AMKS

ALOA Master Keying Specialist


WEBINARS
2021

01. Master Keying Fundamentals

Ralph Forrest-Ball, CML

There are some important things that all locksmiths should know about Master Keying. In this session we cover the mechanics of split pin master keying, what can go wrong, incidental master keys, different methods of master keying, construction master keying, multiplex keyways, and more. You will also learn the Eight Rules of Master Keying which will help keep you and your employees out of trouble.

Spring Schedule

M 2-22	1. Master Keying Fundamentals
Th 2-25	2. Key Schematics and Keying Schedules
M 3-1	3. Progressing from the KBA
Th 3-4	4. Progressing Multiple Pages MK Systems
M 3-8	5. Cross Keying without Key Interchange
Th 3-11	6. Selective Master Keying
M 3-15	7. Rotating Constant
Th 3-18	8. Rotating Constant, Three Levels
M 3-22	9. Designing Master Key Systems
Th 3-25	10. Master Keying SFIC and LFIC
M 3-29	11. Master Keying System Maintenance
Th 4-1	12. Hacking Master and Decoding Key Systems
M 4-5	13. Working with Large Master Key Systems
Th 4-8	14. Keeping Systems Separate
M 4-12	15. Expanding an Exhausted Master Key System
Th 4-15	16. Common Mistakes in Master Keying

This class is part of a sixteen-part series. Students who attend all classes and complete all homework are eligible to take the AMKS exam, to earn the title of ALOA Master Keying Specialist. If you have missed some classes or homework, email your instructor to see about making up the ones you missed.

Contact us:

aloamkhomework@protonmail.com

Lloyd Seliber, CML
lseliber@keyingsolutions.com

Ralph Forrest-Ball, CML
locksmath@outlook.com

https://locksmath.github.io/aloa_main.html

- Homework assignments
  - Online quizzes
  - Written exercises
- Other materials
  - Additional reading
  - Slide presentations
  - Class PowerPoints in pdf format

Choose a display name to identify you.

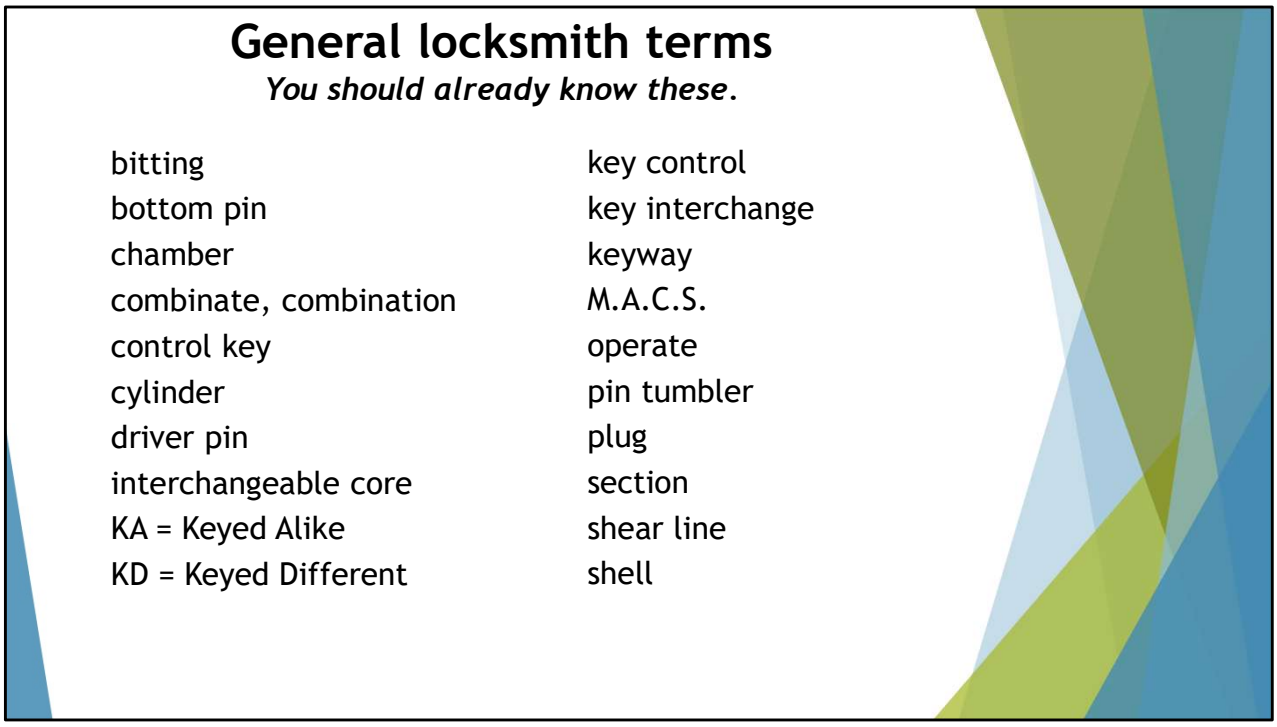
Good examples:

full name	John Q. Smith
initials + ALOA number	JQS123456
first name + last initial	John S.
first initial + last	J. Smith

Spaces and special characters (# $ - % & * *et cetera*) **are** allowed.

Bad examples: mtnbiker38

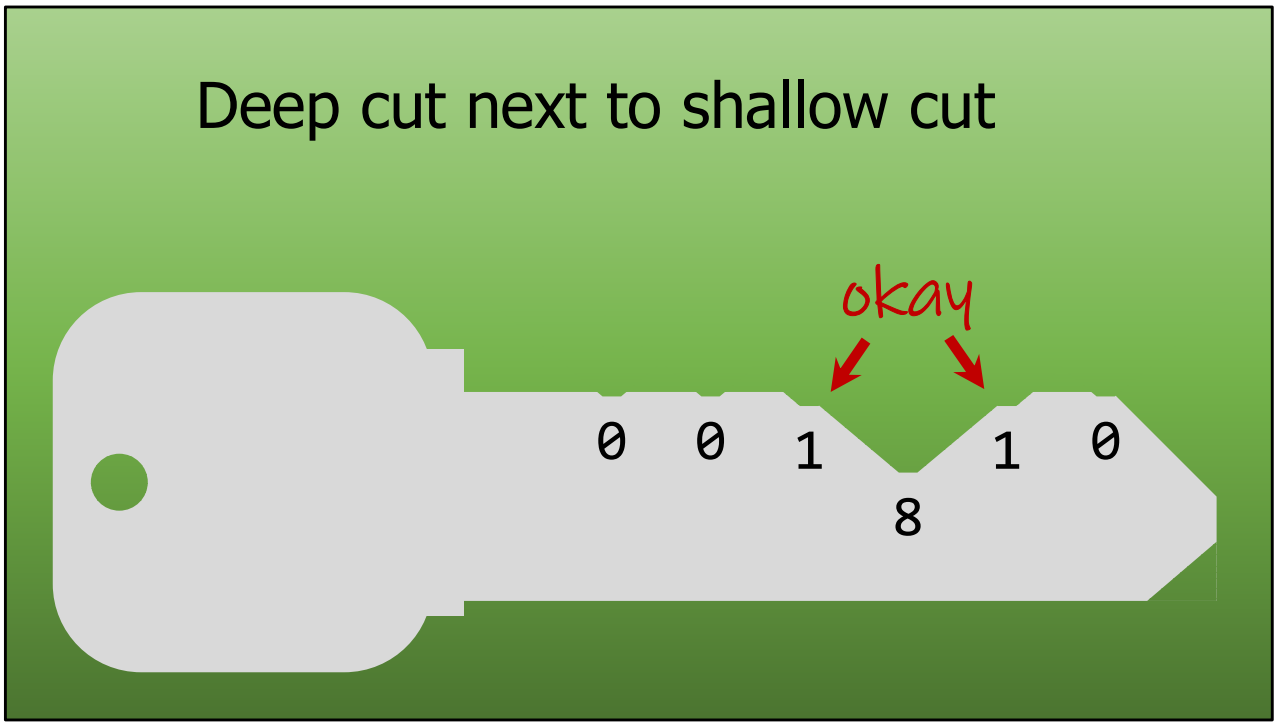
A-1 Locksmith



These are some general locksmith terms which will come in handy when we are discussing master keying. If you don't know some of these terms, now is the time to ask. Let me call your attention to a few of them. When we talk about putting pins into a lock, we might say we "change" the lock, or we "pin" the lock, but the more precise term is **combinate**. The sequence of numbers that describes the cuts on a key is the bitting and the sequence of numbers that describes the pins in the lock is the **combination**. When we talk about using a key in a lock, we might say the key will "fit" the door, or "work" the lock, but the more precise term is **operate**. Conversely, the lock **is operated by** the key. There is a subtle difference between section and keyway. The **keyway** is the shape of the opening in the lock; the **section** is the shape of the blade of the key. There could be multiple different sections that will slide into one keyway. For example, a KW1 key will slide into a WR5 lock.

