REPORT NO.

# LABORATORY EVALUATION OF ALCOHOL SAFETY INTERLOCK SYSTEMS, VOLUME I - SUMMARY REPORT

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APRIL 1973

FINAL REPORT

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Prepared for:
DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
Research Institute
Washington, D.C. 20591

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TECHNICAL REPORT STANDARD TITLE PAGE

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| | PB224 264 | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| LABORATORY EVALUATION OF ALCOHOL SAFETY INTERLOCK SYSTEMS, VOLUME I - SUMMARY REPORT | April, 1973 |
| | 6. Performing Organization Code |
| 7. Author(s) | 8. Performing Organization Report No. |
| E. Donald Sussman, Charles N. Abernethy, III | DOT-TSC-NHTSA-73-3 |
| 9. Performing Organization Name and Address | 10. Work Unit No. |
| Department of Transportation<br>Transportation Systems Center<br>Kendall Square<br>Cambridge, MA 02142 | HS306 |
| | 11. Contract or Grant No. |
| 12. Sponsoring Agency Name and Address | 13. Type of Report and Period Covered |
| Department of Transportation<br>National Highway Traffic Safety Administration<br>Research Institute<br>Washington, DC 20591 | Final Report<br>8/71 - 10/72 |
| | 14. Sponsoring Agency Code |

15. Supplementary Notes


16. Abstract This report contains the results of an experimental and analytical evaluation of instruments and techniques designed to prevent an intoxicated driver from operating his automobile. The prototype "Alcohol Safety Interlock Systems" tested were developed both by private industry and by the Transportation Systems Center and all were drawn from a class of instruments which detect intoxication by measuring changes in the subjects ability to perform a psychomotor task. The final report consists of the following documents:

Volume I, Summary Report - Summarizes all of the ASIS evaluation work performed through July 1972 and the results of the evaluation. Volume I is supported by an extensive appendix.

Volume II, Instrument Screening Experiments - Contains details of the experiments conducted by the Guggenheim Center, Harvard School of Public Health, including experimental procedures, results and some preliminary data analyses.

Volume III, Instrument Performance at High BAL - Contains the results of the experimental work performed by Dunlap and Associates, Inc., covering the performance of subjects with relatively high blood alcohol levels on selected instruments.


| 17. Key Words | 18. Distribution Statement |
|---|---|
| Alcohol, intoxication interlock, intoxicated performance, habitual drinker | DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22151. |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 34 | |

Form DOT F 1700.7 (8-69)

# PREFACE

The work described in this report was performed in support of an overall program at the Transportation Systems Center designed to develop and evaluate Alcohol Safety Interlock Systems (ASIS). This program is sponsored by the Department of Transportation through the National Highway Traffic Safety Administration's Research Institute.

This report contains the results of an experimental and analytical evaluation of instruments and techniques designed to prevent an intoxicated driver from operating his automobile. The prototype ASIS units tested were developed both by private industry and by the Transportation Systems Center; all were drawn from a class of instruments which detect intoxication by measuring changes in a subject's ability to perform a psychomotor task. The report consists of the following documents:

Volume I, Summary Report - A summary of the ASIS evaluation work performed through July 1972. It includes a discussion of the factors considered in selecting candidate devices for testing, the recruitment of human subjects, the experimental techniques used, the criteria used to rate the performance of the devices, and the findings of the evaluation.

Volume Ia, Appendix - A detailed summary of the laboratory work, statistical treatment of the data, and the results of the statistical analysis. Volume I and Volume Ia (the Appendix) comprise a review of the TSC ASIS effort from its its inception in July 1970 through July 1972.

Volume II, Instrument Screening Experiments - Details of the experiments conducted for TSC by the Guggenheim Center, Harvard School of Public Health.

Volume III, Instrument Performance at High BAL - Results of the experimental work performed for TSC by Dunlap and Associates, Inc.

The authors would like to acknowledge that much of the success of this program is due to the efforts of the above organizations and of many individuals. Specifically, much of the original conception of the program and its overall management were the contribution of P.W. Davis. Design and construction of the TSC interlock units were carried out by A. Warner. Aid in the analysis of the data contained in Volume I was provided by J. Nardone, B.A. Kolodziej, and B. Major. Patient computer programming and data processing were contributed by D. Ofsevit.

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# 1. INTRODUCTION

This report describes the Alcohol Safety Interlock System Program currently underway at the Transportation Systems Center (TSC) of the U.S. Department of Transportation. The program is sponsored by the Office of Driver Performance of the National Highway Traffic Safety Administration, in support of the NHTSA Office of Alcohol Countermeasures.

The program was designed to determine the efficacy of systems intended to automatically deny intoxicated drivers the use of their automobiles. The approach involved obtaining or developing candidate systems, evaluating the more promising ones in laboratory tests, and, if warranted, field-testing them.

This report is concerned with those investigations of Alcohol Safety Interlock Systems taking place from mid-1970 through mid-1972. The investigations described include a review of extra-governmental responses to a DOT prospectus, a survey of pertinent literature, and laboratory tests performed under contract to the Transportation Systems Center by the Guggenheim Foundation for Aerospace Health and Medicine of the Harvard School of Public Health, and by Dunlap and Associates Incorporated.

# 2. ASIS CONCEPT

As part of its program to develop methods of reducing the number of alcohol-related traffic accidents, the U.S. Department of Transportation (DOT) is investigating the efficacy of Alcohol Safety Interlock Systems (ASIS). As currently envisioned, these systems are intended to perform two functions:

a. Automatically determine whether the driver is intoxicated.

b. Prevent the driver from operating his vehicle if he is intoxicated.

For the purposes of this report, the term "intoxicated" refers to the physiological and psychological condition of a person with a blood alcochol level (BAL) equal to or greater than 0.10% wt./vol. The term "sober" refers to the state of an individual with a BAL equal to or less than 0.03%. A person is considered functionally impaired when his BAL is between 0.03% and .10%.

