OVERVIEW OF BRIDGE CONTROL SYSTEMS

PAST, PRESENT AND FUTURE

Stephen Hewson, P.E.
Kunde, Sprecher, Yaskin & Associates, Inc.
Bartow, Florida

INTRODUCTION

It seems that for a very long time drawbridges were designed and constructed using traditional techniques which changed very little. However, with the current technological boom, particularly in the field of computers and computer control, design techniques are changing. Designers, contractors and maintenance personnel need to be aware of these advances.

PAST DESIGNS

Past designs in the State of Florida used wound-rotor motors and drum controllers to switch resistance banks. Equipment tended to be of the heavy duty construction prevalent at the time, capable of withstanding excessive overloads and abuses. This equipment was not specifically designed for bridge application. Good and reliable operation depended in large part upon the bridge operator.

Control desks tended to be laid out in a symmetrical manner which "looked good", but did not assist the operator. In one extreme case, the desk was designed to fill up one entire wall of the control house - approximately ten feet. Unfortunately, the control equipment on the desk was spread out to fill up the desk top with the result that the operator had to walk back and forth along the desk to complete operations. Figure 1 shows a more typical layout with operating devices and indicating lights on the front, horizontal section and indicating devices on the rear sloping section.

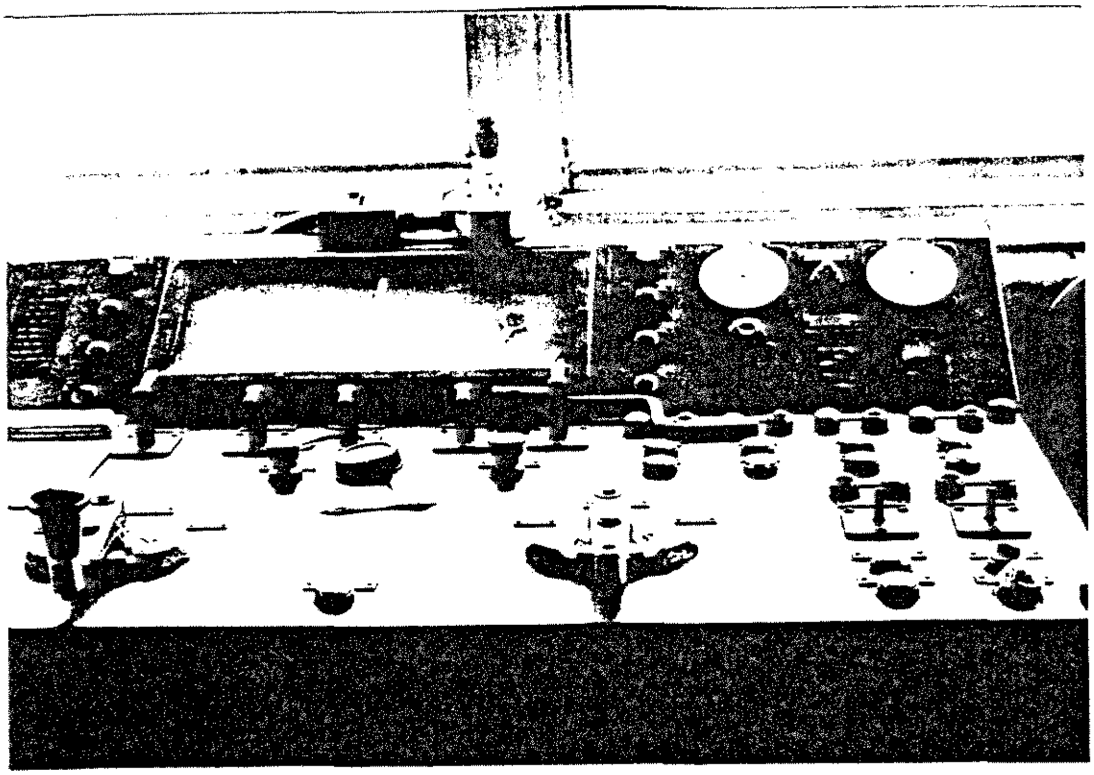


Figure 1. Typical control desk layout.

Control panels tended to be large free-standing structures, front and rear accessible, loaded with contactors, relays, timers, fuses and "miles" of wiring. Figures 2 and 3 illustrate examples of this. Electricians are familiar with this type of installation where all components and wiring can be seen and are comfortable trouble-shooting problems. In general, faulty equipment can be readily replaced with equivalent components, although some of the more specialized items are no longer available and can only be obtained by cannibalizing from other bridges. These panels contain many hazardous items of live equipment, such as knife switches, and require a large area, which on some bridges, is at a premium.

