ASSESSMENT OF CHANGEABLE MESSAGE SIGN TECHNOLOGY

Research, Development, and Technology

Turner-Fairbank Highway Research Center
6300 Georgetown Pike
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Staff Study

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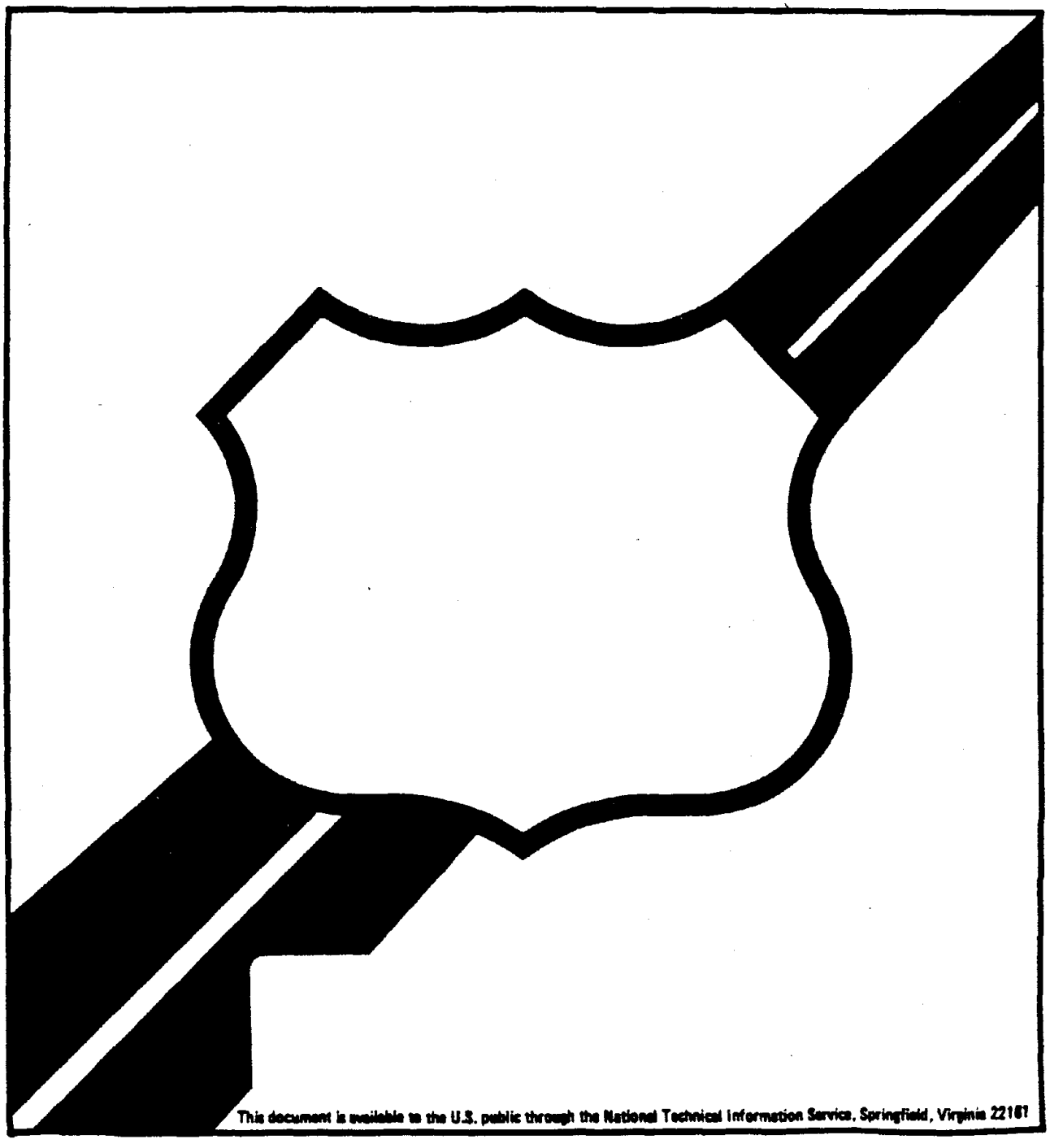

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16. Abstract

This report reviews the operational experience of the three principal types of Changeable Message Signs (CMS) used on freeways and Interstate highways in the continental United States. The three types examined here are the light bulb matrix, rotating drum, and disc matrix. These types have experienced only minor technical improvements since their introduction in the 1970s. Part 1 of the report describes each type, lists operational experience, and reports on new CMS technology. Part 2 reports on the radically new 3-dimensional imaging medium called holography. A survey of current manufacturers of holographic materials was conducted to access the potential use of holography to present more effective sign messages to motorists. Fourteen responses from manufacturers are summarized, and recommendations made for further work on this promising new sign technology.