## 2.1 ASIS CLASSIFICATION

Alcohol Safety Interlock Systems are classified according to the method they use to establish intoxication.

### 2.1.1 Chemical ASIS

Instruments in this class estimate BAL through measurements of the alcohol content in the breath, tissues, body fluids, or wastes. Many law-enforcement agencies measure alcohol present in exhaled alveolar air. The technique is attractive because the test is specific to alcohol, a breath sample is relatively easy to acquire (compared to blood and urine samples), and the result is a quantitative measure which is acceptable as evidence in a court of law.

During the period covered by this report, no ASIS using chemical or electrochemical tests of exhaled alveolar air to determine intoxication were available for evaluation. Research into

electrochemical sensors suitable for ASIS was undertaken by TSC and by several commercial organizations, and suitable sensors are expected to be available for testing and evaluation as part of the ASIS program in the near future. Providing that they meet prior laboratory criteria for factors such as sensitivity, stability, and repeatability, these chemical ASIS will be mainly field-tested in this program.

### 2.1.2 Performance ASIS

A second class of techniques uses the measurement of performance or behavior in psychomotor tasks. This method requires the establishment of a baseline performance level for a sober driver. A reduction in performance below this criterion is taken to indicate intoxication. Conceivably, two types of performance ASIS could be developed: hurdle ASIS, for which the test of performance is taken before the vehicle can be driven, and continuous-monitoring ASIS, for which the performance of the driver is measured during an extended period while the vehicle is being driven.

Hurdle ASIS are quite simple in operation, and may be easily interfaced with existing vehicle designs. However, since a hurdle ASIS determines intoxication in a relatively short test, drivers might be able to pass it by marshaling their abilities for a brief period, although their performance level over longer periods could be quite low. Also, hurdle ASIS could allow a person to start a car immediately after drinking a large quantity of alcohol, since performance degradation might not develop until some time had elapsed. Similarly, hurdle ASIS are not useful in cases where the driver begins drinking after he has started to drive.

A continuous-monitoring ASIS would in theory be responsive to driving performance, the variable of prime interest. It could monitor actual driving behavior, and would be sensitive to any factor which produced a performance decrement. To develop such an ASIS, it would be necessary either to have a metric representing safe driving or to identify some critical aspect of the driving

process which is affected by intoxication. In either case, a normal baseline would have to be established for the entire population. Since no such metric is yet available, and as no aspect of the driving task has been demonstrated to be reliably affected by intoxication, performance-type continuous-monitoring ASIS are presently impractical.

## 2.2 SOURCES OF INFORMATION

In order to acquaint commercial and academic organizations with DOT's interest in ASIS development, and to ensure that all possible ASIS techniques would be considered, the National Highway Traffic Safety Administration issued a prospectus entitled "Some Considerations Related to the Development of an Alcohol Safety Interlock System (ASIS)" in October of 1970. The prospectus was sent to organizations which had previously responded to an announcement in the Commerce Business Daily, or had otherwise expressed interest in this topic. It contained discussions of the need for an ASIS, the various possible techniques available, and the potential problems inherent in the development of an ASIS.

A letter accompanying the prospectus requested (a) descriptions of potential ASIS, (b) discussion of the possible solutions to the problems mentioned, and (c) description of the responding firm's experience and capabilities in this area. Some 25 organizations responded to the prospectus. Their responses were analyzed in conjunction with a general survey of the literature pertaining to various kinds of performance degradation induced by alcohol.

## 2.3 SELECTED TECHNIQUES

Most of the responses contained some of the following: a description of an ASIS developed by the respondent, a description of a potential solution or solutions to the problems, and comments on the problems raised in the prospectus. The responses are discussed in detail in a document entitled "Summary and Evaluation

of Responses Received on the Alcohol Safety Interlock System Prospectus."* Because of the proprietary nature of the material discussed, the distribution of this report has been limited to the Government. A brief discussion of the nonproprietary aspects of the most appropriate suggestions is presented below, together with the information gleaned to date from a continuing review of literature.

### 2.3.1 Measurement of Alcohol in the Breath

Seven of the 25 responding organizations suggested an ASIS based on the detection of alcohol in body tissues, wastes, or breath. In general, the suggestions which dealt with tests on tissue or wastes were neither detailed nor specific. With regard to breath-based tests, two firms suggested devices which were far too expensive to be seriously considered for adoption in a large-scale ASIS program. One source described a gas chromatograph which was estimated to cost several thousand dollars in its then-current form.

Two other sources suggested the use of a sensor based on a catalytic-absorption or catalytic-oxidation process. This technique was expected to have a sensitivity in the range of 300 parts per million (ppm), and thus would be suitable for testing alveolar air.

Suggestions for measures to counteract user attempts to deceive this type of device revolved around a multisensor approach, which would require not only the absence of alcohol in a breath sample of the proper temperature, but also the presence of the gases normally found in alveolar air ($CO_2$ and $H_2O$) in the expected quantities. This technique is intended to make the substitution of some other air supply difficult.

### 2.3.2 Measurement of Performance on a Divided-Attention Task

Seven of the responding organizations suggested that ASIS be based on the measurement of performance on a divided-attention

*DOT Report DOT-TSC-NHTSA-71-2, May 1971

task. A review of the literature revealed evidence that such a technique might be usable. Moskowitz and DePry[1] demonstrated a decrement in the performance of intoxicated subjects over sober ones on a two-task, auditory divided-attention problem, though no decrease in performance was observed on either of the component tasks when they were presented separately.

Though the technique described by Moskowitz and DePry appears to be useful in discriminating between sobriety and intoxication, an auditory-type divided-attention task may not be practical for this particular job. The overall magnitude of the effect at the low BAL's tested (.07% to .08%) was small. However, Moskowitz and DePry reported a 14% increase in error rate over sober performance for a given individual at moderately high (.07% to .08%) BAL's, implying that determination of the within-and between-subject variability in performance will be a major factor in assessing the usefulness of the technique.

