What Is Good Instrument Panel Design?

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WHAT IS GOOD instrument panel design? There are probably as many answers to this question as there are people reading this. Strange? Perhaps not. The multiplicity of answers undoubtedly results from the many and often opposing requirements of an instrument panel. The numerous restrictions imposed on the design demand additional compromises. Because of the many factors involved, any simple description of good instrument panel design runs the risk of being as incomplete and as inaccurate as the description of an elephant by the six blind men in J. G. Saxe's story, "The Blind Men and the Elephant."

To avoid a similar inaccurate definition due to incomplete exposure, let us begin our description of good instrument panel design by defining the four basic roles an instrument panel must perform. These functions are: to serve as an information center, to be the controls center, to enhance comfort and convenience, and to present an attractive appearance.

First, the instrument panel is the information center of the automobile. Here a multitude of data is collected, transformed into a readily intelligible form, and made available to the driver. This information is transmitted by instruments and lights on the panel. Since the driver cannot read any instrument without taking his eyes off the road, instrument reading time is an important safety consideration. Therefore, the information must be available to the driver in such a form that a minimum of his time and effort is required in interpretation and comprehension. The possibilities of misinterpreting the information must be kept to an absolute minimum. For example, if your engine were to overheat, it is imperative that you be informed of this condition before permanent engine damage occurs. This information must be transmitted to you quickly, and in such a manner that it is an unmistakable sign of danger. The same would be true if the engine were to lose oil pressure.

Other information is necessary for the driver to operate the vehicle properly. Loss of alternator or generator output is indicated by an ammeter or generator warning light. The speedometer must provide both an approximate and an accurate indication of vehicle speed. Most of the time the driver need only receive a quick indication of approximate car speed to tell him if he is traveling at a safe rate. At other times, the "boys in blue" will stimulate him to read an exact quantity in order to maintain the maximum speed permissible in a restricted zone. In both cases, he will want to receive the information with the required "driver eyes off the road" time, a minimum consistent with the reading accuracy desired. Additional information provided by the "information center" concerns the fuel supply, the number of miles the vehicle has traveled, and even the time of day. A warning light may act as a reminder to disengage the parking brake. Additional lights will indicate turn signal operation or remind the driver his headlamps are on high beam.

Providing the information so that accurate interpretation is possible in an absolute minimum amount of time requires careful attention to the placement and design of the instruments. The important indicators should be grouped so that they can be scanned quickly as a part of the normal driving

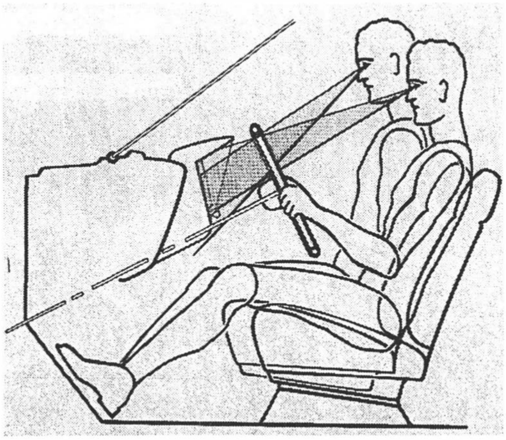

Fig. 1 - Instrument panel as seen through two eye points; long legs,and short torso, and short legs and long torso