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Introduction

Changeable Message Signs (CMSs) have been used on urban highways for more than 20 years. A 1977 FHWA/RD-77/98 state-of-the-art report[1] extensively examined CMS technology and operational experience. A 1979 NCHRP-61 synthesis report[2] examined CMS for freeway traffic advisory and incident management systems. These reports detailed all CMS types used on major highways in the 1970's. Except for minor technical improvements, the same principal types (light bulb, rotating drum, and disc matrix) are still in use in the 1980s. This study in Part 1 reports on a brief survey of user experience using these three types of CMS.

Holography, a radically new three-dimensional imaging medium used by artists and industry, could be the basis for new signing technology of the 1980s and 1990s. A survey of current manufacturers of holographic materials was conducted to assess the potential use of holography to present more effective sign messages to motorists. Results of this survey is reported in Part 2.

Part 1 - Assessment of Current CMSs

I. Introduction

Most of the current CMSs were designed in the 1970s[1]. Many of these same signs are still in operation in the 1980s. A Transportation Research Information Service (TRIS) search on "Changeable/Variable Message Signing" listed 176 records on this subject indicating extensive attention devoted to CMSs. Section II reviews the applications of CMSs and describes the key operating features of the three principal types reported in this study. Section III discusses the informal survey of FHWA's regional and division offices, and State officials responsible for CMSs in their respective jurisdictions. Section IV reviews the current CMSs offered by the principal manufacturers and suppliers.

II. Applications and Types of CMSs

Changeable Message Signs are used to improve highway safety, operations, and use of existing facilities. Table 1[2] lists the applications of all types of CMSs.

TABLE 1

APPLICATIONS OF CHANGEABLE MESSAGE AND
OTHER TYPES OF REAL-TIME DISPLAYS

I. Traffic Management and Diversion

- o Freeway Traffic Advisory and Incident Management
- o Freeway-to-Freeway Diversion
- o Special Events
- o Speed Control

II. Warning of Adverse Conditions

- o Adverse Weather and Environmental Conditions (fog, smog, snow, rain, dust, wind, etc.)
- o Adverse Road Conditions (ice, snow, slippery pavement, high water, etc.)
- o High Truck Loads

III. Control at Crossings

- o Bridge Control
- o Tunnel Control
- o Mountain Pass Control
- o Weigh Station Control
- o Toll Station Control

IV. Control During Construction and Maintenance

- o Warnings
- o Speed Control
- o Path Control

V. Special-Use Lane and Roadway Control

- o Reversible Lanes
- o Exclusive Lanes
- o Contraflow Lanes
- o Restricted Roadways

Table 2 lists the various types of displays used for applications as listed in Table 1.

TABLE 2

TYPES OF DISPLAYS

Category	Type
Background light source	Blank-out when sign not lighted
Mechanical	Fold-out (type I) Scroll Rotating drum
Message light source	Neon Fiber optic Lamp matrix
Electrical/mechanical	Electromagnetic disk matrix Electromechanical flap matrix Electrostatic vane matrix
Manual	Cloth Fold-out (type II) Removable panels

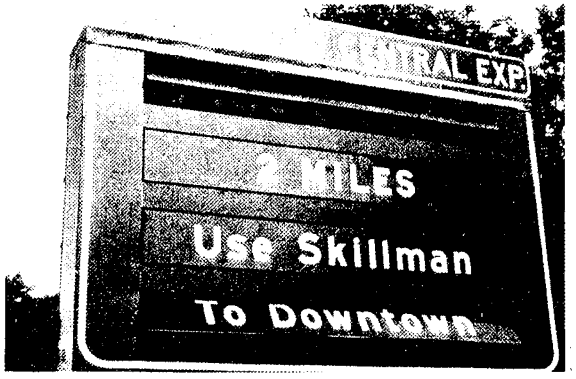
The principal signs studied in this report are rotating drum, lamp matrix, and disc/flap matrix.

