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Vehicle Anti-Theft Security System Design Volume I: Summary Report

Arthur D. Little, Inc., Cambridge, MA

Prepared for

National Highway Traffic Safety Administration, Washington, DC

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VEHICLE ANTI-THEFT SECURITY SYSTEM DESIGN
Volume I: Summary Report

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Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts 02140

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FINAL REPORT

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16. Abstract

This report covers a comprehensive study of automobile theft and anti-theft system design. A vehicle theft survey was conducted consisting of a literature search and interviews with a wide range of expert sources, including law enforcement officials, insurance personnel, automobile manufacturers, and automobile thieves. The data, which include up-to-date statistics on theft rates, motives, methods, and costs, were analyzed to identify and rank the important performance criteria for anti-theft systems.

Based on these criteria, a conceptual design study was conducted to identify anti-theft system concepts. Several promising system concepts were found, and a remote steering lock coded by means of a keyboard in the passenger compartment was selected as optimum for the test system. It was fabricated and installed in a test vehicle.

Prior to the installation of the improved system, the factory-equipped locked vehicle was mobilized by an amateur test subject in 50 seconds. The improved system resisted the efforts of a retired professional auto thief who gave up the effort after nearly 17 minutes. This was well beyond the design goal of 10 minutes.

The ultimate consumer price increase to cover the system is estimated to be between $17 and $36. This is well below the design goal of $50 which was based on the expected average savings in theft costs over the life of the vehicle.

As a result of the survey and the design program, a modified safety standard based on minimum time-to-defeat is recommended as the most straightforward and least design-restrictive approach. An alternative, based on limited accessibility of the vulnerable components, is also recommended if subjective compliance testing must be avoided. However, the latter alternative is inherently more design-restrictive.

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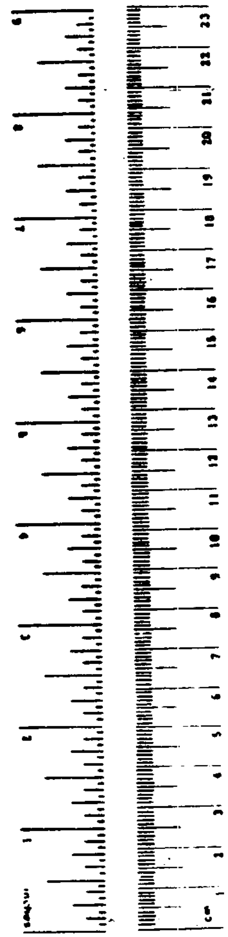
METRIC CONVERSION FACTORS

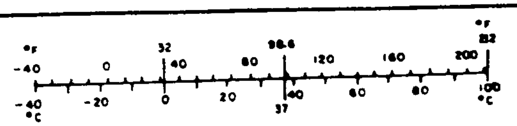
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The author would like to express his appreciation for the opportunity afforded by this program to extend and deepen his background and understanding of the technology of automobile theft. It has been interesting and rewarding work, being a subject containing elements of such diverse fields as engineering, law enforcement, safety technology, sociology, consumer affairs, and insurance. It is hoped that this work will contribute toward a creative, cooperative effort by government and industry to reduce the burden of automobile theft — a burden borne by virtually every U.S. citizen.

Many individuals contributed to the successful conclusion of this program. Consultants included Mr. David Barry, who helped with his general knowledge of the problem, and in marshalling West Coast information sources for the survey; and Mr. Rufus "Tinker" Whittier, who contributed his unique talents as the test subject for the validation tests.

The theft survey would not have been possible without the generous help provided by the many sources of information listed in Appendix B of Volume II. In addition, the assistance of Lt. Courtney at the San Francisco County Jail and Mr. William Quealy at the Middlesex County House of Correction in obtaining the thief interviews was greatly appreciated.

The number of Arthur D. Little, Inc., people who applied their special talents to the program is too great for individual recognition and, thus, thanks must be tendered collectively. However, the design efforts of the principal contributors listed on the title page, the library assistance of Ms. Kathleen Long, the secretarial services of Ms. Donna Sullivan, and the editorial services of Mr. Dana Pierce deserve special acknowledgement.

Finally, but certainly not least, the author would like to thank Mr. Dennis Grieder of NHTSA, Contract Technical Manager, whose cooperation and contribution were essential to the successful completion of the project.

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1. INTRODUCTION

Automobile theft in the U.S. has skyrocketed to monumental proportions in recent years. Vehicle thefts currently total about 1 million annually with total annual costs to the public running greater than $2 billion. Thousands of injuries and hundreds of deaths can be attributed annually to accidents involving stolen vehicles.