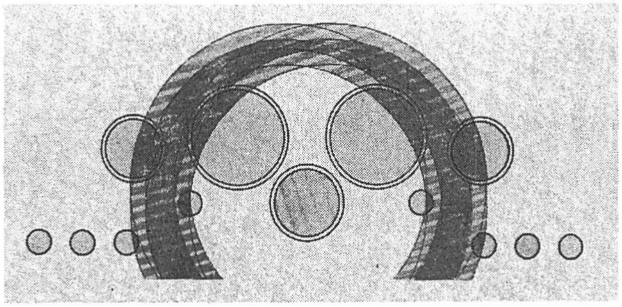

Fig. 2 - Wheel silhouettes as seen through various eye points

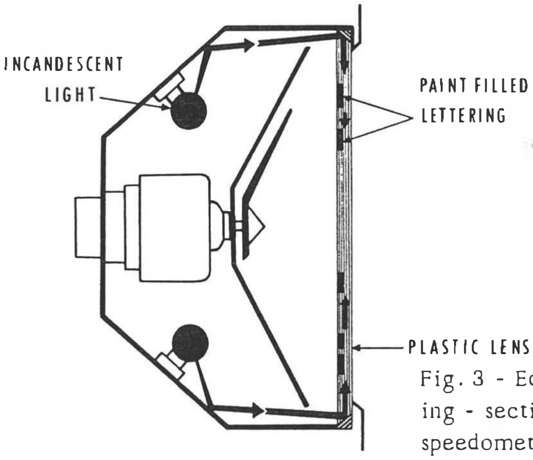

Fig. 3 - Edge lighting - section through speedometer

operation. All warning lights should be located within the driver's field of vision to quickly attract attention when lighted. Instrument search time must be kept at a minimum. Since the steering wheel is positioned between the driver and the instrument panel, it is usually necessary to group the indicators so that they can be viewed through the wheel. This requirement presents a problem because of the wide assortment of driver sizes, proportions, and seating positions. For example, the taller the seated height of the driver, the lower will be his view of the panel through the steering wheel (Fig. 1). Therefore, the lower will be the upper reading limit for instrument placement on the panel. The farther back the seated position of the driver, the narrower is the projected width of the wheel. Since all drivers are not similarly proportioned, the problem is further complicated. Consider the difference in steering wheel projections on the instrument panel of a driver with short legs and a long trunk versus a long legged driver with a short trunk. The former will project a low but wide steering wheel onto the panel. The latter will project a high but narrow steering wheel. The placement of instruments must accommodate both limiting conditions.

The lateral seating position of different drivers varies from the far left with the back leaning against the door to near the center of the car with the right arm on the center arm rest. In addition, any one driver may vary between these extremes during a long trip. To accommodate a large percentage of the drivers most of the time, the allowable panel area for instrument grouping must be further restricted (Fig. 2). In this limited "readily seen" area must be placed instruments of sufficient size to allow adequate nomenclature and graduations for easy identification and interpretation. Consideration must be given to the design of the horn rings and the placement of wheel spokes to minimize their effect on instrument visibility.

The type of indicator used can have a great effect on the reading accuracy and the reading time required. In a series of human factors studies, it was shown that the time required to accurately read vertical or horizontal gages is considerably greater than the time required to read round, semicircular or open window gages. The additional search time required to locate the pointer seems to be the basic difference in reading time or accuracy. Another factor to be considered in instrument design is that angles generally can be quickly read to a finer degree than linear distances. This, however, requires that the pointer pivot be visible. In general, it is preferable to use semicircular or round gages with exposed pointer centers to enhance instrument reading accuracy with a minimum of reading time required.

Illumination of the gages must be provided for night driving. Good lighting will allow the same accuracy and speed of instrument reading during nighttime driving as is possible during the daylight hours. The illumination should not contribute to eye strain and driver fatigue by allowing hot spots, shadows, or glare to occur. Nor should it allow bright light to be reflected into the driver's face. The control of stray light in the passenger compartment can be a problem. Light leakage between mating surfaces of a cluster must be avoided through the design of the mating surfaces to trap light or by the addition of light seals.

A number of types of instrument lighting systems have been developed in an attempt to satisfy the many lighting requirements. Among these are: incandescent lighting, ultraviolet lighting, and electroluminescent lighting.

Incandescent lighting is by far the most popular in automotive application. This is due to its effectiveness and the relatively low cost involved. Among the different applications of incandescent lighting to instrument clusters are: edge lighting, rear lighting, and indirect lighting.

