or the master. Frequently, as in Figure 8-3, he would tour the plant, look at all of the different parts of the process, and sense when everything was running smoothly, based on his experience. There would come a time when he would be walking through the plant and would determine that perhaps the conditions weren't so perfect. He would stop, listen, smell, feel, and look to see what had changed. Many times it wasn't obvious. He had to determine what was different this time, to make note of it, and to come up with a correction. As time went on, the capability of measuring different parameters was developed so sense and measure pressure, temperature, flow, pH and many more factors could be sensed and measured. These were frequently placed in the specific location near the process.

As we pointed out earlier, this was all a form of distributed control. These distributed sensors and measurements were brought into a local area on what was called a control panel. Sometimes there were several local control panels within a large plant because of the limitations on how far you could convey the measurement. Usually, this distance was limited because of pneumatic transmission lines.

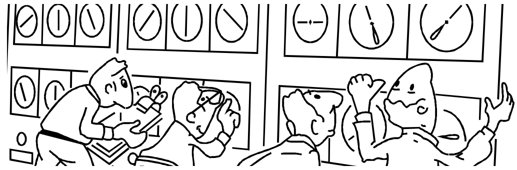

Figure 8-4. Pneumatic Transmission Allowed Local Control Panels

This transmission saved the operator some part of his tour of the plant, so that he could at least look at all the meter positions and recognize the appropriate measurements and with his clipboard make a note of them and compare them with the last time he made those measurements. He still had to tour the plant, but this time, it was only to adjust the valves and the other end elements to modify and alter the process—not to measure it.

Now you will remember, the whole journey recounted here was down the road to better plant productivity. Better plant productivity sometimes meant being able to make more of the product, and do it faster. This could only happen when the operator was able to observe the proper indication of the process conditions and be able to quickly respond to any change in the process. The faster he would recognize change and the faster he could respond to the change, the more confident he could feel in running the process "faster." Up to now, however, the operator's control room was quite frankly scattered about the plant, depending on its size and operations.

As electric sensors, measuring devices, meters, and transmission devices emerged over the years, it became easier to bring all the information to a central panel and even operate the plant from some central location (Figure 8.5). The challenge now was to make the plant values make sense when they were all jumbled together on this panel—because you now had more and more kinds of sensors and more and more of each kind to better measure what was

Figure 8-5. Electronics Made Central Control Panels Possible

going on in the process. This meant that the panel board layout was very critical. The various size and color and shapes and direction of meters sometimes were limited by the technology of manufacturing those devices. For example, gauges often would be concentric or eccentric depending on whether they were driven by bellows or bourdon tubes or other mechanical devices, which expanded and contracted, thus rotating needles in different ways.

Indications for Control of Process—Blame the Early Railroads

In the evolution of man's relationship to the inanimate, the psychology of conveying information has always been complex. The control of mechanisms and machinery in the industrial revolution as it occurred in the United States, first appeared publicly with the operation of the railroads. Now, railroads are a process. You are trying to move goods and people from one point to another, usually in multiple directions, usually on multiple paths, and in the least amount of time—not unlike what happens in a factory. To control the flow of traffic, which moved at different speeds depending on the locomotives pulling it or the weight of the train, a signaling system was set up. It consisted of a large ball suspended from a rope, which was raised or lowered through a set of pulleys (Figure 8-6). When the ball was raised to the high position, it was a clear signal to go, and when the ball was lowered the operator should stop his train. This was the origin of the term high ball as a signal to go. (How this relates to a certain alcoholic party drink of the same name, no one knows, but it can lead to some interesting speculation.)

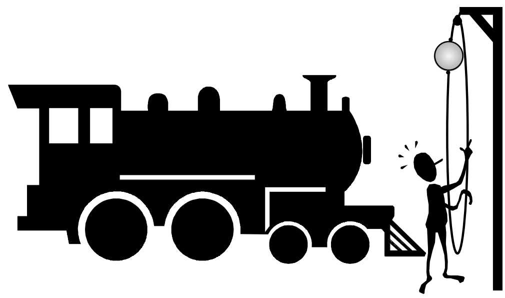

Figure 8-6. Highball: Up Meant Clear to Go

As time went on, a large board was put on a pole and pivoted so that when it swung upward it meant the track was clear, and when it was downward—as if to block the path—it meant stop. When nighttime operations were possible, the board was extended to the other side of the pivot, a lantern was hung behind it, and colored lenses were inserted into the board (Figure 8-7). This caused red to be on the top and green on the bottom, which is why most traffic lights and panel boards still use this orientation. We are still using today the signaling methods that were developed over two centuries ago.

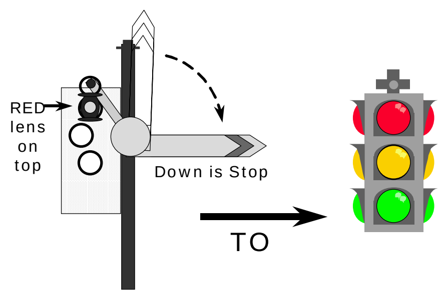

Figure 8-7. Highballs to Semaphores to Traffic Lights

These same signal conventions moved into factory production lines, a de facto standard if you will. People have become used to the fact that when the signal is up, conditions are good or improved, ready to go or full, or complete (Figure 8-8). The down direction means a warning or low, level is down, speed is down, temperature is down, and so on. So, a natural instinct has apparently been generally built into all of us that up is good and down is not so good or stopped. That impression affects how we view most things that operate

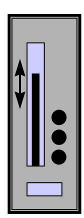

Figure 8-8. In Faceplate Presentations, Up is Generally "Good" (Full, On, High, etc.)

even today when we drive our automobiles or use household appliances. This simple idea should never be overlooked when designing devices to control and convey information to humans who are operating those controls.

Back to Control Room Panels

The layout and organization of a control panel is very essential in helping understand conditions in the process itself. How instruments are clustered and the way those clusters are placed on the control panel give a better understanding of what is happening within the process. Quite often, some flow lines and diagrams are also drawn on these panels, but, of course, these are static, so the ability to understand what was happening in the process is somewhat limited to merely the gauge positions. As plants and processes grow larger, so also do the control panels. Sometimes they became so large that operators would sometimes literally navigate them on roller skates.

To understand what is happening at all ends of the process, alarming devices and alarming annunciators already very important. Flags, bells, klaxons, and other such annunciators are used to alert operators to what part of the panel to run to next to determine if anything that is out of normal. This in turn limits how a complex plant can be run, and of course that limits the productivity of that plant. As it became economically possible to add more sensors and more kinds of sensors, it was necessary, of course, to manage all of that extra data.

This led, fortunately, to the advent of the computer, which offered an opportunity to manage all the data and present the operator with only the part that was important to him or her. The introduction of the video screen around the same time made it possible to bring all of this data to the operator rather than have the operator run out to all the data. So, unlike traditional control panels, the video screen allowed the control panel to come to the operator and make it easier for him or her to look for alarms, chains of events, and all the changing parameters. *BUT REMEMBER*, isolated in the control room the operator no longer has all his or her senses working as when touring the plant (Figure 8-9). Any operator interface must therefore replace those inputs!

Figure 8-9. That Computer Screen Must Convey All the "Feel" of Touring the Plant!

Remember: It is, and has always been, the responsibility of the system engineer to design *ALL* of the control system, especially the way in which the operators fit into the operations plan! In the past, there was little the system engineer could do except make the most out of the instruments and instrument features provided by individual vendors. There was no way to change the faceplates; for example, one could perhaps just paint some lines on the panel in which they were mounted. Today, with the use of video systems, the possibilities have become so expansive as to be confusing. But the responsibility to design everything is still there, even if it is little understood. Maybe the many words and pictures presented will help promote that understanding. User interfaces are as important as the control strategy in improving plant productivity!

9 Video for User Interfaces

The advent of both computers and video screens have made a lasting impact on running processes. In fact, we have hardly scratched the surface of how to use these emerging technologies!

Computers, of course, have been invading all parts of the process plant. Computers are used for finance, order entry, inventory turns, production management, product management, process management, and equipment management. All of these are generally considered to be different and independent functions, and they are often run by different departments using different computers.

But today, computers are becoming more "general purpose" in the construction of their operating system platforms. Distinctions between systems is now primarily a result of the application packages that run on them. Of course, it is necessary to "isolate" computing functions for such needs as having "real-time" control. Nevertheless, the use of multiple microprocessors and network communications makes it possible to share data among the many different groups. But the *presentation* of the data, usually through the video screens of "workstations," varies depending on the function of these different groups.

Video Display Workstations

Interaction with process control generally falls to proprietary operator stations, commercial workstations, and personal computers (PCs). The role of a proprietary operator station is now leaving us in the late 1990s, but we have had several decades of creating and installing large quantities of operator stations to deal with. Many tens of thousands of these continue to perform the real-time operation of process throughout the world.

Commercial workstations were designed for business transactions that could take minutes, or hours, even days. These are not practical time frames in which to run most processes that need interfaces to work within a half-minute or few seconds. As a result, vendors had to make their own unique modifications to cope with the real-time data.

Average computers, and certainly the home computer, could not work with the same kind of graphic processing needed in typical process operation. Operator workstations must also be able to link to the real-time data, receive data as it happens, and cause actions exactly when needed. The network and display capabilities of the average PC could never meet those requirements. This limitation is rapidly changing as the 1990s draw to a close, and we are already seeing some rather dramatic changes.

Through changing technology, we are beginning to see the convergence of what used to be the separate fields of television, computers, and publishing (Figure 9-1). By the millennium we will see computers, television, and publishing functioning within the same kind of electronic hardware. That hardware will also make these *FUNCTIONS* indistinguishable!

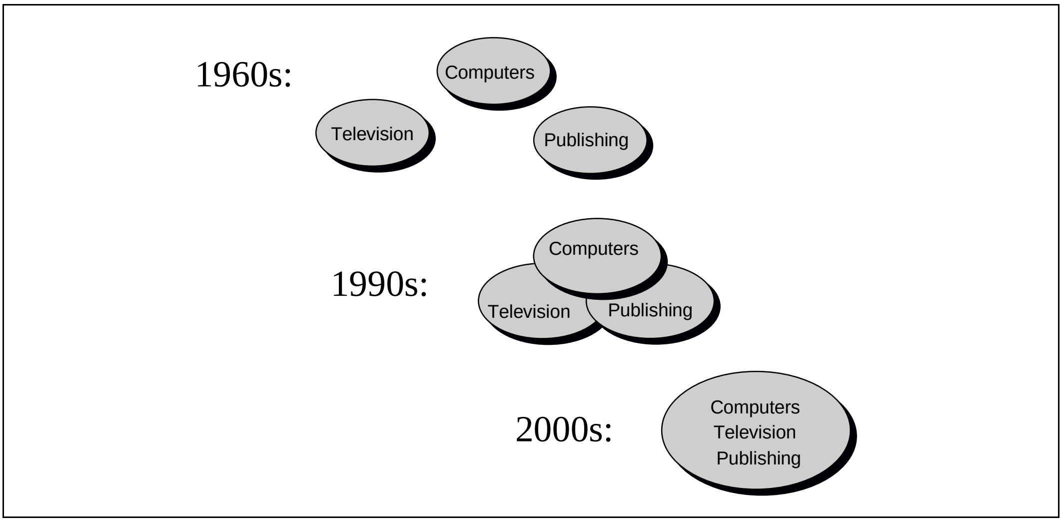

Figure 9-1. Changing Technologies are Causing Workstation Differences to Disappear

This convergence will have a very significant effect on the automation systems as well as human-machine interfaces (HMIs) It is influencing interface capabilities and it's even influencing how we communicate with each other, let alone how we communicate through machines for processes control, factory operations, and businesses.

The workstations of the late 1990s are far superior to today's personal computers..so far. They're replacing many full mainframe computers. These workstations didn't even exist in the mid-1980s. Workstations now provide incredible processing power at low cost; they offer high-resolution graphics, and they are consistent and easy to use. They can be networked. Their performance can be expanded merely by adding newer processors as they are developed. In this way, the user can upgrade without replacing the entire computer and all of the configuration in it. These workstations can do multitasking, which means they can perform multiple tasks in a very short time on the same microprocessor. They typically run in UNIX or some variant of it, but the NT platform is rapidly overtaking UNIX.

Workstation Development

- Far superior to today's desktop PCs (so far)
- Replacing minicomputers
- Did not even exist in the middle 1980s
- Incredible processing power at low cost
- High resolution graphics
- Consistent, easy to use
- Can be networked
- Performance can expand
- Typically run UNIX or variant
- Multitasking (Figure 9-2)
- Expect Windows NT to make more change

The Future Continues to Develop

Most DCS vendors have grown away from providing workstation hardware of their own design. With the improvement of processing power and memory in those stations now provided in general-purpose computers, most vendors found themselves competing in both price and availability. This is unnecessary. The business of controller companies is just that business—controllers. With such good workstations already being made, most vendors have designed software that works with one or more models. With the arrival of software graphics packages, even those are now being carefully incorporated.

As PCs develop more processing power, capabilities, and memory, the scene will change again. Some workstations have been made up of a cluster of personal computers to help overcome the need for real-time data handling. This again makes the workstation itself distributed. Commercial platforms are becoming available that assure the expandability of both capacity and capability without replacing the system. Multitasking of single processor allows many functions to be performed in what appears to be concurrent (Figure 9-2). Working with multiple processors, it really is done concurrently. This helps bring the cost of the workstation down, and the workstation is now approaching the cost of a PC. Of course, the more function you need and the more power you add, the more the price will increase. Workstations allow the user to control and monitor more processes simultaneously, to toy with more "what ifs," to perform a detailed analysis of data, and to do all of this at the same time.

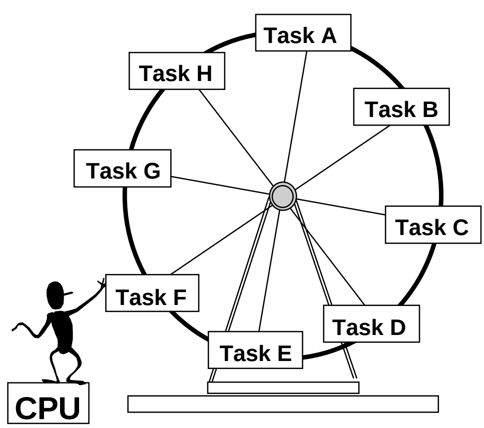

Figure 9-2. Multitasking of Several Functions with a Single Processor

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Multiprocessing—Where the operating system allocates different programs and tasks to different processors without intervention by the operator, saving considerable amounts time.

Multiprogramming—The ability to run multiple copies of an application program on a single computer.

Multitasking—The concurrent execution of two or more tasks or applications usually separate but interrelated by computer at the same time; may also be the concurrent execution of a single program that is used by many tasks (not always real-time).

Context switching multitasking—Multiple applications can be loaded into the computer, but only the one in the foreground is given processor time. This simplest level of multitasking is how Microsoft Windows works; that is, once an application is in the foreground all other applications stop.

Cooperative multitasking—Common to the Macintosh platform, this is a step above context switching; background applications are given processor time but only when the foreground task is idle and allows it, such as while waiting for a keystroke.

Time-slice multitasking—The truest form of multitasking, found on sophisticated workstations, in which each task has the microprocessor's attention for a fraction of a second, and then tasks are then performed in sequential order by priority.

Parallel processing—The concurrent or simultaneous execution of two or more processes or programs, within the same processor, as contrasted with serial or sequential processing.

Coprocessing—A microprocessor that is dedicated to only the task of performing numeric functions very fast and accurately. The coprocessor works in conjunction with the "normal" microprocessor, offloading it to dramatically improve the performance of all the tasks required of the system. Coprocessing is especially useful when you are using math-intensive programs such as spreadsheets and CAD functions.

The demand for more capability and capacity at lower prices will bring about change as nonindustrial usage increases. The higher volume of sales found in the general marketplace will justify workstation vendors in making the effort to improve both function and price.

Workstation Advantages

- Increase and improve users ability to:
  - — Design control strategy
  - — Design functional screen views
    - Operator
    - Engineering
    - Maintenance
    - Business
    - etc.
  - — Deliver completed project faster
  - — Upgrade performance of process

Workstations also increase and improve the user's ability to design control strategy and, in the same machine, design functional screen views. These views within the same station, can be separate for the operator, for the engineering department, for the maintenance department, for the business people, and so on. The views can focus specifically on the required jobs without confusing the user with meaningless data. Sometimes too much data without explanation can cause a well-meaning, but disastrous action. Security codes can be incorporated as passwords so this separation is assured.

Properly used, workstations can be instrumental in delivering completed projects faster. Not only can the configuration process allow you to easily and rapidly "rearrange" control strategy, there are also system tools to help you analyze the appropriateness of the strategy selections and offer alternative suggestions. This can be a part of the "what ifs" which can be incorporated into the control system operation. The workstation can also be a part of the "loop testing" that can be done at the factory test before shipment, saving you valuable time.

Workstation platforms today can allow you to upgrade hardware, such as the latest microprocessors and memory media. This can improve performance without altering the software, sometimes even while the process is in operation.

"Look and Feel"

Graphical user interfaces (GUI) are characterized by their "look and feel." This includes the visual appearance of the objects, such as menus, buttons, dialog boxes; and how selections are made from menus; and so forth. For example, does a pulldown menu appear when the mouse button is pressed or must the mouse be clicked over a menu button? Does stay down while the mouse button is pressed, and is the selection made by dragging the pointer over an entry and releasing the mouse button or must the mouse button be clicked?

During recent years, there have been so called GUI battles, in which different vendors have tried to push their "look and feel" as the standard. Motif is the "look and feel" specified by the Open Software Foundation (OSF), which has Digital, Hewlett-Packard, and IBM behind it. Open Look was the "look and feel" specified by UNIX International, which has Microsystems and AT&T behind it. For a long while it appeared that the emerging de facto standard was Motif. In March 1993, announcements were made for a unified UNIX GUI that would be adopted as standard by the X/Open Consortium. The members of the coalition backing this standard included IBM, Hewlett-Packard, Sunsoft, UNIX System Laboratories, Univell, and the Santa Cruz Operation.

In X-Windows, an application's look and feel come from two sources. One source is the look and feel provided by the window manager that is running on the machine where the applications windows appear. The window manager determines how the desktop paradigm is implemented. That is to say, it determines how the windows are moved around, restacked, converted to an icon, and resized. The window manager manages the windows by placing a "wrapper" around each application's windows. These "wrappers" are referred to as "window decorations" and usually contain a button that pulls down a menu displaying choices such as converting the window to an icon or exiting the application. The wrapper usually contains handles that may be grabbed with the mouse to resize the windows.

The way these figures look, rectangles versus oblongs, two-dimensional versus three-dimensional, and so on, and the way they work, click versus press-and-drag release, and so on, account for the look and feel that comes with the windows manager. The other source of the "look and feel" comes from the application itself, that is, what is inside the "wrapper." If an application is built on a "tool kit," such as Motif from OSF, or Open Look, from Sun, it will exhibit the look and feel of that tool kit.

If a vendor of the control system uses the X-Library calls directly, however, that vendor can define its own look and feel. This has some advantages, especially in the area of process control.

X-Windows in Process Control Systems

As mentioned earlier, X-Windows is a graphical system rich in functionality. Yet something as common to the process controls industry as blinking colors, which are used to denote alarm conditions, is not a standard feature of X-Windows.

Process controls tend to push the capabilities of graphical systems in the following areas:

- Display call-up time and display refresh time
- Real-time updating of many data points, alarms, and dynamic graphical objects
- Displaying large amounts of graphical and textural information simultaneously
- Having the ability to switch quickly between displays from different applications
- Screen resolutions for clear presentations of very dynamic data

Neither the time element or screen resolution are directly addressed by X-Windows. These are hardware issues. It is really the development of low-cost but powerful workstations that has enabled X-Windows to be suitable for process control applications. One advantage of X-Windows is that the applications can be independent of platforms. As mentioned earlier, once an application is developed it can be run on different platforms, which can be selected based on the desired level of performance or on budget constraints.

For many applications, the low end of the middle-range workstations is quite sufficient. If more performance is needed, the same application can be used with a high-end workstation. If less performance will do, such as terminals, used just to monitor a process from a remote location, a low-cost X-Window terminal can be effectively applied. Even personal computers with X-Windows software can be installed and used.

Process control needs to have the ability to display lots of information simultaneously and to switch quickly between different displays. X-Windows offers multiple windows at the same time and the ability to quickly move, resize, convert to icons and restack the windows. With this kind of functionality, it is possible to have a process graphical display in one window while having a systems management display in another. At the same time, alarms could be displayed in yet another window and a display builder configuration in an additional window. Keep in mind that all of this power does not come without cost. In this case, the cost is the need for higher network loading and processing performance for all the increased activity.

Use of Video Screen also Changing

- Originally for peering into process itself
- Then replaced static graphic panels
- Much later to operate plant from faceplate views, replacing panelboard instruments, providing
  - — Overviews
  - — Groups
  - — Details (points)
  - — Alarm lists
- Currently includes dynamic graphics with continuing improvements to interaction

Role of Workstations Is Also in Transition

During the 1950s and 1960s video was used in the control room to show the process itself. This was especially useful when the process was at some distance or was inaccessible, such as when viewing the interior of a furnace. Early uses of video to build and show graphical panels during 1960s and 1970s were to save money in the changing of the artwork needed on traditional panels. But even these took little advantage of the dynamics available, mostly because of the massive and expensive programming required. However, no one considered using video techniques for actual *CONTROL* of the plant. Only when *CONFIGURABLE* techniques rather than programming become available could any kind of interactive graphics be considered practical. We also had to learn how to *USE* the new technologies.

How many video monitors are needed in the control room? In the late 1970s it was assumed you needed one for the overview monitoring of the process, one for the working displays (group views), and one for alarm lists. With the emergence of windowing technology in the late 1980s and early 1990s, these functions could easily be performed on a single monitor. There is, however, the consideration of task analysis. How many individuals are needed to operate the plant or process, and what functions are they to perform? The response given to these question will tell you how many video monitors you need in the control room.

As large screen technology and large projection techniques improve, the use of semi-permanent displays for monitoring overall plant performance may reduce the need for a hierarchy of screen views. This was the purpose of the traditional dedicated operator panel board and control desk instrumentation used in the past. New discoveries involving the way people interact with the processes themselves will have a strong influence on the number and locations of video monitors.

Adjusting Technology to Fit— Use the Medium 10

A number of years ago, Marshall McLuhan of the University of Toronto wrote of society's learning curve as it adapted to each new media type to convey information. His observations of how the development of printing dramatically changed our society as we moved from oral communication to written (and visual) communication. More dramatic social changes will come as we return to oral communication but conveyed, visuals (radio, motion pictures, television). As an example, he described the way visual communication evolved in the entertainment and advertising industries. According to McLuhanan, "The medium is the message" (Figure 10-1).

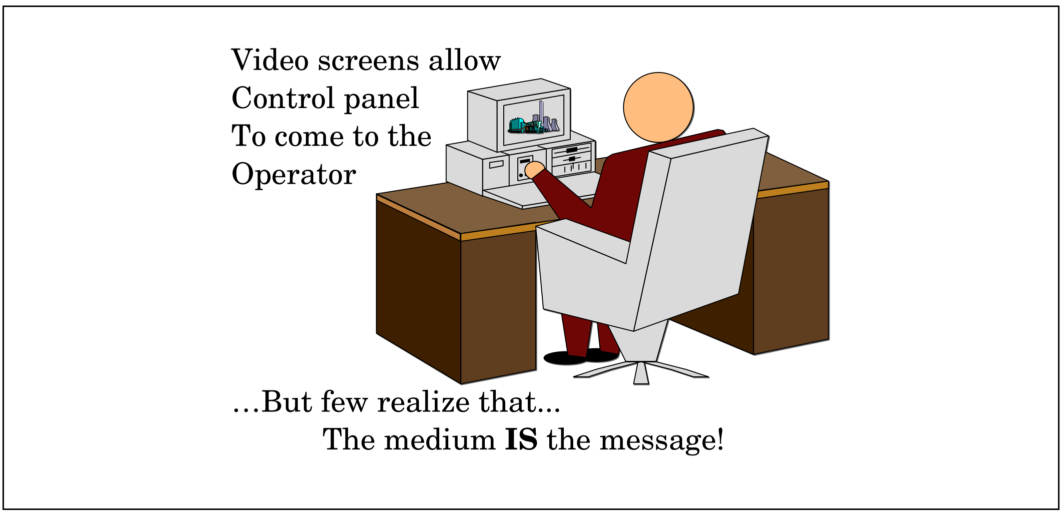


Figure 10-1. Coping with New Technology for Shared Human Interface Displays

It is important to understand how people respond to different media used to communicate between the process and those who try to understand and control it. We are currently experiencing many significant changes in the control room. Keep the control room in mind as consider at the following changes in the entertainment industry, which has also been undergoing great change during this same period of time. Look for all of the concepts to that relate to process control

Theater

In the old control room there was a long panel with meters and gauges but no graphics. In the theater is a stage with a backdrop, but there is very little detail and little, if any, reality to the scenery. The actors convey some of the ideas through their costuming and their positions on the stage, but mostly they convey ideas through their emotion and how well they act. The audience is engulfed in the emotion of that theater. The actors had to learn how to perform in that emotive way so they could convey the full impact of what they were saying. Remember now, it isn't the words that are used, it's how they're said and in what context. The lighting and perhaps some music contribute to the atmosphere. If the actors are any good, within about fifteen minutes of the play's start, the audience will have a pretty good feel for what is going on, and few will notice the lack of scenery detail on the stage.