One of the many reasons for the escalating theft rate, especially the 70% stolen by amateur thieves, is the ease with which most cars can be stolen. Despite evidence that the the theft rate is related to the ease of theft, $10,000 automobiles are still equipped with anti-theft devices that can be defeated in 2 minutes or less by an amateur auto thief with little experience or skill.

Theft protection systems are currently specified by Federal Motor Vehicle Safety Standard No. 114. This standard requires functional performance which prevents unauthorized use in the absence of attack on the anti-theft system itself. However, it provides no definition of attack resistance level.

Thus, there is a clear need for the development and application of improved anti-theft systems and the standards against which they are measured.

The objectives of this program were threefold:

- The identification and selection of cost-effective, anti-theft performance criteria which can reduce the vehicle theft rate;
- The design, fabrication, and testing of an improved anti-theft system that complies with these criteria; and
- The development and recommendation of modifications to FMVSS No. 114 which reflect both the performance criteria and the technical realities imposed on the designer.

The program consisted of four major task areas:

- A vehicle theft survey in which a wide variety of information sources were tapped to obtain an up-to-date picture of theft experience and technology. These data were then analyzed critically to provide a basis for the identification of performance criteria.
- Based on the survey results, the important anti-theft performance criteria were identified and analyzed to determine their relative effectiveness and importance as bases for design goals and standard improvements.
- The performance criteria were then applied in a design study to identify and select design concepts for an improved anti-theft system. The selected concepts were developed, fabricated in prototype form, and tested for effectiveness.
- Finally, based on the results of the performance criteria study and the experience gained in the design program, existing anti-theft standards were studied and recommendations for improvements were developed.

The salient results of these tasks are summarized in this report for the benefit of the reader who does not wish to pursue the details of the work. Volume II, the Technical Report, covers the study effort in complete detail.

2. VEHICLE THEFT SURVEY

The vehicle theft survey consisted of a thorough review of the published literature concerned with vehicle theft and interviews with a wide variety of expert sources, including both law enforcement officials and thieves, to obtain unpublished data and opinion. The results of the survey were then sifted, correlated, and analyzed to isolate the critical data needed as a basis for the development of effective anti-theft performance data.

In addition to special surveys conducted on limited samples of the theft population, general theft data have been compiled by the FBI and the National Automobile Theft Bureau (NATB), an insurance industry investigative organization. However, the NATB records cover only about 20% of all auto thefts and these emphasize the professional segment. Thus, general conclusions drawn from these data can be erroneous when applied to the general theft experience. Moreover, a tendency has been noted in the literature to assume that amateur auto theft carries a low loss due to the fact that the car is recovered. In fact, the best available data show that amateur theft losses are significant and, when combined with the higher amateur theft rate, result in a greater total loss to the consumer than that due to professional operations.

Because the amateur is severely limited in his ability to apply costly theft methods, such as a tow truck, for example, this segment of the theft experience is the one in which improved anti-theft systems can have the greatest impact. Moreover, it is the segment which contributes the bulk of theft-related accidents.

THEFT RATES

The average annual theft rate in the United States is about 7 per 1000 vehicles with a peak local rate of 25 per 1000 in Massachusetts. Some of the variations by manufacturer, model year, geographical area, and vehicle category are shown in Tables 1 through 4.

THEFT MOTIVES

Based upon recovery statistics and analysis of recovered vehicles, the breakdown of theft motives among the four major components is shown in Table 5. Professional ring operations involving resale of the vehicles or large-scale stripping for major body sections are included in the professional category. Small-time theft for profit includes stripping of easily removable items, but the vehicle is usually recovered.

THEFT COSTS

Theft costs include direct losses to consumers, accident costs, and criminal justice system costs. The average direct loss for transportation and small-time stripper thefts is about $1500, while for professional operations it is about $2900. However, there are many more of the former type.

TABLE 1. THEFT RATES* BY MANUFACTURER AND MODEL YEAR

Manufacturer	Model Years 1968 and before	1969-71	1971-75
AMC	7	5	5
Chrysler	7	5	4
Ford	7	8	12
General Motors	13	5	6
Others	14	7	6

*Numbers of annual thefts per 1000 registrations. Data from Reference (18) of Volume II

TABLE 2. MASSACHUSETTS THEFT RATE – JANUARY 1974 (No. of Thefts per 1000 Registrations)

Manufacturer	Average for Vehicles Equipped with Steering Column Locks	Average for Vehicles without Steering Column Locks
AMC	4	5
Chrysler	12	22
Ford	46	11
General Motors	11	17
Total	21	16

Notes: Averages shown are averages of rate by model year for each category.
Data from Reference (6) of Volume II.

