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High Security Locking Devices
A State-of-the-Art Report

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Environmental Design Research Division
Washington, DC 20234

June 1981

Issued January 1982

Prepared for:
Civil Engineering Laboratory
Naval Construction Battalion Center
Port Hueneme, CA 93040

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John S. Stroik

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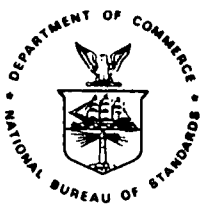

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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ABSTRACT

An investigation was made of available non-military literature and information on high security, unexposed locking devices used on doors in order to identify and document the present state of the art of these devices and systems. Locking devices were investigated both as overall systems and as sub-system components, with existing categories of lock types presented. A new classification system for locks is also presented as a framework for future research and development. Locks are classified by their installation, operation and component characteristics. Intended to provide an overview of available commercial locking devices for the uninitiated researcher as well as anyone interested in the field of locking device design, the report also makes recommendations for future lock development. A glossary of technical terms is included together wth appendices containing an anotated bibliography, notes on master keying and annotated lists of standards, specifications, organizations and manufacturers.

Key Words: Door security; entry control; hardware; locking device classification; lock operation, installation, and characteristics.

Certain commercial equipment and sources are identified in this report in order to make it more useful to the reader. Such identification does not imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the equipment identified is necessarily the best or only available equipment for the purpose described.

The points of view or opinions expressed in this report are those of the author or individuals to whom they are ascribed, and do not necessarily reflect the official positions of either the National Bureau of Standards, the Civil Engineering Laboratory or the Defense Nuclear Agency.

Preface

This report, though limited in scope, provides a framework for understanding prime aspects involved in the design of high-security locking devices. In addition to investigating available literature, requests for information were sent to 282 manufacturers and distributors of equipment; 79 companies responded. Follow-up phone calls and visits were made to some users and manufacturers for additional information. Much information on locks is proprietary, therefore many manufacturers and distributors are not willing to submit anything more than catalogue sales information. This information varies widely in detail. Consequently some devices are more elaborately described than others. The reader is advised to pursue more detailed information on particular devices directly with the manufacturers.

Acknowledgments

In addition to the manufacturers listed in Appendix G, the author appreciates the assistance of the following individuals during the collection of information for this report: Russel Barber, Secret Service; Robert Barnard Department of Defense, Army; Marvin Beasley, Defense Nuclear Agency; Richard Blackmon, Nuclear Regulatory Commission; C. R. Bukholt, Department of Defense, Navy; L. D. Chapman, Sandia Laboratories; Francis Chase, National Bureau of Standards; Jerry Connally; Lawrence Eliason National Bureau of Standards; Robert Ghetti, Department of Energy; Louis Ganzales, General Electric Tempo; Richard Hudnut, Builders Hardware Manufacturers Assoc. Allen LaPointe, Lockmasters; Milton Madsen, Sandia Laboratories; Raymond Moore, National Bureau of Standards; Jake Rabinow, National Bureau of Standards; Bill Reed, Locksmith Ledger; Terry Ruddick, Central Intelligence Agency; Robert Ruhf, Department of the Treasury; G. W. Saunders, Underwriters' Laboratory; Harvey Schock; LaDonna Short, Department of Defense Army; Bruce Varnado, Sandia Laboratories; Russ Waller, Department of State; Stan Wakamiya, National Bureau of Standards; Robert Walker, Central Intelligence Agency; Joseph Williams, Sandia Laboratories.

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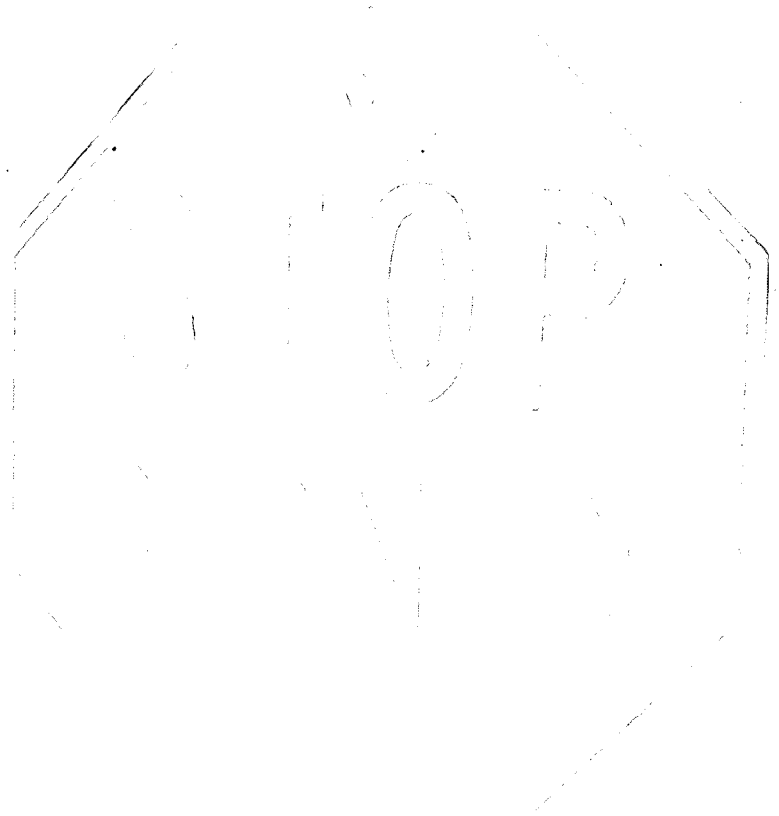


1. INTRODUCTION

Given the number of available locking devices, and the resulting confusion this can create for the uninitiated, this report presents the first systematic review of locking devices as a tool for further investigation and research. In preparing this comprehensive examination of the state of the art of high security locking devices, the author has generated a classification system that subsumes the many existing groupings of locks. This lock classification is used as a framework for describing and illustrating the many factors that differentiate locking devices and affect their performance as part of security systems.

This report has seven chapters followed by a glossary of technical terms and appendices. The first chapter describes the origin, goals and specific limitations of the scope of the overall project. The second chapter describes locking devices starting with conceptual approaches and leading to descriptions of operations of components and sub-components of locks. A classification of locking devices in chapter three forms a framework for relating lock design and operation factors. These factors are divided into installation types, operation types and component characteristics. Chapter four describes and illustrates the group of locks listed under Installation Types. The major grouping of locks entitled Operation Types is described and illustrated in chapter five. Chapter six includes descriptions of the lock component characteristics that are often used to differentiate or name particular groups of locks as well as simply explain the design of the component. These are suggestions for further research and development in chapter seven, together with a summary and conclusion. A glossary of technical terms follows, together with appendices on locating of further material.

1.1 BACKGROUND

Doors are the principal means of unauthorized surreptitious and forced entries into buildings/spaces. Doors are generally the "weak link" in a building security system and offer less penetration resistance than the other structural components except for windows. Thus, the doors on most existing nuclear weapons maintenance and inspection buildings and storage structures offer a much lower level of resistance to unauthorized entry than the structures in which they are installed. Relocking systems are available that will firmly lock the doors in place automatically if the doors are physically attacked. However, most doors are not now equipped with these mechanisms. By contrast, the typical standard high security locking system for the military (consisting of a "high security" hasp and padlock, in most installations) exposes the locking hardware to forcible and surreptitious entry attack, sabotage, and the rigors of the natural environment. Such systems can be rapidly defeated by the use of force and are prone to malfunction and/or lockouts due to the effects of corrosion, dust and freezing weather.

The Department of Defense (DoD) and the Department of Energy (DoE) are interested in new approaches for securing openings which will be significantly more reliable and which will significantly increase forced entry denial time.

1.2 GOALS AND OBJECTIVES

This report's primary goal is to identify and document the present state of the art of non-military high security internal locking systems for doors in order to assist with the development of improved high security locking devices. The sponsors anticipate that directly applicable concepts or technical approaches can be drawn from such an examination and that the availability and use of this information could eliminate the necessity for original research and development in some areas. In order to comprehensively cover a multidisciplinary field such as the design of locking devices

one must investigate all levels of performance and all aspects of lock development. The end objective of the overall research and development effort that this report supports is the development of a locking system for sensitive ordnance structures, among others, which will provide significantly more resistance to attack than the surface-mounted padlock and hasp systems presently in use. Major portions of the necessary investigation are included in other concurrent studies sponsored by the DoD and the DoE. This report is designed to provide an overview of the different types of locking devices available and to explain their physical design and operation. Additional objectives of this report include: the identification of specific new locking systems or subsystems that can be directly applied to high security magazine entrance closures in a practical manner; the identification of locking systems presently in use in private, commercial, institutional and government facilities; the preparation of an annotated source list/ bibliography; the preparation of a state-of-the-art study in a systematic and comprehensive manner.

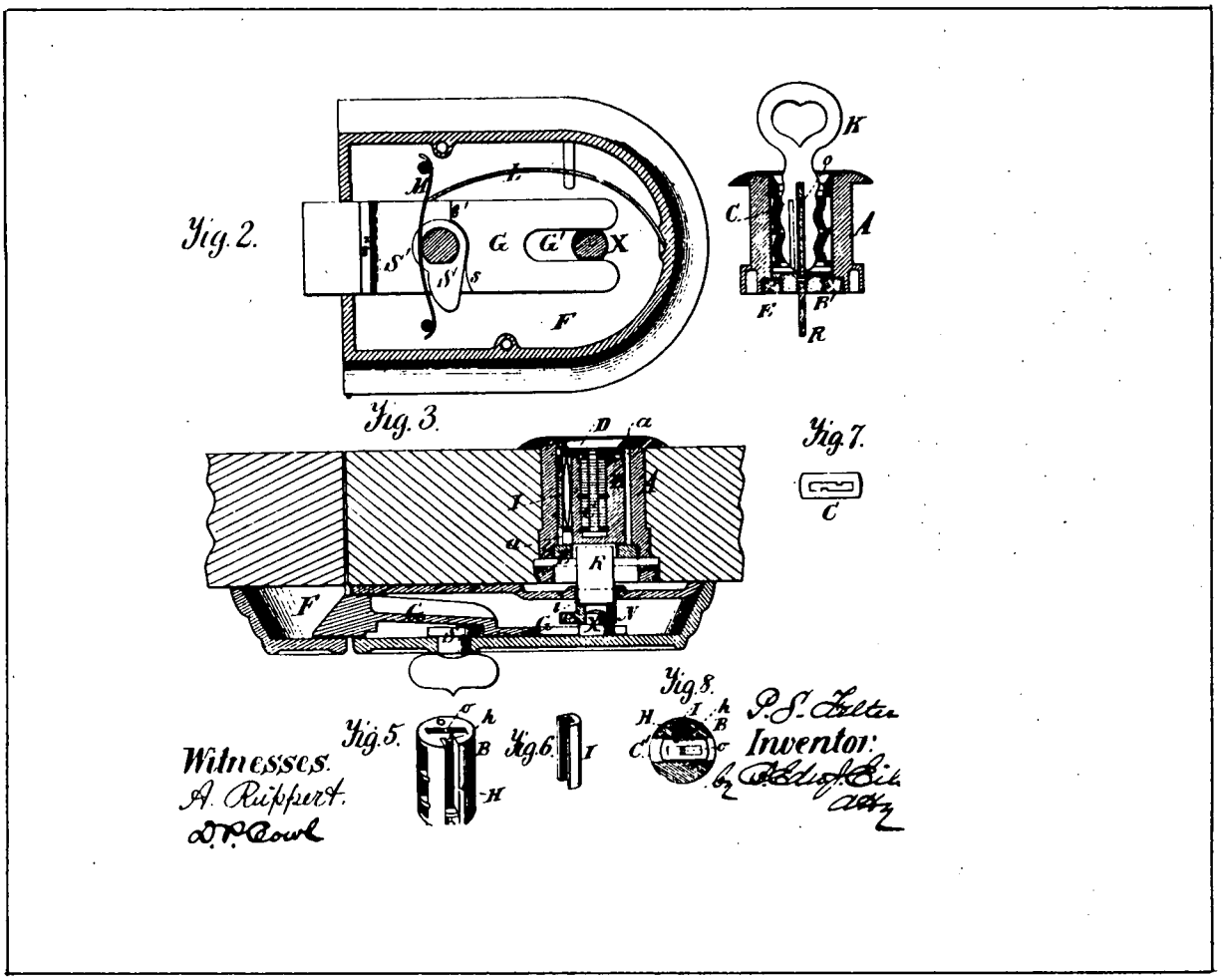
1.3 SCOPE AND METHOD

This project focused on the present state of the art of all types of locking systems and subsystems that are built into doors, and that provide significant resistance to surreptitious and forced entry attacks. Tasks included a literature review, communication and visits with lock manufacturers and users, and particular requests for technical information of the lock manufacturers.

The information in this report provides a database in support of the development of new and/or improved concepts for securing magazine entrance closures. For this reason, it is comprehensive. That is, it includes descriptions of almost all lock systems including some of low security. Even low security locks could include an approach that is applicable, with modification, to more serious needs.

The sponsor limited the study to those devices used in non-DoD governmental, commercial, institutional and industrial settings. This report excludes padlocks, foreign devices not marketed in the U.S., and miscellaneous information on lock trim and superficial features. This report does not address attack methods nor the overall security system of a facility in any detail; instead, the author has concentrated on those factors that differentiate locking devices themselves.

Patent drawing for side bar lock invented by Philo Felter in 1875.



2. REVIEW OF LOCKING DEVICES

Locks come in many forms and have varied uses. They range from a simple hook and eye on a screen door to massive boltworks on a large vault door. Locks are given names according to how they operate, where they are located or what they are expected to do. Locks always have been considered a major component in any physical security system. Indeed, locks continue to fascinate people, particularly because of their inherent puzzle and mystery [13,14].[1] The lock inventor, in effect, raises a challenge to discover

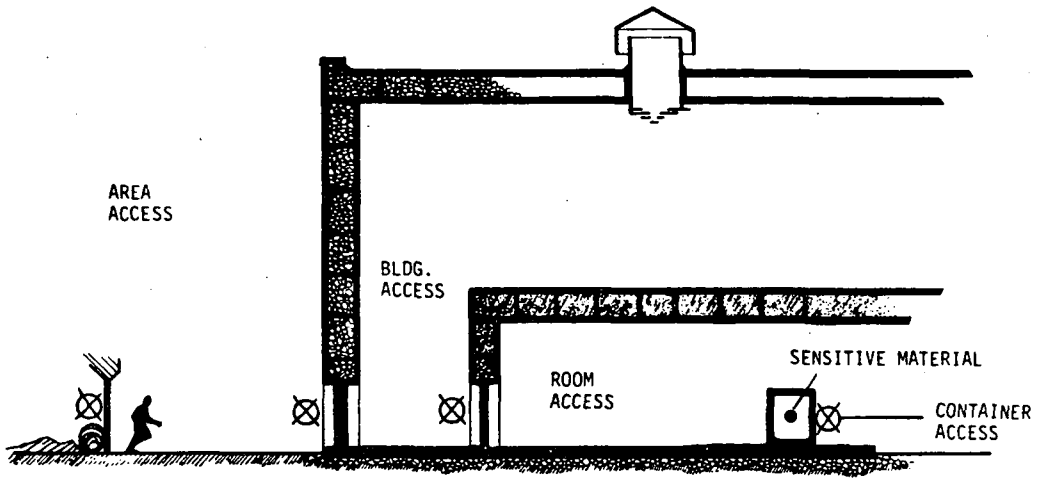
[1] Numbers in brackets indicate references listed at the end of this report.

a solution to his fabricated puzzle. This challenge, over the years, has been accepted eagerly by individuals, other inventors [24] and criminals. The high burglary rates illustrate the criminals' reaction to this challenge. Criminals have become more sophisticated, together with society in general, and have applied pressure on the manufacturers of locking devices [18]. That inventors have accepted this challenge is evident by the great number of patents issued for locks during the past. More patents have been issued for locks than for most other products in the world [28].

This chapter describes locking devices in conceptual terms, presents selected terminology and categories used by the lock industry and others, and presents a brief summary of lock functions and grades. This chapter presents an overview; more detailed descriptions are in the chapters that follow.

2.1 GENERAL DESCRIPTION OF LOCKS

The lock is a small, albeit important, part of the overall security system. Any facility has particular security functions that must be viewed as a total system with a particular structure and set of variables in dynamic relationships [23]. Systems analysis and decision theory have a fundamental part in the design of the overall security system, and the physical locking device is designed to simply delay an adversary while the response forces act to intercept or neutralize the adversary's actions [6]. The detection systems, probable attack modes, and speed of response will have a bearing on the ideal strength and operation of the lock. In addition, factors such as convenience, materials and methods of installation and and maintenance, directly affect the detailed design and cost of the lock.



LOCK LOCATIONS FOR DELAYING AN ADVERSARY ⊗

A lock is defined in Webster's Dictionary as "a fastening (as for a door, box trunk, lid, drawer) in which a bolt is secured by any of various mechanisms and can be released by inserting and turning a key or operating a special device (as a combination, time clock, automatic release button, magnetic solenoid)". A more inclusive definition of a lock is provided by Haberman [12]: "a hardware component of a door (or like) system which performs two important functions: fastening two or more components together, and allowing access by means of the locking and unlocking functions." This definition has the advantage of including locks such as electromagnetic locks and personal characteristics verification systems (i.e.: fingerprint verification). The purpose of a lock is to prevent unauthorized individuals from gaining access to property or the control of people or things. This aim is usually accomplished by designing an assembly composed of five basic parts or components: 1) the BOLT, 2) the BOLT RETAINER or STRIKE, 3) the BOLT ACTUATING MECHANISM, 4) the OBSTACLE, 5) the KEY/CODE.

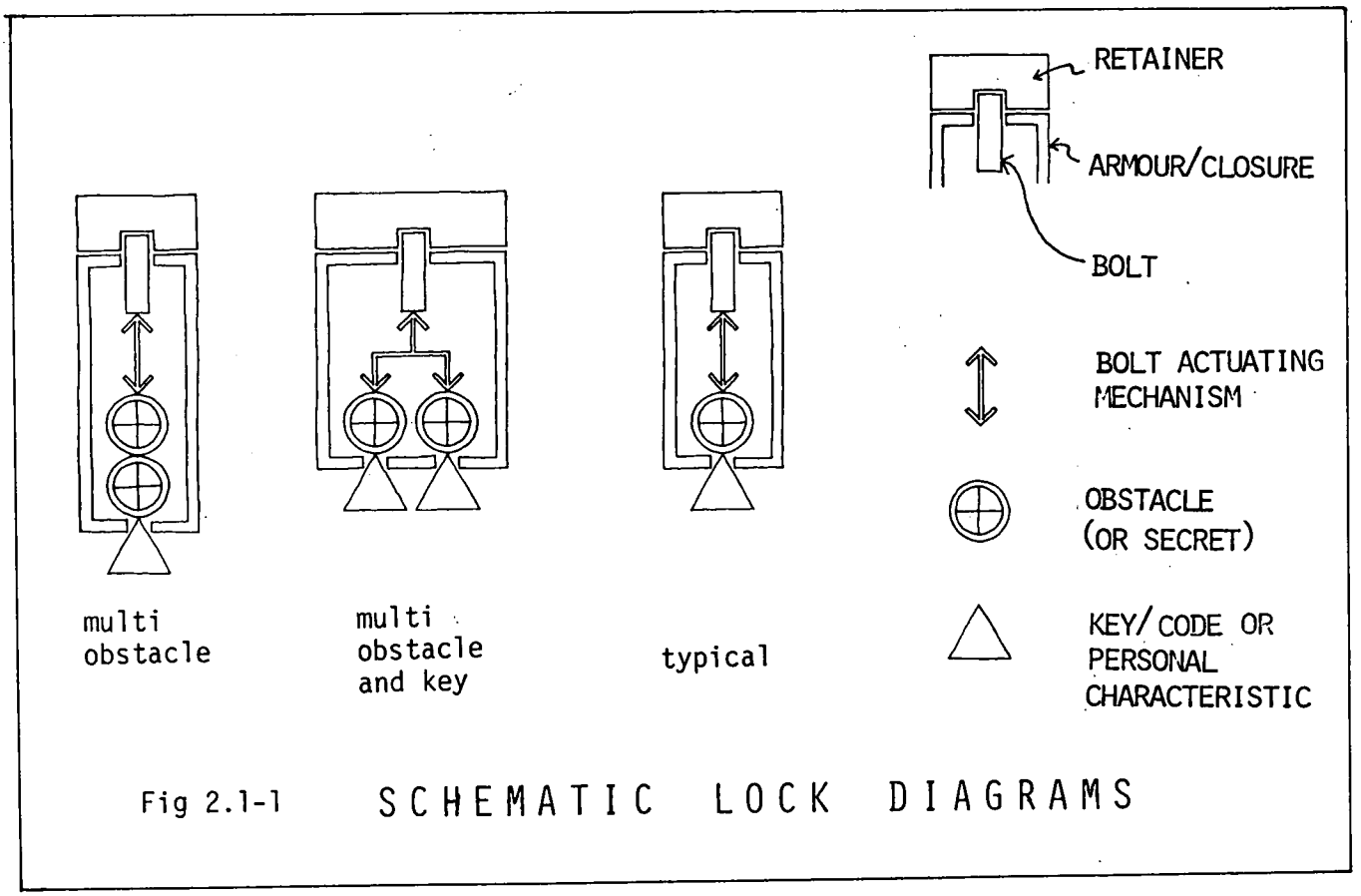


Fig 2.1-1 SCHEMATIC LOCK DIAGRAMS

The assembly is attached to the appropriate parts of a doorway, container or other object is such a way as to allow access only to the person presenting the correct key or code which removes the obstacle, which in turn allows the bolt actuating mechanism to move the bolt out of its retainer

(see Chapter 6, Component Characteristics). Locks place at least one obstacle between the user and the bolt actuating mechanism. The obstacle is any device, method, or combination of devices and methods that limits the operation of the lock to selected individuals. Unless the obstacle(s) can be removed, the bolt remains inoperable. If the bolt and retainer are appropriate in strength and securely installed, it is clear that the critical component of every lock is the obstacle. Designed integrally with the obstacle is the key or code, which contains a set of unique characteristics or secrets that alone can be used to remove the obstacle. Codes also include personal characteristics, such as fingerprints and voice, which are used in some electronic locking systems. The bolt actuating mechanism is any method of physically moving the bolt in and out of its retainer, and includes levers, gears, cams, electric solenoids, etc. The bolt is that part of a lock that secures the movable object (such as door) to a fixed object (such as the frame). The fixed object usually has a bolt retainer or strike attached to it which receives the bolt. Design variations of these components make up the basic differences in locking devices.

2.2 TYPES OF LOCKING DEVICES

The lock industry is diverse and consists of overlapping groups dependent on market demands and constraints. If electronic security devices are included, manufacturers of locking devices and components number well over a thousand. The market for locking devices includes: access control; banks; residential and builders' hardware; commercial; high security; institutional; national defense; transportation. All these markets share a common denominator, the requirement that locking devices resist intruders, and all borrow from the long and rich tradition of locksmithing [16].

Over a period of many years, various industry groups and associations have classified lock types based on particular market demands. This typology has evolved through experience, ad hoc agreements, tradition and sometimes careful consensus. The groupings most commnoly used at ths time are those established or encouraged by the Builders' Hardware Manufacturers Association (BHMA), the Locksmith Ledger (a trade journal), the Federal Government, the American National Standards Institute (ANSI), and, to a lesser degree, other institutions and agencies (see Appendix C, National Organizations).

2.2.1 BHMA

The builders' hardware industry categorizes locks into:

Mortise (series 1000), Preassembled (series 2000), Integral (series 3000), Bored (series 4000), Interconnected Bored, and Auxiliary locks. These names, except for Auxiliary locks which include most other descriptors, describe the design of locks in relation to installation methods. [1,3,5]

2.2.2 Locksmith Ledger

The Locksmith Ledger [17] categorizes locks by industry markets, as follows:

Bank Security Equipment

- Combination Vault and Safe Locks
- Electrical Locks
- Electrical Time Locks
- Mechanical Locks
- Mechanical Time Locks
- Safe Deposit Boxes
- Tear Gas Devices

Builders Hardware

- Door Bolts
- Door Guards
- Electric Door Openers
- Flush Bolts
- Lock Shields
- Mechanical Door Openers
- Strikes

Electric and Electronic Security Items

- Automatic Gate Controls
- Card Operated Locks
- Electrical Bank Locks
- Electrical Door Openers
- Electrical Keyless Locks
- Electrical Pushbutton Door Locks
- Electrical Time Locks
- Electric and Electronic Locks
- Electric Prison Locks
- Electro-Magnetic Locks
- Electro-Magnetic Strikes
- High Security Electrical Locks
- Recording Lock

Lock Devices

- Auxiliary Locks
- Combination Locks (not safes or vaults)
- Cylindrical Locks
- Deadbolt Locks
- Electrical Bank Locks
- High Security Electrical Locks
- High Security Mechanical Locks
- High Security Replacement Cylinders
- Lock Control Systems
- Mechanical Bank Locks
- Mechanical Carage Door Locks
- Mechanical Keyless Locks
- Mechanical Magnetic Locks
- Mechanical Pushbutton Door Locks
- Mechanical Time Locks
- Electrical Garage Door Locks
- Electrical Keyless Locks
- Electrical Pushbutton Door Locks
- Electrical Time Locks
- Electrical Vending Machine Locks
- Electro-Magnetic Locks
- Mechanical Vending Machine Locks
- Mortise Deadlocks
- Mortise Locks
- Mortise Nightlatches
- Rim Locks
- Rim and Mortise Cylinders
- Rim or Surface Deadlocks
- Rim or Surface Nightlatches
- Tubular Locks

Safes, Vaults

Bank Safes	Safe Deposit Box Locks
Burglar-Resistant Safes	Vault Doors
Safe and Vault Locks	

2.2.3 U.S. Patent Office

Patents on locks (called Class 70 Patents by the U.S. Patent Offic) include over 490 headings that describe locks and lock parts in various ways.[1] An excerpt follows of first level headings and second level sub-headings. The number in parentheses is the heading number; number after + is the number of lower level headings under that particular heading. The lower level headings are not included in this excerpt. The Patent Office also includes manual bolts and the like in a separate class, Class 292 - Closure Fasteners.

Class 70 - LOCKS

Miscellaneous (1) +0
Attack-Actuated Defeating Mechanisms (1.5) +0
  With reset mechanisms (1.7) +0
Hasp (2) +0
  Combination lock (3) +2
  Key lock (6) +7
Portable (14) +0
  Fetters (15) +3

  Clamps (19) +0
  Padlocks (20) +36
Special Application (57) +0
  For portable articles (58) +18
  For closures (77) +185
  For control and machine elements (174) + 87
Systems (262) +0
  Operation and control (263) +2
Operating Mechanism (266) +0
  Predetermined time interval controlled (267) +7
  Motor (275) +8
  Combination and key (284) +0
  Combination or key (285) +0
  Combination (286) +49
  Key (336) +94
Parts, attachments, Accessories and Adjuncts (431) +0
  Condition indicators (432) +9
  For combination-operated mechanism (442) +4
  For key-operated mechanism (447) +14

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[1] U.S. Patents Index, U.S. Patent Office, Washington, D.C., 1979

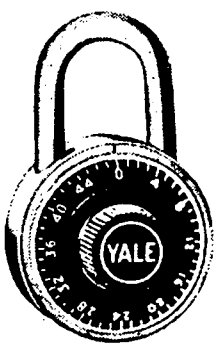
Adjustment provisions (461) +0
Reversible structures (462) +0
Silencers or mufflers (463) +0
Antifriction provisions (464) +0
Energency unlocking or release arrangements (465) +0
Mounting aids, guides and assistors (466) +0

2.2.4 Other

Locks have been categorized by Williams [31] into Key locks and Keyless locks. Key locks include: Warded locks, Wafer locks, Pin-Tumbler locks, Lever locks, and variations of the above. Under Keyless locks he includes: Combination locks, Mechanical Coded locks and Electronic Coded locks. Haberman [12] classifies locks into Mechanical, Electro-Magnetic and Switch locks. Mechanical locks include the Fixed Labyrinth or Warded locks and the Movable Labyrinth or Tumbler locks. Tumbler locks are further differentiated into Disc Tumbler, Pin Tumbler and Lever Tumbler locks. Haberman, separately categorizes a group of locks into Code Combination and Card locks. The Code Combination locks include Mechanical and Electronic types. The Card locks include Magnetic, Capacitive, Embossed, Radio Frequency and Code Circuitry types. Haberman suggests that crucial to any access control is the method of verifying the identify of individuals cleared for access and there are three basic methods (illustrated below) by which the identity of an individual may be established:

1. Something known by the individual (code, password, etc.)
2. Something possessed by the individual (key, identification, etc.)
3. Some characteristic of the individual (voice, fingerprints, etc.)

The reader is probably familiar with the first two methods. The combination lock illustrates the first method and the key for the lock to the car or the front door illustrates the second method. The third method is the object of recent study to develop automated verification systems using sophisticated electronic equipment to verify personal characteristics.



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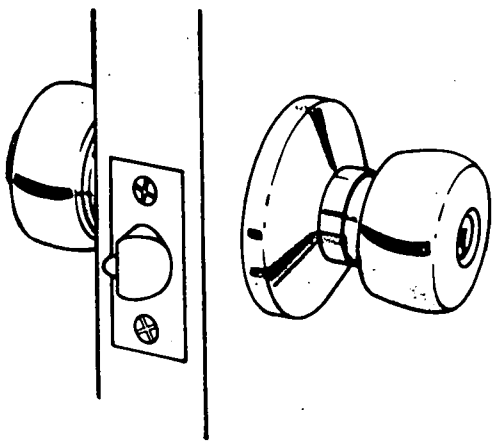

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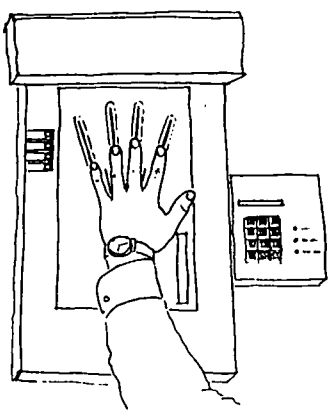


3.

There are additional classifications by manufacturers, consumers and lexicographers. M. J. Roberts in the Construction Industry Thesaurus [25], groups locks by their portability, position, operating position, operating parts, agents of operation and use. A draft thesaurus compiled by members of ASTM Committe F-12 on Security Systems and Equipment broadly divides locks acording to 74 common names including Combination, Double Bitted, Key-In-Knob, Mortise, Rim, Time, Tubular, Two-Point, and many that are not mutually exclusive.

The groupings described above are being used in the market place and serve a useful purpose in differentiating one lock from another for the purchaser and the specification writer. However, none of the available classifications is either comprehensive enough, or concise and consistent enough in a taxonomic sense, to be helpful to the researcher or development engineer [11].

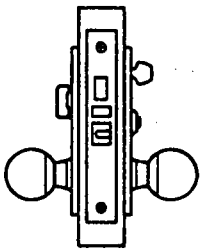
FUNCTIONS FOR
KEY-IN-KNOB LOCK

a) key and turn button
b) single cylinder
c) key and push button
d) push button
e) communicating doorset
f) exit latch
g) plain latch
h) right latch
i) cupboard set
j) double cylinder
k) wardrobe set
l) hotel bedroom doorset
m) lockset adaptor

2.3 LOCK FUNCTIONS

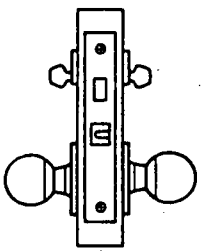
A lock function describes the functional operation of the lock in as much detail as necessary to provide the purchaser with information on exactly which features are included in a particular lock. The lock function is particularly important for specifying locks and can be effective in increasing or decreasing the security performance of a lock. Lock function is usually expressed as an ANSI function classification number [1,3,4,5] or a manufacturer's code number and descriptive title. An understanding of the function features of locks is essential since many of these functions modify the lock and change its operation. For example, a particular manufacturer lists a "Hotel-Motel" function mortise lock to have the following features:

° Guard Bolt deadlocks latch bolt.
° Latch bolt by key outside, knob inside.
° Outside knob always rigid.
° Projecting dead bolt from inside by turn lever or emergency key outside when door is closed shuts out all keys except emergency key.
° Inside knob retracts latch bolt and dead bolt simultaneously.
° Indicator button No. 9 available on order. When dead bolt is projected by inside turn lever, button cannot be pushed in (indicating room is occupied).



The same manufacturer lists a "Storeroom" function mortise lock to have the following features:

° Latch bolt by either knob.
° Dead bolt operated from either side by key.
° Inside knob does not retract dead bolt.



Lock functions vary according to specific needs for lock operations at particular locations. The available function variations can be separated into two groups: 1) lock face variations; 2) outside/inside variations. These function variations are provided, as required, either singly or in combinations. They can be interconnected or interrelated operationally depending on need. Taking the first example above, the Hotel-Motel lock, Table 2.3-1 illustrates the particular relationships required for that lock. Other lock functions can be similarly illustrated.

Table 2.3-1 Function Variations Matrix
Example of Hotel-Motel Lock Function

Outside (0)/Inside (I) Components		Lock Face Components	Latch Bolt	Guard Bolt	Dead Bolt	Stop Button or Toggle	Deadlocking Latchbolt	Split Dead Bolt
			✓*	✓*	✓			
✓	Key (0)		X					
	Key (I)							
	Thumbpiece (0)							
	Thumbpiece (I)							
	Thumbturn (0)							
✓	Thumbturn (I)				X*			
	Knob (0)							
✓	Knob (I)		X		X			
	Lever (0)							
	Lever (I)							
	Key in Knob (0)							
	Key in Knob (I)							
	Push or Turn Button in Knob (0)							
	Push or Turn Button in Knob (I)							
✓	Rigid Knob (0)							
✓	Emergency Key (0)				X*			

Note

✓ = Components included
x = Operation relationship exists between different component groups
* = Interconnection exists in components of same group

Although many of the detailed function variations are provided for convenience of the user, many are designed to increase the effective security of the lock. The inoperative rigid outside knob of the Hotel-Motel lock above, for example, prevents the possibility of a knob torque attack (forcibly twisting) retracting the latch bolt. The separation of the guard bolt from the latch bolt is a fairly effective means of preventing a successful loiding attack (credit card) on the latch bolt. Similar items can be appreciated as methods to accomodate a convenience feature while still keeping the integrity of the lock. These items tend to make the lock more complicated, however, and possibly have more parts to maintain. Another feature of the locking system is master keying, which can have a serious effect on the security of the lock [15]. See appendix E, Master Keying.

2.4 LOCK GRADES

Locking devices are graded for performance in preventing unlawful entry (security), in operating for a considerable length of time (durability) and in preventing the spread of fire (safety).

A good example of lock grading for security is the NILECJ standard [33], a performance standard establishing requirements and methods of test for evaluating the resistance of door assemblies and components (including locks) to forced entry. This standard is published by the Department of Justice and is referenced in ANSI and ASTM standards [1,3,4,5,26]. The performance criteria were established by analysis of available data on burglary methods, by duplication and measurements of the burglary attacks, and finally duplicating the results of the attacks by laboratory tests. There are four classes of resistance. Class I includes attributes for the lowest level of resistance; class IV include attributes for the highest level of resistance. Performance criteria and test methods are described in detail for determining: a) resistance of lock bolts, cylinders and strikes to dynamic and static forces, b) resistance of doors to dynamic forces, c) resistance of hinges to dynamic and static forces, d) resistance of door frames to static forces. Two classification methods are established, one for entire door assemblies, the other for door assembly components. This could serve as a model for the development of criteria for high security locking devices.

A summary of the security grades for locks is shown in table 2.4-1. Safes and vaults are classified according to their resistance to fire and burglary attack (see tables 2.4-2, 2.4-3, and 2.4-4). Locks can be obtained with a pick-resistance certification [32], and be tested for resistance to four levels of burglary attacks [33].

Although the obvious concern in high security locks is the prevention of unlawful entry, the problems involved in providing locks that are durable and safe can not be overlooked. The hardware industry has three grades for lock durability [5]. When used in fire barriers, locks must be certified as being able to continue to secure a labeled fire door for a specific length of time during a fire [21]. The design and materials of locks contribute or detract from security needs, depending on the priorities placed on factors such as cost, convenience (see 2.3 Lock Functions), maintenance, and fire safety. Information on these factors can be obtained from the references included in appendix B, Standards and Specifications.

Table 2.4-1 Security Grades for Locks

Standard	Grade	Description*
UL 437 Key Locks	Key Cylinder	Have at least 1000 key changes and at least .0625 cm (0.025 inch) difference in bitting depths, be able to resist picking, drilling and chiseling for at least 10 minutes.
	Jimmy Resisting Lock	As above plus resist: spreading 2" with a 3 foot jimmy, sawing the bolt and pulling the cylinder during 10 minutes of attack.
	Two-Key Lock	15,000 customer key changes and 64 guard key changes; resist for 45 minutes: picking, rotary force on chisel, and other tests suggested by experts.
UL 768 Combination Locks	Group 1	Resist for 20 hours of manipulation including use of instruments under 22.7 kg (50 lbs) in weight. Provide mechanical bolt immobilization when lock punched. Tolerances of 1 dial graduation for three tumbler locks and 1-1/4 dial graduations for four-tumbler locks.
	Group 1R	As above, plus resist radiological attack for 20 hours.
	Group 2	Tolerances of 1-1/4 dial graduations for three-tumbler locks and 1-1/2 dial graduations for four-tumbler locks.
NILECJ-STD-0306.0 Door Assemblies and Components	Class 1	Cylinder Core Tension - 1,300 N (290 lbf); Bolt Impact - 2 blows 80 J (59 ft lbf).
	Class II	Cylinder Core Tension - 4,800 N (1,080 lbf); Bolt Impact - Class I, plus 2 blows 120 J (89 ft lbf).
	Class III	Cylinder Core Tension - 11,000 N (2,470 lbf); Cylinder Torque - 1- Nm (81 lbf-ft); Cylinder Impact-Five blows 100 J (74 ft-lbf); Bolt Impact-Class II, plus 2 blows 160 J (118 ft lbf)
	Class IV	Cylinder Core Tension - 11,000 N (2,470 lbf); Cylinder Body Tension - 16,000 N (3,600 lbf); Cylinder Torque - 160 Nm (118 lbf-ft); Cylinder Impact-ten blows 100 J (74 ft lbf) Bolt Impact-Class III, plus 2 blows 200 J (148 ft lbf).

*Only primary requirements are included; consult the standards for complete requirements.

Table 2.4-2 Comparative Classification for Burglary - Resistive Safes

Bank Safe Classifications (As Specified by Ins. Services Office)			Commercial U. L. Equivalents		
Class	Door Thick.	Safe Wall Construction	Class	Door Thick.	Safe Wall Construction
A	Less than 1"	Less than 1/2" of Steel or Iron	B (Fire)	Less than 1"	Less than 1/2" of Steel or Iron
B	At least 1"	At least 1/2" of Steel	C	At least 1"	At least 1/2" of Steel
BR*	At least 1-1/2"	At least 1" of Steel	E*	At least 1-1/12"	At least 1" of Steel
	With TL-15 Burglary Label		ER*	With TL-15 Burglary Label	
G	1-1/2" round lug type	At least 1" of Steel Encased in at least 6" reinf. concrete & with 2-movement time-lock if outside of Bank Vault	** F	Safe bearing one of following U. L. Burglary Labels: TL-30; TR-30 or X-60	
	Safe bearing one of following U. L. Burglary Labels: TL-30; TR-30 or X-60				
H	Safe bearing one of following U. L. Burglary Labels: TX-60; TR-60 or TLTR-30		** G ** H	(Broad Form Safe Policy) (Mercantile Safe Policy) Safes bearing one of following U. L. Burglary Labels: TX-60: TR-60 or TLTR-30	
I	Safe bearing one of following U. L. Burglary Labels: TRTL-60 or TXTL-60		** G	(Broad Form Safe Policy) (Mercantile Safe Policy) Safe bearing one of following U. L. Burglary Labels: TRTL-60 or TXTL-60	

* Meets minimum requirements of Bank Protection Act and Credit Union Guidelines for safes.