M.A.C.S. is the Maximum Adjacent Cut Specification. This will be important in master keying because we well generate list of theoretical keys and then need to identify which ones are unusable. For example, the MACS for Schlage is 7. If a bitting list contains 345613, 345615, 345617, and 345619, the last one violates the MACS because it's physically impossible to put a deep 9 cut adjacent to a shallow 1 cut.

All such violations in the bitting list need to be located and marked so we don’t try to use them as keys.



For example, you should already know that problems come up when a key has a deep cut adjacent to a shallow cut. In this example, there's an 8 cut next to a 1 cut, which is pushing the limits of what's acceptable for Schlage locks.

For any two adjacent cuts, subtract the smaller number from the larger number and the difference must be less than (or equal to) 7.

Maximum Adjacent Cut Specification

(MACS)

MACS = 7

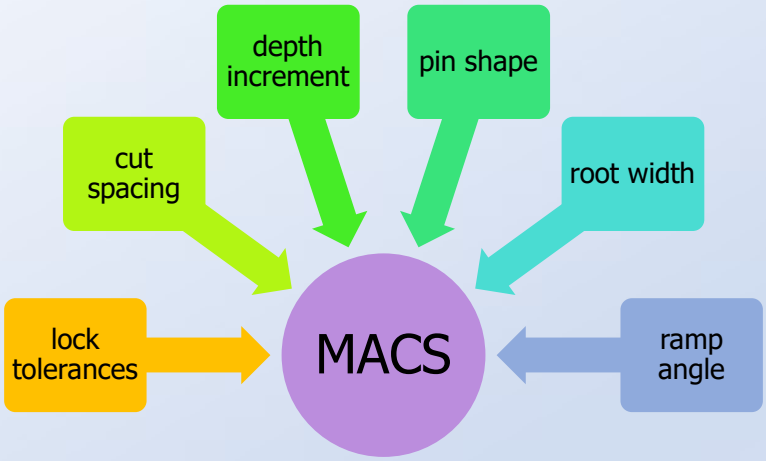
For every pair (a, b)

$|a - b| \leq 7$

0 0	0 1	0 2	0 3	0 4	0 5	0 6	0 7	0 8	0 9
1 0	1 1	1 2	1 3	1 4	1 5	1 6	1 7	1 8	1 9
2 0	2 1	2 2	2 3	2 4	2 5	2 6	2 7	2 8	2 9
3 0	3 1	3 2	3 3	3 4	3 5	3 6	3 7	3 8	3 9
4 0	4 1	4 2	4 3	4 4	4 5	4 6	4 7	4 8	4 9
5 0	5 1	5 2	5 3	5 4	5 5	5 6	5 7	5 8	5 9
6 0	6 1	6 2	6 3	6 4	6 5	6 6	6 7	6 8	6 9
7 0	7 1	7 2	7 3	7 4	7 5	7 6	7 7	7 8	7 9
8 0	8 1	8 2	8 3	8 4	8 5	8 6	8 7	8 8	8 9
9 0	9 1	9 2	9 3	9 4	9 5	9 6	9 7	9 8	9 9

We call this the Maximum Adjacent Cut Specification, or "**MACS**" for short (sounds like "max"). Take any two adjacent cuts and subtract the smaller one from the larger one. The difference must be less than, or equal to, 7. There are 100 possibilities for two adjacent cuts. Six of them are no good. We call them "MACS violations" (shown here in red). You can't put a 1 next to a 9, can't put a 0 next to a 9, can't put a 0 next to an 8.

Factors that determine MACS



But here's something you may not realize about MACS.

MACS is calculated from these factors. If you change any of the factors, it changes the calculation. Some of these are outside your control. Some depend on which pin kit you're using. Some depend on what key machine and cutting wheel you're using.

Schlage cuts should not overlap.

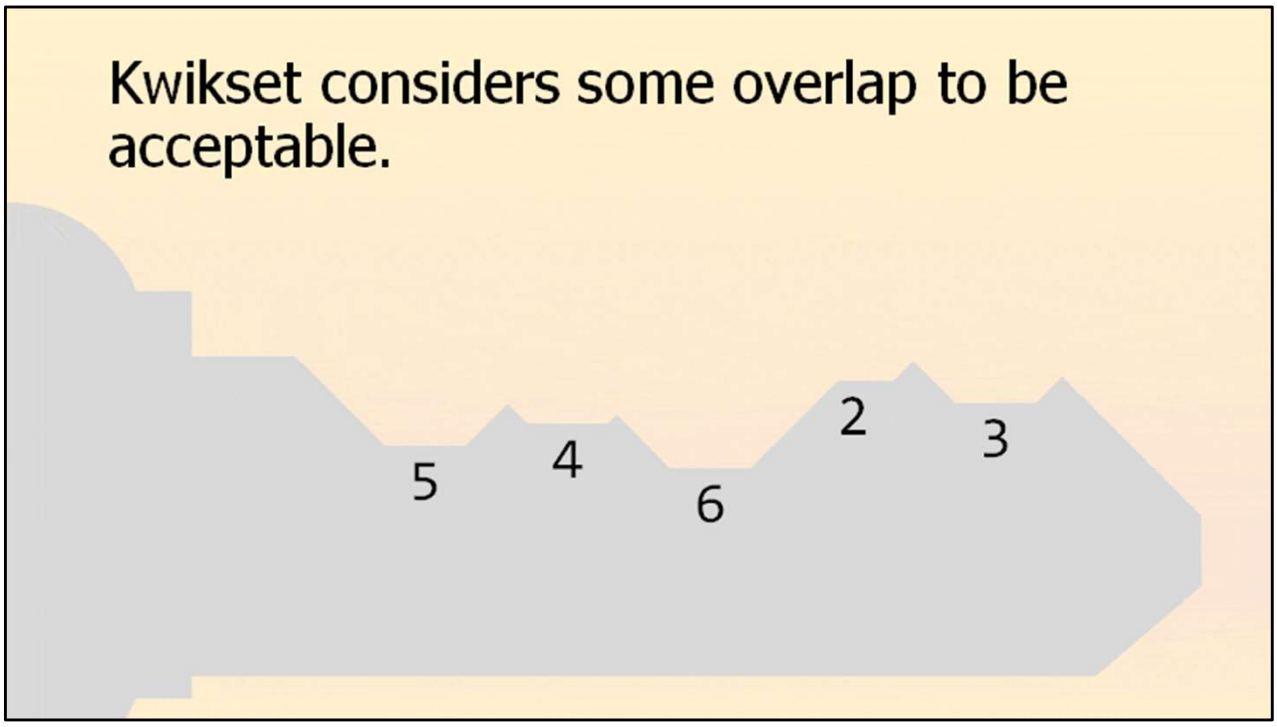
- MACS = 7
- Problems arise with a difference of 6.
- 14MC & 90MC ← too wide
- 14MC ← correct angle
- 90MC ← too steep

With the 14MC cutting wheel, you'll have problems. The angle is correct but the cuts are too wide. If you switch to the 90MC cutting wheel, it allows you to get the full MACS of 7, but then you have reliability issues with having ramps that are too steep.