Edge lighting involves the transmission of light through

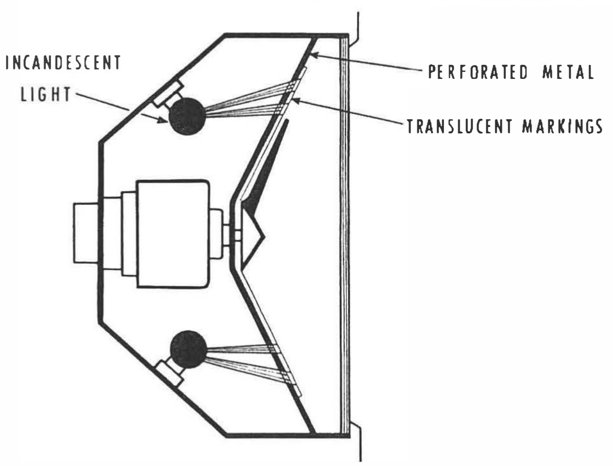

Fig. 4 - Rear lighting - section through speedometer

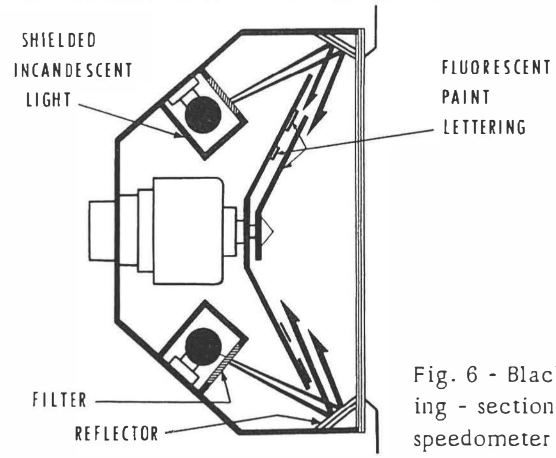

Fig. 6 - Black lighting - section through speedometer

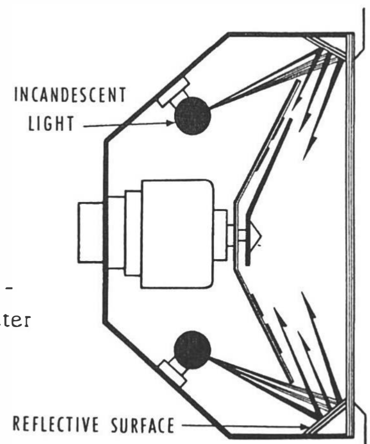

Fig. 5 - Indirect lighting - section through speedometer

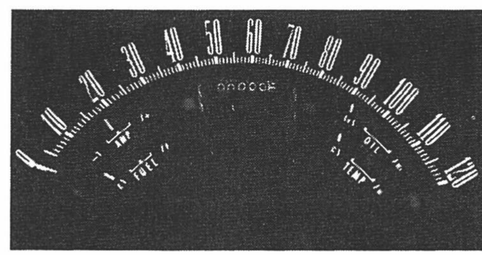

Fig. 7 - Electroluminescent lighting used on instrument panel

a plastic lens. (Fig. 3). Paint filled letters or numerals are impressed in the plastic and interrupt the flow of light. The letters are thus silhouetted. Getting enough light on the pointer is generally a problem with this type of illumination, but it is excellent for nomenclature or printed instruction.

Rear lighting through translucent markings is good for numeral illumination, but again does not light the pointer (Fig. 4). Space behind the surface to be lighted is necessary to accommodate the illumination bulbs. In many designs this extra space requirement can be a handicap.

Indirect lighting uses the inside surfaces of the cluster to reflect light onto the dial faces and the pointers (Fig. 5). Careful design of the reflecting surfaces, dial flanges, and paint treatments can result in an excellent job of lighting at reasonable cost. The color of light can be controlled through the use of colored paint treatments on the reflective surfaces or colored plastic diffusers. When edge or rear lighting is used for dial markings, indirect light is often used to complete the lighting of the pointer.

Lighting problems which tend to be common to these three forms of incandescent lighting are: the control of stray light, and evenness of lighting without shadows or hot spots.

Black lighting refers to the use of ultraviolet or nearly ultraviolet light to excite a fluorescent surface (Fig. 6). This fluorescent surface in turn radiates visible light. In automotive applications, incandescent bulbs are generally used as the light source. The greatest portion of the visible light is filtered. The gauge markings and pointers are painted with a fluorescent paint and glow when excited by the ultraviolet and violet light. The effects usually are dramatic. The number of bulbs required as the source of the ultraviolet light is usually considerably greater than necessary for indirect lighting. The cost of and space required for these additional bulbs plus the filters limit the use of this lighting technique.

A still more dramatic lighting effect has been achieved through the use of electroluminescent lighting (Fig. 7). The principle of electroluminescent lighting involves exciting a phosphor with an alternating field. The electrons in the phosphor are excited alternately from higher to lower energy levels to bring about a photon type of light emission. The electroluminescent lamp is a true area light source. In automotive application, the lamp serves as the dial plate. An opaque coating covers the lamp everywhere except the dial markings. Thus, only the markings glow, contrasting sharply with the background. The pointers themselves are lamps with the phosphor bearing material applied to a wire. The pointer is then painted a fire orange to contrast with the normally blue-green markings. A transistor oscillator power supply provides the lamps with 200 v at 250 cps. Excessive current drain stops the oscillator to preclude any shock hazard. The lighting is crisp, clear, even, and without glare. There is no stray light. Unfortunately the cost penalty usually associated with the system discourages its use in the lower line cars.

It must be kept in mind that the primary purpose of instrument illumination is to allow the same speed and accuracy of instrument reading during night driving as is possible during the daylight hours.

To insure both day and nighttime readibility, careful attention must be paid to the type, style, and colors of the letters used on the gages. For example, white letters on black backgrounds provide excellent contrast for ready legibility. The black background also tends to reflect a low amount of light during night driving. The lower level of light in the passenger compartment can contribute to better visibility and less driver eye strain where the ambient light level is very low as on dark country roads. The less the amount of light spilling out of the cluster the lesser the possibility for, or intensity of reflections in the windshield of the steering wheel or horn ring.