Black and White Cinema

When the cinema was invented, the moving pictures were in black and white, and many more details were visible in the background than in theater. All the actors were usually viewed close up. Because stage actors learn to play to the full audience, including the balcony, and are never really seen "in close up," at first the actors in the cinema looked like they were overacting, with wide sweeping gestures and exaggerated expressions. The makeup stage actors wore was also to convey their emotion across the length of the theater. That makeup looked a little garish on the black-and-white screen, although to be sure in those days some extreme makeup was needed to overcome the contrast problems. In short, the cinema this all required a very new way approach to acting. It took years for the industry to adjust to the new techniques and try all the possibilities. Some actors could not do both stage and screen, so they only performed in one medium. Some could never make the transition at all.

Black and White Cinema with Sound

Before long, black and white cinema included sound. This novelty was quickly used in all pictures, with as much sound as possible—lots of talk, lots of music, lots of everything. It was years before certain producers and directors, such as Alfred Hitchcock, discovered that information could be conveyed with *silence*. By carefully placing the absence of sound, the emotions of anxiety or anticipation, or fear could be evoked to convey information that otherwise wasn't there. This again required a very approach to acting. Again, it took years for the industry to adjust to the new techniques and try all the possibilities. And again, some actors could not do both "talkies" and silent pictures, so they only performed in one medium.

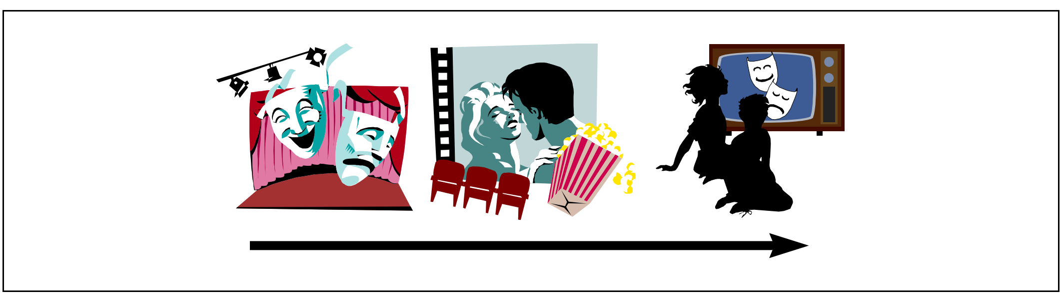


Figure 10-2. Each Medium has Unique Characteristics and Capabilities

Color Cinema

Then came the technology to color motion pictures. The problem was now that everyone filled the screen in like a coloring book, In the landmark film, “Gone with the Wind,” the color was used to evoke emotion, like the oranges and reds during the burning of Atlanta. Though not everyone used color well, outdoor scenes could now be far more effective. It took years for the industry to adjust to the new techniques and try all the possibilities. Some studios never made it.

Radio

Many of the actors and entertainers in the medium of radio had to learn to “speak in pictures.” Those who remember old radio shows, recall envisioning what was going on just by the way the actors expressed themselves, and their choice of words, and the sound effects around them. The audience participated with their imagination to fill in the details. Radio program sponsors who understood this phenomenon did very well selling their products. This again required a very new way to act. It took years for the radio industry to adjust to the new techniques and try all the possibilities. Some actors could not do both radio and cinema and so they only performed in one medium and some could never make the change at all.

Television

Television was just “radio with picture,” until the industry learned how to use exploit the fact that this was a very different medium. Cinema keeps the audience focused by using a dark theater with a huge screen, which today virtually wraps around the audience. Television was a small screen in the middle of a well-lit room in which much unrelated activity might be going on. A far different kind of programming was needed here, especially to keep the audience’s attention on the same channel for all three of the prime viewing hours. Lot of dynamic action was required, with changes every four seconds or better. “Made for TV” doesn’t mean they took out the “dirty words,” it means they had to reformat the image to a different aspect ratio, edit to different time formats, and in the case of many wide-screen films decide which part of the overall to select for the “tiny screen.” This process requires about forty hours of effort for every one-hour broadcast. To keep the audience from switching to competing channels for the three hours primetime, studios review every minute of what goes on the air, including commercials. To return to process controls, some control room operators must be in front of *THEIR* “television set” for eight hours! What has been done for them? And, unlike the TV Viewer, operator loses if operator loses attention, the very expensive product could be destroyed or worse, even the plant could blow up!

> Psychologists tell us that you *cannot* pay attention to the little tiny screen called a TV for more than a few minutes. Commercial video studios spend over forty hours of preparation for every one on the air just to keep your attention for three hours of prime time. So what have you done to keep your control room operator’s attention during his or her eight-hour shift?!

Life Is Not Just Video Games

We could go on to discuss the ramifications of videotapes, computer games, virtual reality, and so on. However, the point is that the video screen is a vital, critical link in plant productivity. Most people have no idea how best to use this vital tool! While the plant engineer is creating a critical control strategy, someone says, “Oh, let’s get some co-op student to crank out a few pictures.” It is quite possible that some co-op students could do an even better job than the manager! The manager probably has not considered that the *PRESENTATION* of information to the operators may very well be half of the entire equation of improved productivity for the process or plant.

Picture, if you will, using your video screen to “walk through your plant.” With today’s technology it is possible to “walk” through the piping and vessels looking for leaks, hot spots, or damaged vessels and equipment. This is already being done wholesale in the video game industry! What’s wrong with this picture?

What you must have in every system is *REAL* feedback to the operator regarding the conditions of the plant. Picture walking through that pipe again. You see a leak thirty feet down from that elbow, at two o’clock high. Now, how do you know that leak is precisely there? There would have to be a detector of some kind at every inch, both laterally and around the circumference, and for every appropriate variable—temperature, pressure, and so on! This is not very practical and certainly very expensive. I never want to say never, but the technology to do this just isn’t there right now. Unlike computer games, operator stations have to have their screens “wired” to a real process (Figure 10-3).

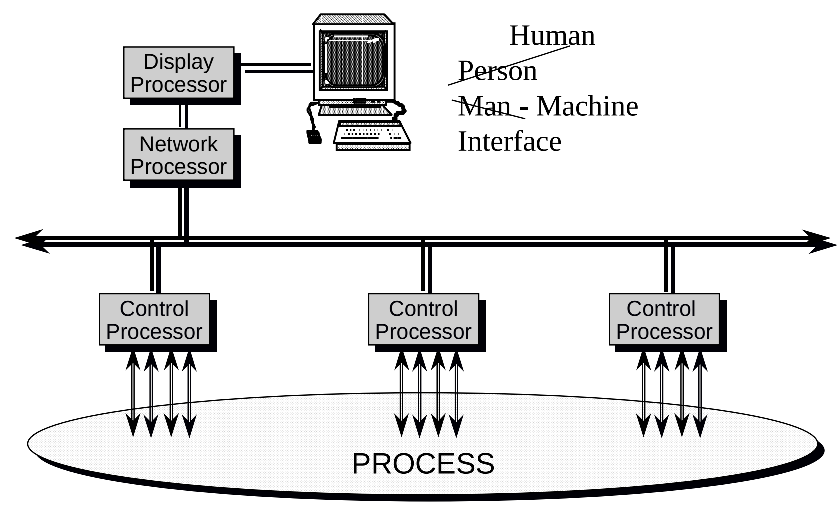


Figure 10-3. Unlike Video Games, the Screen is “Wired to the Process”

The big difference between home computer graphics and a process operator station is that the operator station must do the following:

- Link to real-time data
  — Receive data as it happens
  — Cause actions exactly when needed
- Not allow display and network performances to limit each other
  — High activity of one processor should not slow down the capabilities of the other

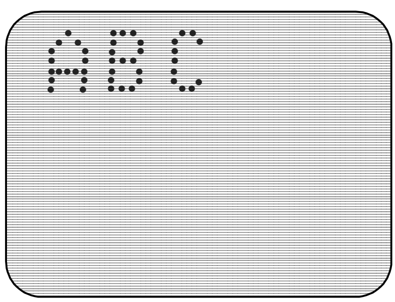
11 Video Monitor Hardware

Just some more "nuts and bolts" on what is rapidly becoming commodity status; that is, the hardware for the workstations. At one time these were rather proprietary with each distributed control system. For some time now all vendors of control systems now merely purchase assembled monitors from any of several suppliers of video equipment. There are many tens of thousands of monitors of earlier technologies that will continue to be operating for many years to come. We discuss in this chapter some of their characteristics.

Screen Size and Resolution

Typical video screen sizes are 19 to 20 inch resolution diagonally and for most purposes this is quite adequate for most consoles. It is not unusual to find a 25 resolution diagonally inch screen or even 40 resolution diagonally inch screens. Projection systems, of course, allow an even larger community projection, perhaps along a wall. Considerations to keep in mind for the console itself include the density of the pixels (dots) and the amount of colors controlled by the processor within the video electronics.

In the mid-1990s typical density had been an array of 640 × 512 pixels, with 1,280 × 1,024 in a high quality screen. By the end of the 1990s, 1,280 × 1,040 is standard. Of course, the computing requirements increase with the density and therefore the cost as well. Like everything else, as the cost of processing power comes down, the higher density machines will increase in availability.



Raster Scan Character Generation

Figure 11-1. Scan Lines are Part of the Screen Resolution for Characters as Well as Pictures

Higher density cannot be achieved without increasing the raster scan across the screen. This is essential to furnish higher graphic resolution. Computer monitors are made to provide denser raster scans than television sets designed for commercial broadcast. Home television sets are limited to broadcast standards, otherwise they could not produce a recognizable image from the received signal.

Commercial broadcast standards vary, and they cannot simply be changed without preventing huge numbers of peoples from viewing. These standards are as follows:

- **NTSC (National System Television Committee)** = 525 lines, 60 Hz, 110 Vac. The world's first compatible TV service, introduced in 1953 and used in North America. "Never Twice the Same Color."
- **PAL (Phase Alternation Line)** = 625 lines, 50 Hz, 220 Vac. Introduced in 1967 and used in the United Kingdom and Europe. "Peace At Last"
- **SECAM (Système Electronique Avec Memoire)** = Introduced in 1967 and used in France and Eastern Europe. "SomEthing Contrary to American Methods."
- **PAL-M** = 525 lines, 50 Hz, 220 Vac. Used in Brazil. "Pay A Little More."
- **HDTV** = High Definition Television with a pixel resolution of 1,920 × 1,080, HDTV is still a broadcast issue (transmitters, receivers, and a large enough audience to justify). The higher volume of commercial products will probably significantly lower costs of current high-resolution monitors now used with computers. There is a very good possibility that other new technologies will emerge from the HDTV market that will be useful in the control room.

Raster Graphics

Tens of thousands of control systems already in operation around the world have character-generated screens that impact both how the characters can change size in a zoom and the monitor's ability to create graphics. Raster graphics, as this is called, require an *x-y* matrix to define the location of the pixels needed to turn each dot on or off. Characters are defined as a single zone or in some systems as a cluster of zones. To further save memory, the pixels are managed within these zones or clusters. Fonts are a fixed size, so when they are "zoomed" the fonts in the particular view may bounce to the next nearest size, with mixed results.

As long as characters are being displayed, the use of alphanumeric characters to control the color for this array is quite suitable. When used for trends, graphics, or piping and instrumentation drawings (P&ID), the character oriented approach requires that these individual characters be linked together to form the graphical display. If the type of characters used matches those needed to construct the desired display, the results will be acceptable. Otherwise, the display will look quite ragged.

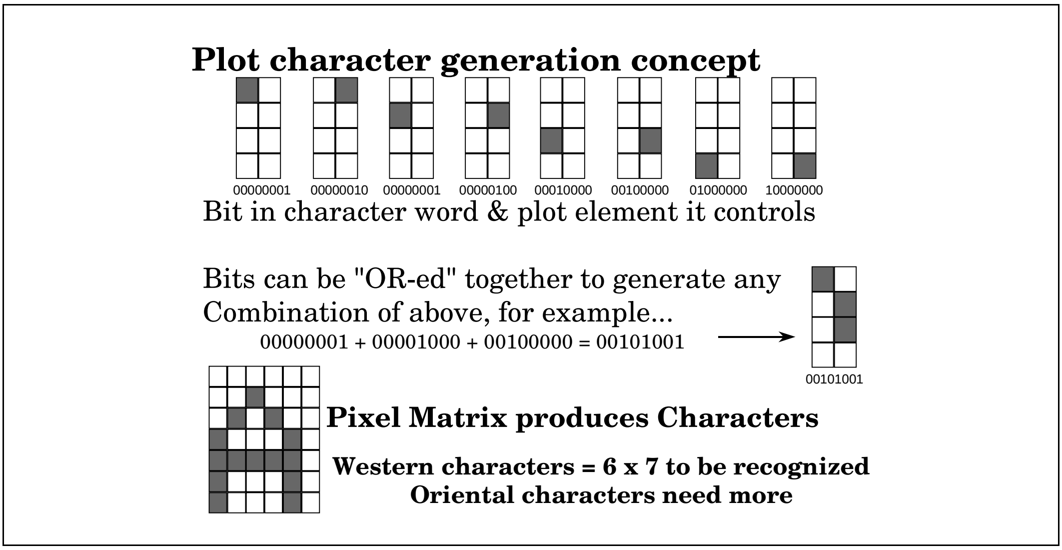


Figure 11-2. Raster Graphics to Plot Characters and Character-Based Graphics

Because of the limits in memory and processing power when most of these systems were designed, each “zone” of pixels typically could be switched to only a single color. If two intersecting lines passed through the same zone, the last selected color “wins,” leaving irregular spikes (within each zone) along its length. Clever placement of lines is needed to avoid this (such as intersecting at the corners of the zones).

Western characters are constructed more simply and require fewer pixels than Eastern language characters to be readily recognized. The characters themselves represent only a portion of a word and several of these characters in a string are used to complete any given word. Oriental characters need more pixels to define their image because those more complex characters represent entire words and phrases and require more pixels than if the same thought were expressed in Western form. The complexity of Oriental characters led some Asian vendors to create systems sold and used in Asian countries, that displayed Western characters and Western transliterated forms of Oriental words. This use of Western phonetic words for Oriental sounds was just to save “real estate” on those screens.

Vector Graphics

In contrast to raster graphics there is vector graphics, a newer technology, that does not define the location of pixel switching in the same way. When defining a line, vector graphics first places end points and then it “connects the dots” to fill in that line. Treated as line segments, rather than individual pixels, they allow a more flexible size of fonts because they can be changed to “any size” (nearly). As a result, they can take on far more shapes and stay smooth. This allows many more illustration techniques, as well as the use of a complete range of type fonts, including some of the more complex characters used in many countries around the world. With vector graphics, these characters all tend to “zoom’ much better, although there are limits.

Cathode ray tubes (CRTs) wear out over time; they will get dim and lose focus. All systems must support the replacement of CRTs through a standard video format. Users should plan on replacing their CRTs at a minimum of five-year intervals.

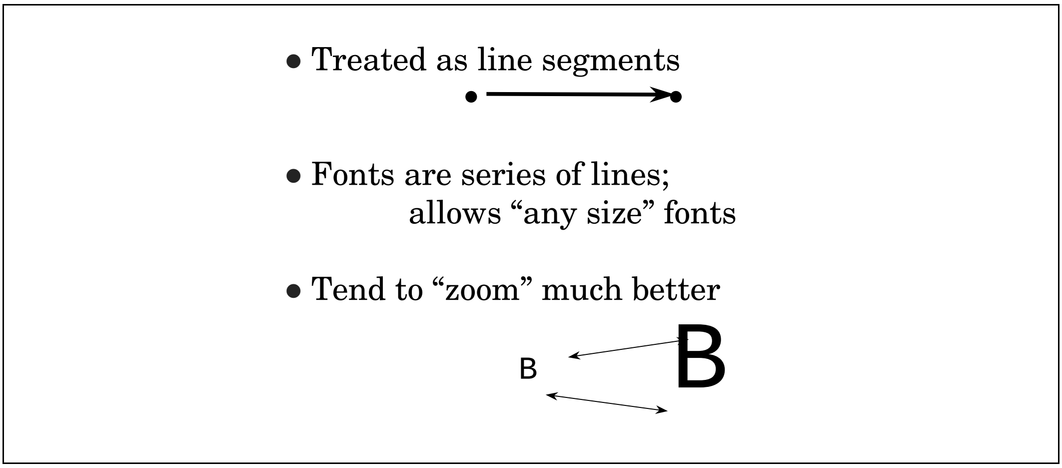


Figure 11-3. Vector Graphics Provide Smoother Lines

The Future of Cathode Ray Tubes (CRTs)

Flat panel displays (FPDs) are rapidly catching up to CRTs in their acceptance in the control room. Some of the many issues that need to be considered are screen brightness, for visibility in bright rooms, and operator visibility at a wide range of viewing angles. The end of the 1990s, the CRT is still the most flexible and least costly solution for complex control system monitoring. As time goes on, of course, the increased use of FPDs in domestic equipment and other commercial enterprises may eventually change the economics of this state of affairs.

A rough estimate of the mean time to failure (MTTF) of an operator station (the CRT and the electronics to drive it) is about 40,000 to 50,000 hours (five years), excluding support items, such as hard drives, keyboards and other input devices. Electronics that are subject to factory floor or outdoor environments and require protective enclosures will likely have reduced ratings.

Much More to Video Monitors

Explaining the many technical aspects of video monitors in depth is outside the scope of this book. Because they play such a vital role in distributed processor systems, you will encounter many terms that need only to be identified, rather than a lengthy explanation. This will no doubt occur when some technician is installing your system, and you find yourself intimidated by technology. For this reason, I have added the following list of definitions:

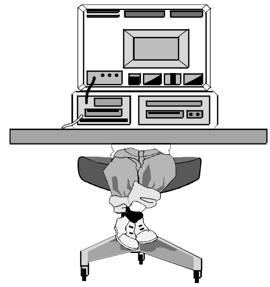


Figure 11-4.
Your Video Technician May Try to Intimidate You with Terminology

active-matrix displays (AMLCDs)—A liquid crystal display (LCD) technique in which the pixels on a screen are controlled by voltage signals applied in rows and columns. An array of thin film transistors (TFTs), one per pixel, keeps the pixels energized at all times with no need to reenergize on each scan. AMDs thus respond faster and are brighter than PMLCDs (see *liquid crystal display* and *passive-matrix displays*).

additive primaries—In color reproduction, red, green and blue; when lights of these colors are added together, they produce sensation of white light.

AGA (Advanced Graphics Architecture)—A chipset for driving high-resolution multimedia tools.

antialiasing—In digital graphics, a technique for reducing the jagged appearance of aliased bit map images, usually by inserting pixels that blend boundaries, especially color boundaries.

artifact—In video development, the area within the image or characteristic of the image that is the result of system limitation, for example, weird shimmering, jaggies, or other undesirable distortion. Also in digital graphics, image imperfections caused by data compression.

ATPG (Automatic Test Pattern Generator)—Used in video raster alignment.

AVD—Audio/video driver.

AVI (Audio Video Interleaved)—A digital file format by Microsoft developed for dynamic graphics.

AVK—Audio/video kernel.

AVL—Audio/video library.

AVSS—Audio/video subsystem.

bit depth—In digital graphics, the number of bits used to represent the color of each pixel in an image. A bit depth of 2 = black and white pixels, 4 = 16 colors or grays, 8 = 256 colors or grays, 16 = 65,536 colors, 24 ≅ 16.7 million colors, and so on.

bit map—In computer imaging, the electronic representation of a page or a chosen area of a page, or illustration indicating the position of every possible spot (zero or one.) A bit map is pixel-based (typically higher resolution on video screen) rather than object-oriented (typically higher resolution on printer).

brightness—also luminance; in video displays, the greatest light that a monitor can emit without losing focus; measured in units called footlamberts.

CGA (Color Graphics Adapter)—A video standard (for IBM PC in 1981) offering 320 × 200 pixels with four colors, or 640 × 200 pixels with two colors; in text mode, up to sixteen possible colors; see *EGA, PGA, SVGA, UXGA, VGA, XGA.*

CLUT (Color Look-Up Table)—Used by a video display station to define its color palette to use an 8-bit or lower digital image file.

CMYK (Cyan, Magenta, Yellow, Black)—Model or color space to convey color information; combining differing amounts of these *subtractive* secondary colors produce all the colors in color space; used by most printers, it works by starting with all light waves (white paper) and then *subtracting* quantities of cyan, magenta, yellow, and black wavelengths with pigments, (theoretically, maximum of CMY produce black, but inks are not pure so usually result is muddy brown, hence addition of black); compare with *RGB*.

color depth—In video development, refers to the number of bits of data used to define the pixels' color (8 bits = 256 colors, 16 bits = 65,536 colors, 24 bits = 16.7 million colors).

component RGB video—In video development, red, green, blue, and luminance signals are processed as separate signals (or components), thus achieving higher quality; generally found in professional-grade equipment; see *composite video and RGB*.

composite video—In video development, a video signal that combines chrominance (colors red-green-blue) and luminance (brightness of black, white, and gray) information into one signal relayed on a single waveform or over a single wire; used by most consumer-grade products.

CRT (Cathode Ray Tube) video screen—Used to display information.

distortion—The extent to which a system or component fails to reproduce accurately at its output the characteristics of the input. Also called pin cushioning in video displays, manifests itself at distortion the sides of the screen image by inward or outward bowing of vertical lines, such as those in spreadsheets and tables. Distortion can vary after a switch of resolution and tends to worsen as a monitor ages.

dithering—Electronic graphic technique of filling the gap between two pixels with another pixel that has an average value of those two so as to minimize difference, to add detail to smooth the resulting line, or to create a color not in the palette supporting the given display.

DTV (DeskTop Video)—Combines animation, image metamorphosis, photography, etc., within a common data manager.

DVI (Digital Video Interactive)—Brand name for a variety of Intel product families having to do with digital video and audio.

EGA (Enhanced Graphics Adapter)—Video standard (for IBM PC in 1984) that allows 16 out of a possible 64 colors to be used; can emulate all modes of earlier CGA, adding 320 × 200, 640 × 200, and 640 × 350 pixels with 16 colors; see *CGA, PGA, SVGA, UXGA, VGA, XGA.*

ELF—Extremely low frequency radiation in CRT-based video monitors; see *VLF*.

field emitter display (FED)—Flat-panel display that works much like a CRT, shooting electrons at colored phosphors (pixels) to create an image on screen, but rather than illuminate the phosphors with a single electron gun, a “flat cathode” chip is placed behind each phosphor, allowing the use of a flat panel in lieu of a bulky picture tube.

field of view—Volume in space defined by angular cone extending outward from the focal plane of an instrument or video screen.

flicker—Flashing of a video screen as the electron beam that creates the image follows its raster pattern.

focus—In video displays, the crispness of text and lines, the contrast of adjacent single-pixel-wide black and white lines.

footlamberts—Unit of brightness in video displays.

full-motion imaging—Video image that is completely smooth; see *raster imaging*.

gamma (γ)—In digital graphic video, gamma measures the contrast that affects the midtones of an image; adjusting gamma allows the brightness values of middle-range gray tones to be changed without altering shadows and highlights.

HDR (High Data Rate)—Usually used in the context of digitizing video information.

HGED (High-Gain Emissive Display)—Flat LCD-like panel containing color phosphors similar to those of CRTs but modified to operate at extremely low voltage (under 100) and activated by a matrix grid instead of beam-steered, high voltage electron gun. Unlike LCDs, the matrix needs no transistors to address pixels; phosphors are instead excited by electrons guided to the grid by a process patented by Telegren, Inc. HGED is less than one-tenth the cost of LCD and has no viewing angle restrictions. It has the brightness, color palette, resolution and refresh rates needed for high-definition video, without the concern of X-ray emissions of near-field viewing.

hypermedia—Hypertext function expanded so that documents contain links not only to other pieces of text but also to other forms of media—sounds, images, and video. Images themselves can be selected to link to sounds or documents, and so on.

interactive video—A fusion of video and computer technology, in which a video program and computer program can be run in tandem under the control of the user. With interactive video, the user’s actions, choices, and decisions genuinely affect how the program unfolds.

interleave—In data communication, to send blocks of data alternately to two or more stations on a multipoint system or to put bits or characters alternately into time slots of time division multiplexer. Also, on a video screen, to alternate raster scan lines so as to transmit higher-resolution frames per second.

liquid crystal display (LCD)—Reflective visual readout of alphanumeric characters, generally of two types: passive-matrix displays (PMLCDs) and active-matrix displays (AMLCDs), which refer to how pixels in display are controlled. See *active-matrix display* and *passive-matrix display.*

luminance—also *brightness*; in video displays, greatest light monitor can emit without losing focus; measured in units called *footlamberts*.

MDA (Monochrome Display Adapter)—Video standard introduced by IBM in 1982 for IBM/PC, PC/XT and AT computers and compatibles that handled only textual data and was eventually replaced by a card.

MMX (MultiMedia eXtension)—Performance-boosting technology incorporating fifty-seven multimedia-centric instructions into Pentium processors by Intel, to achieve a 10 to 20 percent improvement on standard CPU benchmarks and up to 60 percent improved performance when running software specifically designed for audio, video and graphics technology. MMX involves a processing trick known as “single instruction, multiple data,” that enables the MMX chip to package and process many pieces of information as one value rather than in a one-at-a-time sequence that could cause bottlenecks.

MTF (Modulation Transfer Function)—Video focus test to measure the contrast of adjacent single-pixel-wide black and white lines.

