VARICOM TRAFFIC CONTROL AND COMMUNICATION SYSTEM

Lawrence A. Powers

3M National's activity in changeable-message signs began about 5 years ago as an offshoot of sign-contracting work. One of the products of a formal survey to find out what future information needs of motorists would be was a library search in which we examined accident reports, research reports, trade journals, and speeches by highway policy-makers to determine past and current thinking about changeable-message signs. This has become a continuing effort on our part, and we have bound findings into a booklet entitled "The Motorist Needs to Be Warned. . . ."

A second product of that survey was the evolution of the concepts around which we developed the VARICOM traffic control and communication system. Some of those concepts are discussed in this paper.

A changeable-message sign should be fail-safe against the advent of a power failure. The thinking 3 to 5 years ago was that any traffic condition that required a changeable-message sign was sufficiently critical to demand that it continue to operate normally during a power failure. In fact, it was pointed out to us several times that the occasion of the power failure might well be one of the times when the sign is most needed. This is an area of increasing interest apparently because of the worsening power situation. A statement on this point in the new manual for signing and pavement marking on Interstate highways reads: "This reference concerns overhead signs, but should not changeable-message signs be considered on a par with overhead signs?"

We were told repeatedly that vandalism is a continuing problem and that changeable-message signs especially should be resistant to attack. We were told that changeable-message signs should be able to operate under all ambient conditions including extreme temperatures, ice, and snow. The effect of direct sunlight on message legibility was mentioned, particularly the effect during morning and evening rush hours when the sun is at its 2 low points on the horizon.

A second major category that was mentioned even more frequently than the fail-safe requirements was that of message display. Over and over again we were told that changeable-message signs should be able to display the shapes, sizes, and colors as prescribed in the manual. The comments generally were, "A yellow diamond conveys a warning, regardless of the legend."

We were told that a great deal of effort has gone into the specifications for letter type, width of stroke, and spacing of letters to satisfy the varying levels of motorists' ability to see and to read. We were told in the District of Columbia and in Colorado where initial symbol sign testing was under way that symbols will assume a more important role in traffic signing. We were told that changeable-message signs should be able to accurately reproduce these symbols, especially because most of the motorists' symbol signs will be new and will require an educational process.

Operation and maintenance costs were another major area of interest, especially of those who had some previous experience with changeable-message signs. Cost of operation basically is the cost of electricity. Operational cost was emphasized by some people as being a serious handicap in the use of changeable-message signs. Cost of electricity has risen substantially in the past 3 years. An article 3 months ago in the Los Angeles Times announced a 12 percent rate increase on top of a 5 percent increase 9 months before. That is happening throughout the country, and we are told almost daily that it is going to get worse primarily because of delays in building new capacity.

Greater than the concern about operating costs was the concern about maintenance. Other points we picked up during the survey were a general feeling that the sign is only one part of a system, that the communication link and the control center equipment are important also, and that these should be incorporated into a total system. We were told that traffic engineers sometimes change their minds, and the message format, therefore, should be one that could be easily changed. We were told that it would be important for the sign operator to have positive feedback from the sign to confirm that the proper message is properly displayed.

Let me now explain some of the mechanics of the VARICOM sign.

Consider a fascia that incorporates the static message SPEED LIMIT. First of all it will look exactly like a speed limit sign should look. The shape and format are those of a speed limit sign. The letters are black on a white background. The letters themselves are exact reproductions of the prescribed characters. The letter sizes on the changeable portion of the message are 65, 16 in.; TRUCKS, 6 in.; and 55, 16 in.

Now assume that these are the same 3 lines of copy but that the character size of the bottom 2 lines changes when the speed limit is reduced and made common to all vehicles. We give the motorist the reason for the speed reduction to aid in securing a better compliance and at the same time give him an advance warning of the type of hazard he is about to encounter. The reduced speed limit is still on a white background, which makes it regulatory, but it could be on a yellow background, which makes it advisory or warning.