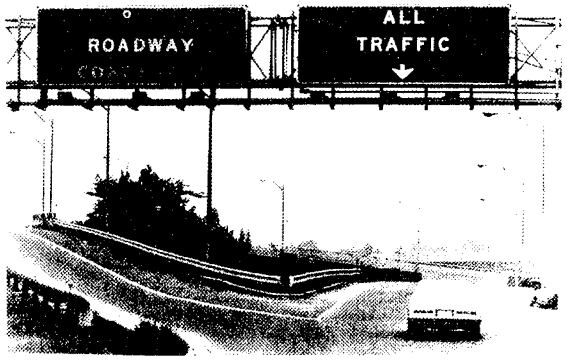
Rotating Drum

Rotating drum signs generally contain one to four multi-faced drums. Each drum consists of a polygon shape, pivoted on the ends, and rotated with a mechanical assembly (see Figure 1). Each face of a drum contains one line of a fixed message formed on the panel. Message panels are either raised sheet metal letters on an aluminum background or paint spray-masked lettering on aluminum, wood, or translucent plastic background. Messages are displayed by rotating the drum(s) to the appropriate viewing position. Signs can be designed to rotate individually or simultaneously.

Lamp Matrix

Light bulb matrix signs were initially developed for commercial advertising. They offer total flexibility of message presentation, are uncomplicated, and very popular. The lamp matrix display (see Figure 2) is formed by an array of incandescent light bulbs for each message line. The array can be either a continuous field of bulbs or a fixed number of matrix modules (5x7 matrix of bulbs per module). The message lines vary from one to four.





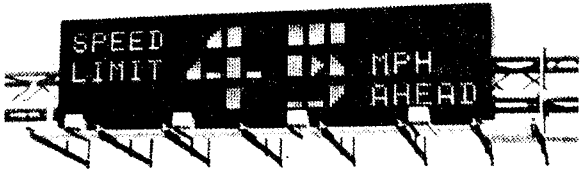


Figure 1. Rotating drum signs (Dallas, Texas, top; New Jersey Turnpike, bottom).

Figure 2. Lamp matrix signs (Los Angeles, California, top; Cincinnati, Ohio, bottom).

Figure 3. Disk matrix sign (Pittsburgh, Pennsylvania).

Messages can be displayed statically or flashed on and off. They can also be sequenced to run message phrases across the sign as do some movie marquees. Messages change almost instantaneously when a new message is selected. Newer display systems with computer equipment provide considerable message flexibility.

Disc Matrix

Disc matrix signs are similar to the lamp matrix with the disc used to form the legend characters (see Figure 3). One side of the disc is flat black to match the sign face background. The other side, which is used to form the message character, is generally a contrasting color such as yellow or white. Messages are displayed by flipping appropriate discs from one side to the other.

Electromagnetic disc matrix signs use a permanent magnet affixed to one side of each disc. Electrically reversing the poles of the electromagnetic causes the disc to flip to another position.

Electrostatic disc matrix signs use a reversible high voltage charge near the disc to cause it to flip. Both sign types consume energy only when changing messages, therefore, they are very economical to operate.

III. Operating Experience with CMSs

All of the FHWA's regional offices were called and asked to discuss their CMS operating experience. Many States have no CMSs. In some cases, division and State contacts were suggested for more detailed information. The following comments are summaries of CMS operating experience for each type of sign used in the continental USA.

Lamp Matrix

Comments both pro and con are listed.

- o High maintenance cost
- o High electrical operating cost
- o Subject to vandalism (shooting bulbs)
- o Sign too bright to read at night because dimming circuits non-existent or malfunctioning
- o Lamp sockets subject to corrosion
- o Highway vibrations cause premature bulb failure
- o Great flexibility in creating attention-getting flashing messages.
- o Used extensively at highway maintenance and reconstruction sites.

Rotating Drum

- Paint peeling from drum due to temperature changes.
- No problems with internally illuminated drum.
- One jurisdiction would like to see a sign that changes messages when the road temperature reaches freezing. (Liability considerations usually preclude this warning.)
- Very reliable sign.

