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PRELIMINARY DESIGN OF THE FORD TM-3 TRIPCOMPUTER

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16. Abstract

This report describes the initial development of the TM-3 tripminder (tripcomputer), an instrument panel module scheduled to be standard equipment on the 1987-1/2 Lincoln Continental. The module consists of 12 pushbuttons and a display showing three lines of seven characters. Using it the driver can obtain information about trip distances and times, fuel economy, and the state of several vehicle systems.

This report focuses on how the module was designed to make it easy to use. The report lists the functional requirements of the product, the target population, the conditions of use, and general ease-of-use guidelines. In addition, it describes all of the preliminary design proposals in detail (down to the level of switch legends and message wording), identifies product-related research needs, and offers general comments as to how the design process might be improved.

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EXECUTIVE SUMMARY

While this summary is part of the final report, it has been written so that it, together with the abstract, may be circulated independently.

The TM-3 tripminder, as currently designed, consists of a 12-button switch cluster located above the radio and a liquid crystal display (LCD) to the left of the switches. Sketches of the components are shown below.

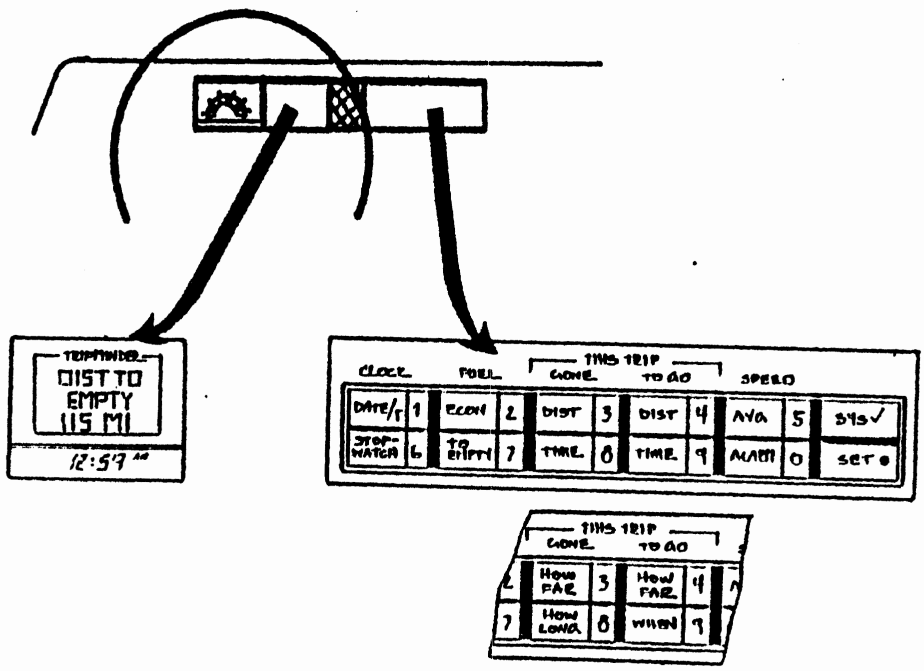


Figure 1. The Current Design

The switch array consists of six columns of two pushbuttons. Columns are separated by barriers to make it less likely a driver would press multiple buttons while wearing gloves and to reinforce the grouping provided by the labels above each column. Simple labels (e.g., "this trip - dist gone") have been used instead of technical jargon (e.g., "trip odo") and that theme has been carried through to the system messages.

To obtain information the driver pushes a button and the associated message appears on the display (e.g., average\economy\xx mpg [where\=new line] which is followed several seconds later by instant\economy\xx mpg). Messages in response to switch actions always repeat the name of the feature selected should the driver forget. Warning messages for this trip computer are quite different from those now used in that they say both what is wrong and suggest what to do. One finding from the Vehicle Maintenance Monitor Study done at Michigan was that drivers often don't understand even the simplest warning displays. They don't know what to do nor do they know what the consequences are of doing nothing. For example, for low AC fluid the message pair is "don't\use Air\Cond" "Air Cond\fluid\low" is suggested.

A major problem with other trip computers is they are difficult to set. For this product one enters the set mode by pressing the set button. That causes the LED on the set button to go on (telling the driver he or she is in the set mode) and causing a message such as "select \item\to set" to appear. The driver then selects an item and receives further guidance from the display what to do next. When setting is complete, the LED goes off.

While most of the design is complete, several questions need to be resolved by testing drivers. Those include questions about which of several alternative switch labels and messages should be used, how long it takes to read messages, and how numbers should be "entered."

One reason this product should be easier to use than its predecessors is that human factors considerations were introduced early in the design cycle. That practice should be continued. In future projects funding for a series of product tests should be planned, with the first user test occurring well before the initial design is defined. In addition, there is an urgent need for basic academic research on how to make products easy to use.

PREFACE

This report describes how the TM-3 tripminder (trip computer) was developed. Much of the work took place in ten meetings held at the Ford Diversified Products Technical Center in Dearborn during November and December of 1983 and January of 1984. Associated with each meeting were background materials (letters, design proposals, and technical data) delivered to Ford by the University before or at the start of each meeting.

Key members of the design team included Paul Green (University of Michigan, UMTRI Human Factors); Terry Thiel (Ford, Electrical and Electronics Division, Advanced Engineering), who was responsible for managing the project; Scott Hunter (Ford, Business Planning); and Dan Ellis (Ford, Design Staff). Also contributing were Al Minsterman concerning general design issues and Gary Woodward (both from Ford, EED, Advanced Engineering) concerning mechanical design.

It was initially planned that the funding provided the University of Michigan to assist in product design would be followed by a subsequent research project. That responsibility has since been assigned to the Ford Automotive Safety Office.

PURPOSE

This purpose of this report is to: (1) describe the initial development of the TM-3 trip computer, emphasizing how human factors (ergonomics) issues were considered as part of the design process; (2) identify what research needs to be done to answer design-related ease-of-use questions; and (3) offer suggestions as to how to improve the design process.

DESIGN REQUIREMENTS

Product Function. The TM-3 trip computer monitors the vehicle and warns the driver of malfunctions. It also allows the driver to query it for assorted trip, time, and vehicle performance data. The product is intended to be standard equipment in the 1987-1/2 FN9 (Lincoln Continental). It consists of a switch cluster, 1" high by 7" wide, located just above the radio in the center of the panel (see Figure 2), plus a 2-7/8 in. wide x 3-3/16 in. high section for a multi-line vacuum-fluorescent message unit and a dedicated clock (with a date display). The display cluster is located between the speedometer and the trip computer controls. A list of the information displayed is shown in Table 1.

