A STUDY OF RESPONSIVE ELECTRONIC VEHICULAR INSTRUMENTATION

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Introduction and Background

The advent of low-cost ultrareliable integrated circuits has made feasible the design of a responsive electronic vehicular instrumentation system that results in significant improvement in the surveillance of highway internal performance factors; e.g. detection and apprehension of violations, location and identification of stolen and/or wanted vehicles, location and identification of disabled vehicles, etc., while reducing the cost. The responsive electronic vehicular instrumentation system (REVIS), shown in Figure 1, consists of a roadside transmitter-receiver-decoder and a vehicular transponder. This system may first be introduced in an evolutionary manner by substituting the transponder for toll schedule cards on turnpikes; a more revolutionary approach yielding improved system performance would be the legislated requirement of compulsory installation of the transponder package in all vehicles manufactured for use in the United States. The roadside transmitter-receiver-decoder continually broadcasts a low power querry code in its narrow capture range that enables the vehicular transponder to respond with a unique identification code; i.e. to uniquely encode 100 million vehicles would require 27 bits, i.e. 2^{27}=134, 217, 728 which is greater than 100 million. The decoder then sequentially adds 10 bits to encode detector identification number and time of encounter. This information is then processed to determine whether the vehicle has violated a predetermined set of rules; any required action being initiated by the system. The following examples illustrate the system operation.

Example One:

A vehicle enters the highway and uniquely identifies itself to detector number one when querried. The time of day is added by detector one to the identity code and these 37 bits are transmitted to detector two. Detector two, in effect a small computer, modifies the received code to update the time of day to an interval of safe arrival;i.e. a minimum and maximum time of arrival. When the vehicle passes detector two within this interval the time of day is transmitted to detector three and the vehicle is surveilled on the highway with no external action required. Should the vehicle not arrive within the allowable time interval corrective and/or punitive action would be initiated. Arrival before the minimum allowable time, indicative of a speeding violation, could result in either a warning to lower its speed communicated to the vehicle by the detector and/or the issuance of a ticket, and in some extremely dangerous situation even the chasing and stopping of the vehicle. Non-arrival before the maximum allowable time interval, indicative of a vehicular stoppage and/or accident could initiate some appropriate response;e.g. either police, a medical unit, or a tow truck could respond to this call for aid.

Example Two:

A vehicle enters the highway and uniquely identifies itself to detector number one when querried. Detector number one, in addition to initiating the surveillance sequence, transmits the vehicle's identification code to a centralized computer where it is compared to a list of stolen and/or wanted vehicles. In the event that is appears on this list notice of required police action is transmitted to the appropriate authority where a decision is made as to the most desirable method of apprehending the vehicle and operator.

The last example illustrates a mode of operation, made possible by a totally secured vehicular transponder, that would result in several significant sociological developments, the elimination of the stolen vehicle profit motive and the improved apprehension of wanted persons. Additionally, since the system cannot be overloaded, 100% detection of speeding violations is assured thereby forcing operator compliance with posted speed limits, a feature not presently possible with existing and/or other proposed traffic control systems. The REVIS simulation was undertaken to quantitatively ascertain the improvement in highway internal performance factors.

Simulation Method

REVIS was simulated in 360 GPSS because the availability of standard numerical attributes vastly simplified the required programming while not seriously requiring additional computing time when compared to other languages. The results to be presented required two man-months to develop, thirty hours of 360/50 CPU time with 256K bits of LCS. The simulation was developed for a ten mile length of highway with detectors uniformly placed at half mile intervals. Use of the MAC RO programming feature was made to simulate each section of highway. Upon leaving eash section of highway a vehicles statistics were gathered; speed, transit time, and parameters to indicate prior vehicular history of detected speeding violations, breakdown, and waiting time at breakdowns were tabulated.