Now, let us consider the fascia in more detail. There are actually 2 housings behind the fascia. The lower housing contains the thermoelectric generator, the on-site power source. The upper housing is the cabinet for the sign itself. That cabinet is fabricated of 12-gauge steel; the message window is ¾-in. plexiglass. Therefore, the sign now is vandal-proof and will withstand small arms fire, shotgun fire, and a coke bottle thrown at 90 mph. The finish on the cabinet, inside and out, is an inorganic zinc primer with an epoxy top coat, the same finish as specified in California for bridge structures so that they resist corrosion.

The cabinet is sealed and locked, and thus an ideal environment is created and maintained for all of the functional parts of the sign—free from dust and insects and protected from extreme temperatures, ice, snow, and even the effects of pollutants in industrial areas. The temperature within the cabinet is always higher than ambient, so moisture is controlled to less than 50 percent. Cabinet temperature will range from 30 to 150 F for ambient temperatures of -40 to +120 F. For temperature control we utilize the heat produced either by the thermoelectric generator for the self-powered unit or by a strip heater in the line-powered unit. The cabinet is thermally insulated except for the message window. The heat loss that occurs through the window serves to keep the window free of ice and snow and even moisture that might otherwise condense on the message area.

All of the functional elements of the line-powered unit are contained within the sign cabinet: the flashing-light assembly is at the top; the radio or line communications equipment is on the left side; the logic package is suspended from the top; the drive train, with a reversible 12-V dc motor, is on the right side; the cam assembly is on the right side of the top drum; the storage battery is on the bottom right side; and the heat source is at the bottom of the cabinet, beneath the message window.

The messages are printed by the silk-screen process onto a polyester film that is transported and stored on the drum, located at the top and bottom of the message window. The time required to change from 1 message to the next is about 1 sec. Our logic system is designed to display as many as 8 different messages.

Certain signs utilize only a special retroreflective panel for message illumination. Units at the Lincoln Tunnel were internally illuminated, but even in those units we retained the retroreflective panel, which is stationary within the sign. A cross section of the sign would show the plexiglass window as the first layer in the cabinet. Behind that is the message film, which moves, and then the retroreflective panel, which does not move. If the sign is internally illuminated, as the signs at the tunnel are, then that assembly is located behind the reflective panel, which is light transmissive.

Thus, when there is a power failure, the reflective panel and the standard automotive storage battery allow the sign to continue to function normally in all respects. Retroreflection provides message illumination; and the battery operates the drive motor, the flashing lights, the logic system, and the radio or line terminal within the sign. It will do this for at least 24 hours; and when the battery reaches a given level of reduced output, the sign will automatically advise the controller that the end is near.

Our units can operate solely from the storage battery and the reflective panel. The advance-warning lights in the on-cycle are the only incandescent bulbs in the unit. Each is a 12-V, 12-W, sealed-beam spotlight located behind a Fresnel lens. That Fresnel lens gives a narrow beam, which can be seen for more than 1 mile. The brightness level of each light is more than 12,000 ft-L. However, when the motorist is close enough to read the message, he has passed out of the advance-warning light beam so that it does not interfere with his ability to read the message.

The logic system utilizes binary code in conventional teletype format. One VARICOM sign system can accommodate 676 signs, each with its own address code. Within a system, each sign listens to all of the commands from the control center but responds only to its particular address. When a sign is addressed, it is instructed to change its message or it is interrogated for its current status. For feedback, the logic is designed to provide 4 bits of information to the controller. We are currently using this to find out what message is displayed, whether it is properly displayed, whether the handset for the motorist-aid phone is off the hook, and whether the battery level is satisfactory. The logic system is totally solid-state, uses integrated circuits, and is of modular construction for easy field replacement.

The communication link may be radio or hard wire. For radio, we utilize UHF-FM in the 450-MHz range. The FCC has set aside 4 pairs of frequencies in this range for highway safety purposes. In March 1970, we received a temporary 1-year license to test the VARICOM system by using 1 pair of those frequencies. Early in 1971, the FCC issued a rule, in answer to a petition by the states of Rhode Island, Connecticut, and Massachusetts, that now permits the use of those frequencies for point-to-point application.