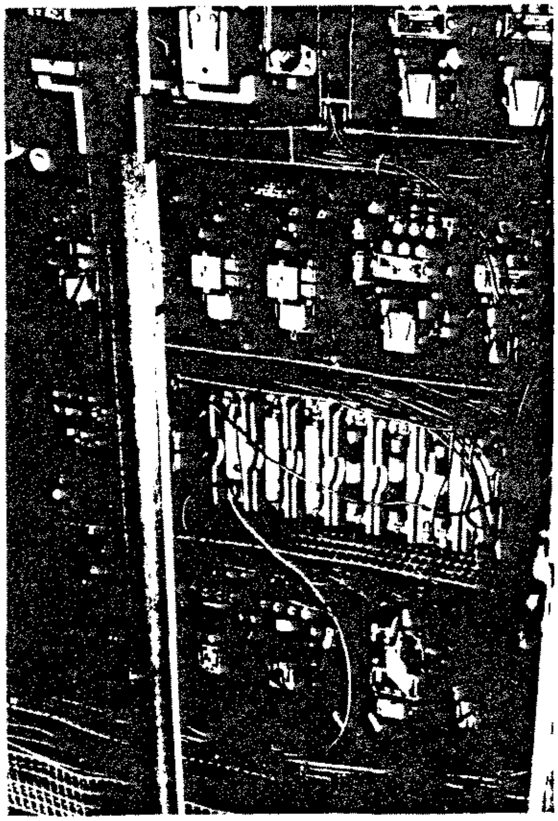


Figure 2.

Figure 3.

Inside typical free-standing control panel.

As you can see from figures 2 and 3, there is no space available within the panels for additional equipment or future expansion. Most older bridges have had additional equipment installed over the years, some planned and some added quickly during a breakdown situation, this results in additional panels and enclosures spread out haphazardly. Good record drawings are not kept and maintenance can only be carried out properly and quickly by the one or two electricians who are familiar with that particular bridge.

Codes and standards for electrical installations on bridges are based on outdated and superseded equipment and practices. They are explicit in only a very narrow limited area, providing only the broadest general guidelines for design engineers. For example, the Florida Department of Transportation Standard Specifications for Road and Bridge Construction has only 12-1/2 pages out of a total of 750 pages devoted to bridge electrics. It requires the main operating

PAST DESIGN (continued)

motors to be crane-type wound-rotor induction motors. Each designer must therefore provide substantial specifications of their own, with the result that every bridge has a different installation. Proper State Standards not only do not exist on paper, but do not exist on bridges either.

PRESENT DESIGN

Present bridge design is in a state of flux as the transition is made from traditional systems and modern equipment is installed, e.g., wound rotor motors and drum controllers are replaced with squirrel cage motors, and solid state variable speed drives and electro-mechanical relays are replaced with programmable controllers. However, much of the equipment is unproven in the harsh corrosive atmosphere within the bridges.

The question which needs to be asked at this time is why change? Existing systems have been installed in hundreds of bridges for many, many years; and have proved that they can do the job. Why do we need to change now? Is the use of new equipment and systems being made just to be trendy or fashionable?

The simple answer to these questions is that changes are being made to improve the system - to make it better. Existing systems are not perfect, they do have faults and inadequacies. We can look at each and every component and see where faults occur and where improvements can be made. Then we can look at the system as a whole and improve the integration of the components. An example of this is with the fully closed limit switch mounted under the main bridge girder. It is usually a heavy duty, plunger type limit switch, mounted in a cast iron enclosure with rubber seals. One of the main faults is that the crossarm inside breaks. It doesn't happen very often, but it happens consistently. The designer now has two choices to make. Notify the manufacturer of the problem, assume that they will make corrections and continue to specify the equipment, or change and look elsewhere to a different manufacturer or different system, such as proximity switches.

This example points to another important factor - maintenance personnel should keep good records of bridge repair work. If possible, records for work on all bridges should be kept at a central location where trends can be

PRESENT DESIGN (continued)

noticed. In any case, manufacturers should be notified of all failures of their equipment so that they can make corrections.