The black background which is so desirable for reduced nighttime reflections, unfortunately, provides excellent contrast to emphasize any daytime reflections in the lenses themselves. These reflections can be caused by light from the side or rear windows, or even the reflected light from the driver's white shirt. The distracting lens reflections can contribute to instrument reading errors and increased reading time. Therefore, if black back dials are used, careful attention must be paid to the shapes and angles of the lenses to insure that these distracting daytime reflections are not visible to the driver.

In summary, the first role of the automotive instrument panel is to serve as the information center of the vehicle. As such, it must collect the data necessary to the driver for proper operation of the vehicle. This information must be available to the driver in a form that can be readily comprehended with a minimum of reading error, and a minimum of reading time required. This must be accomplished for all driving conditions.

The second function of the instrument panel is to provide a control center for the automobile. A multiplicity of controls required for proper operation of the vehicle are located on the instrument panel. Here are located the controls for starting the automobile, selection of the desired passenger compartment temperature, and in some cases, the transmission gear selector and the parking sprag actuator. Numerous other functions are controlled from the panel, such as headlamps, parking lamps, instrument panel lamps, and dome, map, and courtesy lamps. The controls for windshield defogging and defrosting, ventilation, windshield wipers, convertible automatic top lift, and even the control for raising and lowering of a suburban rear window also are located on the instrument panel. In addition, instrument panels may include controls for a rear air conditioning unit, floor air distribution, vehicle speed control or signaling device, radio, and power antenna.

Because of the many functions which must be controlled from the instrument panel, considerable attention must be given to the design and location of these controls. In general, the controls should be a natural extension of the driver: readily recognized, easy to reach, and with no confusion as to their mode of operation. The controls should be grouped as close to the operator as possible for easy accessibility. The best position on the panel is straight ahead of the arms at elbow height. The preferred area horizontally is between the arm straight ahead position and 30 deg outward. The preferred vertical area is between the shoulder and waist level. Since the steering wheel is located between the driver and the control area on the panel, the position of the wheel has a profound effect on the acceptability of a control location for two reasons. The first is the ease of reaching around the wheel. The second is the accessibility of the control between the wheel and the instrument panel. In this respect, even the positioning of the turn signal lever may become critical.

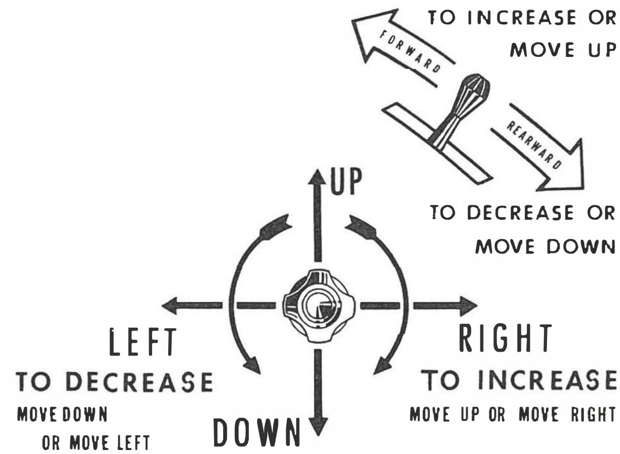

Fig. 8 - "Expected" direction of controls

When determining the general arrangement of controls, careful consideration should be given to the frequency of use of each control. Since all controls cannot be placed at an optimum position, those requiring the highest frequency of use deserve first consideration. In addition to accessibility, care should be taken in the positioning of controls to avoid projections which might be struck by the driver or passenger during a vehicle collision.

A well-designed control provides the driver a feedback to give him knowledge of the completion of his actions. For example, an audible click and/or a detent feel will tell the driver that something has been accomplished. A push button should remain depressed to indicate which button was last actuated. Although the radio buttons do not remain depressed, the movement of the pointer across the dial face provides an indication of action and also records the result of the action.

Another requirement of controls is that they should move in an expected direction (Fig. 8). Levers should move up, forward, or to the right to increase. Conversely they should move down, rearward, or to the left to decrease. Levers should move up or forward to move something up. Conversely they should move down or rearward to move something