Disc Matrix

- Problem reading tri-color disc sign in daylight.
- Sun reflecting off plastic sign face washes out message.
- Some corrosion due to high humidity conditions.
- Some signs difficult to read at night.
- Disc color not always matched to other signs.
- Normally very reliable, low power operation, high message flexibility, many signs over 9-years old.
- Would like to see more uniform disc color from sign to sign; less costly signs; non-reflective cover over sign face; internally illuminated signs.

Summary

The three types of signs reported here continue to find site specific applications. Lamp matrix signs are gradually being replaced with disc matrix signs. With increased sign message display speed and under personal computer control, portable disc signs are more frequently being used at construction sites. In one city (Baltimore), cellular radio units are being incorporated in the portable signs to provide for remote message change when used for traffic diversion.

Some States do not share the same sign experience. For instance, Wyoming had two disc matrix signs from one manufacturer in operation for 10-years with no problems. Montana had one disc matrix sign from a different manufacturer in operation for 9-years with many problems. Parts were obsolete, and the sign was not operating 50 percent of the time. They plan to replace it with another type of sign which will be used to report weather conditions to motorists.

CMS technology is quite mature and competitive. Highway planners and operators are installing increasing numbers of CMS for an information hungry driving public. Many human factor issues, however, remain unresolved including legibility distances, recommended CMS for poor visibility conditions, message content and effectiveness, guidelines on light intensity, size and spacing of bulbs/discs, character spacing, etc. Despite these gaps in knowledge, motorists and highway operators find the signs very useful and depend on them for safety and guidance information.

IV. Current CMS Technology

Manufacturers of disc matrix signs are offering discs in a variety of shapes and sizes. The three principal shapes are round, square, and rectangular with rounded corners. The last shape has the advantage of displaying more characters for the same sign length then either round or square discs[4,5]. Most signs still use an electromagnetic coil to flip the discs. Magnets which control the disc's position are now lighter, requiring less drive power. Electronic drive and control circuits now make use of CMOS, a low power solid state technology, and personal computers to decode, store and control sign messages.

Seven segment displays also use the same electromechanical control mechanisms as the flip disc displays and, therefore, benefit from the same improvements in component and control technology advances[5]. Fiber optic displays, more common in Europe, are now being introduced in this country. They are more expensive, but offer increased legibility in poor weather conditions[6].

Rotating drum signs offering up to six message panels per rotor have changed little over the years. For certain sites where the same information needs are repeated daily, this sign provides a very dependable display.

A new CMS technology using liquid crystal has recently appeared[7]. A layered panel composed of a plastic outer cover, a thin center section of liquid crystal droplets dispersed throughout the plastic with both sides of this center composite covered with a conductive layer of indium tin oxide to align the crystals for transparency, and an outer plastic cover for environmental protection. Since the liquid crystal material is polymerized (solid, not liquid), and suspended within sheets of polyester, the panels can be made into very large sheets. Panels remain operational even with puncture holes. In operation, an electrical signal causes the liquid crystal sheeting to switch from an opaque state to a clear state. The sheet can be used to alternately expose or hide a warning or speed message. It is also used in a small square matrix to create sign messages by allowing a light source behind the sheet to pass through or be blocked. Since there are no moving parts, maintenance and operating costs should be very low.

This brief study should serve to acquaint those interested in CMS with a quick look at operating experience and new technology. The information reported here is not claimed to be all inclusive, but merely representative of the current industry as communicated from users and manufacturers.

PART 2 HOLOGRAPHIC SIGNING

I. Introduction

The increasing frequency of newspaper and magazine articles on holography and its widespread use on major credit cards (500 million) prompted a look at this technology for highway signing use. As an advertising attention getter, it is spectacular in appearance. Hologram producers predict that within a few years, everything from perfume to toothpaste will carry a holographic image on its label or packaging.

Section II reviews the basic principals of holography. Section III reports on the responses to an industry inquiry asking for information concerning new technology/products that could be used for highway signing.