Designers are flooded with an ever-increasing choice of new equipment to use. Every time a new item is installed, a certain amount of risk is involved - will it work?, will it last?, what will happen if it fails? It seems that each new bridge has some "experimental" equipment associated with it. Once the decision is made to incorporate some item of new technology in the bridge, it is very difficult to know where to stop-short of converting the whole bridge.

A few individual manufacturers who have provided bridge equipment for years, and who are aware of technological advances, are carrying out their own experiments and development projects in order to retain their sales positions. For example, one traffic gate manufacturer has responded to the request for improved gates and has developed a new operating system. Another manufacturer of variable speed drives is willing to install one of their drives on a little-used urban bridge, where proper testing and evaluation can be made. If successful, the installation could be used to train maintenance personnel for future installations. Once again, however, the pressure to improve bridge installations prevents this testing from happening because there is not enough time. Instead, the installation is to be made on a high-use, suburban bridge with the additional pressures of satisfying contractural requirements for performance and schedule. It will be difficult to make a thorough analysis at that stage.

An additional problem is, by then, other bridges will have been designed with the same system specified and the first bridge will have to be made to work one way or another. This points out a major difficulty facing designers - that the period between design and actual installation and bridge operation can take many years. Should the designer wait for actual test results, or continue designing with new equipment?

FUTURE DESIGN

Almost every item of equipment on the bridges is undergoing changes as more examples of modern technology are incorporated.

Traffic and pedestrian safety gates are being developed that could operate using hydraulic drive systems and be solar powered.

Leaf operation now can include hydraulic systems. As well as operating the leaves, the hydraulic system can also operate the leaf locks and resistance barrier, if present. The control system is very different than that normally used. Speed control during acceleration and deceleration can be readily provided using adjustable solid state ramp controllers. A joy stick on the control desk can be used by the operator to slow these rates if desired.

Span locks cause problems as the lock bar wears, allowing movement between the leaves. Tapered locks are being developed to prevent the need for constant shim adjustment. The lock bar will be driven further as the receptacle wears. Control sensors that can continue to function correctly during this increased travel, without requiring manual adjustment, need to be installed to give positive indication of full travel.

Navigation lights, both fender mounted and suspended nose lights, are now available as a unit with six lamps in a system which will automatically rotate as a lamp burns out. This will prolong the time between re-lamping. Switching off the red nose mounted light, and switching on the green at the fully open position, can be accomplished by a switch within the unit and save control wiring from the rotating cam switch on the trunnion. Solar powered lights are being developed.

Leaf position sensors and indicators are also being changed. In the past, a synchro transmitter was used to drive a position indicator on the control desk. The indicators were large, expensive and a long delivery item. I estimate that nine out of every ten systems of this type that I have seen have not been working. Other critical locations of the leaf - fully down, nearly down, nearly open and fully open are indicated by lamps on the control desk. With the exception of the fully down limit switch discussed earlier, these positions are obtained with a rotating cam limit switch driven off the trunnion. After the initial setting up, these do not normally cause problems.

Both of these can be replaced by a single unit encoder feeding into a programmable controller. Leaf position on the control desk can be indicated with a LED bar graph device.

FUTURE DESIGN (continued)

Signals from the encoder can be used for control purposes and the programmable controller can also do a position divided by time calculation to check the speed of the leaf. Alternatively, a synchro transmitter feeding through a synchro/digital converter can drive the LED bargraphs.

Another example of a different type of sensor that may be used for leaf position is position/displacement transducer shown in figure 4. The body of the transducer would be fixed to the concrete structure of the bridge and the stainless steel cable attached to the underside of the main bridge girder. The transducer produces an electrical signal proportional to the linear extension of the cable.