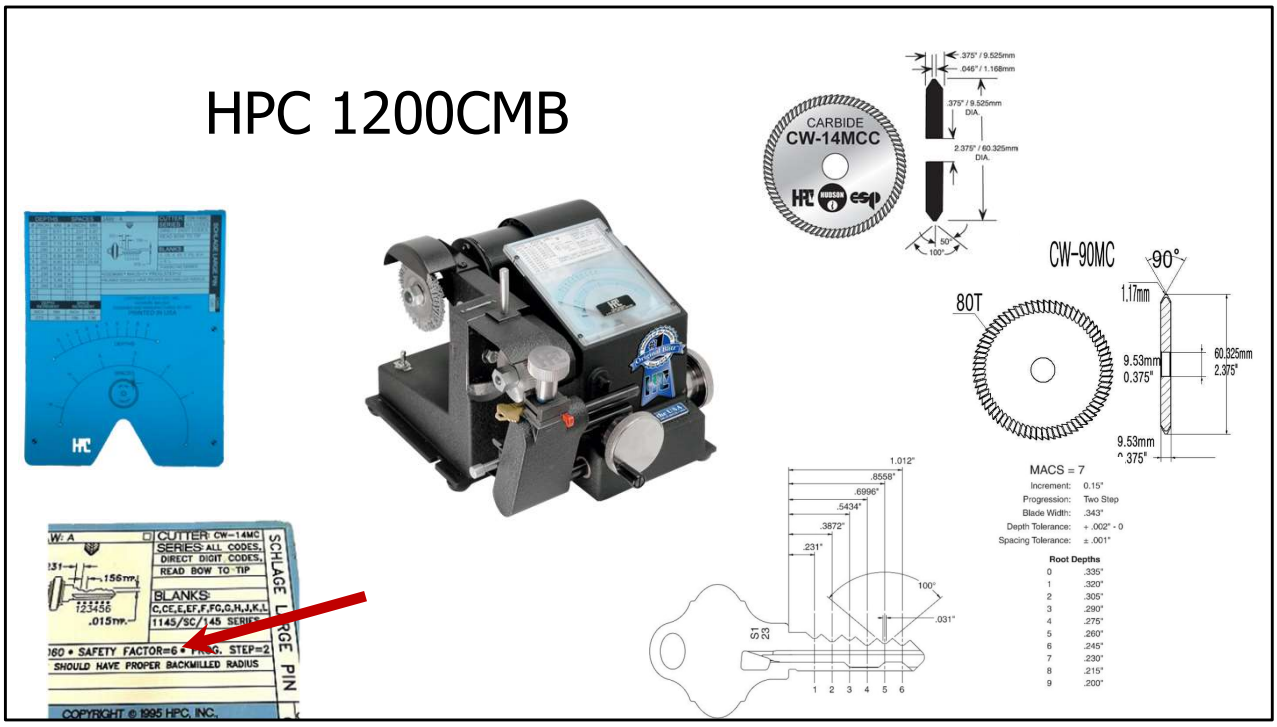
Kwikset allows some overlap.

- MACS = 4
- Problems arise with a difference of 3.
- 14MC & 90MC ← too narrow
- 14MC ← wrong angle
- 90MC ← correct angle

Having cuts too narrow isn't really a problem. You just need to run the machine left and right a bit, to widen each cut. It takes more time, but it gets the job done.



This key is cut to factory specs, yet 30% of the root of the 2 cut in the fourth position is eaten away by the ramp from the 6 cut in the third position. There is a noticeable gap, but this is within the stated MACS of 4.



Generally, you should choose a cutter which is as close as possible to the factory specs. It helps to have more than one option available. If you use an HPC 1200CMB, I strongly recommend that you **get a 90MC cutting wheel** . Neither the 14MC nor the 90MC will give you properly cut Schlage keys (which is why older versions of the HPC code card C45 say “Safety Factor 6”, even though the MACS is 7).

But, for most other brand, including Kwikset, Yale, Corbin-Russwin, and Best, the correct ramp angle is 45 degrees, so the 90MC has the correct angle, not the 14MC.

Kwikset MACS violations

23212	14146	25426	62144	52**61**4x
32332	1**27**46x	66256	36733	43254
5**16**54x	52452	62212		

Schlage MACS violations

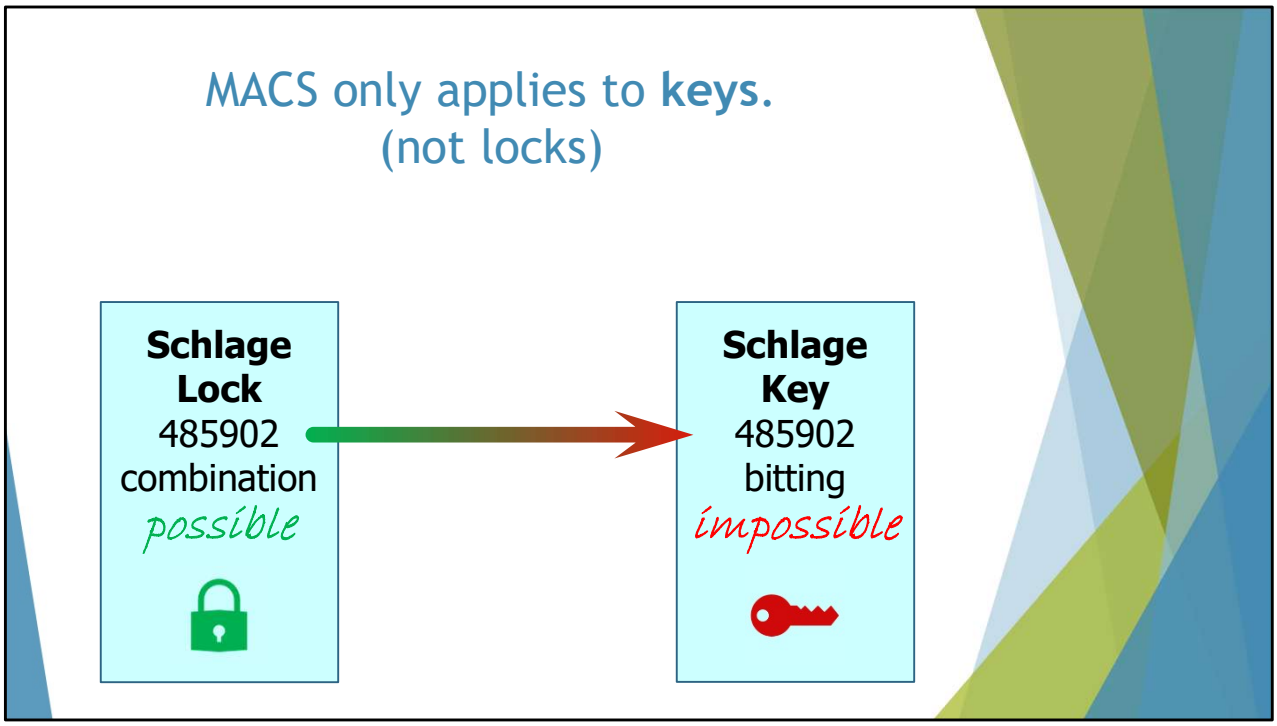
10581	7**19**59x	60455	45889	87**19**5x
01331	57555	84351	06312	26411
11300	11883	12495		

959739	996259	9297**09**x	784997
702740	871**80**0x	552847	625468
018173	8**90**772x	896246	

Sargent MACS violations

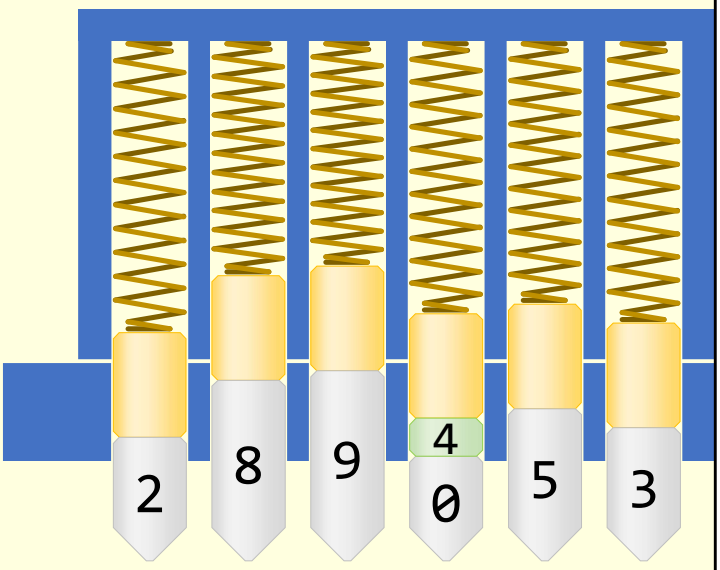
827764	44502**02**6x	698896	656755
089751	247345	858277	055185

The second key is a MACS violation, because, with Sargent, the “0” means “ten”. You can’t put a ten next to a two.



Remember, MACS only applies to keys, not to locks. It's impossible to cut a key to the bitting 485902, but there is no reason we can't put the pins 485902 into a lock. It would just be a lock without a key.

Typical pin-tumbler lock



This may look strange (and perhaps pointless) to have a 9 pin next to a 0 pin, but it doesn't actually violate MACS, because MACS only applies to keys, not pins.