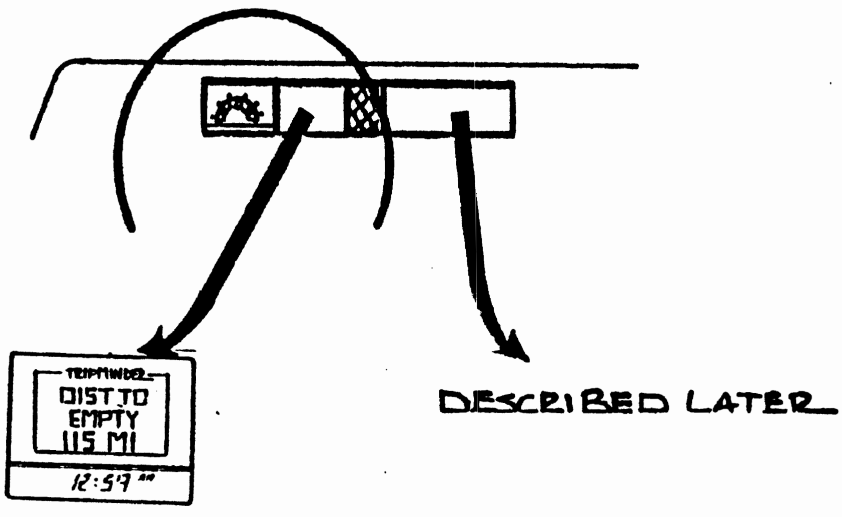


Figure 2. Module Locations

TABLE 1

INFORMATION DISPLAYED

Monitored conditions needing automatic warning messages

systems normal	low washer fluid
30,000 mile service reminder	low oil level
door ajar	low coolant level
decklid ajar	low transmission oil
headlamp out	low power steering fluid
taillamp out	low brake fluid
brake lamp out	brake pad wear
charging system	anti-skid brake system check
low A/C charge	air suspension system
	oil change needed

Trip, time, and performance features (driver-initiated messages)

date/time (dedicated)	elapsed time
average fuel economy	elapsed travel time
instantaneous fuel economy	distance to destination
distance to empty	estimated time of arrival
trip odometer	set/reset
average speed	

User Population. An essential and often forgotten part of the design specifications for a product is a description of the user population. One needs to know not only what the product is supposed to do but who is going to be using it. It is impossible to design a product "user-friendly" if the intended user is not known.

Following is a summary of the expected user population. The information was gathered by Terry Thiel at Paul Green's request. The source is a Ford marketing report that is sufficiently confidential that EED did not want it named.

TABLE 2

USER POPULATION

luxury car owners		new car buyers: luxury cars	
college graduate	54%	manager	11%
professional	49%	proprietor	7%
married	82%	office worker	3%
		sales	10%
median years	48	teacher	3%
under 35 years	22%	professional & technical	21%
35-54 years	42%	farmer	2%
over 54 years	36%	fire/police	1%
		military	-
male	72%	skilled trade	3%
female	28%	equipment operator	1%
		factory laborer	1%
		student	1%
		housewife	8%
		retired	22%
		other	6%

Given the age distribution of expected users, with almost two out of five older than 54 years, care must be taken that the size and style of characters in the message displays make them easily readable by drivers whose near vision may be significantly poorer than that of young drivers. Also noteworthy is the wide range of occupations of the buyer/driver population. Many of these people will not be familiar with the internal workings of cars, and, hence system messages will have to be quite simple.

While figures were not available for the current tripminders, it is expected that by the time TM-3 is released 20-25% of the drivers will have had previous experience with a trip computer (Terry Thiel's estimate.

Conditions of Use

1. It is assumed that the trip computer will be operated under a variety of climatic conditions, including cold weather. Therefore it is

assumed the device should be operable while wearing gloves or light-weight mittens (not arctic mittens). (Because of space constraints, it was not believed possible to make the controls large enough so they could be operated while wearing them.)

2. The device will be operated while the car is in motion (and therefore should be designed to minimize visual and attentional demands on the driver).

3. There are no performance data available on how often trip computers or trip computer functions are used. From a Ford survey done in Europe (again from an unspecified source), the following was reported as to how often drivers say they use trip computer functions. Bear in mind that these relative frequency-of-use figures are influenced by the ease of use of the features of interest.

TABLE 3

WHICH FEATURES DRIVERS SAY THEY USE

30-40%	date/time/fuel economy
20%	distance to empty
15%	distance to arrival
10%	distance traveled
<5%	average speed
15%	estimated time of arrival
<5%	time alarm

It is expected the use of the TM3 will be similar to the previously given figures.

4. There are no sample-specific data available on the type of trips during which drivers used trip computers. General data on travel patterns of car drivers are given in the Nationwide Personal Transportation Study (Edmonds, Greenblatt, Lago, and Morganstein, 1981).

(Note: This report is a summary of 1977 data.) The details of interest are the cross-tabulations for luxury cars.

User Friendliness. An important design requirement for this product was that it must be "user friendly," implying that a product is easy to learn to use and easy to use. Those qualities can be measured through tests with users (usually by recording task times and errors), but those steps are rarely taken except by the major computer manufacturers. (Most products advertised as "user-friendly" are not, despite what the advertising copy says.)

In designing a user-friendly product, several principles should be followed. The six principles discussed here were frequently applied during the design process. (See Schneiderman, 1979, for other suggestions.)

1. Products should behave in a "natural" manner--that is, in ways users have been conditioned to expect. The naturalness principle operates at two levels. For simple actions it implies that system responses are compatible with the user's actions (e.g., pushing a control up, to the right, or clockwise causes something to turn on or increase). For complex actions it means that products operate in a manner people are familiar with (such as alarm clocks, stoves, telephones, etc.). Not only should they fit common models of devices, but the information about them should be expressed in plain English.
2. Products should operate in a consistent manner. Thus, every time a user is asked to perform an action, the same set of rules should be followed. For example, the same command is used to an editor, debugger, or applications package.

3. Products should minimize human physical and mental effort. Details that have minimal impact on the task at hand (for example, the choice of buffer size for a FORTRAN read statement) should be handled automatically by the system. Also, the forces required of users (e.g., for keypresses) should not be excessive (finger friendly), and careful attention should be paid to what people are asked to remember. For example, if a menu is presented on two screens, then people will have to remember what the first set of choices was, something they may not be good at. Further, the number of keystrokes should be minimized. The greater the number of keypresses, the longer an entry takes and the greater the opportunity for error.
4. Products should provide information <u>when</u> people need it. Products should not introduce major delays, either in response to individual keypresses or command sequences.
5. Products should be forgiving. Designers must realize that people will make mistakes and that a means should be provided for users to recover easily from errors.
6. Finally, products should take into account human sensory limitations. Tones should be easily heard and alternative messages distinguishable from each other. Text should be large enough so that it can be read, even by the elderly under poor lighting conditions.