A data base simulation was created by heavily surveilling the highway by police patrol and their radiotelephone callable aides using current police surveillance logic and tactics. Vehicles entered the highway with an exponential distribution at mean flow rates that were varied from 3, 6 to 1800 vehicles/hour. A velocity was randomly assigned to each vehicle resulting in the distribution shown in Figure 2, having a mean of 50 mph. When the velocity exceed the speed limit, in this case 60 mph, one was added to the speeder count. A test on a uniformly distributed random number was made to determine whether each vehicle should have a breakdown; if this test was true a section of highway in which the breakdown was to occur was randomly assigned. Upon entering a section of highway a vehicle noted the presence of a police vehicle and if present modified its speed(if required) to 60 mph to avoid a speeding violation. When a vehicle brokedown it awaited the arrival of police aid with a subsequent additional delay of ten minutes at the site during which time aid was being given. During this interval the police car was unable to perform any other function; this feature of a seized police vehicle attributing to the poor-performance of this method of surveillance. When a vehicle entered a section of the highway with a speed trap, a decision with probability distribution shown in Figure 3 was made whether the vehicle would be chased. It is noted that the model included the possibility of the police falsely apprehending a vehicle traveling below the speed limit. When the police apprehended a vehicle it utilized 10.5 minutes to chase, write the violation, and reposition itself in a surveillance location. After receiving a violation the apprehended vehicle traveled at 55 mph;i. e. a relatively safe velocity below the speed limit.

Police patrolled the highway at 30 minute intervals at 60 mph; a very high surveillance rate intended to generate an overly optimistic data base for comparison with REVIS. It is noted that such a large police generation rate is not cost effective but is rather performance effective for this type of surveillance. Upon arrival at a breakdown police vehicle were delayed 10 minutes and were unavailable for other duties.

Simulation Results:

The results of the data base simulation are shown in Figures 4, 5, and 6. Due to the strategy adopted only speed traps were effective in apprehending speeding violations. Since the police vehicle was seized when it apprehended a vehicle the percentage of speeders apprehended decreased dramatically with increased vehicle rate. It is to be emphasized that in this feature, the basic fact that a police vehicle can only do one thing at a time, that makes this form of surveillance undesireable and not cost effective. The percentage of disabled vehicles awaiting aid at any given time and their mean waiting time also shown. As either vehicle rate or disablement rate increase more vehicle are awaiting aid and they wait for longer times. Typically, at high rates, 40% of the disabled vehicles await aid that arrives approximately 12-15 minutes after the breakdown. The physical mechanism causing the oscillatory nature of the wait time vs. vehicle rate curve is not well understood but has been verified by resimulation with different random number seeds and by several parameter sensitivity checks.

The REVIS simulation was performed by removing the police vehicles from the highway and utilizing the information collected at the half mile interval detectors to determine the need for and generate aid. An aid vehicle (police vehicle, tow truck, ambulance, etc.) entered at the beginning of the ten mile section of highway at 55 mph upon the call for aid. Upon arrival at the breakdown it renders aid for ten minutes and both the aided vehicles reenter the highway. Although the certain apprehension of a speeding violation would result in a significant modification of the velocity profile, and effect entitled vehicular compliance, the velocity profile was not altered to represent this effect thereby presenting the most pessimistic values of system performance.

The result of the REVIS simulation are shown in Figures 7 and 8. Most significantly, the percentage of disabled vehicles awaiting aid never exceeds 12.7%. It should be noted that an even greater improvement in this internal performance factor(40% 12.7% max.) would be obtained by using more cost realistic parameters, i. e. a simulation with longer highway sections, lower police surveillance rates, and multiple entry highways would emphasize these advantages in a more dramatic fashion. Furthermore, the percentage of disabled vehicles awaiting aid decreases with increased disablement rate. This unexpected and beneficial result is explained by the fact that an aiding vehicle is unable to determine which vehicle initiated its call to enter the highway. An increasing disablement rate increases the number of aiding vehicles on the highway thereby improving the REVIS effectiveness. The mean waiting time for aid to arrive at the scene of a disablement is also significantly reduced by REVIS. Although one is unable to draw any conclusions as to the improvement in fatalities per vehicle mile due to a lack of quantitative correlation between the internal and external performance factors, REVIS does significantly get aid to the disablement quicker. As either the vehicle flow rate or disablement rate increases the mean waiting time decreases, a highly desireable result.