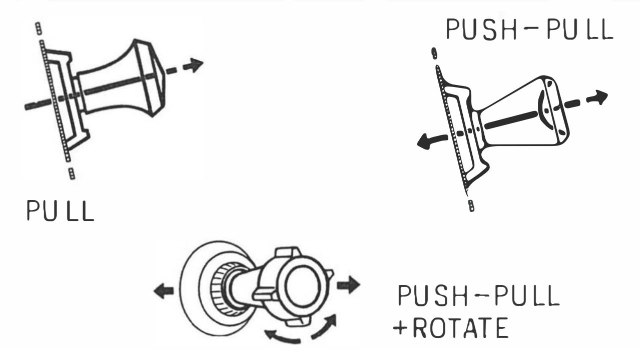

Fig. 9 - Types of control knobs

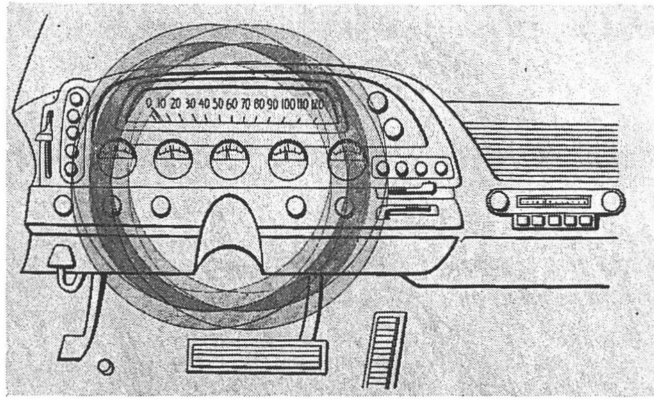

Fig. 10 - Illustration of limited area for instruments and controls

down. Rotary controls should move clockwise to increase, move right, up, or away. Rotary controls should move from "off" in a clockwise direction for "low" and "high" speed and should not have a center "off" position with "low" and "high" on either side.

However, in spite of these examples, the primary consideration of control motion should be re-emphasized. All controls should move in an expected direction. If it is necessary to compromise the normally expected direction of operation due to other considerations, great care should be taken before changing the mode or direction of operation again the following model year. Once having undertaken the process of education, it may be far better to continue in that direction than to create the confusion of constant change. An example of this is the instrument cluster lighting rheostat. The American motoring public has become accustomed to turning the rheostat control to the right to decrease rather than increase the lighting intensity. Any attempt to rectify this now would only create confusion.

Even the design of control knobs deserves careful attention. The knob shapes should suggest the method of actuation of the control. For example, a knob for a push-pull control should be so shaped that it "asks" to be pulled (Fig. 9). A rotary control knob should tend toward the cylindrical or provide obvious turning wings. The location and method of operation of the controls and the shape of the knobs should be designed to allow instant control recognition and a quick reminder of method of operation.

Let me repeat that the controls should be a natural extension of the driver - readily recognizable, easy to reach, and with no confusion as to their mode of operation.

Perhaps you may already note requirements of the first two basic roles of the instrument panel that tend to be conflicting. Let me confirm that these requirements are conflicting. All switches and controls must be in prominent positions within easy reach. Instruments must be in prominent positions and easily seen. Since there is a relatively small area readily seen and easily accessible to the driver, especially within the limitations imposed by the steering wheel, we are defining one of the very basic problems of instrument panel design - space (Fig. 10). In addition to the localized problem of space immediately in front of the driver within easy sight or access, the space problem extends to the rest of the panel. This problem is emphasized by the third basic role of the instrument panel; comfort and convenience.

Many items of comfort and convenience to the occupants of the automobile are provided in the instrument panels. Some of these are analogous to items in our own living room. The automotive radio and speaker provides the comfort and convenience of the household hi-fi console. Many instrument panels have reading lamps. A small closet called a glove box is provided for the storage of small items. For the benefit of those who have an occasional snack at a drive-in restaurant, the instrument panel or the open glove box door can serve as their snack table. The instrument panel also provides warm air registers in the form of defroster outlets. An ash tray, or trays, and cigar lighters are provided for the convenience of the smoker. An ash tray, in order to be useful, must be convenient to the driver. The same is true of the lighter and the radio. These items should also be convenient to the passenger. This dictates a duplication of these components on either end of the panel, or a centralized location.

As indicated, to provide for these additional items of comfort and convenience, space on, or in, the instrument panel is required. Further, the requirement of accessibility provides additional restrictions on the design of the panel.

The driver-owner probably spends more time looking at the instrument panel than any other part of the automobile except the hood ornament. Consequently, every effort must be made to make the panel area attractive. Attractive appearance is the fourth and last basic requirement of the instrument panel. In addition to providing a sense of satisfaction and pride of ownership, the appearance of the instrument panel can provide a strong showroom attraction to the potential customer. Because of the high degree of attention paid to the interior by the women, the appeal of the panel to this segment of the market must be extremely high. Every effort must be made to maximize this attraction through careful attention to form and style. As can be expected, the objectives of best appearance and greatest function are not always compatible. Another area requiring compromise is thus created.

