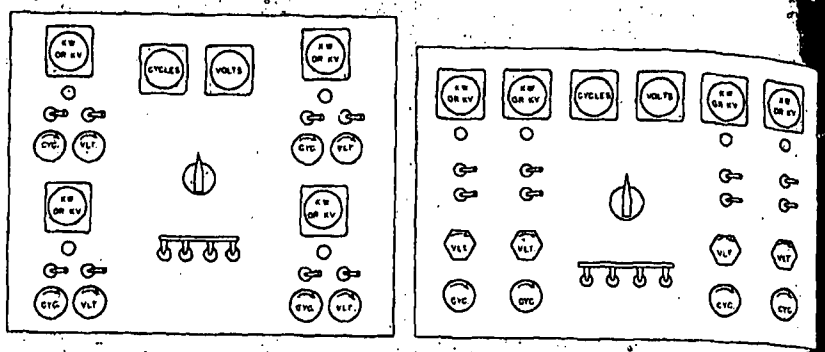
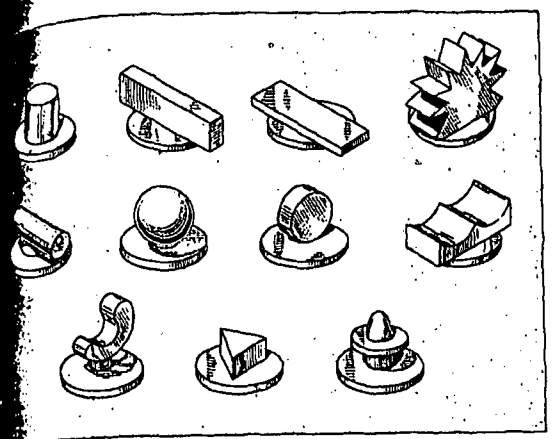


5 Original arrangement of distribution panel did not place instruments in the same order as generators they represent

6 Proposed arrangement of distribution panel places dials and control knobs in the same order as their generators



7 These knobs are results of a human-engineering investigation. Extensive experimentation shows they help positive identification by an operator, minimize error

neering service to analyze the job requirements, study all the proposals, recommend a single design that could be defended scientifically. The human engineers set up experimental materials to simulate the proposed panel arrangements. *The various components*—voltmeters, frequency meter, synchronizing lights, rheostats, snap switches, bus bars—were made out of photostatic copies of full-size drawings. Each was cemented to a small magnet that could hold the component in any position on an iron panel of the same size as the instrument panel. This allowed setting up any arrangement within seconds.

The most difficult part of such an investigation is to set up an experimental design that is scientifically sound. A series of trouble-location problems were designed. These were administered to a series of 16 operators under carefully controlled conditions. The time they required to locate the source of difficulty was taken as the criterion to choose the best instrument arrangement. Half of the problems (four in all) used the graphic feature, the other half did not.

Each of the 16 subjects was presented four different versions of the following problems: source of trouble indicated *by (1) meter alone (2) meter and* warning light (3) meter and bus bar (4) meter, warning light and bus bar.

Performance times were measured by stop watch. Analysis of these times showed no significant difference. The client was then advised not to entail the extra expense of the illuminated bus-bar feature.

Instrument Simplification. Reducing the number of instruments that an operator must read can sometimes simplify his job. An instrument is justified only when it contributes to decision making. Too often instruments are kept on a control board after their original function has become obsolete.

Sometimes instruments can be combined without increasing reading difficulty. *One airline found that fundamental information was given by the* difference in readings of two instruments, rather than the individual readings themselves. By combining the two instruments into one with two pointers, the operator need only respond when there is a space between the two pointers. Presumably, further simplification would be to substitute a light that would function when the two variables failed to synchronize.

System Improvement. Much of human-engineering activity concentrates on improving existing control and display devices. A new trend is to look first at the need for the device before *attempting to improve it. Man-machine* systems have the ultimate aim of producing goods or a service. This should be kept in mind when attempting to improve or modify some internal component of the system. Unfortunately, there often are very complex systems whose performance characteristics no one really knows. This stems from the high degree of specialization of company departments and personnel. Such a situation leads to people getting lost in their worlds without understanding the effect of their performance upon that of others.