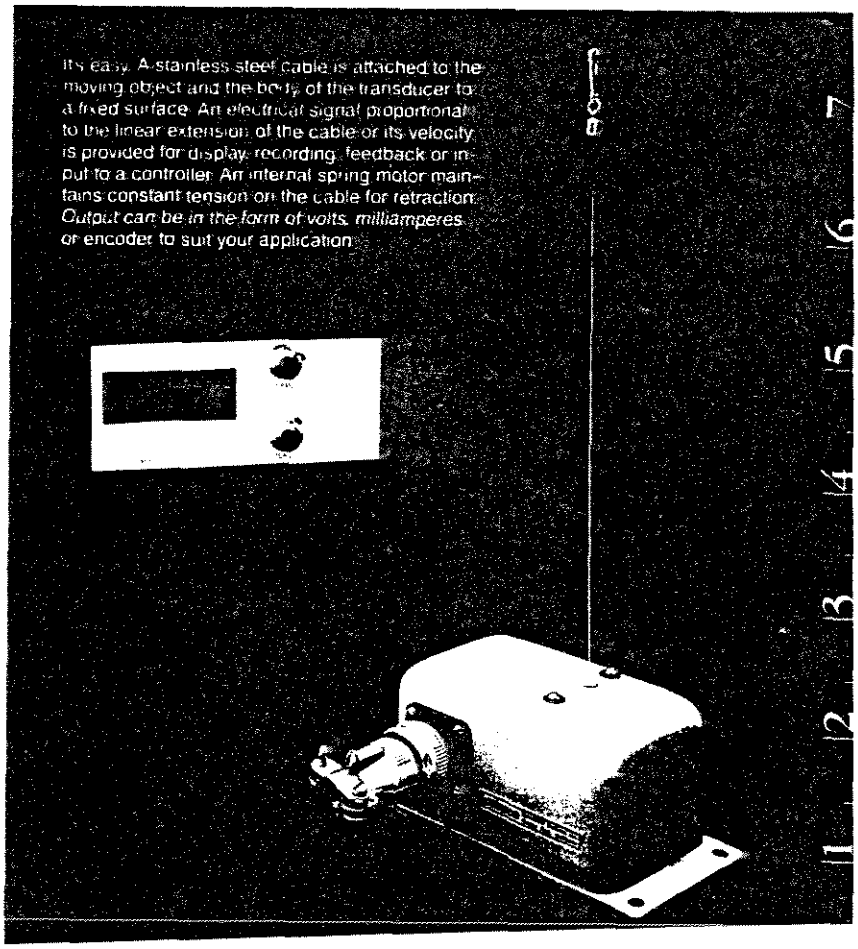


Figure 4. Example of alternate type of transducer.

An available output voltage of 25 volts AC or DC can overcome many of the noise problems associated with lower voltage systems. An underwater unit is available. This is not a perfect application for this unit because the movement of the leaf where the cable would be attached is an arc, not purely linear. However, detailed accuracy is not required over the major portion of the leaf movement and the major advantage offered by this unit with its' ease of installation may make its use beneficial.

The use of modular motor control centers has many advantages over the old style control panels. On rehabilitation projects, where access is a problem, modular units are sometimes all that will fit. They also offer flexibility for future expansion by simply adding more units. They can accommodate variable speed drives, dynamic breaking systems, panelboards, and transformers as well as motor starters.

The installation and use of programmable controllers represents the most radical and far reaching of all developments in bridge control systems. They provide many options and a degree of automatic control which was previously not available and leave the designer with many choices to make regarding how far to go. They also bring with them their own particular problems and inadequacies and it may take years before all the bugs are worked out. It is important to remember that programmable controllers are an electronic device, susceptible to damage from lightning strikes and proper protection must be provided on the I/O's.

Theoretically, there is no reason why bridge operation cannot be entirely automatic in a manner similar to railroad crossings. The control equipment and systems presently available could readily accommodate automatic operations. The difficulty in practice is sensing boat traffic, both as it is approaching the bridge and as it is passing through the channel. There may be one boat or many, and they may be travelling in opposite directions at different speeds. The use of radar or closed circuit television systems is a possibility but their general use has not been studied and it is doubted that the operator serving this function will be replaced in the near future.

After deciding to open and close the leaves however, the remainder of the bridge operation can now be performed automatically and reliably. All that is needed on the control desk is a raise button, a lower button and an emergency stop button. The operator would be totally unaware of each sequence taking place apart from those he can see occuring, e.g., traffic gates being lowered. The only control feature available to him should something go wrong would be the emergency stop button.