Providing the four roles of the instrument panel of: information center, control center, enhancing comfort and con-

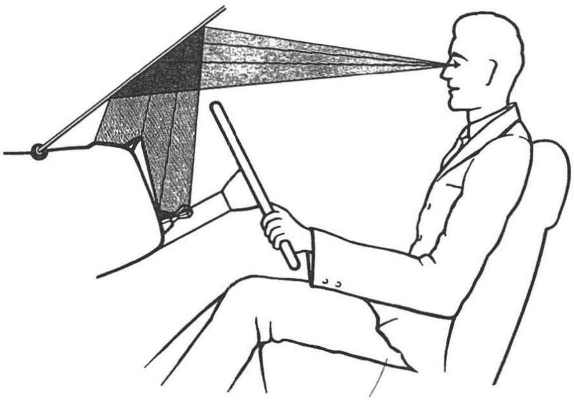

Fig. 11 - Windshield reflections

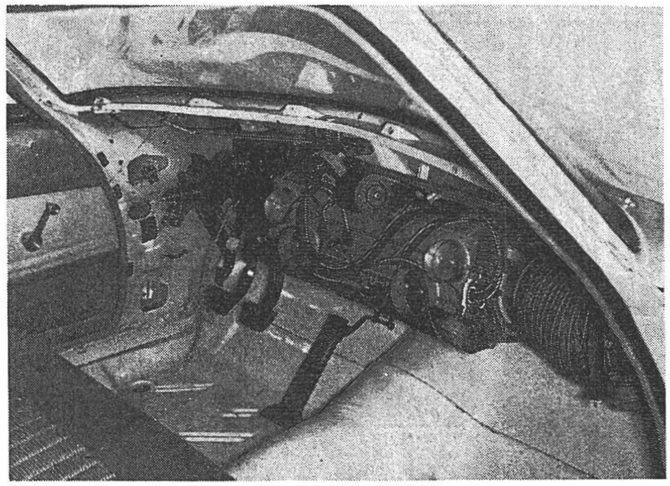

Fig. 12 - Crowded condition in space between the instrument panel, dash, and plenum chamber

venience, and attractive appearance can be equated to a problem of space. The magnitude of the design problem could be greatly reduced if sufficient space, in the proper relationship to the driver, were available. The appearance considerations generally aggravate this problem by imposing restrictions on the amount and distribution of the space available. Further restrictions on the amount of space which can be provided for the instrument panel and its components are imposed by both exterior and interior car design factors.

Some of the factors of exterior design which have an effect on the space available include: the location of the "A" pillars, the location and sweep of the front lower daylight opening line, and the location of the front door opening.

The distance between "A" pillars defines the dimension available for the width of the instrument panel. Since the forward edge of the instrument panel must attach to the cowl bar, the location and shape of the bottom of the windshield (lower daylight opening) will determine this mating surface of the panel. Coupled with stamping considerations, the vertical position of the lower daylight opening generally determines the height of the panel. The sweep and location of this line in the plan view will affect the fore and aft space available for panel components. The projection of the instrument panel into the door opening must be restricted by its effect on the entrance and exit room. The relationship of instrument panel to door opening can also influence the construction of the panel. Closing of the exposed panel ends may require separate stampings with their attendant influence on costs.

The interior design restrictions revolve about the relationship of the driver seating position to the panel, the relationship of the windshield to the driver, and the distance between the front seat and the dash panel.

As previously discussed, the relationship of the instrument and control surfaces to the driver is of great importance. Other relationships of driver to instrument panel are also important. For example, the lower line of the instrument panel must allow for adequate leg and knee clearance for a variety of seated positions and postures. The top of the panel is largely defined by the position of the daylight opening. However, another important requirement must be met. The top of the panel must be low enough in relation to the driver's line of vision so as not to limit his view of the road, either actually or psychologically. A psychological restriction may exist where the top of the panel limits the view of a reasonably large area of the fenders or front end sheet metal. Although the view of the road may be unimpaired, the lack of front end sheet metal visibility may cause the driver to feel his view of the road has been restricted.

The position of the windshield relative to the driver and the top of the instrument panel will determine the existence and position of the daylight reflection of the panel surface in the windshield (Fig. 11). Those of you who have driven in the bright sunlight while peering through the reflection of an instrument panel can attest to the eye strain and driver fatigue which result. Nighttime reflections in the windshield of the lighted instruments and controls are determined by the relationship of the windshield to the driver and the instruments. Similar relationships to the steering wheel, horn ring, or steering column will define the existence and location of their reflection in the windshield. The intensity of these reflections is a function of the amount of light being reflected into the windshield. In design, the first objective is to establish the relationship of the windshield to the driver and the reflecting surfaces so that the driver cannot see the reflections. If this is not possible, the relationships should be such that the reflections do not occur in the driver's normal line or sight. When this is not practical, the intensity of the reflections must be minimized by reducing the amount of light emanating from the instruments and/or reducing the reflectivity of the surface finishes.