** Exceeds minimum requirements of Bank Protection Act and Credit Union Guidelines for safes.

Table 2.4-3 GSA Approved Class 1-5-6 Security Containers

All units have 20 man hours resistance against lock manipulation and radiological attack.	
CLASS I	Insulated (1 hour) 10 minutes forced 30 minutes surreptitious
CLASS V	Not insulated 10 minutes forced 30 minutes surreptitious
CLASS VI	Not insulated No forced entry test requirement 30 minutes surreptitious

Class VI equipment is approved for storage of classified information including top secret. Insulation and forced entry features are not required.
Class II, III, and IV containers are no longer made

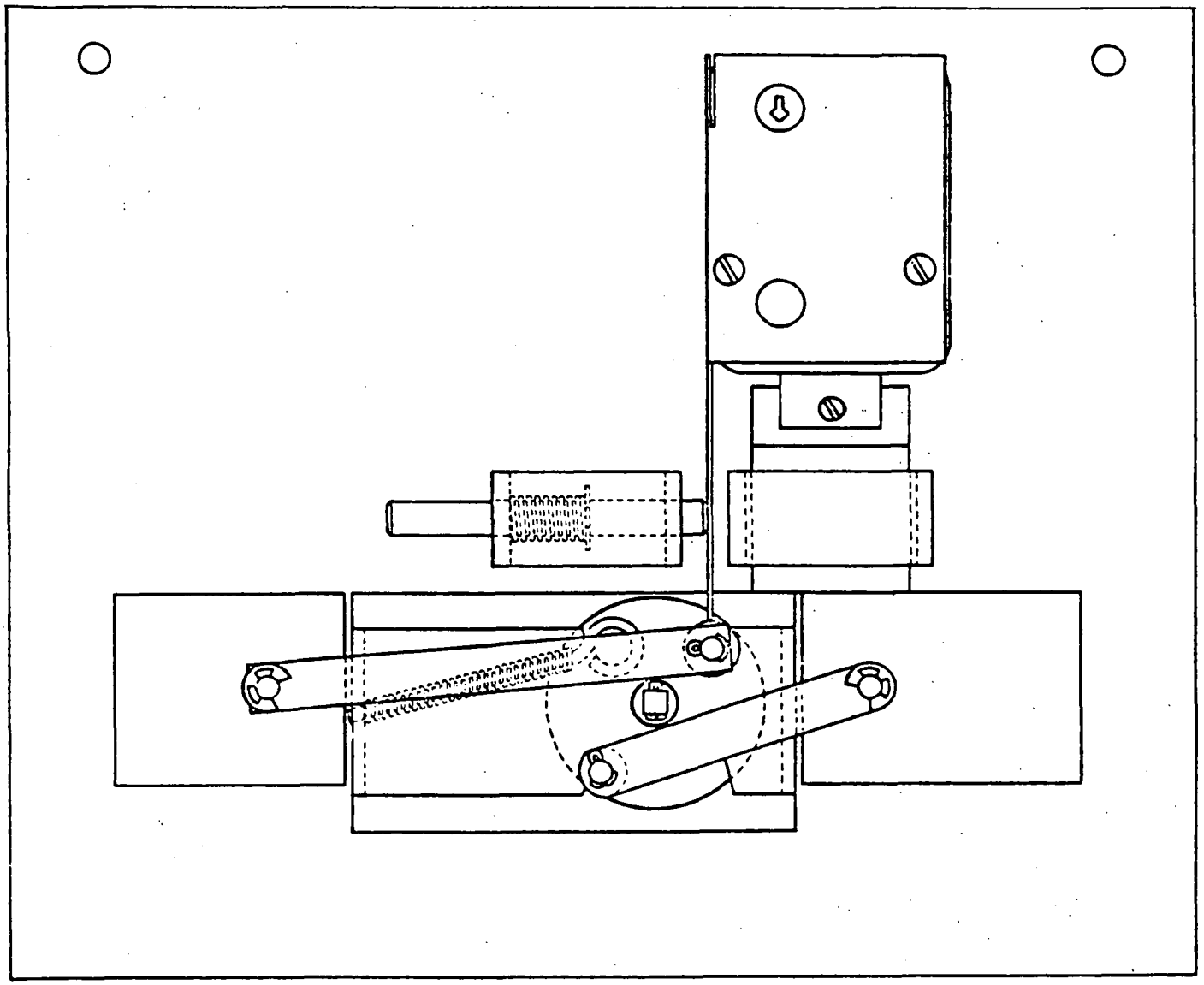
Table 2.4-4 Comparative Classifications for Security Vaults [Insurance Services Office]

Bank		
Class	Door Thick	Vault Wall (Optional) Construction
1	None - iron or steel	brick concrete stone iron or steel No thickness given
2		Eliminated
3	At least 2-1/2"	(a) 1/4" steel lining* or (b) 9" reinf. concrete
4	At least 2-1/2"	(a) 1/2" steel lining* (b) 1/4" S.L. & 9" reinf. conc.
5R	3-1/2"	(a) 1/2" steel lining* (b) 12" reinf. conc.
6R	3-1/2"	(a) 1" steel lining* (b) 1/2" S.L. & 12" reinf. conc. (c) 18" reinf. conc.
9R	7"	(a) 1" steel lining* (b) 1/2" S.L. & 12" reinf. conc. (c) 18" reinf. conc.
10R	9-1/2"	(a) 1-1/2" steel lining* (b) 1" S.L. & 12" reinf. conc. (c) 1/2" S.L. & 18" reinf. conc. (d) 27" reinf. conc. or 18" listed reinf. conc.
11 12 13	16" 20" 25"	Classifications 11, 12 & 13 are recommended by the Bank Vault Industry for construction of security vaults requiring additional protection.

Mercantile		
Class	Door Thick	Vault Wall Construction
B	Less than 1"	brick concrete stone tile of iron or steel No thickness given
C	At least 1"	1/2" steel lining or 9" reinf. conc. or stone; non-reinf. conc. or stone 12" thick
E	At least 1-1/2"	1/2" steel lining or 9" reinf. conc. or stone; non-reinf. conc. or stone 12" thick
E	At least 1-1/2"	1/2" steel lining or 9" reinf. conc. or stone; non-reinf. conc. or stone 12" thick
G	At least 3"	1/2" steel lining or 12" reinf. conc. or stone; non-reinf. conc. or stone 18" thick

* With fire resistant materials to meet local building codes.

Drawing of the inside of a safe door with a double bolt lock.



3. LOCK CLASSIFICATION

This chapter introduces a proposed lock classification system (table 3-1) that takes into account the systems described in chapter 2. Most of the terms in this new system are descriptors of characteristics of the lock's installation, operation or components. These three dimensions are the basic divisions of all lock types and serve to differentiate the locks from each other. This classification serves as an intellectual framework and should be particularly useful in the study, research and development of locking devices. It can be used as a comprehensive check list, a data retrieval system, a specification outline, a tool for analytic evaluation and a framework for standards. Much more comprehensive and less redundant than existing systems, this system is proposed as a replacement for the

TABLE 3-1 Lock Classification System

A. INSTALLATION TYPES

- A.1 Method
  - A.1.1 Internal
  - A.1.2 Surface
  - A.1.3 Dual
- A.2 Application
  - A.2.1 Doors
  - A.2.2 Containers
  - A.2.3 Other
- A.3 Purpose
  - A.3.1 Privacy
  - A.3.2 Safety
  - A.3.3 Control
  - A.3.4 Security

B. OPERATION TYPES

- B.1 Keyed Mechanical
  - B.1.1 Warded
  - B.1.2 Cylinder
  - B.1.3 Lever
  - B.1.4 Magnetic
- B.2 Keyless Mechanical
  - B.2.1 Manual & Passive Bolt
  - B.2.2 Wheel Tumbler
  - B.2.3 Coded Cipher
  - B.2.4 Time Lock
- B.3 Electrical
  - B.3.1 Electromagnetic
- B.4 Electro mechanical
  - B.4.1 Manually Encoded
  - B.4.2 Electronically Encoded
  - B.4.3 Personal Characteristics Verification
  - B.4.4 Others

C. COMPONENT CHARACTERISTICS

- C.1 Bolt
  - C.1.1 Shape
  - C.1.2 Number
  - C.1.3 Size
  - C.1.4 Movement
  - C.1.5 Material
- C.2 Strike/Retainer
  - C.2.1 Design
  - C.2.2 Material
- C.3 Bolt Actuating Mechanism
  - C.3.1 Mechanical Operation
  - C.3.2 Electrical Operation
  - C.3.3 Material
- C.4 Obstacle
  - C.4.1 Operation
  - C.4.2 Design Feature
  - C.4.3 Material
- C.5 Key/Code
  - C.5.1 Physical Differentiation
  - C.5.2 Manual
  - C.5.3 Electronic
  - C.5.4 Magnetic
  - C.5.5 Personal Differentiation
  - C.5.6 Material

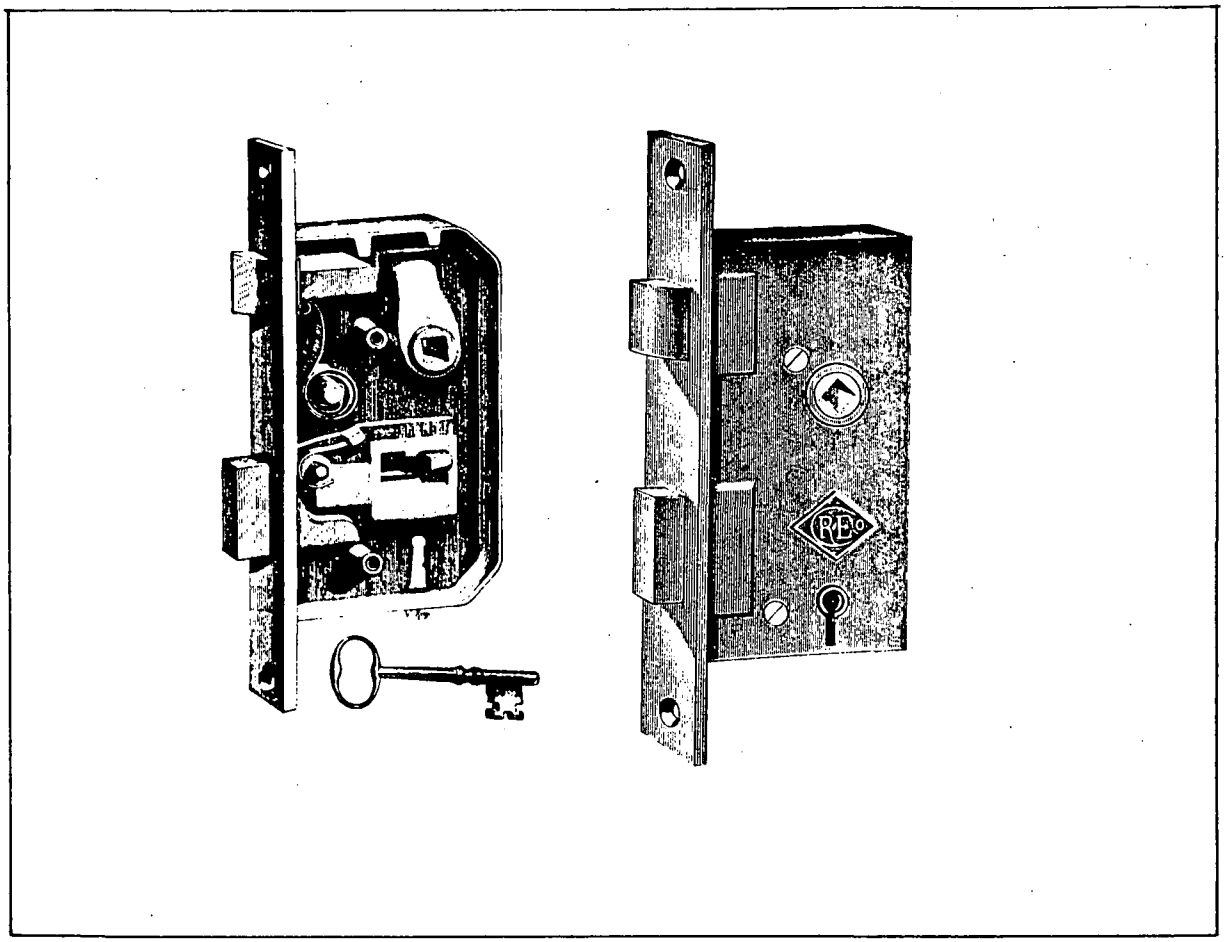
existing ones. Moreover, it is compatible with present methods used for evaluating and selecting locking devices, which should facilitate its use by the industry. The author is using this sytem as an ordering framework for this report, and the reader is encouraged to apply it to other uses, as noted above. It is hoped that this system can be refined with use and serve as a relevant tool for a common understanding of lock performance.

This lock classification system includes most of the technical terms presently used in the industry, though not in this structured form. Very few unfamiliar terms are used and these only where use of existing terms would be inappropriate or misleading. Emphasis is placed on those factors that differentiate locks from each other, and the resulting terms are either primary or secondary descriptors. The primary descriptors are the main headings listed under each group title (A.1-3, B.1-.5, C.1-.5). The secondary descriptors are the subheadings and lower subheadings. The lower subheadings include common names and are listed in the following chapters of this report. The Lock Type Availability Matrix, table 3-1, is presented to illustrate the presently available lock types included in this classification framework. This matrix can also be used to describe a particular lock together with further elaboration of the component characteristics (see chapter 6, Component Characteristics).

TABLE 3-1 Lock Type Availability Matrix

OPERATION TYPES	INSTALLATION TYPES	Method			Application			Purpose			
		Internal	Surface	Dual	Doors	Containers	Other	Privacy	Safety	Control	Security
Keyed Mechanical	Warded	X	X		X	X	X	X			
	Cylinder	X	X	X	X	X	X	X	X	X	X
	Lever	X	X		X		X	X			X
	Magnetic	X	X	X						X	X
Keyless Mechanical	Manual & Passive Bolt		X	X	X	X	X	X	X		X
	Wheel Tumbler	X			X	X	X				X
	Coded Cypher	X	X	X	X	X	X			X	X
	Time Lock	X			X	X					X
Elec.	Electromagnetic	X	X		X				X	X	X
Electro Mechanical	Manually Encoded	X	X		X					X	X
	Electronically Encoded	X	X		X					X	X
	Combined	X	X		X					X	X
	Personal Charac. Verification	X			X					X	X
	Other	X	X	X	X	X	X	X	X	X	X

MORTISE KNOB LOCK
Illustration from 1883 Catalogue,
by Russel & Erwin Mfg. Co.



4. INSTALLATION TYPES

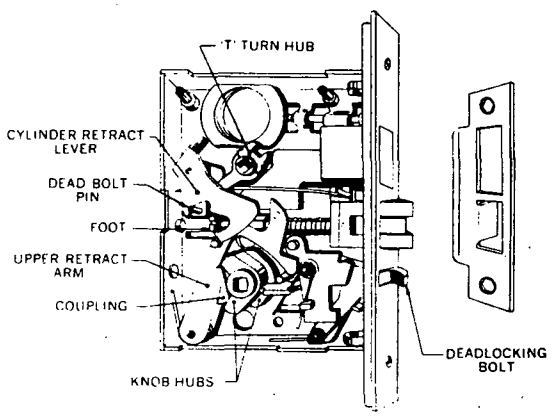
Door locks are generically described according to the method (or HOW) of installation, the application (or WHAT) of installation, and the purpose (or WHY) of installation. These installation descriptors group locks into the markets for which they are designed and except for the method types, tend not to be mutually exclusive. These types apply to both primary and auxiliary locks and can be obtained in various materials, sizes and functions. The installation grouping can be used to indicate the potential exposure and attack level of each lock. For example, the method of surface mounting inside the door provides comparatively less exposure of the lock mechanism than does an internaly installed lock. The installation, further, of this same lock on a factory entrance door with the purpose of high security indicates a comparatively higher potential attack level than say a residential installation.

Table 4-1 Installation Types

Installation Type	Group	Common Names and Sub-Groups
METHOD	Internal	Flash Bolt, Narrow Stile Mortise, Combination, Auxiliary
	Surface	Bar Lock, Slide Bolt, Chain Lock Rim, Night Latch, Interlocking, Auxiliary, Padlocks, Exit Lock
	Dual	Bored, Preassembled, Key-In-Knob, Integral, Interconnected, Auxiliary
APPLICATION	Doors	Pivoted or Tracked, Pedestrain or Vehicle, Swinging, Rolling, Folding, Detention, Vault, Gate, Garage, Custom
	Containers	Safe, Safe Deposit Box, Cabinet, Cash Box, Mail Box, Teller's Locker
	Other	Switch, Vending, Window, Automobile, Special
PURPOSE	Privacy	Latch, Friction, Catch, Hook, Manual Bolt, Convenience Lock, Function Variable, Knob Button
	Safety	Fire Label, Exit Device, Panic Hardware
	Control	Access or Entry Control, Card Lock, Remote, Monitor, Detector, Personnel Identity, Sensor
	Security	Burglary Resistant, Guide or Class (I to IV, 10 to 40) Group (combination lock)

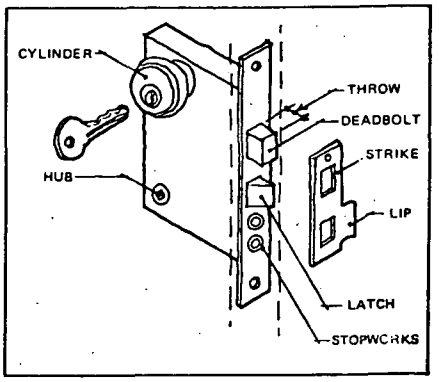
4.1 METHODS OF INSTALLATION

In grouping lock designs, factors that respond to the quesion of HOW a lock is installed, center on the preparation of the object to which that lock is attached. Preparation differs according to the location of the lock mechanism in relation to exposed surfaces. The relative exposure of critical lock components to the user or the attacker is consequently a prime factor that differentiates one lock from another. In the case of doors, locks are installed either within the door, on the surface of the door, or a combination of both. Locks for containers and other objects can be similarly differentiated. For these purpose, lock installation methods are divided into three groups: Internal, Surface and Dual methods. The detail of specifically how the lock is attached (i.e.: screw, weld, rivet, etc; location and type of fastener) has been ignored for grouping lock types since this level of detail is generaly irrelevant to distinguishing one lock from another, although it could effect the durability and performance of the lock.

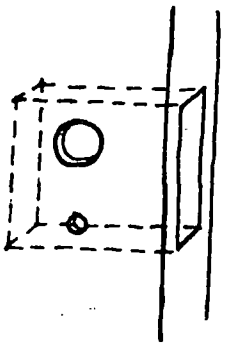


internal mechanism

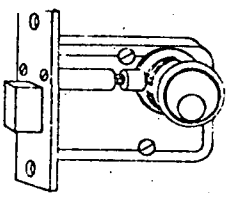
mortise lock



mortise lock components



door preparation, mortise lock

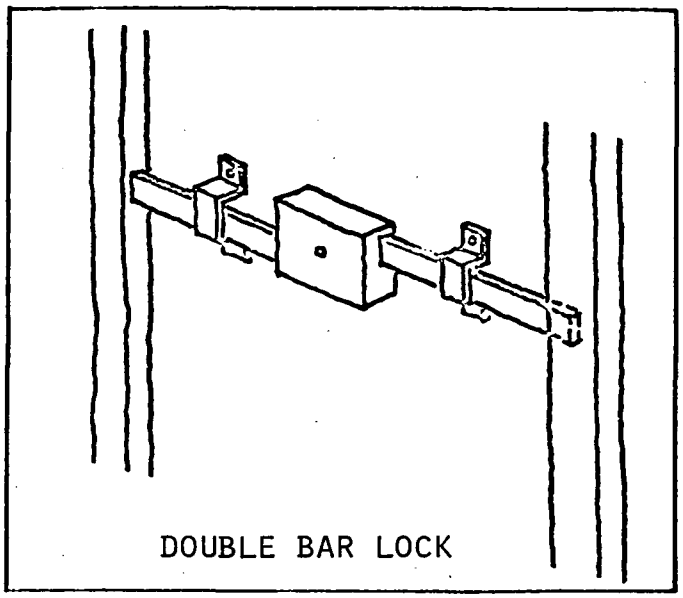


mortise dead bolt

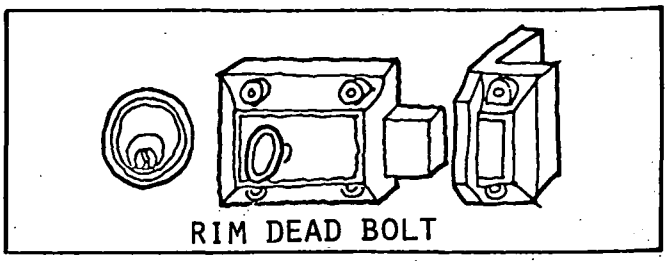
4.1.1 Internal

All locks designed to fit totally within a cavity prepared between the faces of a door and/or the faces of the adjacent frame and wall are, by definition, Internal locks. The essential mechanisms and their containers are hidden from view and protected by the face materials plus, if necessary, other reinforcements. The only projections are bolts, handles, levers or knobs and the faces of the cylinder or keyway. Commonly, these are called MORTISE locks when applied to typical doors. Also falling into this grouping are special locks such as those used for vending machines, safes, certain electronic locks, etc.

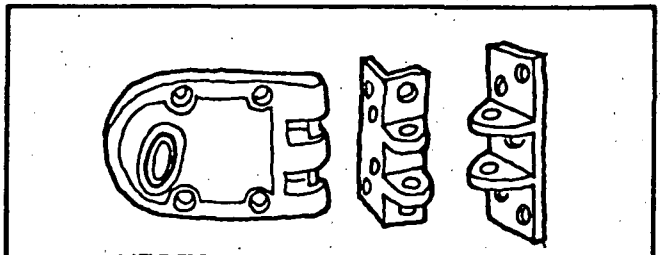
Mortise lock is a term, used in "builder's hardware," that was derived from the preparation afforded a wood door for this type of lock. Wood doors are prepared by cutting a rectangular cavity or mortise in the edge of the doors. Metal doors are also prepared with a cavity in the edge. The lock is installed into the edge of the door and can be removed only when the door is opened. The key cylinder for a mortise lock is usually screwed into the lock case and secured with a set screw. Most cylinders have a cam attached to the rear of the cylinder plug which rotates with the use of a key. The cam couples with the bolt during rotation and moves it into a locked or unlocked position (see 6.3, Bolt Actuating Mechanism). Multi-bolt locks are available that project bolts to two, three or four sides of the door and are internally installed. Electronic locks are available that have no exposed parts, with everything controlled remotely or by proximity of the key/card or person. Combination locks used in containers, safes and vaults are classified as internal but can be obtained with surface or dual methods of installation.



DOUBLE BAR LOCK



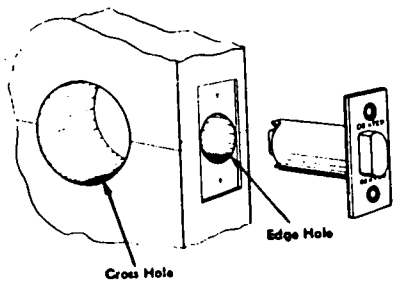
RIM DEAD BOLT



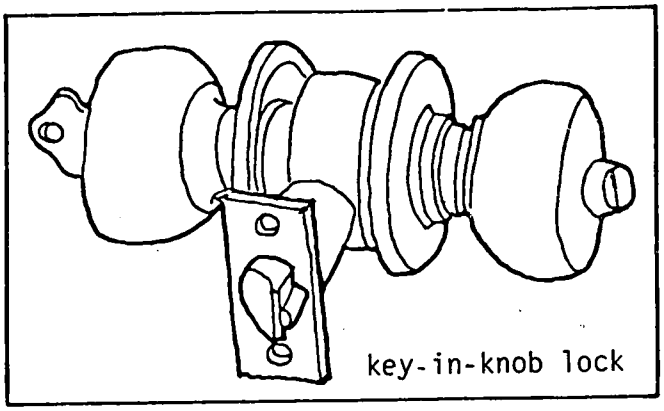
VERTICAL BOLT RIM LOCK

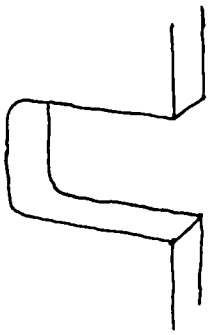
4.1.2 Surface

Locks designed to be installed in such a manner so as to have most of the lock mechanism located on one side of the door, or other item to be secured, are classified as surface mounted locks. This type of lock requires the minimum of preparation. In the case of doorways, the most popular surface installed lock is the Rim lock, the name of which is derived from the fact that the lock is installed on the rim or edge of the door. The only penetration required for the door is for the keyway or cylinder and in some cases, the knob spindle or thumbpiece. This lock has the advantage of requiring the removal of the least amount of material from the door and thereby avoiding weakening of the door. This is, particularly significant for wood doors and is also helpful for steel doors. Typically, surface installed locks use a rim cylinder with a tail piece or bar extension that connects to the bolt actuating mechanism. When the key is inserted and turned, the tail peice rotates and operates a set of levers to move the bolt. The rim cylinder is usually secured to a plate, which, in turn, is attached to the interior face of the door, and serves as the back plate for the case of the bolt actuating mechanism and bolt. The rim lock is available in night latch, dead bolt, interlocking bolt and vertical bolt variations (see section 6.1, Bolt). Surface installed locks include a variation on the slide bolt which has two interlocking "wings," mounted directly on the closure by bolts or welding, and a key operated bolt/cylinder (see p. 66). Padlocks, gate locks and chain locks are also included in this group. Exit locks are normally surface mounted and sometimes operated only by an interior panic bar, without an exterior key cylinder.

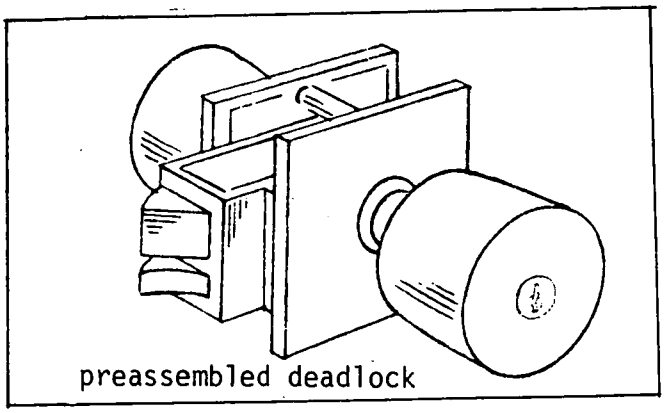


door preparation, bored lock



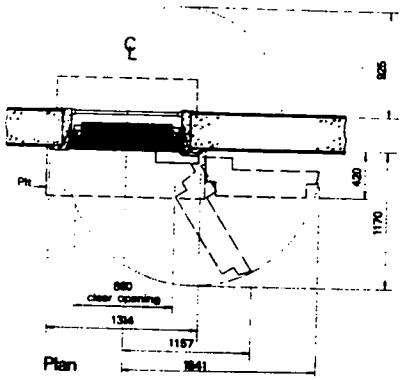


door preparation for preassembled lock

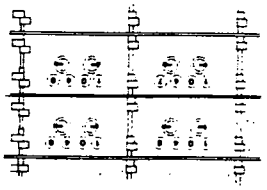


4.1.3 Dual

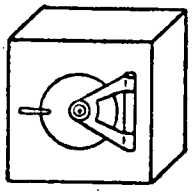
These locks usually have the bolt actuating mechanism installed within the door while the key cylinder(s) and/or other mechanisms are located within the knob or project beyond the face of the door. These combine the features of the internal and surface methods of installation. An example of dual installation is the Bored locks, so called because they are designed to be installed into round holes bored or drilled into wood doors. These locks are most commonly called "Key-in-knob" type locks. They also include Bored dead bolt locks and Interconnected locks and are also called Cylindrical, Tubular and Bore-in locks. Bored dead bolt locks have the key cylinder projecting beyond the face of the door. Interconnected locks are classified in the Dual method of installation even though they can be obtained with the lock control mechanism and the key cylinder located within the face planes of the door. Most Interconnected locks, however, are designed with the cylinder outside the face of the door. In either design they include connecting mechanisms that are located outside the face of the door. Most auxiliary locks used for residential buildings are of the Dual method of installation and the Bored type in which the key cylinder has an extension that interconnects with an extension of the bolt through a set of levers to actuate the bolt. The Preassembled and Integral type Key-in-Knob locks are also included in this group since the cylinder for these locks is contained in the knob, although the preparation of the door is similar to, but not the same as, a mortise lock. The Preassembled and Integral type locks are similar to mortial locks in their bolt actuating mechanisms (section 6.3) and functions (section 2.3).



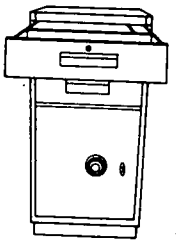
vault



safe deposit boxes



safe



(Tellers') cabinet

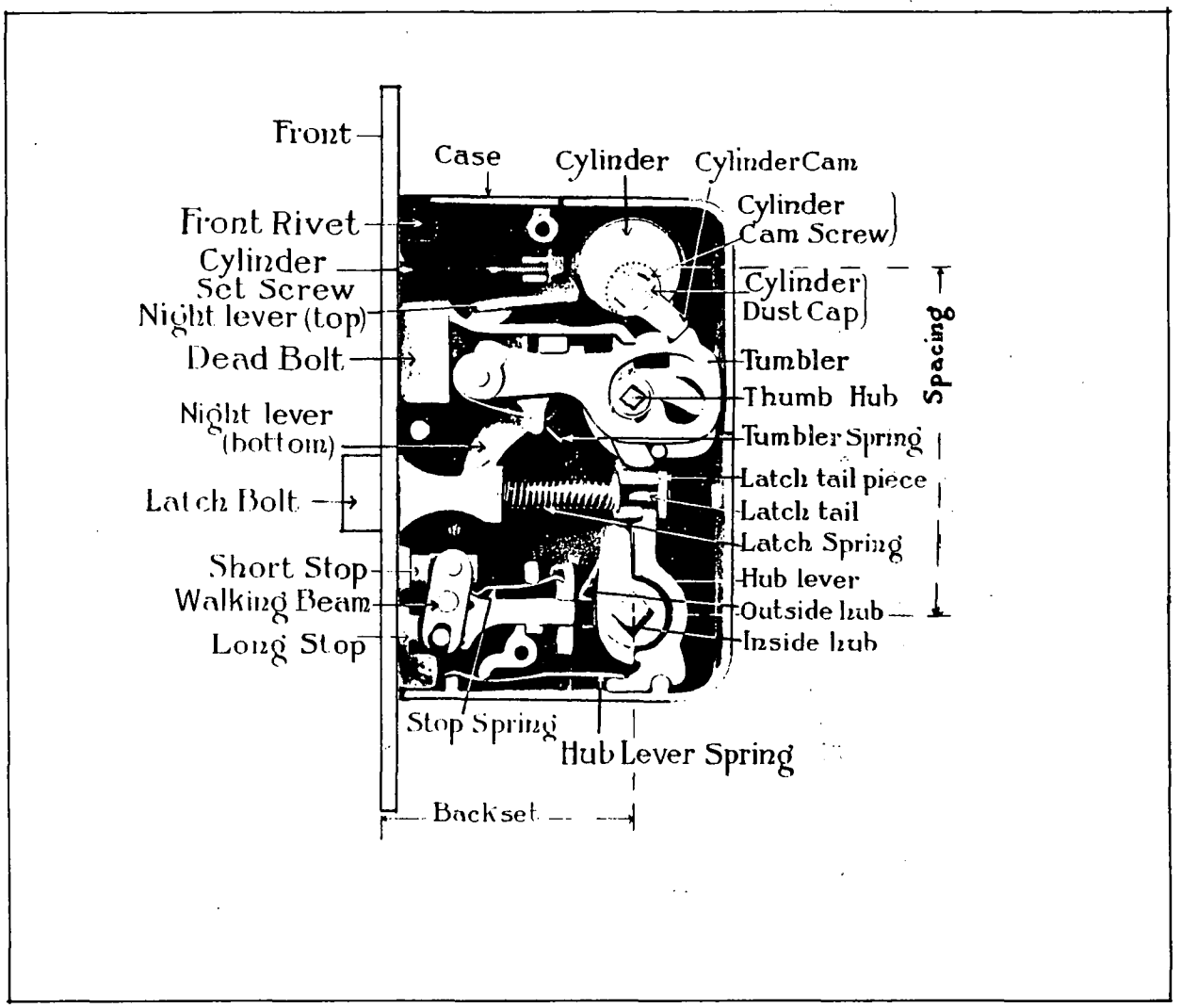
4.2 APPLICATION OF INSTALLATION

Secondary lock descriptors are used to group locks according to the specific objects the locks are designed to secure. The applications most commonly used for locks are for doors and container enclosures. Switches and other control and securing devices also use locks. Doors, either pedestrian or vehicular, can be categorized as pivoted or tracked. Pivoted doors are hung on hinges or on center or offset pivots. Tracked doors either roll, fold or slide. The pivoted doors swing in or out and rely on the pivots and bolt(s) to secure the door within the portal opening. The tracked doors move horizontally or vertically and rely on the tracks at the perimeter of the portal opening, together with the bolt(s), to secure them within the opening. Obviously, the door operation is a critical factor in selecting and designing an appropriate locking device. Container enclosures include applications such as safes, safe deposit boxes, storage cabinets, etc. The detailed operation of these enclosures and the locks can include pushing or turning or sliding and have the added variable possibility of being completely removable or portable. The operation of both doors and other enclosures affects the required operation of the lock (see Chapter 5 Operation Types) and particularly the operation and design of the bolt component (see section 6.1, Bolt). Locks in the Application category very often have the names of the object they are used to secure; examples include the safe deposit box, safe, mail box, teller's locker, vending machine, and switch locks. These are often specifically designed for a particular application and have unique characteristics.

4.3 PURPOSE OF INSTALLATION

Although the concern of this report is locking device security, locks serve purposes other than security and this should be kept in mind. The other purposes are Privacy, Control and Safety. Each purpose usually has associated levels or grades. Therefore, there are different requirements for doors dependent on the needed levels for fire resistance, security limitations of use and. Requirements for fire safety are included in building codes and many "builder's" locks can be obtained with fire safety certification labels [21]. The limitations of use, or controls, are specified according to need and some are explained in the section on lock Function (section 2.3). Criteria for control of personnel, access and crowds can be crucial in the selection of locks and their components. Privacy is closely related to control and in the case of doors, includes accoustic and psychologic needs as well as visual and physical privacy. The level of security required for a particular lock installation can be compromised by other purposes, whether they are primary or secondary in importance, because each purpose requires a different set of criteria. Some of these can be ascertained by compliance to available performance tests such as those included in UL and NILECJ standards (see section 2.4, Lock Grades). Other purposes such as privacy, convenience and control are specified by the purchaser as needed and are provided by the manufacturer as part of a particular lock's features.

Catalogue illustration,
mortise lock by
P F Corbin Company



5. OPERATION TYPES

This grouping of lock types refers to the basic method of moving the lock bolt or changing the locking device from secure mode to unsecure mode and viceversa. Table 5-1 lists the different methods of moving, or operating, locking devices. Locks exclusively dependent on the user to supply all the force required for operation are described as using Mechanical operation. This, in turn, can be divided into Keyed and Keyless Mechanical Operation. A key is any encoded object (including a card) that is used to operate a locking device. Locks that have no moving mechanical parts but which operate electrically are classified as Electrical operation. Locks that combine electrical power and mechanical movements are grouped as Electro-mechanical operation. Manufacturers of particular types of locks are noted paranthetically and their address and telephone number is listed in appendix G.

Table 5-1 Operation Types of Locks

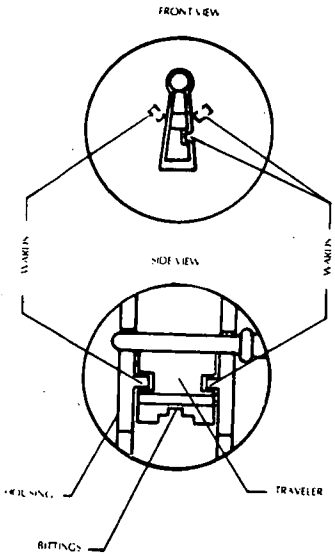
Operation Type	Group	Sub-Group, Common Name
KEYED MECHANICAL	Warded	Padlock, Luggage lock, Barrelor Bit Key locks
	Cylinder Tumbler	Pin Tumbler, Wafer Tumble, Disc Tumbler, Lever Tumbler
	Lever	Lever Lock, Safe Deposit Box
	Magnetic	Card Lock
KEYLESS MECHANICAL	Manual and Passive Bolt	Barrel Bolt, Button, Dog Bolt, Flush Bolt, Thumb Turn
	Wheel Tumbler	Combination
	Coded Cypher	Push-Button
	Time Lock	Time Lock, Time-Delay
ELECTRICAL	Electromagnetic	Magnetic Lock
ELECTRO-MECHANICAL	Manually Encoded	Mechanical Electrical, Electronic Code Combination
	Electronically Encoded	Magnetic Card, Capacitive Card, Radio Frequency, Coded Circuity, Optically Coded
	Personal Characteristics Verification	Fingerprints, Hand Geometry, Voice, Handwriting
	Other	Alarm Integrated, Hydraulic, Pneumatic

5.1 KEYED MECHANICAL OPERATION

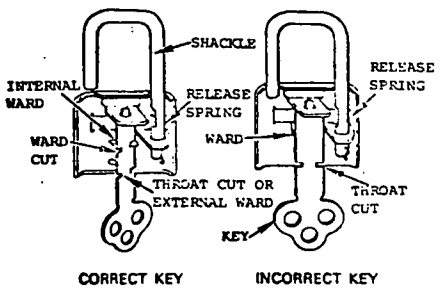
Locks that use an encoded "hand-held" object to actuate the bolt are classified as KEYED MECHANICAL LOCKS. They usually operate by a bitted metal key, but mechanical locks that operate by magnetic cards are also in this category.

5.1.1 Warded Locks

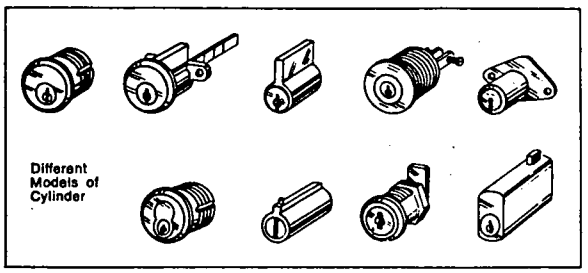
Warded locks are popular but provide limited physical security. They were adequate as security devices one hundred years ago but as defeat methods became more widely known by criminals, warded locks became obsolete and were replaced by new inventions. Warded locks incorporate fixed wards or obstacles in the keyway and within the lock case. A key must clear these obstacles in order to rotate and operate the lock mechanism. Haberman [12] calls these "Fixed Labyrinth" locks which aptly describes the design of wards which block the key's "wing bit" from turning unless its shape matches the wards. Wards are used today primarily in padlocks and are so easily picked that they should not be considered for any serious security need. Warded mortise locks may still be found in very old hotels and residences. Keys to these locks are of the so-called "skeleton" type key, having a long post with a flat rectangular shape at the end (the wing bit). Like the padlock version, these warded locks offer no significant resistance to picking. The other common application is handcuffs. Wards, per se, are presently also used extensively in most keyways by making them paracentric and of unique shapes in order to prevent different keys from entering the keyway and also making picking more difficult than a flat or simple cross section keyway.



warded keyway



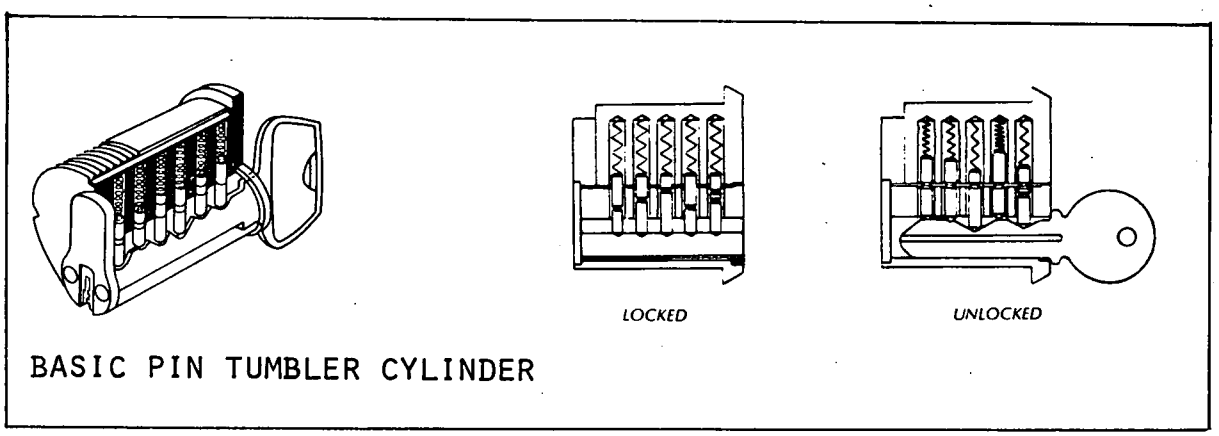
warded padlock



5.1.2 Cylinder Tumbler Locks

The cylinder contains tumblers which must be aligned in a predetermined order so that the core can be turned within its housing or body. These tumblers can be any one of four types:

1) pin, 2) wafer, 3) disc, and 4) lever.



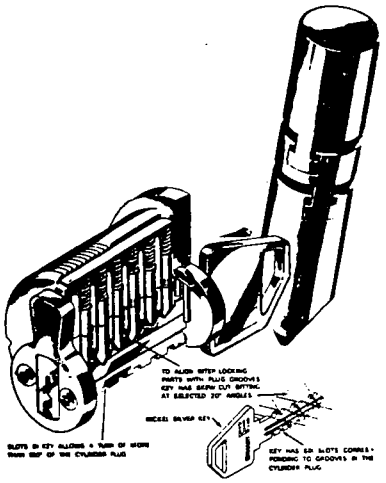
BASIC PIN TUMBLER CYLINDER

5.1.2.1 Pin Tumbler Cylinder

This is the most common cylinder tumbler used in U.S. door locks. The Pin Tumbler cylinder, invented in 1865 by Linus Yale, Jr., was a major breakthrough in lock design and was the forerunner to all cylinder tumble locks [13]. Being much more compact than any previous lock, the Pin Tumbler proved to be the start of miniaturization in industry for many products. It usually consists of five spring-loaded sets of pins less than 1/8" in diameter that are lined-up within the cylinder core and body. Each set of pins is made up of two pins, one on top of the other, which are forced down into the keyway in the cylinder core by the spring. These pins prevent the core from turning within the body unless the joint between the top (driver) and bottom (key) pins lines up exactly with the 'shear line' joint between the core and the body. A key, cut with the precise profile so that the pins are raised to line up their meeting joint with

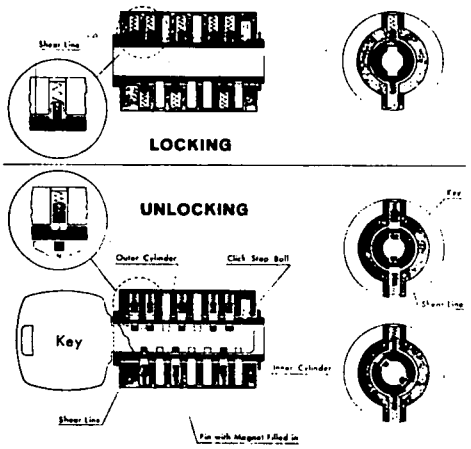
the shear line when the key is inserted into the keyway, enables the core to be turned and a linkage to operate the lock bolt. Variations on this basic operation are described below.