TABLE 3. THEFT RATE* BY YEAR IN CALIFORNIA AND MASSACHUSETTS (California Oct. 23-29, 1977; Massachusetts Jan. - June, 1974)

Model Year	California Rate	Massachusetts Rate
1976	8.6	--
1975	8.6	--
1974	11.2	--
1973	8.6	--
1972	5.9	24
1971	6.9	20
1970	9.1	19
1969	9.2	19
1968	11.6	20
1967	11.0	17
1966	16.9	17
1965	20.9	13
1964	24.7	19
1963	28.0	16
1962 and before	11.2	5

*Number of annual thefts per 1000 registrations.
Source data from References (6) and (17) of Volume II.

TABLE 4. THEFT RATES* BY VEHICLE CATEGORY
(Calculated from NATB Data for 12/1/76 through 05/31/77)

Category	NATB Rate	Estimated Rate Adjusted to National Level
Compacts and Subcompacts	2.93	14.7
Intermediates	2.61	13.0
Full Size	2.65	13.3
Luxury Intermediates		
• Mercedes	1.99	10.0
• Seville	8.74	43.7
Specialty		
Corvette	13.87	69.4

*Number of annual thefts per 1000 registrations.

1. Data from Reference (11) of Volume II for 1976 vehicles stolen in 1976.
2. Adjustment to national level simply made by multiplying the rate by 5 to compensate for the ratio between NATB thefts and the national experience.

TABLE 5. MAJOR THEFT MOTIVES

Motives	Percentage of all Thefts
Professional Car-Theft Operations	20 to 25
Fraudulent Insurance Claims	5 to 10
Small-Time Theft for Profit	20 to 30
Theft for Transportation	40 to 50

The best estimate of the breakdown in costs between the recovered and unrecovered categories is shown in Table 6. The resulting cost for the amateur and small-time stripper category is between $100 and $130 per vehicle over a 10-year vehicle life. Partial thefts where the vehicle is not removed from the scene of the crime can be estimated to cost an additional $82 per vehicle over a 10-year vehicle life. Stolen vehicles are estimated to have caused 1339 injuries and 134 deaths in 1976.

THEFT METHODS

Although a wide range of theft methods have been used, the most prevalent current methods include:

- a "slim-jim" attack on the door lock mechanism through the window slot, or
- a wire or rod through the door frame or window gasket to release the door lock, and
- a slide-hammer to extract the lock cylinder from the steering column lock.

TABLE 6. TOTAL ESTIMATED THEFT COSTS FOR 1976
($ billions)

Cost Component	Vehicle Recovered	Vehicle Not Recovered
Direct Loss[1]	$0.88 to 1.18	$0.72 to 0.963
Accident Costs[2]	$0.06	--
Arrest, Prosecution, and Correction Costs[3]	$0.19	$0.02
Totals	$1.13 to 1.43	$0.74 to 0.98

1. Calculated by applying 55/45% to total direct losses of $1.6 to 2.14 billion.
2. Calculated by assuming that all theft-related accidents are in the joy-riding/small-time stripper group.
3. Calculated by assuming that 90% of all criminal justice system costs are associated with the joy-rider/small-time stripper group.

These methods allow the theft of most vehicles in less than a minute by an amateur thief with readily available tools and no special technical capabilities. The most difficult systems can be defeated within 2 minutes. No changes appear to be planned which will deter a theft beyond a few minutes.

However, it is generally agreed among thieves, law enforcement officials, and investigators that deterrence beyond 10 minutes will discourage most amateur thefts.

Nationally, about 13.6% of all thefts are accomplished with a key that has been left in the ignition.

3. ANTI-THEFT PERFORMANCE CRITERIA

CLASSES OF CRITERIA

Anti-theft system performance specification is unique in comparison with other automotive systems, because the usual functional performance characteristics are trivial. The system designer must recognize that the important criteria relate to the ability of the system to resist attack by an intelligent, adaptive thief whose objective is to defeat the normal functional operation of the system. Thus, performance criteria were found to group logically into three classes: functional, attack resistance, and post-theft.

Post-theft criteria relate to measures which will diminish the value or market for stolen vehicles. These include identification of major parts and improved salvage titling which can have a significant effect on professional theft operations. However, they are generally outside the scope of FMVSS No. 114 and, thus, were not considered further in this program.

Functional and attack resistance criteria were identified in general terms and analyzed for their effects on theft deterrence, consumer acceptability, and cost.

FUNCTIONAL CRITERIA

The important functional criteria are either specified by the current FMVSS No. 114 or are commonly satisfied by current design practice. The only exception is that significantly improved theft deterrence would be provided by a criterion ensuring passive activation of the system so that a vehicle cannot be left unprotected.