The General Motors Corporation response described an ASIS that measured performance on a divided-attention task, which requires rapid memorization of a five-digit display and rapid keyboard entry of the number. During keyboard entry, the driver's attention is momentarily diverted by a visually presented command for a brake-pedal response. This ASIS was obtained from GM; the results of a laboratory evaluation are discussed in the appendix.

A third type of divided-attention task, requiring simultaneous performance of a two-choice complex-reaction task and a tracking task, was developed and fabricated by TSC for evaluation as an ASIS. Both tasks utilize visual stimuli and manual responses. This device was tested in the laboratory evaluation programs; the results are discussed in the appendix. This divided-attention task was later revised and a complex-reaction task which required response to stimuli in the visual periphery substituted. This revised device is expected to be included in the next scheduled laboratory evaluation.

Performance on a divided-attention task as a measure of

intoxication may have some inherent drawbacks; in general, the component tasks are necessarily not simple, and successful performance of the resulting complex task may require extensive training, or even be beyond the sober ability of many of those driving.

### 2.3.3 Measurement of Pursuit-Tracking Task

Four respondents proposed measurement of performance on a Pursuit-Tracking Performance Task as an ASIS technique. Pursuit-tracking tasks require the positional matching of a moving element controlled by a random, pseudorandom, or preprogrammed forcing function with an element controlled by the test subject. Pursuit tracking has long been used as a standard task in psychomotor assessment programs, since performance is a function of the operator's hand steadiness, control precision, and ability to predict the target's future position. Furthermore, the tracking is similar to one of the types of performance necessary for driving.

Laboratory studies described in the response of the Highway Safety Research Institute indicated that significant decrements in various performance measures of a pursuit-tracking task occur at BAL's as low as 0.05%. Since no commercially developed ASIS use this technique, the Transportation Systems Center developed and fabricated a single-axis, position-controlled pursuit-tracking task. This device was included in the laboratory evaluation; the results are discussed in the appendix.

### 2.3.4 Measurement of Performance on a Compensatory-Tracking Task

While compensatory tracking was suggested by only one respondent, there is evidence in the scientific literature that performance on such a task is affected by the ingestion of alcohol. In laboratory studies, degradations in compensatory-tracking performance due to alcohol intoxication have been observed by Mortimer[2] and Gibbs[3].

Compensatory tracking tasks require the centering of a moving element which is driven by a random, pseudorandom, or preprogrammed forcing function. Performance on a compensatory-tracking task

depends on the operator's response latency, decision latency, control precision, and vigilance. The task is easily learned and has often been used to assess psychomotor performance.

No ASIS based on this technique was commercially available at the beginning of the laboratory evaluation. TSC developed and fabricated a one-degree-of-freedom, position-controlled compensatory-tracking task. The results of the laboratory evaluation of this device are discussed in the appendix. After the first phase of the laboratory evaluation had begun, the Raytheon Company developed a candidate ASIS called the Reaction Analyzer, which requires the subject to maintain equal brightness on a pair of lights which represent the relationship between the manual control (a potentiometer) and an undisclosed driven element. This device was included in the second phase of laboratory evaluation. The results are discussed in the appendix. A second-generation version of the Raytheon Reaction Analyzer is expected to be included in the next scheduled laboratory evaluation.

### 2.3.5 Measurement of Performance on a Simple-Reaction-Time Task

Three respondents suggested an ASIS based on measurement of simple-reaction time. In simple jump-reaction tasks, the subject is required to make a simple motor response as quickly as possible after the occurrence of a stimulus. Only one specific stimulus occurs and only one type of response is required. Testing of jump-reaction time is easy, and has good face validity for determining driving ability.

The Nartron Corporation described a device (Safelock) which uses the individual's jump-reaction latency to determine whether the driver is sober or intoxicated. The assumption in this design is that intoxication will result in a high response latency. A second device, developed by Robert D. Smith (QuicKey), compares the reaction time of an intoxicated individual with his previously determined sober response level. The device is calibrated to the user, and from this calibration a response latency band is established. An individual who responds significantly more slowly than

the calibration score is assumed to be intoxicated, and fails. Responses which are considerably faster than the calibration are considered indicative of an attempt to circumvent the test by substituting another individual, a chance response, or evidence of erratic performance.

Since both devices measured the same type of performance, and the QuicKey was described as being sensitive to both increased latency and increased variability of latency, only the QuicKey was included in the laboratory evaluation. The results of the evaluation are discussed in the appendix.

### 2.3.6 Measurement of Steadiness, Dexterity, or Control Precision

Three respondents mentioned changes in hand steadiness, dexterity, or control precision as an ASIS technique. Previous laboratory experimentation on the effects of intoxication on this type of performance measured tracking-type tasks, confounding tracking and steadiness. Therefore, it was decided to evaluate an ASIS device which used this principle. One of the three respondents, A.S. Dwan, Ltd., constructed an ASIS candidate based on this technique. The device, a Prototype Theft Lock, requires considerable precision and hand steadiness to fit the key into the lock and turn it to the start position. The device was included in the laboratory evaluation; the results are discussed in the appendix.

### 2.3.7 Measurement of Critical Flicker-Fusion Frequency

Two respondents suggested that a measurement of the effects of alcohol on flicker fusion be considered as an ASIS technique. The technique has the disadvantage that measurements of flicker fusion are known to be sensitive to variables other than alcohol, such as ambient light, fatigue, and illness. However, the technique is simple and uses an easily learned task.

One of the respondents, Creare, Inc., constructed a device utilizing this effect to detect intoxication. In practice, the driver is required to indicate whether the target is flickering

or steady. If the driver is incorrect on more than some preset number of trials, he is considered intoxicated. This device was included in the laboratory evaluation; the results are discussed in the appendix.