INTERLOCKING PIN TUMBLER - This type of dual action pin requires the pin to be elevated to the shear line while at the same time rotated to a specific point. The top and bottom tumblers of the cylinder are interlocked in a "dove-tail" fashion, and will separate to allow plug rotation at the shear line only after they have been raised to the proper level and rotated to one of the selected 20 degree angles. The chisel-point shape of the bottom pin together with chamfers cut into each notch of the key at the precise number of degrees, cause the pins to rotate to the proper position simultaneously with lifting the pins to matching shear lines.



interlocking pin tumbler cylinder

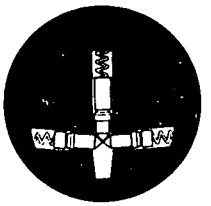
MAGNETIC PIN TUMBLER - In this type of cylinder there are two rows of tumblers positioned in a horizontal plane; one row on each side of the keyway. The hollow, spool-shaped tumblers contain a polarized permanent magnet. While there are cells for seven tumblers in each row, tumblers are not contained in all cells. Small springs force the spool-shaped tumblers into shallow, blind holes in the plug to prevent plug rotation in the locked position. Polarized magnets are imbedded in the key and properly oriented (north or south polarity) so that they will present an opposing magnetic force on all the magnetic tumblers, thus forcing them out of the plug when the key is inserted and thereby freeing the plug for rotation. There is no physical contact between the key and the tumblers. Since the holes in the plug into which the tumblers sit in the locked position are not drilled through to the keyway, picking of the lock by conventional picking techniques is impossible. The spool shape of the tumblers prevents picking of one pin at a time if rotational force also is applied to the plug at the same time.



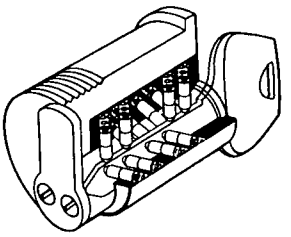
magnetic pin tumbler operation

MULTI-ROW PIN TUMBLER - This cylinder has three rows (sets) of pins and four pins per set. Each set of pins lies in a plane parallel with and intersecting the axis of the lock plug. All pins are oriented normal to the axis of the

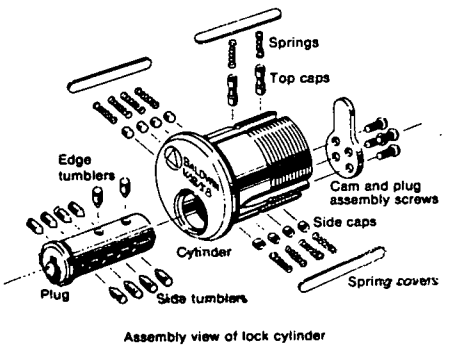
plug. The pin sets are located in planes positioned at approximately nine, twelve and three o'clock relative to a front view of the lock plug. These twelve pins enter the keyway in varying or "scrambled" positions corresponding to key cut locations in normal pin tumbler locks. When the cylinder is locked and the key withdrawn, these pins converge and overlap in the upper half of the keyway, presenting a formidable barrier to lock picks. Precisely milled indentations on the side and top of the key accurately position the different length pins to the shear line position. The key is also milled on the lower half with the correct code, which means there is no right or wrong way to insert the key. This feature, however, enables one to determine the pinning code from one side and one edge only. All of the bottom pins and some of the driver pins are of a mushroom type which increase the pick resistance.



FRONT SECTIONED VIEW OF CYLINDER



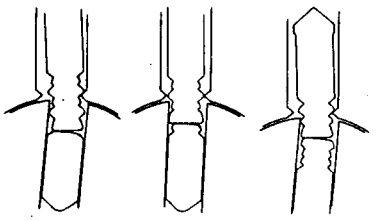
Another cylinder has four rows of pin tumblers arranged in a fashion similar to that of the one described above. The pins lie in different planes, two rows on opposing horizontal planes and two rows on opposing 45 degree planes, with five tumblers per row. The manufacturer has also incorporated a lock-out feature into the cylinder that is intended to deadlock the plug in the event picking is attempted. Two spring-loaded pins are designed to be forced into holes in the plug if it is turned approximately five degrees in either direction by an object other than a key in the keyway.



Assembly view of lock cylinder

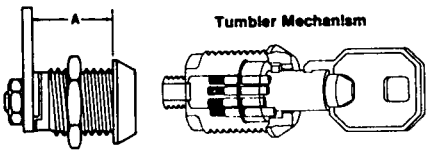
multi-row pin tumbler cylinder

SHAPED-PIN TUMBLER - The Shaped-Pin Tumbler cylinder is a cylinder containing pins that have indentations so that they tend to bind or hang-up at the shear line when picking is attempted. One manufacturer has very irregular series of lands and grooves on the lower end of the driver pins and the upper end of some of the key (lower) pins. Other manufacturers include pins with the shear ends of the pins shaped like a mushroom or spool. These also tend to hang-up at the shear line if picked, and are more simply shaped.



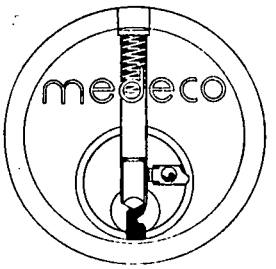
shaped pins binding in cylinder

TUBULAR PIN TUMBLER - The Tubular Pin Tumbler cylinder, often referred to as the Ace lock, after the most popular manufacturer, has seven, eight or nine pin tumbler cells located in a circle around the center post of the plug assembly. To operate, a tubular shaped key is pushed into the circular keyway, which directly pushes the pins (rather than lifting them, as in a conventional pin tumbler) to line-up the pins into a level, circular shear line. For additional security against picking, a seven-pin tumbler is available where three of the pins are hollow with smaller diameter pins within them. Each pin-within-a-pin is split differently from its outer pin so that the inner and outer portions must be pushed to different levels for their shear lines to correspond. In effect, it makes seven pins into ten pins. They also come with mushroom tumblers.

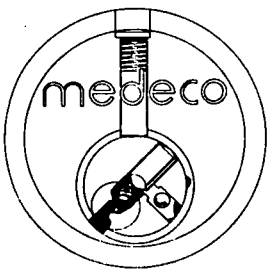


tubular pin tumbler

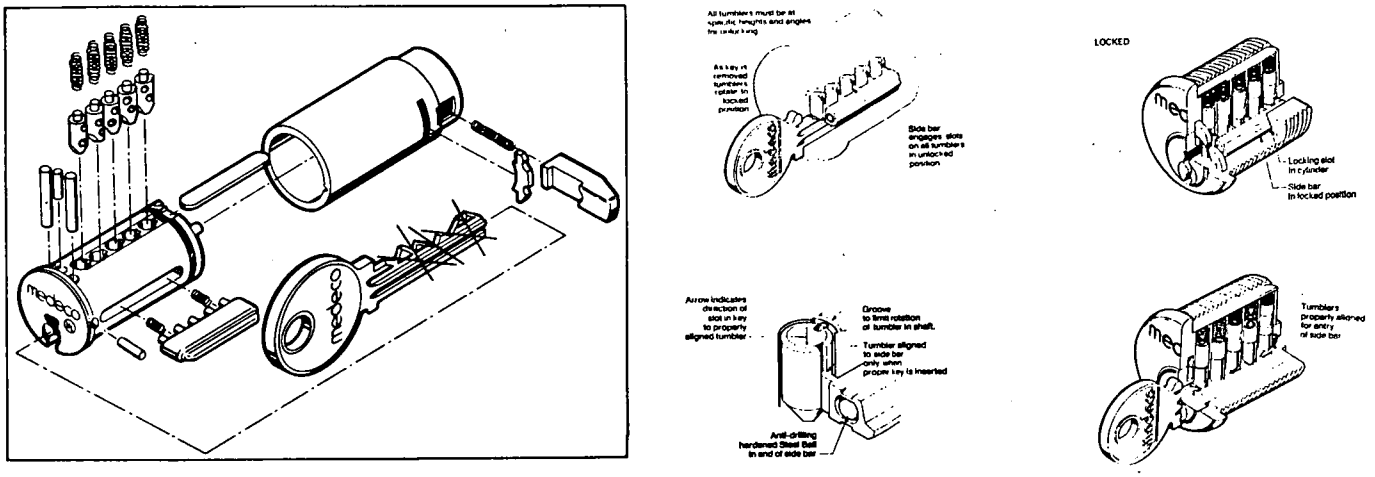
PIN TUMBLER WITH SIDE-BAR - Integral to the Side-Bar Pin Tumbler Cylinder is a dual action pin tumbler mechanism, the first element of which is a series of pin tumblers which must be elevated to the predetermined levels to establish a shear line. The second element of the dual locking action is attained by rotation of each tumbler individually. Angular cuts on the key blade rotate the tumblers. When a tumbler is rotated to the correct position, a notch in the side of each tumbler will aline with and permit entrance of a corresponding projection on the lock sidebar. A portion of the sidebar lies in a slot within the lock shell. To withdraw from the slot, each sidebar projection must enter the notch in the tumbler. If any one of the tumblers is rotated improperly, the sidebar cannot move toward the tumblers and withdraw from the slot.



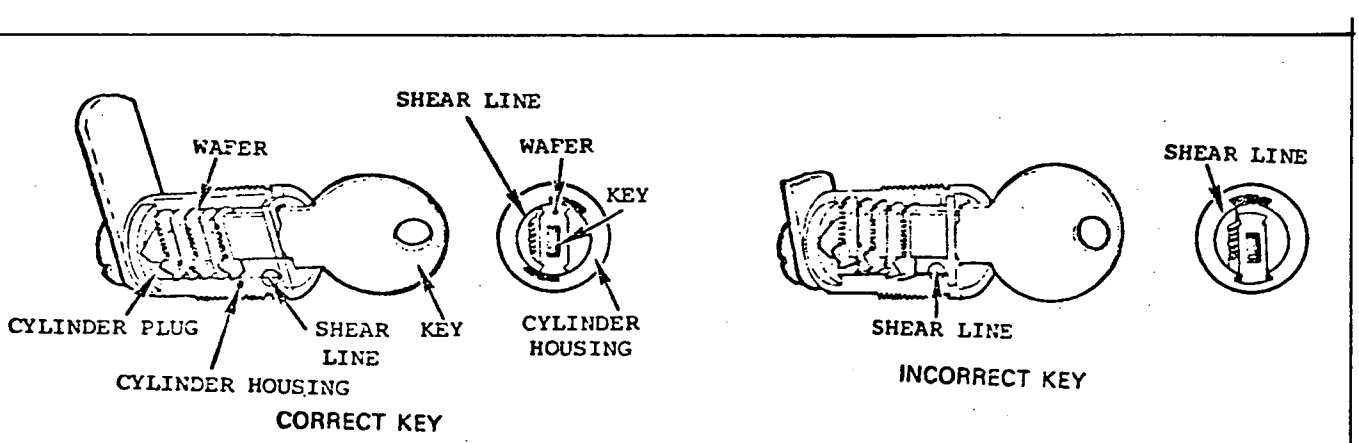
Medeco lock in locked position.



Medeco lock in unlocked position.



operating principles of the medeco side-bar pin tumbler cylinder

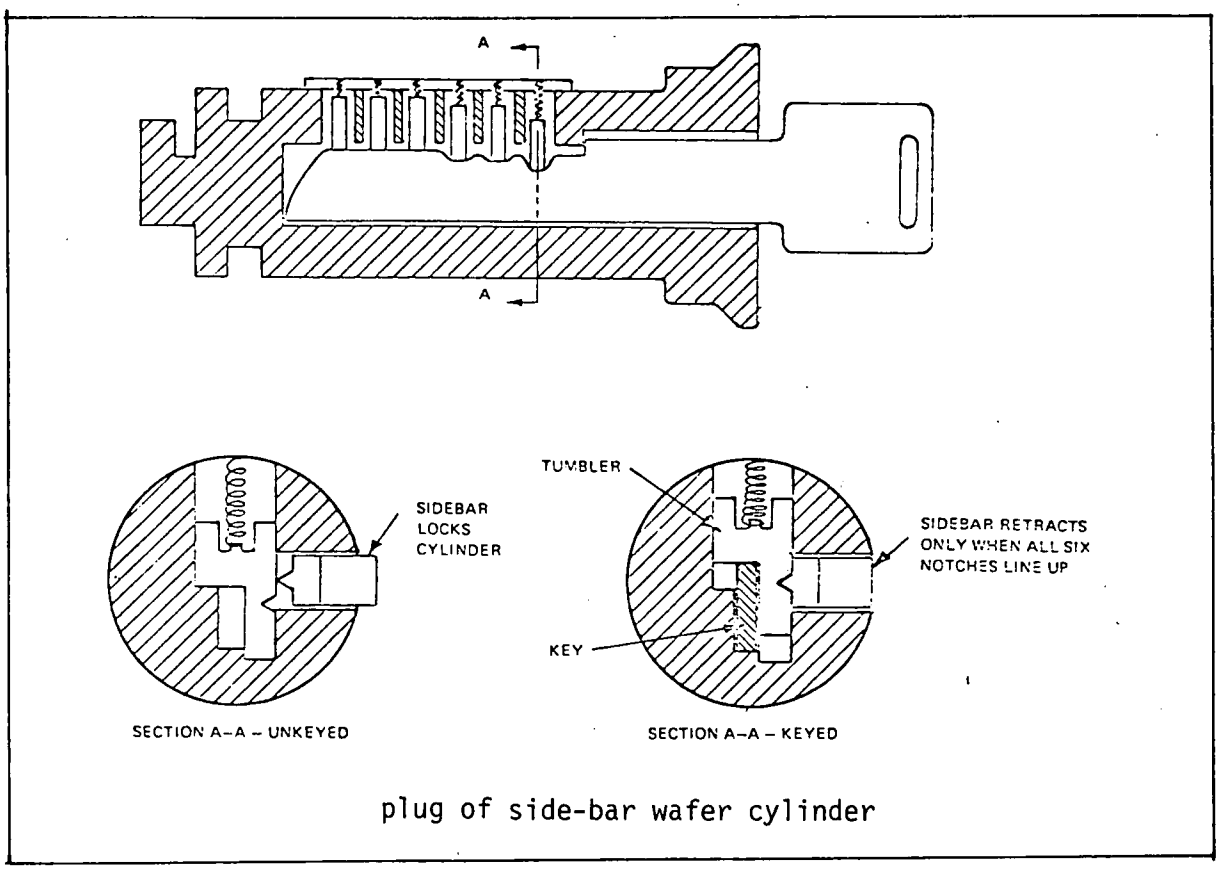


wafer tumbler lock

5.1.2.2 Wafer Tumbler Cylinder

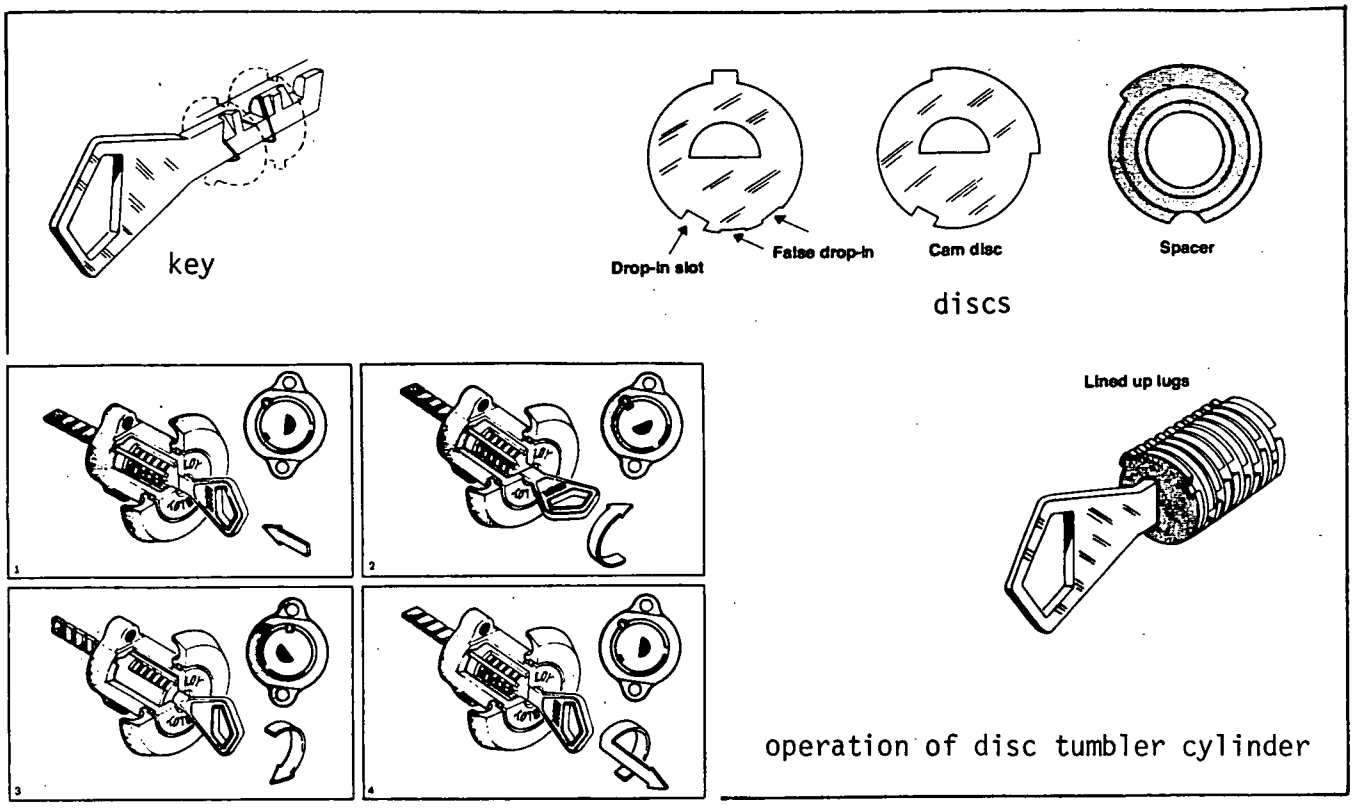
The wafer tumblers are a stack of thin flat pieces of metal that are spring loaded and set within the cylinder core. Either end of the wafers protrude from the core into the cylinder housing. Each wafer has a rectangular cut-out located at one of various locations along the center of the wafer for the penetration of the key. When the proper key is inserted into the cylinder through the wafers, the wafers are aligned by the key cuts so that none protude from the cylinder core, allowing the plug to rotate within the

cylinder housing. The key lifts the wafer projections out of the cylinder housing into the core. Wafer tumblers can be single or double-bitted. In the single-bitted type, the wafers all move in one direction to lift the projection into the core. In the double-bitted type, the wafers move in two directions. The double-bitted type usually include more tumblers (5 to 10) than the single-bitted type. The double-bitted key is therefore cut on both sides. There is a double-bitted wafer cylinder that contains 10 to 15 tumblers designed to come in a pack so that they can easily be changed. This is the so-called plate-wafer cylinder which had been used in the past for most vending machines.



plug of side-bar wafer cylinder

WAFER TUMBLER WITH SIDE-BAR - The side-bar type wafer tumblers are similiar to the standard wafer tumblers except that they have notches located along one edge of the wafer. These notches are cut to receive a bar which otherwise is set in the shear line, thereby preventing the core from turning. When the key lifts the wafers so that all the notches line up with the bar, the bar is able to move into the notches and into the core, thereby freeing the core to turn within the cylinder housing. Side-bar wafer cylinders are common in automobile ignition locks [30].

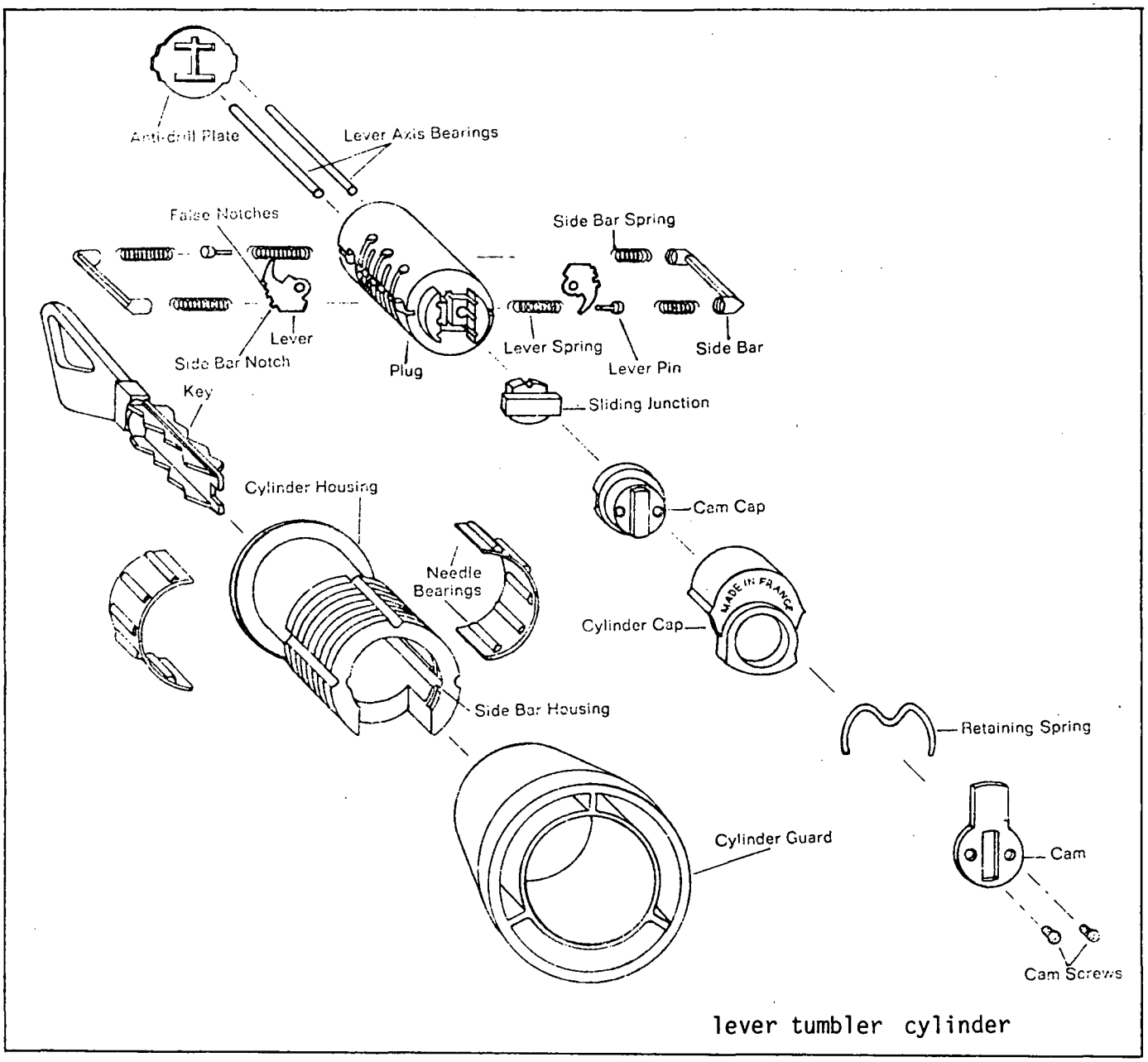


5.1.2.3 Disc Tumbler Cylinder

Disc tumblers are thin, flat pieces of metal, which, unlike wafer tumblers, are circular in shape and revolve like wheel tumblers in a combination lock. One widely known cylinder is designed on the principle of delayed rotary disc tumbler action through use of an unusual angular cut key. A side bar locking mechanism is used. The cylinder ordinarily contains ten discs, although cylinders using up to twelve discs are available. The ten-disc cylinder is said to offer more than ten million possible combination changes.

With use of the proper key, nine of the ten discs in the cylinder revolve 90 degrees within the plug sleeve until the side bar drop-in slots are aligned. The tenth disc is stationary; its design provides a bearing point for the tip of the key as well as for cam action to rotate the sleeve. The key for this lock has the blade flat on one side and rounded on the other to form a semicircle in cross-section. A combination of flat angled cuts are used. As the key is turned, the flat of the key blade pushes against the straight edge of the semicircle keyway. Each disc turns independently as it mates with its cut. When all discs have been rotated by the proper cuts, the side bar drop-in slots will align and permit the side bar to retract into the plug.

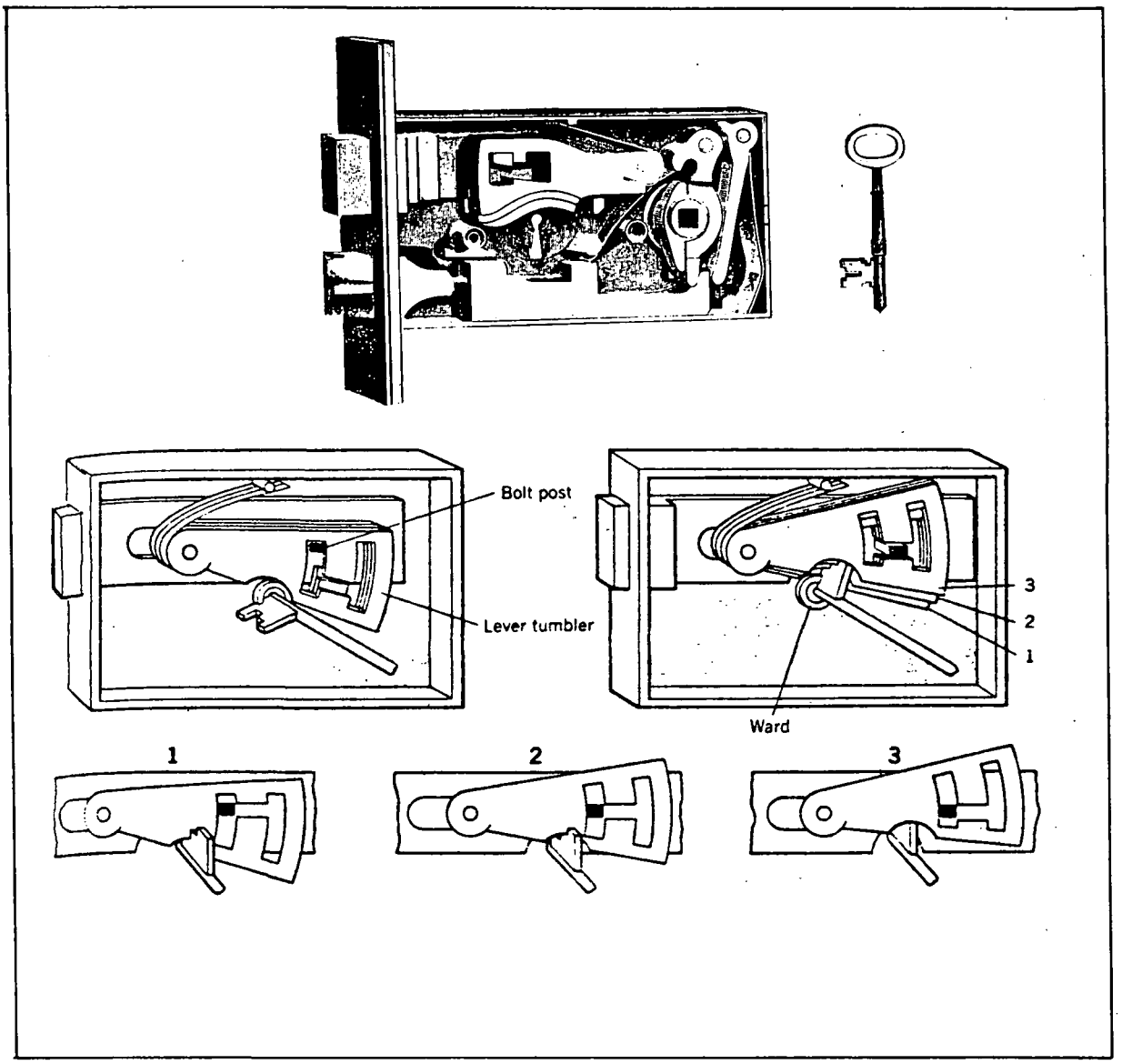
The cylinder then can be turned to permit the tailpiece to retract the bolt of the locking mechanism used with the cylinder. Some discs are also provided with false (partial) slots in order to confuse a lock picker.



lever tumbler cylinder

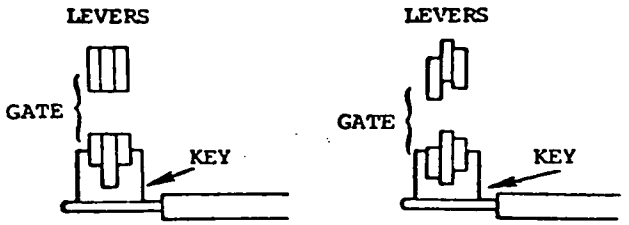
5.1.2.4 Lever Tumbler Cylinder

Currently, the most widely known lever tumbler cylinders are of French and English origin. One French cylinder employs a unique 10-lever system with two side-bars and two pivot points. The levers, thin crescent shaped pieces of metal, pivot within the core and when moved precisely by insertion of the key, side-bar notches on the perimeter of the levers are lined up, allowing the side-bars to enter the core and the core to turn within the housing. False notches are provided to make picking more difficult. The manufacturer claims over 60 billion combinations are possible with this type cylinder. Cylinders similar in operation are manufactured in Great Britain and in the U.S.A.



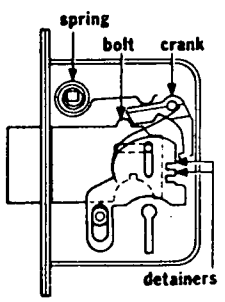
5.1.3 Lever Locks

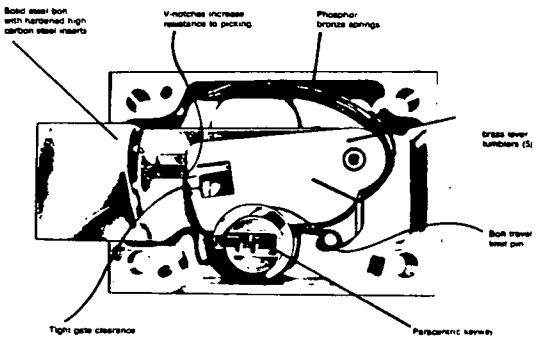
Lever, or Lever Tumbler, Locks were very widely used throughout the world until the economic and convenient Pin Tumbler Cylinder gained popularity during the 1930's. Lever Locks are still very popular outside the U.S., where they are available in a wide range of qualities and styles. The operation of a Lever Lock is a progressive step above the Warded Lock in which the obstructions are fixed. In the Lever Lock, the obstructions are movable and must be set in a precise manner by an especially cut key before the bolt can be moved. The operation of a typical Lever lock can be described as follows: several flat metal levers (or tumblers) are

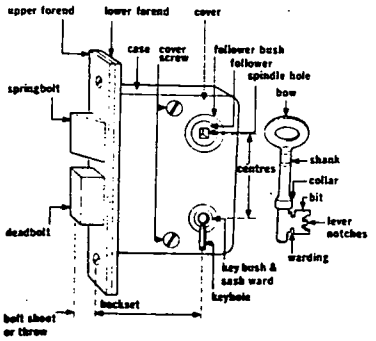


CORRECT KEY INCORRECT KEY

attached by a pin to a common point in such a way that the levers are free to swing slightly and are positioned so that rotation of the key exerts a force to first lift the levers and first directly operate the bolt. Each of the levers has a rectangular gate cut in the free end. The bolt has a protruding fence which rests against the free ends of the levers to prevent retraction of the bolt when it is locked. When the correct key is inserted and rotated, the key cuts on the key elevate the free ends of the levers so that the gates are aligned, thus permitting the fence on the bolt to enter the gates. After the fence enters the gates, bolt retraction is completed by further key rotation.

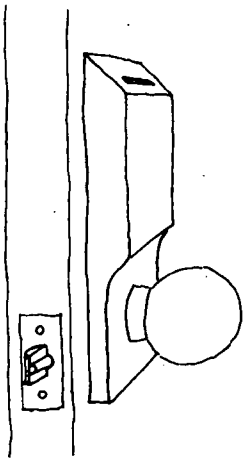




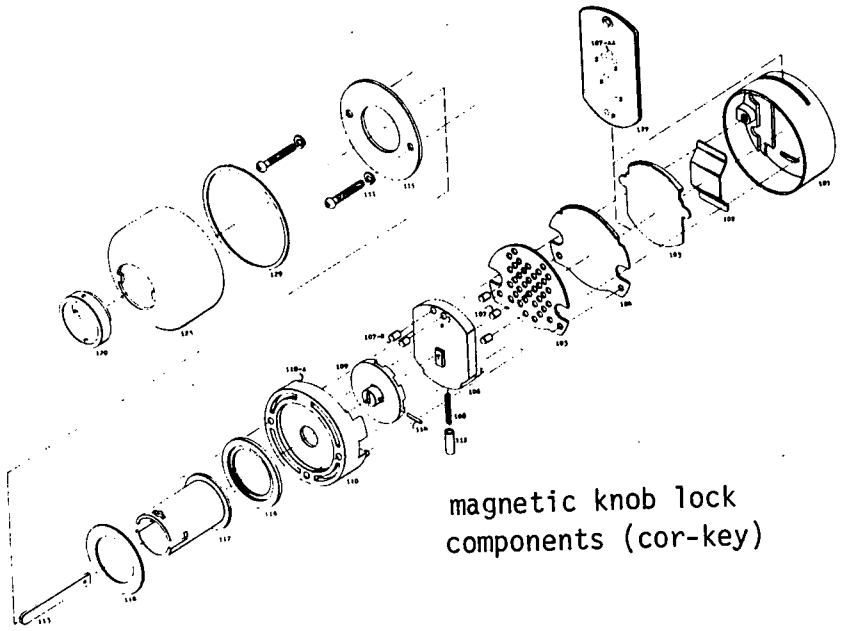


butters system lever lock folger-adam lever lock british lever lock

Large lever locks are commonly used in prison security applications. Larger locks are particularly resistant to picking, primarily due to their massiveness and the strength of the springs on the levers. A further refinement incorporated into some lever locks requires that the key be turned several times in order for the bolt to be completely retracted. In this case, the lock must be picked once for each required key rotation. Another feature, incorporated into some lever locks to increase resistance to picking, is the use of false notches or gates in the free ends of the lever. If the fence prematurely contacts the end of the lever tumblers, as it must do if an attempt is made to pick the lock, the false gates on the levers engage the fence and prevent the movement necessary to align the fence and gates.



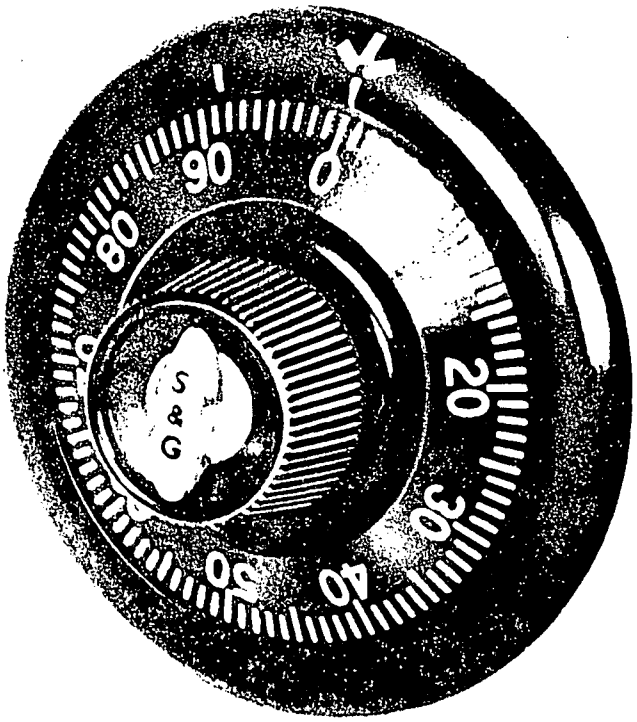
magnetic lock
(cardkey)

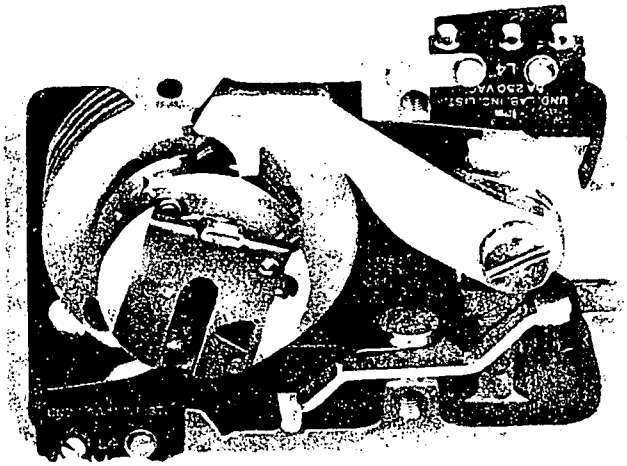


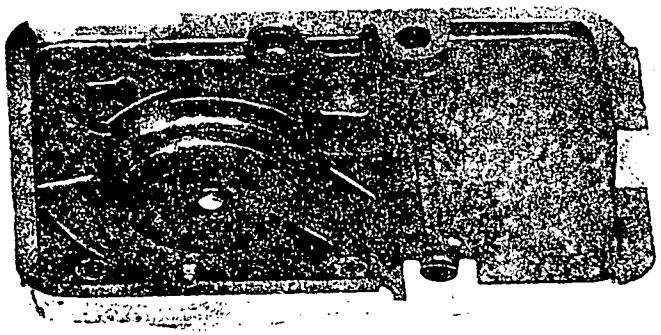
magnetic knob lock
components (cor-key)

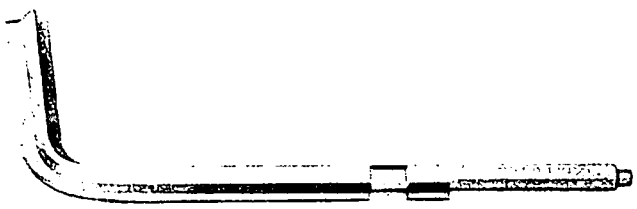
5.1.4 Magnetic Locks

This grouping of locks is made distinct from magnetic pin tumbler locks (see section 5.1.2.1, Pin Tumbler Cylinder) because these do not use a pin tumbler cylinder operation with a metal key and keyhole. In mechanically operated magnetic locks, the "key" is a card, disk, or other object encoded with ferromagnetic inserts and designed to repell specific pins that are otherwise set to prevent operation of the bolt mechanism. For example, in a mechanical lock using a magnetic card, the magnetic card contains a code. The code is in the form of an array of ferromagnetic spots that are polarized so that they can be read by corresponding polarized pins in such a manner that, if they are in the correct location and of the correct polarity, the pins will move to allow the consequent manual withdrawal of the bolt by use of a knob or handle. Other locks use an encoded object to operate that bolt similar to a standard key. This also is differentiated from electromagnetic locks which use magnetic force to secure the door or other object (see section 5.3, Electromagnetic Operation).



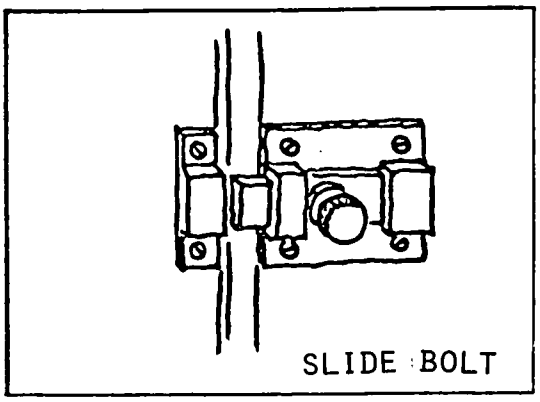


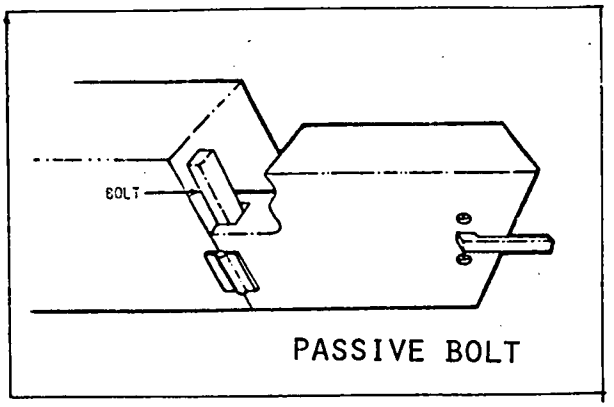


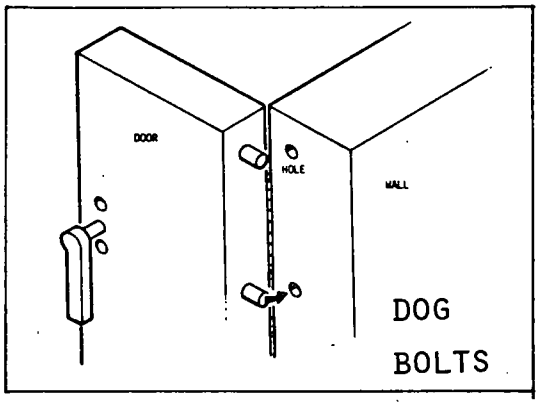


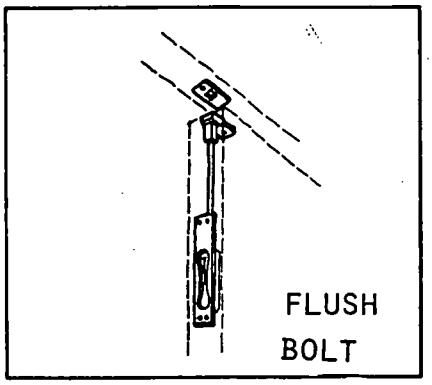
5.2 KEYLESS MECHANICAL OPERATION

Mechanical locks that are operated without the necessity of gaining access to some part of the internal mechanism and obstructions by the use of a key are classified as KEYLESS MECHANICAL LOCKS. Except for manual bolts, they are usually operated by use of a code known only to the approved users, which is applied by turning a numbered wheel or pushing buttons. In addition, time locks are included in this category and are a unique form of the keyless lock. Keyless mechanical locks are divided into four groups: 1) Manual and Passive Bolt, 2) Wheel Tumbler, 3) Coded Cipher, 4) Time locks.