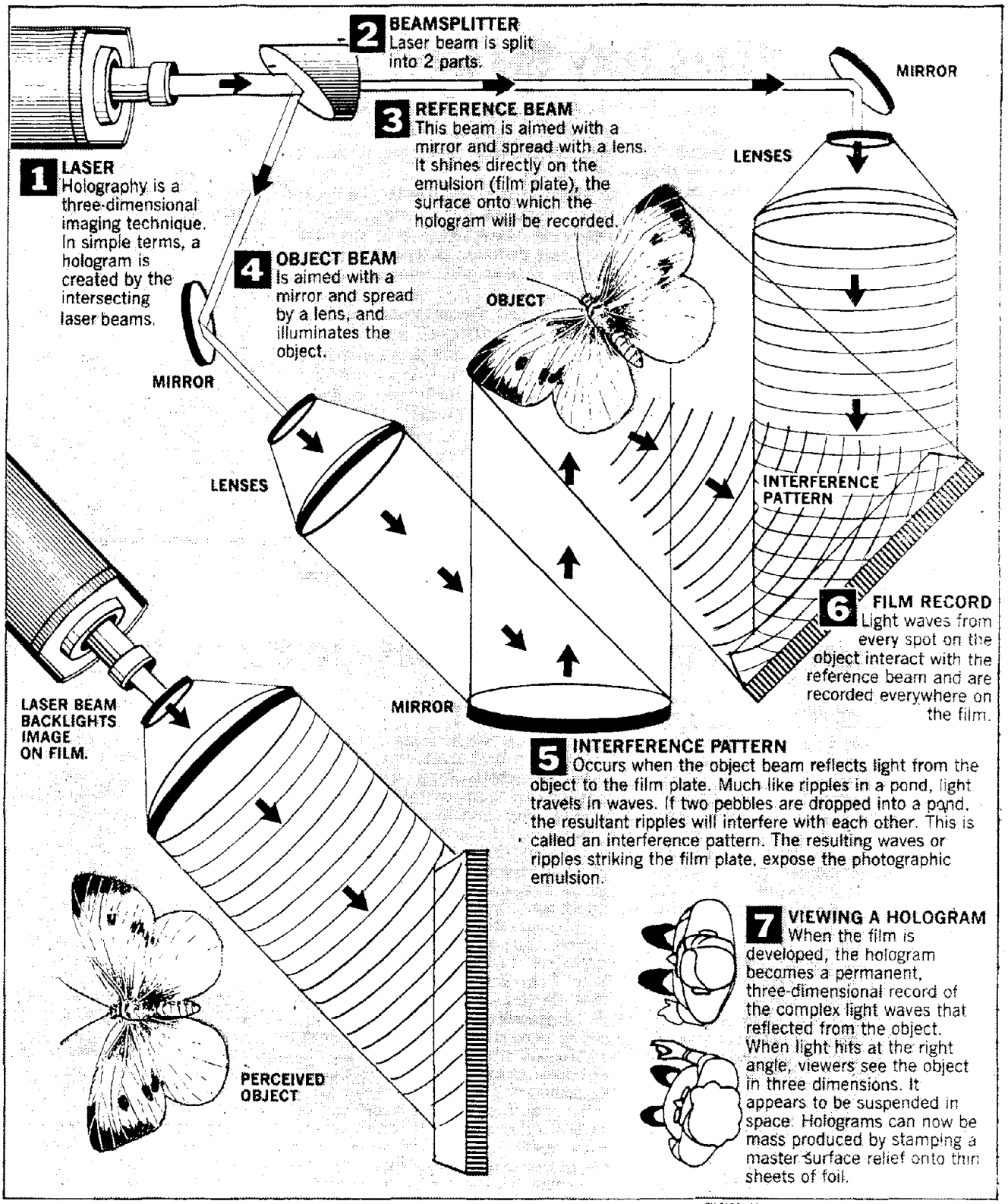
II. Holography

The word holography is derived from the Greek roots: "Holos," meaning whole or complete, and "Graphos," meaning sign or to write. The unique properties of holography enable it to convey information about the shape, contour, and position of the objects recorded in it.

Holography was invented by a Hungarian born scientist named Dennis Gabor in 1947. Gabor was searching for a tool which would improve the quality of photographs from the electron microscope. However, it wasn't until the early 1960s and the advent of the laser, that holograms as we know them were first produced by two researchers working at the University of Michigan in Ann Arbor, Emmett Leith and Juris Upatnieks. Dr. Gabor received the Nobel Prize in Physics in 1971 for his invention of holography. The creation of a hologram is illustrated in Figure 4.