PALC (Plasma Addressed Liquid Crystal)—Technology in which gas-plasma channels perform pixel-triggering duties much like the thin film transistors in active-matrix LCD panels, with standard LCD-style backlighting providing illumination.

passive-matrix displays (PMLCDs)—A liquid crystal display (LCD) technique in which the pixels on a video screen are controlled by voltage signals applied in rows and columns, and the crystals respond by reorienting along field lines to transmit or block light to create the image and then return to their original orientation when the voltage drains away. Compare with *active-matrix displays* and *liquid crystal display.*

PCI (Peripheral Component Interconnect)—Bus architecture by Intel that increases physical capacity for high-speed data transfer in graphically intensive applications such as human-machine interfaces (HMIs) and video systems on personal computers.

PIXEL (Picture Element)—The smallest unit on a video display screen that can be stored, displayed, or addressed. A computed picture is typically composed of an array of 450 × 300, 720 × 560, and so on. In color video, a pixel contains red, green, and blue values, and the color depth refers to the number of bits of data used to define the pixels' color (8 bits = 256 colors, 16 bits = 65,536 colors, 24 bits = 16.7 million colors).

PGA (Professional Graphics Adapter)—For PCAT and PCXT high-resolution graphics; see *CGA, EGA, SVGA, VGA, UXGA, XGA.*

raster imaging—Video image that stutters slightly when depicting motion. See *full-motion imaging.*

raster—In the display on a video screen, the raster is the grid pattern of vertical and horizontal divisions outlining all the small elements of which the picture is composed.

RGB (Red/Green/Blue)—Analog NTSC video signal between commercial monitors and equipment such as VCRs and some computers. Also, a model or color space to convey color information. Combining differing amounts of these additive primary colors produces all the colors in the color space. Used by most monitors and most desktop scanners, RGB works by starting with no light (black) and then *adding* quantities of red, green, or blue light (the maximum of all three produces white.) Compare *CMYK*; see *additive primaries*.

scale-ability—The ability to vary the information content of a program by changing the amount of data that is stored, transmitted, or displayed. In a video image, this translates into creating larger or smaller windows of video on screens.

sharpness—In video displays, the crispness of screen displays, like focus. Sharpness is generally due to the convergence of red, blue, and green electron beams into single white "dot" on the screen.

stochastic screening—In electronic publishing and video screen displays, a digital screening process that converts images into very small dots (14 to 40 microns) of equal size and variable spacing. Second-order screened images have variable size dots and variable spacing; also called frequency modulated (FM) screening.

SVGA (Super Video Graphics Adapter)—Introduced in 1988 as a refinement of VGA that offers higher resolution, of at least 800 × 600 pixels, and greater color compatibility, of at least 16 colors, compared with VGA; see *CGA, EGA, PGA, VGA, UXGA, XGA.*

S-video—In video development, a way of dividing the signal so luminance is on one wire or signal while red-green-blue (RGB) mix is on another. Is of higher quality than composite video. S-video is also called Y/C video for luminance/chrominance (lumination/color); compare with *composite video* and *component video.*) Used in "prosumer" equipment but available on some consumer-grade video products. See Y/X video.

TBC (Time Base Corrector)—Electronic device that corrects inconsistencies in the rhythm of a video signal.

Uniformity—In video displays, the evenness of brightness across the screen display, without which the image appears dirty and the colors distorted.

UXGA (Ultra eXtended Graphics Adapter)—video standard introduced as a refinement of SVGA which offers higher resolution of at least 1600 x 1200 pixels; see *CGA, EGA, PGA, SVGA, VGA, XGA*.

VDS (Variable Definition Syntax)—This is DDL (data definition language) renamed (copyright granted to SP50 Committee by ISP Foundation.) Also, Video Direct Slot; provides port for additional video monitors using a common signal source in a workstation.

VDT—Video display terminal.

VDU—Video display unit.

VESA—Video electronics standards association.

VGA (Video Graphics Adapter)—Video standard introduced in 1987 for IBM PS/2 series which can emulate CGA and EGA modes and additionally provide 640 × 480 pixels with 16 colors and 320 × 200 pixels with 256 colors; see *CGA, EGA, PGA, SVGA, UXGA, XGA.*

Video for Windows (VFW)—In digital graphics display, a multimedia architecture and application suite from Microsoft that provides an outbound architecture that lets applications developers access audio, video, and animation from many different sources through one interface. As an application, it primarily handles video capture and compression, as well as video and audio editing.

Video Ram (VRAM)—Random access memory with parallel-to-serial conversion for generating video display signals. Provides capacity for number of colors and resolution (amount of pixels.)

VIW (Video in Window)—Placing a continuous video image (from, say, an RGB input) into a computer's (typically VGA) screen view.

VLF—Very low frequency radiation in CRT-based video monitors. See *ELF*.

VR (Virtual Reality)—Three-dimensional (3-D) computer simulation of real-world activities and events allowing "walk-through" of various proposed designs or situations; a 3-D doorway versus a 2-D window (video screen).

XGA (eXtended Graphics Adapter)—Raster than VGA and causes less eyestrain, but works only on Micro Channel® 386SX or better PCs; resolution is 1024 × 768 pixels and 256 colors are supported;. see *CGA, EGA, PGA, SVGA, UXGA, VGA*.

Y/C—Video Y (luminance) and C (color) video information on separate signals. Is of higher quality than composite video but not as high as component video. Available on professional and some consumer-grade video products. Same as S-Video. See *composite video*, *component video* and *S-video.*

Exploring Displays 12

Navigating through screen views of your process requires some screen display techniques as well as screen layout. The screen display techniques are somewhat standard among most video equipment suppliers, based upon the computer operating systems that they use. Our discussion here is what is typical.

Other view arrangements, however, will be based upon how the control system vendor has chosen to portray his standard views of his screen hierarchy, if this was done at all. Some vendors with proprietary workstations provide an “out-of-the-box” set portraying overviews, groups, and detail displays in one form or another. Some do not, especially if they connect with “generic” workstation packages from providers of HMI software (only). Still there are few vendors of control systems who create “framework” packages to provide some standard order onto generic workstation packages from those suppliers who sell only HMI software.

Windowing

New technologies offer users the dynamics of using multiple, different windows on the same screen, allowing direct access to diverse areas of the plant. Windowing capability provides users with a powerful way to obtain selected details and support information on the main monitor without losing the principle screen view (Figure 12-1). Windowing capability also gives users the ability to emphasize the important control process information while de-emphasizing the less relevant. However it also keeps the latter always available upon request. While it is helpful to open several windows at the same time to look at different parts of the plant at once, this feature also reduces the need for access to be only by way of a screen hierarchy.

Windows can be tiled so they do not overlap. They can be cascaded, which allows them to be stacked so you see just the edges of each window, usually with a title exposed, and you can select the one you’d rather see.

Windowing borrows terminology from commercial video:

PBP (Picture By Picture)—This is a split screen video display, with simultaneous adjacent views or channels.

PIP (Picture In Picture)—This is a video screen with more than one simultaneous view or channel, usually one or more insets within a larger view. It is usually used with live camera views of process.

POP (Picture Outside Picture)—This is a simultaneous multiple-view video screen but without insets.

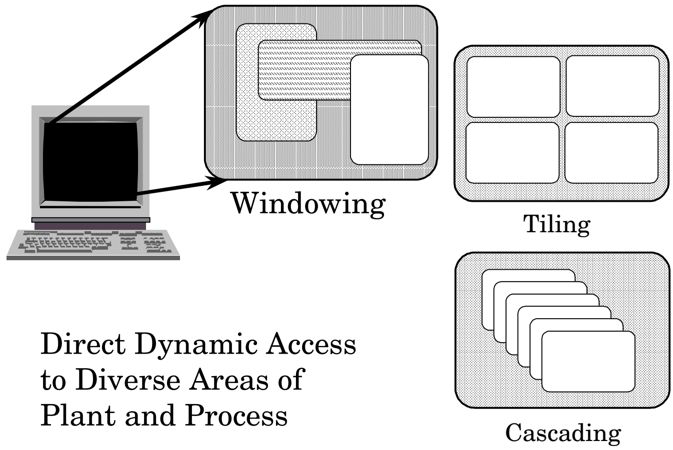


Figure 12-1. Examples of Windowing

There are some practical considerations to keep in mind when using windowing techniques:

- How many screens can be opened before the user gets lost? (Some systems put an arbitrary limit on this.)
- Do all opened views continue to update?
- Do those opened views continue to update at the same rate?
- Do those opened views continue to process data in those areas that are hidden behind other opened views?

In some systems opened views will continue to process data in those areas behind other views. This places considerable pressure on the display generator and can slow the refresh times for all views. If the hidden layers stay live, however, the data is more readily available if these views are rapidly switched.

Zooming

Zooming allows you to “step up to or back from the panel” (Figure 12-2). This may be done in one smooth motion, or it may be done in stages. A possible disadvantage of smooth zooming action is that when you “back away” from a highly detailed display, all that detail clusters down into an unrecognizable blob. There are decluttering mechanisms that switch off certain symbols or switch to a simpler icon as you move out. Then as you move back in, more detail will be added in increments.

Certain creativity in the construction of the illustration could be necessary to avoid confusing the operator. Some prefer switching through a series of stages from close to far to control font and icon sizes within a readable range. Others prefer to merely change views through a select “button” built into the view.

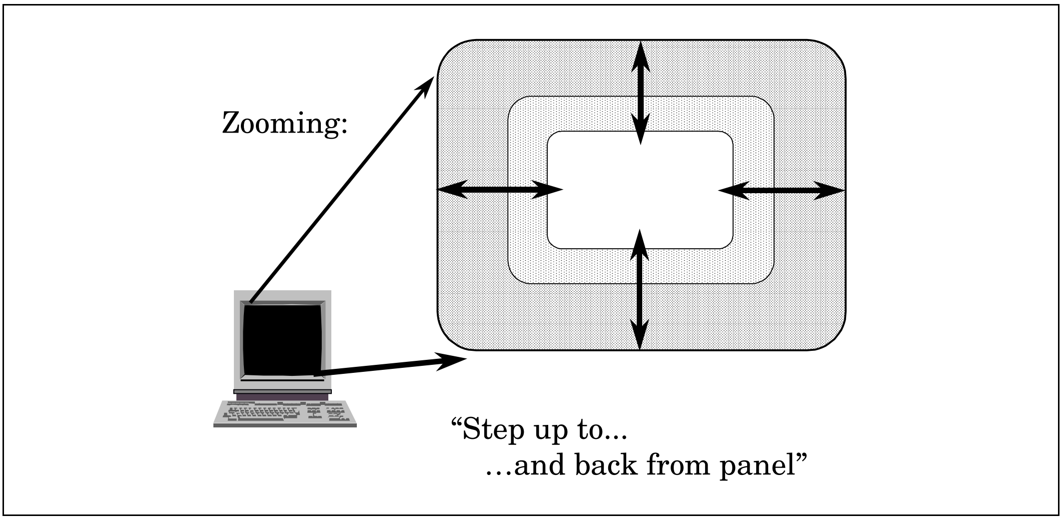


Figure 12-2. Zooming Into/Out of Displays

Panning

Panning provides a feature in which you can literally walk around the panel and it acts like having a smaller open window on a very large page. You slide the window around the different areas of the page to focus on a specific area of interest or concern (Figure 12-3).

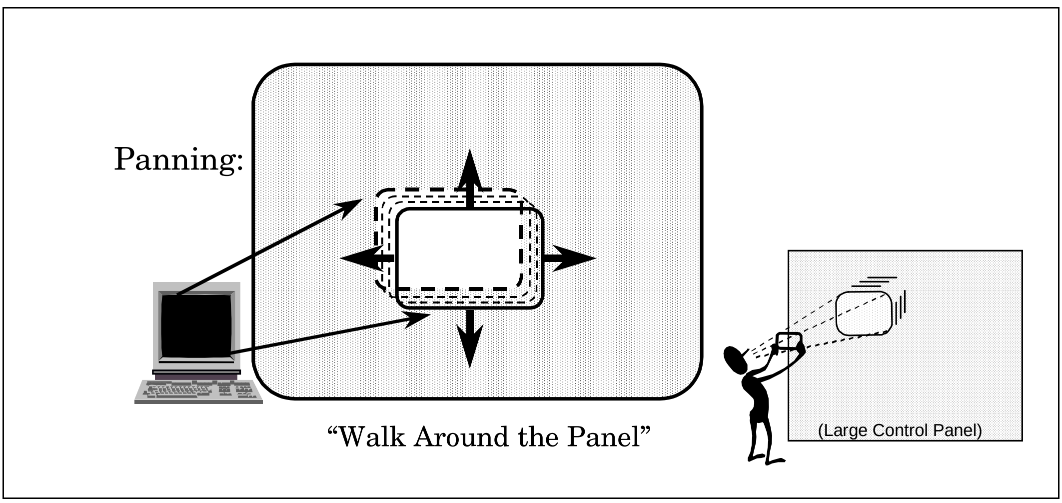


Figure 12-3. "Touring the Plant" by Panning Smaller Window Around Larger "Panel"

Panning, and even zooming, involve issues similar to windowing in general:

- Do you refresh the hidden area?

• Can you get lost in navigation?

Some systems offer an inset with an overview and cursor that you can use as a locator. This feature can also be used as a selector when “diving into” a display.

Video Wall

Console designs permit multiple screens to be clustered together but still functioning as one view. This allows a much larger picture but maintains a high resolution. Examples of this are the commercial “video walls” used for entertainment centers and advertising displays. Be careful how these are used! If you merely transform your usual views to such an array, without making modifications for the change in presentation, you may find some surprises, such as viewing that part of the screen that crosses through the boundaries between the monitors, like the dialog box shown in Figure 12-4!

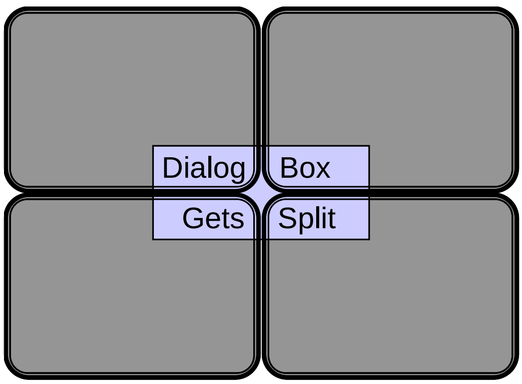


Figure 12-4. Single Views across Multiple Monitors Can Present Problems

Functions of Overview

When the operations manager, plant engineer, or someone just coming on the shift first enters the control room, they don’t require the value of each loop, but rather the overview of the plant operation (Figure 12-5). Standing back from the panel and looking at the entire room, they want to see the current concerns of the process or plant. It is essential to highlight the areas of problems or of potential problems. They are interested in the overall health of the plant.

The overview is one of the three classic views (overview-group-detail) identified by Renzo Dallimonti in the early 1970s as the three standard needs in the typical control room. The view shows some grouping of major loops and process states, sequence stages, alarms that are already there, or areas that are in danger of going into alarm.

A general grouping of loops will show only deviations between set points and process variables for one or two hundred loops. Deviation limits between setpoint and process variable are generally set individually so that “full scale” to the limit mark can be

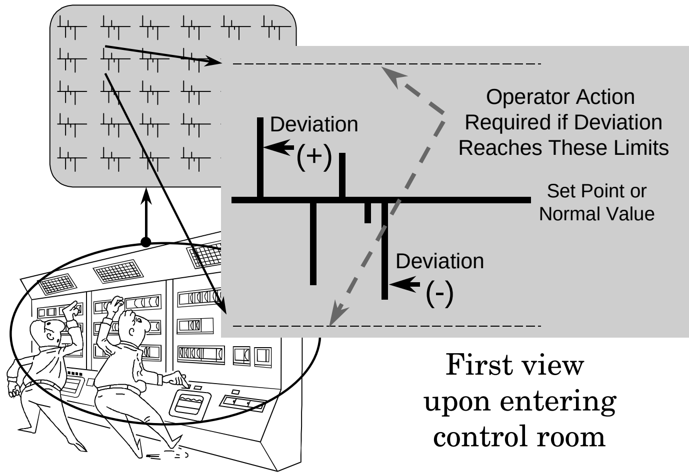


Figure 12-5. General Plant/Process Conditions

3 percent, 11 percent, 26 percent, or whatever is an appropriate critical limit that should be a concern to the operator. Overviews provided by some vendors may also show major steps in sequences, depending upon the information needed at this level.

Invoking one of the groups with a keystroke or a touch on the screen will present you with a group screen view (faceplate or graphic style), which will give you a closer look and provide you with the ability make a change at that level.

Today, this overview screen will very likely be in the form of a dynamic graphic, but the elements are the same. Interactive operator prompts can also be included; for example, to give direction and focus to an alarm or plant upset.

Functions of Group View

After viewing the general health of the process or plant, the operator will walk up to the control panel to make adjustments to the controllers. He or she will only pay attention to those few instruments involved in that portion of the process. This is the origin of the group view (Figure 12-6).

The group view is the second of the three classic views identified by Dallimonti in the early 1970s as the three standard needs in the typical control room. This is the group cluster of loops (ramp generators, sequences, "switches," etc.) that together define a unit process. It is the normal operating view of the "panel," and typically it has no more than eight or sixteen "instruments" in that group. As with the control panel, the operator should be able to view and/or manipulate the process variable, the set point, and the output. When the loop has a problem, the operator will want to see any appropriate alarm limits and perhaps the operating mode to which the controller is set—automatic, manual, or computer, and so on. Of course, he or she will need to see the tag and title of that process loop.

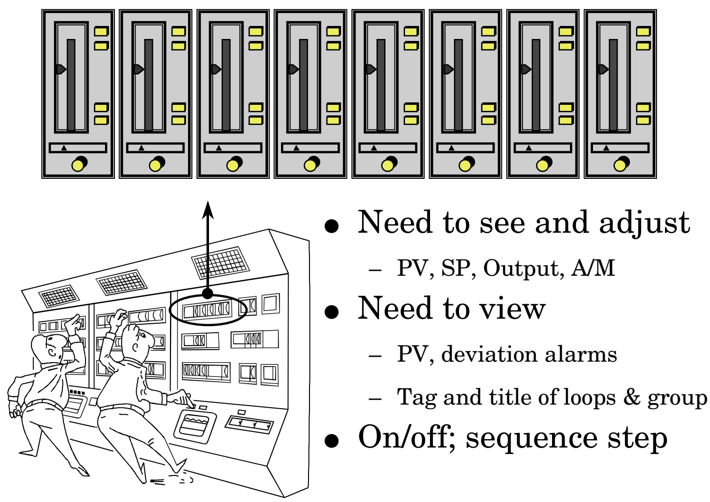


Figure 12-6. Functions in the Operating Level

When an operator invokes one specific controller of that group on the screen, that faceplate should be highlight red in some way to verify that it is ready to receive commands. It is helpful if a line of text also appears that it enhances the information about that loop or function, such as where it is located on the process and in the plant. In addition, more detail regarding the condition of that “device” can appear in a second line of text, such as alarms or diagnostics in natural language (as opposed to alphanumeric codes).

The group originated view with an early grouping of controller faceplates known as “clothesline indicators.” These were a group of instruments designed so that the scales behind the process variable (PV) pointer could be moved with a thumbwheel. The set point was placed by moving that scale to the center of the viewing window. The center was marked by a green line painted across the front of the instrument. When the red process variable pointer was on set point, that pointer fell out of view behind the green line. If the loop was off normal, the red pointer came out from behind the green line and was visible from a distance. The advantage of this was that when a large group of instruments was lined up side by side, a quick glance by the operator was all that was needed to spot discrepancies in the operation. This concept also gave rise to the deviation bar in the overview display.

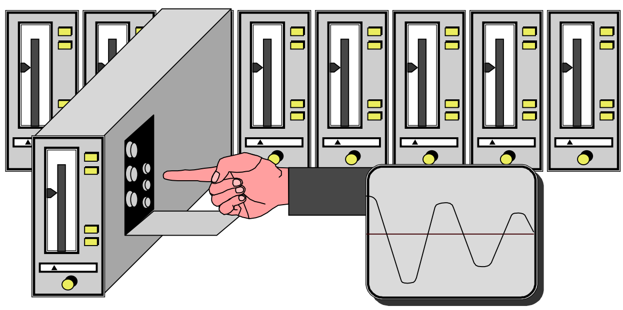
Of course, like the overview, *today the group view usually will be the graphic equivalent of the same function.* Quite often, however, you will find a faceplate either embedded into that graphic view or faceplate “pop-ups” when a cursor is placed over that part of the process needing adjustment.

A major difference between this screen view and the hardware version is that the screen view can provide dynamic operator prompts on the same screen, such as “Must enter Manual,” if the operator tries to adjust the output while operating in automatic.

Many different procedural prompts can assure consistent operation from a crew with a wide variety of individual experiences.

Functions of Point Detail Display

Now, the other operator action that could happen in a control room in a traditional control panel would be the ability to walk up to a group display and slide the instrument out of its case (Figure 12-7). It would now be possible to adjust the control parameters (gain, rate, or reset) of a loop or the alarm settings.



- Like sliding instrument out from case to adjust tuning, alarm settings, etc. …
- On screen, also tuning “chart,” to/from wire list, “hold value,” SP ramp/clamp, etc.

Figure 12-7. Video Screen Version Can Add Tuning Trend to “Instrument” View

This is the third of the three classic views identified by Dallimonti in the early 1970s as the standard needs in the typical control room. This view is now called by some as the Point Display and by others as the Point Detail Display. In the video form, and with the many features that are now easily possible in microprocessor-based controllers today, this view can also be used to adjust set point ramps, set point clamps, emergency shutdown settings, set values for hold ring output at some desired safe setting, and whatever other attributes the vendor supplies with the function blocks for control. A process variable trend for tuning is often added, which can even have some “zoom to close-up” capabilities.

By its nature, the detail view is rarely graphic. It can, however, be used to invoke an input from the to/from wire list within this view. This can be convenient for checking on the condition of the signal source, rather having to run out to the I/O cabinet with a test set of cables and multimeter. By “clicking” on a selection in this input/output list, an additional view appears that shows the conditions of signals coming from a terminal board. From this view comes more detail about that input, such as the signal range, input alarm settings, and the linearization curves that were configured into it.

The view may perhaps instead show that part of the configuration strategy in which this "instrument" is used. With some vendors this is a dynamic piping and instrument diagram (P&ID) that also conveys the quality coding of signals as well as current values.

In Figure 12-8 we see an example of a screen view that shows the progress of a batch operation with windows for operator instructions and interactions; definitions of specific phase parameters; the availability of equipment; material tracking and genealogy; ingredient quantity, location, amount available and consumed, and so on. Some of the requirements of batch operations necessitate more than Dallimonti's "traditional" overview-group-detail scenario.

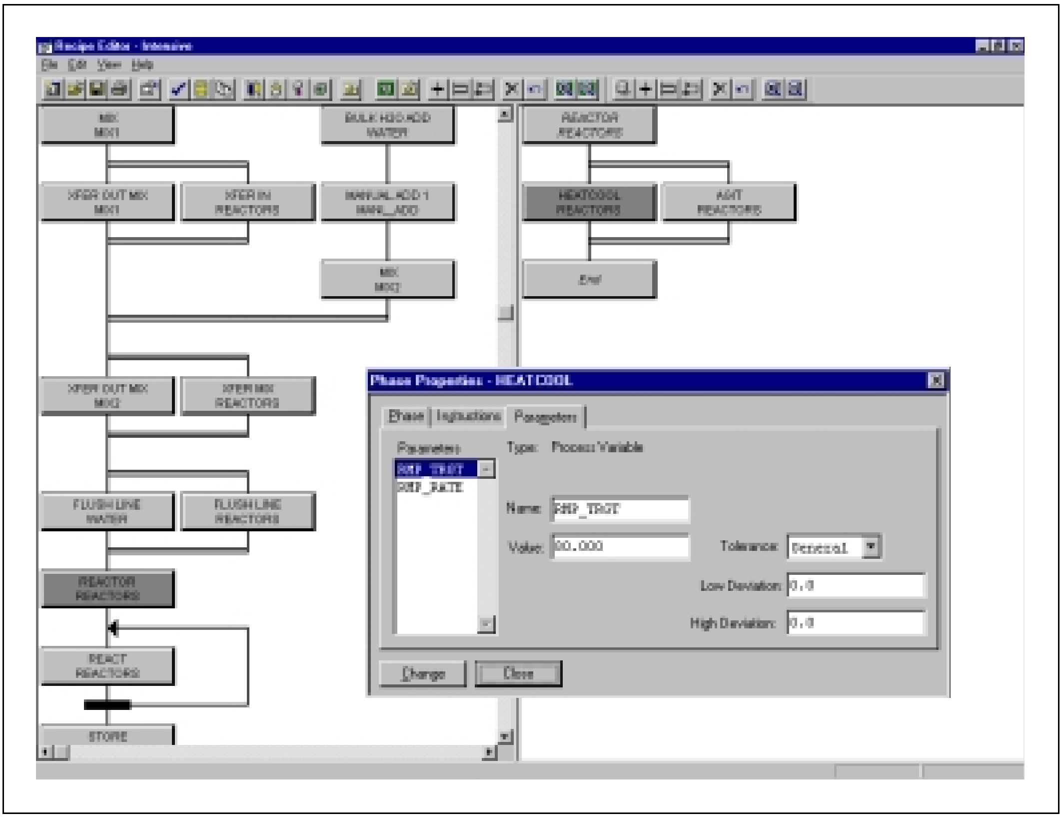


Figure 12-8—Batch Progress View

Additional Views

Besides the fundamental operating views discussed in the preceding sections, there are many more views that will help the user of control systems. There is no limit to the imagination of the system design team, except to not become so carried away that they overwhelm the people who must run the process or plant. The way to develop operating views is to think FUNCTIONALLY.