ATTACK RESISTANCE CRITERIA

Time-to-defeat was found to be the basic attack resistance criterion and obviates the need for any others. However, if used as a basis for a standard, time-to-defeat inherently requires compliance testing with a human subject.

Several second-tier attack resistance criteria were identified and ranked for their effects on theft deterrence, consumer acceptability, and cost. Of these, effective limits on the accessibility of the vulnerable components and the specification of an effective passive or active tamper-detection capability were ranked highest. A criterion ensuring visual conspicuousness and a number of requirements on the code were ranked next. Limits on the accessibility of the door lock system and conspicuousness by alarm were ranked lowest.

Resistance to specific tools was generally found to be a poor way to specify attack resistance. However, amateur theft can be deterred by systems designed only to resist man-portable tools.

A specified level of complexity is a poor way to attack resistance because it inhibits clever design to achieve a simple, reliable anti-theft system.

4. SYSTEM DESIGN AND TESTING

GENERALIZED ANTI-THEFT SYSTEM

The major elements of a generalized anti-theft system are shown functionally in Figure 1. Virtually any anti-theft system designed to prevent the operation of a critical vehicle function or sound an alarm, unless deactivated by an operator with the appropriate code, can be visualized in this way. Specific systems, of course, seldom encompass all of the generalized elements shown.

For example, the standard factory-equipped entry or steering column locks do not provide either a sensor screen or a sensor signal processor. The code-insertion device in each case is a key and the decoders are lock cylinders. The bolt or latch mechanisms are incorporated into the door-latch and steering column mechanisms for the mechanical locking functions. For the ignition and starting functions, the latching mechanism is a switch.

The various signals shown can, in general, be mechanical, electrical, hydraulic, or pneumatic. In the current standard systems, the coded signal is mechanical. The binary signal is mechanical in the case of the door lock and steering wheel lock, and is transduced from mechanical to electrical in the case of the ignition/starting switch.

The operating energy sources can also occur in any media. In the case of the existing locks, they are mechanical and both are supplied by the operator as he turns the key.