In conventional photography using a lens and film, a record is made from the two-dimensional light reflected from the image of an object. With holography, a record is made of the object wave, not the optically formed image of an object. Referring to Figure 4, the object is illuminated by a coherent light source (single frequency) which reflects this light as an object wave. The object wave and a reference beam of the same frequency optically interfere with each other and this interference pattern in recorded on film. The film, when developed, is called a hologram and when viewed with a specific light frequency, reproduces a three-dimensional image of the object. Techniques have been developed to optically create the required reference light frequency from ordinary light right in the hologram. The hologram then consists of a series of alternating clear and opaque strips in the form of a diffraction grating. This permits a viewer to see a three-dimensional colored object using ordinary light.

HOW A HOLOGRAM BECOMES THREE-DIMENSIONAL



BY CAROL PORTER AND JOHNSTONE QUINAN—THE WASHINGTON POST

Figure 4

The Washington Post
June 8, 1986

In industry and research holography has many uses, but probably none more important than those in non-destructive testing and evaluation. Using a technique called Holographic Interferometry, technicians can measure the performance of critical parts of such items as aircraft turbines, nuclear reactors and spacecraft under thermal and vibrational stress. This and other holographic techniques allow scientists to study flow dynamics, and to record bubble chamber events to aid in the detection of sub-atomic particles.

Holography's unique capability to compress and combine optical functions are utilized in the development and production of Holographic Optical Elements (HOEs). Conventional lenses, usually made of glass, plastic, or crystals, focus light to form images. Lenses have one or more curved surfaces that bend the light at the surface between the solid lens and air. A HOE accomplishes the same light bending function as a conventional lens by using holographic film layers in a flat format. HOEs make it possible to produce low-cost, low-size/ weight optical devices for operations where conventional optics would be expensive and impractical. HOEs are being used in supermarket bar-code scanning systems to direct the scanning laser. Large scale HOEs are also being tested as an alternative way to bring sunlight into large office buildings, thereby reducing energy costs. In military and some civilian aircraft, HOEs are being used as the combining elements in the head-up display, and are being tested by auto manufacturers for possible inclusion in passenger car head-up display systems.

The high resolution and visual appeal of holograms make them a valuable new tool in graphic security technology. Holograms appear on credit cards, passports, I.D. badges, and other secure documents as a unique means of authentication. New applications for holography are emerging rapidly, as the medium and its potential become more widely known.[3]

III. Responses to Holographic Signing Inquiry

A "Holographic Directory" published by the Museum of Holography in New York was purchased to obtain the names and addresses of firms involved in this technology. Over 200 names and addresses from around the world were listed. Many were shops retailing holographic art; others were artists interested in the field. Fortunately, the directory listed areas of interest next to each name which narrowed the field of selection. A letter of inquiry was sent to 80 individuals and companies involved in this field. The 80 names and addresses are in Appendix A. A sample letter is shown as Example 1.

Fourteen letter responses were received. Some included samples of commercially available holographic materials, and one sent a 24" x 24" holographic "STOP" sign for evaluation. Since there was no laboratory test facility set up to test this sign, it was shown to several individuals for comment. Comments ranged for "very attention getting" to

U.S. Department
of Transportation
**Federal Highway
Administration**

Research, Development,
and Technology

Turner-Fairbank Highway
Research Center
6300 Georgetown Pike
McLean, Virginia 22101

April 14, 1986

In Reply Refer To:
HSR-10

Mr. Lewis T. Kontnik
Reconnaissance
1612 A Que Street
Washington, D.C. 20009

Dear Mr. Kontnik:

The Federal Highway Administration has a continuing interest in the technology of fixed and changeable message signs. They perform important roles in improving highway safety, operations, and use of existing facilities. As the application of fixed and changeable message signs expands in both urban and rural areas, highway engineers require increased working knowledge of the features, uses, and effectiveness of these systems.