Master keying terms

The sooner you learn these, the better.

split-pin master keying
pin stack
master pin
master key system
key symbol
CK = Change Key
MK = Master Key
CK = Change Key
MK = Master Key
GMK = Grand Master Key
GGM = Great Grand Master
TMK = Top Master Key
incidental master key
construction master key
selective master key

progression
constant
cross keying
maison keying
KBA = Key Bitting Array
bitting list
keying schedule
Rotating Constant Method
Total Position Progression Method
Limited Position Progression Method
Matrix Format
Standard Progression Format
keying conference
access control
credentials

These are terms which you'll need to know for master keying. If you know all these terms now, that's great; it will help you understand what we're talking about. If you don't know them all yet, you'll learn them as we go along. By the end, you should know them all.

Topics for today

How master keying works
- Split Pin Master Keying
- Incidental Keys
- Hazards of Master Keying
- Pinning Charts

Talking to customers
- Master keyed is not the same as keyed alike.
- Advantages and disadvantages of master keying

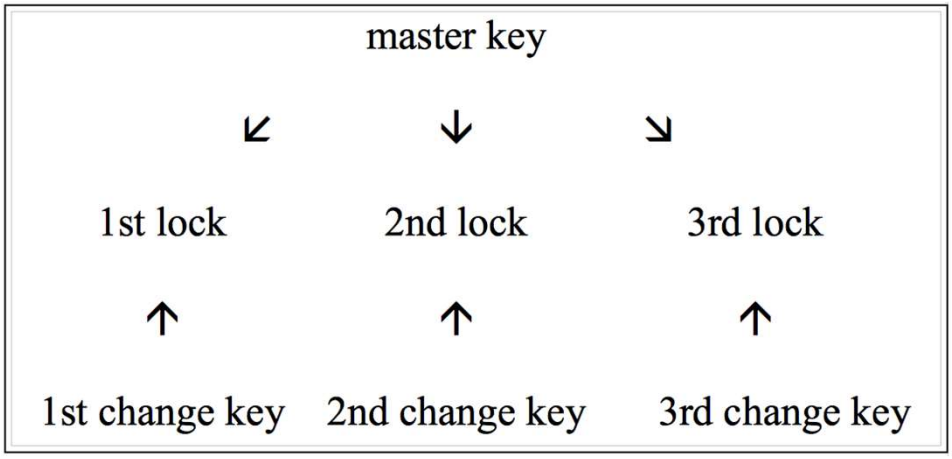
Key duplication
- identifying restricted keys
- identifying a master key – SKCS, the Standard Key Coding System
- using the correct key blank
- what to do when the key doesn't quite work
  - Should you alter the key? Alter the pins? Alter the lock?

Rekeying locks
- Look for master pins **before** you dump everything out.
- Who owns the key? Who owns the lock? Who has authority?
- If the locks are master keyed make sure you get all the old master pins out.

The 8 rules of master keying.

These are the main topics for today's class. These are the topics that every locksmith needs to know about master keying, even if you never create your own master key systems. First, know how to discuss master keying with customers. Second, know the problems that may come up when duplicating keys. Third, know what to look out for when rekeying a cylinder. And finally, eight rules of master keying, to help keep you out of trouble.

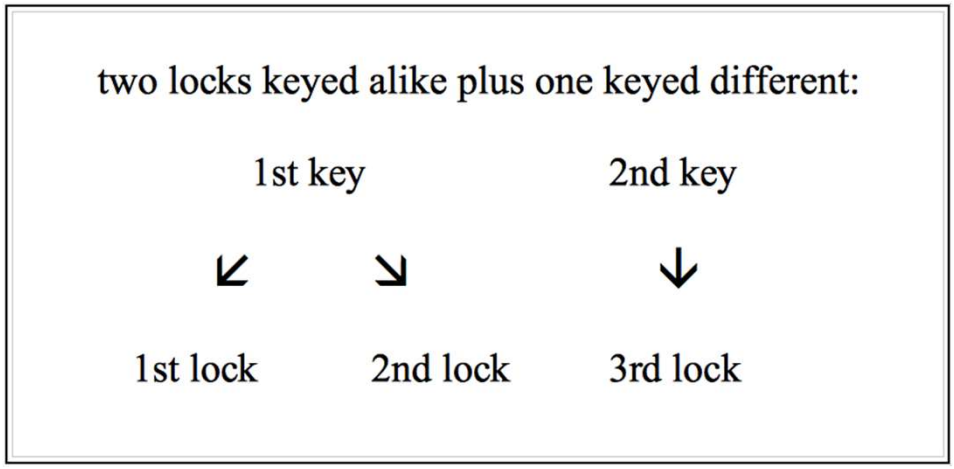
Simple master key system



Simply put, **master keying** involves making two different keys **operate** the same lock. A typical **master key system** consists of one or more **change keys** (each of which operates a particular lock) plus a **master key** which operates them all. There are many ways to accomplish that but we will focus on what's called **split-pin master keying**. It involves putting extra pins into a lock, called **master pins**.

Looking at this diagram, you can see that each lock is operated by exactly two keys.

KA vs. KD



Don’t confuse “master keyed” with “keyed alike”. They are describing different things, and they are in no way mutually exclusive. A lock is master keyed if two different keys operate the same lock. Two locks are keyed alike if the locks use the same keys as each other.

Are these locks single keyed or master keyed? Are they keyed alike or keyed different?

The master key is AA.

There are two change keys, 1AA and 2AA.

1. Front door is keyed to 1AA only.
2. Back door is keyed to 1AA only.
3. Sales office is keyed to 2AA and AA.
4. Supply closet is keyed to 2AA only.
5. Break room is keyed to 1AA and AA.
6. Conference room is keyed to 1AA and AA.

First, let's find the ones that are single keyed.

Are these locks single keyed or master keyed? Are they keyed alike or keyed different?

The master key is AA.

There are two change keys, 1AA and 2AA.

1. Front door is keyed to 1AA only.
2. Back door is keyed to 1AA only.
3. Sales office is keyed to 2AA and AA.
4. Supply closet is keyed to 2AA only.
5. Break room is keyed to 1AA and AA.
6. Conference room is keyed to 1AA and AA.

The ones in red are single keyed. Each of them only operates with one key. All the others operate with two keys.

Now, let's find the ones that are keyed alike.

Are these locks single keyed or master keyed? Are they keyed alike or keyed different?

The master key is AA.

There are two change keys, 1AA and 2AA.

1. Front door is keyed to 1AA only.
2. Back door is keyed to 1AA only.
3. Sales office is keyed to 2AA and AA.
4. Supply closet is keyed to 2AA only.
5. Break room is keyed to 1AA and AA.
6. Conference room is keyed to 1AA and AA.

The two highlighted in yellow are keyed alike to each other.

Are these locks single keyed or master keyed? Are they keyed alike or keyed different?

The master key is AA.

There are two change keys, 1AA and 2AA.

1. Front door is keyed to 1AA only.
2. Back door is keyed to 1AA only.
3. Sales office is keyed to 2AA and AA.
4. Supply closet is keyed to 2AA only.
5. Break room is keyed to 1AA and AA.
6. Conference room is keyed to 1AA and AA.

The two highlighted in blue are keyed alike to each other.

We have two keyed-alike groups. The rest are keyed different.

Are these locks single keyed or master keyed? Are they keyed alike or keyed different?

The master key is AA.

There are two change keys, 1AA and 2AA.

1. Front door is keyed to 1AA only. single keyed, keyed alike
2. Back door is keyed to 1AA only. single keyed, keyed alike
3. Sales office is keyed to 2AA and AA. master keyed, keyed different
4. Supply closet is keyed to 2AA only. single keyed, keyed different
5. Break room is keyed to 1AA and AA. master keyed, keyed alike
6. Conference room is keyed to 1AA and AA. master keyed, keyed alike

As you can see, all four situations are possible: single keyed and keyed alike, single keyed and keyed different, master keyed and keyed alike, master keyed and keyed different.

SKCS = Standard Key Coding System

A symbol for each key. A symbol for each lock.	6AA key → 6AA lock
Master keys: letters	AB is a master key.
Change keys: letters + number	AB12 is a change key.
Lock's label = lowest key	A, AD, and AD4 → AD4.

Each key has a key symbol. Each lock has a key symbol. Often, they are identical. For example, the 6AA key operates the 6AA lock.