For example, the other requirement that was in a traditional panel board was alarm annunciators. However, it is necessary to quickly find the area of concern and just as quickly gain as much information as is needed to make corrections (but not so much data as to overwhelm). While doing this, the operator should also be able to silence any audible alarm and/or acknowledge that alarm. Support views such as alarm lists, which can be used for filtering, qualifying, and sorting problems quickly, should be available. Their design, though somewhat generic, ought to be "custom" designed to the specific need of the processes involved. This will be discussed later in Part D on plant upsets.

Similar problem-tracking views should be available for system diagnostics. When responding to a system alarm (the control system itself had a failure somewhere), the operator, or the maintenance person, should also follow a "trail" leading to the offending component. Lists for sorting, qualifying, and filtering are useful here, as well, but serious consideration should be given to dynamic graphic maps to locate and resolve problems. Additional displays include system summaries, component status, control sequence status, historical and trend information, line safety and tie-in flow summaries, energy costs, maintenance and red-tag (out-of-service) functions, and many sorts of help windows.

All of the technologies for achieving these goals are evolving and will continue to leapfrog through the different vendors as they experience installations in their clients' locations. As time goes on and processing power permits, operator prompts should be included in these views to support and remind operator(s) of best practices.

Other Typical Screen Views

- Ability to use interactive and dynamic displays offers interesting variations on the traditional
  - —I/O connections on terminals show values, limits, alarms, signal conditioning and linearizations
  - —Alarm list by various sortings, qualifiers, filters, etc.
  - —Diagnostic lists, also by various sortings
  - —Equipment "map" can also show locations of failures
  - —Historical data by various sortings, including RDBM
  - —List of alarmed points defeated by plant engineer during start-up or plant repairs
  - —Statistical process control charts (XbarR, etc.)
  - —Just about any type of view desired

Learning to use the video medium, as we said earlier, takes time. Only when people experience the advantages of change in meaningful steps can new ideas what is useful begin to happen. Limitations on screen refresh speeds have been an obstacle to involved graphic displays. Yet as technology overcomes performance restrictions, more creative displays will be tried, and even demanded. That is just one of the exciting components of the controls business.

Historical information is becoming an operator's tool as well as for the engineer and plant manager. This is true especially with the emergence of relational database managers (RDBMs), which help make it possible to sort data quickly into useful information. It follows the same basic rule—think FUNCTIONALLY.

Trending Data Through Video 13

In the operations of a process or plant, you often need to have more than the immediate values; you want to have the perspective of history (Figure 13-1). Some indication to guide future direction, immediate or long-term, helps cause operation repeatability. Trending also helps you show the activities prior to some upset. Then you can play them back at a later time and determine what events occurred leading up to the upset.

Beyond Immediate Values

Traditional trending was done on circular charts or strip charts. What both had in common was messy ink that dried too slowly and clogged the pens or dried too fast and ran down the chart paper, "feathering" into wide blobs and smears.

Circular charts were favored for easy storage of data from each shift, day, week, even month. They were nice and flat and filed easily, and the entire report was on a single sheet. Problems with circular charts were the non-linear scales and the need to change the span of each analog signal, so as to cause the trace to favor the outside third of the scale. Low values fell into the narrow part of the pie shape, making them hard to read. Any change in the measured signal meant the mechanism had to be recalibrated.

Strip charts are linear, but only a small portion can be viewed at any one time. The storage of chart rolls was very cumbersome at best, and retracing a value at some past event that occurred a week, a month, or, heaven forbid, a year ago was a nightmare. I know, I had to more than once. The new video recorders, which emerged in the mid-1990s have been able to provide corrections to these limitations. Their technology came from that developed for the DCSs.

Charts and Clipboards to Video Trend

- Need more than immediate values
- Provides perspective of history
- Indicates future direction
- Allows operation repeatability
- Shows activities prior to upsets
- "Entry" to historical archival

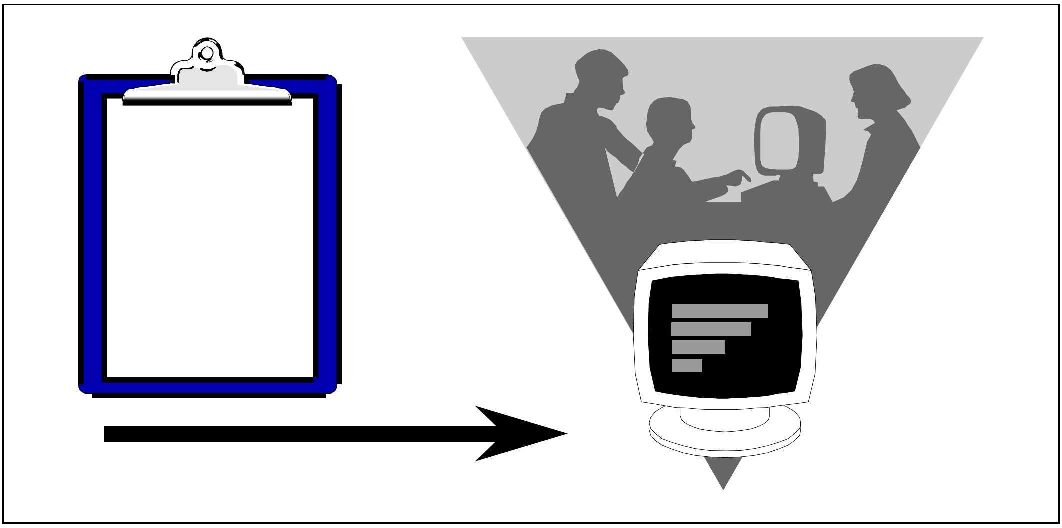


Figure 13-1. Clipboards to Computers—More Thorough Recordkeeping

A New Way to See

With the difficulties presented by traditional trending methods, most parameters were never tracked. Very easy and economical video trending is now allowing many more values in a process to be recorded. This has been leading in turn to the discovery of process characteristics that were never realized before. Many people have learned that they may KNOW a process, but they do not UNDERSTAND it! There have been significant boosts in PRODUCTIVITY as a result of the changes that have been made because of this emerging understanding.

On most systems, the workstation dynamically collects current data and stores it into local history (within that station):

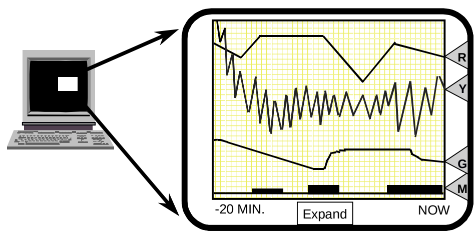
- Active trend, Dynamic trend, and Current trend are just some of the terms used to define displays that show data as it is being collected.
- Historical trend is generally that which is “called up” from local memory.
- Archived trend is data that has been transferred onto some removable media, such as magnetic or optical disk.

Using Trend Displays

Of course, every system handles trends unique to the design of that particular vendor. The features of such systems will vary depending upon the experiences of that vendor in serving customer requests. Expect those features to represent the needs of the industries that vendor serves.

Considerations for trend placement (Figure 13-2) are:

- Will a single trend group fill the screen view for better visibility?
- Will multiple trend groups be placed on the same screen view? (as multiple "windows" tiled, cascaded, or either tiled or cascaded?)
- Can a trend group be embedded within a graphic and other views?
- Can a trend group be a "pop-up" within another view?
- Can "window" be resized as needed on line?
- Can the "window" be repositioned on the screen view as needed on line?



- Trend placement
- Trended points
- Trend trace dynamics

Figure 13-2. Considerations for Trend

Considerations for trended point limitations (Figure 13-2) are:

- How many traces (pens) will fit within a single trend group?
- What is the total number of traces (pens) available per screen (multiple groups)? (There could be a processing performance limitation)
- Can you trend any parameter of any tagged point (process tag): that is, set points, process variables, outputs, status, operating mode, control parameters, and so on.
- What is the total capacity of the number of trended points (traces or "pens")?
- What are the smallest samples that can be taken? (This could be a performance limitation of controller scan time more than a question of screen refresh time or even the data communication network. It could be possible to time-stamp a high scan rate at the I/O, then whenever the data reaches the screen, those values could be presented.)
- What is total capacity of sampled data? (This is a complex question because memory will be consumed much more by smaller samples of a large number of parameters. More on this later.)

Considerations for trend trace dynamics (Figure 13-2) are:

- Is there a choice of colors for each trace?
- Does the trace change colors (it can go red) when the point goes into alarm?
- Can you place discrete and analog values in the same group?
- Will the trace start and stop with the equipment or process? This would indicate rapid recognition of these changes; also no need to save flat lines in memory.
- Can you switch shading on and off while on-line? (Shading will especially improve the visibility of “stray dots” that are off-normal “spikes,” which can otherwise be lost from view.)
- Will the trace shade to base? Can you switch to shade between traces?

Not all systems have the same capabilities!

Analog Value Trending (Figure 13-3)

Note that by allowing span changes to be done individually, as well as by groups, users are able to “play around” with comparisons between different trended points. This is very useful for overcoming the problem that “all the important areas are crunched together at one point”, and assures the readability and correct interpretation of data. View changes like this are harmless as long as the database is not altered or destroyed.

Not all systems have the same capabilities!

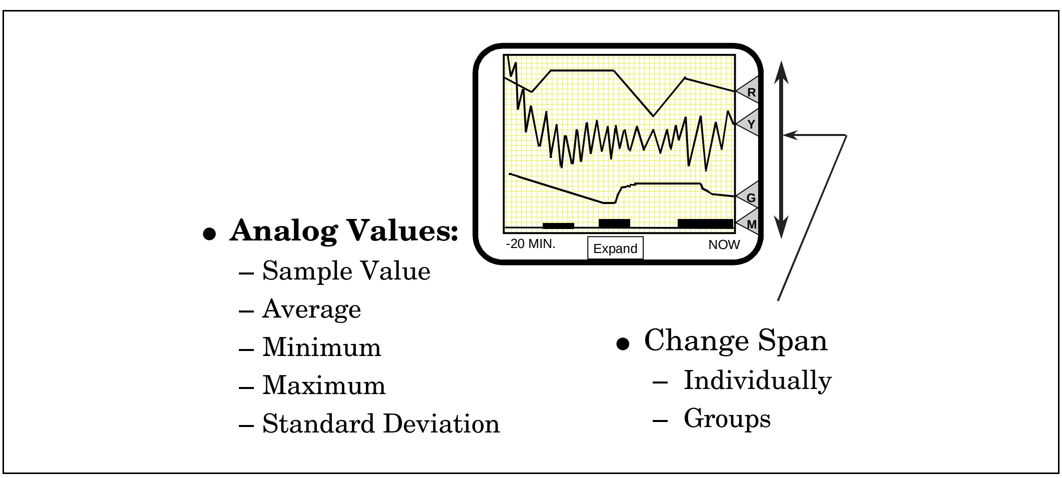
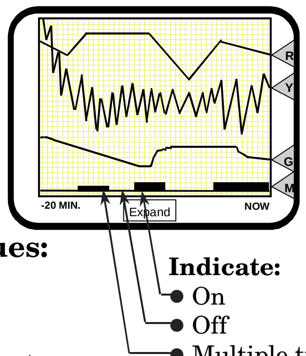


Figure 13-3. Trending Analog Parameters

Discrete Value Trending (Figure 13-4)

Note that discrete values show THREE conditions; ON, OFF, and a mid height for those conditions when the signal was both on and off, such as during a transition during the time increments selected, or when the "switch" is cycling. Having discrete actions shown with analog values allows events to be compared with process fluctuations.

Not all systems have the same capabilities!



- **Discrete values:**
  - – Current state
  - – Start state
  - – Transition count
  - – Average

Indicate:
- On
- Off
- Multiple transitions during time sample

Figure 13-4. Trending Discrete Parameters

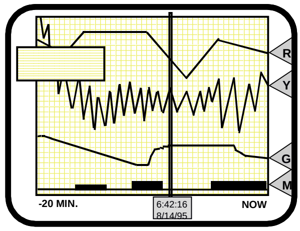
Uses for Trend Cursor (Figure 13-5)

The cursor can be moved over analog and discrete traces to make accurate comparisons at any given time sample. At each intersection, the time and date appears, along with the specific values of the conditions at that point in time. All traces are identified with the process tag, the parameter being measured, and the description of that process tag.

Not all systems have the same capabilities!

Trend Navigation (Figure 13-6)

Panning is moving "back and forth" along the same time divisions within a much longer trend than fits in a single screen. In most systems, this is done in half, quarter, or even eighth screen "jumps." Although processing power is a factor in the choice of which of these "jumps" to move in; the real reason for using these jumps is that a so-called smooth transition is not really smooth because of the nature of time sampling. As



- **Cursor:**
  - Time/date of placement
  - Value/state of intersected traces
  - Tags and titles of all traces viewed
  - Select area of zoom for more detail

Figure 13-5. Cursor Can Select Specific Values and States at Same Moment of Time

a result, there is wave action across the screen that most users find objectionable. Some have even complained of a form of seasickness (trend sickness? timeshift sickness?)!

Zooming can be focused with the cursor enabling you, to "drop down to another layer" of time increments (divisions). Of course, you cannot drop to time increments that were not sampled! If the increments of samples are further apart than the time divisions on the grid, some systems will "connect the dots" to make visibility easier. Otherwise the dots will be too disconnected to make any sense.

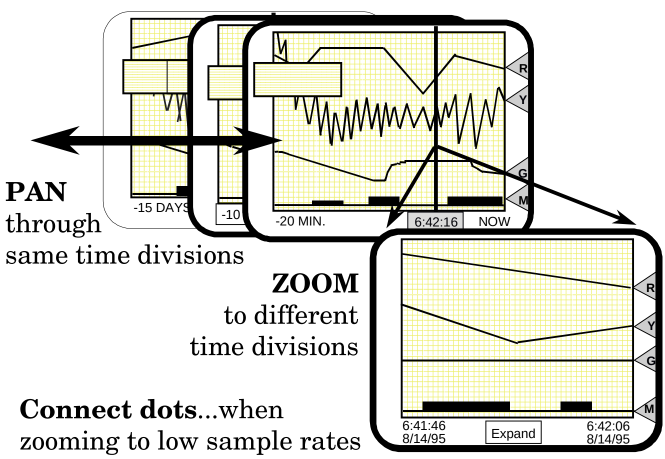


Figure 13-6. Cursor Can Be Used to Zoom In for More Detail

Some Trend Guidelines

Trending is far easier in systems today than it was only a very short while ago. The tendency is to trend everything that moves just because it is there! You should consider trending parameters that have not been observed in the past. It could lead you to understand much more about your process, even if you think you already know enough. You must, however, be organized or you will be buried in data. Some guidelines to consider include the following:

- Use consistent trend layouts throughout the display system.
- Trend multiple variables only when they are related or are needed for comparison to each other.
- Provide labels for all the trended variables, and provide them always in a consistent location.
- When displaying multiple trends, code each label to correspond to its respective trend line by color, shape, or some other means.
- Provide all important labeling, such as trend variable range and time scale.

History, Archiving, and Record-Keeping Subnetworks

All information that moves into the controller, or even that which moves into the I/O modules, whether or not it is viewed or acted upon, can be retained. The hardest part is deciding WHICH data to actually retain. Some users will save data only until a process has successfully completed a run or only after preestablished, continuously uneventful periods of time.

Sometimes an operator may wish to have past data to compare to previous runs of a particular process. This would happen in repetitive operations such as heat treating. In some metalworking processes, the final customer requires a record of the process, especially the annealing or hardening of material. This is certainly true of the pharmaceutical industry, which has critical government regulations requiring documentation.

When trying to picture how historical data is stored within the operator or workstation, picture if you will storage history saved on multiple “trend barrels” (Figure 13-7). The height of the barrel is the number of traces being saved, and the circumference of the barrel changes with the length of time saved, so you can predetermine how many parameters will be saved and how long they will be saved before they “pour off the barrel” or get “painted over.”

The example in Figure 13-7 shows but one way to visualize how data is saved. The idea here merely is to try to understand how memory is often allocated. Even if the station seems to have “infinite memory,” someone will always want to save thousands of points at one millisecond increments for fourteen years!

HISTORICAL DATA is usually that data stored within resident memory within the workstation itself. In each different system, the vendor will have to explain how to precisely calculate the total “pieces of data” that can be saved in history. Essentially, you will have to determine the number of parameters that must be saved and the time increments for

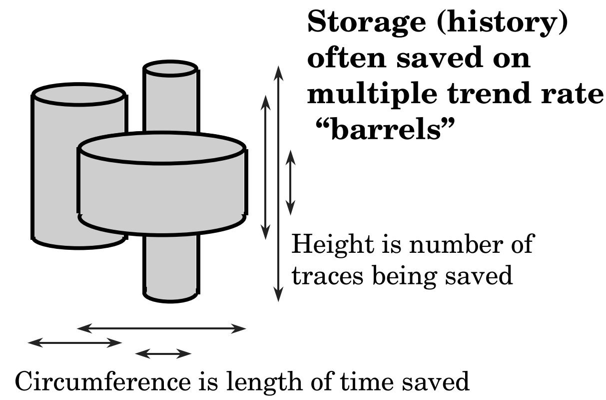


Figure 13-7. One View of How Data is Saved

each parameter. Of course, this calculation will not be so simple because of the internal structuring of the database done by the vendor.

To organize the data so it can easily be retrieved, the vendor may have an assortment of restrictions based upon how the data is grouped within that particular system. For example, all those trends in the same "trend group" must all have the same "save rates" or time increments. When averaged, they all must be done at the same point in time. If they are not, they could not display on the same time grid. Depending upon the digital manipulation methods you may find that larger clusters of points may have to be in the same "save rate" category. Look at the example in Figure 13-7, for instance. How many "drums" are kept in a system? The user may very well have the option of defining each drum "circumference" and "height," but there will have to be some limit to the number of drums that can be provided. In any case, there will be some "wasted space" on each drum.

This is not as great a problem as it may first appear. Usually, there is plenty of overall memory for normal use and provisions to archive data for long-term storage.

Off-Line Storage of Data

Sometimes the volume of history, particularly the collection of all the events that happened on a given shift, day or week, or even month becomes so large that it will not be analyzed until a much later time. This is when an archiving system would be used. Archiving can "continuously" pour data off this drum before it's lost or "painted over," or the system archiving could be designed to create a series of snapshots sometime after it's saved but sometime before it's painted over (Figure 13-8).

In the event of a plant upset, some systems have provisions for capturing a snapshot of all the data around the event on a separate part of memory, or onto another disk, for a "post trip review." This is especially helpful in those systems that sample data at a more dense rate for a few hours or more, then average it when the operation is uneventful.

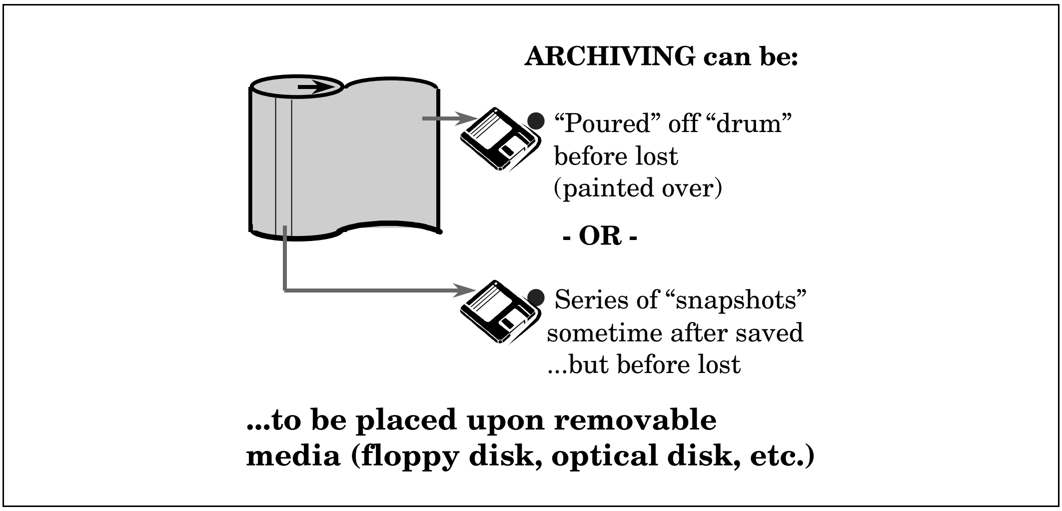


Figure 13-8. Archiving Data Allows It to Be Saved Off Line

Archiving allows the history to be moved onto a removable media whether it is magnetic tape, floppy disk, optical disk, or solid state. Generally, when the historical information is archived, a record is maintained indicating which archived disk volume the information is kept. This may be an automatic and/or a manual process. Nevertheless, it provides a technique for retrieving data that could be months or even years old without having to memorize where everything is located.

The data can then be placed on a removable medium like a floppy disk or an optical disk. Archive data is usually defined as data that is stored on a removable media.

In some systems, a library of the disk titles is kept in a station. At some later time the user may invoke a trend view that includes history that goes further back than what's resident in the station. The station goes into its memory and notifies the user which disk volume number to locate and insert into the station. The station will then be able to blend this additional data into its own resident memory for display in that trend.

Trended, historical, and archived data do not carry the same degree of urgency as alarmed and operating data. The movement of historical data from distant stations will carry a much lower priority in the data management of the "process operating network." Historical and archiving activities for report generation and management reviews are likely to be operated over a separate subnetwork, connected to the operator stations but operating independently of their primary role.

There is a whole field of data compression which is beyond the scope of this text. Nevertheless, when talking to vendors, or their engineers, you may encounter some terms and acronyms that are equally mysterious, but should not intimidate you. Some of them I list here, but I wish I knew even more about this myself (such as what the "SS" stands for in "LZSS" below):

asymmetrical compression—Data compression system that requires more processing capability to compress an image than to decompress it; typically used for mass distribution of programs on media such as CD-ROMs.

CGM(IF) [Computer Graphics Metafile (Interchange Format)]—A standard for archiving and transferring graphics data.

compaction—See *compression*.

compression—Any of several techniques used to reduce the number of bits required to represent information in the storage or transmission of digital data (saving memory or bandwidth), in which the original form of the information can be reconstructed. Also called *compaction*; see a*symmetrical, delta save, JPEG, MPEG, symmetrical, compression.*

DCT (Discrete Cosine Transform)—A data compression technique.

EDM (Engineering Data Management)—Controls access to online and archived engineering data; prevents unauthorized users from getting information and erroneously making changes that others don't know about.

JPEG (Joint Photographic Experts Group)—Working committee under the auspices of the ISO that is attempting to define a proposed universal standard for the digital compression and decompression of still images for use in computer systems and for image exchange between computers. The JPEG algorithm reduces image size by as much as 65:1 while maintaining image integrity by eliminating imperceptible color information.

lossless—Digital data technique that reduces the size of a file without sacrificing any of original data; this tool allows an expanded or restored file to be an exact replica of the original file before compression.

lossy compression—Digital data compression technique in which some data is deliberately discarded so as to achieve massive reductions in the size of the compressed file.

L-Z algorithm—Lossless data compression technique developed by two researchers named Lempel and Ziv.

LZH Compression (Lempel-Ziv-Huffman)—A method of data compression that can reconstruct data exactly like the original with no loss.

LZSS—A refinement of the L-Z algorithm for data compression that can reconstruct data exactly like the original with no loss.

LZW (Lempel-Ziv & Welch)—Patented by Unisys, another refinement of the L-Z algorithm for data compression that can reconstruct data exactly like the original with no loss.

MPEG (Motion Picture Experts Group)—Standards committee under the auspices of the ISO that is working on algorithm standards that will allow the digital compression, storage, and transmission of moving image information such as motion video and CD quality audio and control data at CD-ROM bandwidth. The MPEG algorithm provides interframe compression of video images and can have an effective compression rate of 100:1 to 200:1.

MPEG 2—Proposed standard for ISO adaptation that allows for a higher than normal resolution motion video compression than the MPEG standard.

PLV (Production Level Video)—Video encoding using the oldest digital compression scheme, by Intel/IBM.

RLE (Run Length Encoding)—Data compression technique that saves data by a single count byte and a repeat byte rather than by using memory to save a repetitive group of bytes, for example: 777777 becomes “count of 6 with value of 7 (two bytes).

symmetrical compression—A system that requires equal processing capability for the compression and decompression of an image. This form of compression is used where both compression and decompression is used frequently.

Communication of Information 14

For the past five chapters the discussion has been on the workstation as a tool for humans to communicate with the process. Most of this discussion, however, has really been on how the process provides data. What about how humans provide data to the process? To discuss that, we will have to briefly look into how humans communicate in general.

Communication between people in normal human discourse isn't really about what we say, but *how* we say it. In Figure 14-1 we see that the meaning of our words is only a very small part of how we communicate. We usually communicate with pictures, symbols, and objects. A gift is a form of communication. For example, there is meaning behind a gift of diamonds and it is more than an advertising slogan to "say it with flowers." Even in verbal conversation, the information is usually passed through "body language." There are dramatic differences between the meaning of words, the *way* they are said, and our *use of actions* or pictures. The *correct* picture is truly worth a thousand words. Consider the implications in the control room!