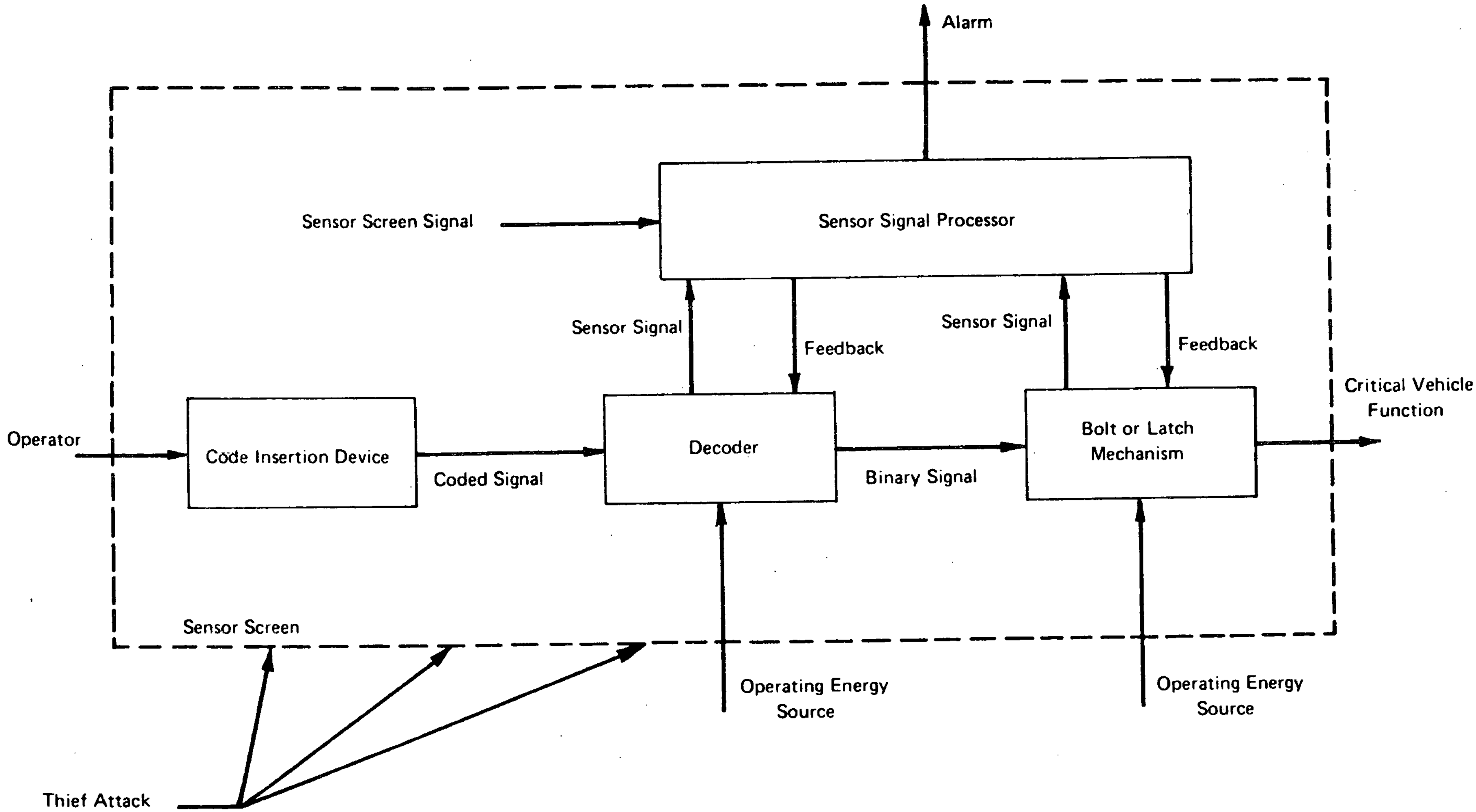

FIGURE 1 GENERALIZED ANTI-THEFT SYSTEM

The sensor screen and sensor signal processor show, in general fashion, the function of any system designed to sense illegal entry or tampering. In general, this type of anti-theft system can sound an alarm, or feed back a blocking signal to the decoder or latch mechanisms, or both. For example, the conventional alarm system, available as optional factory equipment, or purchased as an aftermarket system, uses switches on all entry points as a sensor screen and sounds an alarm. It also feeds back a switch opening in the ignition circuit in case of illegal entry. No commercial system known to this author is currently available which incorporates a tamper sensor on either the decoder or latch mechanism. However, this is a feasible concept and has been proposed in several forms.

This picture of the anti-theft system is useful because it provides a framework within which any proposed system can be discussed. It also shows clearly where the major constituent functions occur and where the vulnerability lies. For example, a thief can quickly obtain access to the binary signal point by means of a slide-hammer or a "slim-jim." If he could only access the coded signal point quickly, he would have great difficulty deactivating the system because of the ease in providing thousands of possible coded signals.

GOALS AND SPECIFICATIONS

Based on the performance criteria, the first step in the design of an advanced anti-theft system was the selection of design goals for the design. These are itemized in several categories below:

- *Functional*

(1) *Mobilization-Protection* — The anti-theft system will prevent at least one automobile function necessary for its self-mobilization, unless deactivated with the proper code.

(2) *Number of Codes* — The system will be capable of coding with at least 1,000 different combinations.

(3) *Entry Protection* — The system will incorporate locks requiring the proper code or key on all entry points, including the engine compartment hood.

(4) *Anti-Key Retention* — The system will incorporate a design feature to ensure that the driver will not leave the mobilization protection system deactivated.

(5) *Passive Activation* — The system will incorporate a design feature to ensure that the mobilization protection function will be activated when the driver leaves the vehicle.

- *Attack Resistance*

The fundamental attack resistance goal to be satisfied by the improved anti-theft system is that it be capable of resisting forcible deactivation for at least 10 minutes. However, this has been translated into a design approach as follows:

(1) *Mobilization* — The vulnerable elements of the mobilization protection system will either be contained in a secure housing located in the engine compartment in a relatively inaccessible location, such that all conceivable methods of attack will take at least 10 minutes; or the mobilization protection system will incorporate a

tamper detector which will cause the system to disable in the locked state when forcibly attacked, in such a way that a 10-minute restoring period is ensured.

(2) *Entry* — The vulnerable elements in the entry protection system will not be accessible from outside the vehicle, except by breaking the window, cutting or deforming the door panel, or forcibly extracting the doorlock cylinder.

(3) *Conspicuousness* — The mobilization protection system will be arranged such that the action of a thief would be visible for effective methods of attack.

(4) *Codes* — The system will be capable of codes which effectively preclude trial-and-error and the decoding of the door-lock combination to obtain the mobilization combination. The code will not be marked on the vehicle.

(5) *Power Restriction* — The system will not require any power source to remain in its locked state.

Although the entry accessibility criterion was not found to have a high importance in evaluating the criteria, it was included as a design goal in order to benefit from the design experience and testing on the prototype system.

- *Safety*

(1) The system will be designed to prevent the inadvertent activation of a lock on any vehicle function which could compromise safety, when the vehicle is in motion.

(2) The system will not require the reinsertion of a code or code-insertion device in order to restart a stalled engine.

(3) The entry locks will be capable of being manually unlocked from inside the vehicle.