### 2.3.8 Measurement of Response Coordination

Two respondents suggested measurements of response coordination as an ASIS technique. One organization, TDL, described a device, the Drunk-Driver Eliminator (DDE), which they have developed as a candidate ASIS. In operation, the driver performs a simple sequential key/brake-pedal task. The driver must turn the ignition key and then immediately depress the brake pedal. A long response latency or inversion of the order of movements is taken to indicate intoxication.

The ASIS described by TDL appears to be simple, very inexpensive, and easily installed in any present vehicle. Although insufficient information was available to allow prediction of the utility of the DDE as an ASIS, the extreme simplicity of the device and its unique nature evoked interest. Therefore, the device was obtained and included in the evaluation. The results are discussed in the appendix.

### 2.3.9 Measurement of Performance on a Complex-Reaction Task

While no respondents suggested the measurement of performance on a complex or choice reaction task as the basis of an ASIS technique, the literature review did reveal that such performance is a simple index of information-processing capacity.[4] Biederman and Kaplan[5] have developed a sensitive version of this task, by requiring the subject to respond to some stimuli with spatially incompatible responses. Since it was considered likely that intoxication would degrade information-processing capacity, a candidate ASIS which used this task, the Complex-Reaction Tester, was designed and a prototype fabricated by TSC.

This device requires the subject to choose one of two responses to each of a set of four possible stimuli. Two of the

stimulus/response combinations are spatially compatible, in that both the stimulus and the response occur on the same side (right or left) of the panel. The other two are spatially incompatible, in that the required response is on the opposite side of the panel from the stimulus.

The results of the evaluation of this device are discussed in the appendix.

# 3. LABORATORY EVALUATION

In order to determine the efficacy of the various ASIS devices described in Section 2, a laboratory evaluation was carried out. It included pilot studies, instrument-screening tests, and testing to establish BAL/performance relationships.

## 3.1 PILOT STUDIES

Research in this segment of the evaluation served to establish adequate procedures for subject recruiting, handling, safety, training and performance testing, alcohol exposure, and alcohol-level determinations. Subjects represented two basic groups: social subjects (paid volunteer drivers of at least 21 years of age) and Registry subjects (drivers convicted of driving while intoxicated, identified through lists prepared by the Massachusetts Registry of Motor Vehicles).

In Massachusetts, at the time of the study, individuals were rarely convicted of driving while intoxicated if they had BAL's of less than 0.18%. Therefore, it was expected that the Registry subjects would be experienced and heavy drinkers. This was borne out in the laboratory evaluation.

Subjects were required to practice intensively on all devices until they had reached a predetermined performance criterion or had completed a preset number of trials.

Subjects ingested low-congener alcohol mixed with fruit juice in quantities calculated to reach average peak alcohol levels ranging between 0.10% and 0.22%.

Blood alcohol was determine by measuring exhaled alveolar air with a Stephenson Breathalyzer calibrated with Nalco prepared standard samples. The measure was termed a Breath Alcohol Equivalent (BAQ) to the BAL.

## 3.2 INSTRUMENT SCREENING TESTS*

### 3.2.1 Devices Selected

On the basis of the prospectus responses, review of pertinent literature, examination of available candidate ASIS devices by TSC staff, and information gathered during the pilot studies, the following devices were selected to undergo laboratory screening tests. Devices were obtained through loan, lease, or purchase.

PROTOTYPE THEFT-PROOF LOCK - Developed by A.S. Dwan, Ltd., this unit is an ignition lock which requires the driver to carefully set a numbered combination and insert the ignition key with precision. If the driver sets the combination incorrectly, is clumsy in inserting the key, or exceeds the time allowed on the task, he is prevented from starting his vehicle.

CRITICAL FLICKER-FUSION TESTER - Developed by Creare Incorporated, this requires the operator to discriminate between flickering and steady visual stimuli in order to start his vehicle. The device's ability to determine intoxication is dependent upon a reduction in the critical flicker-fushion frequency which accompanies intoxication.

PHYSTESTER - Developed by the Delco Electronics Division of General Motors, this unit requires that the driver perform a divided-attention task to start his vehicle. The driver must first enter a combination on a touch-tone-type keyboard. If he does this correctly, a random five-digit number is displayed. The driver must rapidly memorize this number and enter it on the keyboard. At some time during this process a visual stimulus signaling a required brake application will appear on the display. The subject must promptly depress the brake pedal while continuing to enter the number. Failure to perform any

*The testing described in this section was performed by the Guggenheim Center for Aerospace Health and Safety, Harvard School of Public Health, Boston, MA, under Contract DOT-TSC-213.

of those steps in the time alloted is taken to indicate intoxication.

QUICKEY - Developed by Robert D. Smith, this unit requires the driver to provide a simple reaction response to visual stimuli. For each subject, a characteristic response latency for the QuicKey is established. This response latency is used to set a passing band such that only a latency which is within ten percent of the characteristic response latency will allow the subject to pass. Responses which are either slower or faster than required by the band limits cause failure. This device determines intoxication through the detection of both increased response variability and increased response latency.

DRUNK-DRIVER ELIMINATOR - Developed by the TDL Group of Companies, this unit requires the driver to make closely coordinated and sequenced manual and pedal responses. Responses too widely separated in time, or inverted in sequence, are considered to indicate intoxication.

The reivew also revealed a number of principles which might be suitable for an ASIS, but had not been tried out. Three ASIS prototypes were developed by TSC to allow testing of these principles. The following paragraphs briefly describe these TSC-developed units.

COMPENSATORY-TRACKING TESTER - This unit requires the driver to perform a compensatory-tracking task. If the driver's absolute-error score exceeds a pass/fail threshold, he cannot start his vehicle. The threshold is set individually for each driver.