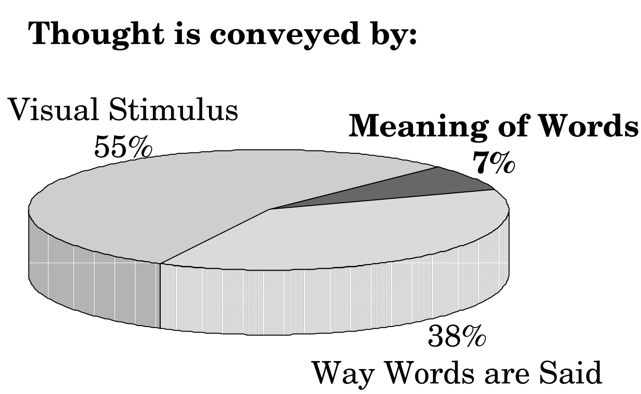


Figure 14-1. Dramatic Differences Between Communication Methods

Interacting with Processes

We have seen that much processing is needed to enable the human interface with the process. That is why so often a sophisticated workstation is used. In Figure 14-2, however, we see that graphic presentations are only 10 percent of what the workstation is doing. Although the other 90 percent involve a lot of computational effort, these stations are really designed to help us understand through pictures. Sometimes pictures are the *only* way to understand. It's a fact that optical paths to our brain carry the equivalent of fifty million words per minute, which is ten million times more than the ears can handle. That's why we learn more easily, quickly, and accurately with pictures. According to Louis Platt, CEO of Hewlett-Packard, what is challenging is to meet this potential with realism, speed, standards, and integration with other media.

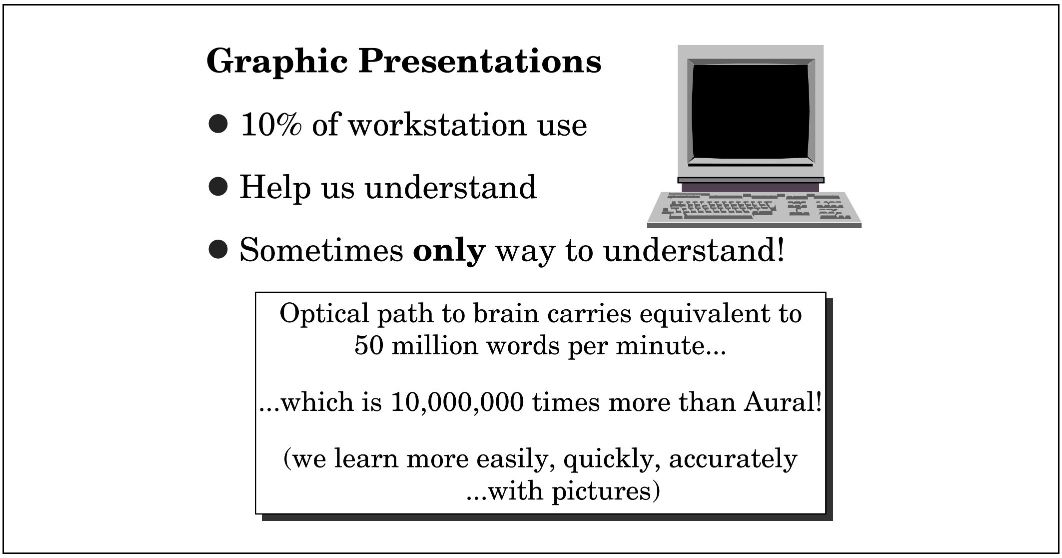


Figure 14-2. Use of Graphic Workstations

Certainly, the graphical monitor must show and do all FUNCTIONS originally included on the traditional control panel (Figure 14-3):

- Meters and gauges (present conditions)
- Recorders (past conditions)
- Hand switches (manual actions and responses)
- Controllers (automatic actions and responses)
- Mimic display (graphic guide to understanding)
- Annunciators (alarm focus for attention)
- Other functions

Time As a Parameter—Analog or Digital?

Remember, certain operations are intuitive, and their appearance on the screen should be consistent with the operator's experience in his or her own life. Let's take the example of an analog portrayal of a parameter such as time. Many of us have probably been raised in a household with both analog and digital clocks. The analog clock portrayed time as a pattern around a circular face, with the progression of time proceeding in increments of sixty-sixty seconds, sixty minutes, and so on. As a result, the average

Carefully consider role of Graphic Monitor:

- Do all functions of traditional panel
- Picture and animate process
- Show process variables (analog and discrete)
- Signal alarms and upsets
- Show change in status and conditions
- Provide instructions
- Present analysis for higher order decisions

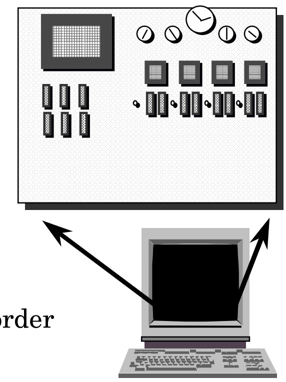


Figure 14-3. Graphic Monitor Is More than Just a Control Panel

faceplate of an analog clock would show the numbers one through twelve evenly spaced around the circle.

When my oldest son was growing up and learning to tell time, we didn't have any visible digital clocks in the house. He had to figure out somehow that there were occasions when 11 meant 5, as in five minutes to the hour. Over time, he adjusted to a base 60 and did in fact learn how to figure time. When my youngest daughter was being raised, there were digital clocks that she could see in the house, and if she were asked what time it was, she would quickly reply that it was, say, 2:50. To her, however, that seemed to mean that it was halfway between two and three o'clock. Without the analog clock's representation of the base 60 system, she initially had no concept of how time was being used.

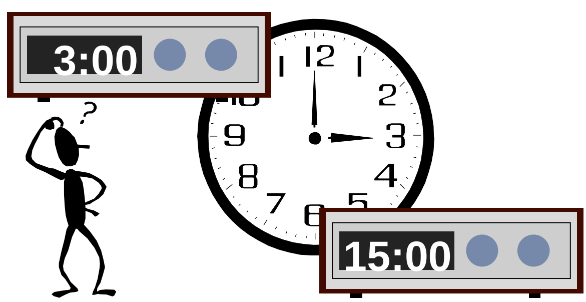


Figure 14-4. Analog vs. Digital Presentation?

Now, think carefully, is time absolute or a relative measurement (Figure 14-4)? Unlike all other measurements, it could be argued that it is both, but if you think about it, how do you *functionally* use time in the normal course of events?: Usually to determine how much time *until* something happens or how much time since something happened. So, we're always looking for some *relative* placement within time, which is an analog concept. Therefore, we usually like to think of using time with an analog display rather than just digital values.

Many of our clocks use fancy displays, roman numerals, or no numerals at all. Yet none of this variety prevents us from using them quite easily, even accurately (for the purpose intended). In fact, the latest digital clocks are showing *digital* displays of an analog hand position. So it is with most of the things we measure. We try to translate many measurements into some analog sense because most of the parameters we encounter in nature are analog, not digital. *Most of our presentations should portray information, not data.*

So out of context, digital numbers could be confusing, particularly if the operator isn't used to looking at the digits themselves and relating them to a particular analog function. If an absolute value is being used, the *digital* representation is important, particularly if you're dealing with precision to multiple decimal places. But if you're looking at the approximate direction or action as with time, sometimes the analog display is far more informative.

Display Elements

Display elements consist of letters, numbers, shapes, and/or colors. In developing display elements, it is important to consider the best coding method for proper communication with the intended audience. Display organization and the coding of information are covered later in this module. A number of display elements are described in ISA-TR77.60.04-1996, which include the following:

- **Numerical value**—A digital readout of a parameter value that uses the amount of digits given to provide the precision (the exact value) needed. It requires a label or symbol to identify its meaning, including appropriate units of measure.
- **Analog indicator (bar chart or meter)**—Shows the relative value of a parameter, using a continuous change in the size or position of a shape. This element is best used for conveying qualitative information, such as the direction of movement, relationship among values, and (inferred) rate of change. Bar charts are the usual method for comparison readings, but some users may be more familiar with, and prefer, using the pointer and scale of a meter. Pointers may be combined with a bar to show a target (set point on a process variable measurement) or alarm limits, used as scale markings, and even used with numerical values if both comparison and precision are needed. If pointers are used as scale markings, do not use more than the precision of the reading can support.

Generally, five scale markers along a 0 to100 percent bar graph are all that is needed to provide the right balance between having enough to understand and cluttering of view.

- **Discrete indicator**—Used to display a device status that can have one, two, or more discrete states. Each state must be easily distinguishable. States are displayed with labeling (ON/OFF), supplemented with color-coding (red/green), and possibly enhanced with shape coding (breaker OPEN/CLOSED). Labeling or coding is critical since misinterpretation by the user would cause him or her to infer the opposite of the intended message. Avoid using color alone as a means of conveying device status.

- **Mimic (process or system graphic display)**—A symbolic picture reflecting the user model (archetype) of a process, including relationships among variables. To avoid misrepresentation and any resulting confusion, care must be taken to conform the mimic to that model. See the next chapter for more discussion of mimic displays.
- **Plots or Graphs**—Show a parameter-to-parameter plot and are useful for process diagnostics, such as marking normal versus abnormal operating regions.
- **Trends**—Show the history of one or more variables, including the rate of change, the approach to limits, and a way of comparing current activities with similar operations from the past. More on this trending data through video is found in the previous chapter.
- **Tables and lists**—Used to show large amounts of information, so they must be well organized and coded to reduce the time required to read or interpret them. Guidelines for tables and lists include:

  — Label rows on the left, columns on the top.
  — Align lists of data vertically with labels on the left and the type fonts left justified. The corresponding numerical data for these labels should be on the right and right-justified and if a decimal is involved, right-justified to that decimal (so the decimals align top to bottom)
  — Separate rows of more than three to five items from each other with spacing.

- **Text**—Is very flexible but is probably the least desirable display item because it is slow to read and interpret. Text should be limited to labels and brief messages such as operator prompts and "help" messages. Color suggestions include the following:

  — Dark colored text (red, blue, black, etc.) should have a light background.
  — Light colored text (white, green, yellow, etc.) should have a dark background.

  It may seem foolish to state these obvious points, but, amazingly, these ideas are not always followed. This is not to suggest that the entire background must be dark or light; often it is appropriate to just have the band immediately behind the characters be the contrasting color.

- Combining these elements into a standard library for the process or for plantwide use is highly recommended. Sometimes the vendor offers something of a library to use as a start. Using these will save time, but with many systems you are not limited to that basic library. Do not be afraid to experiment, but also look into why the vendor chose the design he or she provided. There may be good reason. Some typical examples include the following:

  — **Control station**, often called a faceplate, is a combination of labels, bar graphs, meter pointers, numeric value fields, discrete status fields, and push-button hot spots (selection targets) arranged as a standard "instrument" symbol familiar to the user.
  — **Selection target** is a combination of shapes and labels for creating standard symbols used in display call-up selection, control selection, sequential action list and so on.
  — **Trend/Indicator** window with standardized "chart recorder" elements, which has been discussed in the previous chapter.

Use the Full Potential of Graphic Creation

Imagine if you will that you just unearthed a large stone covered with hieroglyphics. You know it tells you everything you need to locate an ancient king's treasure! Try to read it. What, you can't? All the data is there, isn't it? Why can't you do what it says and find the treasure? Oh, then you have to learn to translate the meaning of the symbols! What, there's more? Oh yes, that's right, you will then have to learn how those symbols are used in context with each other.

All humans communicate in "idiom" or what you might call "local jargon," which uses *combinations* of words differently than you would expect—the same words mean different things when used in different phrases. Gee, my kids do that all the time! Without an understanding of idiom, what you're telling me is that you have all the data, but NO information!

The idea of the graphical monitor is to show more than the functions that were originally on the control panel. These were meters, gauges, recorders, hand switches, controllers, annunciators, and sometimes a static mimic display. Today, you have the opportunity to carefully consider the *complete* capability of the graphical monitor, that is, the ability to picture and animate the view of the process to show the effects of process variables, both analog and discrete; to dynamically show change in status and conditions; to signal alarms and upsets; to provide instructions and present analysis for higher order decisions (Figure 14-5). In developing these graphics, you must understand the transition of personnel from the use of traditional panels to the *different* use of video screens, and you must use this different medium to its full potential. Remember that the purpose of graphics is to provide *information*, not data.

Developing Graphics

- Must understand transition... from traditional control panels... to video screens
- Must use this different media to full potential
- Must provide information, ...NOT DATA!

Figure 14-5. Graphics Are More than Pretty Pictures!

Goal for Creating Video Screen Views:

Try to allow the user to interact directly with the process itself as much as possible and not have to be aware that he or she is a piece of interacting with equipment.

Video Screen Animation 15

As already mentioned, the video screen provides unique opportunities for communication of the process conditions to the operator. This communication must be unambiguous. It must be done in a way that reduces the effort needed by the operator to fully comprehend the significance of any changes, good or bad. The animation potential of screen views gives us powerful capabilities to bridge that gap between unfolding events and operator understanding. It is imperative for the system engineer to understand the full use of these too.

Dynamic Displays

When creating the display, you can assign hot spots or enter fields anywhere on that view and you can activate them with a cursor. When you activate a hot spot, it provides status changes or value entries, parameter changes, menu selection, screen changes, or guided response to plant upsets. When you touch a hot spot it will sometimes open up a dialog box for some appropriate entry, such as a value, text, or response to a list of choices (Figure 15-1). You may also have pulldowns where you reach up to the top of the screen or window under a listed topic and then click to pull down all the subheadings under that topic.

- **Assign "hot spots" and "enter fields" anywhere...for cursor activated:**
  - – Status changes
  - – Value entries
  - – Parameter changes
  - – Menu selections
  - – Screen changes
  - – Guided responses to plant upsets

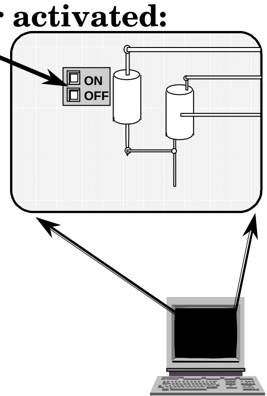


Figure 15-1—Action Capabilities through Animated Screen Views

Tool bars may also be available that have icons for different actions and are continually viewed on the screen or requested upon making some selection. Hot keys look like pushbuttons on a screen, which, when you cursor and click on them, appear to depress, as if you were pressing a button. That movement is important because you need to have some feedback, both visual and audial, to know that you made an action. In this way, when you make an "imaged" keystroke on the screen (or for that matter on any keyboard) you want to have some way of knowing that the action has *begun*, even if the screen does not yet reflect the *completion* of that action.

Hot spots, called poke points by some, allow you point to a certain part of the mimic, which responds with a "pop-up" showing a series of buttons permitting the entry of selections or a choice of actions. This pop-up can offer an on-off function or an analog drive that ramps a set point, output, or other function. Perhaps the pop-up portrays a small instrument faceplate embedded at that point that displays during the time you're on that poke point.

Natural Language

Keep in mind that you want to provide the operator with as close to a natural language dialog as possible in any screen view and especially within dialog boxes. *This is an opportunity to significantly improve productivity.* Try to avoid local jargon unless it is industry-specific and promotes quick understanding with all users of your system!

IF-THEN-ELSE Statements for Screen Dynamics

One interesting feature in animation is the use of an IF-THEN-ELSE statement with the math equations built into the graphics package. These allow for special entry requirements by the operator, special viewing requirements, and for complex animation needs. An example is the ability for an operator to pull up a specific view that would show different fields of information, depending upon process conditions. Another possibility is to have a view automatically presented to the operator because of an action in the process (such as a critical plant upset), but only if that action will not jeopardize that operator's current actions (which might make things worse).

Perhaps during a plant upset the operator would be given the option of entering values or actions only because of certain activities in the process, otherwise these entries or actions would not be available. For example, if a particular alarm occurred *and* there was a given condition in an adjacent part of the plant *and* some preestablished range of values existed in specific other loops *or* the operation is in a particular stage, *then* the operator would have the ability to only make a limited selection of actions. Other capabilities, even ones normally available, would be blocked or not even in view. With other conditions of plant environment, stage of operation, and specific loop upsets, *different* selection criteria would show up for the operator, and all other options would be masked from him.

Picture an operator presented with an emergency condition. He would have the option, for example, of pressing a button that says, "emergency down," meaning to shut the process down in an orderly way. That same operator action would result in a different process change depending upon what other conditions existed in the process and plant.

This IF-THEN-ELSE feature is very useful for presenting an appropriate screen display for unique conditions. Remember, the object of the game here is not to present the operator with as much data as possible but rather to present to the operator information that is appropriate for the condition of the plant. So this animating feature seems to be very useful in helping to filter out some of the options of operator actions. *What is important here is that this SCREEN feature be used for animation NOT for control action!* In other words, you want to be able to portray information on the screen, but you do not want to use this feature to create automatic action down in the controller itself. Only features and processors in the controller should be used for control action.

On Constructing Mimic Displays

Guidelines for building mimics, which are based upon ISA-TR77.60.04-1996 include the following:

- Conform abstract symbols to common electrical or mechanical symbol conventions as much as possible.
- Reduce the details of goal/task/function analysis data to present only the required content so as to avoid clutter.
- Provide labeling inside symbols wherever possible.
- Locate data used with symbols in a consistent position (always under, or to the left, etc.).
- Locate data for mimic lines and symbols as near as practicable to those items.
- Distinguish dynamic display symbols from nondynamic symbols (those static symbols needed for coherence of the mimic.) The user must recognize those symbols that are providing information about a state or condition.
- Use redundant coding of dynamic symbols, for example a valve can be red or green, show OPEN or CLOSED labels, and hollow or filled symbol to express its state.
- Use dynamic mimic flow lines to show the operation of the process if this is important information for understanding the process conditions. The presence of flow or pressure can be shown by line color or by hollow or filled pipes (area between two parallel lines). Flow direction can be shown with arrows and also with alternating line segments that blink like “chase lights.”
- Use dynamic electrical line mimics to show charged or uncharged lines. The presence of power can be shown both with color and with the symbol of an open or closed breaker.
- Make touch screen or mouse targets distinguishable with respect to the kind of information to be accessed. Targets that call up controls should be coded differently from those that access other displays. Similarly, analog control call-up targets should be distinguishable from discrete or digital ones. All targets must be identified (a three-dimensional effect is useful to imply a “button” metaphor.) Nontargets must not share a similar appearance.

Color As a Dynamic

Part of animating displays is the use of color conditionals for two positional discrete status. Displays may also show a series of colors, marking the passage of some value through several thresholds of analog indication, such as temperature levels. In this way, an operator can quickly view the progress of temperature change within a vessel at a glance when a precise reading of values may not be necessary. Color conditionals can also be used for blink action rates. Blink actions can show motion or show the progression of events across the screen through the optical illusions brought about by these dynamics.

Of course, colors may be used to trigger events. If you “clicked” on a pump, you might want it switched ON or OFF. The pump may be red when it is OFF. It may turn yellow in a start-up stage and then turn green when it’s running.

In a screen that is highly congested, color can help to highlight special groups of information. Grouping is perhaps one of the most efficient uses of color for screen display purposes.

Combined Capabilities

Combining animation capabilities gives you some very good dynamics while freeing the operator from studying unnecessary details. For example, a tank may be automatically filling or emptying, perhaps because product within is being consumed at another part of the operations or is being filled by a process upstream from it. A bar graph could show the level. The bar graph would probably be more useful in showing the level of the tank, because the tank is only a variation of a bar graph. Bar graphs can also be used downward as well as up and are sometimes based in the center to “grow” both ways simultaneously.

Back to our tank; you could use a fill pattern to indicate the change of chemical composition, for example, pH or conductivity. Change in pattern could indicate thresholds of composition values. At the same time, there may be a temperature constituent. Temperature could possibly be shown through changes in the color of the fill, level through the “bar graph” height, and composition through changes in the pattern of the fill, all at a glance by the operator, without the need to read individual numbers or the faceplates of instruments. All of these parameters would, of course occur concurrently.

If the analysis reached some critical point, the fill could begin to flash. This could also trigger a message specific to the problem (level, temperature, composition, pressure, vessel wall stress, fluid on the floor around the vessel, etc.). Be careful, however, that you don’t make the activity so involved that it distracts or confuses the operator. All of these changes of parameters, of course, depend a lot on what is important in the process. Good screen management will unambiguously present to the operator the conditions of the process and what actions you expect him or her to take because of them. You want to use shapes and colors to *help* the operator!

Not by Color Alone

The use of color is a supplementary thing. *Color should be used only to enhance information.* Color provides redundant coding, as well as a shape (text is a shape) as pointed out in Figure 15-3. Consider, for example, if the operator has a diminished capability to distinguish colors. At least 10 percent of males and some small number of females have one of the forms of color blindness. None of us sees colors exactly in the same way nor very likely with the same intensity. Research on color indicates that in the human brain it is processed in parallel. Interestingly enough, shapes are processed in serial, so your perception of them is different. Furthermore, humans have trouble distinguishing the meaning of more than four colors simultaneously. Colors, therefore, should be used sparingly and consistently to help the user understand the desired message.

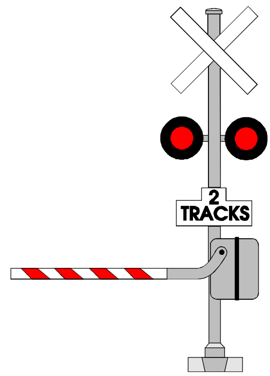
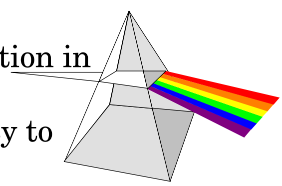


Figure 15-2. Example of Using Color, Shape, and Dynamics to Draw Attention to a Situation

Benefits of Color

- Improve visualization
- Provide more information in less space
- Assist creating priority to alarms and messages
- Reduce response time - draws attention to specific area



Color caveat

- ONLY information enhancer!
- Redundant with shape!

Figure 15-3. Color Should Be Used CAREFULLY

Using shapes as a primary indicator, for example, would mean making a pump solid when it's running and a hollow when it's off. This would provide the more secure communication and as a supplement to that might also include the use of red or green. The purpose of supplemental color is to improve visualization, to provide more information in less space, to assist in conveying priority in alarm messages, and to reduce response time by drawing attention to a specific area.

Considerations for Color Use

Color for coding has two general uses—to convey meaning and to distinguish one item from another. Some guidelines for use of color are as follows:

- Define the meaning of each color consistently
- Be consistent in using this meaning throughout the system
- Use color as a *redundant* indicator
- Keep large background areas neutral, such as gray or black (25 to 50 percent is best to avoid glare). With higher resolution color choices, teal and manila are becoming popular as neutral backgrounds that offer good contrast to other color lines and objects
- Use compatible color combinations (“circus” combinations distract from task)
- Avoid using more than seven (give or take 2) colors
- Use color to indicate quality, not quantity
- Match colors with those already in use on other (legacy) systems
- Use bright colors (white, yellow, light green, cyan) for dynamic values and symbols and important data
- Use dark colors (red, indigo) for static and “background” symbols
- Avoid dark red or dark blue for symbols or alphanumeric characters, especially hen used against a dark background
- Place text and numeric values against contrasting backgrounds (perhaps small “windows”)

> Red text as an alarm message should always be displayed against a light background (yellow or white) that background can be a band standing behind only the text (like a small “window”). Text messages should NEVER blink to draw attention. This makes them hard to read, defeating their function. It is better to blink the background color to promote attention and legibility!

Using a neutral background is consistent with reducing the big display of colors, which only distracts the operator. You should design with no more than seven colors. Look for colors with high contrast, such as blue and white or black and white. When you get beyond the magic number of seven, plus or minus two, then you start to lose the operator in a sea of colors that begins to feel more like a circus display than a good medium for the needed information. To convey meaning, the limit on colors used should be four or five. If you merely want to distinguish between different items, the range of colorscan is broader. Since the eyes are quite sensitive to color differences, the limitation of four or five optimum colors is not as important. An example of this is the use of subtle shading to create the illusion of depth, which could actually reduce the feeling of clutter. For the most part, any combination of text and background colors is suitable, so long as the combination maintains adequate luminescence and/or chromatic contrast.

Limit the Colors

Choose from any of 256 × 256 colors, but use only 7! (Actually, recommendations vary from 4 to 11, depending upon who is the expert.) As the number of colors increases, the relative effectiveness of the color-codes decreases. Perhaps allow for some color shades to show curvature of vessels. Too many colors, especially incompatible ones, will obscure, not enhance information.

The idea of compatible color combinations is to make the total appearance pleasing to the eye. This is not just a nicety; it is essential for directing the operator's attention towards what is not natural versus what is natural in the process operation. The human eye perceives color only in the center of the retina. Actual color perception depends on the different degrees to which various wavelengths of light stimulate the eye. Placing two colors with wavelengths at opposite ends of the color spectrum next to each other will strain the eye muscles trying to focus on them. It is best to avoid such combinations.

Picking color combinations for the screen is not the same as picking the color combinations in a room. Color has many psychological impacts and they should very much be considered when laying out the control room and establishing its atmosphere. These impacts are not as critical in the displays. Part of the reason for this is that rarely do you have operators staring at the same screen all day. Yes, in some plants the operator DOES, but in most places the operator periodically addresses the screen display in addition to several other activities in the control room. That is not to say that common sense color schemes shouldn't be used, but the primary goal of the colors that appear on the screen is to help the operator recognize changes in the process.

What Colors Should I Use?

The use of color consistently throughout the plant may be part of an overall code or scheme adopted by that plant or in that industry. For example, a typical color scheme for lines of text and numerals might use green for normal, red as an alarm, yellow for out of scan, cyan for of instrument range, blue as a raw signal, magenta as deleted from the database, and white for the text. But keep in mind, no two plants are alike. It's a good idea to place data values of importance in a bright color (white, yellow, light green, and cyan) to make them more noticeable.