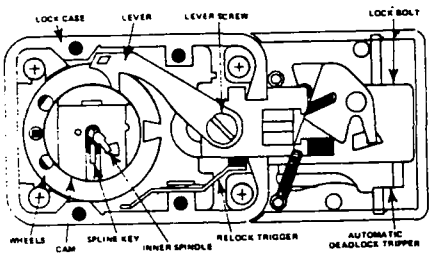




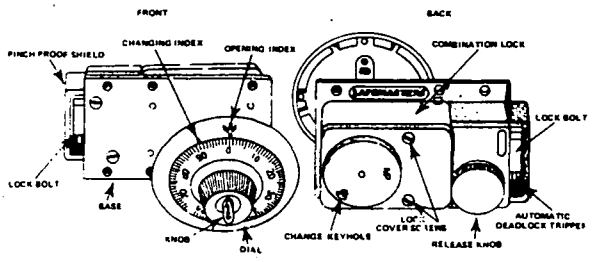
5.2.1 Manual and Passive Bolt Locks

Manual Bolt locks are mainly interior bolts such as the slide bolts, lever bolts, flush bolts, hook bolts, etc. operated by simply directly pushing or placing the bolt to secure the door to the frame/wall. It can be argued whether, strictly speaking, manual bolts are locks at all. For the purpose of this classification, however, they should not be ignored since they can provide considerable resistance to attack from the opposite side of the door. The bolt is a prime component of all locks (except the electromagnetic) and forms the starting point in designing any lock.

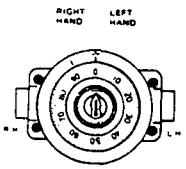
Passive, or dog, bolts are used at the hinge side of a door that swings out with exposed hinges. The object of the passive bolt is to interlock the door with the hinge jamb so that the door will remain within the jamb frame even if the hinges are removed. The bolts can be fixed to the door and enter holes in the frame or visa versa. The same or better performance can be provided by designing the door and frame to continuously interlock at the hinge jamb.



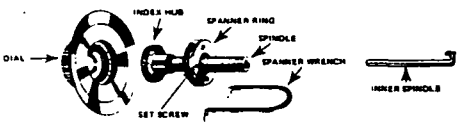
combination lock mechanism



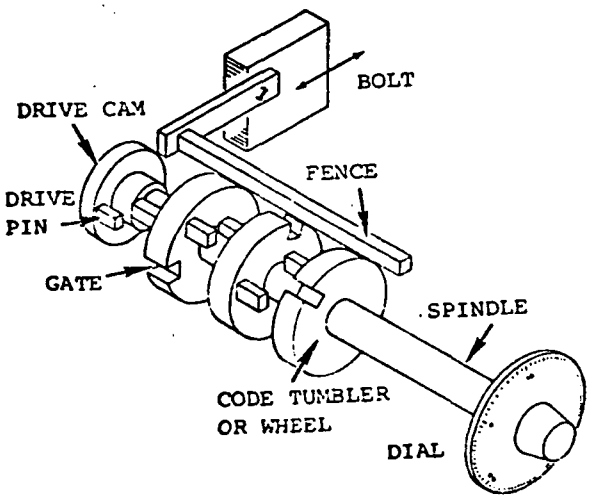
lock nomenclature



dial



spindle

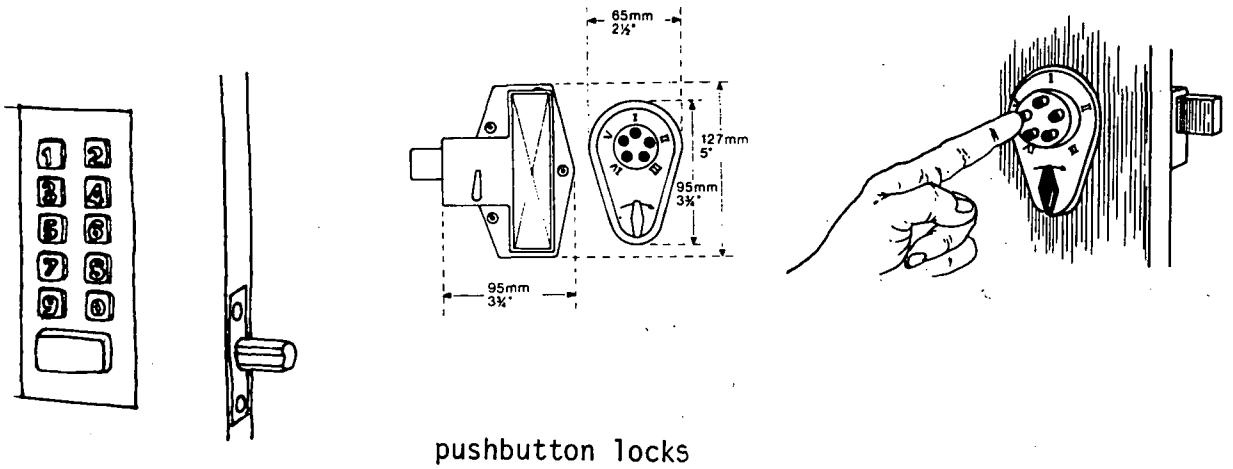


combination lock exaggerated view

5.2.2 Wheel Tumbler Locks

These locks, also called combination locks, contain a dial which is usually divided into sections marked with numbers. The dial may be the only portion of the lock that is visible. The combination dial transmits its motion to code tumblers or wheels located within the lock case. Combination locks typically have three or four tumblers (see illustrations above). A drive cam is fixed directly to the combination dial spindle. When the dial is moved, the drive cam also moves. Each tumbler has a gate located on its

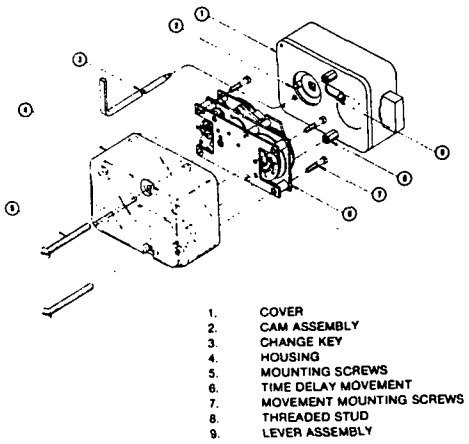
circumference and a drive pin which sits on its flat surface. The tumblers rotate around a spindle. Rotation of the tumblers is controlled by contact between the tumbler drive pins. The tumbler farthest from the drive cam aligns with the first combination number. When the correct combination is dialed, the gates of all the tumblers are aligned so that the fence moves into the gates, allowing the bolt to be retracted. Combination locks may have almost one million possible combinations and are better protected from forcible attacks than a keylock since no direct access to the lock mechanism itself is required for normal operation. Refinements in combination locks to resist manipulation include keeping the fence away from (not resting on) the tumbler, using nylon tumblers to resist decoding with X-rays, and sound baffles or generated noise to resist decoding with listening devices. Combinations locks are graded according to levels of resistance (see section 2.4, Lock Grades).



pushbutton locks

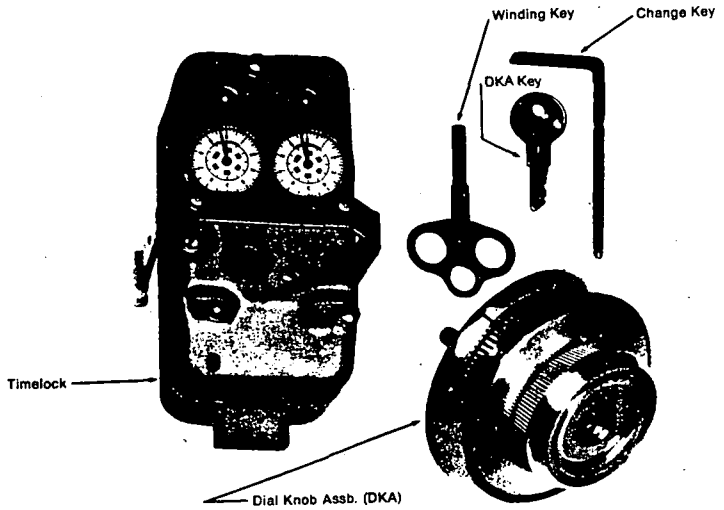
5.2.3 Coded Cipher Locks

The mechanically operated Cipher or Pushbottom lock requires buttons to be depressed in a preset sequence. This moves a set of interconnected wheels and ratchets into positions where they line up to allow movement of the bolt. The bolt is then withdrawn manually from the strike.



1. COVER
2. CAM ASSEMBLY
3. CHANGE KEY
4. HOUSING
5. MOUNTING SCREWS
6. TIME DELAY MOVEMENT
7. MOVEMENT MOUNTING SCREWS
8. THREADED STUD
9. LEVER ASSEMBLY

time delay lock components

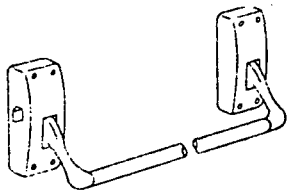


time lock

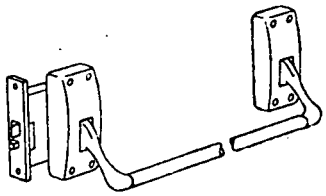
5.2.4 Time Locks

The Time Locks release a lever or other obstacle between the bolt operating mechanism and the Wheel Tumbler Lock only during a predetermined period of time. The Time Lock contains two or three independently running chronometers. They are either manually or electrically wound, or they are run by a self contained power supply. They can be set for up to 120 hours and are designed so that if any one chrometer should fail, the remaining one(s) will act as back-up. Time locks can be used in conjunction with or independently of wheel tumbler locks on vault doors.

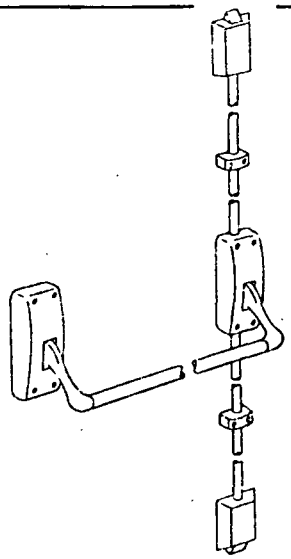
Similar Time Delay locks are available for safes which delay the operation of locks from 15 to 30 minutes after the code is dialed into the connected Wheel Tumbler Lock. Furthermore it relocks automatically three minutes after the delay period elapses whether or not the safe has been opened.



rim exit device



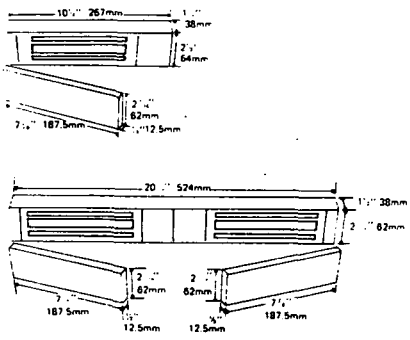
mortise exit device



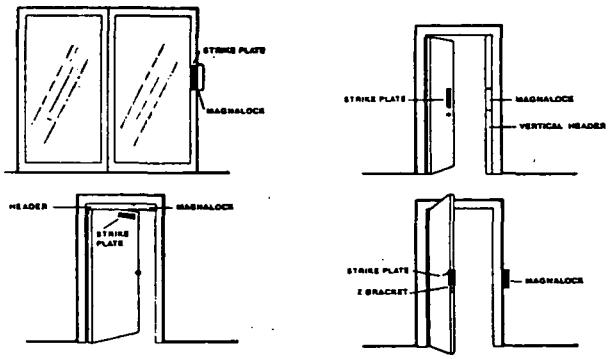
vertical rod exit device

5.2.5 Exit Devices

Designed for emergency exiting, exit devices are used in all public buildings and wherever personnel could be otherwise trapped in a burning building. Primarily designed for keyless operation, they are also available keyed from the outside and with keys to "dog" or lock the cross-bar down. Exit devices are available in rim, vertical mortise or concealed designs and in two grades; they often have more than one operating bolt [2].



electromagnetic locks

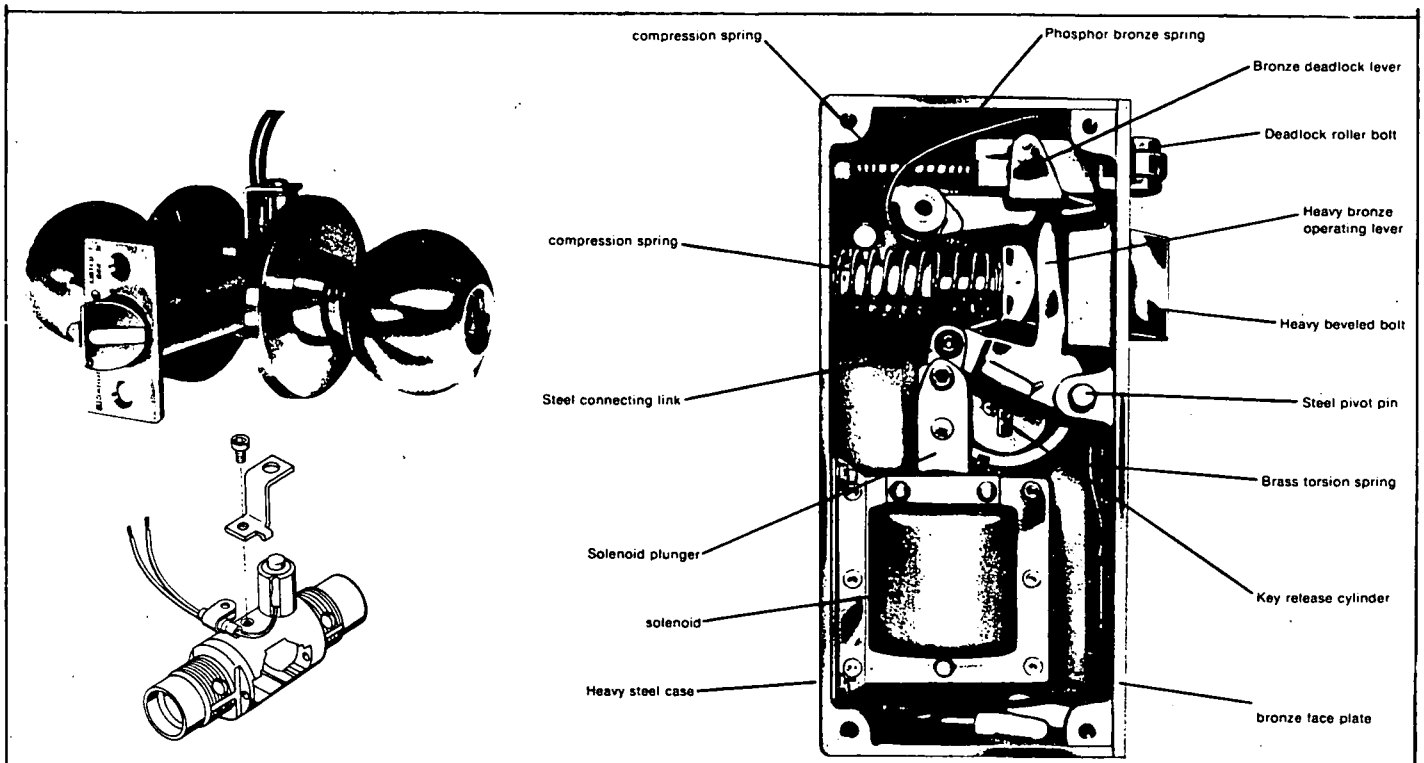


electromagnetic lock mounting locations

5.3 ELECTROMAGNETIC OPERATION

The only totally electric locking device is the Electro Magnetic lock that uses electronic code input devices. Basic to this type of lock is an armature, surface-mounted on the door's surface, and an electromagnet, normally installed under the top of the door frame. This lock, which has no mechanically moving parts, magnetically bonds the door and door frame together

when energized and releases them when de-energized. The magnetic field takes the place of a bolt and its strength is directly related to the size and amount of power used for the particular device. The holding force can be normally varied between 350 to 1500 lbs for each device and such locks are available with higher forces up to 3000lbs. Usually designed for 200 ma of current at 12v DC and 300 ma at 24v DC, they are also available for 12 and 24v AC. They are usually remotely operated by an electric switch or can be operated by any of a large number of card and electronic control systems or a mechanical switch lock. The Electro Magnetic lock can be used only in fail-safe modes. A fail-safe device is locked when energized and unlocks in case of power failure. If a fail-secure mode is required, a separate relocking mechanism must also be included.



electrically operated bolts

5.4 ELECTRO MECHANICAL OPERATION

This type of operation includes all locking devices that require some sort of electric power with or without electronic controls, combined with the mechanical movement of bolts and/or strikes. These are divided into Manually and Electronically encoded locks. The manually encoded locks require the user to push buttons or turn wheels etc. The electronically encoded locks require

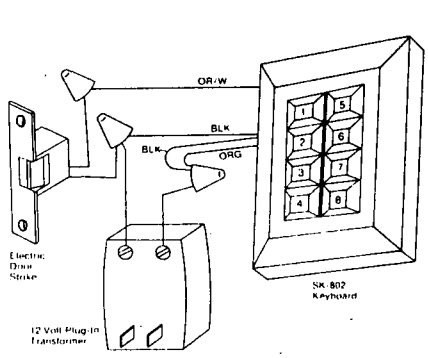
a card or a device that verifies a personal characteristic of the user. Both manually and electronically encoded locks use electric solenoids which operate the bolt or release the strike. These can also be operated by a switch controlled by a guard or receptionist.

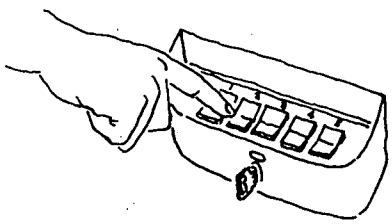
5.4.1 Manually Encoded

These include the popular Mechanical-Electrical locks and the Electronic Code Combination Locks, both of which use an ELECTRO-MAGNETIC STRIKE or BOLT that operates by applying or removing electrical power to a solenoid-operated bolt or strike. The two major components are a solenoid-operated bolt/strike/lockset, and its associated power supply or transformer, generally a low-voltage type (12 or 24 volts AC or DC). The Bolt normally operates in a fail secure mode but can be obtained with a fail-safe feature.

5.4.1.1 Mechanical-Electrical Locks

These locks usually combine a mechanical key lock together with an electromagnetic solenoid strike controlled remotely. Key locks are also available that have integrated electric controlled bolts. In these locks, keys are the usual method for encoding the cylinder tumblers and thereby operating the lock, while a remote switch overides the cylinder when necessary. A SWITCH LOCK also fits into this group since it is usually key-operated and controls an electric circuit of some sort.



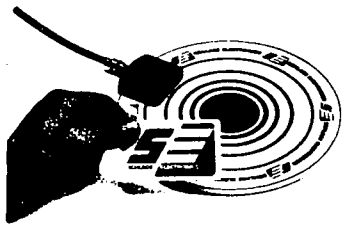


electronic push button locks

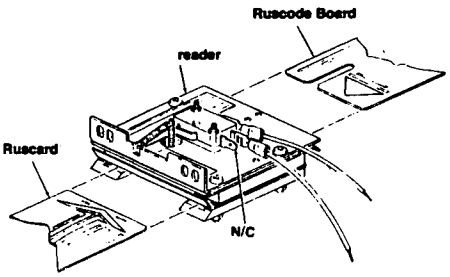
5.4.1.2 Electronic Code Combination Locks

Code Combination locks rely on a code known to the user, specifically a numerical or alphanumerical code. Typically, code combination locks are intended for unattended, self-contained use at a single entry point. A single, common code is provided to all authorized personnel. Codes are composed of three to six characterers, usually numbers. Electronic code combination locks use solid-state digital devices and circuitry to register the code and to compare it with a preset code. Entry of a correct digital code will cause a switch to open or close which energizes or de-energizes electric latches or strikes. Code changes are accomplished by plugging pins into a circuit board or by resetting microswitches. Typically, code change circuitry is included in a separate control unit which is connected

by wires to a keyboard. Keyboards for both mechanical and electronic combination locks are either of the push-button type or three-position rocker switches.



electronic card/key



5.4.2 Electronically Encoded

These include the various card lock systems: Magnetic, Capacitive, Embossed, Radio Frequency, Code Circuitry. These systems, used primarily for access control, include electronic card readers and central processors. In addition, locks that are operated by both card/key and manual encoding are included in this group. Access control systems using Optically Coded Cards and Fingerprint or Hand Geometry Verification devices are frequently connected to electromagnetic bolts or strikes and are therefore also included. The card readers include a relay or switch which is opened or closed when a properly coded card is used. The switch energizes or de-energizes an electric latch or strike. Some locks include the use of access time zones either through the use of an external timer which slightly changes the code circuitry of the card reader or by actually changing the code reader cartridge. This allows a different common code for each time zone. Time zones permit individuals to gain access only during specified time periods and to be rejected at all other times. A technique available with some magnetic card locks to limit the effectiveness of collusion is an "anti-pass back" feature. Card locks featuring anti-pass back usually employ both an enter card reader and exit card reader. The enter card reader modifies the code on the card so that it can be used only with an exit card reader, and vice versa. Thus, an individual who has gained access cannot "pass back" a card to an accomplice.

If the Card Lock is connected to a central system, the code on the card is read by the reader and then transmitted to a central processor, usually over a dedicated wire cable or a telephone line. The received card code is compared within the central processor to a previously asigned code. If the codes are equivalent, authorization is granted, and a signal is transmitted back to the reader location to actuate a relay which energizes or de-energizes an electric strike or latch. Because of the storage capability of the central processor, each individual who has entry authorization can be assigned a unique code. With the use of a central processor as a comparator for stored and entered credentials, features in addition to identity verification are possible. These features include automatic entry/exit recording and

display, allowance for different levels of access, limits on the time periods in which entry is authorized for different doors, speed in adding or deleting individuals from the system, and employment of an anti-passback feature. An advantage of a system with a central processor is that an individual's card code also can be eliminated from the file quickly and consequently cannot be used thereafter at any card reader connected to the processor. [12]

5.4.2.1 Magnetic Card Locks

Magnetic card locks include the use of a card magnetically coded with a common code. For some cards this data is encoded on a strip of magnetic tape, which can be either attached to the outside surface of the card or embedded within the card. The data is read by a magnetic pickup or reader head as the card is inserted into or withdrawn from the reader. Another type of magnetic card contains data in an array of ferromagnetic spots that are polarized so that they can be read as the presence or absence of data bits. The cards may be readily re-encoded by reversing the polarity of any of the magnetic spots. Magnetic card readers for both types of cards may contain replaceable code reader cartridges into which the cards are inserted. In order to change the code for the lock, the cartridge is replaced.

5.4.2.2 Capacitive Card Locks

Capacitive card locks include the use of a card capacitively coded with a common code. That is, the cards have embedded in them a piece of metal foil, sections of which are removed when the card is coded. The presence or absence of the foil changes the capacitance of different areas of the card. The capacitance changes are determined by the reader in the terminal. Features similar to the magnetic card locks are also available.

5.4.2.3 Embossed Card Locks

Embossed card locks include the use of an embossed card coded with a common code. Such cards are widely used as credit cards and as pass badges. They usually contain such information as name, address, identification number, and validation or expiration data in raised letters, and they also have a space for a signature. The card readers include a relay or switch which is opened or closed to energize or de-energize an electric latch or strike when a properly coded card is used. Some locks allow the use of time zones by changing the code reader cartridge. This allows a different common code for each time zone which permits individuals to gain access only during specified time periods and to be rejected at all other times.

5.4.2.4 Radio Frequency Card Locks

Radio Frequency (or RF) interrogation/response card locks include the use of a card containing tuned circuits coded with a common code. When the card is brought within 6 in. (15 cm) of a transmitter-receiver sensor which sweeps through a specified frequency range, the frequencies re-radiated by each of the tuned circuits in the card are sensed by the receiver portion

of the sensor. The sensor is a flat disc with a radius of 5 in (12.5 cm) and is mounted on a surface or wall. Because RF energy is used in the card validation process, the card does not have to be inserted into a card reader. Radio Frequency card control units contain replaceable oscillator crystals. In order to change the code for the lock, a crystal is replaced. The cardreading units usually include a relay or switch which is opened or closed to energize or de-energize an electric latch or strike when a properly coded card is used.

5.4.2.5 Coded Circuitry Card Locks

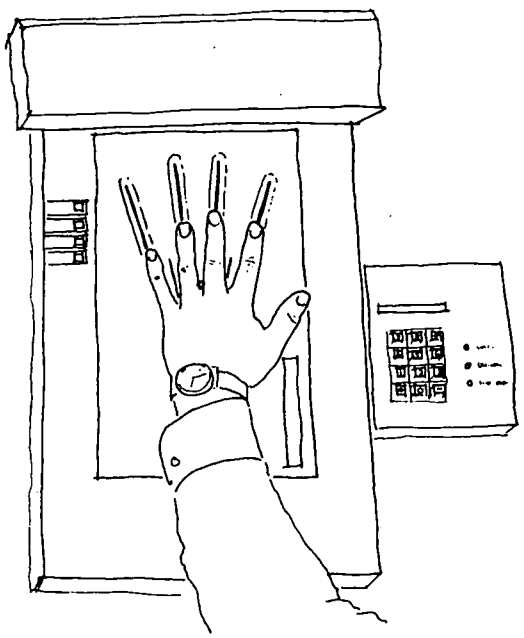
Coded Circuitry card locks include the use of a card with a common code, which is determined by a printed circuit laminated within each card. Connectors on one end of the card provide electrical contacts for the card reader. The code for each lock is determined by a replaceable printed circuit card in the associated control unit. The card readers include a relay or switch which is opened or closed to energize or de-energize an electric latch or strike when a properly coded card is used. These locks have features similar to Magnetic Card Locks.

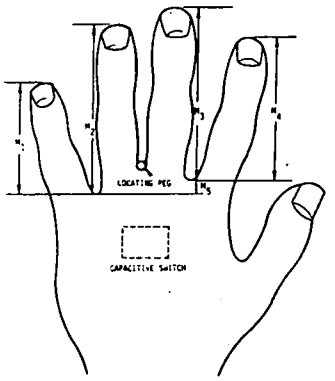
5.4.2.6 Code Combination and Card Locks

Code Combination and Card locks rely on both a numerical or alphanumerical code, known to the user and a coded card. Typically, code combination and card locks are intended for unattended, self-contained use at a single door. A unique, personal code composed of four to six characters, usually numbers, is provided to all authorized personnel. The code combination manually set by a would-be entrant is compared within the lock to the code present on a coded card. If the code combination corresponds with the card code, entry (or exit) is permitted. Code Combination and Card locks use digital, solid-state devices and circuitry to register the code and to compare it with the code read from the card. Keyboards are typically of the touch tone, push-button type with 10 or 12 buttons; cards are typially magnetically coded. (See sections 5.4.1.2, Electronic Code Combination Locks, and 5.4.2.1, Magnetic Card Locks.)

5.4.2.7 Optically Coded Card Systems

These systems use an optically coded card also called a differential-optics card, which is designed with a geometric array of dots offering different levels of optical density thereby allowing penetration of varying degree by infrared light beams. The card itself is opaque to ordinary light yet each dot of the pattern may be any of 10 levels of optical density when scanned by the card reader. The number of combinations make it possible to encode up to 65,000 different access cards without repetition.





hand geometry measurements

5.4.3 Personal Characteristics Verification

Access control systems are particularly able to exploit the availability of sophisticated methodologies for verifying the identity of individuals by directly measuring a unique personal characteristic or ability of the individuals. Direct visual verification by a guard can be enhanced by ready access to a photo on file via closed circuit TV (CCTV). Beyond that, characteristics such as fingerprints, hand geometry, speech and handwriting can be measured. One or more of these are presently being incorporated in automated identity verification systems. These, in turn, are connected to and operate the door locking devices.

5.4.3.1 Fingerprint Verification Systems

There are two basic approaches to automating the matching of fingerprints. One method consists of a direct optical comparison between the "search" print (the print entered by the individual) and the file print. In the other method, the search print is optically scanned and converted to an electrical signal, and a list of significant detailed features of the fingerprint

("minutiae") and their location is compiled in digital form. The minutiae, which consist of ridge endings and ridge bifurcations, may then be compared with a similar list on file in the processing unit [9].

5.4.3.2 Hand Geometry Verification Systems

Similar to the Fingerprint verification system, this system is used where additional identity of an individual must be established. The equipment measures the length of the fingers. The individual to be identified carries a card with identifying information plus the data representing the profile of the hand measurements. The user inserts the card into the recognition device and then positions a hand upon the sensing area. Finger geometry is then measured and compared with the data read from the card. If a match is obtained, the user's identity is considered to be verified. Alternatively, the profile data may be stored centrally. In this case, the individual first supplies identifying information on the system and positions a hand upon the sensing area. The measurements are then made and transmitted to the central location for comparison with the profile data. The system can then response appropriately, based upon whether or not a match is obtained [10,22].

5.4.3.3 Voice

Voice characteristics of an individual can be measured and stored for later comparison in order to verify the identification of the individual speaker. Presently, voice measurements can be usefully made of waveform envelope, voice pitch period, relative amplitude spectrum, and vocal tract resonant frequencies (formants). Prototype systems have been developed which employ recognition of relative amplitude spectrum and vocal tract resonant frequencies [8].

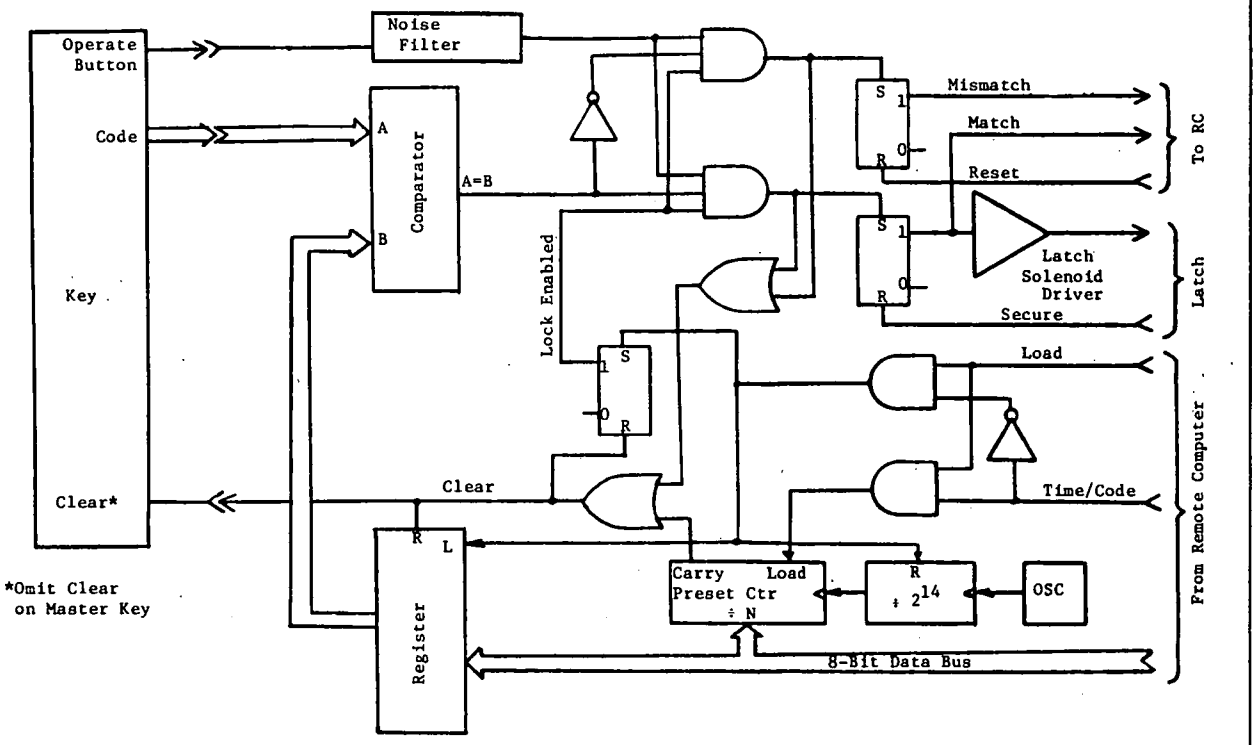
5.4.3.4 Handwriting

Automated handwriting verification systems have been developed to accurately measure handwriting dynamics over time. Statistical evaluation can be done of the signature pressure, velocity, acceleration, etc. These measurements, which are unique to the individual, can be correlated with a matching algorithm in the enrollment data base to verify the user. Systems have been developed which use from one to three axes of dynamic measurements, measured by transducer or strain gauges in the tablet and/or the pen [10].

5.5 OTHER SYSTEMS

Many locks can be interconnected to alarm systems and are specifically designed as alarm integrated locks. Additional automated or machine-aided manual entry-control systems are available that connect sophisticated sensing and identifying devices to the remote door lock operator. These devices include TV monitors, explosives detectors, metal detectors, -ray systems, sensitive nuclear material (SNM) detectors and others [10]. Combinations of these devices are presently being used for personnel search rooms at high security locations.

An interesting proposal for accessing a special weapons storage magazine, suggested by Moore et al. [20], is the use of a particular electronic locking system. This proposal uses an electronic key carried by one of the persons authorized to enter the storage area. When access to a magazine is authorized, a computer generates a random number that is loaded into the battery-operated electronic key and stored in the computer for later transmission to the remote microprocessor associated with the magazine lock. An interval timer in the key is started, and at the expiration of this interval the number is erased from the key memory. After telephoning the Guard Control Center, the electronic key is plugged into an appropriate receptacle on the exterior of the magazine and the resulting match of the random numbers in the key and lock within the acceptance time interval releases the latch. If the match does not occur, the enable period is terminated and an alarm condition is reported to the central station. There are two types of keys: single use keys and master keys. When a single use key is used to open an electronic lock, the random number which it contained is erased. Master keys retain the random number with which they have been loaded and can be used to open any number of locks that have been loaded with the corresponding number; they are erased only at the expiration of the time period with which they were loaded.



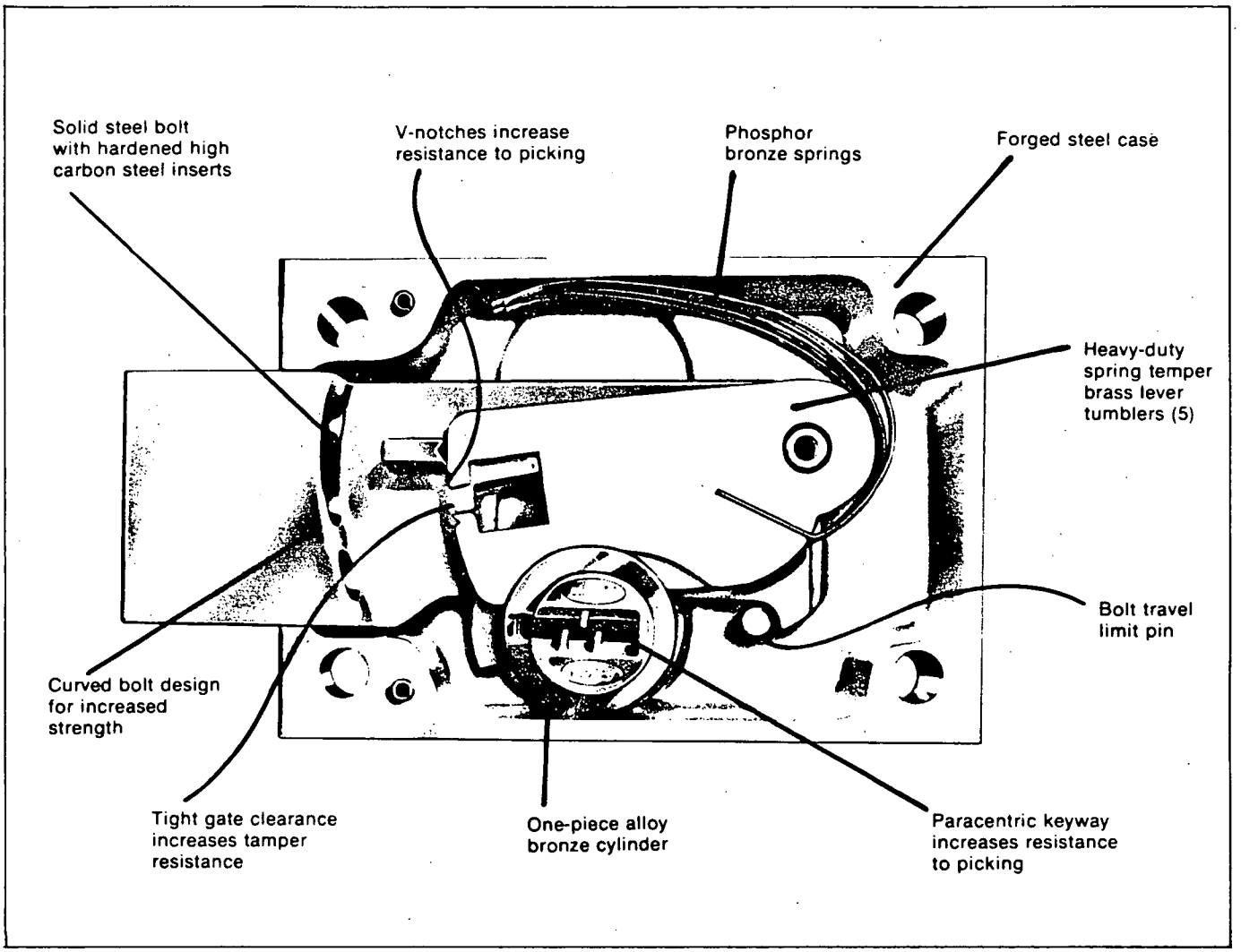
ELECTRONIC LOCKING SYSTEM

A schematic diagram, on the previous page, illustrates the logic involved in this locking system and is part of a proposed computer-based security system which includes intrusion detection equipment, diverse alarms, general radio and telephone systems, guard activity sensors, access control equipment, meterological and environmental sensors, and deterrent systems with appropriate response initiatives. It includes various fail-secure modes and a manual override mechanism to accomodate malfunctions. The override mechanism is also unique in that it a) requires a special tool to operate, and b) will sound a high intensity audible alarm when actuation is started, and c) will ensure that actuation can not be completed before the expiration of a predetermined time interval, and d) at the end of this time interval will physically withdraw the bolt of the electronic lock from its strike, and e) will force an electronic safe/arm device to the "safe" position to prevent the inadvertent actution of a forced entry deterrent action.

Another device recently developed and proposed is an Electronic Padlock for the commercial transport industry which uses a battery operated portable keyboard to input the Code into the padlock through a hard wired key.

Hydraulic and pneumatic locks are also available to a limited degree and are particularly applicable to places not completely dependent on electric current and which require remote control. Hydraulic or pneumatic operation can also be of advantage for installations requiring quick response on very heavy bolts and doors.

Catalogue illustration
security lever lock by
Folger Adam Company



6. COMPONENT CHARACTERISTICS

This group of descriptors includes those specific characteristics attributed to particular components of a locking device. For the purpose of this category, the prime components of locking devices are: 1) the BOLT, 2) the STRIKE and/or RETAINER, e) the BOLT ACTUATING MECHANISM, 4) the OBSTACLE, 5) the KEY/CODE, 6) the ARMOUR. These are listed in table 6-1 Component Characteristics, which lists separate attributes and their descriptive indicators with each component. It is understood that some characteristics are sometimes attributed to a set of components, in which case a judgment is made as to which component is more prominent in being affected and the characteristic is listed with that component. In fact, many of the descriptors refer to a method of affecting the interface between two

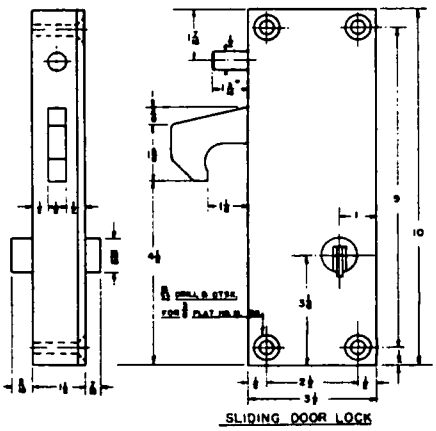
Table 6-1 Component Characteristics of Locking Devices

Component	Attributes	Specific Indicators
Bolt	Shape	Rectangular, Cylindrical, Wedge, Full Height, Compounded, Hook, Rotary, Latch, Integral
	Number	1, 2, 3, 4 or more
	Size	Standards: 1/4", 7/16", 1/2", or 5/8", 11/16", 1", 1-1/16, 1-1/8" or 1-1/4" x 3/8", 1/2", 9/16", 5/8", 3/4", or 1" throw; Custom or Heavy Duty: larger sizes
	Movement	Sliding, Pivoting, Rolling, Revolving
	Material	Mild Steel, High Carbon Steel, Stainless Steel, Brass, Various Alloys, Cast Iron, Various Inserts
Strike/ Retainer	Design	Strike Plate, Box Strike, Integral, Rim, Electric (Solonoid), Custom
	Material	Mild Steel, High Carbon Steel, Stainless Steel, Brass, Various Alloys
Bolt Actuating Mechanism	Electrical Operation	Solenoid, Motor, Pneumatic, Hydraulic, Fail Safe, Fail Secure, Remote, Adjacent
	Mechanical Operation	Spring, Cam and Lever, Gear, Dead Locking, Double Throw Pneumatic, Hydraulic, Positively or Intermittently Coupled
	Material	As above plus Spring Steel
Obstacle	Operation	Wards, Cylinder Tumblers, Lever Tumblers, Wheel Tumblers, Electronic Reader, Push Buttons, Manual Bolt (inside)
	Design Features	Bi-Access Keyway, Bicentric Cylinder, Changeable Combination and/or Core, Double Cylinder, Double Nose, Hardened Barrier, Key Holding, Masterkeying, Paracentric Keyway, Picking Lock-out, Time Recording, Programmable Relay, Time Zone, Anti-Passback Central Processor, Key Bypass, etc.
	Material	As above
Key/ Code	Manual	Combination, Push Buttons, Keyed Cylinder, Keyed Levers, Push Bolt
	Electronic, Magnetic	Embossed Code, Radio Frequency Code, Coded Circuitry, Optically Coded, Capacitive Code, Magnetic Code
	Personal Differentiation	Voice, Fingerprint, Handwriting, Hand Geometry, Facial Characteristics, Retina Pattern, Electrocardiogram Pattern, Size
	Differentiation	Rectangular, Wing Bit, Half Cylinder, Compound Shape, Flat, Corrugated, Paracentric, Tubular, Card
	Material	Metal, Plastic, Other
Armour	Protection	Resistance: Sawing, Impact, Drilling, X-Rays, Gamma Rays, Radiographic Reading
	Design	Case, Closure, Cover, Frame, Insert, Wall

components. As stated previously, many of the types listed in this classification network are not mutually exclusive. Component characteristics, in particular, have descriptors that might apply to not only other components, but to operation and installation types.