PURSUIT-TRACKING TESTER WITH SECONDARY DETECTION TASK - This device requires the driver to perform a pursuit-tracking task and simultaneously respond promptly and correctly to a pair of visual stimuli. If the driver's tracking score shows error above a preset threshold, or if he responds too slowly or incorrectly to the visual stimuli, it is taken as an indication of intoxication.

COMPLEX-REACTION TESTER - This unit requires the driver to perform a complex-reaction task which has both compatible and incompatible stimulus/response combinations. The driver is presented with a four-stimulus display. The stimuli are composed of four lights arranged as the corners of a rectangle. The display stimuli form two vertical pairs, since the horizontal dimension of the vehicle is much greater than the vertical. The driver must respond to stimuli in the upper corners by pressing the button on the same side as the stimulus. (This is considered a compatible or same response.) The driver must respond to stimuli on the lower corners by pressing the button on the opposite side of the rectangle from the stimuli. (This is considered an incompatible or opposite response.) Slow or incorrect responses are taken to indicate intoxication.

### 3.2.2 Procedure

The screening tests were designed to determine the accuracy with which the techniques embodied in the candidate devices measured intoxication. For these tests social subjects and Registry subjects, as described earlier, were trained in the operation of each candidate device over a period of 1 to 3 days, depending on the device. Subjects were then tested at various blood-alcohol levels on each of the devices.

The tests were conducted in the following manner. After entering the experimental area, subjects were tested for BAQ, and initial tests were made of their performance on the ASIS devices they had been trained on. Next, experimental subjects received neutral spirits alcohol mixed with the fruit juice of their choice. Control subjects received fruit juice alone. Twenty minutes later, testing on the candidate devices was resumed; it continued for approximately 40 minutes. Midway in the 40-minute period, a BAQ determination was made. Exactly one hour after the administration of the first drink, the second drink was administered. Twently minutes later, performance testing resumed, with BAQ determined midway in the testing period. One

hour after the second drink, a third was administered and the cycle repeated. The peak alcohol levels (approximately 0.11% BAQ) were reached after the third drink. For the next three hours no alcohol was administered, but the performance testing and BAQ determinations were continued. The experimental design is discussed in detail in the appendix.

### 3.2.3 Results of Screening Tests

The purpose of these experiments was to determine how closely the subject's performance on each candidate device correlated with blood alcohol level. Pearson-product-moment coefficients of correlation (r) between an appropriate index of subject performance and the BAQ for each subject at the time of the performance were calculated for each device. The devices were then ranked in terms of the magnitude of the r calculated. Tests of statistical significances were made for each coefficient to determine whether the difference between the computed coefficient and a coefficient of zero (no correlation) were due to chance variation or to the number of statistical tests performed. Credence was given only to coefficients of correlation associated with probabilities of being due to chance of less than or equal to .01 ($P \leq .01$). The following correlation coefficients between test performance and BAQ were calculated:

| | |
|---|---|
| Prototype Theft Lock | R = 0.156* |
| Critical Flicker-Fusion Tester | R = 0.107* |
| Phystester | R = 0.393*** |
| QuicKey | R = 0.343*** |
| Drunk-Driver Eliminator | R = 0.045* |
| Compensatory-Tracking Tester | R = 0.329** |
| Pursuit-Tracking Tester with Secondary Task (Tracking Accuracy) | R = 0.392*** |
| Complex-Reaction Tester (Errors) | R = 0.153** |

*$p > .05$
**$p \leq .01$
***$p \leq .005$

### 3.2.4 Selection of Devices for Future Testing

Devices were selected for future testing on the basis of the following factors: 1) the observed correlation between subject performance and BAQ; 2) the extent of preinstallation driver training required for successful use of the device; 3) whether the intrinsic design of the device required determination of a pass/fail threshold for each driver, or a single universal threshold could be set for all drivers; 4) the relative cost/complexity of the device. (This last criterion was used only to discriminate between the Pursuit-Tracking Tester with Secondary Task and the Compensatory-Tracking Tester, since these devices had similar coefficients of correlation but the design of the Pursuit-Tracking Tester with Secondary Task was considerably more complex.)

The following four devices were chosen:

Compensatory Tracking Tester: R = 0.329; considerable training required, individual threshold required, cost/complexity low.

QuicKey: R = 0.343; moderate training required, individual threshold required, cost/complexity moderate.

Complex Reaction-Time Tester: R = 0.153; little training required, universal threshold, cost/complexity moderate.

Phystester: R = 0.393; considerable training required, universal threshold, cost/complexity high.

The Prototype Theft Lock, Critical Flicker-Fusion Tester, and the Drunk-Driver Eliminator were dropped because the correlation of the performance indices with BAQ was very low. Further testing of the Pursuit-Tracking Tester with Secondary Task was postponed until a more thorough examination of divided attention tasks could be made.*

## 3.3 PASS/FAIL EVALUATION

This series of experiments was intended to allow prediction of the range of performance in actual use to be expected from

*An improved version of this device is currently being tested.

each of the four devices selected in the screening test. The pass/fail criterion testing was performed in two series. The first, in which peak BAQ levels in excess of .10% were reached, is referred to as the Low-BAQ Series. The second, in which BAQ levels in excess of .18% BAQ were reached, is referred to as the High-BAQ Series.

### 3.3.1 Low-BAQ Series*

#### 3.3.1.1 Pass/Fail Criteria

a) QuicKey - The procedure for establishing the pass/fail cutoff points from the quantitative data was provided by the manufacturer. Each subject's maximum allowable response time was the eighth fastest reaction time out of his last 50 training repetitions (the 16th percentile). His minimum permissible score was set at 15% below this value. The subject's response time during testing had to be within these boundaries in order for him to pass.

b) Complex-Reaction Tester - Subjects were allowed no more than one error (either pressing the wrong button or taking more than 0.9 seconds to respond) out of eight presentations.

c) Compensatory-Tracking Tester - The mean and standard deviation of the last 36 repetitions of training were calculated for each subject. Any score greater than the sum of the mean tracking error score plus one standard deviation was scored as a failure; any score less than or equal to this was passing.

d) Phystester - The pass/fail criterion for this device was provided by the manufacturer. Subjects had 1.5 seconds' display time to memorize the number, and had to complete the dual task of entering the five digits on the keyboard and pressing the brake pedal within 3.5 seconds in order to pass.