The color convention for power plants is to use green for OFF (safe) and red for ON (hot, energized). In the paper industry, which has rotating machinery, red means OFF (stop) and green means ON (running, online). Industries involved with furnaces and heaters sometimes use red for hot (thermally) and green for cold. In the chemical industry, colors are used for different chemicals and gases.

More important than the choice of colors is to be *consistent* with the them so that any operator in any other part of the plant will easily understand their significance. Many corporations have multiple plants and strive to have a consistent display that means the same thing to every individual, on every shift, and in every location of their operations. When designing screen views, be aware of differences between distinct cultural perceptions of color and shape, especially for operations located in foreign countries.

A Video Screen Designer's Opinion

What I found empirically, then supported with some literature research, is that background colors should be of similar luminance to the surroundings—in most cases 25% to 50% gray (0% is black, 100% is white). I found that the highest contrast could be had with green on black, followed by yellow, then white and cyan on black. Red and blue are difficult against any background—as is magenta for similar reasons. All of this is for a computer screen, of course, and would be different on a physical instrument or panel.

When building screen views, I used large gray areas with black windows to emphasize alphanumeric data and indicators. I also used dynamic background colors to display secondary data on a gray background in normal cases, and changing to a higher contrast background in an alarm case.

I look at the screen's dynamic range. If everything is maximum contrast, then the screen looks cluttered. If most of the screen is low contrast, then only the most important high contrast dynamic values call attention. I think Renzo Dallimonti was a proponent of having everything in shades of gray unless attention needed to be called to a particular item. Then, the **change** would be perceived even before the color.

I also would do a dynamic range test on a screen by ranking the importance of objects. This is done by standing far enough away that I can no longer read anything, and then slowly approach the screen. Objects should become readable in their order of importance, which should also track from high to low contrast. If everything becomes visible at the same time far from the screen, contrast is too high... or if everything becomes visible at the same time when very close to the screen, contrast is too low. In either case the screen would look cluttered due to the lack of dynamic range.

Separation of data items is a tricky business. I think a soft 3D metaphor gives the perception of separation without being too cluttered. For example, you can make a 3D frame with white highlight and black shadow on a 50% gray background. But it would be less cluttered with a 75% gray highlight and 25% gray shadow...softer, but still effective.

Marc Lombardi, Human Interface Designer formerly of Honeywell and Leeds & Northrup

Not All Systems Are Alike

There are many different animation capabilities built into the various vendor products and they will vary from one company to another. Some companies provide only operator interface packages to function with other systems, typically PCs with programmable logic controllers (PLCs). Many of those companies originally served the needs of PLC companies that traditionally did not have operator interface packages beyond an on-off switch arrangement. These graphical packages generally run in "plain vanilla" PCs and come with software packages that can be attached to a variety of programmable logic control products.

These PC-based graphical packages are also used for several single loop products that are networked into small DCS-type systems. They have concentrated on the operator interface rather than on the control tactics. These packages provide a wide variety of animation capabilities, but their flexibility in being "all things to all people" reduces their chances of contributing to convenient structure. They are like having a blank sheet of paper and a dictionary of thousands of words but with little or no ability to provide sentence structure. The challenge is to interconnect those wonderful capabilities with the control system vendor's product.

Proprietary distributed control systems, however, were originally left to their own devices. At the time they initially developed their operator interfaces there were no standard packages, and each vendor had to create its own. These creations generally were developed around the control capabilities of that particular vendor and were ordinarily tightly interlocked with them. Although the processors themselves were distributed, the linking of the animated display and that vendor's control scheme was critical in minimizing the configuration limitations of the interconnection between them.

For this reason, not every vendor provided the same level of animation. However, now that operator interfaces are becoming more standard through the adoption of common architectures like the UNIX, MS-DOS, Windows, and Windows NT platforms, there will be, and already is emerging a more standardized approach to some of these animation features. There still remain many clever interlocks and features that individual vendors had "hard coded" in the early days. What is elusive, however is how to economically port these interlocks and features into the current platforms, which may have more universal capabilities but lack some of the specific features of the control actions of each vendor.

A Word on Performance

With so much graphic and animation capability, it is tempting to get carried away with cleverness. Such excess features will pay the price of performance for video screen "call-ups" and refresh rates. You will quickly find yourself pressing a key to make an *appointment* for a screen view! Remember that the overuse of animation and clever graphic pictures can seriously impact performance of the operator station. In addition, the processors used in the operator display should be reserved exclusively for graphic animation. Keeping them separate will ensure a secure system, and you will not have a problem in the plant if for some reason the communication link is lost.

Screen Navigation 16

The challenge of using graphic monitors is not just presenting the process to the operator, but also to present the operator to the process. How should the operator communicate to the process what must happen next? We are still exploring technologies which again have only begun to touch on methods to keep the interface tool (operator station) as transparent as possible. Of course, having said that, we must currently look to some very tried-and-true techniques of navigation and entry.

Video Screen Access Tools

There are several techniques (Figure 16-1) an operator can use to cause an action once he or she understands what's going on with the process or in the plant. With a few tools, he or she can make a change in the operation or perhaps change the view to get a better understanding of the operation. Ideas regarding what tools are needed vary with the requirements of the plant. Consider the nature the plant and the operator's environment of the operator to determine which of these tools are best.

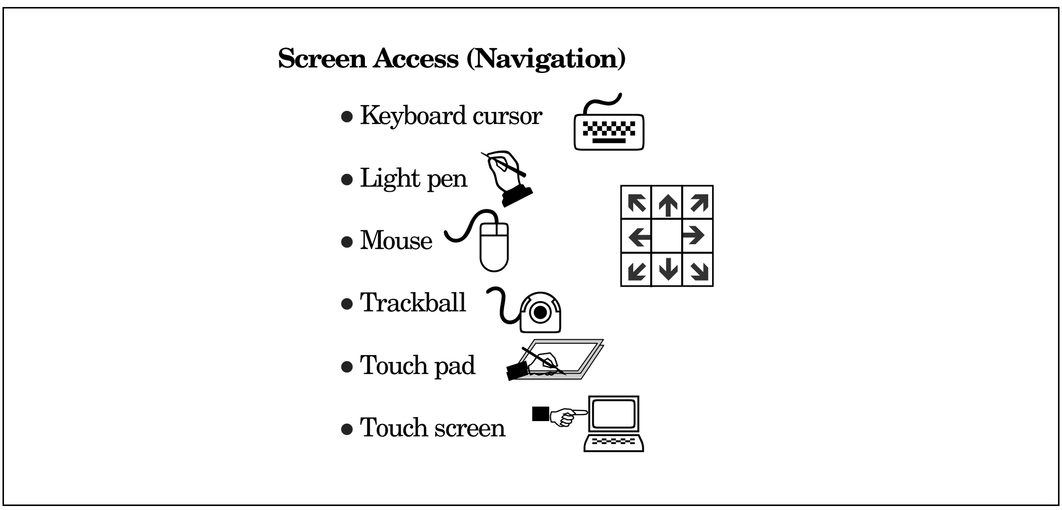


Figure 16-1. Control of Process is Navigational, Not Transactional

Screens typically used in business are for *transaction* functions, whereas the manipulation of control actions in a process through video screens is a *navigation* function.

Operators, in a bank, for example, will search their record's to verify account information, then modify those records as they complete the transaction of exchanging funds. An information finder in the video kiosk at a shopping mall is another example. Compared to process requirements, neither of these functions is time critical.

Some operator functions are, in fact, a transaction, such as to recording or retrieving historical information for comparison or analyzing. This is not a control action, and the microprocessors can operate at a more “leisurely” pace. Typically, keyboards are best suited for this, but well-designed screen views can be very impressive.

In the control room, however, operators respond to process changes by locating and pointing to the appropriate “instruments” and then altering their settings to correct for those changes. These actions are very similar to navigating a vehicle. It may surprise some people, but the “point-and-click” action with a cursor comes closest to the manipulation of traditional control panel functions. Once experienced is gained at it, point and click is probably the most comfortable method by which operators can gain access to the appropriate reaction process needs. The cursor offers many features for navigating through screen views and operational choices.

Regardless of the mechanism used, the whole idea of an operator access is that it too should be extremely consistent with the natural operation of that plant. As with screen views, any operator, no matter on which shift or which operation in that company, should expect certain actions and operating tools to result in the same responses in the plant. This should be true whether the actions are initiated through the layout of the keyboard, the use of a light pen, or the action of the mouse (right-click actions versus left-click, for example).

Access devices, such as a touch screen, mouse, trackball, or their equivalent, keep the user’s eyes focused on the data and action involved. They are generally preferable to the keyboard, which distracts the user from the performance of the keys’ functions. Tab key cursor control is not recommended!

Keyboards

The most obvious navigation tool is the keyboard (Figure 16-2). Some keyboards are very specific to a process and are laid out much like an instrument faceplate. These operator-specific keyboards made it possible to switch from automatic to manual operating modes, to adjust set point control when in automatic, drive the output valve when in manual, and sometimes access the alarm levels or tune a loop. Typically supplied by proprietary distributed control systems, they were designed to complement the screen views of the DCS’s vendor. They generally went with the overview-group-detail (point) views we discussed in a previous chapter.

The QWERTY Keyboard

Named for the first alphabetic characters on the upper left of the typewriter keyboard, this “de facto industry standard” since the 1880s was *designed to be as inefficient as possible*! (so as to prevent speed typists from jamming the mechanism). Because it was used for nearly a half a century before the development of the electric typewriter, people around the world became used to the QWERTY keyboard layout. Many dozens of better designs have been suggested and implemented in the last three-quarters of a century, but none of them have become popular enough to justify any kind of standard. August Dvorak developed a layout that requires a good typist's fingers to travel only one mile in a normal workday, compared to twenty minutes with the QWERTY layout. These typists achieve twice the speed, make half the errors, and need only eighteen hours of training rather than fifty-six. The rejected Dvorak died in 1975, a bitter man: "I'm tired of trying to do something worthwhile for the human race; they simply don't want to change!"

Keyboard Layout

- Typewriter (QWERTY)
- Alphabetical
- Numerical – calculator
- Numerical – telephone
- Control pad – discrete actions
- Control pad – process actions
- Display pad
- Operator function pad
- Special-function keys

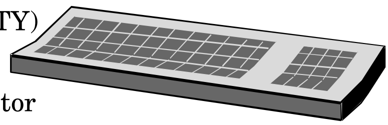


Figure 16-2. Keyboards: Operator-Specific? Process-Specific? "Standard?"

For years it has been assumed that most control room operators were not unfamiliar with the standard typewriter layout. Several vendors furnished alphabetic layouts on their "operator's keyboard." I know of one company that offered both the QWERTY and the alphabetical keyboards for anyone buying its system. After eight years of holding both versions in stock, they discovered that no one bought the alphabetic version when given the opportunity. All bought the QWERTY layout!

The other common keypad design question is how to allow numerical entry. The layout of the keypad could be that of a calculator or that of a telephone; each is different. Typically, a telephone is a three-by-four key matrix with the numeral one at the top. Early telephone rotary dials carried both numerals and alphabetic characters, both in ascending order. In the migration to touch pads, it seemed logical to have both begin at the top, to reduce dialing errors.

Typical calculator keyboards and keypads, however, are set "upside down from the telephone." This is probably because that was the position in the original mechanical calculators, where the internal gearing required that orientation so as to maintain "right-side-up" view of the digits while allowing incremental change from units through tens, hundreds, and so on. The numerals were arranged in columns of ten rows, with the number nine key at the top and zero key at the bottom in each row.

The migration to touch pads kept the larger numerals at the top for users who grew up with mechanical calculators and had to use both during their gradual transition.

For whatever reason, this apparently has not caused anybody any trouble. When you face a calculator or telephone, you seem to automatically go to the correct key, even if you use them interchangeably. It must be one of the paradoxes of the human system to be able to accommodate such switches. However, it would not be easy to make the abrupt change between those two keypad layouts if they alternated within control system keyboards. So whatever mechanism you choose, it should be consistent throughout the control system used by all the operators.

On operator-specific keyboards, another set of keys beyond discrete and loop control actions needs to be able to pick out specific requirements such as trend views, group views (instrument faceplate or mimic displays), and especially alarm-handling views.

The ability to respond to an alarm may require that the keyboard have its own display, such as you would have on an annunciator panel. Also needed are keys for other operator functions such as printing out a report, silencing an alarm, acknowledging an alarm, or similar arrangements. Then there are always the special-function keys that may be unique to that system, that process, or that plant. Some vendors supply special-function keys for the user with any of these needs.

Keystroke Actions

Several actions may come from a keystroke:

- A single touch produces a momentary contact, even if held down.
- A single touch latches contact and a second touch releases it.
- A single touch latches contact in one state and a second touch causes a second state (flip-flop).
- A single touch maintains the contact state as long as the key is held down (or perhaps causing a smooth ramp action).
- A single touch causes repeated short contacts as long as the key is held down (perhaps causes ramp action in repeated small steps).
- A single touch causes repeated short contacts as the key is held down for the first few seconds, then increases the number of contact increments while still held down. If the finger is lifted, the "slower" speed resumes are replaced.

The last item, using the "two-speed repeat action," allows this method to be used to drive an analog value a short distance with one touch, but if it is held it will speed up the change to reach a new position or value faster. If the user wants to stop more precisely, then by removing his or her finger from the key for a moment, he or she can then "bump up" the value to the desired point. This also helps with rapid cross-screen excursions.

Considerable controversy has occurred over the years about the best layout for keyboards used by process control operators:

- Should it be process-specific? Operator-specific?
- Should it be an alphabetical or the QWERTY key layout?
  — Should there even be any alphabetic keys?
- Should number pads be in the telephone or calculator layout? (often calculator)
- What keys, and layout of keys, should be used for process actions?
  — Auto/man-Raise/lower (separate for SP versus PV or mode-specific?)
  — Other?
- What keys and layout of keys should be used for discrete actions?
  — Up/down-On/off-Start/stop-Forward/Reverse-Reset-etc.
- What keystroke actions should be included? Where? When? When held down?
  — Single action unlatched-Single action latched-Flip-flop
  — Repeat action-Continuous steady drive
  — Non linear continuous drive
  (During full stroke should action speed up?)
- Should certain displays have unique keys?
  — Overview-Group-Detail (Point)-Trend
- Should certain functions have unique keys?
  — Print-Save-Last view-etc.
- What about plant upset?
  — Alarm acknowledge-Silence
  — Defeat (during start-up, maintenance, etc.)
  — Restore (after start-up or maintenance)
  — Emergency down key (various functions: all loops, only those shown, only those out of normal)
- Any industry-specific, plant-specific, or process-specific keys?

Keystroke Feedback

Important with any keyboard type, but especially important with the membrane type, is the absolute need for a sensory feedback. This ought to be some sound, like a beep or click, so you know that you pressed that key. This is essential. A sense of responding to the finger's pressure for the sake of tactile confirmation is critical, especially with membrane keyboards. Some offer this by using the pop-back "oilcan" effect.

Moreover, the operator should not only hear something but see something. This could be an intermediate state, something acknowledging that the key was pushed, but it should never show that the action is completed until there is a real feedback from the process itself verifying that the action was indeed completed. You do not want a screen simulation of process results. Consider some indication that the action has been requested but not yet completed, such as a color or shape that is associated with the equipment involved. Another method is to show the image of a depressed key on the video screen. One advantage of the video approach is that when activated the "key" has the ability to "change labels" (on can become off).

On one actual occasion an operator pushed the key to switch a loop from automatic to manual. There was a delay in the screen action before the operator was informed this keystroke was pushed. As a result, the operator pushed again to make sure of the action and toggled the loop back to automatic, creating a severe plant upset.

The system should respond to every user entry! It must be positive, obvious, and natural. Having no response is not allowed! When a request is invoked, there should be an instantaneous reaction (within two seconds). If the nature of the request requires longer processing time, then a response should show that the course of action is underway and even, when possible, how long it will take for the action to begin.

"Soft Keys"

Keys on a keyboard that change meaning in accordance with whatever screen display is being viewed are called "soft keys." In the earlier days of DCS, these took the form of several unlabeled keys at the base of the screen (usually eight) and labeled images of keys on the screen itself. For example, when you're looking at an overview display, the selector keys underneath that overview would determine which group you were getting. When in a group display, if there are eight groups on a screen, each of those keys represented a group. If a point detail display, then each of these keys might represent set point, process variable, output, or a tuning parameter. This is fine as long as these keys are used to select a screen view. In my opinion, however, soft keys should *never* be used for control action of a process.

A variation of this idea is the use of multiple functions on any instrument, whether it be stand-alone hardware or located on a video screen. For example, some vendors have decided to save space and appearance by providing one set of raise/lower buttons on a three-mode (PID) controller faceplate (hardware or screen view). If the loop is in "Auto[matic]," they drive the set point; when in "Man[ual]," they drive the output. Arggh! When the operator wants to drive a valve, he or she should always push the same button. He or she should not have to look to see what state the loop is in. Now, what if during an upset the operator thinks that a loop happens to be in automatic, stabs at the operating mode button to switch to manual, and didn't quite act on it. He missed, but thought he hit it—and now thinks he is driving the set point when in fact he's starting to drive the output, or worse, the reverse happened! Separate drive buttons for each control action is imperative!

The operator should always find critical action keys in the same place, these keys should always be in the same location, and they must always have the same meaning! This is equally true of the location of controls on screen views themselves: always be consistent with functions and locations! During normal operation there is time to carefully look for the correct keys, but during any kind of plant upset there must never be any ambiguity about control action.

Keyboard Role

Serious consideration must be paid to how a keyboard is going to be used. Is it something the operator is continually using, or is it something he or she occasionally uses. Should the keyboard be permanently attached, or should it be a plug-in. You may prefer to only plug it in on those occasions when it's needed, and remove it until it's needed at another time.

A number of years back, IBM researched the best position for typewriters and computers where the keypunch operators were working an eight-hour day entering data. The study found that the ideal keyboard angle was 10 degrees. This is probably true in a control room as well. But this goes back to the question of how the keyboard being used and by whom.

The size and shape of the keys are important. For occasional use, you can get away with smaller keys, but take much care to determine whether the person using it needs to wear a glove or has some ability limitations regarding when and where to push a given button. For example, in an emergency condition you don't want the operator to fish around looking for the right little tiny button to push. For emergency needs, there should be some very obviously clear "Push here when in trouble" arrangement (on a keyboard or on a touch screen).

Keyboard Considerations

- Continuous use versus occasional use
- Sealed versus not sealed
- Attached versus separate
- Size & shape of keys
- Depth key must travel
- Feedback sense to action
  — Click (aural feedback)
  — Resistance to pressure (sensory)
  — Visual (response on screen)
- Keyboard angle (10°)
- Shielding from
  — Radio Frequency Interference (RFI)
  — Electromagnetic Interference (EMI)
  — Other environment

Some guidelines for operator keyboard entry functions include the following:

- Provide a logical arrangement for function keys.
- Group function keys when many function keys are required.

- Provide on-screen entry fields with a cursor that shows the location of the next keyed entry for multiple-key entry (like typing with a word processor).
- Provide some means of distinguishing fields for (typing in) multiple-key entries so they are not confused with fields for current data displays.
- Locate edit fields, for changing current data, so they are in a consistent adjacent location to the items (values, text, etc.) to be changed. This is usually below or to the right but, in any case, should always be a consistent prompt location.
- Highlight the data to be entered, so it can easily be reviewed to ensure it is correct before invoking an enter key (or some similar entry action that is in addition to the creation of the entry statement or value).

Keyboard Types:

Mechanical

- Hermetically sealed reed relay

Electromechanical

- Magnet and saturable core
- Hall effect
- Capacitance

Membrane

- Flat surface
- Tactile feel (oil can effect)

To Seal or Not to Seal?

The use of a membrane is not the only way to seal a keyboard. Hermetically sealed relays are just as secure even though the keyboard itself shows discrete keys on the surface. Under the keyboard, the circuit card itself should be protected from spills and can be coated with a material to seal all of the electronic components. Then the actual keys presented on the surface will still look like traditional keys on a keyboard and depress and respond like the familiar keys with which most people are comfortable. Membrane keys have a place in an industrial floor where there is heavy dust, small filings, heavy humidity, or similar difficult environments. It is far easier to clean a membrane.

A Fluid Experience

A user spilled coffee onto the flat membrane keyboard of one vendor, and the fluid ran over the membrane as it should but then leaked through the side to short-circuit the edge connectors within the case!

Protection for keyboards must also include shielding radio frequency interferences (RFIs) from communication devices or electromagnetic interferences (EMIs) from lighting fixtures and appliances. Both can trigger "keystrokes" without an operator pushing anything. A surge or spike in some voltage level somewhere can also give a false signal to a keyboard and cause the operation to think a keystroke was made.

Mouse or Trackball

One advantage of a mouse and trackball over a touch screen is that the targets can be smaller because the selection is more precise. The mouse and trackball action is generally more secure because it doesn't suffer from problems of parallax when placing it in position and requires more deliberate actions. Both the mouse and the trackball are suitable for stand-up use as well as sit-down positions. One disadvantage is that the ball tends to pick up dirt easily, especially in dusty environments. Another possible drawback stems from the fact that these are easier and more precise tools that can be used on smaller screen targets, so the human tendency will be to provide many more targets. When that happens, the user must locate the cursor, then have a much better feel for the locations of the many targets. Both of these actions could require that more time be spent placing the cursor on the target. Again, layout is everything in problems like these.

Touch Screen Access Tools

A touch screen is a video screen (cathode ray tube) with which the user can interact by touching icons on a screen display rather than through a keyboard or mouse. It is ideal for selection-based activities because you invoke information and create responses just where you expect them to be on the screen. Touch screen is a natural human interface in that you actually interact with the process itself as portrayed on the screen, reducing the awareness of the system in between. Touch screen technology offers an operator only appropriate selections, that is, there is no need for unnecessary options to confuse decision making. Unlike operator-specific or process-specific keyboards, touch screen devices can readily be modified to fit changing operator or process requirements. Partly because of this, it is far easier and faster to train users on it.

Several Touch Screen Technologies Are Being Used Today:

- Capacitive overlay
- Resistive overlay
- Scanning infrared
- Strain gauge
- Forced vector
- Guided acoustical wave
- Surface acoustical wave

Vendors of each of these products have been continually working to improve the different technologies. Currently, there are many articles by people who analyzed each of these technologies and created comparisons through matrix tables. Although a noble effort, new development within each of these technologies has changed, and vendors have made improvements to overcome several of the limitations of each of these types.

Selecting through Touch Screen Targets

Employing a touch screen, the user must know when the correct target area has been reached. The field can blink, switch to reversed video, or draw a box around the text or zone. Now the question is how to execute. The action can occur when the finger first touches the screen. But what if the operator first touches the screen but isn't quite on the target or changes his or her mind and he slides his or her finger to a new target? What causes it to activate? It is very important to decide how that screen is activated so a purposeful action on the screen is distinguished from an accidental touch.

Another touch screen method is to activate when the finger is removed from the screen. In this way, the operator can make a location correction and assure that the proper target is invoked. If he gets into an ambiguous position or changes his mind, he can slide to a neutral territory and remove his finger.

Requiring two keystrokes or two touches of the screen is another way to distinguish when an action is intended or accidental. It also depends on whether you need to touch the screen with two hands. This is a dilemma. What if the operator is required to have something in the other hand, such as a clipboard or a microphone, or what if the operator has no other hand? Now, what should the touch screen action require? Should it require striking an enter key as a second action, which is possible using only one hand? This would take time, particularly if there's a sequence of actions that the operator must make. These issues are why some do not like touch screens.

The two acoustical wave technologies are interesting because they add the dimension of sensing the pressure of the stylus or finger on the screen. Although not yet exploited, they both have the potential to act more like a mouse in function. They permit the user to glide a single finger over the screen to locate an area of control. The screen responds by displaying a cursor, then when the finger presses harder, the action is created. One vendor claims that sixteen levels of pressure on the screen can be detected. A second hand or second keystroke is not needed to verify the selected function.

The latest technologies that have the potential to be the most "mouse like:"

GAW—Guided Acoustical Wave: Type of touch screen that channels acoustical energy into the full volume of the screen material; compare with SAW.

SAW—Surface Acoustical Wave: Type of touch screen that confines most of the acoustical energy to the surface of the screen; compare with GAW.

The response of the touch screen is very important. Just as with any keystroke or operator action, there should be some way to let the operator know that the "keystroke" was completed. Remember now, this is on a hard video screen. There is no oilcan effect or other tactile impression. There ought to be a sound, however, just as with conventional keyboards. Certainly, visual feedback can be the same as discussed earlier using color change, shape change, the “key” appearing to be pressed down, and so on.

Touch Screen Considerations

One advantage of a touch screen, as compared with a mouse, is the automatic movement of the cursor to the selected location. There is no looking for the cursor location before you start, it is on the end of your hand. The disadvantages are that significantly larger targets are required because the fingertip is too large for small, adjacent targets. Fingerprint smudges can also affect screen legibility, especially when glare is a problem.

Vibration

The touch screen should be visually transparent. Most use overlays that reduce screen brightness by varying degrees. The worst offenders are technologies, resistive and capacitive. This is becoming less of a problem, but some people feel very strongly about this. Infrared has no overlay.