- *Cost*

The design of the system will be consistent with an increase in consumer price in very large production quantities of $50 or less. This is well within the anticipated cost savings which can result as determined by the theft survey, even if less than half of current amateur thefts are deterred.

- *Maintainability*

The design of the system will be consistent with disassembly, part replacement, and reassembly in a time period of about an hour. This is comparable to the servicing times for current designs. The possible requirement that the vehicle be towed to a service facility in the case of an unsuccessful attack is felt to be a reasonable tradeoff, in view of the fact that the owner would still have the vehicle.

- *Reliability*

The design of the system will be consistent, after development, for high-volume production, with a reliability comparable with existing automotive mechanisms and electrical components.

CONCEPTUAL DESIGN

A conceptual design study was conducted, including a systematic concept generation and evaluation process, to identify as many promising anti-theft concepts as possible. This morphological approach included the identification of methods characteristic to each energy or signal transmission medium for code insertion, decoding, latching, and vehicle function lock. The study included both mobilization protection systems and sensor screen concepts. The latter class included both alarm and tamper protection systems. In addition, a number of improvements to entry protection systems were identified and evaluated.

Preliminary screening of the concepts identified two promising classes of code insertion/decoding systems:

- The non-remote decoder which uses a conventional key and is protected by a sensor screen to prevent attack; and
- The remote decoder using a conventional key or keyboard and located, along with the latching mechanism, such that access by a thief will require excessive time delay.

SELECTION

The latter concept was selected for the test system of this program because it provided the highest degree of confidence that the design goals would be met in the initial trial and the least modification of existing vehicle systems on the test vehicle. Keyboard code insertion was selected for the test system to avoid developing a reader for a conventional key or using expensive card or tape readers. It also inherently avoids providing an additional mechanism to ensure that the key is not left in the system.

Several possible vehicle functions are available for mobilization protection. However, for the test system, a steering lock was selected because it offered the most convenient option for packaging the electronic decoder circuitry in a relatively cool environment. This basis for selection applies primarily for a retrofit system, and another type of lock could easily be used for a production design.

DESCRIPTION OF THE TEST SYSTEM

The remote steering lock with keyboard code insertion was designed in detail for the test vehicle, a 1977 Dodge Colt, and two test units were fabricated. Figure 2 shows a photograph of the lock mounted on the steering gearbox, along with the keyboard unit which is located in the passenger compartment.

In addition, interior baffles were added to the doorlock system to deter "slim-jim" attack, the interior release was modified to use a rotary knob, and a commercial hood lock was installed.

The resulting test system meets all the design goals listed in the Goals and Specifications section presented earlier.

The increase in vehicle price resulting from the replacement of the existing steering column lock with a remote steering lock of this basic design, if produced in very high volumes and factory-installed, is estimated to fall between $17 and $36.

TEST RESULTS

Prior to the installation of the test system, a theft test on the factory-equipped vehicle was conducted. A "slim-jim" attack was used on the doorlock and a slide-hammer on the steering