Thus a "user-friendly" product is natural, consistent, minimizes human effort, is timely, forgiving, and takes human sensory limitations into account.

EXISTING PRODUCTS

The first step taken in the development of this new product was to review the operability of existing Ford trip computers and obtain an owner's manual for them. A 1/2-inch VHS tape was produced in which Terry Thiel described to Paul Green how the three current products operate. Covered were the 1982 Continental product, the EAO or mid-series (European Automotive Operations) product and the NAAO or low-series (North American Automotive Operations) product. In addition a brief description of the operation of the 1981 message center (Mark/ Lincoln EIC (Electronic Information Center) was then included. The tape and the discussion that follows focuses on the Continental, the product closest to the one under development. (See Cilibraise, 1982, for a formal description of Ford trip computers.)

The tape revealed several areas in which ease-of-use could be improved. (Even the Ford technical expert had to refer to a manual to be able to explain the operation of those trip computers.) First, it is very difficult to reset the device. It is not clear whether one should hit the reset key and then the function to be reset, or vice-versa. Once one is in reset mode, there is no message stating such. Also, there are problems with the way numbers are entered (left to right versus right to left). The increment/decrement approach (holding a button down to increase or decrease a set value), used in lower series models, appears to be more confusing than the direct-entry approach. (See Heintz, Haller, and Bouis, 1982, for performance data.)

A second set of problems relates to what time or distance a button or displayed value refers to (this trip, destination, since last reset, instantaneous).

Finally, problems arose because the messages were too cryptic. The 1982 Continental display consists of two lines. There is room for only five digits on the top line and six characters on the second. A user-friendly design must have enough message capacity to provide users clear, easily understandable messages.

GENERAL HUMAN FACTORS CONSIDERATIONS

What kind of control should be used for feature selection?

The general human factors wisdom is that for selecting between three to nine alternatives, a rotary selector switch is best choice, though there are situations where a slide switch, thumb wheel, or pushbutton array might be appropriate. (See Platt and Kolesnik, 1966; McCormick and Sanders, 1982; or Pew, 1983 for details.)

What kind of control should be used for numeric data entry?

The preferred controls for numeric entry are rotary dials (found on telephones) and numeric keypads. Dials tend to be slower but more accurate (Miner and Revesman, 1962; Rothert, 1963). Other methods include increment/decrement buttons (hold down the increment button to make the value increase, the decrement button to make it decrease) and those buttons with a "speed assist." (Holding down either of those buttons and a "fast" button makes the display change more rapidly.) Setting with increment/decrement buttons is very slow.

Which controls should be used for this application?

The human factors literature on multifunction controls suggests that controls used for state selection and numeric entry should be separate (Reising, Calhoun, Bateman, and Herron, 1977). However, in this case there is not enough room for separate controls. Consequently, one type of control must be able to do double duty. Of the possibilities, a pushbutton matrix is the best choice.

There are several ways the buttons can be labeled. The data from Lutz and Chapanis (1955) suggest that switches should be numbered from left to right by row. Their data and other evidence indicate the preferred numbering sequence is 1, 2, 3,...0. If one asks engineers for the appropriate sequence, they will say 0, 1, 2,... because they think of the real number system. Others will offer the sequence 1, 2,..0 because they think of counting, with 0 a replacement for 10.

DESIGN PROPOSALS

Ford Proposal 1 - Switch Arrangement

Prior to any discussion of the human factors considerations, Ford proposal #1 was developed by the Design staff. It is shown in Figure 3. The design is a simple revision of the Continental tripminder with buttons grouped in two rows instead of one and some changes in labeling. The design cleverly uses different backgrounds (black or grey) to group controls together, though the background differences may be too subtle and not visible at night. The design shares several shortcomings with the current design--confusing labels, no indication of when one is in the set mode, and some problems with switch grouping. The design is, however, an improvement over the current Continental tripminder.

Michigan Proposal 1 - Switch Arrangement

This proposal is shown in Figure 4. The design consists of two rows of five buttons in the center with a slide switch on the left and a toggle switch on the right. The central switches are grouped by placing barriers between them and labels next to them. (The barriers will also

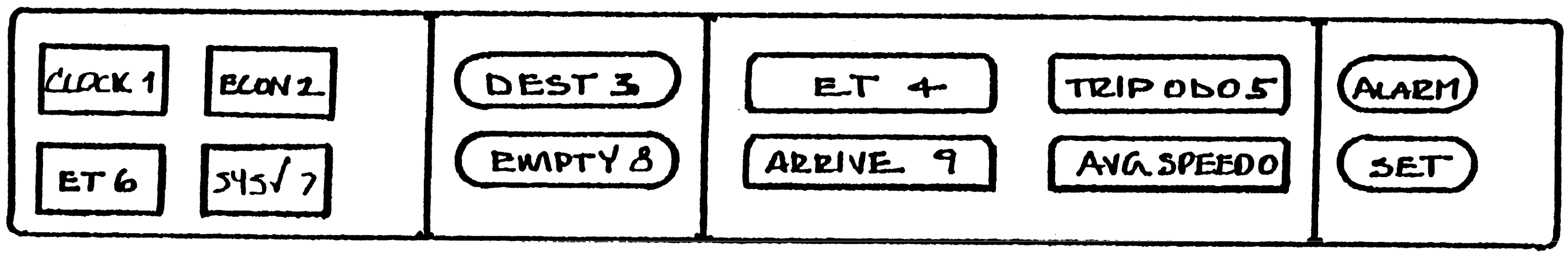
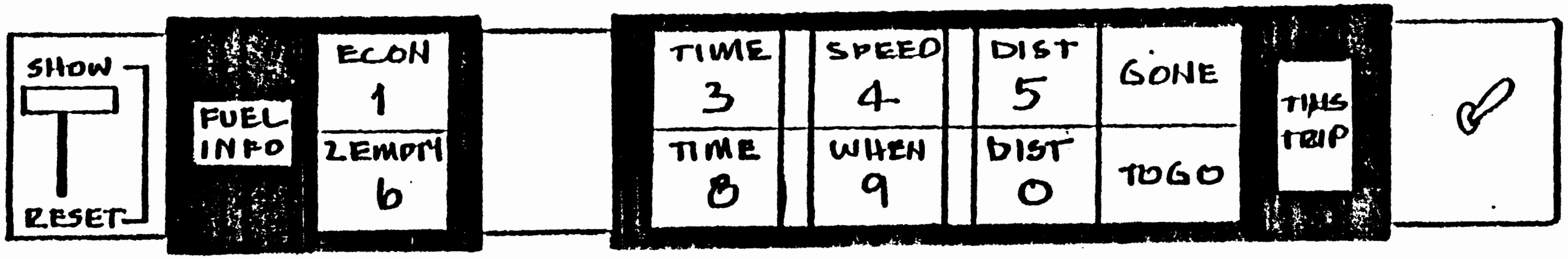