Electrical utilities find that centralized control in power plants reduces *labor costs. But centralized control* often means more instruments to watch and *raises questions* as to best control-room layout. Increasing use of automatic controls gives the operator less opportunity to practice skills he must use in an emergency. Here we have a curious situation in which the operator has relatively little to do most of the time (leading to boredom), but during an emergency he *must immediately* do many things he never has done in exactly the same way before. One investigator has pointed out that where automatic equipment is used, there is a strong tendency to neglect even minor maintenance duties so that equipment failures still occur.

Several sources influence decisions *on power-plant control, and controver*sial issues constantly arise. For example, designs of major equipment—boiler, turbine, generator, feedwater system—are each assigned to the various experts in those fields. But the over-all information on the operation of all these components is fed into a single room. One man often must operate all these units with understanding and skill.

Some power-plant experts wonder whether too much is being asked of the operator. They realize that they must distinguish between facts and fancies or fads. They wish to supplement their engineering knowledge with factual information on human behavior. More dependable information is needed on such things as: color of instruments, color of panels, use of graphics, heights of instruments, relationship between switches, relays, protective devices and measurement of important related variables.

Many of these items are controversial issues that must be faced every time a new installation is considered. In some instances, the buyer has strong opinions that all switches and controls should be clustered, and separated from the related instruments. Other buyers feel just as strongly that switches and controls should be arranged directly with associated instruments. Issues of this nature cause difficulty where buyer-designer relations must be kept amicable.

In a paper before the Pennsylvania Electric Assn, John C Fleming, The Bristol Co, showed that as boiler capacities increased the number of insurance claims increased:

Plant capacity, 1000 lb steam per hr	*Number of claims yearly*
25 to 50	One for every 58 boilers
100 to 400	One for every 17 boilers
900 and up	One for every 8 boilers

Claims vary from very expensive to minor. Many of the causes can be attributed to the human element. He points out that the modern power plant is a man-machine system in which the interconnecting link is the instrument and the automatic controller. The engineer must be supplemented by those who understand the characteristics of man so that the over-all system requirements can be established.

Plant instrument users demand meters of greater readability. But this represents only a surface attack on the problem. It is more important to find out what kind of information is needed in the first place and how valuable an effect the use of certain indicators will have on system performance. System analysis has shown repeatedly that being able to do certain things better can actually cause poorer over-all system performance.

Survey. Observation of control-room activities in a power plant during a single watch period uncovered these conditions that could cause operating mistakes:

1. The system frequency meter, a *major indicator*, was on a side panel rather than the main board.

2. The frequency meter had a range of 58 to 62 cycles with graduations of 0.1 cycles. Spacing of graduations decreased with increasing distance from midpoint of 60 cycles, making it difficult to estimate pointer position from center of room.

3. A voltmeter with 0- to 20-kv range was marked for normal operation at 13.8 kv. The meter face had white figures on black background, with 13.8 kv marked in red. Meter could not be read accurately because red did not contrast sufficiently with the black, and blunt dial pointer obscured scale markings.

4. Recording voltmeters and ammeters could not be read accurately because of thick stylus line; recording paper could be moved appreciably because of loose fit in drive sprockets.

5. Controls on the main board were not arranged in a pattern similar to their indicators. This increased chances of operator using wrong control.

6. Indicators on panel were legible at no more than two feet from panel. Some meters were too high to be read without parallax errors.

7. Meters on back of board were only 12 to 30 inches above floor. Making operator squat to read increases chance of error.

8. Four movable telephones had lights on a panel to indicate which was ringing. But since phones were being moved about their position bore no relation to the lights. Several times operator picked up wrong phone.

9. Totalizing wattmeters on back of the main board required hourly check readings. Possible danger signals appearing on the front indicators would be missed by an operator who was reading the meters in back.

10. Load indicator in the turbine room was in such a position that the control-room operator had to lean out of a window and crane his neck to check its reading.

Summary. Problems of instrumentation and control that human engineers have dealt with to date are similar to those currently found in central stations. Human engineering appears to offer a ready means of improving the effectiveness of control panels and their individual components. It is important to analyze the man-machine system as a whole to determine both the need and the value of specific improvements.