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*These tests were performed by the Guggenheim Center for Aerospace Medicine, Harvard School of Public Health, Boston, MA, under Contract No. DOT-TSC-213.

3.3.1.2 Procedure - Substantial monetary rewards were given to the subjects immediately after completion of each successful attempt on each device. This was done in order to simulate the kind of motivational context which is to be expected when an individual with an ASIS actually attempts to start his or her vehicle. During the Low-BAQ Series each subject was allowed three attempts or trials on the Phystester, Compensatory-Tracking Task, and Complex-Reaction Tester. However, only one trial on the QuicKey occurred during each of the seven testing blocks during the testing day. For each trial in which the subject was successful on the Phystester, Compensatory-Tracking Tester, or Complex-Reaction Tester, he received a token worth $.50. For each successful attempt on the QuicKey, the subject received a token worth $1.50.

The tokens were presented immediately after each trial and redeemed at the end of the series. The differential reward was due to the nature of the ASIS tasks and the time required to complete each. During a single day a subject could have earned up to $42.00, if he had successfully completed all attempts. No subject was able to perform this well.

3.3.1.3 Results - Performance of the ASIS was gauged in terms of the percentage of no-starts recorded for the subjects at each BAQ. A no-start was recorded when an individual passed less than some proportion of successive trials at a given alcohol level. The proportion of failed trials resulting in a no-start was determined through post-hoc manipulation of the trial performance data to achieve the greatest difference in the percentage of no-starts between sober and intoxicated subjects, commensurate with a sober failure rate of less than 10%.

For the Complex-Reaction Tester, the Compensatory-Tracking Tester, and the Phystester, failure of more than one out of three trials was a no-start. For the QuicKey, failure to achieve a reaction latency within the window representing sober performance within two minutes was a no-start. Figure 1 depicts the percentage of no-starts observed for the devices tested for subjects in the following BAQ ranges: BAQ $\leq$ .03% (sober), .03% > BAQ > .10%