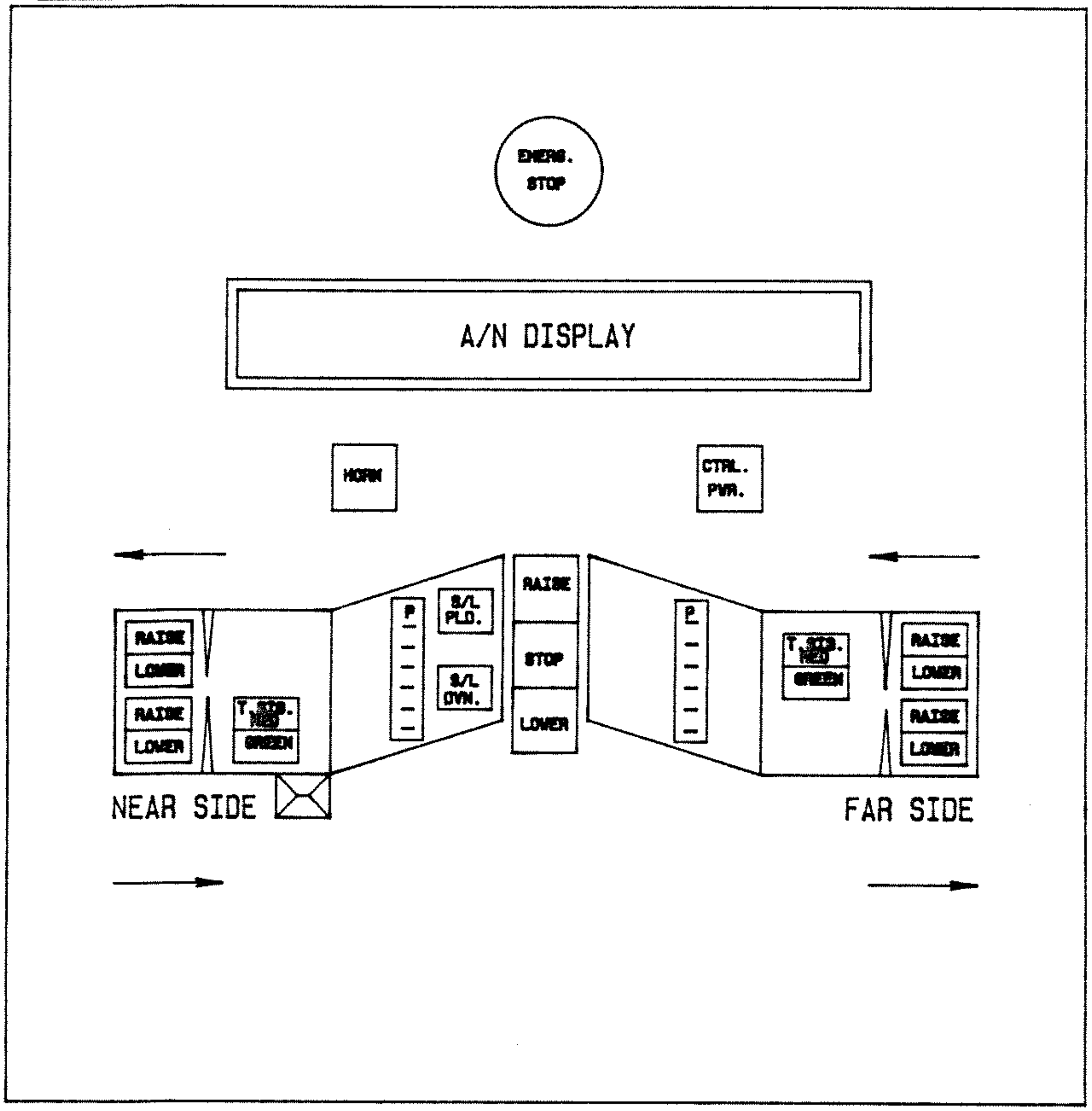
Obviously this is not a practical system. The operator and maintenance personnel need to know at what stage the sequence was when faults occur and the operator needs to be able to by-pass faults and at least return the bridge to normal position if possible. Other control devices and indicators are needed on the control desk.

It is also desirable that certain functions during the operating sequence be carried out manually as part of the normal "automatic" operation. For example lowering the traffic safety gates in an area where vehicles tend to run the gates, or driving the span locks after the leaves are lowered and may be bouncing.

The programmable controller can also be used to drive an alpha-numeric display mounted on the control desk to serve two functions. First, it can advise each operation as the sequence progresses and prompt the operator for manual input when required. This can occur in both automatic and manual or step mode. Secondly, the display can show error messages and prompt the operator for corrective actions. The control desk layout thus becomes as that shown in figure 5. Note that the simplified bridge outline ties all the controls together. This diagram is for a two leaf bridge but can be easily modified for a single leaf or for four leaves. This layout forms the "automatic" section of the control desk.