Master keys have letters (usually two). Change keys have letters plus a number.

SKCS = Standard Key Coding System

highest key = Top Master Key (TMK)

two-levels

- master key: two letters
- change keys: numbers in front

three levels

- grand master key: one letter
- master keys: two letters
- change keys: numbers at the back

Examples of Key Symbols

5AA is a change key in a two level system, under AA

AA5 is a change key in a three level system, under AA and A.

A4 is a change key in a three level system, directly under A.

SKD1 is a single-keyed lock whose key stands alone.

AB6(NMK) is a single-keyed version of the AB6 lock.
AB6 is operated by 3 keys: AB6, AB, and A.
AB6(NMK) is operated by 1 key: AB6 only.

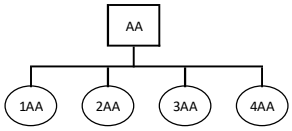
XAB6 is a cross-keyed version of the AB6 lock.
XAB6 op by AB7, AB, and A ← operates with 4 keys.

X1X is a cross-keyed lock that does not have its own key.
X1X op by AB1-AB9, AB and A ← operates with 11 keys.

AA is a master key. It might be the top key of a two-level system, or one of the master keys in the middle of a three-level system. 3AA is definitely a change key, because it has a number. The number is in front, so this is part of a two-level system. The master key above it is AA. AA5 is also a change key, but it's part of a three-level, shown by the fact that the number is after the letters. The master key above it is AA. But that's not all. There is also a grand master key A above that. AB has no numbers, therefore it's a master key. Specifically, it's in the middle level of a three-level system. The grand master key above it is A. The change keys below it are AB1, AB2, et cetera. A1 has a number after the letters, so it must be a change key in a three-level system. The master key above it is the grand master key A. There is no master key in between A and A1. SKD1 is a change key for a single keyed lock. Note: SKD does not mean Keyed Different (KD). Single keyed locks can indeed be keyed alike. AB6 is a change key in a three-level system, under the AB master, which is under the A grand master key. A lock labeled AB6 would operate with three keys: the AB6 change key, the AB master, and the A grand master. XAB6 is a cross-keyed lock which operates with four keys instead of three. The extra key is the AB7 key. X1X is a cross-keyed lock which operates with six keys. It does not have its own change key. Notice that

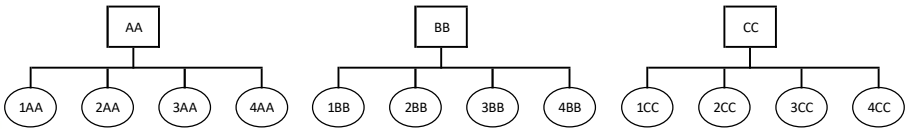
we did not say this lock operates with the AA master.

Simple master key system, two levels



In a two-level system, we usually call the master key AA.

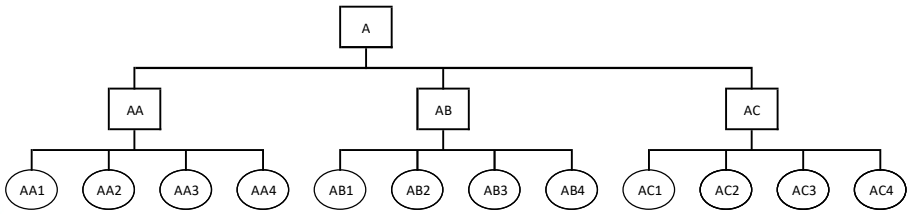
Several two-level systems



If there's already an AA system at that location, we can make another master key system with its own master key, BB. If we need another one, it's CC.

What if we wanted a grand master key that covers everything?

A three-level system



In this situation, we don't call the master keys AA, BB, and CC. We call them AA, AB, and AC, to indicate that all three master keys are under the grand master key A.

Again, if there's already an "A" system at this location, we could call the new one "B", to avoid confusion, and it would have master keys BA, BB, and BC.

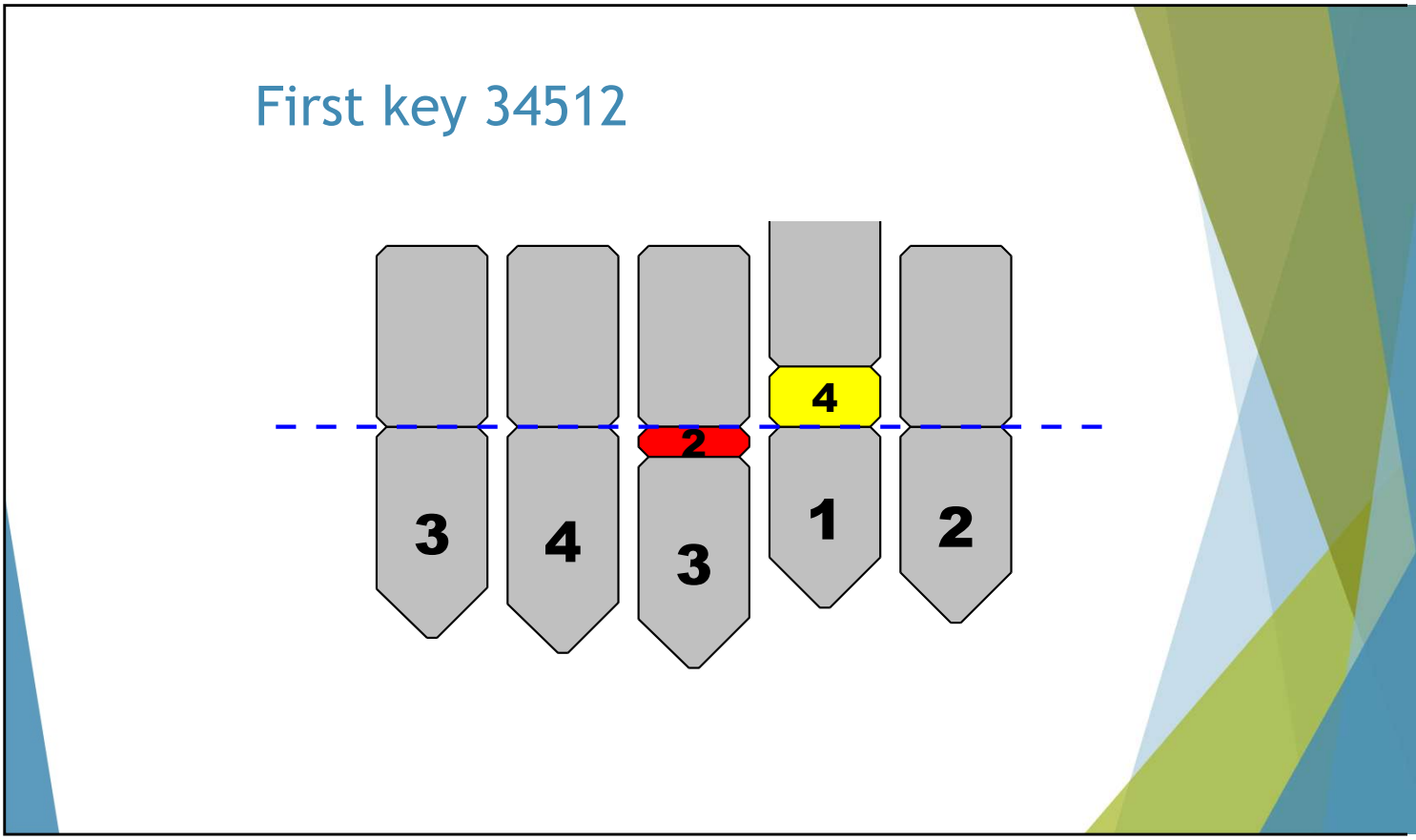
Talking to a customer

When a customer says, “I want one key to work everything.”

Do they mean they want the locks single keyed and keyed alike?

Or do they mean they want the locks master keyed, each with its own change key plus a master key that operates them all?