Most touch screens can tolerate physical shock and vibration, but both the force vector and strain gauge version are especially sensitive. The thin glass in the acoustical versions could be susceptible to shock. No changes to the system should be caused by induced fields from EMI, RFI, or any other influences. Cell phones, other communicators, appliances, and machinery may impact capacitive and resistive overlays.

Figure 16-3. Most Touchscreen Versions are Tolerant of Shock and Vibration

The alignment of the screen to the operator’s finger is important to avoid parallax. The resolution targeting must consider the average finger size and a gloved hand. The infrared type tends to be more of an offender, but all have some limitations.

The installation and maintenance should be simple and straightforward. This is an area that is also changing as technology improves. The frequency of calibration may be higher with capacitive.

Some touch screen *layout* considerations are as follows:

- *Place the targets consistently.* Just as with a keyboard, the targets should always be where they’re expected. Alarm Acknowledge should always be in a consistent place on the screen, in every screen. Operator Response to Plant should be found in expected locations so that there’s no question or ambiguity about it.
- *Provide differentiation among the targets* to make them easily distinguishable for the function performed. That is, the call-up of full screen displays (screen changes) should differ from pop-up windows for expanded information and also differ from control selection requests.
- *Keep the number of targets to a minimum* so that the operator doesn’t have high density and too much confusion on the screen.

- *Surround each target with a dead zone* to prevent an operator from accidentally touching an adjacent target.
- *Make the target as large as possible*. A minimum of three-quarters of an inch by three-quarters of an inch for critical functions that must be made quickly. Smaller targets are acceptable if immediate and accurate response is not required. Even though the capability is for high resolution, there should be reduced ambiguity about touching the target.
- *Make all targets rectangular*, if possible, for while this is not absolutely required, quite often it is far easier on the operator and, for that matter, the designer as well.
- *Label the targets clearly*, again, with consistency, just as with colors, with shapes, and with all the other aspects of a screen view. Consistency makes for a better operation.
- *Highlight the selected target* so the user knows the correct selection is made.
- *Provide a multiple "keystroke" action* to confirm that the invoked function or entry is truly the one to be implemented. This avoids an accidental touch that triggers unwanted action.
- *Provide visible and auditory feedback* when the action is invoked. As we said before, let the operator know the entry was made successfully.
- *Provide all consoles (sit-down or stand-up versions) with suitable armrests*. This makes the user's arm extension to the screen as small as practicable and supports a more precise target selection that is easier to achieve.

Navigational Designs

Various standard features are embedded in systems today that help the user make the proper action for each occasion. That is, they provide some focus during plant upset, as well as consistent direction during routine functions, especially ones that require many steps for their performance (start-up, shut-down, changeover, etc.). These are frequently screen call-up sequences directed by on-screen selections:

- **Display targets** (hot spots) provide immediate access to any form of pop-up, which in turn, can include menu selections or control faceplates for operator actions. Because of its fast user-response system, this approach is very suitable for the real-time user.
- **Maps/menus** are a special form of display/pop-up in which a selected display can be called up by the user. These may include structured menu tables or menus coded by display elements (hot spots), which, in turn, can be used to make further decisions. Consistency of symbolic representation, selection, and selection response is critical in any use of coded display elements.
- **Context-sensitive** help allows "help displays" and/or any associated displays to the action at hand to be called up based upon the current display, the control faceplate selected, or the state of the process. These associated displays or pop-up windows can provide interlock, override, and/or permissive information for the related device.

Make touch screen or mouse targets distinguishable with respect to the kind of information to be accessed. Targets that call up controls should be coded differently from those that access other displays. Similarly, analog control call-up targets should be distinguishable from discrete or digital ones. All targets must be identified (a three-dimensional effect is useful to imply a “button” metaphor). Nontargets must not have a similar appearance.

Entries for Control

Earlier in this chapter we discussed the need to use display elements that are standard throughout the plant. This reduces confusion during plant upsets and ensures consistent operation during normal running. Based upon ISA-TR77.60.04-1996, the following guidelines are offered.

Control station—a standard control station display element should

- Provide consistent target functions, including the way targets are presented across all controllers, so that if the operator can click and drag a bar graph to change a variable, it should be expected this can be done in all similar devices as well.
- Use standard keyboard interaction, so that separate keys are consistently used to provide the different needed functions, to avoid errors through ambiguity.
- Provide a consistent location for the basic display elements that comprise the control station, such as labels, bar graphs, meter pointers, numeric values, digital indicators and the like.

Optimum user interaction—guidelines include:

- Provide coding to highlight which items can be selected to be actually controlled by the operator, which control is currently active, and which is not controllable. This differentiation is critical for mimics, where some devices are not controlled by the specific operator (level of training, level of responsibility, etc.)
- Provide clear indication of control states, such as
  — Is the item automatically controlled?
  — Is it manually inhibited by other actions?
  — What is the current operating mode (auto, manual, local control, etc.) of plant areas, units, loops, or equipment?
- Follow a consistent loop-operating philosophy for control of an analog process variable or a discrete state of equipment. This should include
  — A well-defined act for selecting a control. (A two-step operation should be provided for any significant control action, including a means for deselection.)
  — A feedback that the control is active.
  — A separate, second act to adjust the selected control.
  — A feedback from the actual piece of equipment being controlled (not just a verification of the requesting signal).

— A means to invoke context-sensitive help if control is not allowed for the selected device (such as through an interlock).
— A Cancel Selected target or button to clear the currently selected object.

- Perform analog control adjustments by
  — Selecting and entering a target value that has an acceptable slew rate built into the firmware, which drives the change
  — Having raise/lower keys on a keyboard or displayed on the screen view and have them accessible with either a cursor or a touch screen.
  — Selecting a target element at the top of a bar graph of the variable and dragging it to the desired position, so the variable will move at a predetermined acceptable sleMw rate.
- Design displays for sequential automatic control functions to include display windows that
  — List all sequence steps and start/run permissives.
  — Indicate the current sequence step.
  — Indicate the target sequence step.
  — Indicate the steps satisfied.
  — List the inhibits present that prevent further progress.
  — Display the elapsed time for any time-based holds.
  — Include controls to start/stop the sequence
  — Provide direct feedback indicating completion or failure to complete a second command.
- Never allow an item to be controlled but not observed (e.g., if a set point raise key is active, the set point must be displayed).

Audio Access in the Control Room

One other method of human-to-process interface that we did not mention in our list in the beginning of this chapter is the fascinating, but unproved, realm of using audio as a communication medium. Though so natural for humans, it is not fully understood enough to be applied to the subtleties of a control room. We shouldn't feel badly about this. If we are to believe archaeologists, speech as a communicating tool among humans seems to have appeared very late in our development.

There are two sides to this. The voice to the operator from the control system (presumably through the operator interface), and the voice of the operator as an access to the operations. Remember our earlier observation in a previous chapter (Figure 14.2) that the optical path to the brain carries the equivalent of fifty million words a minute, and that's over ten million times more than the aural reaction of the brain. We can learn more easily, quickly, and accurately with pictures then we can with sound. This difference may also be involved in the cause/effect of the late development of speech in humans. By nature, we are more a visual people.

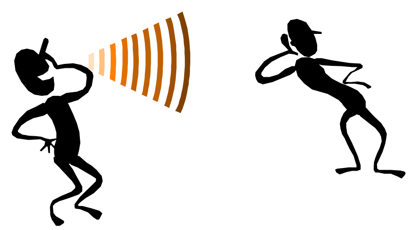


Figure 16-4. More Must be Learned for Effective Use of Audio in the Control Room

Voice Commands

The interpretation of voice commands involves the quality of the microphone, background noise, and, as we have said, the many speech idiosyncrasies of humans. Grammar, accents, inflection, pauses and red tones are all part of the challenge. Systems used commercially at the end of the 1990s either limit the vocabulary of the user by informing him or her of the words to select or required a trial-and-error “training period” so the computer can learn the voice patterns and foibles of each user. Also by the end of the decade, Microsoft had already invested over $50 million to develop the easy ability to instruct computers through spoken commands for word processing, spreadsheets, and so on. There is at least one alarm monitoring system that can place a phone call to announce plant status and respond to specific interrogations regarding conditions.

I can see where a “hands-free” approach could be useful in a control room in selecting screen views for plant conditions. This would probably be necessary only during plant upsets, which is a dangerous time to require that an operator speak precisely. Considering the complexities of human communication, I would personally have reservations about using voice commands to set control parameters (set points and outputs) during stressful situations. How does the process know the difference between asking for an action, inquiring for information, or having a discussion with an nearby partner in the control room that might impact the action or strategy of the process. Much still needs to be done in this field beyond just the “mechanics” of voice recognition.

Pretty Girls in the Airport

We still have to consider that the aural range of operators is not consistent, either spoken or heard. My own experience while going through a very busy airport several years ago confirmed this. I noticed that there were voice directions, a pleasant female voice giving information about which stairway to use to get to another level. Upon reaching that lower level, I began going down an escalator and “she” gave information as to what to expect at the foot of the stairs (walk, ride a gliding footpath, or take a tram). When I was standing by the tram, “she” said when the tram was coming and which door to use. Once inside the tram, “her” voice also asked passengers to stand clear of the door, brace for the acceleration, and brace when the tram stopped as well as announcing we were approaching.

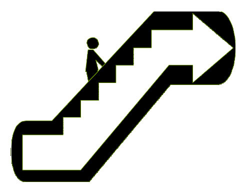


Figure 16-5. The “Girl in the Wall” at the Airport Gave Information

All this was fine and good, but I noticed a change about a year later while going through the same airport. Here again was the pretty girl somewhere behind the walls melodiously telling us all of those same instructions until I got on the tram. There the pretty girl had been fired and replaced by a machine! This very mechanical voice curtly commanded us to “Stand clear of the door” and as the door

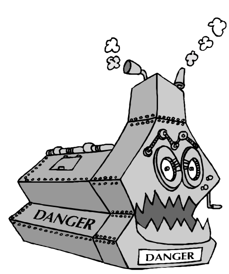


Figure 16-6. The Machine on the Tram Gave Warnings

closed, "Car will accelerate" and so on. Well, I had to ask the management why this change occurred.

Control Room Lesson from the Girls

I was informed that for giving informational data, the pleasant, fluctuating, melodious voice was very nice and helpful. When it came to warnings and attentions and alerts, however, a mechanical voice was needed that would be heard by all. The fact was that the frequency range of the melodious girl's voice was often not heard by all of the travelers. In fact, the full range was only heard by about 60 percent of them. So the mechanical voice, which had a very limited frequency range, was designed to fit the many varied, and even very limited, frequency ranges of most people.

I reflected on the impact of this for the control room. These natural variations and limitations would change the kind of information that could be portrayed to the ears instead of the eyes, and how you would distinguish absolute urgent actions from suggestions. Because the information receptivity of the eyes is far more acute and processing speeds than that of ears, it would seem that most information would be best conveyed through the video screen rather than through loudspeakers. Loudspeakers could be used mostly for alarms, plant upsets, similar warnings. These should be *duplicated* on the screen, so that once the audible message passed the memory of that information would be reinforced. Now the operator would never overlook or forget information given in the past and records could be more easily kept.

We may have to live with the limitations of bells, whistles, Klaxons, buzzers, and the like. Much can still be accomplished inexpensively with multiple tones, tone levels, and, yes, some voice warnings. As for voice inputs, well, science is coming along with that, but more progress needs to be made to be truly effective.

Human Information Processing 17

With automation we have tried to emulate all of the activities of the human facilities. The brain is the information processor that tells we humans how to perform. Our challenge is to discover how to learn from this to really create and use meaningful operator interfaces.

How We Think and Do

Looking at the human being as a computer, we can identify different actions within our brains (Figure 17-1). Of course, it probably works just as well the other way, looking at computers as human, at least to some limited extent. That's because in all design, probably our best model or template for any kind of computing function, communication function, or even motor function comes from that wonderful model called the human being. Within the human brain, we can see several operations.

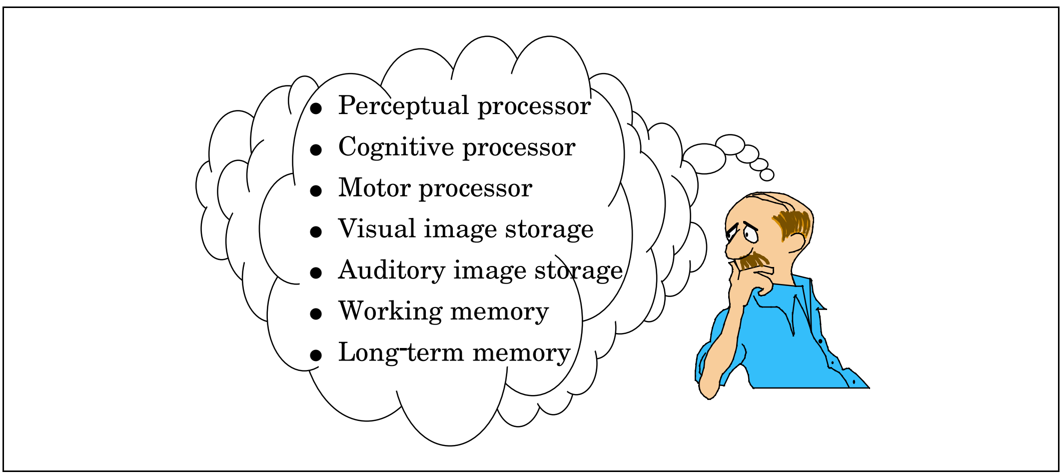


Figure 17-1. Computers Mimic Human Brain Processing Categories

The brain's perceptual processor is where we perceive actions or recognize what's going on around us through various inputs, tactile feel, auditory and visual frequencies, and probably several frequency senses we haven't yet identified. We have designed process sensors based upon many of these human capabilities.

The cognitive processor is where we possess the ability to define our experience or to apply our reasoning power to previously learned information. From this capability we determine the significance of all those things we are perceiving through our many sensors. We have also attempted to mimic this function with our measuring devices and controllers. Some exciting refinements are being explored through our efforts to develop practical forms of fuzzy logic, neural networks, genetic algorithms, and chaos theory, all of which we learn from nature and other life forms.

The motor processor is the response to all of those perceptual and cognitive capabilities, the conversion of our decisions into actions. It is where we make our limbs respond to what we have been perceiving and computing in our head and resolve it into some form of decision. Motor processes give very subtle directions to our limbs, even for extremely complex functions. A good example is writing, which involves the operation of several motor actions in arms, hands, and fingers, using the writing tool to record in symbols the concepts working in our brain. The whole process of writing involves constant feedback and optimizing control.

For all of this to happen well, we also need to have different storage areas, from which we transfer the concepts from our perceptions into our cognitive processors. The brain must store as well as process information. There is visual image storage, and there's another area for auditory image storage. These are then combined with a working memory, which is what we're using to process the information now at hand, and a long-term memory, which is a storage place for of all those earlier perceptions, images, and auditory and cognitive operations that we've experienced in the past.

GUI—[*pronounced:* gooey] Graphical user interface; operating system or environment that displays program choices and options on the screen as icons (pictures or symbols) and often as windows. Selections are typically made with a mouse or trackball (point and click). Invented at Xerox in 1970s, was first used on the Apple Macintosh and later on Microsoft Windows, Digital Research GEM, and X-Windows.

How many versions are there of this term? More than are listed here!

- **CHI**—Computer human interface
- **CUI**—Common user interface
- **EUI**—End user interface
- **ES**—Engineering station
- **HCI**—Human-computer interface
- **HMI**—Human-machine interface.
- **HPI**—Human process interface
- **MMI**—Man-machine interface
- **MS**—Managing station; maintenance station
- **OI**—Operator interface.
- **OS**—Operator station
- **UI**—User interface I

Think of the Interface

How should the operator interact directly with the process? Everything between the operator and the process should be very transparent. This interface is really a gauge of how well we have people interact with a more sophisticated technology. This brings up two fundamental questions that must be asked before designing any operator interface, or for that matter any interface between a person and the function you want operated upon. These two fundamental questions are as follows:

1. **Why do you want this interface?** What is the fundamental purpose for putting this interface here and having something happen through it? You are defining what is really supposed to go on rather than all the nice neat little toys that go with it.
2. **Why would you not want to get rid of this interface?** What you really have to ask yourself is "Do I really need it?" What would happen if I did not have it at all? Very carefully think this one out, and write down all the reasons why it must be there. That will give you the first clue about what functions should occur on that interface.

Differentiate User Needs

The designer of this interface must think like the user who is going to use it, and take into consideration all the phases of the system functions. Be sure to design screen views and dynamics to fit the requirements of each user. What people work with this particular process?

- Plant or process operator?
- Maintenance technician?
- Plant or process engineer?
- Automation engineer?
- Quality assurance personnel?
- Business manager?

All these people have different functions to perform, and therefore they need different information from the control system. The presentation of the data for converting this into information is probably going to be significantly different for each of these six people, or for any other people who should use it. The tools that each of these people need to perform their functions on the process or on the plant will also be different. Yes, sometimes there will be things in common, but more typically even if those common things are performed they are performed in a different context. If you have an action item that can be created from the screen, it's probably going to be surrounded by different forms of information depending on that person's role.

Operator Action Philosophies

Surprisingly, there's only a small body of work on the design principles for operator interfaces. Some of the most interesting contributions have come from researchers at the Georgia Tech Multi-Satellite Operations Control Center, who authoritatively tested the implementation of a new real-time operator interface on a variety of operators.

Such research is expensive, which may account for its rarity. Most research on human-computer interaction is relatively narrow in scope, focusing on individual aspects of shape, coding, color, and menu design. Incorporating all the different aspects of computer capabilities and human aptitude into a usable product is one of the jobs of any serious designer. To achieve success in interface design, it is necessary to understand the ways in which humans think conceptually and to understand how they process this information physically. The physical and conceptual are closely related when working with any type of interface. Designers should ask themselves what type of information is useful to the field operator.

Consider some important issues involved in designing the operator interface:

- Easy to navigate through video screens
- Reduced chances for misunderstanding
- Accurate representations of process or functions
- Consistent and predictable operation
- Pleasant and engaging interface that conforms to operator's understanding

Two major elements determine the display type:

- **Display content**—established by user functions (task analysis)
- **Display organization**—must be logical to the user

Users with different responsibilities may need the same content to be organized according to their specific responsibilities. The display types provided should offer enough flexibility so that, when used in conjunction with the display system's capabilities, a user's needs can be comfortably accommodated. For example, some operators may prefer to operate from process mimics, where others may prefer to work the control station faceplates. The amount of detail on the screen at any moment in time should be left to the discretion of the user.

In planning video screen display types, it is important to consider various techniques for expediting display recognition, including the following:

- Reduce the display types; use flexibility only in response to specific user's preferences.
- Enhance user recognition with consistent formats and methods for showing information.
- Use standard elements such as symbols, colors, names and abbreviations for all displays, even if the display content and organization varies because the intended functions are different.

When a standard format and especially a standard layout are used, displays will tend to look alike. To avoid confusion and errors, it is equally important to make each display and layout distinguishable from each other by using unique titling and possibly other coding techniques.

For example, if multiple units of the same process are accessed from a common console, the unit number must be clearly displayed. Consider using along with that number some shape and color (like a unique team logo) for that unit alone, and with everything that is associated with it. Another method would be to use a different background color or “wallpaper” pattern. Refrain from getting carried away with the idea and creating a visual circus!

Intuitive versus Learning by Rote

User behavior for programming was organized by Schneiderman and Mayer in 1979 into either syntactic or semantic knowledge. Syntactic knowledge is learned by rote, involves little system understanding, and is only short-term. An example of syntactic knowledge is using combination keys such as “CTRL-C” to copy a selection or “CTL-ALT-DEL” to close an application, as is done with many DOS-based computing applications. These actions or key assignments are frequently different with each different system, so the knowledge is not transferable to other systems in even the same plant.

Semantic knowledge, on the other hand, is taught through concepts, relationships, and analogies. Semantic knowledge is often conveyed through pictures, is task-based, and once learned is not easily forgotten. An example of semantic knowledge is the use a picture of file folders or icons that resemble the functions performed, as is done in Macintosh computer applications.

By not working with abstractions, users usually have a much better idea of what the program does. This semantic thought process is one of the ways humans break complex problems into manageable pieces. Learning is much faster, and the user becomes far more comfortable with the operation. Semantic knowledge leads quickly from running the process to managing the process.

Range and Uses of Operator Interfaces

In *Networks for Factory Automation*, we will discuss the linking of local process control and factory automation systems directly into the corporate business planning systems. The focus today is not only process control and process management but also equipment management, production management, order management, procurement management, personnel management, and financial management. All of these fall under the category of business planning. In the future, using an operator interface will change significantly. For example, in the process management area, you are monitoring the parameters of the process itself, the accuracy of sensors, the operations of the valves, and so on. Today, in addition to controlling the recovery of plant upsets, there is also environmental monitoring, product yields, predictive maintenance of the process equipment, and many other requirements.

The system designer must provide tools through the screen displays that are capable of navigation through many more diverse activities. They must support the operator’s ease of access to a large database and simplified decision making through presentation, interaction, and analysis displays. The operator is also responding to plant upsets and alarms or changes in process conditions. He or she must follow intuitive screen prompts and must navigate through the screen displays and various windows to discover the different aspects of the operating plant.

Under the area of business activity, there's financial management and product production management. Product production management is the raw material usage, the inventory, the logistics of getting the material to where the operations occur. It is also production scheduling, production monitoring, the product's quality control, material movement and storage, energy usage, the unit product's production costs, lab analysis, and so on.

Philosophical Issues

Key issue:

— Do customers and vendors really know what the *application* needs?

Technology is not the issue:

— The issue is commercializing technology into useful products!

— We have ten years of technology we are not yet using!

The human today is a manager:

— The computer/distributed control system *operates*

— The human *manages*

Process control is the art of making food, pharmaceuticals, steel, glass, paper, cement, power, clean water, and the like. The *computer* merely helps perform the art better and make it repeatable!

On a level above project management is financial management, which includes invoicing and billing; the accounting functions of general ledger, accounts receivable, and accounts payable; purchase order tracking, and sales and marketing forecasting for the products. This enterprise resource planning (ERP) must dynamically link with the production management to preorder materials as the inventory of raw material goes down as well as track the requirements of customers and their orders to determine how to optimally custom fit each production day to meet the customer's requirements.

This dynamic linking of two types of information flow presents both interesting possibilities for the concept of the control room and also some exciting challenges. The operator is now exposed to business parameters that previously only existed in paper reports that came out monthly or quarterly. These become new parameters that impact daily production. This is untested territory for both the business as well as the production side! The real challenge is now to the system designer.

The architecture required for these roles is being modified along with the technology it requires. Perhaps some day we will see no difference in the architecture, but for the time being one must be concerned with the proper execution times for achieving these different functions as well as the nature of the operator and screen views needed for each of these functions. Keep in mind that any presentation must take into consideration the proper audience.

More Philosophical Issues

An interesting dilemma in developing any control system is the question, "Do system customers and system vendors really know what the application needs?" Many times the excitement over the technology and the clever operational features that can be performed by this technology obscure the actual requirements of the process or the plant. Everyone seems to be caught up with the "gee whiz" of the technology, and they forget what they're supposed to do with it. Technology is not the issue. The issue is commercializing the technology into useful products. We have ten years of technology we're not even using yet for improving product construction and performance, especially in process control. In the operations of a plant, the human is a manager, while the computer or the distributed control system operates the functions. That's different than what happened in control rooms in the past. Keep in mind that all process control is an art, not a science. It is the art of making food, the art of making pharmaceuticals, steel, glass, paper, or cement. The computer merely helps perform the art better makes it more repeatable.

Human Factor Considerations

- Eliminate unnecessary handling of data

  Use a control and data acquisition system to convert, record, store, log, alarm, and trend data

- Minimize the stress caused by of a process upset...

  Use a control and data acquisition system to help identify the problem

- Present current information

  Instantaneous values should be no less than one to two seconds old

- Minimize operator interactions

  Reduce keystrokes, push buttons, display paging, hunt and search

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Remember:

- The fastest form of input for human: visual
- Provide timely *information*, not data
- Facilitate operator interaction with the process control equipment should become transparent

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Human Factor Considerations

An important factor in the development of screen views are the actions the operator needs to take in response to the information presented to him or her. The idea is to eliminate the unnecessary handling of data. The data should be converted into information so the operator doesn't have to process the data in his or her head and decide what to do with it. This is exactly the role that a computer can perform admirably. You should use the control and data acquisition system to convert the data, record it, store it, log it, alarm it, and trend it. You should use the functions of a computer to minimize the stress of a process upset and use this control and data acquisition system to help identify the upset problem. You should use the computer system to present current information; an instantaneous value should be no more than one or two seconds old. The system should minimize the number of operator interactions by reducing keystrokes, the amount of display paging, and any required hunt and search for information. Of course, above all you should remember that the fastest input for humans is the visual.

Screen Design & Conflict

- Not enough data-increases the need to search several screens
- Too much data-dilutes the significance of any specific information
- How much can an operator monitor?
- How much can an operator control?

Design Conflicts

I can't emphasize enough that the purpose of this control system or the computer is to provide timely information, not data, and to facilitate the operator's interaction with the process itself. The control equipment should become transparent. Of course, making it transparent presents some interesting dilemmas. The screen design conflict is that if you do not have enough data, it increases the need to search the several screens for this data. If you have too much data, it dilutes the significance of any specific information. So you have to decide how much an operator can monitor and how much an operator can control. Big difference. A shepherd can monitor three hundred sheep, but he or she can only shear one at a time. The age-old problem of trying to determine how much control an operator can manage or how many controllers an operator should try to manipulate probably can be best evaluated by the average person, not from within the plant but by looking at common activities they do everyday.