It is probably not wise however, to rely solely on the programmable controller and automatic operation. If a fault occurs, or if an item of equipment is temporarily out of service for repair, the operator has to perform manually at least by-pass operations. Also, there are other items such as voltmeter, ammeter, lighting switches, etc. which, while not essential for basic bridge operation, are desirable for maintenance personnel and the operator's ease of access. All of these items can be grouped together on a separate section of the control desk under the general heading of manual or diagnostic section. Figure 6 shows a typical arrangement. Notice that the basic layout of the bridge controls are similar to that of the automatic section shown in figure 5, and contrast this layout to that of figure 1. Manual

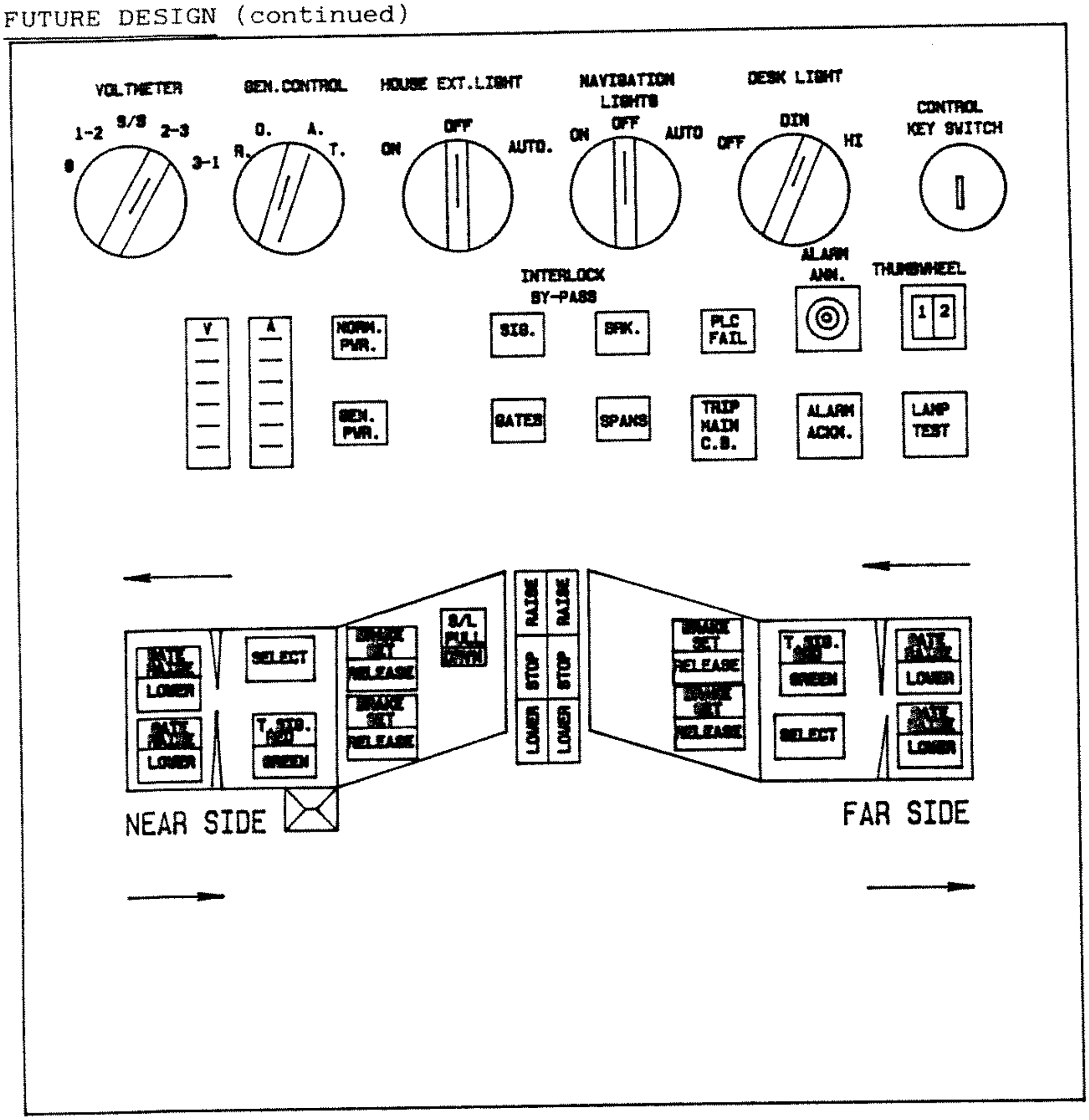
FUTURE DESIGN (continued)