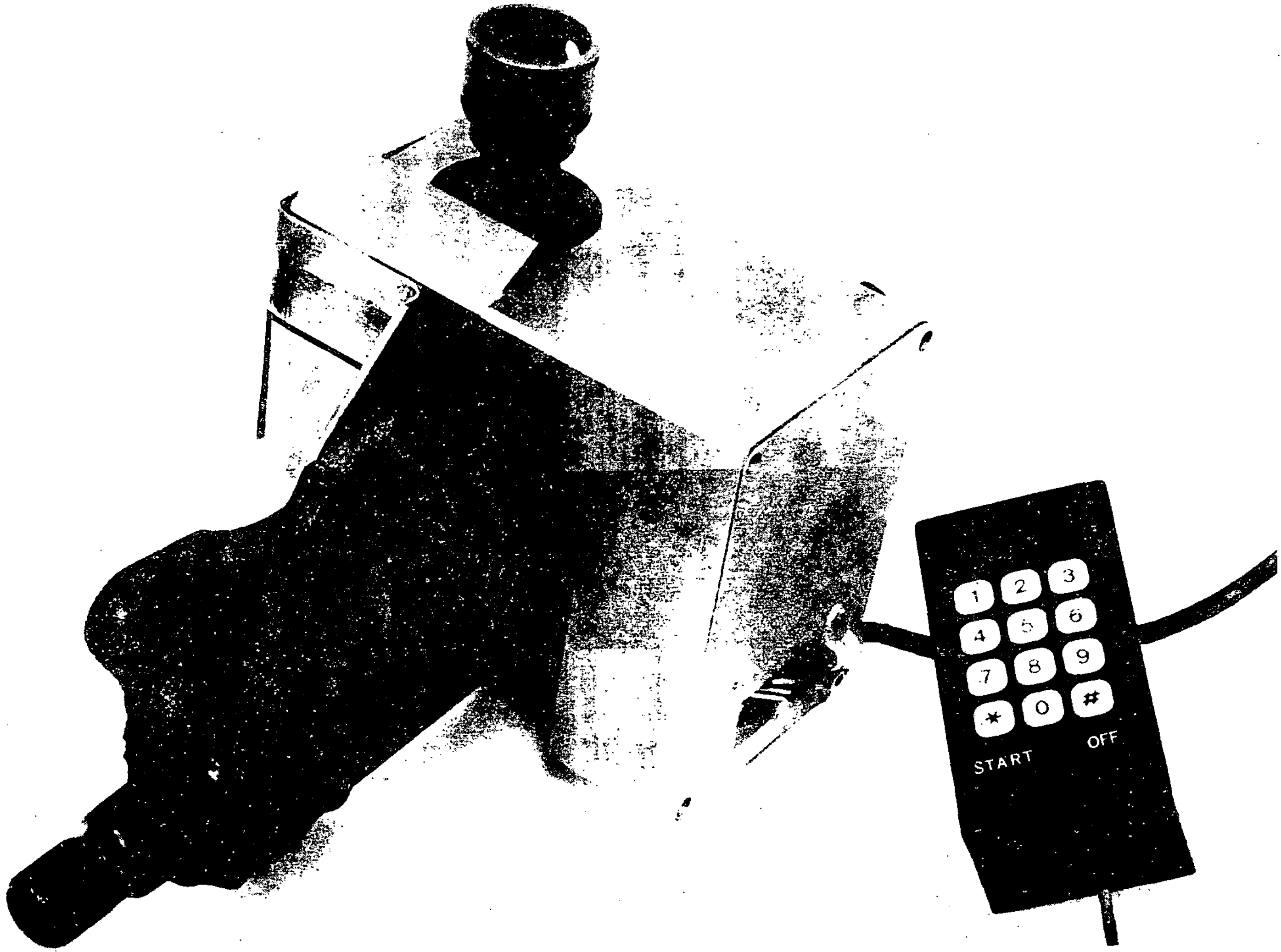

FIGURE 2 REMOTE STEERING LOCK AND KEYBOARD UNIT

column lock. The author served as a test subject for this test. It was his first attack on a Dodge Colt lock and on a steering column lock mounted in a vehicle. In this trial, the door was unlocked in a few seconds and the steering column lock was defeated in an additional 40 seconds. The total time from approach to the vehicle to the point where it was driven off was about 50 seconds.

After a series of functional and thermal bench tests, the remote steering lock was installed in the test vehicle, shaken down by road testing, and made ready for the validation test. An independent expert test subject, Mr. Rufus H. Whittier, was retained for the test. After a complete briefing on the principles and configuration of the test system, the validation time trial was conducted. The doorlock and hoodlock were defeated within a period of 2 minutes and 50 seconds. However, the remote steering lock could not be defeated within a period of 16 minutes and 40 seconds. The subject gave up the attack as fruitless at this point. In his opinion, this car would never be stolen on the street without a tow truck.

5. ANTI-THEFT STANDARD DEVELOPMENT

After studying existing anti-theft standards in the light of the performance criteria and the design program, it was concluded that the most direct, and least design-restrictive method for specifying attack resistance is in terms of a minimum defeat-time. However, this inherently carries with it a need to test compliance with a human test subject. It is felt that effective compliance test methods and expert technicians can be developed for this purpose.

If the time-to-defeat approach is found unacceptable, it is alternatively possible to specify attack resistance objectively in terms of limits on the method of housing and locating the vulnerable parts of the system. This alternative is inherently more design-restrictive and, in fact, is known to preclude certain promising anti-theft concepts.

Specimen modifications for FMVSS No. 114 following these two alternative approaches were formulated as follows:

ALTERNATIVE A — MINIMUM DEFEAT-TIME

1. *Purpose and Scope*

   This standard specifies requirements for theft protection to reduce the incidence of accidents resulting from unauthorized use.

2. *Application*

   This standard applies to passenger cars, light trucks, and multi-purpose passenger vehicles.

3. *Definitions*

   "Authorizing Code" means a combination of numbers or signals manually applied to or stored on a code-insertion device which permits deactivation of the theft-protection system.

   "Critical Function" means a vehicle function necessary to the controlled self-mobilization of the vehicle.

4. *Requirements*

4.1 Each vehicle shall have a theft-protection system that, when activated, will prevent —

(a) controlled self-mobilization of the vehicle, and

(b) defeat by a test subject without advance knowledge of the authorizing code within a period of 10 minutes using tools that are man-portable to the attack scene.