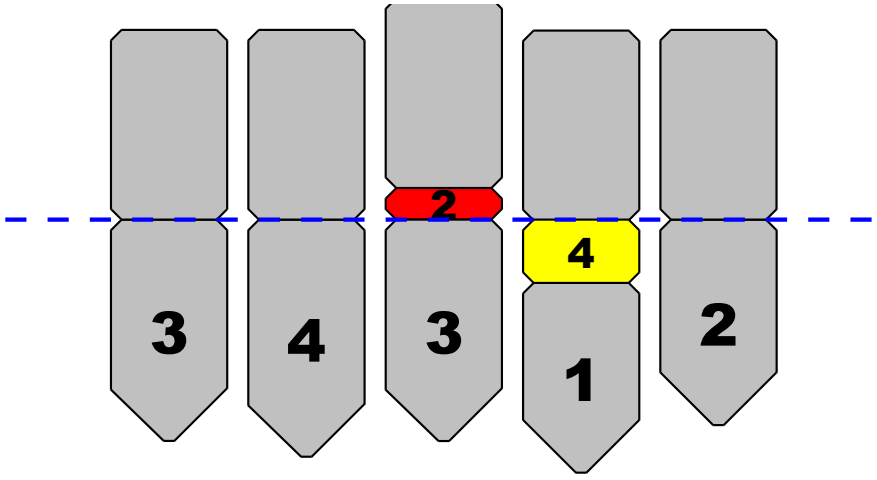
Either of those could be what they mean. You need to ask for clarification.



This is a master keyed lock, with master pins in chambers three and four. The key 34512 should operate this lock. The plug will turn because every chamber has a break in the pin stack at the shear line (shown with a blue dotted line). For example, in the third chamber, we see a bottom pin #3 and a master pin #2, which together are exactly the same length as a bottom pin #5. The third cut on the key is a 5, so the top of the master pin should just meet the shear line.

Notice that the #4 master pin (shown in yellow) is exactly twice a long as the #2 master pin (shown in red). This is true for master pins, but not for bottom pins. The #4 bottom pin is not twice as long as the #2 bottom pin.

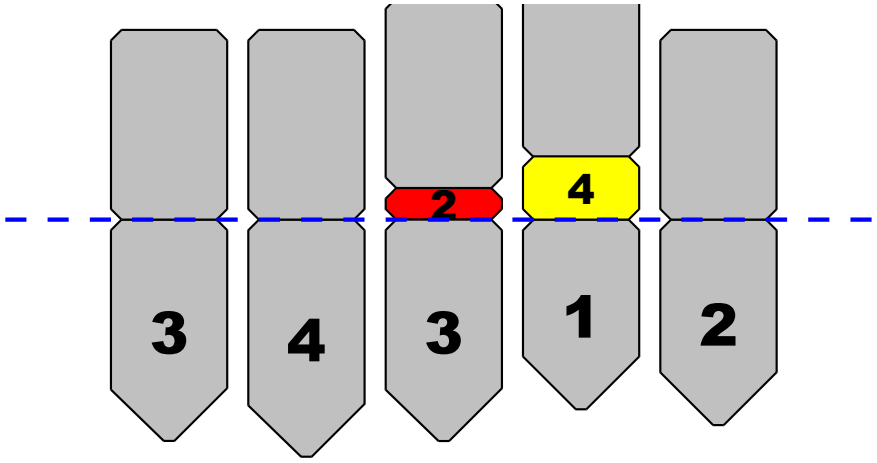
Second key 34352



The 34352 key will also operate that same lock. The #2 master pin in the third chamber is now above the shear line and the yellow pin in the fourth chamber is below it.

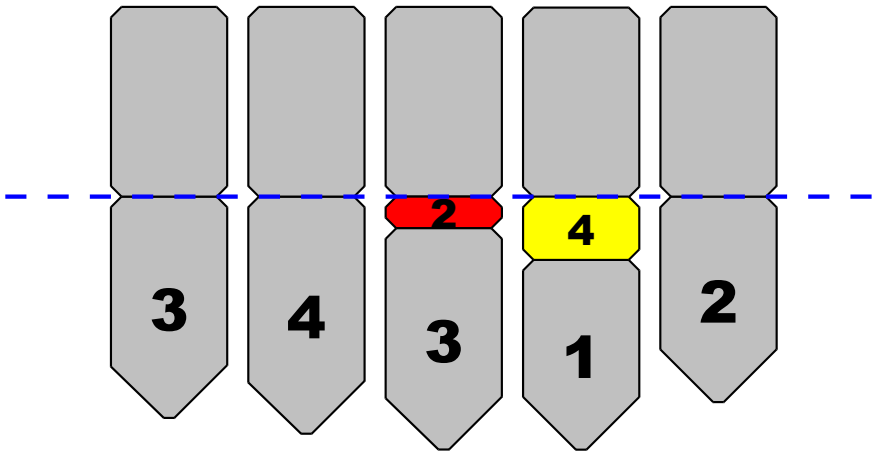
This lock was combinated so it would operate with both 34512 and 34352.

Incidental key 34312



But look. This key also operates.

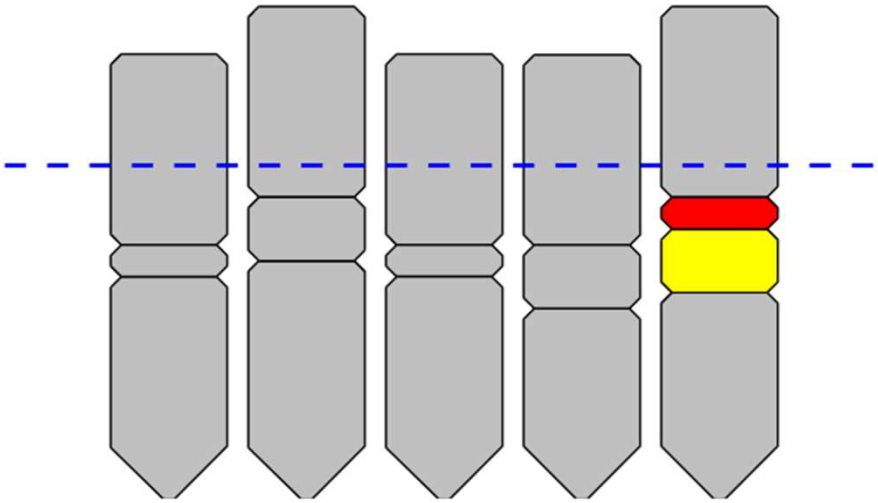
Incidental key 34552



And this one. These are called incidental keys. They happen when you put master pins into more than one chamber. When you add a master pin into one more chamber, it doubles the total number of keys which could operate the lock. This makes the locks easier to pick, easier to bump, more prone to jamming, and more vulnerable to key interchange.

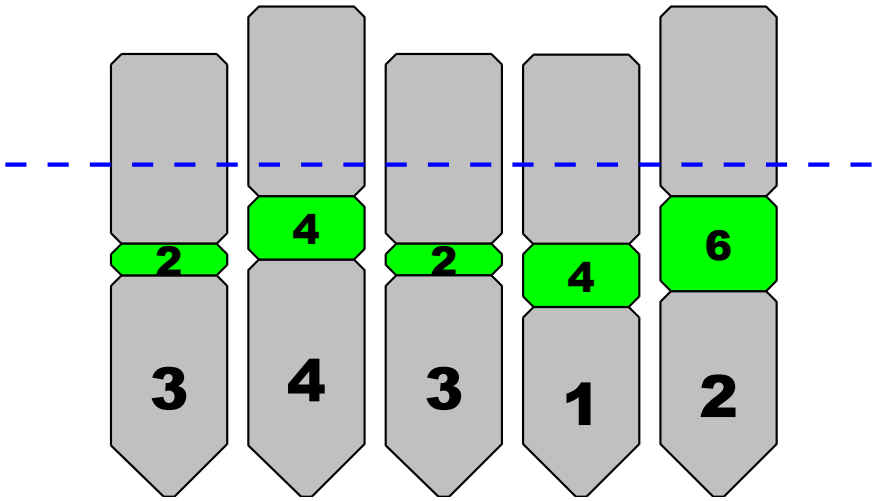
We'll talk more about this when we get to rule number six.

There are 48 keys that could operate this lock.