'AUTOMATIC' SECTION

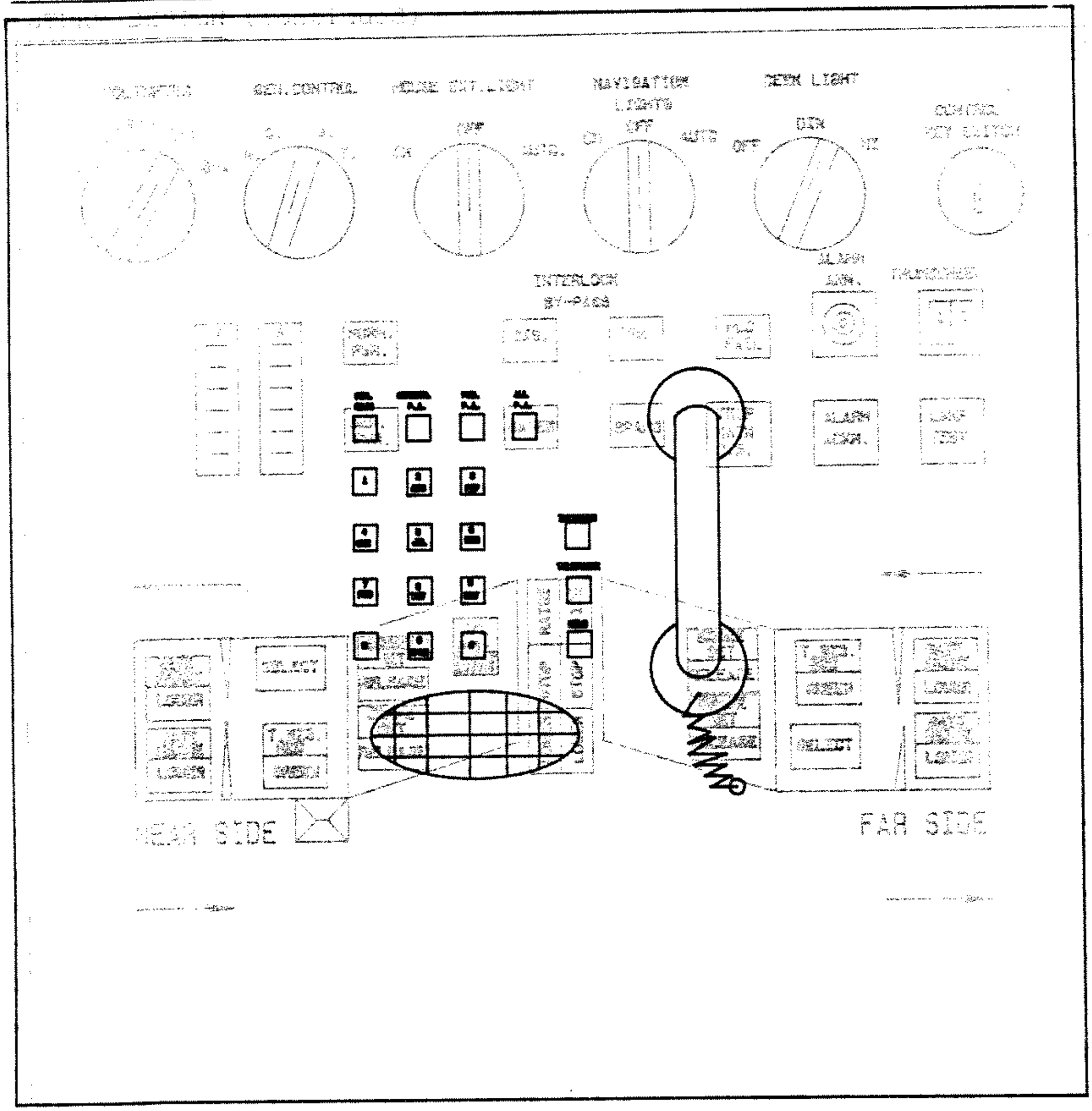
Figure 5.