Conclusions and Further Work:

The REVIS simulation has shown that significant improvement in vehicular surveillance on a highway may be obtained by removing the police from the highway and introducing an electronic surveillance method. It has been estimated that an integrated circuit transponder could be manufactured and securely installed in new vehicles for under $50 thereby decreasing the cost of patrolling the highway and freeing trained police manpower for other more effective duties. Several internal performance factors have been shown to improve without the added effect of vehicular compliance due to assured apprehension of speeding violations. Additionally, it has been shown that this system allows new methods of police surveillance to be used in locating stolen and/or wanted vehicles.

The simulation of REVIS is presently being expanded to further test parameter sensitivity and the effect of multiple entrances. The possibility of communication between the vehicle and the roadside to exchange desired operator information is being considered.

Acknowledgement:

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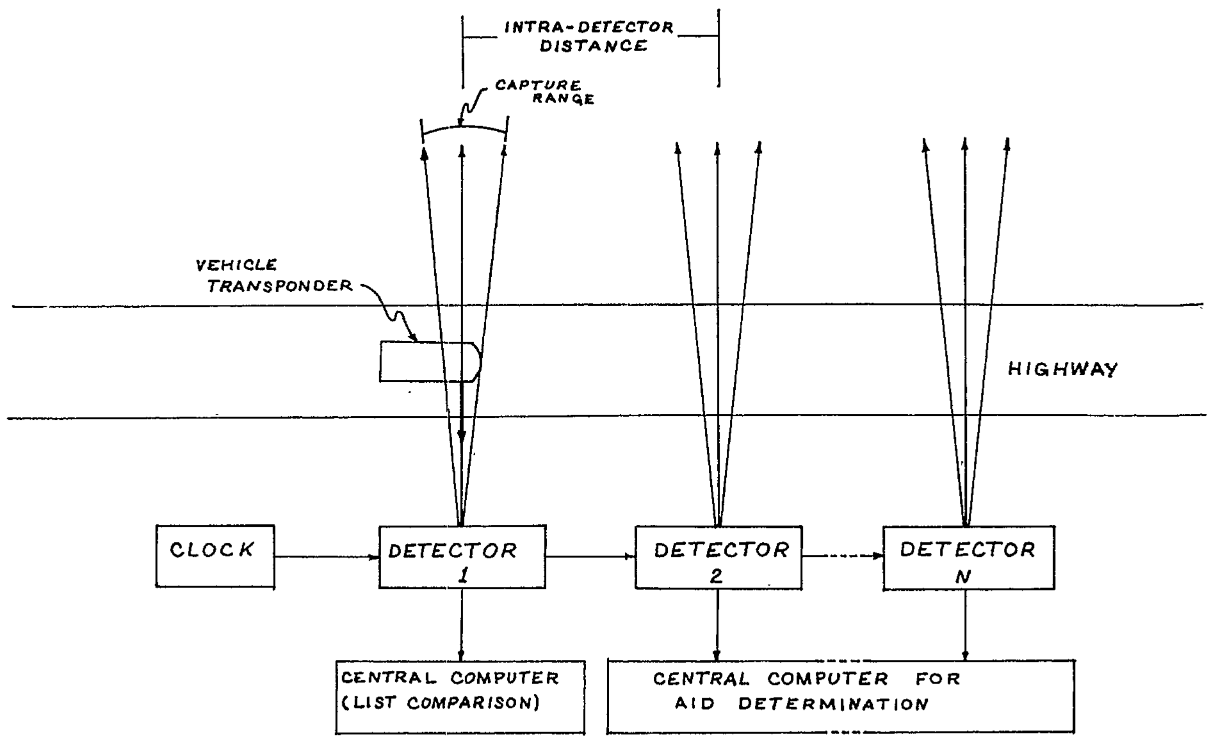
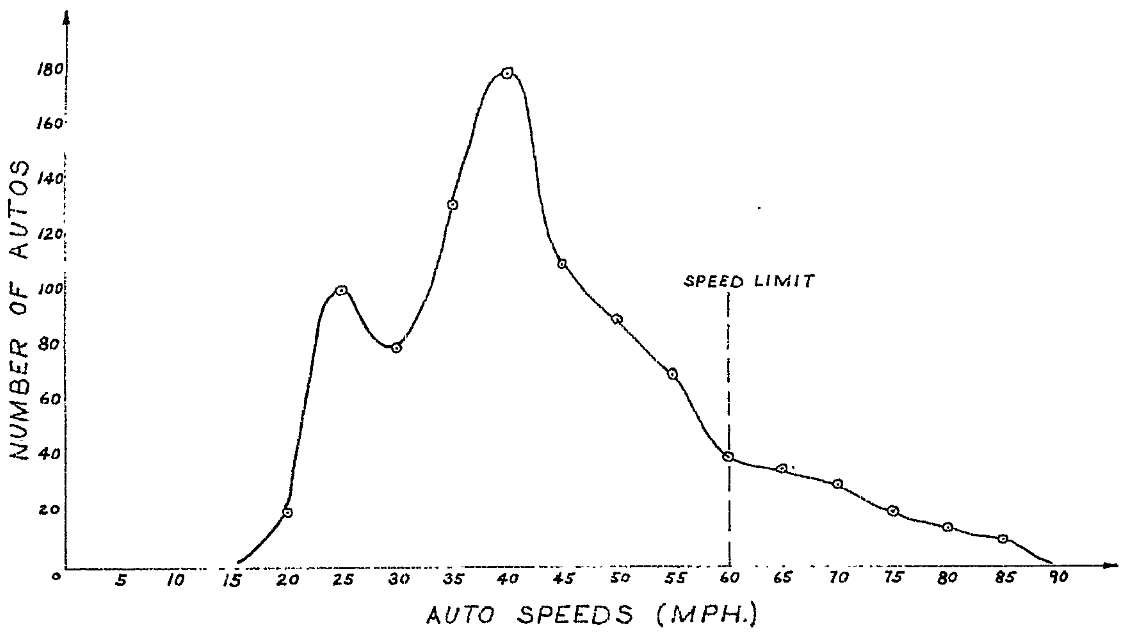