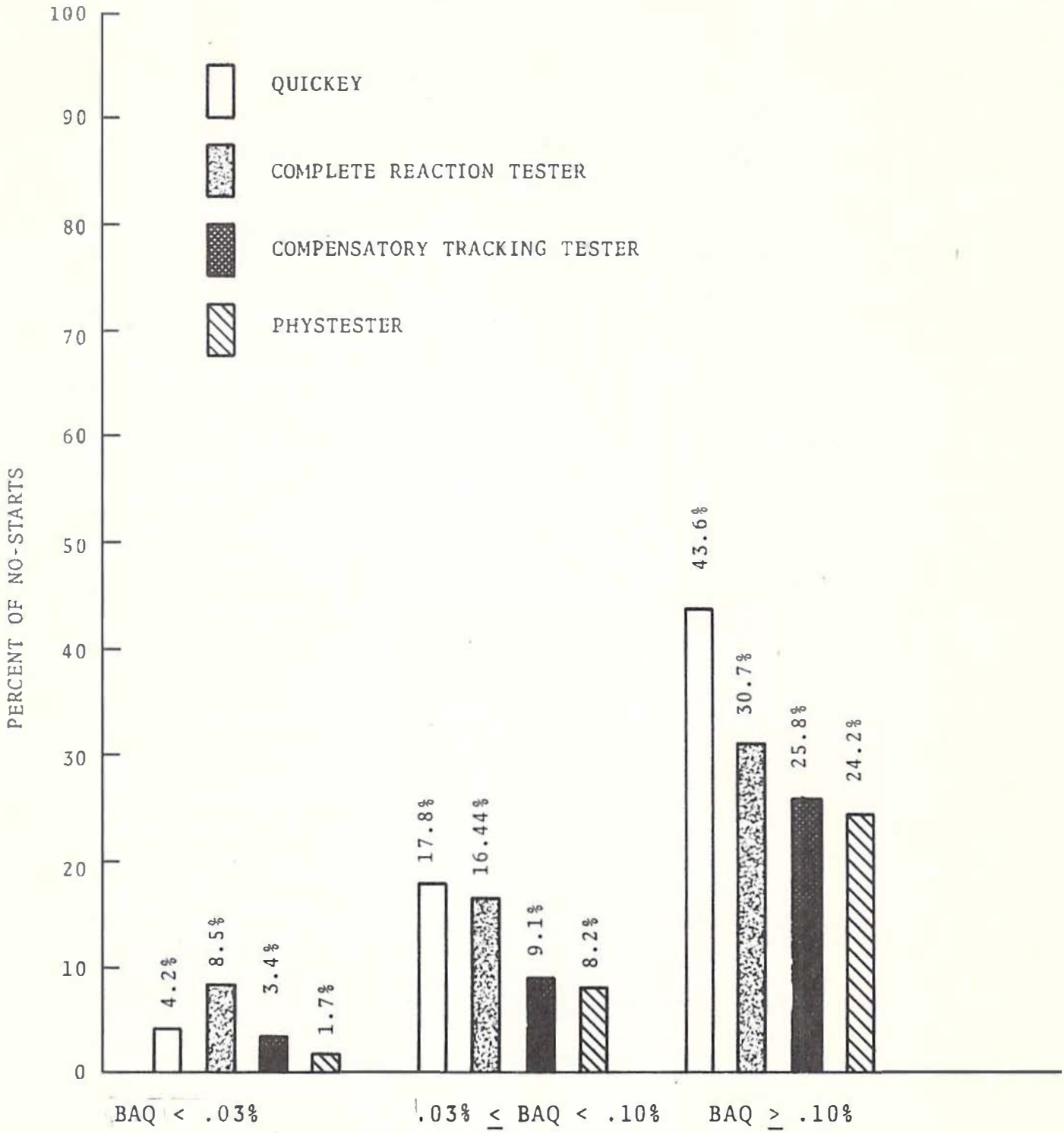


Figure 1. Percentage of No-Starts Observed in Low-BAQ Test Series

(incapacitated); BAQ ≥ .10% (intoxicated). As may be seen from the figure, the two devices which use universal thresholds have similar no-start differentials of 22% (the difference between the percentage of no-starts for intoxicated subjects, or correct rejections, and the number of no-starts for sober subjects, or incorrect rejections). The observed no-start differential for the two devices which require individually set thresholds are quite different. QuicKey had an observed differential of approximately 39%. The Compensatory-Tracking Tester had an observed no-start differential of approximately 22%. The devices may be ranked in terms of the observed no-start differential as follows:

| | |
|---|---|
| QuicKey | 39.4% |
| Phystester | 22.5% |
| Compensatory-Tracking Tester | 22.4% |
| Complex-Reaction Tester | 22.2% |

It is obvious that there was little difference between the observed no-start differential for the last three devices.

### 3.3.2 High-BAQ Series

3.3.2.1 Devices Tested - In the High-BAQ Series* of tests, three of the candidate ASIS devices (QuicKey, Complex-Reaction Tester, and Phystester) were evaluated using alternative pass/fail criteria and no-start criteria. The Compensatory-Tracking Tester was replaced by a somewhat different tracking task, the Reaction Analyzer (developed by Raytheon Co.). Testing was also begun, and terminated due to failure of the test unit, on a ASIS candidate device developed by the Nartron Wire Corporation.

There were a number of significant differences in the procedures used in the Low-BAQ and High-BAQ Series. Peak BAQ's in excess of .18% were reached for most subjects in the High-BAQ Series. Subjects were carefully selected on the basis of previous

*Testing in this series was conducted by Dunlap and Associates, Inc., Darian, CT under Contract DOT-TSC-251.

frequent use of alcohol and previous frequent achievement of BAQ's in excess of .15%, rather than drunk-driving convictions. Thirty-seven subjects were used (20 male, 17 female).

The payoff systems used to motivate the subjects were manipulated so as to allow sufficient flexibility to explore various pass/fail criteria and no-start strategies. These features are discussed in detail in the report prepared by Dunlap and Associates, Inc., DOT-TSC-251-4.

3.3.2.2 Procedure - The following pay schemes provided the optimum performance on the ASIS candidate devices named:

QuicKey - Subjects were allowed to make as many responses as possible during the two-minute period. $.50 was paid for all responses falling into the window which represented a pass. A single two-minute trial was given during on each of seven blocks of the testing day.

Complex Reaction Tester - Subjects were given $.25 per successful trial, with a total of three trials per block. Subjects were given a 100% bonus for each block of three in which they passed all trials.

Reaction Analyzer - Subjects were given $.25 per successful trial, with a bonus of 100% if they passed all trials in the block of five.

Phystester - Subjects were given $.25 per successful trial, with a bonus of 100% if they passed all trials in the block of five.

3.3.2.3 No-Start Strategies - The following no-start strategies provided optimum no-start differentials:

QuicKey - Less than one response in the "window" in the two-minute trial resulted in a no-start.

Complex Reaction Tester - Failure on any of the three trials resulted in a no-start.

Reaction Analyzer - Failure on any of the first three trials resulted in a no-start. (The last two trials were dropped from consideration).

Phystester - Failure on any of the first three trials resulted in a no-start. (The last two trials were dropped).

3.3.2.4 Results - Figure 2 graphically depicts the observed percentages of no-starts at four BAQ ranges: BAQ < .03% (sober), .03% ≤ BAQ < .10% (incapacitated), .10% ≤ BAQ < .18% (intoxicated), and .18% ≤ BAQ (very intoxicated).

The candidate ASIS devices may be ranked according to the optimum observed differential between sober no-starts (false rejection) and very intoxicated no-starts (correct rejection) as follows:

| | |
|---|---|
| Phystester | 60.2% |
| Reaction Analyzer | 58.5% |
| QuicKey | 53.4% |
| Complex-Reaction Tester | 50.3% |

Table 1 provides the observed no-start percentages for all of the devices tested both in the High and Low-BAQ test series at each of the BAQ ranges.

An obvious method of circumventing an ASIS requiring individual pass/fail thresholds is to "hold back" during training so that a spuriously low threshold will be set. This problem was investigated during the High-BAQ Series of tests. Subjects were requested to attempt to hold back, and they were generally successful. Therefore, if techniques requiring individual thresholds are used, care must be devoted to eliminating "jiggery-pokery" during the establishment of these thresholds.

Other data gathered during these experiments are relevant to the implementation of an ASIS program. As far as the drinking history of subjects is concerned, it was found that Registry