FUTURE DESIGN (continued)



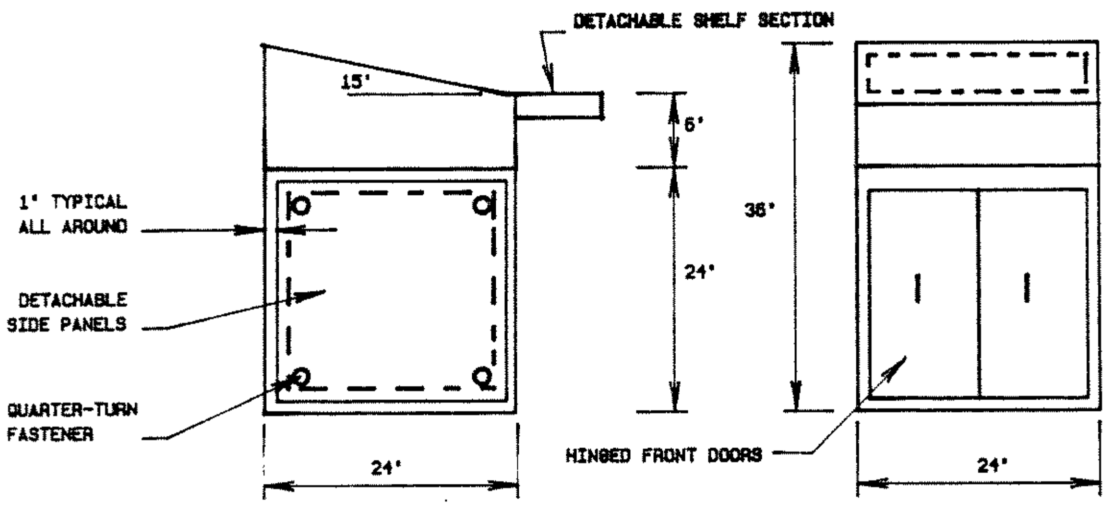
'DIAGNOSTIC' SECTION
Figure 6.

FUTURE DESIGN (continued)

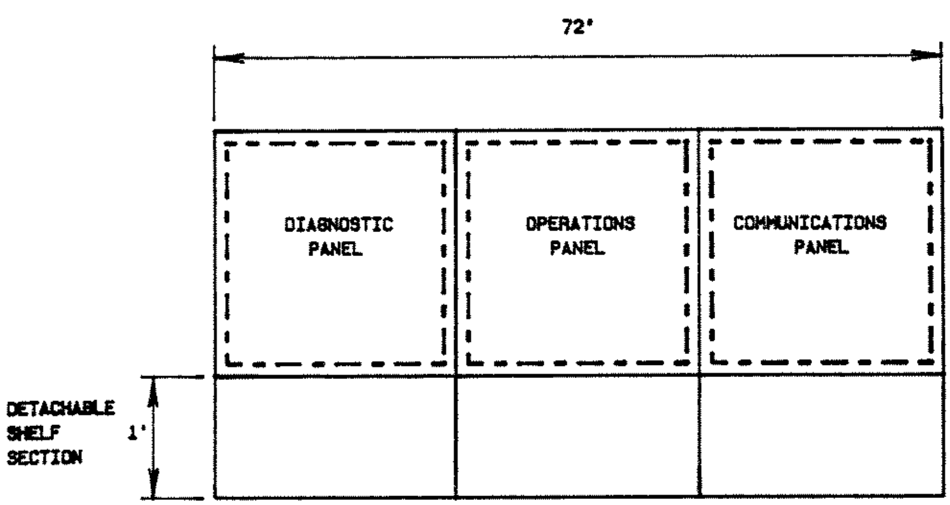


'COMMUNICATIONS' SECTION
Figure 6.

FUTURE DESIGN (continued)



CONSOLE CABINET-SINGLE UNIT



CONTROL CONSOLE LAYOUT-ASSEMBLED

Figure 8.

operation can be selected through a selector switch mounted in this section.

If desired, a third section for communications can be added, incorporating a telephone handset and keypad, selector buttons for telephone or intercom, intercom call button, speaker phone for hands-free operation and possibly a marine radio. Figure 7 shows a layout of this type.

Each of the three sections described above need only be approximately two feet square with a sloping top and having normal desk height. For a retrofit project, the three sections can be shipped individually and assembled within the control house, although mounting a programmable controllor within the control desk would make it desirable to ship the two control sections joined as one unit. Figure 8 shows a typical assembled desk.

CONCLUSION

The use of programmable controllers will continue to grow as will the functions they serve. At present, a number of functions of the programmable controller are duplicated by variable speed drives and there should be an effort made to integrate these units. There are many other uses that can be made of the programmable controller in the future but present applications need to be evaluated first.

As described above, a good portion of the control system and components can be replaced with newer equipment. The future will answer the questions of which items can perform reliably and are worth keeping and which items should be discarded.