FIGURE 1 - REVIS

FIGURE 2



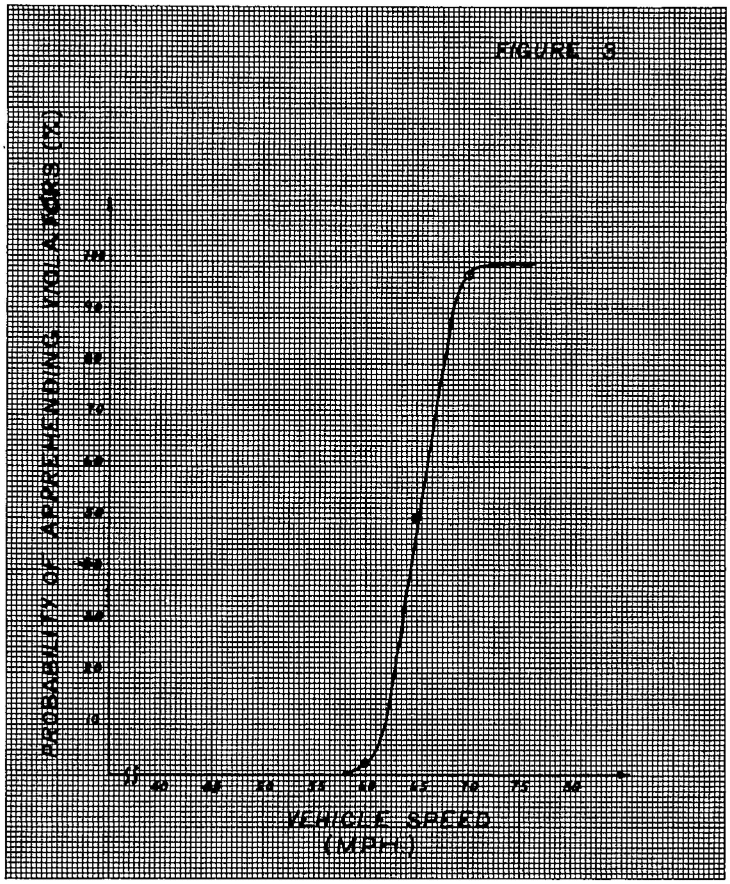


FIGURE 3
PROBABILITY OF APPREHENDING VIOLATORS (%)
VEHICLE SPEED
(MPH.)

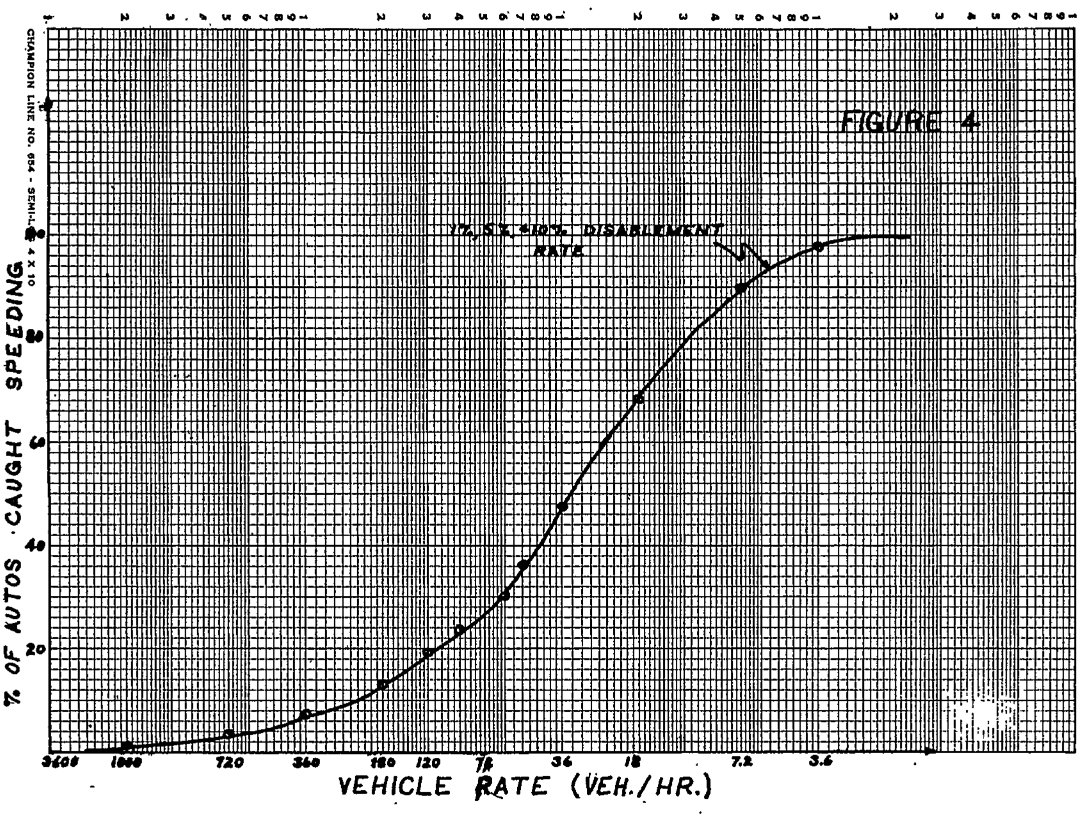


FIGURE 4
1%, 5% & 10% DISABLEMENT RATE
% OF AUTOS CAUGHT SPEEDING
20
40
60
80
3600
1800
720
360
180
120
72
36
18
7.2
3.6
VEHICLE RATE (VEH./HR.)