The test program we conducted under the temporary FCC license ran from March 1970 to March 1971. It included 4 signs using a combination of radio and leased telephone lines. Our interest in the test was to gain data on the use of those frequencies under varying conditions, to detect weaknesses in the system, and to quantify maintenance requirements. During the 1-year test we initiated more than $\frac{1}{3}$ million sign station commands and interrogations, which mean more than $\frac{2}{3}$ million transmissions. The design goal for unscheduled maintenance requirements for the entire system was a 2-year interval for each sign, on the basis of 50 message changes per day. That translates to 36,500 message changes. By November 1970 we had achieved that goal.

Normally, we utilize AFSK for data transmission for both radio and hard-wire communication, and terminals are at the base station and in each sign station. However, for 1 or 2 signs located only a short distance from the control center, we can use a simple dc loop, and, in fact, that is the technique used at the Lincoln Tunnel.

We have incorporated into the logic and communication links a capability for a motorist-aid phone. We accomplish this as a digital overlay type of transmission to combine command-code data and voice signals. Thus, we can utilize a common power source and communication link for both the sign and the motorist-aid phone. The mechanics of the phone are that when the stranded motorist lifts the handset a light or buzzer or both are activated at the control center. The controller pushes the proper button on the console to activate the phone at the sign and, thus, to begin a 2-way, duplex voice communication.

Control-center equipment may be a simple teletype that could, but probably never will, be used for a very small system. The next step is a hard-wired console that permits pushbutton control and status display of the system. This console automatically scans the entire system, continuously interrogates each sign in turn, and provides a constant updating of the status display.

The human-factors aspect of the console is one of great importance to ensure error-free operation by the controller. From his standpoint, to change a message he merely pushes the proper message button for the sign he wishes to change. The newly depressed button flashes until the scanner interrogates the sign and receives confirmation that the proper message is properly displayed. At that point the button is lighted constantly to provide a status display. As a system approaches 40 units, we suggest the use of a small computer to replace the hard-wired scanner. If space is scarce in the control center, some variation in the pushbutton and status-display board will be desirable. Our signs at the Lincoln Tunnel are activated manually through the existing computer. When that system is totally operational, the computer will activate and interrogate the signs directly.

The cost of the interface between the computer and the VARICOM signs was about $1,000. Initial cost varies substantially depending on the kind of installation; we have submitted proposals starting from $6,000 per sign. Typically, however, the per-sign cost for a limited number of units using line power and line communications, including all communications and control center equipment and the necessary technical field service, is about $10,000. Cost of operation for line power is 12 kW-h/day times the electrical rate, which averages 3 to 5 cents/kW-h, or about 36 to 60 cents per day. Self-powered units consume about 1 gal/day of propane at a cost of 14 cents/gal, so the cost is 14 cents/day.

For maintenance of line-powered and line-communication units, we suggest 1 preventive maintenance call per year. Our results to date show 1 unscheduled maintenance call once every 2 years at 50 message changes per day.

I would like to conclude by discussing some applications that are possible with the VARICOM system.

Using the thermoelectric generator and radio for the communication link now makes it possible to operate a totally free-standing, changeable-message sign. In our survey, 1 New England state and 2 western states indicated a need for changeable-message signs that could not be installed because of the cost of providing power and telephone lines. Since then, several additional traffic engineers have indicated this to be a problem, even in much less remote areas. VARICOM makes it possible to combine changeable-message signs with static signs, such as the speed limit sign discussed earlier.

It is also possible to combine signs when the changeable portion of the sign is a very small part of the total sign. With external illumination, the changeable sign and the static sign both assume the same brightness; thus, the brightness of the one does not interfere with the legibility of the other.

The 12-V electrical system raises the possibility of an economical and portable changeable-message sign. Sequentially flashing amber lights can be used to give advance-directional information. Exact reproduction of the symbols in the new manual is now possible.