4.2 The theft-protection system required by 4.1 shall be designed to activate automatically when the driver shuts off the engine and leaves the vehicle in such a way that no function critical to safe operation can be locked inadvertently while the vehicle is in motion.

4.3 If a removable code-insertion device is used, the system required by 4.1 shall not be capable of retaining the device in the OFF or LOCKED state.

4.4 The number of different authorizing codes for the system required by 4.1 of each manufacturer shall be at least 1000, each with a frequency of occurrence of approximately 1 per 1000 vehicles.

ALTERNATIVE B — LIMITED ACCESSIBILITY

1. *Purpose and Scope*

This standard specifies requirements for theft protection to reduce the incidence of accidents resulting from unauthorized use.

2. *Application*

This standard applies to passenger cars, light trucks, and multi-purpose passenger vehicles.

3. *Definitions*

"Authorizing Code" means a combination of numbers or signals manually applied to or stored on a code-insertion device which permits deactivation of the theft-protection system.

"Critical Function" means a vehicle function necessary to the controlled self-mobilization of the vehicle.

"Decoder" means a device which responds to the authorizing code to deactivate the theft-protection system.

"Latch" means a locking device which prevents some vehicle function critical to controlled self-mobilization of the vehicle, unless deactivated by the decoder.

4. *Requirements*

4.1 Each vehicle shall have a theft-protection system that, when activated, will prevent controlled self-mobilization of the vehicle by a person without the authorizing code.

4.2 The vulnerable elements in the system required by 4.1, including the decoder, latch, and any signal path carrying a simple lock-unlock signal shall be located —

(a) in a major engine, drivetrain, or control system housing, and

(b) in such a place as to be accessible for mechanical attack or disassembly only from underneath the vehicle.

4.3 The standard time allowed for warranty removal and replacement of the housing of 4.2(a) shall be 10 minutes or more.

4.4 The theft-protection system required by 4.1 shall activate automatically when the driver shuts off the engine and leaves the vehicle in such a way that no function critical to safe operation can be locked inadvertently while the vehicle is in motion.

4.5 If a removable code-insertion device is used, the system required by 4.1 shall not be capable of retaining the device in the OFF or LOCKED state.

4.6 The number of different authorizing codes for the system required by 4.1 of each manufacturer shall be at least 1000, each with a frequency of occurrence of approximately 1 per 1000 vehicles.

4.7 The authorizing code for the system of 4.1 shall be different from any code used for the door locks or other locks on the same vehicle and no code shall be recorded anywhere on the vehicle.

4.8 Once activated, the system of 4.1 shall remain passively activated independent of any power source.

6. CONCLUSIONS

The most important conclusion from the vehicle theft survey is that the combined cost of amateur joy-rider and small-time stripper theft is more than $1 billion annually. Thus, amateur theft alone costs $100 to $130 per vehicle over a 10-year vehicle life.

Moreover, these thefts are being accomplished with readily available tools and no special technical capabilities. Most cars can be stolen in less than 2 minutes; many in 30 to 60 seconds. Most of these thefts could be deterred by an anti-theft system that requires at least 10 minutes or a tow truck to defeat.

The salient technical conclusion that can be drawn from the results of the design study is that cost-effective anti-theft systems which can be expected to reduce the number of automobile thefts drastically are entirely feasible as factory-installed devices. At least one such design concept has been shown to result in a consumer price increase which is below $36 and a defeat time, without a tow truck of well over 10 minutes.

However, to mandate the result by safety standard requires the inclusion of effective attack resistance criteria in the standard. The most direct — and least design-restrictive — way to accomplish this is to specify a minimum defeat-time. This, of course, results in compliance testing problems. Unfortunately, the only alternative is to specify objective requirements concerning packaging and accessibility of the vulnerable elements of the system. This alternative is inherently more design-restrictive.

7. RECOMMENDATIONS

One objective of this program was, of course, the recommendation of improvements for FMVSS No. 114. These have been made in Chapter 5. However, the research and development work also suggests a number of specific areas where further work is desirable to improve anti-theft technology and the standard against which the systems are measured. These are as follows:

- *Development Testing* — A production prototype system, packaged as a production unit, should be developed and tested rigorously, using every possible method of attack to establish the minimum defeat time.
- *Field Testing* — A phased field test program is recommended with a careful initial study to ensure that meaningful conclusions will follow from the results.
- *Tamper Detector Development* — A design and development program is recommended to implement the promising tamper detector approach which has the potential advantage of a low-cost modification to the current type of lock.
- *Development of Defeat Time Testing* — A study is recommended to obtain the required information and opinion on defeat-time compliance testing and to design the technical test methods.