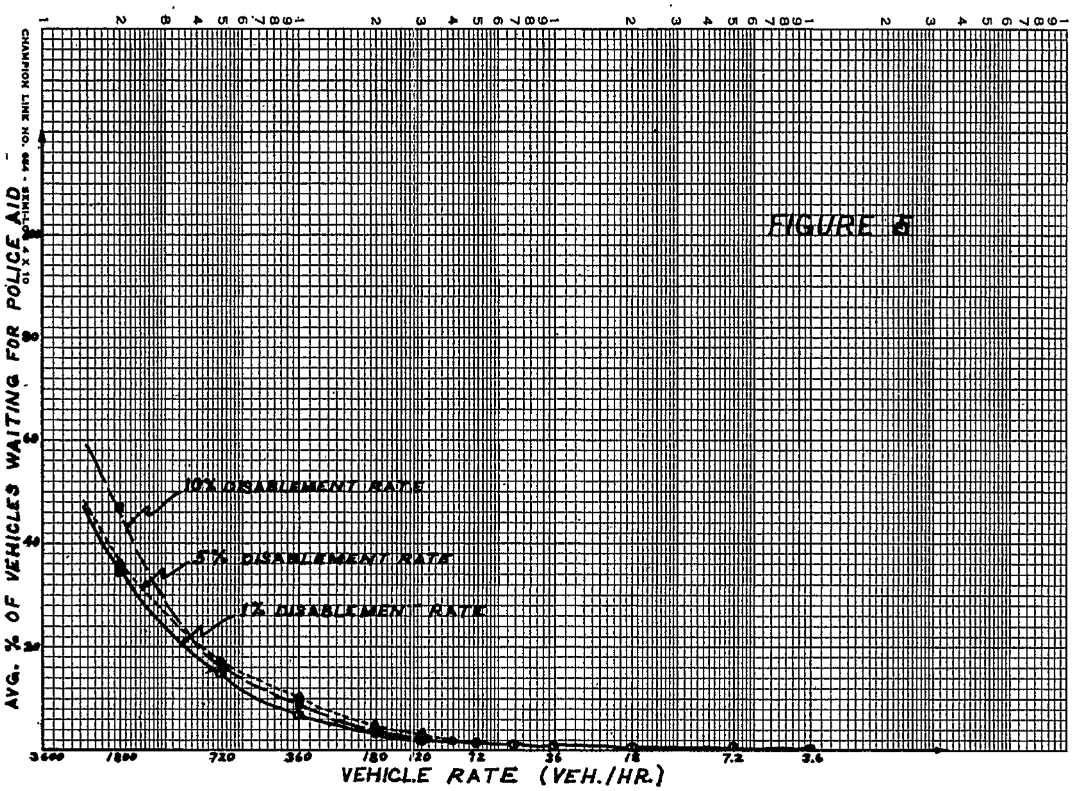


FIGURE 5

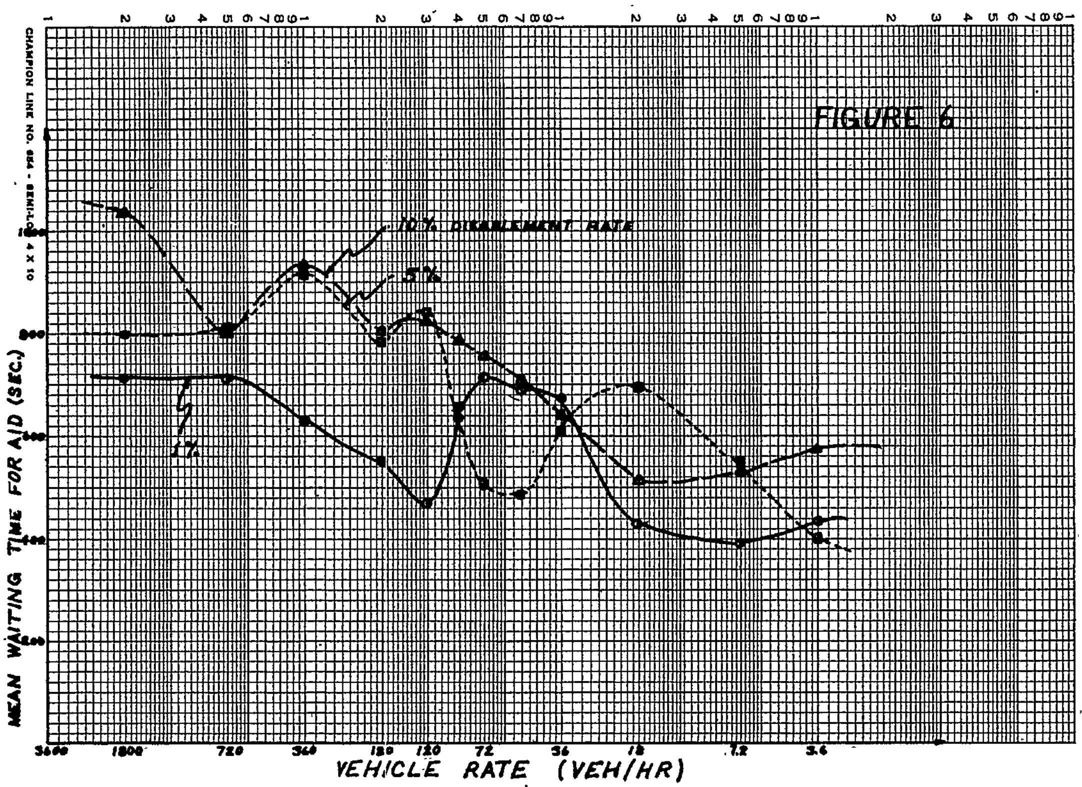


FIGURE 6

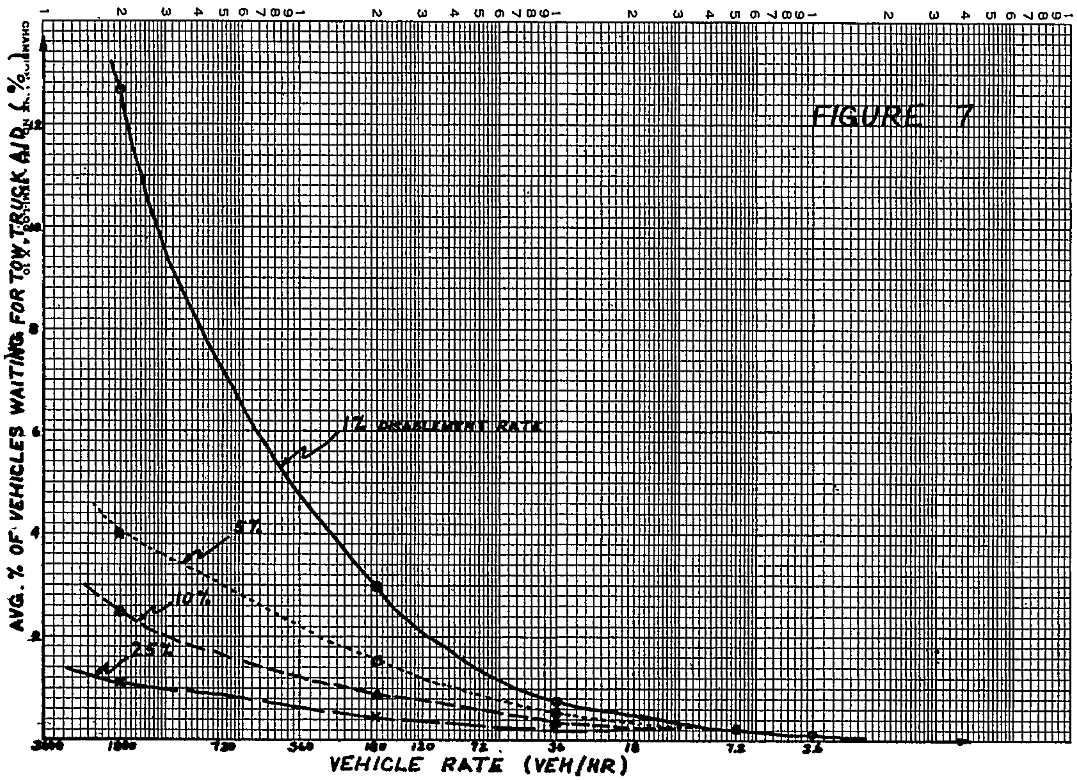


FIGURE 7