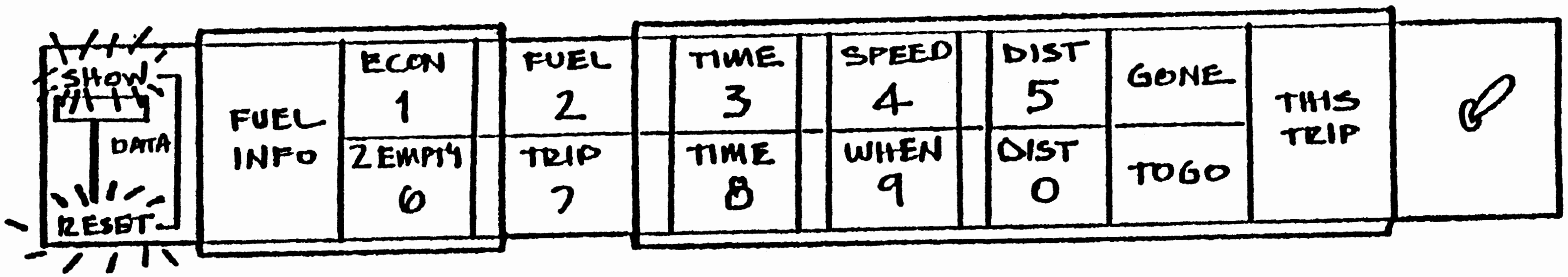
Figure 3. Ford Proposal 1

reduce the possibilities for accidental operation of controls while wearing gloves or mittens.) Further grouping is provided by surrounding each group with a color-coded bezel. A major difference between this design and the current one is the show/set slide switch. The switch is to be sprung and is normally in the show position with the word "show" illuminated. Features are selected by pushing the button (e.g., "date/time," "stopwatch," etc.) for that feature. Moving the switch to the "set" position will cause the word "set" to light up, put the device in the set mode, and turn off the light for the word "show." Also illuminated will be the names of the features that can be set (but not the digit legends on the button faces). After a feature has been selected, the feature names are turned off and the digits are illuminated along with the word "next." (The "next" button is used to signal that a data field is complete.) The set operation can be ended at any time by pushing the slide switch to the "show" position.

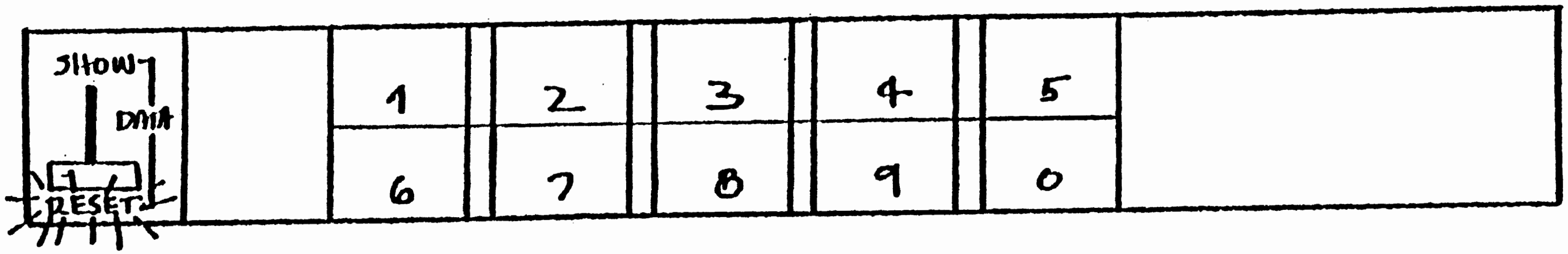
The advantages of this design are that it provides a clear indication of the mode the system is in (by illuminating either the words "show" or "set"), provides selective illumination of only those entries available (features or digits), takes advantage of functional grouping to label displays, and provides for a method to abort setting if the driver gets lost in the setting process. The weaknesses of the design are that it is difficult and expensive to build (two lights are required for each button), button size is reduced by using panel space for group legends, and buttons are not provided for all functions (system check, speed alarm). (This oversight was due to incomplete information on the design features.) In addition, color coding was used, which was not permissible. (Having one cluster that was other



(A) "POWER-UP" mode - all labels "ON"



(B) "SHOW" mode



(C) "RESET" mode - enter data

Figure 4. Michigan Proposal 1

than black, white, or shades of grey would "clash" with the others.) Finally, the English/metric toggle switch had been previously located on another cluster and therefore wasn't needed.

Michigan Proposal 2 - Switch Arrangement and Messages

Shown in Figure 5 is the second Michigan proposal of which there are two versions (alternative labeling of the trip functions). In this design the show/set switch was changed to a rocker switch and located on the right. A system check switch was added on the left, and an alarm switch was added to the main switch grouping. The switch group legends were moved to above the switch groups and the backgrounds around the switch groups were made varying shades of grey (brightness coding) instead of being color coded. These changes were made so the product satisfied the design requirements. Also, the slide switch was replaced with a rocker switch because it would be easier to manipulate with gloves and because some felt it would be more "visually harmonious" with the rest of the instrument panel. It was intended that the rocker switch latch in the set position in a manner similar to the slide switch of the previous proposal.

While this design was an improvement over previous designs, it was felt that all the switches could not be illuminated using only three bulbs and that it would be better (cheaper) to redesign the switch arrangement than the lighting scheme. It was also felt that the added cost of a latching rocker switch was too great in view of the performance improvements.

At about this time, the subject of a cover over part of the trip computer arose. Some Ford executives had proposed that a door be installed on the device so that only the clock and fuel buttons would

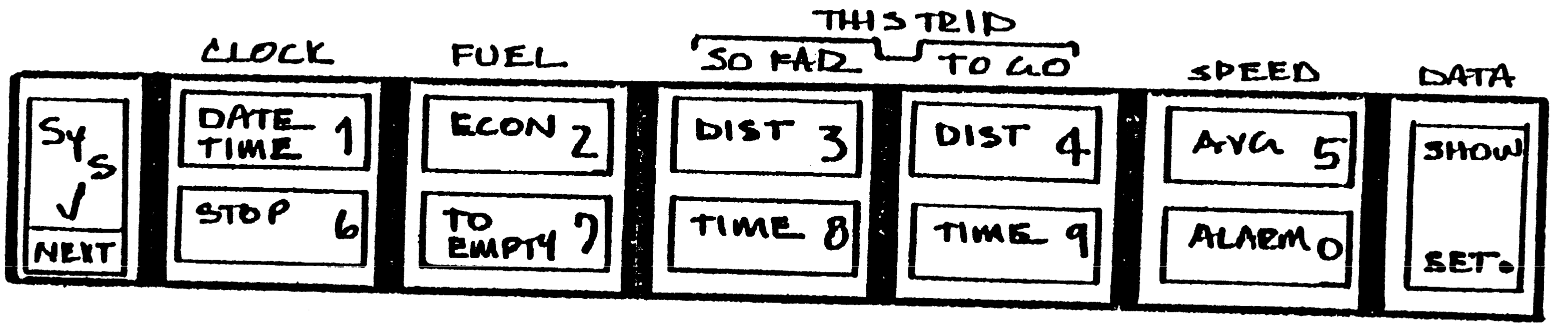


Figure 5. Michigan Proposal 2

normally be visible. The design team believes a door will interfere with both seeing and operating the controls. It will also decrease the space available for labeling and be an added hazard in the event of an accident. It should not be installed.