The third category of interior dimensional restrictions involves the distance between the dash and the driver. The positioning of the vertical surface of the instrument panel between these two extremes must satisfy two requirements. First, the instrument panel must be far enough forward and away from the driver to contribute a feeling of spaciousness and comfort to the front seat occupants. Secondly, the positioning of the instrument panel surface relative to the dash and plenum chamber must provide clearance for the com-

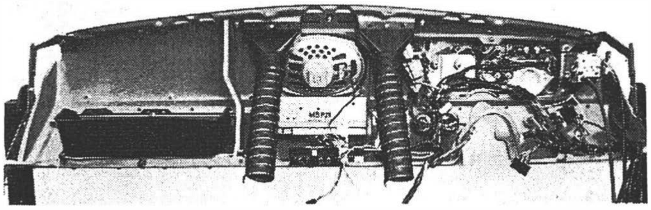

Fig. 13 - Radio, speaker, glove box, and speedometer

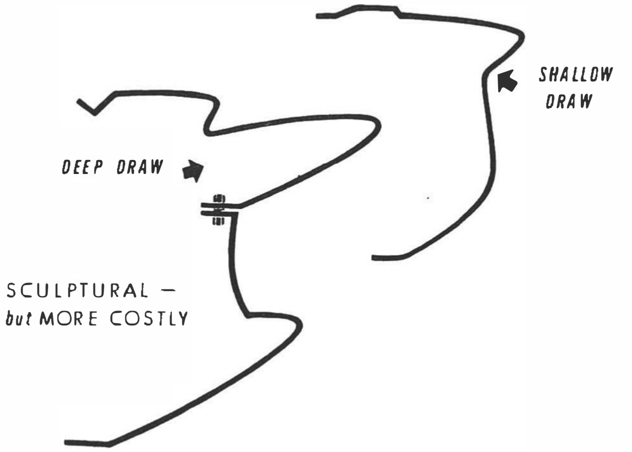

Fig. 14 - One piece and two piece panel sections

ponents mounted on the dash and the components behind the instrument panel. This requirement presents one of the most important, and in many cases least recognized aspects of instrument panel design. It has been said that two basic design problems exist for instrument panels. The first problem is the design of the visible portion of the panel and its components, which we have already discussed. The second is the design of the components behind the instrument panel.

Have you ever looked behind an instrument panel? If you have, I'm sure you have an appreciation for the layout and design problems involved. Included in the multitude of components which must be accommodated in the space between the instrument panel and the dash and plenum chamber are the heater and/or air conditioning units, air conditioning outlet hoses, defroster risers, and ventilation ducts (Fig. 12). In addition there are clutch and brake pedals and brackets, parking brake mechanism, windshield wiper motor and links, and steering column support brackets. There are also wiring harnesses, dash mounted wiring disconnects, fuse blocks, speedometer cables and a multiplicity of vacuum hoses and/or bowden cables to control heating, air conditioning, and ventilation. The space available for these components is bounded on three sides by the dash, plenum chamber, and instrument panel. The ends, of course, are bounded by the interior width of the car. The fourth side, the bottom, is restricted by the provision for adequate foot clearance for the driver and passengers, and the limitations imposed by the occupants on component visibility under the instrument panel surface. The size and location of these components often have an effect on the size and/or location of some of the instrument panel components; such as radio, speaker, glove box, and speedometers (Fig. 13). The location and shape of the instrument panel are also affected.

Therefore, the space necessary to provide the four basic roles of the instrument panel is limited by exterior factors of greenhouse design, and the interior relationships of the driver to the windshield and the dash panel. Other factors of design must also be considered. These factors include: safety, serviceability, cost and weight, and appearance face lift requirements.

Previously mentioned safety considerations have included: (1) the requirement of providing for rapid and accurate instrument reading, (2) the location of controls to minimize the possibility of contact during vehicle collision, and the design of controls to minimize the possibility of misuse. In addition, the configuration and/or material of the control knob itself must minimize the possibility of human injury should contact occur during a collision. The configuration of the instrument panel should eliminate any sharp projections. A positive safety plus can be provided by designing the instrument panel to absorb energy during impact. Either of the approaches of panel configuration and/or material could be acceptable. The contribution to safety of instrument panel crash padding is familiar to all of us.

In a discussion of serviceability, not only must the service of components in the panel be considered but also the service of those components between the instrument panel and the dash. The service consideration of a windshield wiper motor or heater assembly located behind the panel must be as important as the service consideration of a gauge, radio, or cluster illumination bulb located in the panel. The same space problem which makes it difficult to accommodate all of the necessary components with proper operating and assembly clearances turns the service problem into a designer's nightmare.