Periodically, information concerning current sign technology and products is gathered and disseminated to Federal, State, and municipal highway authorities to provide a data base for decision-making. We are soliciting your help in providing information concerning new technology/products that could be used in the highway environment. Of special interest is the potential use of holography to present more effective sign messages to motorists. Information concerning this subject should be directed to Mr. Richard C. Lavigne, Federal Highway Administration, HSR-10, 6300 Georgetown Pike, McLean, Virginia, 22101.

Thank you for your assistance.

Sincerely yours,

Richard C. Lavigne
Traffic Systems Division

Example 1

feelings of nausea. Much development work would have to be done to refine the technical aspects of the sign as well as the human factor implications to produce an acceptable highway sign.

Appendix B lists the names and addresses of the respondents. The following are summaries of key comments made by the respondents.

Technology

- Holographic images are seen because light is altered while traveling through a medium that has holographic information etched in that medium. If there is no light, there is no image.

- Holograms must be lit by a single directed light source. Any stray or ambient light will also re-create holographic images from their own perspectives.

- Injection molding could be a very cost-effective way to produce commercial quantities of holograms.

Applications

- A Canadian research company has developed a prototype multi-faced optical grating applied as a pressure sensitive roll-on to enhance reflectivity on roadside signs. Pattern is holographically derived to control direction of refraction as well as colors. It can be applied on either PVC or polyester, and will be weather proof and long lasting. Tests will be done in late 1986.

- A self-adhesive mylar sticker applied to posts at roadside to warn of curves could be applied under 3-seconds at very low costs.

- A 3-inch square hologram activated with car headlights could show "green" when approaching safely, "yellow" for caution, and "red" warning a driver he is about to go off the highway.

- Holograms could be used for head-up display in new vehicles.

Advantages

- For highway signs, three dimensionality will have little value. Major benefits will accrue from the rainbow of colors available.

- Directionality is the most important feature. Messages and/or color can change as a function of viewing position.

- Retroreflective signs could carry different messages when illuminated from different directions.

- Holographic signs which contain multiple messages may provide an economical and efficient means of displaying highway signage. (This technique is proprietary to Advanced Environmental Research Group, U.S. Patent Pending.) Advantages are:

  1. Economy of space (multiple billboards in same space)
  2. Achromatic or chromatic signage (color blind aid)
  3. Lightweight
  4. Transparent (over a specified field of view)
  5. Angle selective with auto tracking (viewing range, distance and angle)
  6. Enhanced night signage
  7. Durability
  8. Cost effective
  9. Mass producible

- Some "embossed" holograms have weathering characteristics because they are actually "stamped" into a material, as opposed to a film which is exposed and can deteriorate.

- Relief master holograms may be printed or embossed into inexpensive polyester mylar for less than one cent per square inch.

- Messages can be projected away from the plane of the hologram.

Disadvantages

- Many present types of holographic films and materials do not hold up under weathering, heat, cold, wind, humidity and ultra violet light.

Conclusions

This initial investigation has shown the holographic industry is indeed brimming with ideas and enthusiasm for innovative new signing products. It is apparent this new technology has the capability of providing a new generation of safety and informational highway signing to complement and enhance those presently in use. A first step towards this goal will be a careful analysis of current signing needs and preparation of preliminary holographic signing specifications. This activity will be conducted in an approved staff study to be started in early 1987.

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1. Dorsey, W., "Variable Message Signing for Traffic Surveillance and Control," FHWA, Report No. FHWA/RD-77/98 (January 1977).

2. "Changeable Message Signs," NCHRP Synthesis 61 (1979), 37 pp.

3. Cole Parmer Instrument Company, 1987-88.

4. Vultron, Inc., 2600 Bond St., Auburn Heights, MI 48057, (313) 853-2200.

5. Lake Technologies, Inc., 28248 County Rd. 561, P.O. Box 1008, Tavares, FL 32778, (904) 343-3200.

6. The Staver Co., Inc., 41-51 Saxon Ave., Bay Shore, NY 11706, (516) 666-8000.

7. Fiberoptic Display System, Inc., P.O. Box 7006, Cumberland, RI 02864, (401) 333-1086.

8. Dynamic High Technology, 3189 Danville Blvd., P.O. Box 174, Alamo, CA, (415) 838-0544.

APPENDIX A

Letter of Inquiry Addresses

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