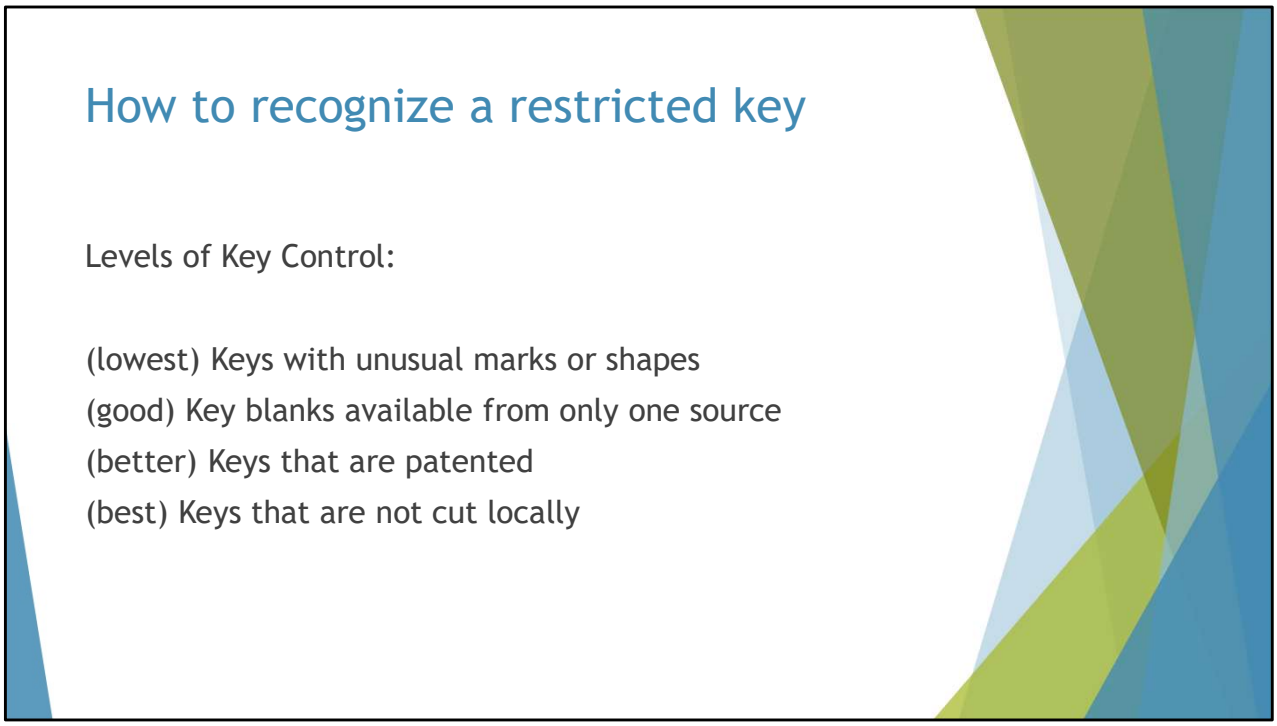
This lock can be operated by 2x2x2x2x3=48 keys. One is the change key, one is the master key, and the other 46 are incidental keys. This show how things quickly get out of hand when you have too many master pins.

If we know the change key, we can figure out the master key.



If you know what the pins are, and you know what the change key is, you can figure out what the master key is. This means all master key systems can be hacked. That's an important thing to know. It's one of the reasons that it's usually not a good idea to master key a residence (unless there's a good reason, such as needing quick access for medical emergencies).

The master key for this lock is **54358**. We'll discuss this in more detail later.



When you teach an apprentice to duplicate keys, one important thing they need to know is how to recognize a restricted key.

The lowest level of key control is a key with unusual marks or shapes, such as a neuter bow key with the words “Do Not Duplicate” stamped on it. This alone does not make it a restricted key. A restricted key is a key that is only available from one source. Stamping a Schlage SC4 “Do Not Duplicate” doesn’t change the fact that SC4 key blanks are available from multiple sources, not just from Schlage. It’s not a restricted key.

The ALOA policy for unrestricted keys stamped “Do Not Duplicate” is to follow the same procedure you follow for any other restricted key. Do you ask for ID when you duplicate a regular house key? If not, then you should not ask for ID when you duplicate a DND key.

The next level is restricted keys, which are only available from one source. This gives the supplier the ability to make rules about who can get keys and who can’t. But there’s no legal protection to stop someone else from producing the key blanks. For that, you need to move up to the next level, patented keys. The patent is what allows them to protect their monopoly.

But patents eventually expire.

The highest level is keys that are restricted **and** patented **and** not cut locally, such as the Medeco DL keyway. This helps to ensure that the correct procedures are followed. The more people who have the ability to cut the keys, the more the chance that one of them might break the rules.

Key Symbols for Change Keys

Change keys always have a number.

2 levels? Numbers before letters.

1AA 27AA 7BB

3 levels or more? Number after letters.

AA2 AB3 GGM1 A4 BH3

If a key is stamped with standard key symbols, you can recognize change keys by the fact that they have a number, either at the front or at the end. There are some rare exceptions to this rule. A cross-keyed cylinder has an X at the front. Technically, “cross-keyed” describes the lock, not the key, so the X should not appear on the key itself. However, you will sometimes see an X on the primary change key for a cross-keyed lock. If the 23AA key fits a lock which is cross-keyed to operate with 22AA and 21AA and AA, the symbol for that lock is X23AA and the key is still 23AA but it may be stamped X23AA.

Key Symbols for Master Keys

A (or some other single letter)

AA (or some other double letter)

AB (any pair of letters)

ABC (any three letters)

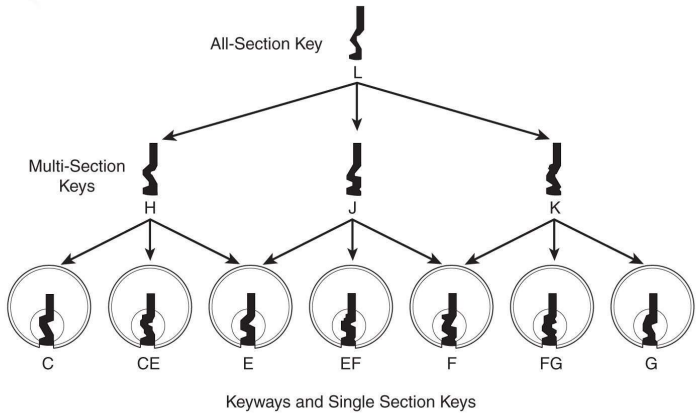
GGM

GGG

A single letter is probably a grand master key. “A” is, by far, the most common. This would be a system with at least three levels, maybe more. A double letter is probably a master key (not a grand master). It could be the top key of a two-level system, or it may be a low-level master key in a system with three levels or more. “AA” is, by far, the most common. If the two letters are different from each other, the first letter is usually “A”, but could be anything. If there’s three letters, that is probably a low-level master key in a system with at least four levels. GGM means Great Grand Master. GGG means Great Great Grandmaster. Either of those would be the top key of a system with at least four or five levels.

With this knowledge, an apprentice locksmith may recognize a master key. If a customer asks for 14 duplicates of a key stamped “GGM”, you might ask, “Are you sure you want 14 copies of this master key?” and they might reply, “Oops, I meant to get 14 copies of this other key here, that says BA7.”

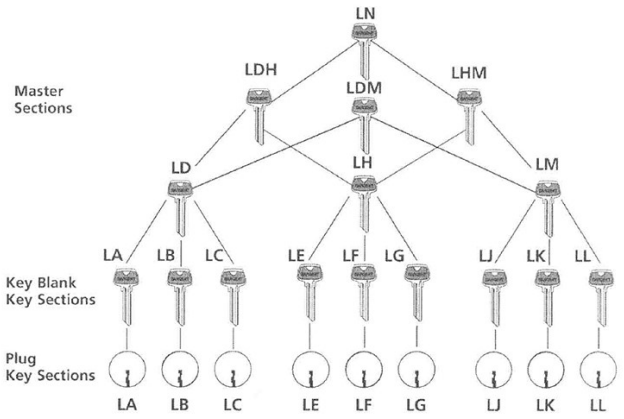
Schlage Obverse Multiplex Keyways



One method for master keying large facilities is sectional master keying with multiplex keyways. For example, you could have a three-level master key system in one building, where every lock in that building uses the Schlage C keyway, and then use the exact same numbers to create an identical master key system in the building next door but every lock uses the Schlage E keyway. Then if you copy either grand master key onto a Schlage H blank, you get a GGM key which work both buildings.