6.1 BOLT

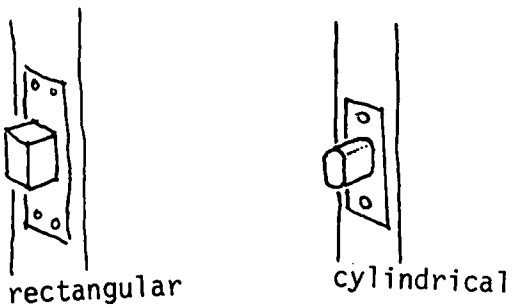
A bolt is usually a secured piece of metal which is placed between the door and its direction of travel in such a manner so as to prevent the door from opening. It can be of various SHAPES, NUMBERS, SIZES, AND MATERIALS and its placement accomplished by many methods of MOVEMENT.



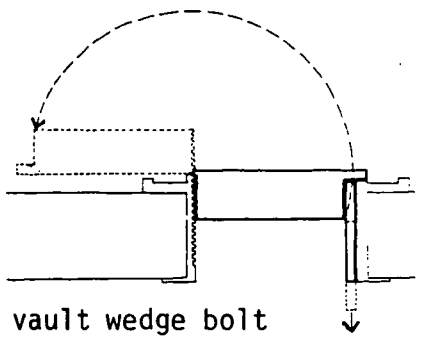
hook bolt lock

6.1.1 Shapes

Most bolts are Rectangular in shape so as to distribute any forces that might be applied in the most even manner. A rectangular shape also is easier to machine for necessary projections and recesses for gates, connections, etc., and is more stable by design to resist twisting torque and bending forces. Cylindrical shaped bolts are common for the Bored type locks since they are designed to operate in a round hole and can be cut from bar stock. The Cylindrical shape is also commonly used for manually operated bolts and multi-bolted locks in safes, vaults and cremone locks. A Wedge shaped bolt, the continuous height of the door, is used in some thick vault doors which prevents the door from opening by virtue of its filling the space required to be free for the door edge to swing through its opening arc. Some vault doors also use continuous height rectangular bolts. An interesting development in exit locks for double doors in the use of full height bolts (or moving astragals) in the meeting stiles that either project when closed or revolve on a ratchet in order to form a barrier against penetration of a hook wire through the gap between pairs

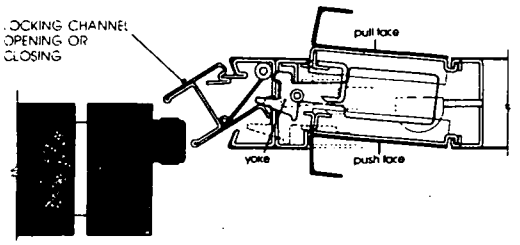


rectangular cylindrical

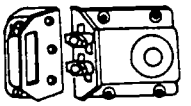


vault wedge bolt

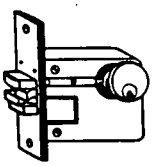
of doors. These devices could be adapted into full height dead bolts and some manufacturers presently provide an unique full height interlocking bolt system as part of their commercial door systems (e.g. Amarlite, Howmet, Kawneer, Openings). Compounded shapes are seen in the so-called vertical dead bolts, which have a pair of cylindrically shaped ends as part of a vertically sliding rectangular bolt. Similar to this is the Hook bolt used for sliding doors and integral interlocking and Rotary dead bolt locks. Latch bolts usually have beveled ends to retract into the lock when contacting the strike plate edge and thereafter snap into the strike plate retainer hole by force of a spring. A unique Bolt/Cylinder is available (by Tufloc) as part of a surface mounted, self-contained locking device with an integral hasp. This bolt is the actual cylinder housing which slides in and out of its retainer to operate the lock. Another unique bolt used in conjunction with commercial entrance doors of glass is a flat cylinder-shaped bolt that rolls rather than sliding or pivoting (by Blumcraft). Notice should be taken of locks like the Ingersoll Rim Automatic Deadlock which includes a self dead locking mechanism that latches automatically (engages by closing the door) with either a hook or flat bar type bolt.



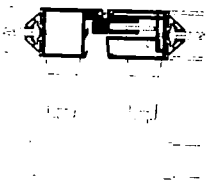
full height bolt
by OPENINGS



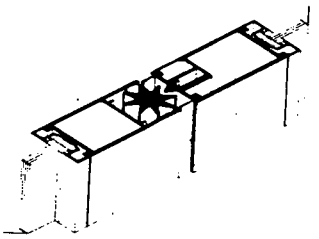
rotary dead
bolt lock



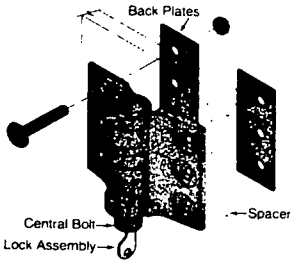
expanding
dead bolt lock



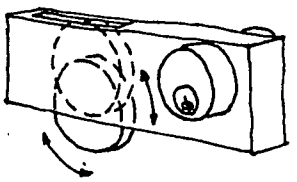
sliding
astragal



revolving astragal



tufloc bolt/cylinder

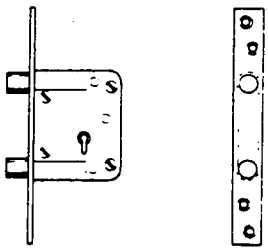


rolling bolt

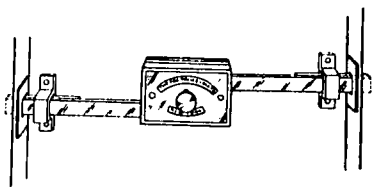
Ingersoll rim lock

6.1.2 Number

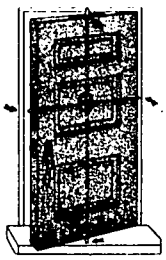
Most locks have one bolt at a single point. Since most locks are operated by cylinder locks with very small keys, there is a limit to the force that can be applied and therefore the lock it is used with one bolt of optimal size. Where larger and sturdier keys or gear operation are part of the lock design, more than one bolt becomes practical for operation. Multi-bolted locks for doors are now available from at least 3 commercial manufacturers (Mul-T-Lock, Fichet, Adams Rite). Exit locks and narrow stile locks can also have two or three bolts as part of their design.



twin-bolt deadlock



cross-bar lock



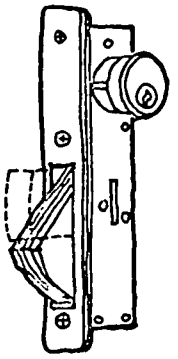
four point lock

6.1.3 Sizes

Sizes vary considerably and, although it can be said that a larger bolt should be stronger, even more important is the way the bolt is connected to the lock/door and how it will distribute forces applied to it due to both attack and normal operation. This observation illustrates the need for standard performance tests rather than merely specifying a large size for the bolt. There are practical limits to bolt size imposed by the size of the key and the design of the lock operation. Many bolts have projections of one inch or more in order to make it more difficult to pry the frame strike from securing the bolt, but a longer projection provides a longer lever arm which results in larger forces being applied to the bolt connections during an attack. Therefore, bolt size alone does not predict a level of security.

6.1.4 Movement

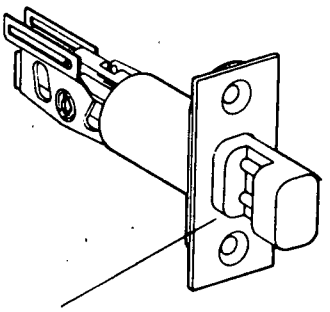
Related to its shape is the method of movement for the bolt to secure an object. Methods of movement include Sliding, Pivoting and Rolling or Revolving bolts. Passive bolts (section 5.2.1) engage retainer devices by sliding or pivoting action of the door or cover.



pivoted bolt lock

6.1.5 Materials

Materials used for bolts are usually of cast metal while the best are of stainless steel, or a hardened steel. Cast bolts with Hardened Steel Inserts are also quite common to make sawing more difficult while at the same time providing a bolt that will be economic and not corrode. Cast metal could be too brittle for high security bolts and can break under impact force. (see section 6.6, Materials) In an electromagnetic lock with no moving parts, the Electromagnetic Force takes the place of a bolt by bonding the door to the frame (see section 5.3 Electomagnetic Operation).



hardened steel inserts

6.2 STRIKE/RETAINER

Critical to the security of any bolt is the design and material of the srike/retainer which is the bolt receptacle and its immediate surroundings. This is a very simple component with a straightforward need of stability. The characteristics that affect stability are few: appropriate shape, adequate securing method and being sized for adequate strength. Strikes are available as:

Strike Plates - metal plate, with cut hole for the bolt, secured to the frame.

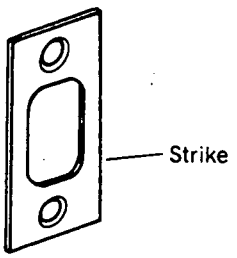
Box Strikes - box shaped metal to protect the bolt projection, secured into the frame.

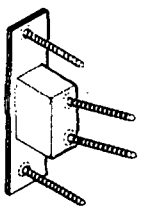
Integral Strikes - precisely cut recess in a solid metal frame, usually for a safe or vault

Rim Strikes - to accomodate rim lock bolts, surface applied

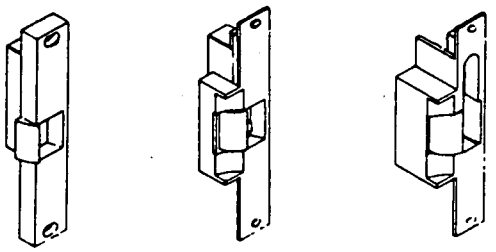
Electric Strikes - solenoid operated by a remote or adjacent switch.

There are many custom and oversized strike plates on the market designed for particular installations. Special strikes, for example, are required for locks where the bolt is thrown from the jamb into the door.





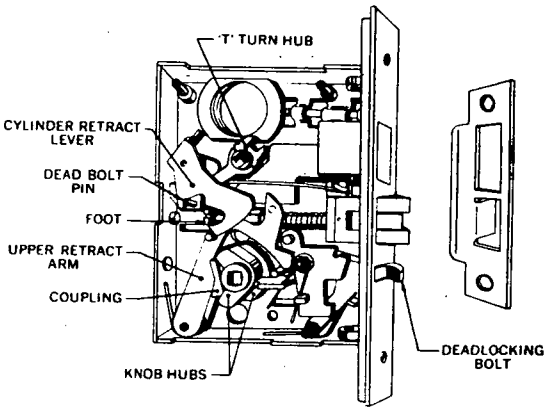
box strike



electric strikes

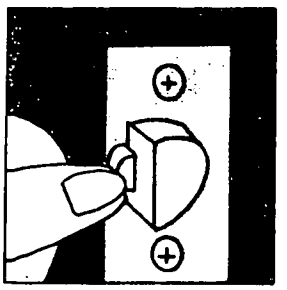
6.3 BOLT ACTUATING MECHANISM

This part of a lock is that connection between the locking bolt and the obstacle and can include simply a cam and spring in a spring latch bolt or a very complicated set of levers, gears, electric solenoids and electronic controls in a large vault door.



mortise lock
bolt-actuating mechanism

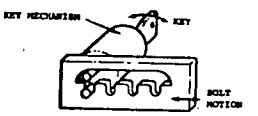
Bolt mechanisms are divided into two general categories according to the type of power used to move the bolt: Electrical or Mechanical (or manual). Some locking devices are designed to use either or both types of operating power. The operation of electric bolts is controlled by either application or removal of electrical power to a Solenoid-Operated or Motor-Operated bolt. The bolt operates in one of two modes: Fail-Secure (unlocked when energized) or Fail-Safe (locked when energized). Auxiliary power supplies are usually required. Most electrically powered mechanisms are Remote from the input device although many are Adjacent.



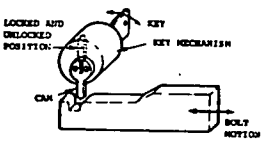
dead-locking latch

Mechanical bolts are constrained in their projected positions either by a spring or by interference from a solid barrier. The bolt or latch function is usually designated as a Spring-Loaded Latch, a Dead-Locking Latch, or a Deadbolt.

A Spring-Loaded Latch is a latch which is automatically projected by spring action. Spring latches are not usually positively coupled (see below) to their key/combination mechanism and, therefore, can be easily defeated. Where locks have a DeadLocking Latch, the use of a plunger or secondary bolt in conjunction with a spring latch is common. The plunger is depressed as the door is shut, placing a barrier in the path of the spring latch which restricts its movement.



positively coupled



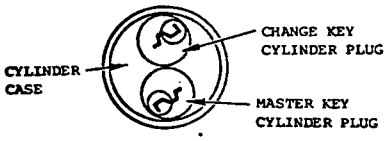
intermittently coupled

A Deadbolt has no spring action and becomes locked against pressure on the end of the bolt when it is fully projected. Deadbolts are either Positively Coupled or Intermittently-Coupled to the key mechanism. Those key locks which are positively coupled require correct key operation for unlocking. Intermittently

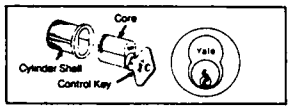
coupled deadbolt locks can often be defeated by bolt manipulation without rotation (operation) of the mechanism. Some bolts include a Double Throw mechanism which requires the cylinder to turn twice for full projection. This makes the cylinder more difficult to pick in addition to permitting the bolt to project further. Rarer forms of Bolt Actuating Mechanisms include Pneumatic and Hydraulic operation. These systems are usually combined with door closing mechanisms and operated by electrical switches and electronic controls (Honeywell, Johnson, Reliable Security, Stanley).

6.4 OBSTACLE

A critical part of any lock is the obstacle placed between the user and the operating or open mode of the door or closure. Different types of locks place different kinds of obstacles between the user and the operating or securing component that physically locks the closure. The design of the obstacle usually differentiates one type of lock from another, and the sophistication and dependability of the obstacle usually determines the level of security provided together with the practical application of a locking device. The obstacle can be a mechanical set of pins or wheels, for example, or it can be an electronic sensing device designed to identify an individual's speech characteristics. In the case of a mechanical lock, the obstacle is usually a series of tumblers, each of which must be set in a precise position before the bolt operating mechanism can move. These tumblers can be set precisely by someone knowing the secret code or having a matching encoded key. Additional obstacles include components such as: time mechanisms, a guard or another user, electronic codes, and simple physical barriers. Obstacles include almost all the items described in Chapter 5, Operation Types, including Wards, Cylinder Tumblers, Lever Tumblers, Wheel Tumblers, Electronic Coding and Decoding devices, Push Buttons, Magnetic Card and Key Readers. They are most commonly tumblers of some sort. Characteristics available for some tumblers include: Bi-Acess keyways, Bicentric cylinders (Yale) Changeable Combinations, Changeable or Removable Cores,



bicentric cylinder



removable core cylinder

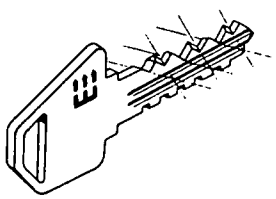
Double Cylinders, Double Nose locks, Hardened Barriers, Key Holding, Masterkeying (see Appendix E), Change Codes, Paracentric Keyways, and Picking Lockouts.

An important characteristic of all tumbler obstacles is Pick Resistance [1 16]. Pick resistance varies according to:

a. Inconsistencies in keying requirements relating to masterkeying and grandmaster-keying.
b. Variations between manufacturers concerning pin lengths, hole drilling, tolerances and key cuts.
c. The experience of the picker, location of the cylinder to be picked and type of lock function used.

Electronic locking systems have a great many characteristics that apply to the locking device obstacle, most of which were noted in Section 5.4, Electro-Mechanical Operation. Particular characteristics such as Sequential Locking, Door Interlocks, automatic Code Change, Anti-Passback, Time Zoning, Time Recording, etc, can more easily be made a part of the obstacle in an electronic system than in a strictly mechanical system.

6.5 KEY/CODE



The key is a specifically unique object in relation to a lock which provides the bearer with exclusive ability to operate a single lock or a group of locks. From the large wooden keys of 4000 years ago to the plastic cards of today, keys have come in various materials and shapes [29]. Inherent to any key or card is a code that, enables the operator to remove an obstacle or a set of obstacles placed between the key and the door-securing mechanism. A code can also be a set of digits that are placed into the device by pushing buttons or turning a dial or dials. Some devices use electronics to set and read the code. Characteristic features available in electronic systems seem almost limitless. Many

were described in Section 5.4 Electromechanical Operation, and mentioned in Section 6.4, Obstacle.

The particular types of available cards, also described previously, include Magnetic, Capacitive, Embossed, Radio Frequency, Code Circuitry, and Optically Coded cards. Access Control Systems also include methods that can operate the lock by verifying personal characteristics for each individual. Included in these methods are Fingerprint, Hand Geometry, Speech, Handwriting, Retina Pattern, Acoustic Transfer Function, and Electrocardiogram Pattern verification systems.

SMOOTH-KEY PROFILE

CONVENTIONAL SAW-TOOTH PROFILE

The conventional metal key is available in a variety of forms: Flat, Corrugated, Paracentric, Tubular, Wing Bit, and HalfCylinder, depending on the design of the cylinder or lock. Their operation is basically the same. They are inserted into a keyway by which force the tumblers are moved by corresponding cuts in the key blade or wing, enabling the key to be turned which usually engages a bolt operating mechanism. The key handle is designed to be large and strong enough to operate the cylinder and lock. The Fichet key is most unusual. It is a 4-wing key which enables as few as two or three cuts on each blade to be separated allowing ten depths per cut. The structural Strength of the Fichet key is also much greater than usual keys, allowing the key and cylinder to be used for devices requiring considerable force. Folger-Adam Co. also makes large keys corresponding to their larger cylinders and lever locks. These unusual keys are stronger and difficult to both duplicate and misplace.

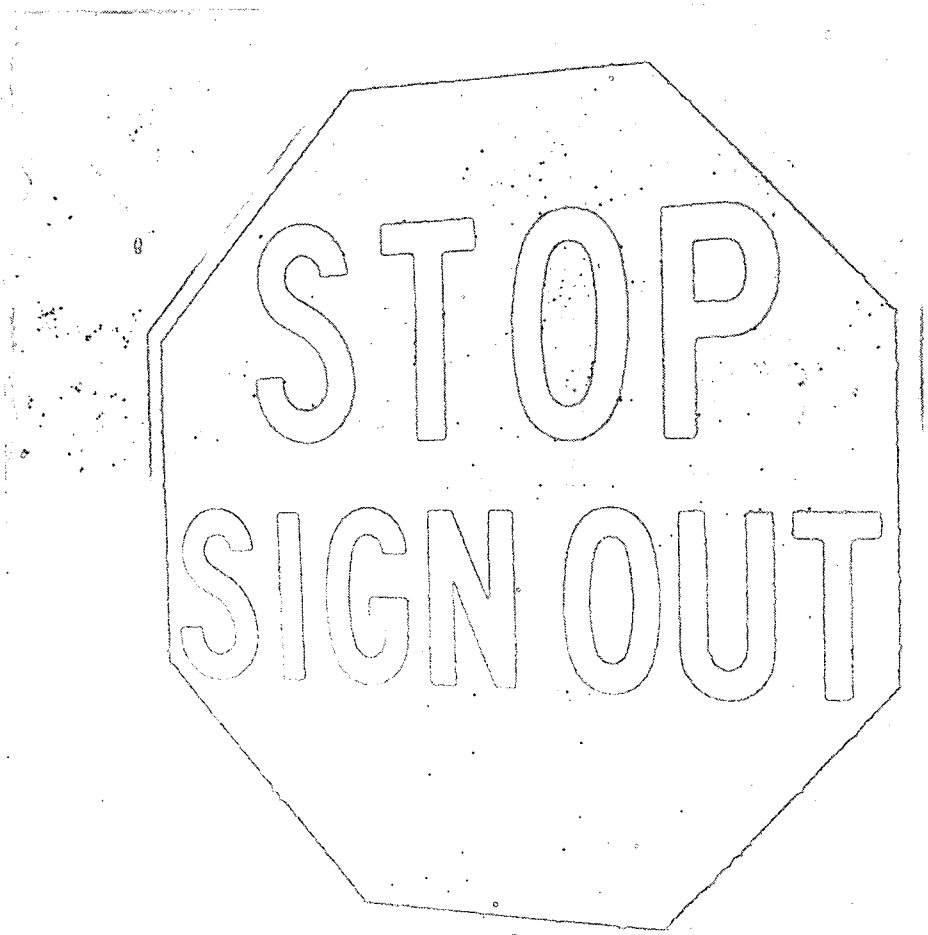
Electronic keys are available in either Active or Passive forms: the active electronic key is battery operated and transmits a code to the lock, passive electronic keys are typically cards which are read by an appropriate reader. Also available are metal or plastic keys similar to conventional keys, that are encoded similarly to the cards.

6.6 MATERIALS

Every component of a locking device requires the selection of appropriate materials in its manufacture. In high security installations, in particular, the material must be able to resist severe physical attacks and have the durability required for long use under extreme conditions [7]. Softer material is generally less resistant to tensile and compressive forces but more resistant to impact forces. A soft material will tend to yield and absorb energy under impact such as the force applied with a hammer and chisel whereas a hard material may fracture, if the hard material cannot absorb the concentrated energy applied by impact and the small area of contact at the chisel edge. See Appendix F, Selection Of Materials For Lock Components, for a brief review that touches on factors which should be considered when selecting a material for a particular component. The prime factors include the materials hardness, brittle behavior, notch toughness, and tensile strength.

6.7 ARMOUR

An obvious, but nonetheless important, component is the protection given the lock itself, against violet physical attack. This armour encloses all the vital parts of the lock and must be designed and secured in such a manner as to resist all expected types of attack. Depending on the location of the lock mechanism and bolt, the armour can be the lock case, the closure material, the wall, the frame or parts of the above, the material is usually a steel of specific characteristics (see 6.6 Materials, above) and can be obtained to resist drilling, saving and impact attacks together with resisting x-rays, gamma rays, and radiographic reading (by Shwayder).



7. SUMMARY, RECOMMENDATIONS AND CONCLUSION

Locking devices are available in a wide variety of types, each with its characteristic combination of design, performance, operation, function and components. If manufacturers of electronic security devices are included, an estimate of the number of U.S. manufacturers of locking devices and components reaches well over one thousand. Given this variety, analytic and evaluation methods must be developed to assist both manufacturers and purchasers of locking devices. This report, one part of a larger project to improve high security locking devices, contains the start of a systmatic approach to the study of locks and should assist in establishing basic

principles for the development that will improve the performance of all locking devices and benefit the manufacturers as well as the consumers.

7.1 SUMMARY

This report summarizes available information on locking devices in a manner that will be useful to those to studying locking concepts and intending develop innovative devices. Starting with a general description and review of the existing types, functions and grades of locks, the different types are described according to their installation and operation. Following this is a description of various component characteristics that differentiate locks.

Installation types are grouped into those that emphasize their installation methods, their applications or their purposes. Installation types include the most common door locks available such as the mortise locks and the bored, or key-in-knob, locks. Operation types are separated according to the kind of power or force used to move parts of the locking device, and includes mechanical, electrical or electromechanical operations. The mechanical operation types include keyed and keyless types. These are further grouped into descriptors such as cylinder tumbler, wheel tumbler, electromagnetic and electronically encoded locks, among others. Components of locks are further classified and grouped according to attributes and specific indicators. Components include the bolt and its retainer, the bolt actuating mechanism, the obstacle the key or code, and the armour.

The present market place includes locking devices of great variety and competitiveness. As sythesized in this report, there are more than 35 operation types and sub-types, 15 installation types, and 100 component characteristics. Many of these types and characteristics are not mutually exclusive, so that the available or potential variety is great.

7.2 RECOMMENDATIONS

Recommendations are made as a result of preparing this report, in three areas: 1) Standards, 2) General Study and Research, 3) Specific Product Development.

7.2.1 Recommended Standards

This report does not discuss lock performance and resistance to attack methods in any detail. Nevertheless, two reasons for deficient lock performance must be noted:

1. the lock will not resist forcible attacks if a component is not designed with adequate strength
2. there are surreptitious attack methods which can nondestructively by-pass the usual access obstacle(s) placed in the way of operating the securing mechanism or device (i.e.: in a mechanical system, lock picking).

Many types of locking devices often address one of these points without adequately accomodating the other. Elaborate electronic controls can be used for a door which can be kicked open, or a fortress-like doorway can have a lock that can be easily picked. An adequate lock can be made useless by the improper installation of a strike plate or door frame. These comments are obvious to anyone involved in physical security and yet this problem continues.

One major reason for the aforementioned problem, and most other problems in physical security, is the lack of comprehensive standards for high security locking devices. Therefore, it is recommended that work begin immediately to develop comprehensive test methods and performance standards for high security locking devices. The first step should be preparing controlled standardized laboratory tests. This will enable manufacturers and users to ascertain an agreed upon level of performance for each product. The manufacturer can benefit since a large "factor of safety" will not need to be designed into the product (overdesign) as it seems to be in many present products in order to accommodate subjective evaluation by users. The user will benefit since such tests will establish the level of performance available for a particular product. The second step should be the initiation of necessary communications among manufacturers, their Associations, the users and government agencies in a forum such as the MERADCOM/ DNA Lock Workshop or the existing ASTM Committee F-12 on Security Systems and Equipment. This will encourage the efficient implementation of the standard test methods together with the development of innovative locking devices.

7.2.2 General Recommendations for Study and Research

a) Additional State-of-the-Art Studies - It is suggested that further studies into the present state of the art for locking devices be commenced that will analyze in depth *every* system and product available. Particular emphasis should be placed on the evaluation of electronic and mechanical systems in order to enhance their strengths and reduce their weaknesses. Detailed information on the operation and maintenance of locking devices should be encouraged, for a controlled audience, in a standardized format which will help performance specifications to be developed which in turn encourages innovation. Existing designs and concepts should be analyzed for possible adaptation to high security uses. This includes those low security devices which could be improved or modified for selected applications. As an example, the key-in-knob lock is not a high security device for any application, and yet the common wafer tumblers have been adapted for use in automobile ignition locks and the installation method has been adapted for use in dead bolt locks.

b) Patent and Historical Search and Analysis - The modern pin-tumbler lock is based on the same principles the ancient Egyptians used some 4000 years ago for their locks. Practical ideas could be generated from the study of locks that are no longer being manufactured, or locks that are patented but are yet to be manufactured.

c) Evaluation Methodology - Using the classification network included in this report as a base, a methodology should be prepared for users to thoroughly evaluate locking device attributes in concert with the development of standards and methods of test for high security locking devices.

d) Glossary - An industry-wide comprehensive glossary should be prepared. An examination of the terms and definitions included at the end of this report illustrates the existence of a great deal of overlap in different parts of the industry and the need for more clarity in the use of words. A comprehensive glossary, which includes the terms used in the electronic segment of the industry, should be prepared in the forum environment of ASTM Committee F-12.

7.2.3 Recommendations for Specific Product Development

a) Multiple Point Locks - Multiple point locks are commercially available for comparatively low security (residential and light commercial) and high security (banks) needs. The economy and ease of use of the low security items and the attack resistance of the vault door should be merged for a practical multiple point locking system applicable to high security needs.

b) Technical Transfer - Adaption and application of methods used for existing locking in correction and detention institutions, custom doors, automobile locks, and vending machine locks. Many locking devices presently being used can be simply modified for use in full scale mock-ups of high security doors. It is suggested that the above noted locks, and others, be adapted as required for controlled field tests in order to provide data for the selection of interim products until more appropriate products are developed.

c) Protected Lock Mechanism - Locks are located in doors because of tradition and the need to combine the lock with a latching mechanism. This need not be the case for high security doorways. Many electronic lock controls are presently being installed in the wall adjacent to the door. The locking mechanism can be better protected by the wall if the bolts can be projected from behind the wall. The mechanism should be as far inside as possible and at least protected by the full depth of the door similar to the case of a rim lock. Electronic or electro-mechanical controls can more easily be remotely located and thereby eliminate holes in the door for keys.

d) Full Height Bolts - Using a concept derived form two sources--a bank vault door and the unique locking device manufactured by Openings Inc., a prototype study model should be built which will illustrate the practicality of having an integral full height operating bolt.

7.3 CONCLUSION

It is said that more patents have been issued for locks than for most other products in the world. Perhaps it is important that we continue to develop new locks and thereby keep ahead of those that insist on figuring out ways to defeat them. This approach entails constantly replacing existing lock sys-systems with systems based on new concepts whenever it becomes necessary. On the other hand, the key to this dilemma does lie in the key (or the code).

The object of any security system is to limit access to only one person or group of persons preselected for access. This objective is undermined if the system is compromised. The system is usually compromised by one of two methods: obtaining and using the key or code, or destroying the operating mode of the securing mechanism. In each case, security has been degraded. Carrying this logic forward, we are led to the conclusion that locking devices should not have keys or codes but be able to sense and respond to the uniqueness of individuals rather than what they possess or know. This has been approached in electronic systems that join the sciences of mechanics and biotechnology to the science of electronics in order to provide very sophisticated security systems. Locking devices are being tremendously affected by the trends in Enty-Control Systems which are becoming more and more comprehensive in their application and usefulness. Electronic systems are being used more extensively each year so that new products are almost exclusively in the electronic industry. These improvements have been generally confined to the surveilance, identification and detection components of the total security system because of the present acceptance of dependable mechanical/manual locking components to fall-back on in case of power or system failure. This is particularly true in areas where life-safety is paramount. Often, a very sophisticated electronic security/safety system will include very oridinary locks that can easily be defeated. This is changing rapidly. Locks using electronic keys/cards and/or manual digital inputs have become economically viable and to be preferred over strictly mechanical locks. While, in the past, electronic applications to security were only found in military and high security environments, they are now being sold to the homeowner by hardware stores. Managers of commercial and institutional environments have particularly become aware of the availability of more sophisticated security equipment and are insisting on their use.

The most significant advances in security methods for the military parallel advances in computer and electronic technology. There are comprehensive computer security systems for buildings that are programmed to do everything from recording personnel movements to reporting on the proper functioning of various equipment. These systems are active, rather than passive. This means that a time factor is part of the access control system such that each access point can allow or disallow entry, alarm a response to various situations, record the name of the person, time and other data, and reset the person's route or schedule. Although most military work is associated with detection, alarm and response systems, it promises to provide practicable locking devices in the future that should be superior to everything commonly used today.

In summarizing the objective of this report several conclusions should also be briefly mentioned:

1. In order to identify and document the state-of-the art in high security locking devices it was found necessary to include methods and devices presently used in low or medium security environments, for the sake of comprehensiveness.

2. Although no significant non-military locking systems or subsystems were found in the literature or in the field that can be used as-is, methods and products exist that can be modified and/or adapted for use. Some of these have been presented and further insight could be gained by investigating the potential of each.

3. The classification system of locks developed for use in this report should serve as an intellectual framework for the future study, research and development of high security locking devices.

4. The annotated bibliography and source list included in the Appendices together with the glossary of technical terms should be particularly useful to anyone interested in becoming more familiar with locking device methods and products.

The value and resistance of a particular locking device relies a great deal on its strength and the mystery of the secret method that accompanies the device. This is a case where the old adage, "The less that is known about it, the better," is actually true. The mystique of lock picking in the past grew to a point that huge sums of money were offered to anyone who could defeat a lock that was thought to be unpickable. Today, inventors still spend great amounts of time in developing and getting patented, ingenious new "unpickable" locks only to find that someone else has ingeniously discovered a method of picking or decoding the same lock. The search continues to go on for the perfect lock--one that is economical in both cost and maintenance, that is convenient to use, easy to control and practically unpenetrable by enemy or criminal attack.

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GLOSSARY OF TECHNICAL TERMS

This glossary is a compilation of definitions of selected words from various existing publications. Many more words than are mentioned in this report are included. Some defintions were accepted as written, others were combined and edited by the author. In cases of two definitions that cannot easily be reconciled, both are included. Only words directly related to locks, their components or operation are included. Most maintenance and attack terms are excluded together with definitions that were unclear. Many terms are included that are used with typical locking devices rather than high security locking devices in order to provide a relatively comprehensive glossary. The glossary, however, is not complete. Definitions applicable particularly to electronic/electrical devices will require expansion as glossaries relevant to such devices become available.

The three principal sources used for this glossary are the author's publication "Terms and Definitions for Door and Window Security" (NBS SP 480-22, 1977), "Glossary of Lock Terminology" (Locksmith Ledger, 1975), and "Glossary of Locksmith Terms" (IMDO U.S. Army 1973). In addition, the following were reviewed for some terms not included in the above noted documents and also to corroborate the definitions of specific words: "Standard Definitions of Terms Relating to Combination Locks" ANSI/ASTM F 471-76 (ASTM, 1976), "GLOSSARY", (Belsaw Institute of Locksmithing, 1974), "Combination Lock Glossary", (Lockmasters School), definitions in Reports and Standards by US Navy Civil Engineering Laboratory, Builders Hardware Manufacturers Association (BHMA), Underwriters Laboratories (UL), other government publications and various manufacturers' glossaries.

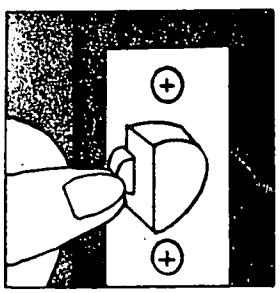
ACE KEY (trade name) - see tubular key

ACE LOCK (trade name) - see tubular cylinder

ANGLE (Cut) - Angle of indentations or cuts made in a key to make it fit the lock.

ANTI-FRICTION LATCH BOLT - The latch bolt of a lock which has been equipped with a device for lessening the friction between bolt and strike. Usually a small trigger attached to the bolt which contacts the strike and exerts a lever action to depress the bolt.

ANTI-PICK LATCH - A spring latch protected from end pressure to prevent retraction of the latch bolt with a knife or similar object. Also known as DEAD LOCKING LATCH BOLT.



ARMORED FRONT - A lock front which consists of two plates: one, the under plate, is fastened to the case and is unfinished, the other, the finish plate, is fastened to the under plate and when in place covers the cylinder set screws thus protecting them from tampering. Used on mortise locks.

AUXILIARY DEADLOCKING LATCHBOLT - An additional bolt which has a plunger which is depressed by the strike when the door is closed, and automatically deadlocks the bolt against end pressure. Also called Dead Latch.

AUXILIARY LOCK - A lock having a latch bolt or a dead bolt operated by a key or a thumbturn or both. This lock is often used in addition to another lock, which may or may not be key operated.

BACK PLATE (of a combination lock) - A metal plate on the inside of a door which is used to secure a pin or disc tumbler rim lock cylinder to the door by means of retaining screws. The tail piece of the cylinder extends through a hole in the back plate.

BACK PLATE (of a cylinder lock) - A small metal plate applied on the inside of a door through which the cylinder retaining screws and connecting bar are attached.

BACKSET OF A FLUSH BOLT - The distance from the lock face a edge of a door to the centerline of the bolt.

BACKSET (of a lock) - The horizontal distance from the face of the lock to the center line of knob, hub, keyhole, or cylinder. On locks with a beveled front, this distance is measured from the center of the lock face. On rabbeted doors, it is measured from the lower step of the center of the lock face. (To avoid confusion, it is better to indicate this as backset, longside, _____ inches.)

BACKSET (of strike) - The distance from the door stop to the edge of the strike cutout.

BAR LOCK - A lock used primarily in automobiles, having a spring-loaded metal bar incorporated in the cylinder mechanism, adding to the security of the lock. (see SIDE BAR)

BARREL BOLT - A cylindrical sliding bolt mounted on a plate containing a guide or case designed for surface mounting and manual, keyless operation.

BARREL KEY - A key having a round post with a hole in the end which allows the key to fit and turn on a pin in the lock. Used mainly for cabinet locks and sometimes called a pipe key. Similar to a tubular key.

BARRICADE BOLT - A massive metal bar that engages large strikes on both jambs of a door. Barricade bolts are available with locking devices, and are completely removed from the door when not in use.

BARRON's LOCK - A warded type lock employing a tumbler which contains a gate to allow a stump on the bolt to pass through, or a stump on the lever tumbler to pass through the bolt.

BELL KEY - A type of disc tumbler key named for its manufacturer. A cross section of the key somewhat resembles a dumbbell. Used mainly on slot and vending machines.

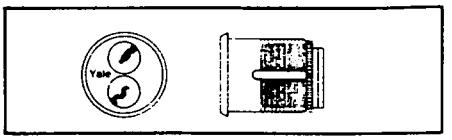
BEVEL (of a door) - The angle of the lock edge of the door in relation to its face. The standard bevel is 0.32 cm in 5.1 cm (1/8 in in 2 in.)

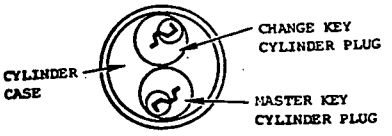
BEVEL (of a latch bolt) - a term used to indicate the direction in which a latch bolt is inclined: regular bevel for doors opening in, reverse bevel for doors opening out.

BEVEL (of a lock front) - The angle of a lock front when not at a right angle to the lock case, allowing the front to be applied flush with the edge of a beveled door.

BI-ACCESS KEYWAY - a lever tumbler cylinder that is able to be operated from both sides of the same cylinder (by Ingersoll).

BICENTRIC PIN TUMBLER CYLINDER - The name of a cylinder having two plugs and two set of pins, each having different combinations. This cylinder requires two separate keys, used simultaneously, to operate it when interconnected, or the cores can be operated independently where one is reserved for a master key.





BIT KEY - A key with a bit projecting from the end of a round shank. Similar to the barrel key, but with a solid rather than hollow shank.

BIT (of a KEY) - The projection from the tip of a bit key which is cut to allow the key to turn past obstacles or wards in the lock or to avtivate lever tumblers and thereby permit the lock bolt to be actuated.

BITTING - A cut, or a series of cuts in the bit, made in order to move the tumblers to the release position (see CUTS).

BLADE - The part of a flat key that fits into the keyway of a lock. The blade may have top and bottom cuts or just top cuts to open the lock.

BLADE TUMBLER - See disc tumbler.

BLANK (BLANK KEY) - An uncut key or the unfinished key as it comes from the manufacturer before any cuts have been made.

BOLT - 1) That part of a lock which, when actuated, is projected (or "thrown") from the lock into a retaining member, such as a strike plate, to prevent a door or window from moving or opening. See also DEAD BOLT, FLUSH BOLT, and LATCH BOLT. 2) The component or part of a combination lock that locks or blocks another mechanism from operating until it is retracted.

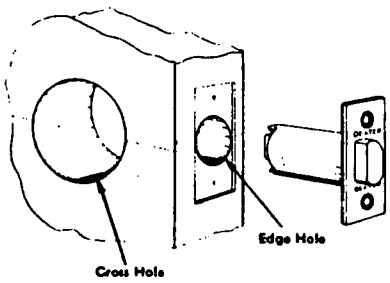
BOLT ACTUATING HANDLE - Handle of a safe, vault, or filing cabinet which actuates the bolt linkage. The bolt actuating handle is operated after the correct combination has

been dialed and the combination lock bolt has been thrown.

BOLT ACTUATOR - Located inside the case of a combination lock and attached to the interior end of the spindle. When the combination has been properly aligned, the dial knob is turned and the bolt actuator moves the bolt to open the lock.

BOLT PROJECTION (BOLT THROW) - The distance from the edge of the door, at the bolt centerline, to the furthest point on the bolt in the projected position.

BOLT WORK LINKAGE - Actuated by the bolt handle to throw the bolts of a safe, vault, or filing cabinet into the opening position after the correct combination has been dialed.



BORED LOCK (or LATCH) - A lock or latch whose parts are intended for installation in holes bored in the face and edge of a door. See also KEY-IN-KNOB LOCK and CYLINDRICAL LOCKS.

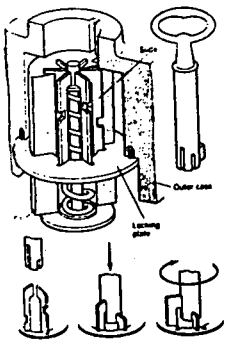
BOTTOM BOLT - Any bolt designed for use on the bottom of a door only.

BOTTOM PINS - In a pin tumbler cylinder, the pin tumblers which determine the combination of a pin tumbler cylinder and are directly contacted by the key. They are varied in length and usually tapered at one end, enabling them to fit into the "V" cuts made in a key. When the proper key is inserted, the bottom pins level off at the cylinder core shearline, allowing the core to turn and actuate the lock.

BOW OF KEY - The part of the key which does not enter the lock, and allows the key to be held for operation by the user. The handle or head of a key.

BOX STRIKE - A strike that has a metal box or housing to fully enclose the projected bolt and/or latch.

BRAMAH LOCK - A lock of very old design using sliding bars with notches cut in the sides. All notches must be aligned by pushing the key into the lock before the cylinder will turn. A barrel-type key with cuts around the cylinder end is used. Forerunner of the tubular lock.

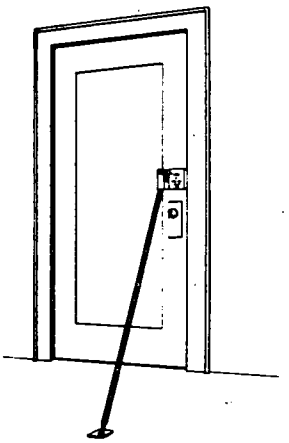


BREAKWAY STRIKE - A strike used in a remote control electric door lock, in which the strike is electromagnetically retracted for operation (see ELECTRIC STRIKE).

BURGLAR PROOF SPINDLE - Part of a combination lock, a tapered or shouldered spindle hardened pins so designed to prevent punching, pulling, and drilling. Also known as BURGLAR-RESISTANT SPINDLE, DRIVE PROOF SPINDLE, UPPER or PUNCH PROOF SPINDLE.