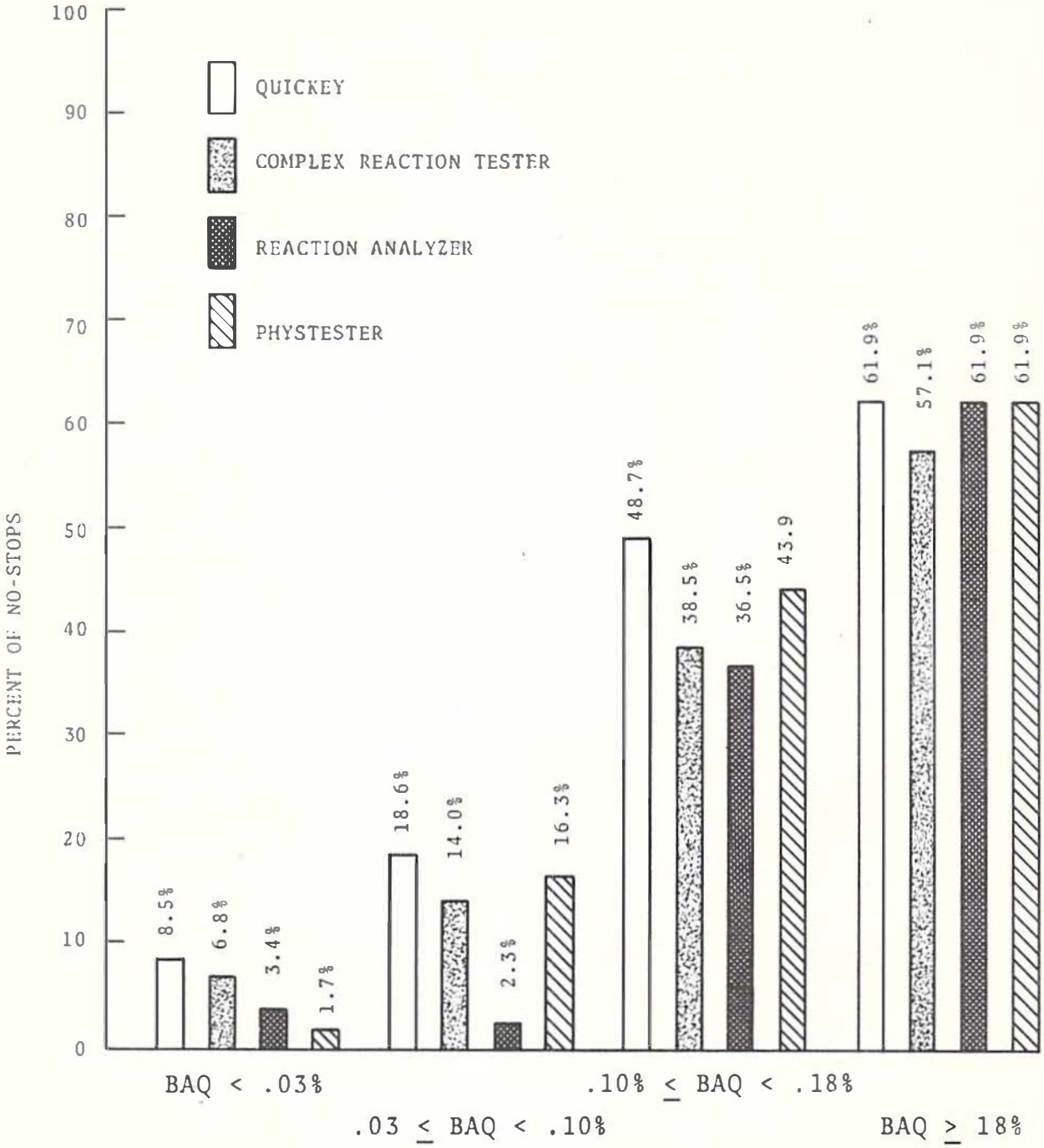


Figure 2. Percentage of No-Starts Observed in High-BAQ Test Series

TABLE 1. PERCENTAGE OF NO-STARTS OBSERVED IN BOTH BAQ TEST SERIES

a. Low-BAQ Series

| BAQ Range | QuicKey | ASIS Candidate Devices | | |
|---|---|---|---|---|
| | | Complex-Reaction Tester | Compensatory-Tracking Tester | Phystester |
| BAQ <. 03% | 4.2% | 8.5% | 3.4% | 1.7% |
| .03% ≤ BAQ <. 10% | 17.8% | 16.44% | 9.1% | 8.2% |
| BAQ ≥. 10% | 43.6% | 30.7% | 25.8% | 24.2% |
| No-Start Differential | 39.4% | 22.2% | 22.4% | 22.5% |

b. High-BAQ Series

| BAQ Range | QuicKey | ASIS Candidate Devices | | |
|---|---|---|---|---|
| | | Complex-Reaction Tester | Reaction Analyzer | Phystester |
| BAQ <. 03% | 8.5% | 6.8% | 3.4% | 1.7% |
| .03% ≤ BAQ <. 10% | 18.6% | 14.0% | 2.3% | 16.3% |
| .10% ≤ BAQ < .18% | 48.7% | 38.5% | 36.5% | 43.9% |
| BAQ ≥. 18% | 61.9% | 57.1% | 61.9% | 61.9% |
| No-Start Differential | 53.4% | 50.3% | 58.5% | 60.2% |

subjects (having a history of at least one arrest for driving while intoxicated) performed no better or worse than social subjects.

Gender had no statistically significant effects upon performance on any of the devices tested. The age of subjects did play a role in performance, but this was eliminated by improved training procedures. IQ scores were correlated with performance on the Complex-Reaction Tester, but this seems to be a marginally significant effect and may be an artifact.

While alternate pass/fail strategies and start/no-start criteria were explored, it was found that using different strategies or criteria simultaneously increased or decreased the number of sober and intoxicated no-starts by an essentially constant factor.

# 4. SUMMARY

On the basis of prospectuses from industry and a review of pertinent literature, 12 performance-type candidate ASIS were obtained and examined by DOT/TSC. Ten of these devices underwent laboratory screening evaluations designed to determine to what extent performance on each device was correlated with blood alcohol level.

The following types of performance were found to be affected by blood alcohol level:

Hand steadiness

Perception of visual flicker

Pursuit tracking

Compensatory tracking

Divided-attention performance

Manual jump-reaction response

Manual complex-reaction response

Five devices underwent further laboratory testing to determine the percentage of prevented starts which could be expected at various blood-alcohol levels. The best discriminator was a divided-attention task. With this task, no-start rates of .17% for sober subjects and 61.9% for the same subjects when very intoxicated (BAQ $\leq$ .18%) were recorded.

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