The 1984 Toyota Cressida has a door covering the entire trip computer. While the only experience in using it has been Paul Green's efforts while the car was at the 84 Detroit Auto Show, they have not been favorable.

Also included in Michigan proposal 2, and given some discussion, was the wording of messages. As part of that discussion it became clear that it was important to repeat the name of the feature being displayed in the message. For example, it was initially proposed that the first fuel economy message be "average\mpg\xxx" (where "\" means new line). However, since the button is labeled "econ" a better message would be "average\economy\xxx mpg." Accordingly, messages for fuel economy, distance to empty, and average speed, among others, were later revised.

Michigan Proposal 3 - Switch Arrangement and Messages

Based on further discussion, the switch arrangement shown in Figure 6 was developed. This is the currently accepted arrangement. It is not clear which of two labeling schemes shown in Figure 6 is best. That question needs to be resolved experimentally. The factor having the greatest influence over the design was what could be illuminated. The design came about because it was not felt to be technically feasible to illuminate two rows of seven pushbuttons, but two rows of six could be. An important difference between previous proposals and the current design is the addition of an LED to indicate when the device is in the set mode.

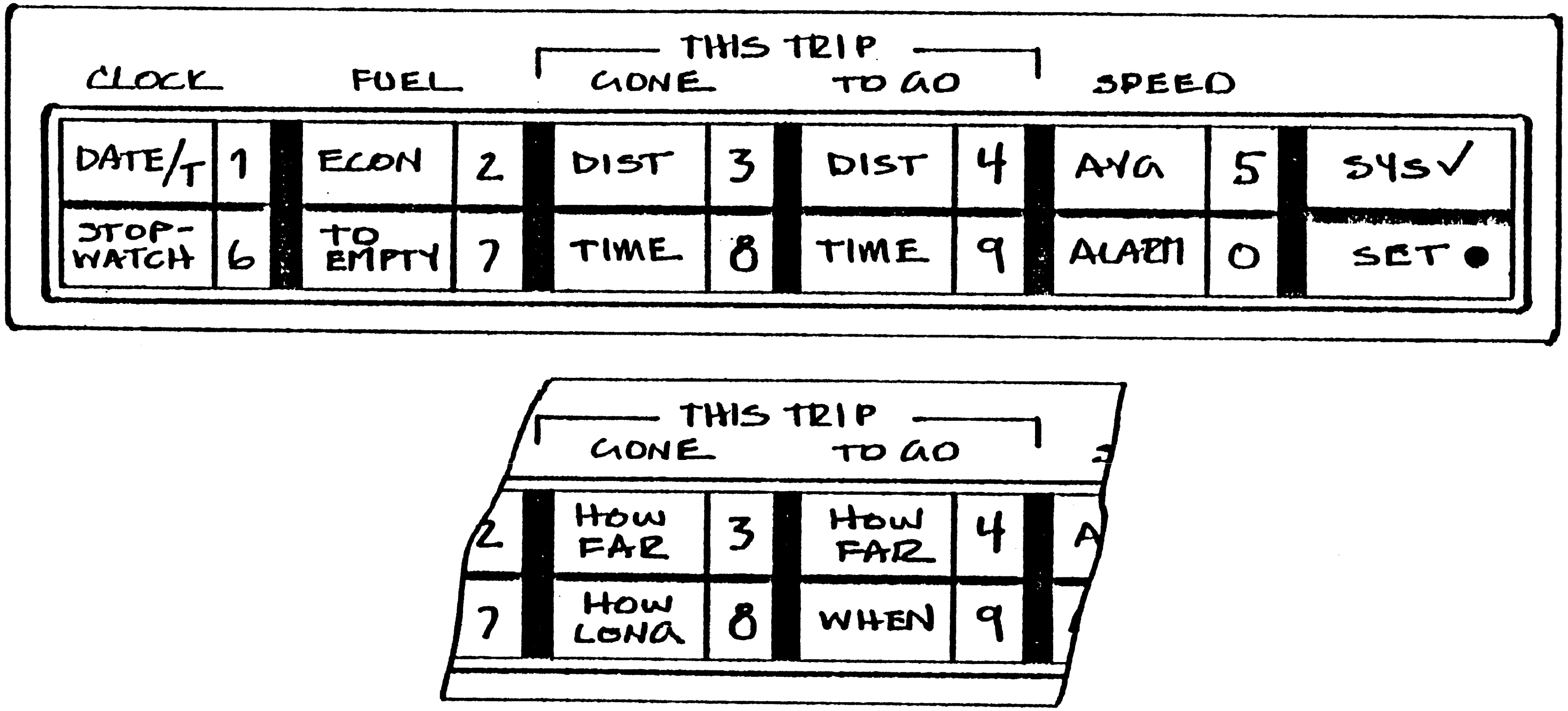


Figure 6. Michigan Proposal 3

Other key features include:

a) Vertical barriers 1/8" wide x 1/4" tall between switch groups;

b) A barrier separating the system check from the set switch;

c) Different colors for the feature labels and digit labels;

d) When the car is started, all legends and lights should be illuminated. The trip computer should then run through a system check with the suggested message sequence being \engine\normal, fluid\levels\normal, \brakes\normal, \lights\normal, all\systems\normal. (Note: While the word "ok" has been used in the past, drivers in a related situation (reading gauges) felt "normal" was a better label than "ok" (Green and Levine, 1982).)

e) Normally, information requested by the driver remains on the display until the engine is turned off, a warning message interrupt occurs, or the driver clears it. The natural tendency of drivers will be to try to clear the display by repeatedly striking a feature button, thinking it is stuck. The number of presses required and the time window are to be determined.

f) When a button is pressed, a short beep should be sounded.

g) If a person hits an illegal key the message pair "can't \use key\x now", "\try\again" should appear. Also a long beep should be sounded.