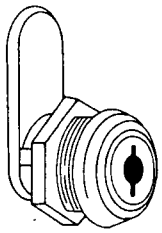
BURGLAR RESISTANT RATING - Rating of a lock as to its capability for resisting illegal entry. Usually expressed as the length of time required to accomplish entry by skill and/or force.

BUTTRESS LOCK - A lock which secures a door by wedging a bar between the door and the floor. Some incorporate a movable steel rod which fits into metal receiving slots on the door and in the floor. Also called POLICE BOLT/BRACE.



BYPASS KEY - Used with a bypass lock.

BYPASS LOCK - A secondary locking mechanism interconnected with and designed to bypass a primary mechanism and operate the bolt(s).



CAM - 1) The part of a lock or cylinder which rotates to actuate the bolt or latch as the key is turned. The cam may also act as a bolt. 2) A rotating piece attached to the end of the cylinder plug to engage the locking mechanism.

CAM, ANTI-MANIPULATION - In a combination lock, the cam has two gateways for dual levers of the lock. A ridged track on the bottom of the cam rides on a spring, creating a continuous clicking.

CAM, DRIVE - In a combination lock, the drive cam is connected to the spindle, it actuates the wheels with its drive pin, and is gated to accept the lever nose and retract the bolt. Contians: 1) Drive pin, 2) Bearing, 3) Gating, and 4) Spline.

CAM, LAZY - A cam which moves less distance than the rotation of the cylinder core.

CAM, LOCK - A handle or knob fitted to the rear of a mortise lock to provide easy operation from inside the door. Widely used on residential mortise front door locks.

CAM, MANIPULATION RESISTANT - In combination locks it is of a dual construction which rides on a spring loaded ball bearing and causes interference where the drive cam gateway contacts the lever nose.

CAM, ROLLER - In a combination lock, the cam roller pushes the lever/accelerator spring assembly onto a shelf which prevents lever/wheel contact.

CAM SLIDE - In a combination lock, connected to the inner end of the spindle and, when rotated, slides into the gate of the drive cam.

CAM, TIME LOCK MECHANISM - In a combination lock, the pin on the drive cam winds the timing mechanism of the lock when the opening combination is dialed.

CANE BOLT - A heavy manually operated cane-shaped bolt with the top bent at right angles, used on the bottom of doors.

CAP, CYLINDER - A cover attached to end of the cylinder opposite the keyhole which blocks insertion of picking tools through keyway into bolt-releasing mechanism.

CARRYING BAR - A flat, narrow steel bar, on the inside of a vault door, which moves the bolts when the door is opened or closed.

CARRYING BAR CAM - A device attached to the bolt handle on the outside of a vault door. The cam actuates the carrying bars which move the bolts when opening or closing the vault door.

CASE (of a lock) - The housing in which a lock mechanism is mounted and enclosed.

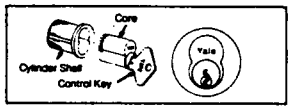
CENTERING PIN or POST - See DRILL PIN.

CHAIN BOLT - A vertical spring-loaded bolt mounted at the top of a door. It is manually actuated by a chain.

CHAIN DOOR INTERVIEWER - An auxiliary locking device which allows a door to be opened slightly, but restrains it from being fully opened. It consists of a chain with one end attached to the door jamb and the other attached to a keyed metal piece which slides in a slotted metal plate attached to the door. Some chain door interviewers incorporate a keyed lock operated from the inside.

CHANGEABLE COMBINATION - A feature where the lock combination can be easily changed when required--common to all electronic locks and wheel combination locks.

CHANGEABLE CORE or REMOVABLE CORE - A cylinder designed to be easily removable from the outside by use of a special key.



CHANGE KEY - A key that will operate only one lock or a group of keyed-alike locks, as distinguished from a master key. See also KEYED-ALIKE CYLINDERS and MASTER KEY SYSTEM.

CHANGE KEY COMBINATION - A key used in resetting a key change combination or lever lock.

CHANGERS - 1) The number of possible key changes or combination changes to a lock cylinder. 2) The different key bittings or tumbler arrangements possible in a series of locks.

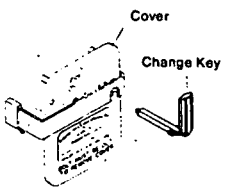
CLUTCH - The mechanism in each wheel of a key change combination lock that allows the new combination to be set.

CODE - 1) An arrangement of numbers or letters which are used to specify an operating combination for the bitting of a key or for the tumblers of a cylinder core. 2) A preset arrangement of characteristics which, if entered, operates a specific locking device.

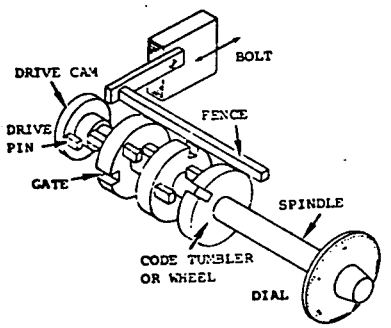
CODE KEY - A record of the key change or bitting corresponding to a particular key change number.

COMBINATION - 1) the sequence and depth of cuts on a key, 2) the sequence of numbers to which a combination lock is set.

COMBINATION CHANGE KEY - A key used in resetting a key change combination in a combination lock.



COMBINATION LOCK - A lock in which no key is used to actuate the lock mechanism. Instead, a dial is rotated or buttons are pushed to correspond to a set of characters in a certain sequence, thereby setting the mechanism into the open mode.



COMBINATION TUMBLER - See WHEEL.

COMBINATION WHEEL ASSEMBLY - A complete set of wheels on a post or curb containing tension washers, spacing washers, fly, and a retaining washer. Also known as a NEST or WHEEL PACK.

COMBINED ESCUTCHEON - An escutcheon cut for both knob and keyhole or cylinder.

COMPENSATING HUB - A hub that compensates for shrinking or swelling of doors and other minor applications, offset to project the spindle at right angles to the surface of the door.

CONNECTING BAR - A flat metal bar attached to the core of a cylinder lock to operate the bolt mechanism.

CONSTRUCTION MASTER KEYING - A keying system used to allow the use of a single key for all locks during the construction of large projects. In one such system, the cylinder cores of all locks contain an insert that permits the use of a special master key. When the construction is completed, the insert is removed and the lock then accepts its own change key and no longer accepts the construction master key.

CONTROL KEY - The key of an interchangeable core cylinder lock which is used to remove the lock core. Also a key used by bank guards to open safety deposit boxes in conjunction with the depositor's key.

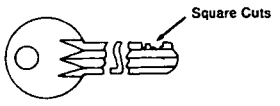
CONTROLLED RING DRIVER PIN - The top pin of a pin tumbler lock.

CONVENTIONAL LOCKS - A term commonly used to describe mortise locks.

CORE (of a cylinder) - The round central part of a lock cylinder, containing the keyway and rotated by the key to operate the lock mechanism. Also known as the PLUG.

CORE KEY - See CONTROL KEY.

CORRUGATED KEY - A key with pressed longitudinal corrugations in its shank to correspond with an irregularly shaped keyway.



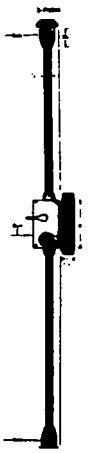
COUNTERFEIT KEY - Made from a blank of another manufacturer, the opposite of a genuine key.

COVER - Lid which secures to the lock case in a combination lock by two flat head screws.

COVER ARM - 1) During change of combination, the cover arm raises a lever to permit the drive cam to turn. 2) A device in a combination lock that prevents the lever from entering the drive cam gateway on "0" change locks during combination changes.

CRASH BAR - See PANIC BAR

CREMONE BOLT - A surface-mounted manual locking device that locks a door or sash into the frame at both the top and bottom when a knob or lever is turned.



CROWS FOOT - See INDEX, OPENING.

CURB - A component for holding the tumblers in place (see also WHEEL POST).

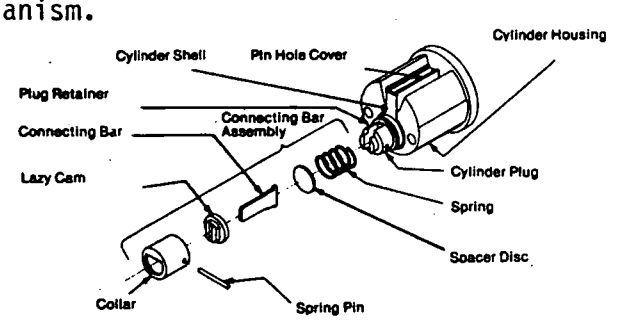
CURB ANCHOR PIN - A part of the lock case which holds the curb or wheel post in place opposite the curb screw in a combination lock.

CURB CENTER - Center or curb over which the wheels are placed in a combination lock.

CUT-OUT - A preparation of the door for hardware and/or accessories.

CUTS - The indention made in a key to make it fit the tumblers of a lock. Any notch made in a key is known as a cut, whether it is square, round, or V-shaped. Also called bitting.

CYLINDER - The cylindrical subassembly of a lock containing a cylinder plug with keyway and a cylinder body with a tumbler mechanism.

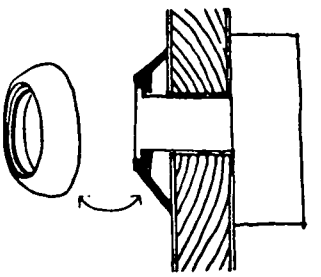


CYLINDER BODY - The portion of a cylinder that surrounds the plug and contains the tumbler mechanism.

CYLINDER COMBINATION - Usually, the combination for a given cylinder which is stamped into the bow of its keys.

CYLINDER CORE (or PLUG) - The central part of a cylinder, containing the keyway, which is rotated by the key to operate the lock mechanism.

CYLINDER GUARD RING - A hardened metal ring, surrounding the exposed portion of a lock cylinder, which protects the cylinder from being wrenched, turned, pried, cut, or pulled with attack tools.

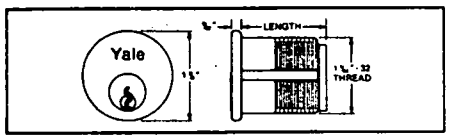


CYLINDER HINGED SHIELD - A steel guard plate designed like a hasp which is installed over a cylinder lock so that when the hinge is locked down in place with a padlock, no entry can be made to pull, pick, or tamper with the cylinder lock.

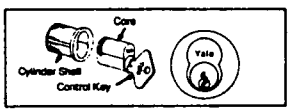
CYLINDER HOUSING - The portion of a lock that surrounds and retains the cylinder body. It can be a knob, part of a lock case or other anchoring means.

CYLINDER LOCK - A lock in which the locking mechanism is controlled by a cylinder which contains the tumblers and keyway.

CYLINDER, MORTISE TYPE - A lock cylinder that has a threaded housing which screws directly into the lock case, with a cam or other device engaging the bolt actuating mechanism.

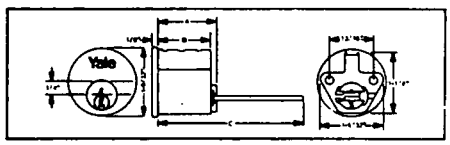


CYLINDER, REMOVABLE CORE - A cylinder whose core may be removed by the use of a special key.



CYLINDER PLUG - see CYLINDER CORE.

CYLINDER, RIM TYPE - A lock cylinder that is held in place against its rim, by screws from the interior face of the door.



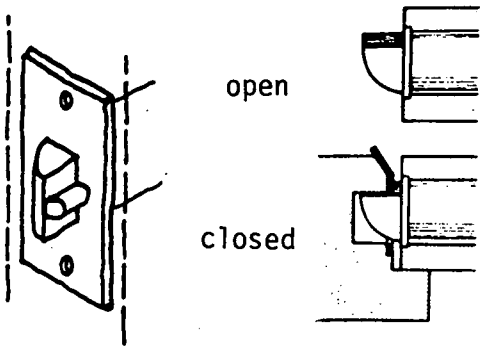
CYLINDER SCREW - A set screw that retains a mortise cylinder in place and prevents it from being turned after installation.

CYLINDRICAL (locks and latches) - see BORED LOCK (or LATCH)

DEAD BOLT - A lock bolt which does not have an automatic spring action and a bevelled end, as opposed to a latch bolt which does. The bolt must be actuated to a projected position by a key or thumb turn and when projected is locked against end pressure returning the bolt into its case.

DEAD BOLT TAILPIECE - That part of the dead bolt which remains inside the lock when the bolt is in the locked position. The tailpiece is slotted to accept the tumblers or keybit or the cylinder cam/mechansim.

DEAD LATCH - A spring-actuated latch bolt having a bevelled end and mechanically connected to an auxiliary plunger that automatically locks the projected latch bolt when the door is closed thus preventing the bolt from being retracted by end pressure.



DEAD LOCK - A lock equipped with a dead bolt only.

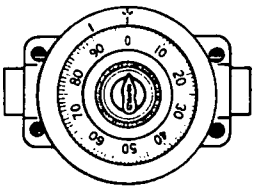
DEAD LOCKING LATCH (BOLT) - See DEAD LATCH.

DEMASTERING - A process whereby a locking system which has been master keyed is altered through changing the keying system. Demastering is a reverse process of master keying or mastering.

DEPTH KEY - Any key in a set of sample keys with a code to enable a locksmith to cut keys from a number alone. Also known as a GUIDE KEY.

DERIVATIVE CODE - A lock code in which there is a close relationship between the lock code number and the cuts in the key.

DIAL - In a combination lock, a numerically calibrated revolving knob used to dial the combination and operate the lock bolt.



DIAL LOCK - A combination lock.

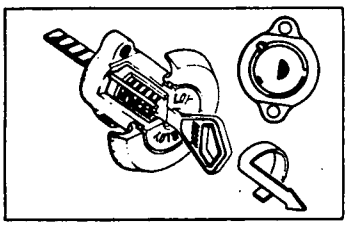
DIAL RING - The metal disc (located directly behind and around the dial on combination locks) which contains the opening, L.O.B.C., and changing indices.

DIAL & RING, SPY PROOF - Restricts unauthorized observation while dialing the combination. Also known as DIAL SHIELD.

DIAL RING, KEY LOCKING - A dial ring containing a key lock to lock the dial and prevent rotation.

DIAL SHIELD - The housing which shields the dial from unauthorized observation. Also known as the SPY PROOF DIAL.

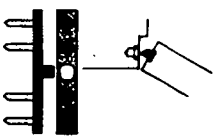
DISC TUMBLER (in a cylinder) - (1) A spring-loaded flat plate that slides in a slot which runs through the diameter of the cylinder. Inserting the proper key lines up the disc tumblers within the lock's shear line and enables the core to be turned. Also called WAFER TUMBLER. (2) Flat circular tumblers that revolve, by use of a key, in order to align slots for a side bar to drop into (Abloy Cylinder).



DISCS - Formerly, the wheels of a combination lock. The term DISC has been replaced by WHEEL. Also used instead of WAFER and DISC TUMBLERS.

DISPLAY KEY - See SHUT-OUT KEY.

DOG BOLT - Fixed, passive bolt projecting from the frame or closure or door at pivot edge (inserts into strike by the action of the closure's closing arc).

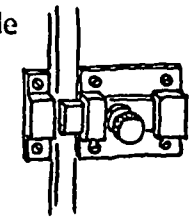


DOGGING DEVICE - A mechanism which fastens the cross bar of a panic exit device in the fully depressed position, and retains the latch bolt or bolts in the retracted position to permit free operation of the door from either side.

DOGGING KEY - A key or key-type wrench used to lock down, in the open position, the cross bar of a panic exit device.

DOOR ASSEMBLY - A unit composed of parts or components which make up a closure for a passageway through a wall. It consists of a door, hinges, locking device or devices, operational contacts (such as handles, knobs, push plates), miscellaneous hardware and closeres, the frame including the head and jambs, the anchorage devices to the surrounding wall, and the immediate surrounding portion of wall.

DOOR BOLT - A rod or bar manually operated without a key, attached to a door to provide a means of securing it.



DOOR CAVITY - That space inside a safe or vault door in which the lock case and the locking bars are located.

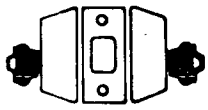
DOOR GUARD - A cover which is mounted on an outward opening door at the strike to prevent opening the lock with a shove knife, pry bar, or other similar instruments.

DOUBLE-ACTING DOOR - A swinging door equipped with hardware which permits it to open in either direction.

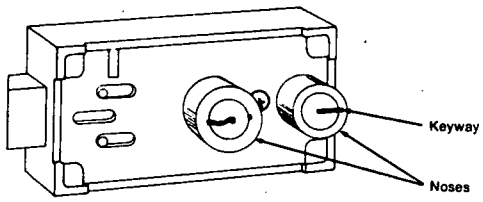
DOUBLE BITTED KEY - A key having cuts on two sides, to activate the tumblers of a lock.

DOUBLE CUSTODY LOCK - A lock requiring two keys to effect an opening. Generally found on safe deposit boxes. Also called DOUBLE NOSE LOCK.

DOUBLE CYLINDER DEAD LOCK - A lock containing two cylinders, one on each side of the door, either one of which can operate a dead bolt with the use of a proper key.



DOUBLE NOSE LOCKS - Used in safe deposit boxes are usually lever locks with two keyways, both of which must be turned to actuate the bolt. Also called DOUBLE CUSTODY LOCKS.



DOUBLE THROW BOLT - A bolt which can be projected beyond its normal first position by automatic or manual operation to a second or fully extended position thus providing added security. (This type of bolt is used throughout Europe and is predominant in Germany.)

DOUBLE THROW LOCK - A lock incorporating a double throw bolt.

DOUBLE BITTED LOCKS - Designed for use with a double bitted key.

DRILL PIN - A round pin, sometimes referred to as a CENTERING PIN or POST, which projects from the inside of the lock case opposite the keyway to receive a barrel or pipe key.

DRILLED KEY - A key with a round post and having a hole in the end which fits over a pin on the lock.

DRIVE CAM - 1) In a combination lock, a cam which is fastened to the spindle and turns over it and the dial. The drive cam actuates the wheels through a drive pin and is gated in order to retract the bolt. The drive cam contains a drive pin, bearing gating, spline, and cam slide. 2) The assembly which actuates the wheels in a combination lock by means of a drive pin. It is also gated to retract the bolt. The slide is operated by the knob and the inner spindle controls the gating. When retracted, the slide also limits the drive cam movement.

DRIVE DISC - See DRIVE WHEEL.

DRIVE PIN - A small projection on the drive cam and wheels which drives the wheel closest to it in order to align the wheel.

DRIVE PIN SCREW - Inserted manually into a threaded perforation in a screw change wheel at a selected position to change the combination.

DRIVE PROOF SPINDLE - See BURGLAR PROOF SPINDLE.

DRIVE WHEEL - The wheel in a combination lock which is connected to the dial by the lock spindle.

DRIVER PINS - Part of the set of pin tumblers in a pin tumbler cylinder, usually flat on both ends, which push against the flat ends of the bottom pins. They are projected by individual coil springs into the cylinder core until they are forced from the core by the bottom pins when the proper key is inserted into the keyway.

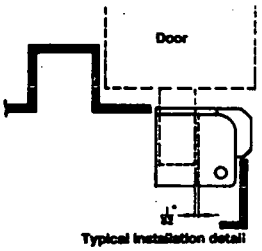
DROP - In a pin tumbler cylinder, the drop represents the difference in thousandths of an inch between any two adjacent pin sizes. The drop should be consistent for adjacent pins throughout the complete run of the cuts.

DROP ESCUTCHEON - A pivoted covering or weather guard for a keyway which prevents rain or dust from entering. The cover slides aside in order to insert the key.

DROP RING - A ring handle attached to the spindle which operates a lock or latch. The ring is pivoted to remain in a dropped position when not in use.

DUMMY CYLINDER - A mock cylinder without an operating mechanism, used for appearance only.

DUST-PROOF STRIKE - A strike with a spring plunger that completely covers the bolt hole when the bolt is not projected.



ELECTRIC STRIKE - An electrically operated device that replaces a conventional strike plate and allows a door to be opened by using electric switches at remote locations to release a pivoted bolt receptor.

EMERGENCY KEY - Operates any lock in a system which has been locked by the change, master, grand master, or lock-out keys. It controls the function of the lock in the same manner as the master key. In addition, it will operate when the dead bolt is thrown from the inside, even though the change key remains inside the lock. This key can also be used to

make all keys inoperative except the master and guard key. Also known as Lockout Key.

END WARD - A ward cut made in the end of a bit key.

ESCUTCHEON PLATE - A surface-mounted cover plate, either protective or ornamental, containing openings for any or all of the controlling members of a lock such as the knob, handle, cylinder or keyhole.

ESCUTCHEON, KEY - A plate containing an opening for a key only.

ESPAGNOLETTE BOLT - A fastening device for inswinging French windows or doors, the device is applied to the surface of the window or door. It has hooks fastening the top and bottom plus a bolt or hook locking the sash at the center. One turn of the handle operates all three locking positions.

EXTENSION LINK - A metal device that can be linked to the latch of a cylindrical lock to increase the back set.

EXIT DEVICE - A door locking device designed to grant instant exit by pressing on a cross bar that releases the locking bolt or latch; also known as panic hardware.

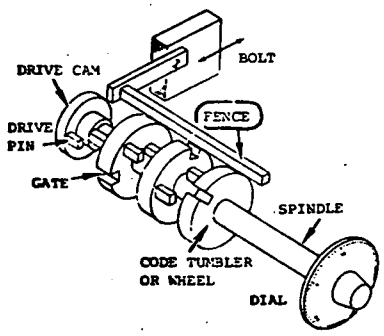
FACE (of a lock) - The exposed surface of mortise and other lock which is located in the edge of a door.

FACEPLATE - The part of a mortise lock or rim lock through which the bolt protrudes and by which the lock is fastened to the door. Also known as FRONT.

FALSE GATE - A gate in the levers of or in the wheels of combination locks which will serve to confuse an inexperienced operator who attempts to pick or manipulate the lock. The lever, which normally allows the bolt to be retracted to open the lock, will not accept the fence at the false position.

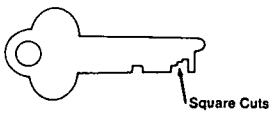
FENCE - 1) A metallic projection (usually attached to the tail of the dead bolt) which

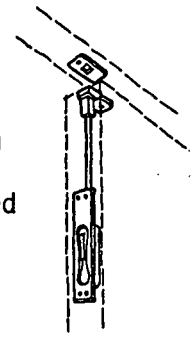
passes through the gates of the wheels or the lever tumblers when they are properly aligned, permitting the bolt to be projected or retracted. 2) (In a combination lock) A part of the lever that fits into the tumbler gates, permitting the lever to engage the drive cam.



FIRE EXIT BOLT - See EXIT DEVICE.

FLAT KEY - A key of flat steel without grooves or corrugations which usually has square-cut bitting on one or both sides.





FLUSH BOLT - A door bolt so designed that, when installed, the operating handle is flush with the face or edge of the door. Usually installed at the top and bottom of the inactive leaf of a double door.

FLY - A metal stamping on a combination lock wheel so constructed as to move within a small arc of travel which is limited by the main body of the wheel. The fly is actuated by the drive pin of the adjacent wheel or drive cam and permits alignment of the gate on a particular number when the number is dialed either clockwise or counterclockwise. If the wheel has no fly, the opening combination will differ when dialed clockwise than when dialed counterclockwise.

FRONT (of a lock) - See FACE PLATE.

GATE - In lever locks, a notch in the end of a lever tumbler which, when aligned with the fence of the lock bolt allows the bolt, to be withdrawn from the strike. In combination locks, the notch in a wheel tumbler which must be aligned to allow the fence to enter and operate the bolt mechanism.

GATING - Refers to the arrangement of the gates in a combination lock.

GEARED DRIVE - The mechanical system in a combination lock in which a spindle, projecting from the lock case proper, actuates the drive cam through a gear mounted on the spindle inside the lock case. Also know as OFFSET DRIVE.

GEARED ROLLER FENCE - A device in a combination lock that serves to retract the bolt when the proper combination has been aligned and is geared to the drive cam, it includes: 1) fence - projects across preriphery of the wheels, and 2) nose - portion which contacts the drive cam.

GENUINE KEY BLANK - A key blank furnished by the manufacturer of the lock with which the key is to be used. Also called a GENUINE.

GRAND MASTER KEY - A key designed to operate all locks under several master keys in a system.

GREAT GRAND MASTER KEY - Operates a number of groups of locks, each group being under the control of a master key or a grand master key.

GROUP I - Designation of the Underwriters Laboratories for combination locks which are tested for 20 manhours against manipulation.

GROUP IR - The designation of the Underwriters Laboratories for combination locks which have been tested for 20 manhours against manipulation and 20 manhours against radiological attack.

GUARD LOCK - A lock which secures or checks another lock. That part of the mechanism of a safe deposit lock which is controlled by the attendant's key as distinguished from that part of the mechanism actuated by the depositor's key. Sometimes a guard lock secures or covers a keyhole.

GUARD PLATE - A piece of metal attached to a door frame, door edge, or over the lock cylinder for the purpose of reinforcing the locking system against burglary attacks.

GUARDED FRONT AND STRIKE - A mechanical interlocking method which prevents latch bolt manipulation when a door is closed. Designed particularly for psychiatric institution and school building locks.

GUIDE KEY - See DEPTH KEY.

HALF MOON RETAINER - In combination locks, used to secure a wheel pack on the wheel post. Fits over the top of the wheel pack and snaps around the wheel post. Usually referred to as a SNAP RING or SPIRALLOCK in newer assemblies.

HAND - 1) A term used to indicate the adaptability of a door lock to left hand or right hand doors. Also used to indicate, on combination locks, the position of the bolt with respect to the dial and dial index. See VERTICAL UP and VERTICAL DOWN. 2) A term used to indicate the direction of swing or movement and/or locking side of a door.

HAND CHANGE - A method of changing the combinations of locks by disassembling and manually rearranging the relative position of the drive pin to the gate on various wheels of the lock. Types of hand changes are mesh change, screw change, and hole change.

HANDED (locks, etc.) - A term used to indicate that the article designated is for use only on righthanded doors or left-handed doors but not on both.

HAND OF COMBINATION LOCK INSTALLATION - The spindle is splined in one of four positions to permit these various mounting applications: 1) right hand horizontal, 2) left hand horizontal, 3) vertical up, and 4) vertical down.

HARDENED BARRIERS - Are inserts or covers that protect the cylinder, keyway or bolt from drilling and/or sawing. (includes, cover plate, cylinder protection, lock case protection, armour, protective envelope)

HARD PLATE - A hardened steel plate, usually 1/8 inch or more in thickness and fastened to the interior of the door, on which the lock

It is intended to prevent drilling or punching through the door to gain access to the lock case.

HIGH CUT - A key which has practically no cuts. Designated as "0" bitted.

HOLD-BACK FEATURE - A mechanism on a latch which serves to hold the latch bolt in the retracted position.

HOLLOW POST KEY - See BARREL KEY.

HOUSING - see CYLINDER BODY

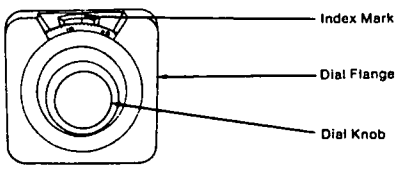
HUB - The part of a lock through which the spindle passes to actuate the mechanism.

HUB SPRING - The spring fitted around the body of the hub to restore it to its normal position after having been turned.

INDEX, CHANGING - The index mark on the dial ring used when changing the combination. The changing index mark may be located anywhere on the dial ring.

INDEX, L.O.B.C. - In a combination lock, L.O.B.C. means the lock cover is "Locked On By Combination." The opening combination must be dialed to this index mark to remove the lock cover and/or change the combination.

INDEX, OPENING - The index mark on the dial ring of a combiation lock used when dialing the combination to open the lock. Commonly referred to as the CROWS FOOT.



INDIRECT DRIVE - See GEARED DRIVE.

INDIVIDUAL KEY - See CHANGE KEY.

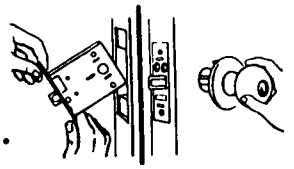
INNER PLATE - Sometimes referred to as the rear door plate. The inside plate of a vault door assembly.

INNER SPINDLE ASSEMBLY - In a combination lock, a component of the manipulation-resistant series of combination locks that connects the knob with the cam slide.

INSIDE CASE - The inner portion of the lock case which contains the latch bolt, tailpiece, tailpiece spring, locking slide, and hubs.

INSTANT LOCKER - A lock constructed to lock automatically by spring action upon closing the door.

INTEGRAL LOCK (or LATCH) - Similar to a Mortise lock except that the key cylinder is located in the knob. Series 3000 Lock of the ANSI Standard for Locks and Lock Trim (A156.2).



INTERLOCK - Used in banks and other financial institutions. A set of doors used to pass through a vestibule, only one of which can be opened at one time. When one door is unlocked, the other door remains inoperative until such time as the first door closes and relocks.

INTERLOCKING BOLT - See vertical BOLT LOCK

JAMB/STRIKE - That component of a door assembly which receives and holds the extended lock bolt. The strike and jamb are considered a combined unity for security.

JAMB/WALL - That component of a door assembly to which a door is attached and secured by means of the hinges. The wall and jamb are considered a combined unity for security.

JIMMY-PIN - A sturdy projection, which is installed in the hinge edge of a door near a hinge and fits into a hole in the door jamb and prevents removal of the door if the hinge pins are removed. Also known as DOG BOLT.

JIMMY RESISTANT LOCK - See VERTICAL BOLT LOCK.

JOINTED SPINDLE - A two-piece spindle used in cylinder locks having a handle on one side and a knob on the other.

KEEPER - Synonymous with STRIKE.

KEY - An instrument designed and fabricated or cut to fit a particular lock or group of locks which, when used, actuates a lock bolt into the

locked or unlocked position. It is uniquely coded to provide exclusive actuating ability to its possessor.

KEY CHANGE - The combination of cuts in a key which enable it to operate the lock for which it is intended.

KEY CHANGES - The different combinations that are available, or that can be used in a specific cylinder.

KEY CHANGE NUMBER - The recorded code number indicating the key change (usually stamped on the key).

KEY CHANGE PROGRESSIONS - To prevent the possibility of any change key operating more than one cylinder, all depths are separated by "two's." For example, a typical progression could start with change key 134412, and the following changes would be 134414, 134416, 134432, 134434, and 134436, etc., for a total of 15,625 changes. In practice, however, there are about 12,000 key combinations starting with this change number.

KEY CHANGE WHEEL - In a combination lock, one of the wheels of a wheel pack which contains meshing teeth. This wheel is so designed as to allow the change key to be inserted into the clutch of the key change wheel which is then dialed to a preselected numerical position which provides one of the numbers of a new combination set on the lock. The key change wheel contains a gate, drive pin, and clutch.

KEY CHANGING COMBINATION LOCK - A combination lock in which the combination can be reset without removing the lock cover by use of a special key which operates clutches in the wheel pack.

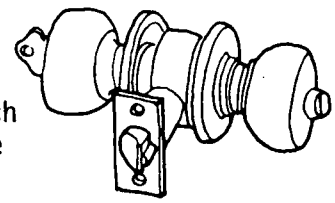
KEY CHANGING LOCK - A lock in which the key code of the tumblers can be changed to correspond with the change key.

KEY CODE NUMBER - A coded number which will indicate the correct setting of the key bitting when properly deciphered.

KEY CONTROL SYSTEM - A group of components enabling the user to contain and control the use of keys in an orderly and secure manner. The components include means of storage, identifying tags and record-keeping materials.

KEY HOLDING - Is a feature found in some cylinders where the key cannot be removed unless the bolt is projected.

KEY HOLE - See KEYWAY



KEY-IN-KNOB LOCK - A lock having the key cylinder and the other lock mechanism, such as a push or turn button, contained in the knobs.

KEY LOCKING DIAL or RING - In a combination lock, an arrangement whereby a lock, either in the dial or dial ring, locks the dial against turning.

KEY PLATE - A small escutcheon having only a keyhole. Also used to describe the modern apertured number plates used in safe deposit boxes to designate the box number.

KEY SHOULDER (Top and Bottom) - That portion of the key where the bow and blade meet.

KEY SLIDE BUTTON - Opens the key slide in the back of a combination lock when it is unlocked.

KEY, SPLINE - See SPLINE KEY.

KEYED-ALIKE CYLINDERS - Cylinders which are set to be operated by the same key. (Not to be confused with master-keyed cylinders).

KEYED-DIFFERENT CYLINDERS - Cylinders requiring different keys for their operation.

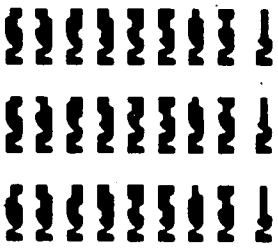
KEYHOLE - The opening in a lock designed to receive the key. See KEYWAY.

KEYHOLE LOCK - A small pin tumbler mechanism designed to block the keyhole of a bit key lock. Sometimes called KEYHOLE PLUG or INSERT LOCK.

KEYHOLE LOCKOUT - Devices which are inserted into the keyway to block the entrance of any key. These must be unlocked and removed before the key may be inserted.

KEYING - Locks offer the possibility of very complex keying arrangements. These are the basic terms: INDIVIDUAL KEY, a key for an individual cylinder, KEYED ALIKE, all cylinders may be operated by the same key (not to be confused with master keyed), KEYED DIFFERENT, a different key operates each cylinder or group of cylinders, MASTER KEY, a key to operate a group of cylinders each of which may be set to a different individual key, MASTER KEYED, all cylinders in a group can be operated by one master key, although all cylinders may be keyed different (not to be confused with keyed alike). KEYING SYSTEM - A planned arrangement for setting up key changes in a group or series of locks.

KEYWAY - 1) The longitudinal slot in the cylinder core or hole with millings in the sides identical to those on the proper key, thus allowing the key to enter the full distance of the blade or shank. 2) The aperature in lock cylinders which receives the key and closely engages with it throughout its length.



KEYWAY GUARD - Metallic plate which guards the keyway on a combination lock. It is actuated when the slide button is pushed up after the lock has been opened. This action removes the keyway guard so that the change key may be inserted in order to reset the combination.

KNOB - A projecting handle, usually spherical, for operating the lock. It is attached to the outer end of the spindle and actuates the cam slide when rotated.

KNOB ASSEMBLY - Comprised of knobs on both sides of the door including housing, cap, plunger unit, spindle, and catch.

KNOB BOLT - Part of a door lock, the bolt of which is controlled by a knob or thumbpiece from one or both sides of the door. The knob bolt is not actuated by a key.

KNOB HUB - The movable part of a mortise door lock, through which the handle is inserted. When the handle is turned, the knob hub has a projection on its side which contacts the knob hub lever. In turn, the knob hub lever moves the latch bolt to either the open or lock position.

KNOB HUB LEVER - Connected to the latch bolt of a mortise lock, it opens or closes the door lock when actuated by the rotation of the door handle.

KNOB LATCH - A securing latch, being a spring projected leveled bolt operated by a knob only.

KNOB LOCK - A door lock having a spring latch operated by knobs in connection with a dead locking mechanism.

KNOB LOCKING RING - Horseshoe-shaped ring which is inserted around the shaft of the knob or butterfly in the dial knob of a combination lock to hold it in place.

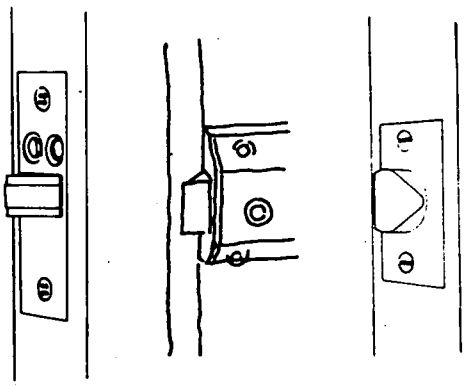
KNOB ROSE - A small plate which acts as a knob shank bearing and as a protective or ornamental shield which is applied to the surface of the door.

KNOB SHANK - The projecting stem of a knob into which the spindle is fastened.

KNOB SPINDLE - The bar connecting with the knob and passing through the hub of the lock for the purpose of actuating the bolt.

KNOB TOP - The grip of the knob attached to the shank, that part of the knob which the hand grasps.

LATCH BOLT - A metal lock component having a beveled end which projects form the lock front by spring action in its extended position, but may be forced back into the lock case by end pressure or drawn back by action of the lock mechanism. When the door is closed, the latch bolt projects into a hole provided in the strike, thus holding the door in a closed position.



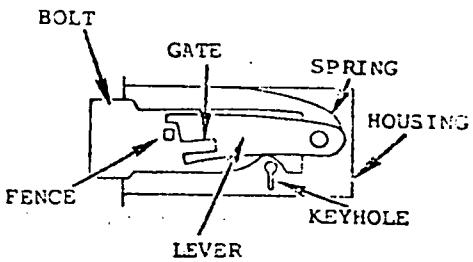
LEADING EDGE - See LOCK EDGE.

LEVER - A spring-loaded part in lever locks which, when properly positioned by a key, permits movement of the bolt work. See LEVER TUMBLER.

LEVER (Combination Lock) - Serves to retract the bolt when the proper combination has been aligned. The fence is integral to the lever and is a projecting bar which fits into the gates of the wheels when they are properly aligned. The nose portion of the lever contacts the drive cam.

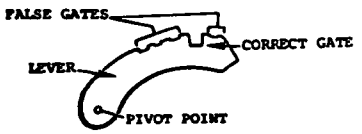
LEVER HANDLE - A bar-like grip which is rotated in a vertical plane about a horizontal axis at one of its ends, designed to operate a latch or bolt.

LEVER LOCK - A key-operated lock that usually incorporates three or more lever tumblers, which must be raised to a specific level so that the fence of the bolt is aligned with the gate of each tumbler in order to withdraw



the bolt. Lever locks are commonly used in storage lockers, safety deposit boxes, and European door locks. Also called LEVER TUMBLER LOCK.

LEVER TUMBLER - A flat metal arm, pivoted on one end with a gate in the opposite end. The top edge is spring-loaded. The bitting of the key rotates against the bottom edge, raising the lever tumbler to align the gate with the bolt fence. Both the position of the gate and the curvature of the bottom edge of the lever tumbler can be varied to establish the key code. Lever tumblers are also used in some cylinder locks of much smaller proportionate size.



LIP (of a strike) - The curved projecting part of a strike plate which guides the spring bolt to the latch point.

L.O.B.C. - See INDEX L.O.B.C.

LOCK - A fastening (as for a door, box, trunk, lid, drawer) in which a bolt is secured by any of various mechanisms and can be released by inserting and turning a key or operating a special device (as a combination, time clock, automatic release button, magnetic solenoid). (Webster's Dictionary)

LOCK BACKSET - Distance from edge of door to center line of cylinder or knob.

LOCK CASE - The housing in which all component parts of the lock are installed or attached.

LOCK CODE - See CODE KEY.

LOCK CYLINDER - A locking mechanism which is fitted with pin or other tumblers and operated by a paracentric or milled key. A standard cylinder is one with a diameter of not less than 1-1/8 inches at back of the head and with not less than five pin tumblers.

LOCK EDGE - The vertical edge or stile of a door in which a lock may be installed. Also called the leading edge, the lock stile or the strike edge.

LOCK REINFORCEMENT - A reinforcing plate of metal parts attached inside of the door to receive a lock.

LOCK SET - A lock, complete with tumblers, bolt and actuating mechanisms, case, strike and lock trim.

LOCK STILE - See LOCK EDGE.

LOCK TRIM - Exposed items such as knobs, handles, escutcheons, mounting srews, etc., which when furnished with the lock make a complete lock set.

LOCKOUT - A design feature that enables one to eliminate other keys from entering the lock or cylinder.

LOCKOUT KEY - See EMERGENCY KEY.

LOW CUT - A deep cut in the key.

LUG - A projection on a combination lock disc which contacts the adjacent wheel causing it to turn when the dial is rotated.

MANIPULATION-PROOF LOCK - A manufacturer's description applied to his combination lock which has specific features (more accurately described as manipulation resistant).

MASTER DISC TUMBLER - See MASTER PIN.

MASTER GUARD KEY - Operates any lock subject to the master, grand, or display key. It is so constructed that when used on locks subject to a guard key, it makes all master, grand, and display keys inoperative. It DOES NOT act as an emergency key.

MASTER KEY - The key which is cut to provide means for operating all locks in a series or group of locks, each lock having a separate specific combination and change key.

MASTER KEY COLLAR - An exterior auxiliary sleeve used over the regular plug, in master keyed Corbin cylinders. The change key actuates the regular plug, in addition to the auxiliary sleeve. This eliminates the necessity for additional master pins and provides for improved security.

MASTER KEY SYSTEM - A method of keying locks which allows a single key to operate multiple locks, each of which will also operate with an individual change key. Several levels of master keying are possible: a single master key is one which will operate all locks of two or more master key systems, a great grand master key will operate all locks of two or more grand master key system. Master key systems are used primarily with pin and disk tumbler locks and, to a limited extent in the U.S., with lever or warded locks.

MASTER KEYING (or MASTERING) - The process of setting up the key changes in a group or series of locks in a master keyed system.

MASTER PIN or DISC - Cylinder tumbler pin or disc tumbler used for the setting of the second or third combinations in a cylinder when setting up a master key combination. Tumbler master pins are made by adding extra segment(s) to the usual pin pairs. The disc type are cut in the center slot in such a way to accept the special master key blank required.

MASTER RING - A metal sleeve that encircles a conventional plug and is an integral part of the cylinder. The master ring is designed to expand the number of possible safe key changes in a given keying system. Its use is often confined to very large installations where a great number of locks must come under a master system.

MASTER RING CYLINDER - A double cylinder containing two shear lines. One shear line is used for the conventional plug and the other is used for pins that rest in the master ring.

MASTER WAFERS - The tumblers used in pin tumbler locks specifically for master keying.

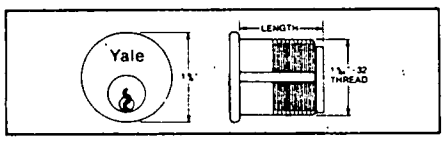
MILLED KEY - A cylinder lock key stamped from brass or nickel silver and then grooved by a milling machine so that it will fit into the keyway.

MONO LOCK - See Preassembled Lock.