The usual parameters of cost and weight cannot be ignored in any discussion of design. Since any discussion of cost and weight usually involves the details of construction and material, we will limit our discussion to general comments in these areas. Because of the relationship of the windshield to the driver and the instrument cluster, some form of a brow or ledge above the instruments is required. This brow serves to prevent the light from the instruments from reflecting directly into the windshield. The basic relationship determines the sizes of the brow required. Three approaches to providing this brow are presently used. The first is to provide the brow directly in the panel by its configuration (Fig. 14). The instrument cluster is then place directly into the panel. For purpose of definition, the instrument cluster I speak of is the assembly or assemblies of instruments - all gages plus the speedometer. The second approach is similar to the first; however, the brow is a separate piece attached to the panel. This separate piece can be a soft material, sheet metal, or a casting. The third approach is to provide a separate casting or housing of either a soft or hard

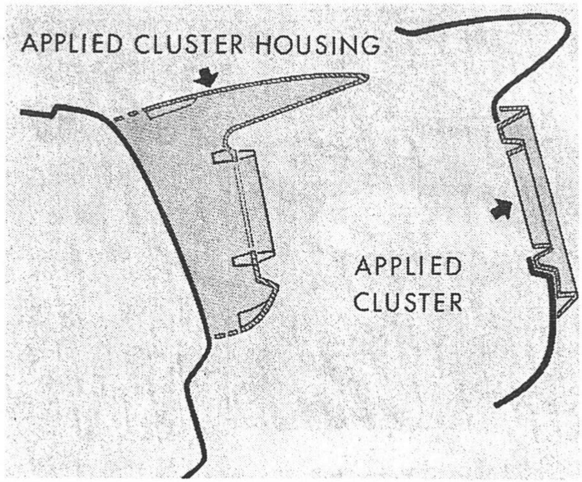

Fig. 15 - Applied cluster type panel sections

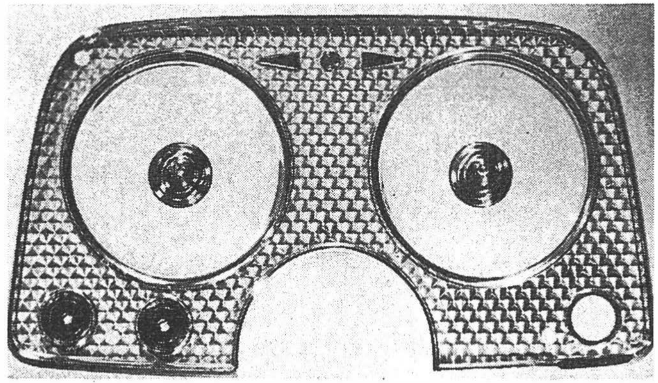

Fig. 16 - Cluster face and lens molded of acrylic

material which is mounted onto the instrument panel and in turn accepts the instrument cluster (Fig. 15). The approach taken with any car line depends to a large extent upon the appearance and styling approach desired. In some cases, the method of final assembly may become the determining consideration. In general, the greater the number of pieces involved the greater the cost.

The use of plastics has become of interest in an attempt to minimize the weight implications of separate cluster housings and to enhance safety by providing an impact absorbing material. In the 1961 Valiant, the use of plastic reduced the weight of the housing approximately 75%. Further weight reductions were possible in the 1962 Valiant by integrating the cluster housing and the back casting into one piece in plastic. In this application the housing weight was reduced by 80% from the equivalent design in zinc. Plastic in another application not only accommodated the mounting of the instruments but also provided the base for the printed circuitry. The copper of the printed circuit was applied directly to the plastic. Plastic has also been used to reduce the cost of expensive decorative areas of the cluster face. In the 1960 Valiant the complete cluster face and lens were molded of acrylic in one piece (Fig. 16). The bright chrome appearance was achieved by vacuum metalizing. It was possible to obtain a simulated engine turn texture on the bezel face by putting the texture directly into the mold.

The instrument panel also provides an area for model year face lift as important as the front end sheet metal or a rear quarter panel. The frequency and degree of change required, along with the general need for minimizing the tooling expenditure in a face-lift year, provides another interesting series of design problems.

In summary, the basic problem of instrument panel design is space. The space requirements are established in providing:

1. The driver the information and controls necessary for proper operation of the vehicle.

2. Items of comfort and convenience for both the driver and the front seat passengers.

The limitations imposed in providing the required space are generally a result of basic car design. These factors include both exterior and interior basic dimensions. The exterior factors involve the location and angle of the windshield, the location of the "A" pillars, front door opening line, and lower daylight opening. The interior relationship of the dash to driver provides the space for the instrument panel and components in the panel and also the components behind the panel. The style and appearance required of the panel to provide a vehicle sales aid establishes both a space requirement for proper execution and a space restriction for panel components. Good instrument panel design requires knowledge of the driver's anatomical dimensions and psychological make-up. Careful attention must be paid to the details of the types and location of instruments, the location and operation of controls, serviceability of the components in and underneath the panel, driver and front seat passenger safety, and cost and weight.

Stated briefly: good instrument panel design involves achieving the best compromise within the limited space available of the many requirements of an instrument panel.