Also resolved in proposal 3 were the messages in response to specific data requests. They follow, listed by feature.

a) Date\Time (button 1) \Jan 6\ -or- \Jan 6\1984 (It is not clear if information about the year will be available.)

b) Stopwatch (button 6) - called elapsed time on the feature list
message 1: use set\to zero\
message 2: 1=start\2=stop\x:xx:xx
(The third line shows the time, which changes if the clock is running. It is very important to show seconds. People expect it of a stopwatch. Further, that data helps distinguish it from the trip clock.)

c) Econ (button 2) - average and instantaneous fuel economy
message 1: average\economy\xxx mpg ..average\economy\xxx lkm
message 2: instant\economy\xxx mpg .. instant\economy\xxx lkm
(The message pair depends on the setting of the English\metric switch. It is unclear if "lkm" (liters per 100 kilometers) will be understood.

d) To Empty (button 7) - distance to empty dist to\empty\xxx mi ... dist to\empty\xxx km

e) How Far [Gone] or Dist [So Far] (button 3) - trip odometer
gone\xxx\miles .. gone\xxx\km -or-
xxx\miles\so far .. \xxx\km\so far

f) How Long [Gone] or Time [So Far] (button 8) - elapsed travel time
gone\xx hrs\xx mins -or- so far\xx hrs\xx mins -or-
trip\time\xx:xx -or- travel\time\xx:xx
(The label chosen should agree with the button label and be chosen to minimize confusion with clock functions.)

g) Dist [To Go] or How Far [To Go] (button 4) - distance to destination
xxx\miles\to go .. xxx\km\to go
(If the button is labeled "dist", then the message and label will not agree, a potential problem.)

h) Time [To Go] or When [To Go] or How Long [To Go] (button 9) estimated time of arrival + new function, travel time remaining
message 1: arrive\at\xx:xx p (or xx:xx a)
message 2: xx hrs\xx mins\to go

i) Avg [Speed] (button 5), average speed
average\speed\xxx mph -or- average\speed\xxx kmh
("Ave" could be mistaken for avenue speed, how fast one should drive on city streets.)

j) Alarm [Speed] (button 0) - speed alarm
speed\alarm\xx mph -or- speed\alarm\xxx kph
(Should the abbreviation be kmh or kph?)

The suggested setting procedure follows. There are several open issues, described below, as to how setting should occur. They need to be resolved experimentally.

a) When the set button is pressed the set LED goes on a message appears (\set\what? -or- set\which item? -or- choose\item\to set -or- select\item\to set)

b) It is unclear how the computer will know that the entry of a data field is complete and should go on (by hitting the system check button, by hitting the set button, by waiting until the field is full, etc.). One solution would be to put an extra label on the system check button ("go on", "next", "more") that would only be illuminated during setting. It should be accompanied by a message (hit "go\on" for\more -or- next\to\enter). Possibly flashing the LED could be used as some kind of signal. There is concern that using the set button to both enter the set mode and enter data will be confusing to drivers. Multiple uses of the set button is one of the major weaknesses of the current Continental tripminder.

c) If a simple means can be thought of to allow drivers to abort a setting action, a message should appear (e.g., ----\set\aborted where\---=the function name). To reinforce this occurrence, the beeper should sound twice.

d) Leading zeros should be accepted in the setting mode.

e) When asked to set a value, the current value should be displayed and the digits flash. As numbers are entered they should replace the old values and not flash. Thus, midway through an entry some digits will flash and others won't. How digits should be entered and shifted in the display field needs further consideration.

The messages displayed while each feature is set follow.

a) Date/Time
message 1: set\date \time
message 2: set day\1=mon\2=tue.. (day on dedicated display flashes)
(It is not clear if mon=1 or sun=1. Ask some drivers. It would be better if the computer could determine the day of the week from the date.)
Hit next or set to go on.
message 3: Jan 11\1=Jan\2=Feb.. (flash month on line 1)
Hit next or set to go on.
message 4: enter\date\Jan 11 (flash 11 on line 3)
Hit next or set to go on.
...Use a similar sequence for setting the year.
message 5: enter\hour\1-12 (flash hour on dedicated display)
Hit next or set to go on.
message 6: enter\minute\1-60 (flash minute on dedicated display)
Hit next or set to go on.
message 7: \1=am\2=pm (flash am or pm on dedicated display)
Hit next or set to go on.
Should the system review all settings for date and time when done?
message 8: date \time\reset -or- date or\time changed (if change was made) -or- date \time\set (if no change made)

b) Stopwatch
stop-\watch\zeroed (should not start then)
Q: Should the system then go to the mode to operate the stopwatch?

c) Econ
average\econ\reset

d) To Empty

can't\set to\empty

e) How Far [Gone]
gone\xxx mi\so far .. gone\xxx km\so far
-or- dist\gone\xxx mi .. dist\gone\xxx km (flash xxx)
(Another message is needed (enter\dist\gone or enter\how far\gone or set\how far\gone)).

f) How Long [Gone]
message 1: set hrs\gone\xx:xx (flash hours)
message 2: set min\gone\xx:xx (flash minutes)

g) How Far [To Go]
set how\far go\xxx mi ... set how\far go\xxx km
(flash xxx)

h) How Long [To Go]
message 1: set hrs\to go\xx:xx (flash hours)
message 2: set min\to to\xx:xx (flash minutes)

i) Avg [Speed]
average\speed\reset
(Should the average speed then be displayed?)

j) Alarm [Speed]
speed\alarm\xx mph .. speed\alarm\xx kph
(flash speed)

Michigan Proposal 4 - Warning Messages

Because the messages were considered late in the development process, they have not been reviewed as thoroughly as other aspects of the design. A good message suggests the conditions causing the problem (e.g., low coolant level), what's wrong (the engine is overheating\is too hot), what to do (add coolant), when to do it (within the next 10 minutes), and what will happen if it is not attended to (the prognosis - the engine will boil over and the car will stop). An excellent discussion of the issues concerning message system design was written by Gene Farber and distributed as part of the TM-4 effort (Preliminary Human Factors Review of Smart Gauge Features). A copy is in Appendix A.