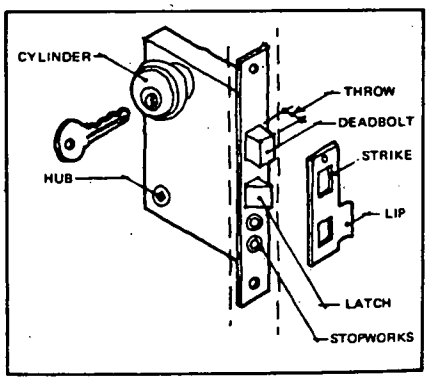
MORTISE - A rectangular cavity made to receive a lock or other hardware, also, the act of making such a cavity.

MORTISE BOLT - A bolt designed to be installed in a mortise rather than on the surface. The bolt is operated by a knob, lever or equivalent.

MORTISE CYLINDER - This term usually means a pin tumbler cylinder used for mortise locks. These cylinders are fitted or screwed into the mortise lock after the lock has been installed in the door.



typical mortise cylinder



MORTISE LOCK - A lock designed for installation in a mortise, as distinguished from a bored lock or a rim lock.

MORTISE STRIKE - A strike plate designed to be used with a mortise lock.

MULTIPLE CUSTODY LOCK - Any lock dependent upon two or more keys or combinations for security. Each key or combination must be used to effect an entry.

MUSHROOM TUMBLER - A type of tumbler used in pin tumbler locks to add security against picking. The diameter of the driver pin behind the end in contact with the bottom pin is reduced so that the mushroom head will catch the edge

of the cylinder body at the shear line when it is at a slight angle to its cavity. Similar to the SPOOL TUMBLER.

NECK - That part of the stem of a bit key between the shoulder and the bit.

NEST - See COMBINATION WHEEL ASSEMBLY.

NECKED BOLT - A bolt, the projecting end of which is bent to engage a strike not in line with the body of the bolt.

NIGHT KEY - A key (for the operation of a nightlatch) which controls the night works and operates the latch bolt.

NIGHT LATCH - An auxiliary lock having a spring latch bolt and functioning independently of the regular lock of the door.

NIGHT WORKS - The stop buttons and mechanism which deadlocks the latch from the outside knob or thumbpiece.

NOSE PLATE - A small plate which surrounds the face of the cylinder to give a finished appearance on certain types of cylinder locks where the cylinder is permanently attached to the lock.

OFFSET DRIVE - See GEARED DRIVE.

ONE-WAY SCREW - A screw specifically designed to resist being removed, once installed. Also known as TAMPER RESISTANT.

OPENING INDEX - The index on the dial ring of a combination lock which is used as the guide mark for dialing combinations.

OPERATING KEY - See CHANGE KEY.

OUTER RING (of Wheel Tumbler) - Outer surface or edge of a wheel in a combination lock.

OUTSIDE RING (of Wheel Tumbler) - Outer surface or edge of a wheel in a combination lock.

OUTSIDE CASE - The outside portion of the lock case which contains the latch bolt, tailpiece, tailpiece spring, locking slide, and the hubs.

OUTSIDE DRIVE - A combination lock that is geardriven by a spindle located outside the lock case on either the end, top, or bottom of the lock case.

OUTSIDE ROSE - Decorative circular cover on outside of door through which the outside knob passes.

PANIC BAR - The cross bar or lever of a panic exit device which serves as a push bar to actuate the lock. Also known as CRASH BAR.

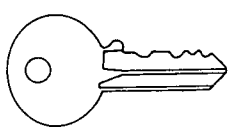
PANIC BOLTS - Bolts that provide top and bottom fastenings connected with CRASH bars for the inside of emergency doors at theaters, schools, and all public buildings, in case of emergency, pressure of people against the bars unfastens the bolts allowing the door or doors to open

PANIC EXIT DEVICE - See EXIT DEVICE.

PANIC HARDWARE - An exterior door locking mechanism which is always operable from inside the building by pressure on a panic bar or lever. Also called EXIT DEVICE or PANIC EXIT DEVICE.

PARACENTRIC - A term used in connection with the keyway cylinder plugs having projections on the sides of the keyway that extend beyond the vertical center line of the keyway. A form of a ward (see), used primarily to make picking more difficult and to limit the accessibility of the keyway to prescribed key designs.

PARACENTRIC KEY - A term used to distinguish a milled cylinder key from other types, such as a bit key, flat key, tubular key, etc. Designed to fit a paracentric keyway, it's cross section is such that the longitudinal indent(s) extends beyond the vertical center line of the key.



PATIO LOCK - A lock designed with a push button or a turn-locking outside knob. When so locked, there is no entrance by key from the outside.

PEAK - A high point in a cut key separated from other peaks by notches.

PERMUTATION LOCK - Another term for a combination lock.

PICK GUARD - Designed to deter any known tampering device from entering the keyway of the lock. Only the key itself will bypass the pick guard and enter the keyway (manufacturer's claim).

PICK KEY - A key altered (by cutting away) so that it will open any or all of a group of locks. Sometimes called a SKELETON KEY.

PICK PROOF LOCK - A manufacturer's description applied to his cylinder lock with specific features (more accurately described as pick-resistant).

PICK RESISTANCE - That level of resistance to surreptitious manipulation of the lock tumblers in order to unlock a lock. Resistance depends on the difficulty involved in bypassing the normal operation, which in turn depends on the availability of picking information and devices.

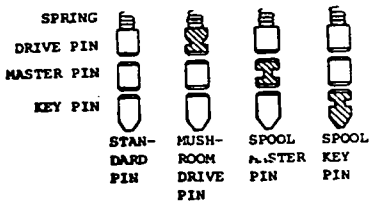
PICKING LOCKOUT - A feature of a lock that automatically relocks with a secondary device if picking is attempted and after the plug is rotated 3 to 5 degrees (by Kaba).

PIN CHAMBER CAPS - A small piece of metal used to cover holes in the cylinder shell to prevent the pins from falling out.

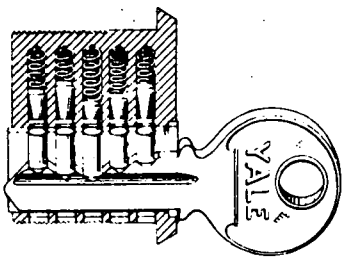
PIN CHAMBER HOLES - Drilled apertures, in the cylinder and plug, where the pins and drivers are housed.

PIN TUMBLERS - These tumblers are part of a pin tumbler cylinder, and are often more precisely called or defined as either bottom pins, master pins, or drivers. They are usually made of brass and are varied in length. Bottom pins

have one end tapered to fit in the "V" cut of a cylinder key, while both master pins and drivers are usually flat on both ends. It is with these pin tumblers, used in varying lengths, that the combination of the cylinder is determined. Also see Bottom Pin, Driver Pin, Master Pin.



PIN TUMBLER LOCK CYLINDER - A lock cylinder employing metal pins (tumblers) to prevent the rotation of the core until the correct key is inserted into the keyway. Small coil compression springs hold the pins in the locked position until the key is inserted.



PIN TUMBLER SPRINGS - These are small coil compression springs. They are used in cylinders made with pin tumbler mechanisms and are found behind or above the driver pins.

PIPE KEY - See BARREL KEY.

PLUG (of a cylinder) - The central round, movable part within the body or shell, containing the keyway and rotated by the key to activate the lock mechanism. Also called the CORE.

PLUG CHAMBERS - Drilled holes in the plug to hold bottom pins.

PLUG FACE - Front exposed portion of plug.

PLUG RETAINER - A variously shaped part often fixed to the rear of the core in a lock cylinder to retain or hold the core firmly in the cylinder.

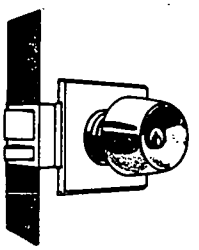
PLUG TRAVEL STOP PIN - A pin which prevents rotation of the cylinder plug in a right or left direction.

POLICE BOLT - See BUTTRESS LOCK

POSITIONING STUD - A stud that centers the dial knob when it is mounted on the dial and escutcheon. Usually located in the top center of the pressure spring which fits inside the dial knob of a combination lock.

POST - The round part of a bit key to which the wing or bit is attached.

PREASSEMBLED LOCK - A lock that has all the parts assembled into a unit at the factory and, when installed in a rectangular section cut out of the door at the lock edge, requires little or no assembly. Series 2000 lock of ANSI Standard for Locks and Lock Trim (A156.2). Also called mono lock and unit lock.



PRIVACY LOCK - A lock, usually for an interior door, secured by a button, thumbturn, etc., and not designed for key operation.

PROJECTION - See BOLT PROJECTION.

PUSH KEY - 1) A key which operates the Ace type of lock. 2) A key which positions the tumblers by an inward rather than a rotary motion. Also called a THRUST KEY.

PUZZLE LOCK - Outnoded term for a COMBINATION LOCK.

RABBETED LOCK - A lock in which the front is formed into two planes or steps corresponding to the rabbeted edge of a door or window.

RELOCK LEVER or PIN - An anti-manipulation device In a combination lock, a spring loaded lever or pin which blocks the locking bolt in the locked position when the back cover of the lock is removed, loosened or tampered with, even if the proper combination is dialed.

RELOCKER - A burglar-resistant safety device on a combination lock or on the bolt work of a safe door. Damage to the main lock (or bolt actuating mechanism) by force actuates the auxiliary mechanism which trips a relocking trigger on the auxiliary bolt work and prevents the lock from opening.

RELOCKER BOLT - Bolt which projects when the relocker is set off.

RELOCKING DEVICE - A mechanism separate from the combination lock which deadlocks the safe boltwork in the event the lock is forcibly attacked. It may also incorporate a thermal or shock-releasing device.

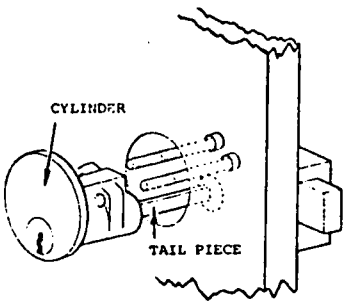
REMOVABLE CORE - See CHANGEABLE CORE.

RESTRICTED KEYWAY - A special keyway and key blank for high security locks, with a configuration which is not freely available and which must be specifically requested from the manufacturer.

REVERSE BEVEL (of a Lock) - See BEVEL (of a Lock front).

REVERSIBLE LOCK - A lock which may be used for either hand of a door.

RIDING DISC - A combination wheel other than the driving wheel.

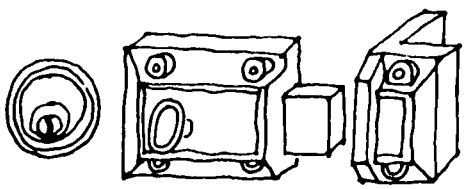


RIM CYLINDER - A pin or disc tumbler cylinder usually used with a rim lock. See CYLINDER, RIM.

RIM CYLINDER LOCK - A lock which incorporates a rim cylinder.

RIM HARDWARE - Hardare designed to be installed on the inside surface of a door or window and their frames.

RIM LATCH - A latch installed on the inside surface of a door and frame.



RIM LOCK - A lock designed to be mounted on the surface of a door and frame.

RIM STRIKE - A strike intended for use with a rim lock, secured to the jamb and projecting from the inside surface.

ROLLER FENCE - In a combination lock serves to retract the bolt when the proper combination has been aligned. See FENCE

ROOT - Bottom of a cut in a key blade.

ROUNDED FRONT - A lock front conforming to the rounded edge of a double-acting door (usually has a 2-1/4 inch radius).

SCREW TYPE LOCK - A Mortise lock cylinder.

SECTIONAL KEYING - A method employed to increase the number of key changes in a system by four or eight times by using the same change numbers over again in each section.

SECURITY SYSTEM - Another name for a Master Keying system (which is misleading since master keying provides convenience usually at the expense of security).

SHANK - That part of a key between the bow or handle and the bit or wing.

SHANK (of a knob) - The projecting stem of a knob into which the spindle is fastened.

SHEAR LINE - The meeting surface between the shell and the core of a lock cylinder, the line at which the pins or discs of a lock cylinder must be aligned in order to permit rotation of the core.

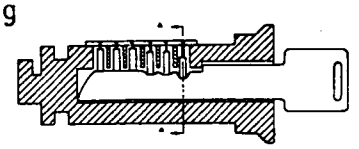
SHELL - A lock cylinder, exclusive of the core. Also called HOUSING or BODY.

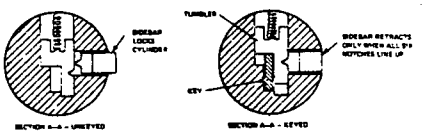
SHOULDER - Refers to the two, or sometimes one, projections on a key blank between the head and the blade, which prevent the key from being inserted too far into the cylinder. It is also used as a guide when lining up keys for duplication.

SHUT-OUT KEY - A change key so constructed that it makes a master key or a grand master key (or both) inoperative. It is used primarily in hotel keying. It assures the user absolute security against any key except the emergency key. Also called a DISPLAY KEY.

SIDE BAR - The part of a side bar lock which prevents the plug from being turned when in a locked position.

SIDE BAR LOCK - A type of lock including a disc or a wafer or a pin tumbler cylinder containing tumblers with dual operations: they must be lined up at a shear line and allow a side bar to set into the tumblers, thereby freeing the shear line for operation of the core.





SINGLE BITTED KEY - A key which has cuts on one side of the blank only.

SINGLE CYLINDER LOCK - Has the cylinder only on one side and usually a turn knob on the other side.

SKELETON KEY - See PICK KEY.

SLIDE BOLT - A simple bolt lock which is operated directly by hand without using a key, a turnpiece, or other actuating mechanism. Slide bolts can normally only be operated from the inside.

SLIDING DOOR LOCK - A device having a hook-shaped or expanding bolt to interlock with the strike.

SPACE WASHER - A thin washer inserted between each wheel, keyed or otherwise, designed to prevent rotation of the wheels of a combination lock by friction. Also called SPACING WASHER.

SPACING OF KEY - The distance between the center of one valley or cut and the center of the next valley or cut of a key.

SPINDLE - 1) The shaft that fits into the shank of a door knob or handle, and that serves as its axis of rotation. 2) The shaft of a door lock to which the knobs are attached. It is

also a threaded shaft which connects the dial and drive cam of a combination lock, the spindle is usually provided with one or more keyways, at the drive cam end, to accept the spindle spline key.

SPINDLE, BURGLAR PROOF - In a combination lock, a tapered or shouldered spindle entirely hardened, or with hardened pins, so designed to prevent punching, pulling and drilling. Also known as DRIVE PROOF.

SPINDLE SPLINE KEY - A thin piece of metal which prevents the drive wheel from turning on the spline.

SPINDLE, SWIVEL - A spindle which has a swivel joint in the center which allows one end of the spindle to turn while the other remains stationary. Used on locks with built-in latch or stop work.

SPINDLE, THREADED - A type of spindle which has the knob screwed on and held in position by set screws bearing on the surface of the spindle (usually found in better grade locks).

SPLINE KEY - That part of a combination lock which secures the position of the drive cam or wheel to the spindle in relation to the correct dial calibration.

SPLIT HUB - A hub made in two parts for certain locks, to enable the inside handle, for instance, to turn one part of the hub and withdraw the bolt when the other part of the hub and the outside handle have been put out of action or remain in the locked position.

SPOOL MASTER - The master key disc in a set of discs of a disc cylinder.

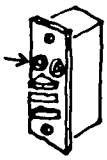
SPOOL TUMBLER - A type of tumbler shaped like a spool used in pin tumbler locks to add security against picking. Operates on the same principal as the MUSHROOM TUMBLER (see).

SPRING BOLT - See LATCH.

SPRING BOLT WITH ANTI-LOIDING DEVICE - See DEAD LATCH.

STEM (of a Key) - See POST.

STOP (of a lock) - A button or other device that serves to lock and unlock a latch bolt against actuation by the outside knob or thumb piece. Another type holds the bolt retracted.



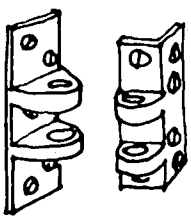
STOP KEY - Inserted in a keyhole from one side of the lock, it prevents use of a key from the opposite side. Also called KEYHOLE LOCK.

STRIKE - A metal plate attached to or mortised into a door jamb to receive and hold a projected latch bolt and/or dead bolt in order to secure the door to the jamb. Sometimes called KEEPER.

STRIKE, BOX - See BOX STRIKE.

STRIKE, DUSTPROOF - A strike which is placed in the threshold or sill of an opening, or in the floor, to receive a flush bolt, and is equipped with a springloaded follower to cover the recess and keep out dirt.

STRIKE, INTERLOCKING - A strike which receives and holds a vertical, rotary, or hook dead bolt.



STRIKE JAMB - Vertical member of the door frame prepared for the installation of strike.

STRIKE STILE - Vertical member of an inactive door leaf, of a pair of doors, which receives the strike.

SUBMASTER KEY - See CHANGE KEY.

SUBSEQUENT LOCKER - A term applied to a time lock constructed to operate by the action of clockwork at a predetermined time.

SUBTREASURY LOCK - A lock used on small chest or boxes inside a fireproof safe.

SURFACE STRIKE - See RIM STRIKE.

SWINGING BOLT - A bolt that is hinged to a lock front and is projected and retracted with a swinging rather than a sliding action. Also called hinged or pivot bolt.

SWINGING LATCH BOLT - A bolt that is hinged to a lock front and is retracted with a swinging rather than a sliding action. Sometimes called HINGED LATCH BOLT.

SWIVEL SPINDLE - See SPINDLE, SWIVEL.

TABLE NUT - A hexagonal nut used to attach the dial ring to the tube.

TAILPIECE - A metal bar projecting from the back of a rim or bored lock cylinder engaging the lock mechanism and when rotated by the key either locks or unlocks the lock. See CONNECTING BAR.

TALON - The notch in the tailpiece of a dead bolt which the rotating member engages to throw or retract the bolt.

TAMPER-RESISTANT - See ONE-WAY SCREW.

TEMPLATE HARDWARE - Hardware manufactured within template tolerances.

THERMAL RELOCKING COMPONENT - A small tab of soft metal with a low melting point (usually approximately 160°F) used to activate the relocking device when the lock is attacked by heat.

THREADED SPINDLE - See SPINDLE, THREADED.

THREE-POINT LOCK - A locking device required on fire label double doors to lock the active door at three points--the normal position plus top and bottom.

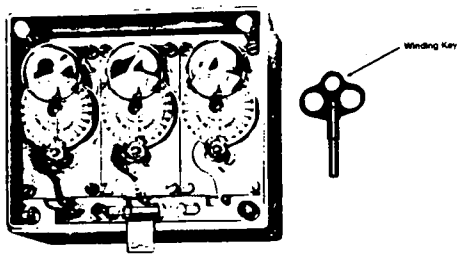
THROW (of a dead bolt or latch bolt) - 1) Measurement of the maximum projection when bolt is fully extended. 2) The distance penetrated by the bolt or latch into the bolt or latch receptacle (strike) on the door jamb or window frame. Also see BOLT PROJECTION.

THRUST KEY - See PUSH KEY

THUMB TURN - 1) A knob which is gripped between the thumb and forefinger, and turned to project or retract a bolt. 2) The knob located in the center of the dial of a combination lock. When the thumb turn is rotated it actuates the lock cam operated dead bolt on the inside of the door. Also BUTTERFLY or ARROW KNOB.

TIMBINATION LOCK - A combination lock supplemented by a double clock movement turning arrangement to delay opening of the lock from five to thirty minutes (as set).

TIME LOCK - Supplemented to a combination lock, a time lock may be set to remain locked for periods of 1 to 120 hours. Time locks have two or more movements and. In the event one stops, the other(s) allows the lock to be opened independently.



TIME LOCK MECHANISM LEVER - That part of the timing mechanism which blocks the pin on the lever to prevent retraction of the bolt until the proper amount of time has elapsed.

TIP - The opposite end of the key from the bow.

TOP PINS - Pins set in the top of the cylinder body with driver springs underneath to provide resilience when the key is inserted in the keyway. Also known as DRIVERS or DRIVER PINS.

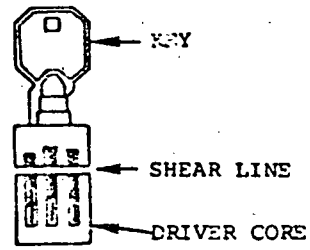
TOTALIZER - A coding system to guard against dusting push buttons of an electromechanical lock, a totalizer requires that all buttons be depressed. The opening combination is depressed first and then the penalty buttons are depressed. Since this requires that all buttons be pushed, any dusting powder will have been removed.

TRIPLE BIT KEY - A metal key which is cut on three sides or surfaces.

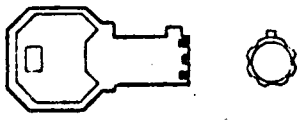
TUBE - Surrounds and protects the spindle of combination locks and is attached to the tube horn and dial ring. The tube connects and coordinates the dial ring with the case and inner workings of the lock.

TUBE HORN - An integral part of the case of combination locks to which the tube is attached. (Not used in all locks)

TUBULAR CYLINDER - 1) A type of pin tumbler cylinder in which the pins are installed in a circle around the axis of the cylinder, and move perpendicularly to the face of the cylinder. The shear line of the driver and bottom tumblers is a plane parallel to the face of the cylinder. 2) A cylinder which is permanently attached to the case of a rim or semi-mortise lock. Most frequently used on rim night latches and cabinet locks.



TUBULAR KEY - A tubular-shaped key with cuts around the periphery of the bitting end usually extending in depth toward the bow, sometimes known as an ACE KEY.



TUBULAR LOCK (or Latch) - A lock having a cylindrically-shaped case and requiring a bored, round hole rather than a chiseled, rectangular mortise. (see BORED LOCK).

TUMBLER - A movable obstruction in a lock which must be adjusted to a particular position, as by a key or dial, before the bolt can be thrown.

TUMBLER GATE - See GATE.

TUMBLER, OUTER RING - See OUTER RING (of Wheel Tumbler).

TUMBLER POST - See WHEEL POST.

TURN PIECE - See THUMB TURN.

TWO-POINT LATCH - A device sometimes required on three hour fire doors to lock the inactive leaf of a pair of doors at top and bottom.

UNIT LOCK - See PREASSEMBLED LOCK.

UNIVERSAL - A term used to describe a lock, a door closer or other device which can be used on doors of any hand without change or alteration.

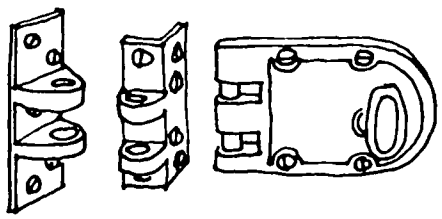
UPRIGHT LOCK - A combination lock with major dimensions which are vertical.

VAULT LOCK - A dial combination lock sometimes equipped with a time lock used for safeguarding vaults (usually installed in pairs).

VAULT LOCK WHEEL PACK - A set of wheels, fly, spacing washers, tension washer, retaining washer and a wheel bridge which allows for RH, LH and LOBC combination changes.

VENEERED FRONT (of a Lock) - An additional front plate, used to cover the front of an inferior material, permanently attached to the primary front. (Not to be confused with armored front.)

VERTICAL BOLT LOCK - A lock having two or more deadbolts which move vertically into receptors in the strike component of the lock attached to the door jamb. Also called INTERLOCKING or JIMMY RESISTANT.



VERTICAL DOWN - In a combination lock the spindle is splined in a vertical down position so that the lock bolt opens and closes in a down-and-up direction.

VERTICAL UP - In a combination lock the spindle is splined in a vertical up position so that the lock bolt opens and closes in an up-and-down direction.

WAFER LOCK - A lock mechanism employing flat metal wafer tumblers.

WARD -An obstruction within the lock which prevents the wrong key from entering or turning in a lock.

WARDED KEY - A key having grooves or notches designed to clear the wards of the lock.

WARDED LOCK - A lock containing internal obstacles which block the entrance or rotation of all but the correct key.

WHEEL - A circular disc which is part of a wheel pack or nest. Found in key change, mesh change, and hole change combination locks.

WHEEL ARM - In combination locks, the wheel arm raises the lever which permits the drive cam to turn during a change of combination.

WHEEL GATE - See GATE.

WHEEL, KEY CHANGE - In a combination lock, an assembly having an inner and outer hub with meshing teeth. When disengaged by a key, their relationship may be changed to a selected number by dialing.

WHEEL, MESH CHANGE - In a combination lock, a disc having two components with meshing teeth. When disengaged by hand, may be relocated in a selected numerical position to change the combination.

WHEEL PACK - In a combination lock, a set of wheels, flys and spacing washers supported by a tension washer and secured with a retaining washer.

WHEEL POST - A post for positioning the wheels and around which they rotate.

WHEEL, X-RAY PROOF - In a combination lock, the outer area of the wheel, where the gateway is located, is made of Nylon, Lexan or Delron to prevent X-ray methods from determining the combination of the lock.

WING KEY - See BIT (of a Key).

Appendix A

ANNOTATED BIBLIOGRAPHY

The publications listed below generally fall into three categories: historical, technical description, and performance evaluation. The publications include books, periodicals and government reports. Most are written for locksmiths and physical security administrators.

The sources that are listed are those the author believes will be useful to the reader interested in both general and detailed operation of locks, their components, and auxiliary control devices. Perhaps the most detailed information can be obtained from manufacturers' service manuals, and particular issues of the periodical 'Locksmith Ledger.' There is in fact a scarcity of theoretical literature on mechanical locking devices because of the very limited audience. There are no academic textbooks or comprehensive publications that directly address locks because of the nature of lock development, manufacture and marketing. The present literature is that which is practical and directly applicable to locking devices available today. The reader should not overlook, also, the practicality of searching the patent archives (which is beyond the scope of this effort), since more patents have been issued for locks than any other single object.

BOOKS

Many of the published books on locks are either historical in nature or oriented to the general public/consumer. Only a few of these have been cited, to give the reader an impression of the popular literature. The other listed books, of which only a few are available, are written primarily for locksmiths.

GOVERNMENT REPORTS AND PUBLICATIONS

Much of the documented serious study of security devices has been done for or by the U.S. Dept. of Defense, U.S. Nuclear Regulatory Commission, and the U.S. Dept of Energy. Some of this work is classified and not in the available literature. Other work, however, is readily available, some with controlled distribution. A majority of the work is concerned with electronic surveillance and detection; only those reports that have some application to locking systems are listed Reports are listed according to the prime agency or laboratory responsible. U.S. Dept. of Defense reports are not included in the scope of this report, although some of the included laboratory reports are used by the Department. Certain groups in the armed forces are presently engaged in the evaluation of locking devices and therefore are storehouses of considerable information.

PERIODICALS

U.S. periodicals are included that are specifically oriented to locksmiths and the physical security industry. Periodicals for the construction

industry, general public and bulletins from various government agencies sometimes have articles of interest to the reader engaged in the security field.

American Society for Industrial Security, Security Management, 200 K St., N.W., Suite 651, Washington, D.C. 20006, (202) 331-7887.
- monthly, articles on policies and methods of theft prevention and control.

"Auxiliary Door Locks" (evaluation) Consumers' Research Magazine, V 62, p. 70 Oct. 1979
- evaluation of 34 commercial devices.

Brownell, Adon H., Architectural Hardware Specifications Handbook, Chilton Book Co., Phila., 1971.
- written for the architect, specification writer and building contractor
- also by the same author - "Hardware Age Builders' Hardware Handbook"

"Carnahan Conference Proceedings", College of Engineering, Office of Research and Engineering Services, U. of Kentucky, Lexington.
- annual conferences on crime prevention and countermeasures with emphasis on electronic equipment.

Cole, Richard B. The Application of Security Systems and Hardware, Charles C. Thomas, Springfield, IL., 1970.
- a guideline for the small business firm and the general public.

Compton, J. H. Basic Instructions for Opening Locks, Pennsylvania, 1970.
- a guideline for Locksmiths with detailed instructions on opening locks by picking.

Doddington, G. R., "Personal Identity Verification Using Voice," paper presented at ELECTRO 76 Conference, May 1976.

Door Locking Systems Study, American Machine and Foundry Co., Advanced Systems Lab. AMF-ASL-E-153-1020-1, NTIS PB-195 222, Wash. D.C., Jan. 1968.
- a planning study for the development of minimum safety performance standards for motor vehicle door locks. Of particular interest is the methodology of the study.

"Door and Window Locks", Consumer Reports, March 1979 p. 132-141.
- discussion and ratings of replacement locks, auxiliary locks, high security cylinders, lock guards, window locks.

"Door Locks", Consumer Reports, Feb. 1971, 36:93-103.
- discussion and rating of key-in-knob locks, mortise, locks vertical-bolt, locks auxiliary lockers, high-security cylinders, and special purpose locks.

Eleccion, Marce. "Automatic Fingerprint Identification," IEEE Spectrum, 10, No. 9, September 1973.
- a paper describing the technical parameters of electronic fingerprint identification equipment.

Eras, Vincent J., Locks and Keys Throughout the Ages, Kent: Bailey Bros. and Swinfen Ltd., England, 1974.
- a history of locks with emphasis on European collections, together with descriptions of their operation. Includes descriptions of modern locks and their applications.

Fainberg, A. and A. M. Bieber, Jr. Barrier Penetration, Brookhaven National Laboratory, NUREG/CR-0181, U.S. Nuclear Regulatory Comm., Wash., D.C., Nov. 1978.
- reports on penetration times for attacks on: a corrugated steel vehicle door, hollow steel door, substantial steel door, class 6 vault door, among other barriers. Reference is Barrier Technology Handbook SAND-77-0777 (Sandia Laboratories). Includes Detailed Drawings and Summary Tables.

Gonzales, L. A., Bibliography of the McInerney Collection, Locks and Physical Security at the U.S. Naval Civil Engineering Laboratory, General Elec. Co. - TEMPO, for Defense Nuclear Agency, Washington, D.C. (Draft) Jan 1980.
- includes compilation of five indexes, a citation list of the complete collection, and a thesaurus of subject headings and descriptors.

Gonzales, L. A., Patents Catalogue of High Security Locks, General Elec. Co. - TEMPO, for Defense Nuclear Agency, Washington, D.C. (Draft) Nov 1979.
- includes copies of 56 selected patents, of which 26 are for padlocks.

Haberman, Wolf and Others, Physical Protection Equipment Study, Five Reports prepared by the MITRE Corp. for the U.S. Nuclear Regulatory Commission, NTIS, Washington, D.C., 1978.

NUREG-0270 Guidelines for the Development of a Methodology for Measuring Level of Effectiveness of Physical Protection Facilities at Fixed-Site Facilities, Jan 1978.
NUREG-0271 Physical Protection Equipment Study: Final Report, Jan 1978.
NUREG-0272 Cross Reference Index for Equipment Catalog and Evaluation Guide, Jan 1978.
NUREG-0273 Guide for the Evaluation of Physical Protection Equipment, Jan 1978.
NUREG-0274 Catalog of Physical Protection Equipment, Jan 1978.
- a series of reports including: a catalogue of equipment with performance and physical data, references and standards, an evaluation guide for comparing various types of equipment, guidelines for methodology development and recommendations for improving security.

Healy, Richard J. Design for Security, John Wiley & Sons Inc., N.Y., 1968
- defines the hazards each organization or business must face and describes in detail how defenses can be planned. It shows how designing physical facilities can raise the level of security.
- discusses techniques and equipment for security protection.

Hennessy, Thomas F., Early Locks and Lockmakers of America, Nickerson and Collins, Des Plaines, IL, 1976
- an historic account of lock manufacturers in America from the early nineteenth century on. Contains some period illustrations of old locks. The author is Curator of the Lock Museum of America in Terryville, Connecticut.

Hopf, Peter S., Editor, Handbook of Building Security Planning and Design, McGraw-Hill Book Co., N.Y. 1979.
- information on the practical aspects of planning and designing for the physical security of buildings. Provides design guidance to help determine the most appropriate security provisions for each type of building.

Hopkins, Albert A., The Lure of the Lock, The General Society of Mechanics and Tradesmen, New York, 1928.
- excellent historic treatise on locks included in the John M. Mossman Collection of Locks in the Society's museum at that time.

Locksmith Gazette, 5221 Mt. Ariane Terr., San Diega, CA 92111
- quarterly for the locksmith trade.

Locksmith Ledger and Security Register, Nickerson & Collins Co., Publisher, 1800 Oakton, St., Des Plaines, IL 60018
- monthly with very wide circulation, contains descriptions of particular locks' operations and maintenance in addition to business suggestions. The January issues include a Security Guide Directory of Manufacturers with a cross-referenced index.

Locksmith Ledger Publications - various titles, for 'how-to' booklets containing especially written material as well as reprints of articles from past issues of the monthly periodical LOCKSMITH LEDGER, including the following partial list: TECHNICAL TIPS, HOW TO OPEN LOCKS WITHOUT KEYS OR PICKS, SAFE MAN'S GUIDE (4VOLS), ELECTRO MECHANICAL LOCKS, HOW TO MAKE KEYS BY IMPRESSION. Locksmith Ledger, Des Plaines, IL. 60018

National Bureau of Standards (NBS), Washington, D.C.
- NBS has been engaged by various agencies to do research and test development for access control devices, surveilance and detection, doors and windows.

Fechter, J. V., Robertson, E. M. Catalog of Security Equipment, NBS-SP-480-35, 1978.
- Listing of security equipment for homes and businesses

Moore, R. T., Barrier Penetration Tests, NBS Tech Note 837, June 1974
- Tests of resistance of barriers to penetration, useful for test designs and controls.

Moore, R. T., et al. Computerized Site Security Monitor and Response System Phase II Final Report, NBSIR 79-1725, 1979
- sponsored by the Defense Nuclear Agency, this report suggests an integrated computer-based physical security system for nuclear weapons storage sites. Includes a unique electronic locking system.

Moore, R. T. Penetration Tests on J-S11DS Barriers NBSIR 73-223 86P., June 1973.
- Results of penetration tests against structural barriers and a GSA Class 6 vault door. Useful for methodology of tests and documentation.

A Study of Handcuff Improvements, NBSIR 80-1989, 1980
- study of designs for improving the security of present day ratchet and pawl metallic handcuffs. Two new lock features which significantly improve the lock were developod.

Stroik, J. S., Terms and Definitions for Door and Window Security, NBS-SP-480-20, 1977
- a glossary for residential and commercial buildings.

National Locksmith, 9733, W. Soreng Ave., Schiller Park, IL 60176
- monthly, with articles on security products and methods. Includes KEYNOTES, the bulletin of the Associated Locksmiths of America.

Reed General Code Book, Locksmith Ledger, Des Plaines, IL, 1979
- four volumes, including exploded views, service instructions, etc., for all commercially available locks

Robinson, Robert L. Professional Locksmithing, Nelson-Hall, Chicago: (1973).
- a guideline for the Locksmith.

SANDIA LABORATORIES, Albuquerque, N.M.
Sandia has done extensive work on nuclear security for the U.S. Dept. of Energy and others. Some of the conceptual and theoretical work should also be able to be exploited and applied in other institutions and industries.

Barrier Technology Handbook - SAND 77-0777 (controlled), Apr. 1978
- defines the role of barriers and methods for the assessment and upgrading of physical protection. Seventeen sections cover most types of non-lethal physical barriers. Advanced concepts resulting from tests on existing and prototype barriers are presented.

Entry Control Systems Handbook - SAND 77-1033 (controlled), Sep. 1977, revised Sep. 1978.
- provides information on the selection, procurement, installation, testing and maintenance of elements of an entry control system. These elements include: (1) personnel identify verification systems, (2) metal detectors, (3) explosives detectors, (4) special nuclear material (SNM) monitors, (5) package search systems, and

(6) equipment used to control and report status of the various elements. Also included is a discussion of integrating these elements into an operationally-effective entry control system.

Suber, L. Physical Protection of Special Nuclear Material in the Commercial Fuel Cycle, Volume III, SAND 75-0457, March 1976 (CNSI).

Williams, Joseph V. Lock Handbook (U), SAND 78-0500 (confidential) Sandia Laboratories for the U.S. Dept of Energy (June 1979).
- general descriptions of key and keyless locks with various methods used to defeat locks and general information on ways to make locks more resistant to defeat. Includes a summary of defeat times using specific methods against particular padlocks and door locks. (Williams is also author of a more extensive study of keyless locks being published.)

Security World, Security World Publishing Co. Inc., 2639 S. La Cienega Blvd., Los Angeles, CA 90034,
- monthly, articles on loss prevention and security equipment. Also published by the same company - SECURITY DISTRIBUTING AND MARKETING.

Sloane, Eugene A. The Complete Book of Locks, Keys, Burglar and Smoke Alarms, and other Security Devices. William Morrow, New York, 1977
- a review for the general public

Strobl, Walter M. Crime Prevention Through Physical Security Marcel Dekker Inc., New York, 1978
- written for security personnel, as a review of principles and details of physical security in industrial buildings, warehouses, computer areas, high rise buildings, hospitals, banks, retail stores, construction sites, schools and universities, including locks, illumination, fire and anti-intrusion alarms, and closed circuit television.

Tobias, Marc W. Locks, Safes, and Security: A Handbook for Law Enforcement Personnel, Charles C. Thomas, Springfield, 1971
- concise and clear overview of all aspects of lock operations and defeat methods for commercial locks, explains the general workings of different lock types and their components.
- is the available publication closest to a textbook on locks.

Appendix B

STANDARDS AND SPECIFICATIONS

The standards and specifications in use today include both prescriptive and performance requirements. Experientially determined the prescriptive standards very seldom are able to justify the requirements with anything other than an agreement of experts Consequently groups that require particularly specific high security resistance usually do their own testing every time a new need arises. These tests attempt to duplicate actual attacks on the system and, because nothing else is available, they are forced to serve the purpose. Most of the tests used to date, however are usually not based on controlled laboratory experiments, because of either funding limitations or time restrictions. In addition, because of the confidential nature of the tests, they are not adequately documented to form a useful body of literature. Reliance is then placed on those people (the "experts") having the experience and knowledge, which is the most reliable source at this time, to determine the performance of particular locking systems. Although subjective judgment is used considerably, it is more and more being supplemented by laboratory of tests in controlled settings. Some of the present standards include test methods that can reproduce results with considerable accuracy. It is hoped that enough interest will be generated in the near future so that reliable standards can be developed for all high security locking devices.

The following annotated list of standards and specifications includes many document titles that are not considered directly relevant for high security locking devices. They are included because although they cannot be used, as is, for high security applications, they should be helpful to the reader engaged in preparing new standards and specifications or in developing new locking devices.

American National Standards Institute (ANSI), Auxiliary Locks and Associated Products, ANSI 156.5 (BHMA 501) New York, 1978
- contains security requirements only for the cylinder plug pulling test and reference to UL 437 Key Locks for picking and drilling the cylinder.

American National Standards Institute (ANSI), Interconnected Locks and Latches, ANSI 156.12, (BHMA 611) New York, 1979
- strength tests for all grades contain tests of security performance, including: impacts on the knob, cylinder, cylinder ring and bolt, torque tests on the knob, cylinder plug and body and ring; pulling tests on the cylinder plug and body. - references ANSI/ASTM F 476-76 (see ASTM).

American National Standards Institute (ANSI), Locks and Lock Trim, ANSI A156.2 (BHMA 601) New York, 1976
- requirements for typical builders hardware; minimal security requirements are included with test criteria and recommended test equipment.

American National Standards Institute (ANSI), Magnetic-Stripe Encoding for Credit Cards, ANSI X4.16 New York, August 1976.

American Society for Testing and Materials (ASTM) Standard Definitions of Terms Relating to Combination Locks, ANSI/ASTM F471-76, Phila., 1976.

American Society for Testing and Materials (ASTM), Standard Test Methods for Security of Swinging Door Assemblies, ANSI/ASTM F476-76, Phila., 1976.
- similar to NILECJ STD 0306.00 - Physical Security of Door Assemblies and Components (see U.S. Dept. of Justice)

Builders Hardware Manufacturers Association, Standard for Mortise Locks and Latches, BHMA 621, New York, 1979 (Proposed ANSI A 156.13)
- contains requirements for security grade locks, including knob and cylinder and bolt impact tests, knob and cylinder torque tests, bolt sawing tests, among others.
- this is in effect, a suplement to ANSI A156.2 and makes reference to ANSI/ASTM F476-76.

Underwriters Laboratories, Standards for Safety, Access Control System Units, UL 294, Northbrook, IL., 1974, rev. Oct 1978
- prescriptive requirements for fabrication and installation of the system and components, performance requirements for system and component attributes. Includes destructive and nondestructive attack tests of 5 minutes which can be reduced to 2 minutes if the attacks cause an alarm.

Underwriters Laboratories, Standards for Safety, Burglary-Resistant Electric Door Strikes, UL 1034, Northbrook, IL, 1974, rev. Oct. 1978.
- construction and performance requirements for strikes used to secure and release doors by applying or removing electrical power. Includes a pressure test of 300 pound force and a tool attack of 5 minutes.

Underwriters Laboratories, Standards for Safety, Burglary Resistant Safes, UL 687, Northbrook, IL, 1977, rev. Feb. 1979.
- construction and performance requirements for safes of the classes TL-15, TL-30, TRTL-30, TRTL-60, TXTL-60. Includes tests of resistance to drifting, drilling, handle forcing, door sledging, wedging and explosives, for time corresponding to the number sufix in minutes.

Underwriters Laboratories, Standards for Safety, Combination Locks, UL 768, Northbrook, IL, 1978, rev. Jul. 1979.
- addresses combination locks investigated primarily for correctness of design and accuracy of construction to guard against unauthorized opening of the combination lock by sense of sight, touch, or hearing. They may or may not have built-in protection against forcible entry. Combination locks are classified as Group 1, Group 1R, or Group 2, according to the degree of protection afforded against unauthorized entry and to suitability.
  - Group 1 - Highly resistant to manipulation for 20-man-hours, detection devices may not exceed 50 pounds.
  - Group 1R - Same as Group 1 plus 20 man-hours of radiological resistance attack.
  - Group 2 - Reasonably resistant to unauthorized entry.

Underwriters Laboratories, Standards for Safety, Delayed-Action Timelocks, UL 887, Northbrook, IL, 1977, rev. Sep. 1978.
- construction and performance requirements for timelocks on doors of safes, chests, vaults and the like. Performance requirements include only endurance and accuracy after tests for temperature, humidity, vibration and dust, no requirements for attack resistance.