AVG. % OF VEHICLES WAITING FOR TOW TRUCK AID (%)
1% DISABLEMENT RATE
5%
10%
25%
3600
1800
720
360
180
120
72
36
18
7.2
3.6
VEHICLE RATE (VEH/HR)

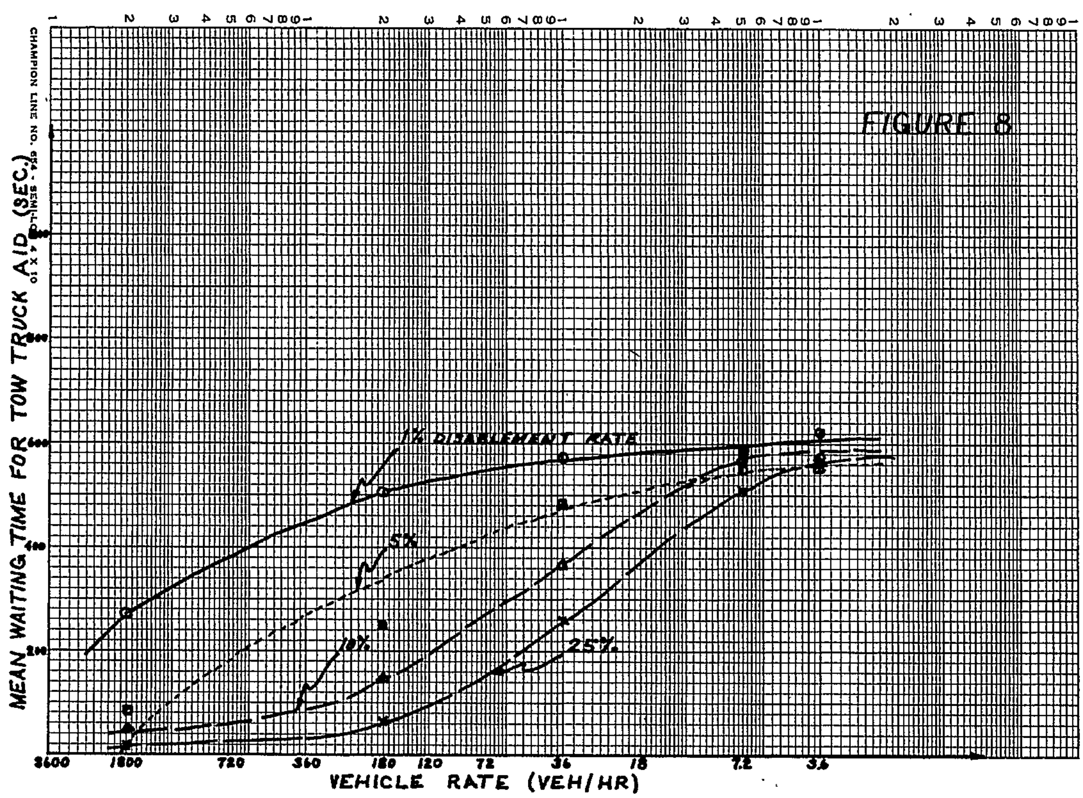


FIGURE 8
MEAN WAITING TIME FOR TOW TRUCK AID (SEC.)
1% DISABLEMENT RATE
5%
10%
25%
3600
1800
720
360
180
120
72
36
18
7.2
3.6
VEHICLE RATE (VEH/HR)