The suggested messages follow.

a) head lamp

head-\light\out

b) tail lamp
   tail-\light\out

c) brake light
   brake\light\out
   (Is a second message needed for the first three features? - replace ...

d) brake/tail light fuse
   message 1: get new\r light\fuse
   message 2: no rear\lights\...fuse

e) anti-skid
   message 1: may\skid if\slippery
   message 2: brake\computer\problem

f) air suspension
   message 1: \drive\slowly
   message 2: air\shocks\out -or- air\shocks\broken
   (not a very good message)

g) 30,000 mile checkup
   message 1: \go to\dealer
   message 2: 30,000\mile\checkup

h) oil change
   message 1: when\conven-\ient (Is this needed?)
   message 2: time\for oil\change

i) trunk ajar
   trunk\is\open -or- \trunk\open -or- \close\trunk

j) door ajar
   door\is\open -or- \door\open -or- \close\door

k) battery voltage
   message 1: stop at\service\station -or- check...
   message 2: low\battery\voltage

l) charging system
   message 1: check\belts,\wiring.. -or- may be\hard to\start
   message 2: charge\system\bad -or- electri-\cal sys\problem

m) oil level
   message 1: time to\add\oil -or- add\some\oil -or- \needs\oil (Is message 1 needed?)
   message 2: low\oil\level -or- oil\level\is low -or- oil 1\qt or\so low -or- oil is\about 1\qt low

n) steering fluid
   message 1: may be\hard to\steer -or- getting\hard to\steer
   message 2: low\steerng\fluid -or- add\steerng\fluid -or- needs\steerng\fluid

o) coolant level
   message 1: add\anti-\freeze (Many drivers think water is needed.)
   message 2: low\coolant\level

p) AC fluid
   message 1: don't\use air\cond
   message 2: AirCond\fluid\low
   (Drivers won't know what freon is.)

q) washer fluid
   low\washer\fluid

r) transmission fluid
   low\trans\fluid

(What could go wrong when the level is low?)

s) brake fluid
   message 1: car is\hard to\stop
   message 2: low\brake\fluid
      (Is a message needed about how soon?)

t) brake pads (This feature may be added in the future.)
   message 1: car is\hard to\stop
   message 2: brake\pads\worn -or- brake\shoes\worn

RESEARCH NEEDS

As part of the design process, several specific issues arose which could not be resolved from existing data. They should be addressed in formal experiments.

Question 1: How should the date and time be entered?

Should the "enter" key be the set key or some other key?
Should digits be entered from left to right or right to left?
Should digits scroll horizontally as they are entered?

Question 2: Which of the two alternative sets of labels should be used for the trip function switches?

Question 3: In many instances alternative messages have been proposed. Which are the most informative?

Question 4: What is the most legible character font for a 16 segment display?

(Note: The literature should be examined to see if this question has been examined before.)

In addition several more general concerns were identified.

Question 5: How long does it take to read a message sequence as a function of the number of messages in the series, the length of each message (number of characters, number of lines), and the technical detail of the message?

Question 6: What is the tradeoff between message reading time and message understanding as a function of message length? (This information is needed to determine where multiple messages should be shown.)

Question 7: What aspects of the design cause problems for drivers?

To address these questions, two experiments are proposed. To avoid production delays, this research should begin immediately. In the first experiment 20 older drivers would be asked to operate a model of the device. The would be shown a sketch of the switch panel and asked to point to the switches they would depress. The experimenter would manually operate a tone generator (to provide auditory feedback) as required, and messages generated by the system (written on cards) would be shown to subjects. Using either the University of Michigan time study or questionnaire administering programs for the IBM PC, the sequence of user actions and possibly the times would be recorded.

This laboratory experiment is intended to answer questions about switch labeling and message understanding. It will also provide for the open-ended examination of the system as a whole.

After completing the first experiment, participants would be asked to perform a simulated time and date entry task. The simulation will be written to run on the IBM PC. User response times and errors would be recorded. Both parts of this experiment would be much easier to do if rapid prototyping tools existed. The development of those tools was proposed in the five-year plan (Green, 1983), currently not funded.

After the initial laboratory experiments have been completed and what was learned has been incorporated into the product, a second experiment should be undertaken. In that experiment drivers will be asked to operate a TM3 prototype while on the road. The time to operate each switch, errors, and, using an eye camera (such as the UMTRI NAC eye camera), eye fixation durations should be recorded. The purpose of this experiment is to determine the tradeoff between message length and reading time, and message understanding. This experiment will also identify any outstanding problems with the design.

HOW TO IMPROVE THE DESIGN PROCESS

It has been the author's experience that long-term thinking beyond the projects at hand, and reviews of what has been learned from development efforts, can be very helpful to EED. This section briefly discusses a few principles relating to such activities.

Gould and Lewis (1983) identify four basic principles that should be followed if a product is to be "user friendly." First there is a need for an early focus on users and tasks. The human factors specialist needs to be involved early in the design process. One does not end up with a user-friendly product by a few post hoc changes of switch labels and messages. Including human factors specialists on cluster component design teams should be the rule, not the exception, as was this project.

A second principle is that design should be interactive. A panel of intended users (in this case luxury car owners) should work closely with the design team. This principle is difficult to carry out, and has major cost and security implications. While it is understood that focus groups were used prior to the design phase, none were involved in the design. Ways to follow that principle should be determined.

A third principle is that of empirical measurement. Intended users should use simulations and prototypes of the device. Their performance should be recorded. Formal tests were not planned or funded as part of the initial design phase. They should have been. Since they weren't planned early on, it is going to take much longer to get them going, if they are done at all. Money for testing design concepts should be included in the budget for every product with which the driver is in direct contact.

A fourth principle is that design is iterative. The quality of the design is proportional to the number of loops through the design-test sequence. Engineers view design as a strictly empiric process, which it is for classical structural and circuit design problems. However, human behavior is not as well understood as that of I beams or resistors, and consequently it is essential that sufficient tests be included in the design process. Thus, money should be budgeted not just for one test but a series of tests. Some of those should occur while the product is still being defined. Furthermore, it is also essential that a knowledge base be assembled, both of ways to speed up the testing process by developing new methods and tools for evaluating human performance, and data describing how people respond to alternative product designs. Except for the gauge study (Green and Levine, 1982), Ford has funded only a few very narrow, product-specific human factors experiments. It is extremely difficult to generalize from them. Consequently, each time an issue arises, an experiment needs to be conducted to address it. Unfortunately, the fast-paced design process does not provide ample time to experimentally evaluate all the alternatives. Some of that work needs to be done in advance.

The basic research needed would best be done by a university. A plan identifying what should be done has already been submitted (Green, 1983). While that document has been reviewed favorably by Ford (Beard, 1983), no steps have been taken to fund it. It should be.

Finally, this project has demonstrated that great strides can be made towards "user-friendly" products by seeking the advice of human factors experts early in the design phase. However, much more needs to be done in supporting both basic and applied research on human factors and instrumentation. The financial returns from such research are somewhat indirect and removed in time, but they are nonetheless real and can be very substantial.

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APPENDIX

PRELIMINARY HUMAN FACTORS REVIEW OF SMART GAUGE FEATURES

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There are five general human factors issues that should be considered in the design of the "Smart Gauge" system. These are:

1) Message generation: the interrelated problems of message initiation, duration, repetition, recall, review, and cancellation.

2) Driver controls to operate the system.

3) Categorizing messages as reminder caution or warning.

4) Message wording.

5) Human Engineering: display size, brightness, contrast, font, location, type, and operating parameters.