How Much Can an Operator Control?

Let's examine this question by looking at the art of driving an automobile How many loops can an operator control at the same time? How many parameters can you control while driving your automobile? The controls of an automobile include the following:

1. A steering wheel 2. A brake 3. An accelerator 4. Perhaps a clutch.

Now, picture yourself driving with only those four controls through a nice winding "s" curve in heavy traffic. Midway through the curve, just *try* to also change the radio station! And that's only *five* operations!

Look carefully at your plant and see what you are expecting of the operator, not just in normal operations, but in plant upset conditions.

Moral: A shepherd can monitor three hundred sheep but he can only shear them one at a time!

Menu Structure Guidelines

Serious consideration must be given to how the operators manipulate and maneuver around the process or plant. This certainly is more involved in larger plant structures. The scope and job of an operator doesn't stop with the immediate process but also extends into the things that happen adjacent to that operator. What is happening upstream and downstream from this operation? How do the actions occurring here impact other portions of the process or plant?

The system designer must analyze the task that is required, and the information needed to do it. Having done this, the designer must define the structure that will best provide the tools to do this task. What should be the hierarchy of the menu structure? What are the relationships *between* the tasks and the functions performed in each view? What is the logical movement between these views (tasks and functions)? How do we keep the operator from getting lost in the windowing? What occasions need toolbars, poke points, pulldowns, pop-ups, hot spots, or hot keys? All these different, technically clever features should be done consistently throughout the system, so that every time a specific operation is needed, the actions for performing it well are consistent no matter who is operating!

The most mistreatment comes through the absence of clear labels and the inconsistent layout of all the screen views. Whenever any action is made, there should be immediate feedback on when the request is made that is *separate* from when the action actually occurs. Never, ever, should the operator see on the screen a response to an action that derives from a simulation of that action rather than from the actual occurrence of the result of his action.

Menu and Screen Structure Guidelines

- *Analyze* task required and information needed to do it.
- Determine who will do the task.
- Decide when the task needs to be done (event and/or time-based?)
- Have well-defined objectives to guide content and organization.
- Define *appropriate* access structure to be used:
  — Hierarchical
  — Pulldown
  — Windowing
  — Pop-ups
  — Toolbar
  — Hot spots

  — Poke points
  — Hot keys

- Navigate *consistently* throughout the system
- Use *clear* labeling.
- Use *consistent* layout.
- Provide *immediate* feedback:
  — When request is made
  — When action occurs
- Provide aesthetic balance!

Often overlooked in menu and screen structure is aesthetic balance! There should be an appropriate blend of colors, and an appearance and use of shapes that it is pleasing enough to not look out of place. We are not talking about just making pretty pictures here! This is more like good page layout in a document. The layout contributes significantly to *conveying* the information from the content on a page to the reader. ("Didn't you get my note?" "I got your note, I just didn't know that's what you said!" Has this ever happened to you?) Poor layout and color combinations will distract the reader from, important information or even hide it altogether.

Display Organization and Content

Based upon ISA-TR77.60.04-1996, the following considerations are offered for general content and layout; emphasizing important items, providing easy recognition for the user, and for grouping, labeling, and coding conventions. Keep in mind that whenever rules are laid down, there will be contradictions in their specific use! Trade-offs will be required, but always consider which option will have the greatest impact upon process/plant performance.

You must consider the general content and layout:

- Provide the necessary content but only what is sufficient to support the display objective.
- Arrange the content so that it is not too dense.

Crowded displays make it difficult to locate information. A rule of thumb is to provide a minimum of 25 percent to 40 percent blank space. For systems with a limited number of monitors, it may be necessary to increase display density to avoid the need for excessive paging between displays. A good effective display design will allow more information to go on a single page without clutter. Careful use of windowing will also help!

- Show the data that is most relevant for the display objective (e.g., capability loss may be more important than resultant low flow).

- Organize elements by the order they will be used (e.g., top to bottom, left to right), with more frequently used elements given more prominence.
- Make comparisons easier by placing those elements to be compared close to one another.
- Match the level of abstraction with the display objective (i.e., summary overviews may need only deviations from intended marks, without absolute values, while detailed process displays will need more concrete values).

You must emphasize important items:

- Establish a consistent focal point for each screen, such as centering the title at the top of the display to serve as a starting point for viewing the display.
- Place those elements that have priority over others in prominent locations.
- Avoid displaying alarm conditions or status conditions that are in normal (unalarmed) condition (i.e., not active, alarm warnings are off) in the regularly used mimic displays. This is not to be confused, however with the need to show normal equipment status (on-off, fill-empty, etc.) which may be needed to monitor plant operations.

Instead of displaying alarm conditions that are in normal, consider alarm *group* summaries instead. These make possible the analysis of alarm *patterns* using certain fixed-layout displays that show all possible alarmed points within a unit process, both in and out of alarm.

- Avoid showing secondary equipment if the current status is satisfactory
- Display limit indications only when the limit is reached, or when knowledge of the limit (and the approach to it) is needed as part of process/plant performance.

You must make the displays easy for the user to recognize:

- Comply with the user's way of thinking about the system
- Take advantage of the physical relationships of the process/plant that are known by the user, such as the locations of equipment involved.
- Maintain consistency in display design with the displays already in use, such as in "legacy" control systems already installed in the plant, especially if the users are rotated about the several systems. This does not mean you should avoid using valuable features of the new system, just make their use, as much as possible an intuitive extension of what has already been learned.
- Take advantage of any existing conventions and practices, particularly if they are well known and accepted. This is particularly important in the seemingly mundane area of plant abbreviations, symbol standards, or color codes.

You must use logical grouping and labeling:

- Make the *grouping* immediately recognizable without the need to read the specific data.
- Use spacing rather than lines to separate groups of data and or equipment, to reduce clutter.
- Group data by functional relationships. Consider the data's user, however, and realize that different occasions will determine whether it will be best to group by importance (priorities), frequency, sequence of use, location, or alphabetical (numerical), or chronological order.
- Make the grouping consistent with all similar type displays.
- Label all data, unless it truly is intuitive and easily inferred from the display layout.
- Make labels short, unique, and distinctive.
- Establish labeling conventions for size, location, and case (upper or lower). Size should be consistent or by some hierarchical standard. Locate labels consistently with respect to data-preferably to the left of or above the data field. (Upper and lowercase lettering is more readable; don't use all upper case).
- Avoid the use of solids to establish boarders; they add to the complexity of the views.
- Place data value "text" that is more important in bright colors (white, yellow, light green, cyan) to make it appear more noticeable.
- Place less important values in lower intensity colors, as much as half as bright.

You must use coding conventions accepted throughout the process and/or plant:

- Establish plant wide (or a least process wide) coding conventions to maintain consistency across the displays. Primary coding should emphasize pattern and shapes over colors.

Shapes are quick and easy to recognize and independent of any color coding. Shapes are especially effective for identifying components and their operational status.

- Code to natural expectations (a larger pump should have a larger symbol).
- Employ codes already known to the users (plant color coding, abbreviations, drawing symbols, etc.).
- Use obvious codes (up arrow as the symbol for "increase," etc.). Avoid ambiguity (PRNT may be better than PR if the system also has functions for Primary, Previous, etc.).
- Establish a "shapes" library to assure uniformity; use standard symbols familiar to the user.
- Make shapes clearly distinct; 10 to 15 are easily distinguishable.

- Use space to ensure the legibility of alphanumeric characters when used in conjunction with a shape. For example, place the label within the shape whenever possible.

Use shapes consistently for the same equipment or to convey the same meaning. Simple shapes should reflect equipment shape as much as possible.

- Provide definitions for special uncommonly used codes, such as using single or short-phrased terms in the appropriate color and if appropriate, a small adjacent color block so this can be referenced by those who see some colors as shades of gray. Use “help” screens for definitions.
- Avoid overusing of codes, which add clutter and require the constant interpretation of the user, which diminishes his or her focus on the task being performed.
- Use a dark or neutral screen background. The *overall* screen background should match ambient conditions, in which 25 percent to 50 percent gray is considered best because it masks glare. The coding of display elements will achieve better contrast if they are set against a darker or black background on their specific field. Examples of this are a small “window” just for text, numerals in yellow on black background, and a green bar chart fill on a black background in an instrument faceplate.
- Use a different background for “pop-up” windows to distinguish them from the main screen and to ensure that the background provides a good contrast with the established color code (such as light gray for a “pop-up”).

More discussion on the use of colors can be found in Chapter 15.

You must develop a method to highlight changes:

Highlighting is a way of coding so as to catch the user’s attention and should be limited to two or three items on any one display to be effective. Highlighting includes the following:

- *Reverse video*: effective for alarms so as to overcome the low perceived brightness of red.
- *Increased brightness*: increases color intensity or switches to a brighter color when invoked.
- *Flashing*: Extremely useful for attracting attention, but to be effective, it must not be overused. It should be reserved for alarms or for possible target detection in a high-density display. The user should be able to suppress the flashing action.

Flashing text becomes unreadable! The best alarms flash near the text.

Hierarchies of Views

In very large processes, or especially in large plants, not everything is not going to fit on the same screen view. The connection *between* screen views is very critical here. It is imperative that there be some hierarchical concept of how the screen views go together so the operator can intuitively navigate from one view to the other. Display structures provided by vendors of real-time distributed process control systems are most commonly organized in a hierarchical structure. These group displays according to levels of detail, where each display serves as a menu to information above or below its level.

To return to Renzo Dallimonti's original concept form the 1960s and early 1970s, let's, look at the old panel as an overview. Step up to a group of instruments on that panel to observe and manipulate control actions. Slide one of the instruments in that group out of the case to access the control parameters, tuning parameters, or alarm connections so that each loop runs properly. We talked about these three concepts in Chapter 12, which is fine in a process plant in using closed loop control. Let's expand that idea into an overall large plant operation of any kind. Within some plant unit, there could be many small groups of instrumentation clustered in a given process located. Several of these units can be within each of the areas of a plant. The terminology for this scenario will change with every plant, but the concept occurs in nearly all of them.

Our example in Figure 17-2 may be more involved than is needed for a small system. Nevertheless, even a small system needs some logical order. Our example is intended merely to show that there can be many levels. Symmetry is not intended here because most plants are not really symmetrical. Of course all this is "idealistic," but to be *idea-listic* is to develop ideas.

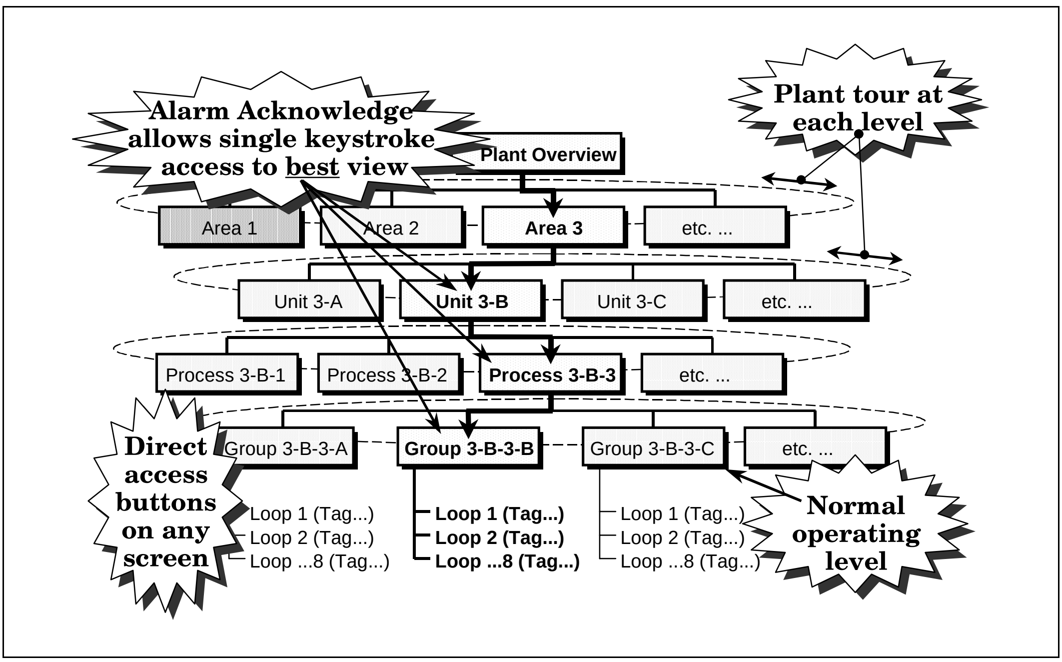

Figure 17- 2. Good Screen Hierarchies are Imperative For Good Navigation

At the top view in Figure 17-2 is an overall understanding of the plant operations, with the focus placed on the general health of each area below it. Besides showing which areas have alarmed conditions, this perspective should assist the viewer in learning where potential problems are developing. Some sort of warning lights or, better, messages are appropriate here. At each level "below," there must be some logical direction toward the next level, perhaps by merely "clicking" on a highlighted area. The pattern is repeated at each level. If an aberration in the plant is being traced, the operator could drill down into the hierarchy by "following the flashing icons."

Keep in mind that movement between screens should be *consistent* but also *appropriate* to the operations of that view!

In addition to drilling through the levels of a hierarchy of views, the operator must also have the ability to "tour the plant" at each level. Sometimes, for example, there are multiple units of the same process, such a boilers in a power utility. This plant tour may easily be accomplished by paging through the screen views at any level. Moving between adjacent views can be done with pointers embedded within the views, such as arrows on process piping, signal "wires," and other parts of the diagram that lead off screen to adjacent views.

Constructing screen hierarchies and navigation are discussed further in *Alarms and Plant Upsets in Distributed Control*, following a necessary discussion of the nature and types of alarms and their handling.

Generally overviews in the upper level(s) of the hierarchy are informational and make possible the monitoring of the general conditions of the different processes within the plant. Rarely would you expect an operating function to occur in one of these views, but they may occur such as to turn a particular process on or off as you do in a start-up condition. In a start-up situation, you ought to consider showing multiple steps as prompts. If some difficulty arises during the procedure you are then led to an adjacent set of procedures to overcome it. The middle level consists of the control displays from which the process/plant is run. The lowest level are the details "within" the controllers and diagnostic displays.

From whatever screen view within any system, the operator must always see the alarm activity and have direct access to any other operating view, alarm analysis view(s), and process tagged point in the system without having to "climb" through any hierarchies of screen views!

Straight hierarchical views are not the only way to organize viewing structures. Two other approaches have also been used successfully:

- **Sequential structure** is where movement from one display to the next is governed by a sequence of procedures. Such a technique is helpful in managing start-up, shut-down, and changeover procedures. Good use of this approach takes advantage of pop-ups in a windowing environment, which were not available in the earlier systems.
- **Spatial structure** is where the video screen structure matches a mental map of the physical layout of the process and/or plant layout. This is an expansion of the fundamental concept of "touring the plant" in some order that is very intuitively logical to the operating crew.

With recently emerging technologies, many new ideas can come from experimentation. Such experimentation requires a rather flexible system that allows the user to start in a simple hierarchical structure, then move easily into some new version as the opportunity presents itself. All these techniques can be embedded into the other structures for a blended "mix and match."

Borrow from Video Games

As the system designer, you will have to have a very good picture of the process in your mind, both functionally and physically. Somehow, you *must* convey that same understanding to *every* operator, no matter their experience level or tenure (this is, after all, the real world). A good model of this challenge are video games, which take the player (new or experienced) through all kinds of mazes toward some goal. Got the idea? Of course, the big difference is that this is no game, and you cannot have any of *your* players *guessing* how to solve the puzzle!

In your overview, you are in the main control room. Look around at all that should be available to enable the operator to understand the plant operations. This could also include a map, either physical or functional or both. To begin any tour(s) you want the operator to take, you must provide "doorways" and directions. There must be doorways, emergency exits, and escape hatches in each screen view for logical progression for and eventuality. Take him or her through well-marked corridors and pathways to each needed operating location. Clearly mark any detours caused by changes in conditions (or even temporarily for maintenance and repairs). "Stairways and elevators" to other levels of the hierarchy must be equally well marked, with no ambiguity.

Within any one of those operational rooms, there should be other "doorways" to step through, and each "doorway" should lead the operator into more details of the equipment for that operation, and perhaps more specific control actions if necessary within that operation. Again, the operator can move around within that area of the plant, finding clearly marked information about that area and what can happen to the process as well as all the controls to cause it to happen or to make corrections. There could be further doorways within this room into other closets, if you will, of specific information and actions, such as the tuning of a controller or the viewing of inputs and outputs and so on, within that other room. Depending on the complexity of the plant, these will depend very much on the levels of the rooms within that plant.

Upon any upset, there must always be clear "emergency exits and escape hatches" (I suppose it will be better to "dematerialize and rematerialize") to allow the operator to instantly either

1. Go *directly* to the location of the upset to make corrective action, or
2. Go to *directly* to some "war room" where a proper analysis of the situation allows the operator to determine what needs to be done, in what order, and how to get to each task (better yet, how to bring each task to the operator).

In both circumstances, there must be prompts, suggestions, and check-off lists for as much information as possible to support the activity.

Remember that the operator just came out of another part of the process or plant. This area may have a parameters and different set of conditions to consider. The more this new area differs, the more important it is to get that operator the correct information, with the tools to make the right response. Proper presentation can take the form of instrument faceplates, dialog boxes, prompts and messages, more complete alarm conditions, and certainly good visuals. Equally important, there must be a route just as direct returning to the interrupted task or specific directions for the next required tasks after the correcting activity.

Alarm Response "Keys" Must Always Be Available:

ACKnowledge, SILence, FILTER, and direct access to go to any alarmed point in context of its most appropriate operating view and also direct access to the alarm summary list for analysis.

Remember the last or back "key." Many users prefer it to toggle, only one "layer."

Remember "utilities" like print (screen), report system (health).

The Operator's Perception Is Reality!

The video game analogy fits most any kind of manufacturing or process control system. More than cute imagery, I present this view to help you to seriously try to perceive what should happen in screen view designs. Recall that in Chapter 10 we discussed "The medium is the message!"

A hierarchy of views must be thought out very carefully! Most systems have a technique for maneuvering between views. Exploit it. Use all of your creativity so the operator is operating as intuitively as possible without having to learning some strange, cryptic function. To do this means that the designer of the plant has to understand the culture of the operators who are going to run that plant. Consider appropriate control room culture; what if operators at two different station make conflicting commands to the same process? This could be the culture of different countries or, more typically, the cultures of different industries. How do people think in a paper plant compared to a power plant or a steel mill? What has been their tradition, which might be centuries old? Then that tradition should be followed as closely as possible.

This doesn't mean you shouldn't introduce new ideas, but the ideas should be introduced within the concepts of those traditions. Now, of course, running a plant well, under normal conditions is relatively easy. It's just like, having once learned to drive an automobile, running on a nice clear day on an open road is relatively easy even if you're on a road you've never traveled before. What's critical, however, is how you respond when a serious accident starts to unfold. What do you do in a critical plant upset? That's the key. So you must look at all the conditions that can happen in a plant and think the way an operator thinks within his or her culture.

What About Control Rooms?

My emphasis has been primarily on the much ignored and abused area of good, workable screen displays. I personally believe this is the area where people have the least experience. This is not to say the control room itself is not important. The uptime and long-term reliability of a computer control system will be the ultimate benefit of initial site planning. Designing as you go, without forethought, can lead to devastating costs and extended installation schedules.

The color schemes on the screen display have to be consistent with the operation of the plant. They should also be pleasant enough so the operator isn't distracted from the operation. The psychology of restful and exciting colors, however, is not as important on the screen as it is in the room itself. A room layout in which the upper portion of the room is lighter and the lower portion darker is standard psychology material that can be investigated in other books. The physical specifications for equipment installation are discussed in Part J, on control system implementation.

Plant Manager/Engineer Requirements:

- Code requirements
- Expected control room functions
- work flow patterns
- Future expansion
- Security (fire, flood, files, foe)

Physically, control rooms must have the proper ergonomic layout. Be concerned about the height of the seats, whether their height can be changed, the position of the operator's arms with respect to the keyboard, and the distance of the operator's eyes from the screen views. Do not overlook the way in which that control room is used. Is the operator continually sitting in front of the screen all day or as in most plants, is he or she merely coming by that operator station to make adjustments to the control system in the midst of doing other duties? Is the operator also required to walk around other parts of the room or for that matter, in other parts of the plant? Pay attention to where the operator sits all day, the layout of the furniture, and the placements of screens and keyboards.

Operator Requirements:

- *Lighting*—Use a mix of incandescent and fluorescent; spotlight certain work spaces; avoid glare; and think of good areas for the monitor and keyboard for writing, for the printer, for the office, for equipment service, and storage, and for the entrance and exit.

- *Noise*—Avoid droning as well as loudness (under STC rating of 52)
- *Color*—Consider in conjunction with lighting—keep them coordinated to reduce fatigue. Need to be appropriate for purpose (cool and relaxing, warm and stimulating), light over dark.
- *Vision*—Consider along with lighting; any wall graphics must be visible from normal operating position (and readable); and screen views must be readable.
- *Ergonomic*—Goes together with all the above; use the proper chair and table heights and styles for the work intended (adjustable); consider accessibility of normal working "tools" (retrieving, reaching, etc.); consider the personnel's with respect to age range for vision, noise, lighting, personal hygiene, and the like.

The operator's performance involves vision, color, noise and lighting. The operator's equipment requirements and the ergonomic demands are part of this design. Other considerations in the room are how the equipment is laid out, the relationship between the kinds of equipment and screens the operator must use, the space required for that equipment, and the access for the maintenance of that equipment. The temperature and other environmental requirements, floor loading, vibrations, and cable restrictions are all integral to the control room layout. From the plant manager's viewpoint; you must view the system; assure appropriate work flow; coordinate the functions of the room itself, plan for future expansion and the code requirements per building, and protect the control room from fire, flood, loss of files, and even interference from outsiders.

Control System Requirements

- Equipment delivery and temporary storage
- Equipment relationships
- Maintenance requirements and accessibility
- Space requirements (footprint, working area needed)
- Floor loading
- Vibration and shock
- Temperature, humidity, altitude if appropriate
- Power
- Air flow
- Noise
- Lighting

Operator Interfaces Outside the Control Room

While an advantage of a distributed control system is in the distribution of the computation, these systems have centralized information going into the control room. Generally, there are databases resident in many places, such as within each controller. The data from these remote locations, however, is gathered so all the information is available at one location so an operator to has an understanding of the overall operations in a plant. This is also the same data to be used in a plant computer. In many systems, there have also been local operator interfaces, often video-based, at specific controller locations. The data within these was only local to that specific operation. Technology is allowing even newer opportunities for change.

The freedom now given us by the expansion of memory capacity and microprocessor power allows these local operating points to have access to whatever information is available to other parts of the system. The operators are no longer limited to some "remote" central console but are able to move closer to the process again. The difference is that they take with them information from all of the plant, not just the central console but also from any computer connected to it or the system!

Transmission techniques now allow a small portable handheld video screen and operator keyboard to be carried with the operator as he or she tours the plant as in days of old. Technology growth is allowing operator to tour the plant again, but with access to all of the console, which changes control room strategies. Now the operator has a first-hand view of the process and can crawl around, smell, feel and hear everything that's going on, all while performing a very thorough link to the actual controls and all the plant information. Returning to the plant floor like in "the old days," he or she is no longer limited to running only some local control point when he or she sees a problem.

Going a step further, because of the technology developed by the military, it is quite practical now to have these field connections linked to helmet devices. Using "heads-up" displays, the operator can see and hear process operations directly from screens suspended from the helmet and microphones attached to them. A small keyboard could be worn at the belt or connected to the shirt, very much as seen in some science fiction shows, except that today it is possible. The practical uses of these helmets probably will first be as a way of tuning a loop or calibrating a remote transmitter, particularly one that's high on a refinery tower or out on a pipeline. Nevertheless, as these tools become economically available, it is quite clear that customers using them will find new and different uses that the vendors could never have imagined.

A major control systems vendor already has a new wireless operator interface. The operator has small "heads-up" view screen in front of one eye and a combination mouse/keyboard mounted on a forearm. This allows the operator to roam the process while still viewing the process data and being able to take corrective action.

Business Views of Processes?

The other direction is to take the control parameters up into the boardroom. This has been touted by many vendors as a wonderful opportunity to display the controls on the screen in the boardroom, perhaps for the purpose of discussing the operating conditions. This would be fine for a management discussion on the operation of the plant, but it would be very dangerous to have that kind of view used to *operate* the plant. The operations of the plant should be left in the hands of the operators. Management screen views of the process should NEVER permit access to operational changes to the process. Process control should never be manipulated by managers sitting in a boardroom who aren't in direct contact with the actual events. Such a boardroom view will certainly be a valuable tool for analyzing the plant in conjunction with the business operations, but never, ever should this capability be used to perform plant controls.

Another advantage of the new technology can be a desktop or briefcase notebook interface. Just as you have notebook computers and briefcase computers for business, so also you could display operations in a plant. Again, this would be not for the manipulation of the plant processes but perhaps for the manipulation of the *information* that goes into the database. In this way, the manager of a plant could show prospective customers how well their plant performing some of the functions for that client, or perhaps the progress of that client's order. In some industries, we are evolving toward having customer-directed custom products. The representative of the factory could actually go to the customer and suggest different changes in the production mix. This could be entered into the enterprise resource management part of the package, but certainly not into the production line itself at that point. Nevertheless, such an option would provide a powerful opportunity for dialogue between the manufacturer and his customer regarding the specific requirements that customer needs.

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