Underwriters Laboratories, Standards for Safety, Key-Locked Safes (Class KL), UL 786, Northbrook, IL, 1978.
- construction and performance requirements for key-locked safes with a limited amount of resistance to burglary. Includes requirements of 45 minute resistance to lock picking, drilling, door sledging and wedging, "fishing", and special attacks. Does not include attacks using grinding tools, electric arc, oxy-fuel gas cutting torch, or explosives.

Underwriters Laboratories, Standards for Safety, Key Locks, UL 437, Northbook, IL., 1979.
- covers rim or mortise type locking assemblies. Locking cylinders must resist expert forcible entry for 5 minutes when common hand and electrical tools are used. Surreptitious pick and impression resistance times are required to be 10 minutes minimum.

Underwriters Laboratories, Standards for Safety, Relocking Devices for Safes and Vaults, UL 140, Northbrook, IL, 1978, rev. Oct. 1978.
- requires the relock device to operate when: the lock spindle is punched or driven through the back of the lock case, the bolt- throwing connection(s) is sheared, the mechanism is manipulated or picked, a cutting torch is used on the connection between the lock and bolts, a mechanical force is applied against the master connection, an opening is attempted to be made.

Underwriters Laboratories, Standards for Safety, Tellers' Lockers, UL 901, Northbrook, IL., 1979.
- construction and performance requirements for teller's lockers having timelocks of 15 minutes minimum delay. Includes requirement of 10 minute resistance to common tool attacks.

The list of Federal Specifications, Standards and Guides that follows include documents that have various levels of description and requirements. They usually reference other standards and must be included in any comprehensive data base or source of information. Military specifications and guidelines, beyond the scope of this list, should also be consulted.

U.S. Department of Justice, Physical Security of Door Assemblies and Components, prepared by NBS for U.S. Dept. of Justice, NILECJ-STD-0306.00, Washington, D.C., Dec. 1975.
- includes test methods to evaluate the security performance of locking devices. The test methods are oriented toward residential and commercial establishments, and do not include highly sophisticated or explosive attacks. They are useful in being objective laboratory tests and should

serve as a base for further test method development. Included are performance tests for resisting impact, torque, pulling and pressure on various components.

U.S. Federal Specification, Door, Vault, Security, AA-D-600B, Washington, D.C., March 26, 1969.

U.S. Federal Specification, Hardware, Builders, Locks and Door Trim. Cylinder Entrance Door Lock Type 121A and 122A. FF-jH-106/1, Washington, D.C., July 19, 1974.

U.S. Federal Specification, Hardware, Builders', Locks and Door Trim: Cylinder Entrance Door Lock Type 123A and 123B, FF-H-106/2, Washington, D.C., July 19, 1974.

U.S. Federal Specification, Hardware, Builders', Locks and Door Trim: General Specifications For, FF-H-106C/GEN, Washington, D.C., July 19, 1974.

U.S. Federal Specification, Safe, Office, Fire Resistant, Burglary Protection, AA-S-81b, Washington, D.C., Oct 9, 1962.

U.S. Federal Specification, Safe, Tool Resistant, Uninsulated, Security, AA-S 1518A, Washington, D.C., June 1, 1970.

U.S. Nuclear Regulatory Commission, Assurance of Safety and Safeguards During an Emergency - Locking Systems, IE Bulletin 77-08, Washington, D.C., 1977.
- requires that nuclear power plants provide for prompt emergency ingress into electrically locked safety-related areas by providing auxiliary power, and where locking devices fail in the secure mode, to provide for mechanical key operated override procedures, and unimpeded emergency egress.

U.S. Nuclear Regulatory Commission, Control of Personnel Access to Protected Areas, Vital Areas, and Material Access Areas, Regulatory Guide, No. 5.7, Washington, D.C., June 1973.

U.S. Nuclear Regulatory Commission, General Use of Locks in the Protection and Control of Facilities and Special Nuclear Materials, Regulatory Guide, No. 5.12, Washington, D.C., Nov. 1973.
- states that key locks should provide a high degree of resistance to opening by force and tamper techniques and should meet Underwriters Laboratories Standard UL437. Combination locks should be three- or four-position, dial-type, changeable-combination locks which meet the Underwriters Laboratories Standard UL 768. Electric locks should be used inside the protected area as a means of access control only if a magentic card-key system is coupled with a pushbutton system and integrated into the alarm system. This lock combination should have features that resist tampering with the combination-changing mechanism and that alarm after a set number of errors in punching the combinations is made. Pushbutton mechanical locks are not recommended for use at this time.

U.S. Nuclear Regulatory Commission, Protection of Nuclear Power Plants Against Industrial Sabotage, Regulatory Guide No. 1.17, Washington, D.C., June 1973. - policy guidelines

Appendix C

NATIONAL ORGANIZATIONS

Many individuals and groups with particular expertise have been or are presently engaged in work directly related to locking devices. This work includes the development of standards, evaluation and testing methods, research, product development, and simply sharing information. This list is presented as a guide to the organizations outside of the Department of Defense doing ongoing work which has, or has not been published yet, and those groups interested in sharing information.

American Hardware Manufacturers
Association (AHMA)
117 E. Palatine Rd.
Palatine, IL 60067
312-991-4040

American Society for Industrial Security
2000 K St., NW, Suite 651
Washington, D.C. 20006
202-331-7887

American Society for Testing and Materials (ASTM)
Committee F-12, Security Systems & Equipment
1916 Race St.
Philadelphia, PA 19103
215-299-5400

Associated Locksmiths of America
3003 Live Oak St.
Dallas, TX 75204
214-827-1701

Builders Hardware Manufacturers Association (BHMA)
60 East 42nd St.
New York, NY 10017
212-682-8142

Carnahan Conference
College of Enginnering
University of Kentucky
Lexington, KY 40506
606-258-9000

Defense Industrial Security Institute
Defense General Supply Center
Richmond, Virginia 23297
804-275-4891

Door and Hardware Institute
1815 N. Ft. Myer Dr., Suite 412
Arlington, VA 22209
703-527-2060

Institute of Nuclear Materials Management
c/o Goodyear Atomic Corp.
P.O. Box 628
Piketon, OH 45661
614-289-2331

Law Enforcement Standards Laboratory
National Bureau of Standards
Washingotn, D.C. 20234
301-921-3161

Lawrence Berkeley Laboratories
1 Cyclotron Rd.
Berkely, CA 94720
415-843-2740

Los Alamos Scientific Laboratories
P.O. Box 1663
Los Alamos, NM
505-667-5061

National Burglar and Fire Alarm Association
1101 Connecticut Ave.
Washington, D.C. 20036
202-857-1130

National Crime Prevention Institute
University of Louisville
Shelby Campus
Louisville, Kentucky 41222
800-626-3550

National Institute of Justice (NIJ)
[formerly, National Institute of Law Enforcement
and Criminal Justice (NILECJ)]
U.S. Dept. of Justice
Washington, D.C. 20531
301-492-9094

National Locksmith Suppliers Association
95 E. Valley Stream Blvd.
Valley Stream, NY 11580
516-825-6673

Sandia Laboratories
171 P.O. Box 5800
Albuquerque, NM 87185
505-264-8066

Underwriters Laboratories
1285 Walt Whitman Road
Melville, NY 11725
516-271-6200

U.S. Department of Energy
Office of Safeguards and Security
Washington, D.C. 20545
301-353-5671

Appendix D

LOCKSMITH SCHOOLS

The locksmith schools are a good source of basic information on the operation and maintenance of existing locks. Most provide published lesson books for correspondence courses or concentrated classes. School personnel can provide practical assistance in the development of new locking devices.

Belsaw Institute
315 Westport Rd.
Kansas City, MO 64111
(816) 561-9255

California Institute of Locksmithing
14425 Sherman Way
Van Nuys, CA 91405
(213) 944-7425

Central City Occupational Center
c/o William J. Hornbeck
1646 S. Olive St.
Los Angeles, CA 90015
(213) 625-5579

Golden Gate School of Lock Technology
3722 San Pablo Ave.
Oakland, Ca 94608
(415) 654-2622

Locksmith Business Management School
P.O. Box 8525
Emeryville, CA 94608
(415) 654-2622

Lockmasters
476 North A1A
Satellite Beach, FL 32937
(305) 777-2175

Locksmithing Institute
1500 Cardinal Dr.
Little Falls, NJ 07424
(201) 256-4512

National Crime Prevention Institute
University of Louisville, Shelby Campus
Louisville, KY 41222
(502) 588-6987

National School of Locksmithing and Alarms
600 W. Jackson Blvd.
Chicago, IL 60606
(312) 930-1999

New York School of Locksmithing
152 W. 42nd St.
New York, NY 10036
(212) 354-8777, (800) 223-6466

North Bennett St. Industrial School
39 N. Bennett St.
Boston, MA 02113
(617) 227-0155)

Security Systems Management School
1500 Cardinal Dr.
Little Falls, NJ 07424
(201) 265-4512

Universal School of Masterlocksmithing, Inc.
P.O. Box 254868
Sacramento, CA 195825
(916) 645-8593

Wisconsin Institute of Locksmithing
8050 N. Port Washington Rd.
Milwaukee, WI 53217
(414) 352-0330

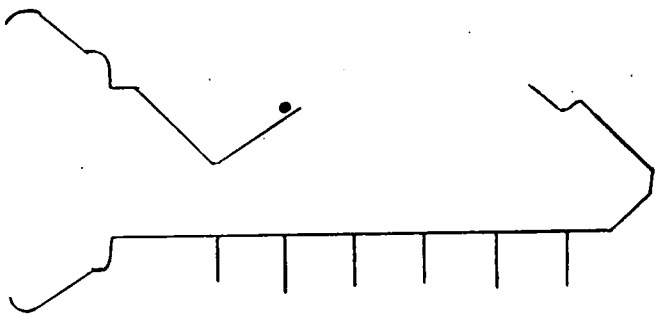
Appendix E

MASTER KEYING[1]

THE CHANGE KEY, FIRST LEVEL OF KEYING

A cylinder that has six pin chambers can be loaded with a "bottom" pin that is available in ten different lengths (called "increments"). This means that theoretically there are one million possible numeric combinations (called "key changes"). This doesn't mean that in practice this is true. There are two problems. One is called the problem of adjacency. The other is psychological.

An example of the former would be the physical impossibility of cutting a key with the change number 908091. The angle or slope of cuts is such that a key with these depths in the order given is unworkable. Even allowing for differences among manufacturers, the degree of the slopes of cuts overlap. Thus the angle of cut sloping up from the first "9" depth would remove adjacent metal so the next depth of "0" could not be made. Illustrated, it would look something like this:



(Figure 1)

The dot indicates where a number "0" cut would bottom out if there were any metal there to cut in to. The lines drawn at the bottom of the key indicate the location of each pin chamber in the cylinders to which the depth cuts in the key must correspond.

A good practice then would be to avoid 9-0, 9-1 and 8-0 adjacent cuts. If this is done, the one million possible changes are reduced to 753,754. Another point is the difficulty of inserting a key cut alternately shallow and deep into the cylinder. As the key goes in it raises pins into the pin

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[1] Excerpt from a publication of the American Society of Achitectural Hardware Consultants, 1973 by Richard A. Hudnut, A.H.C.

chambers and these pins fall back into the depth cuts successively until the key is inserted all the way. Steep angles would cause pins to hang up and in some cases, would catch and a pin would not rise. The key then could not be inserted or, if at all, with difficulty.

The so-called "psychological" problem can be illustrated by the change number, "222222". The user would be suspicious of the looks of a key cut to this combination, and, of course, if anyone should try to pick a cylinder which had all the bottom pins the same length, it should be an easy job. If, for example, we decide not to use any keys having more than four cuts of the same depth, an additional 1500 combinations would be eliminated. Removing all of the changes creating these problems reduces the one million possible numeric combinations to approximately 752,000. Bear in mind that so far we have not introduced a master key!

THE MASTER KEY, SECOND LEVEL OF KEYING

By providing a single master key, the number of possible numeric combinations is reduced again. The illustrations below show a cutaway cylinder containing pins to allow a master key (687846) and a change key (455221) to operate the cylinder. All increments shown are two or more. The reason for this is that the difference in successive pin lengths is only 0.015" (sometimes less). A master pin that is only 0.015" is not long enough to afford security and can also easily turn in the pin chamber. Keys cut only one increment from each other in one or more depth positions can sometimes operate cylinders (especially worn ones) for which they were not intended.

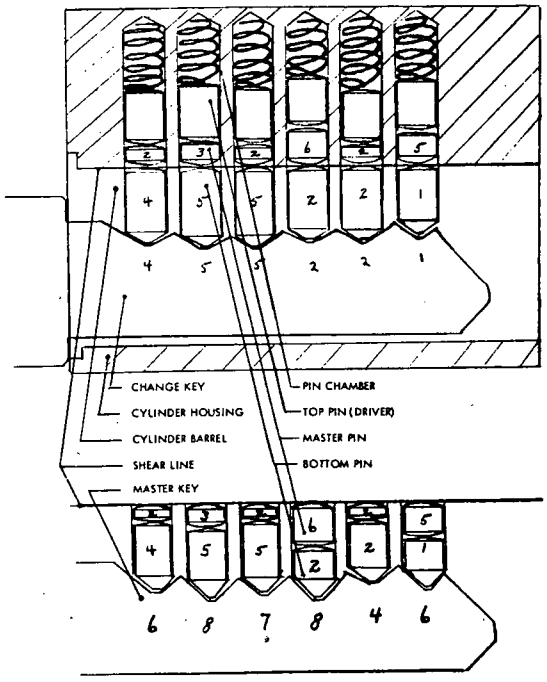


Figure 2

The following are all the key changes that will operate this same cylinder. Try it for yourself by working out the depth cuts of any of these changes and comparing them with the combinations possible as shown in the drawing.

*455221	457246	485841	655226	657821	685841
455226	457821	485846	655241	657826	685846
455241	457826	487221	655246	657841	687221
455246	457841	487226	655821	657846	687226
455821	457846	487241	655826	685221	687241
455826	485221	487246	655841	685226	687246
455841	485226	487821	655846	685241	687821
455846	485241	487826	657221	685246	687826
457221	485246	487826	657226	685821	687841
457226	485821	487846	657241	685826	**687846
457241	485826	655221	657246		

* = change key, ** = master key

Note there are 64 different keys that can operate this cylinder, although all that is wanted is one change key and one master key to do the job. This means that when all 6 chambers contain master pins for every change key established under one master key, 62 others (64 minus 2) are eliminated!

As will be explained later, the maximum number of theoretical changes possible under a single master key is 4,096. This requires master pins in each chamber, however, and it is good security practice to leave at least one pin chamber "pure".

By this it is meant no master pins should be used in one pin chamber, only a bottom pin and the driver. If this practice is observed, and, it should be, there are only 1,024 key changes available. Carrying this logic another step, if two pin chambers are left pure, therefore creating still a higher level of security, there are only 256 change combinations available. We can now understand why is is so important to allow for any desired extensions of the system at its inception. It is naturally to the owner's best interests for his system to have the maximum amount of security possible within the needs of his building(s).

To explain the above, work from the other direction and leave all the pin chambers but one pure. Remembering that 0.015" is the average increment between pins and since this is not sufficient, there are five positions that can be used (i.e., pin numbers 0, 2, 4, 6 and 8 or 1, 3, 5, 7 and 9). Using only 5 pin lengths per chamber gives a theoretical total of 15,625 combinations. One of these positions, however, must establish the master key shear line. An example of this would be:

Master key	045678		
Change #1	245678	8 245678	master pin bottom pins
Change #2	445678	6 445678	master pin bottom pins
Change #3	645678	4 645678	master pin bottom pins
Change #4	845678	2 845678	master pin bottom pins

Therefore as seen in the example above, a numeric relationship in master keying is one to four. If a family of more than 4 changes under a master key is desired, an additional pin chamber must contain master pins. Using two pin chambers provides 4 x 4 or 16 changes. Employing three gives 16 x 4 or 64, four pin chambers 64 x 4 or 256 five pin chambers 256 x 4 or 1024 and finally, by using all six, we are back to where we started with 1024 x 4 or 4096, or 4 to the 6th power.

Recall that theoretically there were 752,000 possible stock or non-master keyed cylinders available and then by introducing a master key with which only five pin lengths per chamber are used, the possible number of combinations was reduced to 15,625 (5 to the 6th power). The difference between 15,625 and 4,096, namely 11,529, represents keys that "interchange" or included both master key levels and change levels as illustrated in the chart of key changes following Figure 2. Actually, these, too, are theoretical figures. Just as we had to reduce the one million combinations to 752,000 stock keys because of adjacency problems and psychologically poor cuts, it is necessary to reduce the 4,096 figure. A conservative reduction is 10 percent or 3,686.

THE GRAND MASTER KEY AND GREAT GRAND MASTER KEY, THIRD AND FOURTH LEVELS OF KEYING

Now let's talk about the grand master key, second only to the great grand master key. At this point, it becomes difficult to consider the number of combinations eliminated every time one master key is established. Suffice to say that when using standard cylinders, the available number of change keys is drastically reduced.

To get around this problem, different "key sections" are employed. This means that two or more master keys can be used which are of different configurations fitting cylinder barrels which have been "broached" to accommodate the keys. Master key "AA", or change keys under it, for example, won't fit into a cylinder which is operated by master key "AB" and its change keys and vice versa. But grand master key "A" will fit into and operate either cylinder. Thus, the same changes can be repeated under

different master keys because even though the combiantions are the same, the keys will not fit into cylinders operated by a different master key. This is called a "Multiple Key System".

Some manufacturers have developed their own unique methods of being able to supply a greater number of secure changes under various levels of master keying. Since their methods are proprietary, it is not appropriate to describe them here, but they can be consulted directly by the reader.

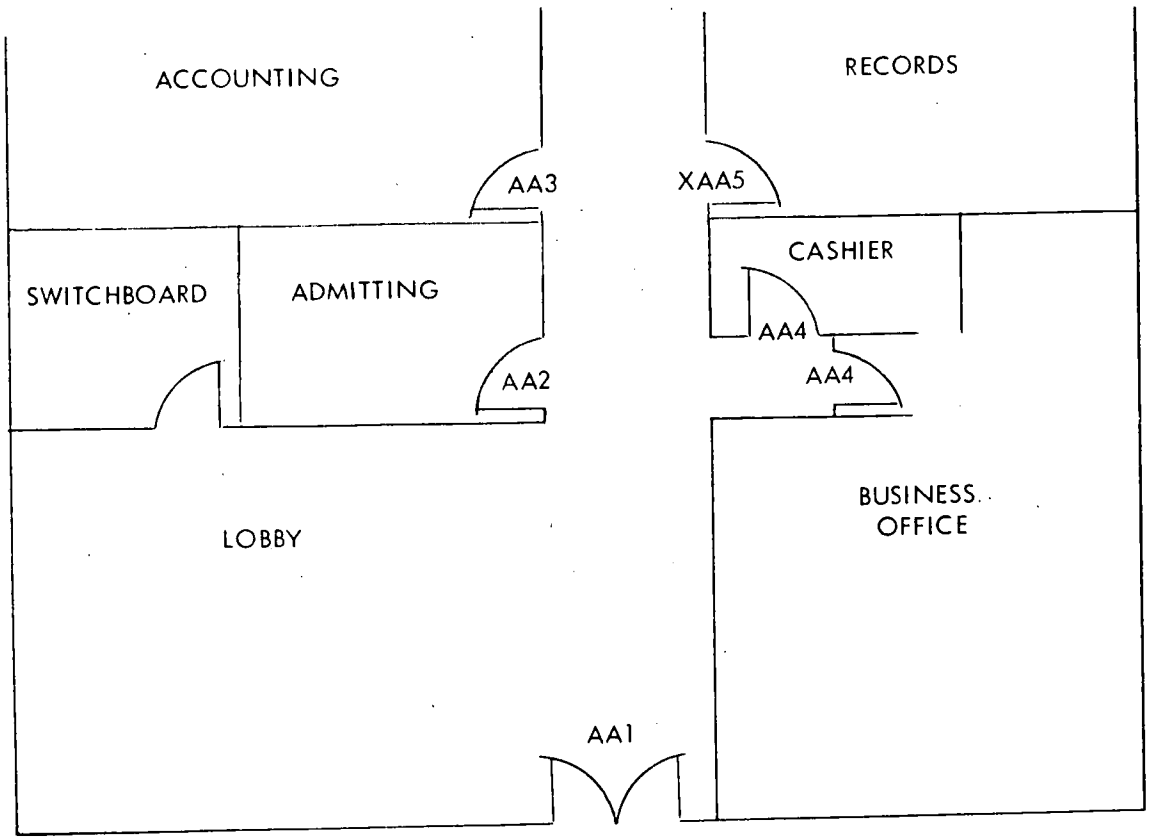


FIGURE 3

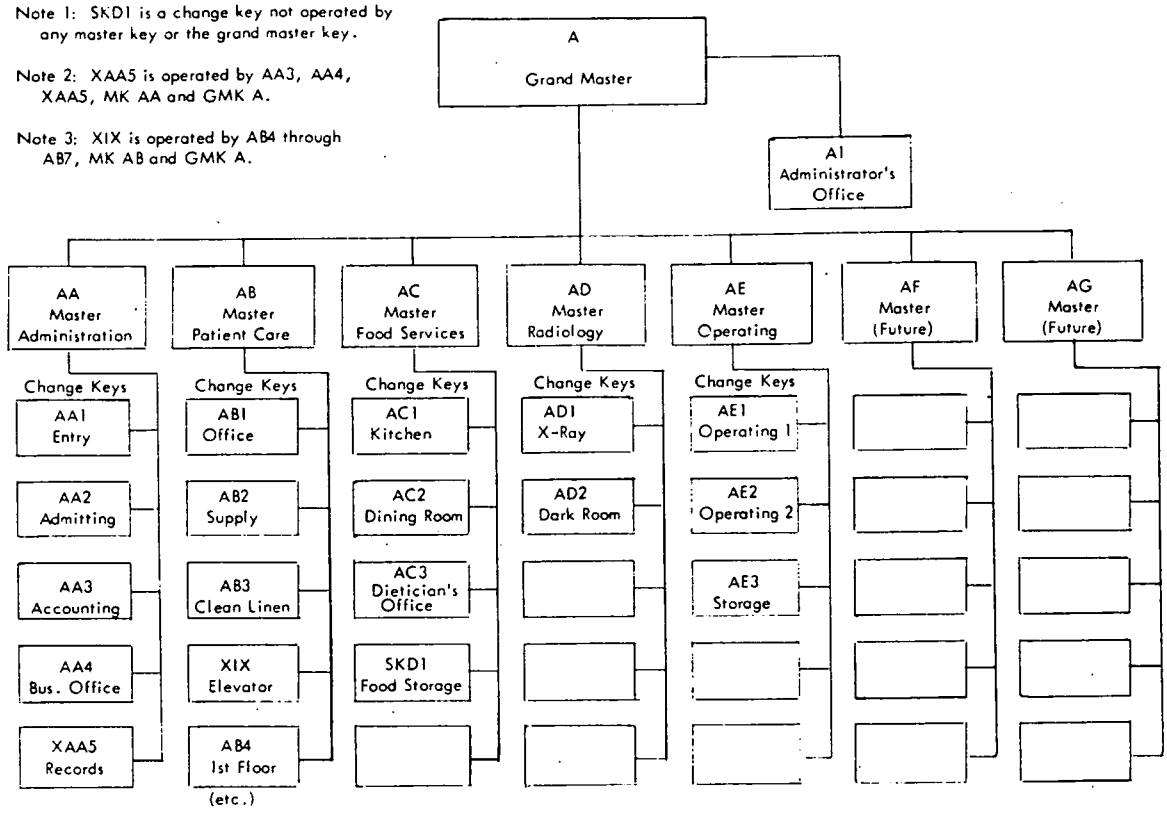
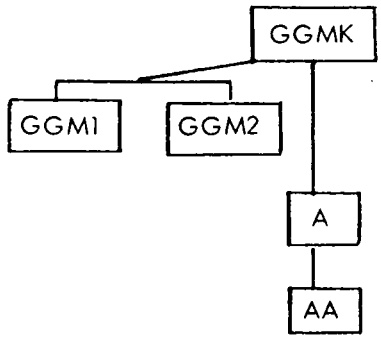


FIGURE 4

CHANGES UNDER GREAT GRAND MASTER KEY ONLY.



Great Grand Master Key

Changes under GGMK

Grand Master Key

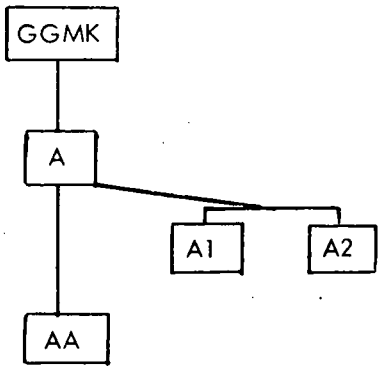
Master Key

GGM1 is operated by change key "GGM1" and "GGMK" only.

GGM2 is operated by change key "GGM2" and "GGMK" only.

FIGURE 5

CHANGES UNDER GGMK AND GRAND MASTER KEY ONLY



Great Grand Master Key

Grand Master Key

Changes under Grand Master Key

Master Key

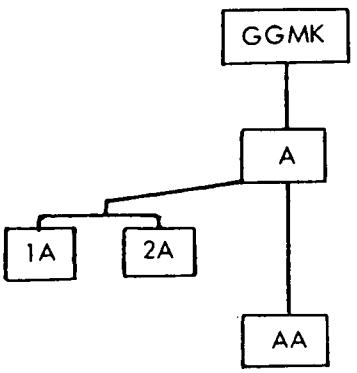
A1 is operated by Change Key "A1", "A" Grand Master Key and "GGMK" only.

A2 is operated by Change Key "A2", "A" Grand Master Key and "GGMK" only.

FIGURE 6

CHANGES UNDER GRAND MASTER KEY ONLY.

PREFIX CHANGE NUMBER



Great Grand Master Key

Grand Master Key

Changes under Grand Master Key only.

Master Key

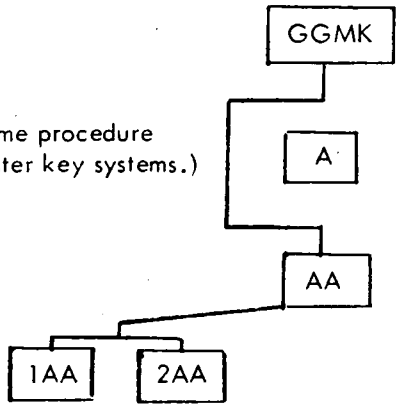
1A is operated by "1A" change key and "A" Grand Master Key only.
Not operated by "GGMK".

2A is operated by "2A" change key and "A" Grand Master Key only.
Not operated by "GGMK".

FIGURE 7

CHANGE UNDER MASTER KEY AND GGMK ONLY.

PREFIX CHANGE NUMBER



Great Grand Master Key

Grand Master Key

Master Key

Changes under Master Key and GGMK only

(Note: This is the same procedure as used for single master key systems.)

1AA is operated by "1AA" change key, "AA Master Key and by the Great Grand Master Key.

2AA is operated by "2AA" change key, "AA" Master Key and by the Great Grand Master Key.

FIGURE 8

Appendix F

SELECTION OF MATERIALS FOR LOCK COMPONENTS[1]

Undue emphasis has been placed on the hardness of a material to resist physical attacks against the security of a component. In fact, in order to select appropriate materials, other properties must also be taken into account. Besides hardness, these properties include brittle behavior, notch toughness and tensile strength.

A practical example of low security in a relatively hard material has been shown when the linkage to the bolt in a commercial lock (advertised as Jimmy Proof) failed under an impact blow with the side of a human hand.[2] The material in the linkage could not absorb the impact energy because it probably contained a sharp break (stress riser) in its geometry and because the basic properties of the material represented brittle behavior.

Brittle behavior is characterized by:

1. Low impact energy absorption
2. Structural defects
   (a) Sharp geometry changes (notches, pits, unfilleted angles)
   (b) Gas voids
   (c) Micro cracks
   (d) Non-metallic inclusions
3. Low tensil elongation
4. Low bend ductility
5. High nil-ductility transition temperature
6. Low notch toughness

A second practical example of low security of a hard material was shown where the hardened steel multiple bolts on a circular safe door were fractured and the burglar went away with the contents of the safe and the door. A steel bar was welded across the front of the safe door to provide a lever. The end of the bar was struck with a sledge hammer and the impact energy was transmitted through the door to the 5 hardened steel bolts. The bolts failed because they could not absorb the energy even though hardened steel bolts have high tensile strength (on the order of 100,000 psi). Notch toughness is the property of a material which indicates the resistance of the material to the impact attacks previously described. Notch toughness is usually evaluated by testing prescribed specimens at known temperatures in a single-blow pendulum-type impact machine. Results are reported in footpounds of impact energy absorbed by the test specimen.[3]

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[1] Excerpt from Cilimberg, R., "Some Materials Considerations for the Security of Doors", NBS internal memo, June 1973.

[2] Demonstration by William Toepfler NBS, 1973

[3] Metals Handbook, "Properties and Selection of Metals", Vol. 1, 8th Edition, American Society for Metals, Metals Park, 1961.

The variation in impact resistance compared with the variation in hardness of a single batch of quenched and tempered 4340 steel tested at 70°F with a Charpy V-notch impact machine is summarized in Table AF,1

Table AF-1 Correlation of Test Results From Impact Machines Made by Two Different Manufacturers

HARDNESS Rockwell C	Charpy V-notch, 70°F Energy Absorption ft-lbf	MACHINE
43-46	17.7	A
32.5-36.5	48.6	A
26-29	78.4	A
43-46	12.6	B
32.5-36.5	49.1	B
26-29	77.9	B

This data indicates that if high hardness of steel is the only criterion for the resistance to attack by slow application of force then failure could occur in this material by impact attack. Impact resistance varies with composition, heat treatment, temperature, and defect characteristics. This variation poses a problem for establishing an impact performance test on a commercial component because a statistical number of components could pass the component test and other purchased components could fail in service due to inadequate material properties. A logical approach to this problem would be to establish a relationship between component performance test results, Charpy V-notch test results, and hardness test results for materials categories. The importance of this relationship is to develop an inexpensive nondestructive performance test to allow valid inspection of components.

Tensile strength is also one of the important properties of materials relative to physical security as indicated in various specifications. Tensile strength establishes the resistance of a material to relatively slow application of tensile and compression stresses which might be applied with a "jimmy" bar. Hardness test values can often be used as a quick nondestructive indication of the tensile strength of a metal or alloy. Hardness is also an indicator of the wear resistance or durability of a material with wear resistance increasing as hardness increases. It is important to test for tensile strength and hardness when obtaining notch ductility data in order to establish optimum materials performance properties relative to the component's security performance results.

Security hardware is often finished by coating with chromium, zinc, cadmium, nickel or other systems to protect the base material from corrosion. It may be necessary to obtain notch ductility data on coated specimens since electroplating may impair notch toughness of steel alloys.

The importance of any grading system for security is to determine whether there is a relationship between durability and security. This relationship

might be determined by performing security performance tests on various grades of locks before and after durability performance tests. The question to be answered is what effect does wear and corrosion have on the security of commercial components.

Appendix G

LIST OF MANUFACTURERS

The manufacturers listed in this section participated in this study by furnishing information in response to a mail and telephone request of locking device manufacturers. NBS requested information of 282 manufacturers and received response from 79. The original list from which we selected our mailing list, was that published by the Locksmith Ledger, January 1979. In addition, other manufacturers were suggested by representatives of government agencies listed in the Acknowledgements Section of this report. If manufacturers of electronic security devices are included, an estimate of the number of U.S. manufacturers of locking devices and components should reach well over one thousand.

Manufacturers' Literature

Most of the active and larger manufacturers provide catalogue information and service manuals. The catalogues are usually oriented toward individuals interested in ordering the products. The service manuals are written for the locksmith or others interested in repairing or maintaining the products. There are also advertisements in the professional and trade journals that are aimed at selling the products to designers, specification writers, locksmiths, distributors, and the general public. The catalogue and advertisement information is usually very general in nature, or else it might extoll one detailed feature of the product. The service manuals vary in the amount and quality of information but usually are very detailed in illustrating every separate part of the product. A detailed description of the operation of the product, is usually not available in the form of analytical diagrams and explanations. In this regard, the articles written for the Locksmith Ledger, are probably more helpful for those interested in the operation of a new or popular locking device (see Bibliography, Appendix A).

Because the nature of locks require a certain degree of secrecy, it is understandable and desirable that information about the detailed operation of particular locks not be easily obtainable. Because of the time limitation of this investigation, the author did not attempt to analyze the service manuals or actual products of each manufacturer. The products and manufactures referenced in the report and those manufacturers included in this Appendix are those that were responsive to the author's request for information or are thought to have the most impact in the field of high security locking devices.

Name	Address	Telephone
ABC Lock Co.	2740 E. Indianapolis Ave Fresno, CA 93726	209-229-9152
Abloy, Inc.	5603 Howard St. Niles, IL 60648	312-647-9650

Name	Address	Telephone
Accurate Lock & Hardward Co.	25 Diaz Street Stamford, CT 06902	203-325-3841
Adams Rite Mfg. Co.	4040 S. Captiol Ave. City of Industry, CA 91749	213-699-0511
AFCO Security Products	148 Ferris Ave. White Plains, NY	212-733-2200
Alarm Lock Corp.	33 S. Service Rd. Jericho, NY 11753	516-333-2420
American Amplifier & Television Corp.	5380 Eisenhower Ave. Alexandria, VA 22304	703-751-0600
Arrow Lock Corp.	49-0 Glennwood Rd. Brooklyn, NY 11234	212-253-6500
BMR Security Prod. Corp. Div. Waterbury Lock	203 Broad St. Nilford, CT 06460	203-874-1710
Bach Sound Systems Co.	65-69 162nd St. Flushing, NY 11365	212-591-1550
Baldwin Hardware Mfg. Corp. (KABA 8)	841 Wyomissing Blvd. Reading, PA 19603	215-777-7811
Betlar Security Systems	512 L.W.E. Chambersburg, PA 17201	717-263-3412
Blumcraft of Pittsburgh	458 Melwood St. Pittsburgh, PA 15213	412-681-2400
Bolen Industries Inc.	789 Main St. Hackensack, NJ 07601	201-489-7722
Brinks Locking Systems Inc.	P.O. Box 233 Napperville Road Plainsville, IL 60544	815-436-7530
Builders Hardware Industries, Inc.	61 Brightside Ave. E. Northport, L.I., NY 11731	516-261-1588
CAHS, Inc.	550 S. Columbus Ave. Mount Vernon, NY 10550	914-668-3800
Cardkey Systems	20339 Nordhoff St. Chatsworth, CA 91311	213-882-8111

Name	Address	Telephone
Chicago Lock Co.	4311 W. Belmont Ave. Chicago, IL 60641	312-282-7177
Colonial Lock Co.	172 Main St. Terryvill, CT 06786	203-584-0311
Componentry Research and Development Enterprises Inc., Corde, Locking Sys. Div.	14-56 Bell Blvd. Bayside, NY 11360	212-423-3116
Continental Instruments Corp.	170 Lauman Lane Hicksville, NY 11801	516-938-0800
Corkey Control Systems Inc.	8622 Bellonca Ave. Los Angeles, CA 90045	213-670-5545
Custom Line, Inc.	2092 N. Lincoln Ave. P.O. Box Z Altadena, CA 91001	213-681-0433
Dalton Mfg. Co.	130 S. Bemiston Clayton, MO 63105	314-727-7567
Del Norte Technology, Inc., Mil Access Control Systems	1100 Pamela Dr. P.O. Box 696 Euless, TX 76039	817-267-3541
Detex Corporation	4147 N. Ravenswood Ave. Chicago, IL 60613	312-348-3377
Dialoc Corp. of America	P.O. Box 1, Highway 30 Denison, IA 51442	712-263-5646
Diebold Inc.	818 Mulberry Rd., S.E. Canton, OH 44711	216-489-4000
Edwards Co., Inc.	90 Connecticut Ave. Norwalk, CT 06856	203-838-8441
Essex International	6233 Concord Ave. Detroit, MI 48211	313-571-8000
Federal Inc.	P.O. Box 637 Southington, CT 06489	203-621-5845
Fichet, Inc./Jenser International	P.O. Box 92 Halesite, NY 11743	516-367-4560

Name	Address	Telephone
Folger Adam Co.	700 Railroad St. P.O. Box 688 Joliet, IL 60434	815-723-3438
Fort Lock Corp.	3000 N. River Rd. River Grove, IL 60171	312-456-1100
Fox Police Lock Co.	46 W. 21st St. New York, NY 10010	212-614-0211
Globalman Products	P.O. Box 246 El Toro, CA 92630	714-533-4400
L. J. Hanchett Hanchett Entry System Inc.	3510 E. Mountain View Phoenix, AZ 85028	602-996-8720
Harloc Products Corp.	135 Wood St. West Haven, CT 06516	203-934-2683
Holmes-Hally Industries	7460 Bandini Blvd. Los Angeles, CA 90040	213-728-3311
Ilco/Unican Corp.	400 Fawn Dr. Rocky Mount, NC 27801	919-446-3321
Intercontinental Security Products Ind.	1901 North West 20th Street Miami, FL 33142	305-324-4014
Keefe Lock Co.	1324 Parkside Ave. Trenton, NJ 08638	609-882-7345
Key Control Systems, Inc.	P.O. box 96A Weil Rd. Bechtelsville, PA 19505	215-845-7585
La Gard Inc.	23635 Madison St. Torrance, CA 90505	213-378-0255
Latch-Gard Div. of Air Flo Co., Inc.	P.O. Box 1285 Elkhart, In 46515	219-293-9581
Lock Corporation of America	6301 W. Mill Rd. Milwaukee, WI 53218	414-353-3600
Lock Technology Corp.	685 Main St. New Rochelle, NY 10801	914-632-4373
Lori Corp. (KABA Lock)	6 Old Turnpike Rd Southington, Connecticut 06489	203-621-3601

Name	Address	Telephone
M.A.G. Engineering	13711 Alma Ave. Gardena, CA 90249	213-321-9942
MRL, Inc.	7644 Fullerton Rd Springfield, VA 22153	703-569-0195
Marks Hardware Inc.,	31 East Mall Plainview, NY 11803	516-293-3030
Master Lock Co.	2600 N. 32nd St. Milwaukee, WI 53210	414-444-2800
Maverick Industries, Inc.	P.O. Box 41 Linwood, KS 66052	913-723-3493
Maxton Lock Co., Inc.	401 E. 74th St., Suite 12L New York, NY 10021	212-628-4222
Medeco Security Locks, Inc.	U.S. 11, W. Allegheny Dr. P.O. Box 1075 Salem, VA 24153	703-387-0481
Mosler Co. Safe Div., Nuclear Products Div.	1561 Grand Blvd. Hamilton, OH 45012	513-867-4000
Mul-T-Lock Corp.	167 Madison Ave. New York, NY 10016	212-889-9545
Omnia Industries, Inc.	49 Park Street Montclair, NJ 07042	201-746-4300
Openings	2005 Pontiac Rd. Pontiac, Mich. 48057	313-373-0565
Overly Manufacturing Co.	574 W. Otterman St. Greensburg, PA 15601	412-834-7300
Quad-Guard Co.	2937 So. LaBrea Ave. Los Angles, CA 90016	213-938-9132
Reliable Security Systems Inc.	907 N. 23rd St. Columbus, Ohio 43219	614-253-0981
Russwin Sales Group (Emhart)	225 Episcopal Rd. Berlin, Connecticut 06037	203-225-7411
Sargent & Co. (Div. of Walter Kidde & Co. Inc.)	100 Sargent Dr. New Haven, Conn. 06509	203-562-2151

Name	Address	Telephone
Sargent & Greenleaf Inc.	1 Security Drive Nicholsville, Kentucky 40356	606-885-9411
Schlage Lock Co.	2401 Bayshore Blvd. San Francisco, CA 94119	415-467-1100
Securitron Magnalock Corp.	P.O. Box 49875 West Los Angles, CA 90049	213-472-4779
Sen DEC Corp.	54 West Avenue Fairport, N.Y. 14450	716-425-2860
Sentry Door Lock Guards, Inc.	114 S.W. 3rd Ave. Dania, FL 33004	305-922-1604
Shwayder Co., The	2335 E. Lincoln Birmingham, MI 48008	313-645-9511
Silent Watchman Corp., The	4861 McGaw Rd P.O. Box 7893 Columbus, OH 43207	614-491-5200
Simplex Security Systems, Inc.	10 Front St. Collinsville, CT 06022	203-693-8391
Trine Mfg. Div. of Square D Co.	1430 Ferris Place Bronx, NY 10461	212-829-4796
U.S. Home Security Systems	1725 23rd St. Sacramento, CA 95816	916-443-6441
Von Duprin, Inc.	400 W. Maryland St. Indianapolis, IN 46225	317-637-5521
Weslock Co. Div. TRE Corp.	13344 S. Main St. Los Angeles, CA 90061	213-770-0880
Yale Security Products	P.O. Box 25288 Charlotte, NC 28212	704-283-2101

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

An investigation was made of the literature and information related to high security, internal locking devices. The purpose of this work was to identify and document the present state-of-the-art of these devices and systems used on doors. This document supports an R & D effort to develop a locking system for sensitive ordnance structure doorways that will take the place of existing surface mounted padlocks and hasps. Locking systems were investigated both overall and their subsystem components, including bolt-works, bolt-work driving subsystems, locking mechanisms and the protective envelope. Usual categories of lock types are presented, and a new combined summary of locking device classifications is suggested to act as a standard basis for future research and development of standards. This classification divides locks by their operation, installation and component characteristics. A review of the literature includes an annotated bibliography, annotated lists of standards and specifications, national organizations and locksmith schools, a selected list of manufacturers and a glossary compiled from available glossaries. An appendix includes selected samples of manufacturers' catalogue information. As a result of this investigation, the author provides specific recommendations concerning the needs of more technical study and research together with suggested development and implementation of standard test methods.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)
Door security; entry control; hardware; locking device classification; lock operation, installation, and characteristics.

13. AVAILABILITY

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