These issues are interrelated to some extent. For example, control logic depends on the resolution of item 1, and wording depends on how messages are categorized. Our preliminary thoughts on some of these issues are summarized below:

Message Generation

By message generation is meant the internal logic governing the first and subsequent appearances of messages, display duration, how long a message is retained for re-display, and the control of message review, recall, and cancellation functions. These comments are intended only to highlight the range of implementation possibilities that should be considered.

Message generation considerations will differ between reminders, cautions, and warnings. The following pertains to reminder messages.

Initiation: A message appears for first time when the triggering conditions are met. If there are to be "OK" messages to neutralize the reminder, then there will have to be enough smoothing in the system to eliminate cycling back and forth between the reminder and the OK.

Duration: How long a message is displayed after it first appears depends on a number of factors. If the Smart Gauge display space is also used to display continuously updated information such as time, then message duration will be determined by time-sharing considerations. Otherwise the choices are as follows:

- The message is displayed continuously.
- The message is displayed for some arbitrary duration.
- The message is displayed until cancelled by the driver.

In all these cases the display would be terminated by abatement of the originating condition or by the appearance of a new message.

Repetition: When should a reminder message by repeated? Alternatives are as follows:

1) Message reappears at regular intervals for as long as the initiating condition obtains, or until the driver cancels the message.
2) Messages sequence automatically each time car is started, for as long as initiating conditions continue or until the driver cancels a message.
3) Once shown, a message is not repeated unless the driver elects to recall/review messages.

Recall/Review: What is the status of messages which are not currently being displayed but for which the initiating condition still exists? Presumably such messages are still "in the system" and available for recall or review. How this function is to be implemented will depend on how some of the issues raised above are resolved. For example, if messages are displayed for a relatively brief duration, a driver might miss one if he is busy when it appears. In this case he would need, at a minimum, some way to recall the message. An alternative (or in addition) to automatic review of a stack-up of messages is to provide the driver with a review control. Implementation of the recall/review functions are briefly discussed below and under Controls.

Message Acknowledgment/Cancellation: Whether or not an acknowledgment/ cancellation control is needed and exactly how it might be implemented depends on the message duration/review/recall policy. If the system is designed so that only the most recent message is retained for recall, then no cancellation function is needed. On the other hand, the system could be designed to retain a list of messages for subsequent review, for example, as a service station. A cancellation control would allow the driver to selectively purge satisfied reminders. Another possible implementation for a cancellation switch in a simple system with no message memory would be to use it to kill the display.

Message Light/Beeper: An issue related to the above considerations is the role of the attention light and annunciator tone. How should these be used after the initial presentation (or subsequent system-initiated presentation) of the message? Should the light stay on for as long as there are messages in the system? - until the driver recalls or cancels the message? - for as long as the initiating condition exists? Or should the light be used only in conjunction with system-initiated messages.

CONTROLS

What controls are needed and how they will be implemented depends on the operating logic of the system with regard to message generation, retention, and recall, as discussed above. The present conceptual arrangement as illustrated in an ECC Summary paper shows only a RECALL (last message) control. No additional control would be needed to implement a review function: the RECALL control could be designed so that repeatedly pressing it or just holding it down would step through all retained messages. Another control that might be needed, again depending on operating logic, is a cancel control. This would be used to cancel or erase the currently displayed messages in a system designed to retain messages indefinitely.

A function that would be needed in a time-sharing implementation is a RESUME control. This would terminate the smart gauge message display and return the display to the control of the sharing system, e.g., clock, navigation, etc.

Finally, a "demonstration mode" control is desirable for showroom demonstrations and also to allow customers to show off the Smart Gauge features to friends. This control need not be located in prime instrument panel space.

COMMENTS ON MESSAGE CONTENT

General Consideration: Three kinds of information can be presented:

1) Describing a symptom (ENGINE HOT).

2) Describing the cause (LOW RADIATOR FLUID).

3) Telling the driver what to do (ADD RADIATOR FLUID).

In most cases the diagnostic message conveys an advisory meaning and vice versa. For example, the messages CHECK COOLANT LEVEL and LOW COOLANT LEVEL both convey advisory and diagnostic meanings. At the "reminder" level, either an advisory or diagnostic wording constitutes an adequate message. For cautions and warnings the driver should be informed of the symptoms as well, to let him know why he is being advised to act, and also to convey the importance of the advisory. To accommodate the needed wording it may be necessary to break the message into two parts which could alternate, e.g.:

1) ENGINE TOO HOT/LOW COOLANT.

2) PULL OFF ROAD/STOP ENGINE.

(The slash (/) is used here to separate the upper and lower lines of the message.) This assumes that the display size is to be as represented in the illustrations we have seen (two lines, 15 characters per line).

COMMENTS ON SPECIFIC MESSAGES:

1) Fuel status - There is no need for a low fuel reminder. The fuel gauge does that. Very low fuel should be a caution; and there should be a warning when there is fuel remaining for only a few more miles of driving. Warning status is appropriate here because of the possible hazard of running out of gas on the highway.

2) Washer fluid - According "caution" status to a low washer fluid condition seems inappropriate.

3) Low oil level/pressure - What about the condition in which there is low pressure but adequate oil level? What will the driver do when he checks the oil level in response to the caution or reminder and finds the level o.k.?

With regard to the warnings, it's probably not a good idea to have a "STOP ENGINE NOW" message. Some drivers would probably stop on the road in heavy traffic in response to such a message. Better would be: LOW OIL/PULL OVER/STOP ENGINE. This applies to all "STOP ENGINE" warnings.

This is an instance in which a multiple "frame" message might be appropriate. For example:

Frame 1 PULL OFF ROAD/STOP ENGINE

Frame 2 OIL VERY LOW

4) Because of the potential hazard, it's probably not a good idea to advise the driver to CHECK COOLANT. Better would be LOW RADIATOR FLUID OR LOW RADIATOR PRESSURE and let the diagnostic convey the implicit advisory to check the cooling system or have it checked.

5) The cooling system overload caution presented is conceived as an advisory which tells the driver how to reduce the load. This is another message that may require multiple frames, e.g.:

1) COOLING SYSTEM/OVERLOAD

2) TURN OFF/AIR CONDITIONER

3) RUN ENGINE/AT FAST TIME

6) The thermostat-stuck-open condition should produce a caution; the stuck-closed condition, a warning.

7) Shouldn't there be a POWER STEERING FLUID LOW caution message?

8) The RELEASE PARKING BRAKE reminder may not be a good idea for the smart gauge since it would come on routinely every time the car is started. The PARKING BRAKE NOT RELEASED caution message is o.k.

9) Electrical system warnings. Is there a condition of imminent loss of ignition or lights that can be sensed? If so, there should be a warning.