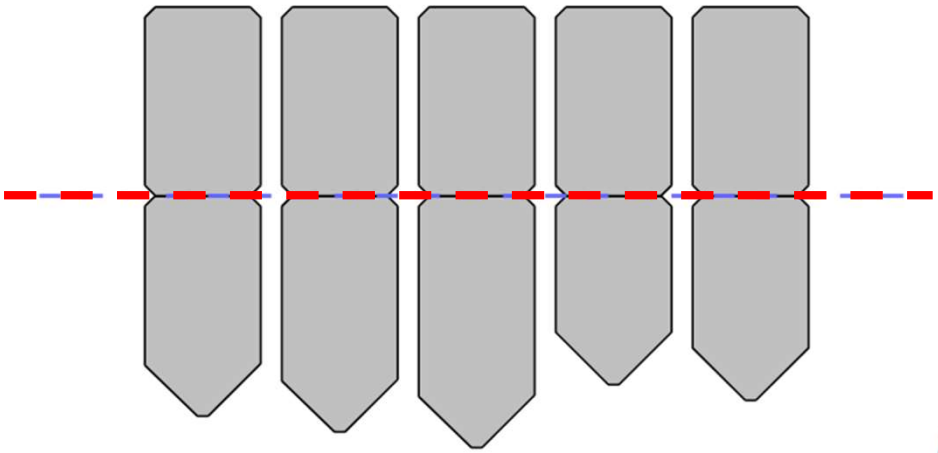
For this reason, you should teach a new apprentice to only use the same key blank as the key the customer presents for duplication. If a customer asks for copies of a Schlage E and you're out of E's, but you have H's, don't be tempted to use the H blank instead. You could be inadvertently elevating their grand master key to a great grand master.

Sargent L-series Multiplex Keyways



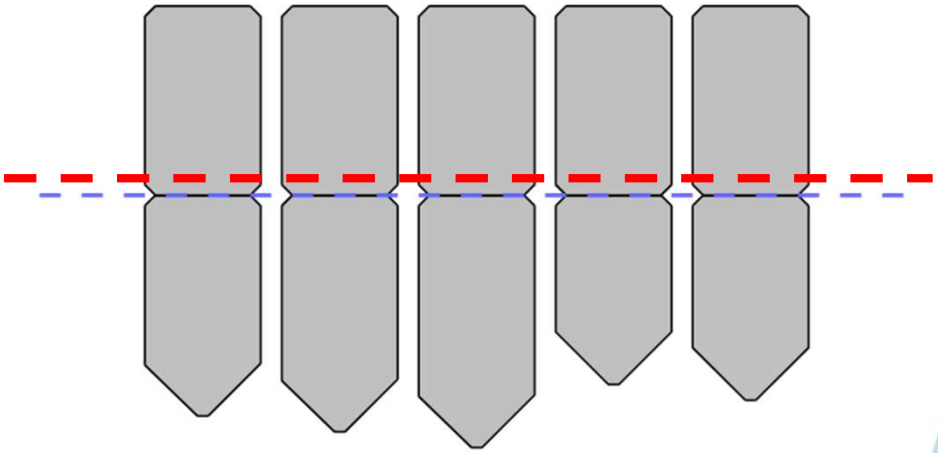
Of course, Schlage isn't the only one with multiplex keyways. Sargent uses them too. Here's the L-series tree. An LD blank will fit LA, LB, and LC locks, for example. Other brands with multiplex keyways include Yale and Corbin-Russwin.

Correctly cut key



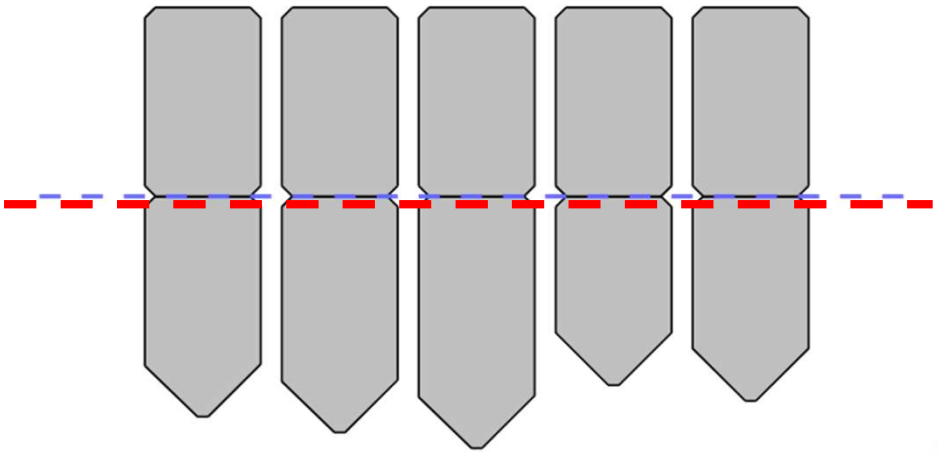
The red dashed line is the “shear line”

“clicky”: Key is cut too deep.



The red dashed line is the “shear line”. A key that’s cut too deep doesn’t want to turn, at first. Then you wiggle it, jiggle it, hold your tongue just right, and it turns. After it starts turning, it turns easily.

“stiff”: Key is cut too shallow.

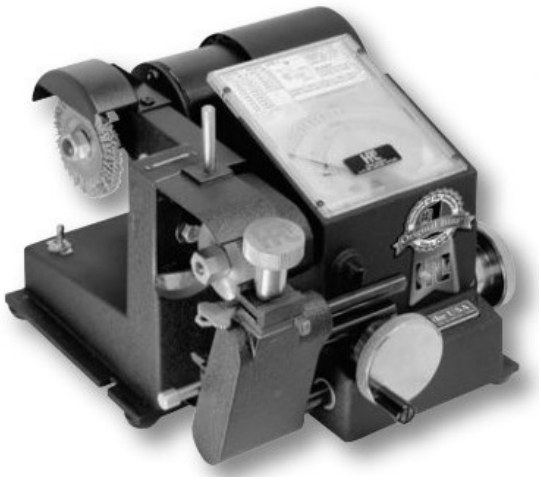


A key that’s cut too shallow lifts the pins too high. The key is difficult to turn, perhaps getting more difficult the farther you turn it, and often leaving dimples in the roots of the cuts.

.003 universal pin kit

A universal kit can be used to combinate a wide variety of locks (but not Best SFIC, which uses smaller diameter pins). When you train an apprentice, you probably will teach them that, when the key feels clicky, you can compensate by using a longer pin, and when the key feels stiff, you can compensate by using a shorter pin. That's probably not a good idea with master keying. It would be better to just make sure the key was cut properly in the first place. Recalibrate you key machine if you have to. Adjusting the key is better than adjusting the pins. Adjusting the lock itself (such as filing the plug) is usually a very bad idea. If you see a filed plug, replace it.

HPC 1200CMB



Keys in a master key system will be cut by code. To do this, you'll use a code machine, such as this HPC Blitz. Make sure it's calibrated. Check it frequently when you're cutting lots of keys in a master key system. Keep a micrometer handy and spot check some of the keys. I like to check every tenth key, at least. The actual cuts should be within .002 inches of the factory spec.

An even better option would be a computer-controlled code machine, preferable one that clamps the key blanks automatically. But, if your shop can't afford that, a code machine like the HPC is still better than making keys with depth and space keys, and a duplicator. Unfortunately, as we discussed earlier, the HPC doesn't have a cutting wheel that's the right dimensions for Schlage keys.

Reading a Pinning Chart

```
top         24-246
bottom      344012
```

The top row is the top pins and the bottom row is the bottom pins. Notice that all the master pins are even numbers. When you combinate a lock, the first chamber gets a bottom pin 3 and then a master pin 2 on top of it. Second chamber, bottom pin 4 and master pin 4. Third chamber, bottom pin 4 and no master pin. Fourth chamber, bottom pin 0 and master pin 2. Then bottom pin 1 and master pin 4, finally bottom pin 2 and master pin 6.

Reading a Pinning Chart

```
bottom      344012
top         24-246
```

Some people like to write pinning charts with the bottom pins on the top. You need to be flexible, depending on who your coworkers are. Every apprentice needs to know the shop policies about how you keep your records, such as pinning charts, bitting lists, keying schedules, et cetera. If you keep master key systems on a computer, it should require a password. If you keep paper records, they should be in a locked file cabinet.

When rekeying a lock where you don't expect any master pins…

same color?

same shape?

Look carefully at the pins before you dump them from the plug. Are they all the same color? If not, some of them might be master pins. Try dumping just one chamber at a time. If you find master pins you didn't expect, it's time for a conversation with the customer.

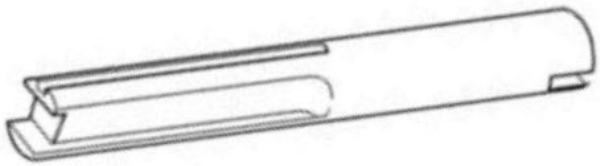
Who owns the lock?
Who owns the key?
Who owns the master key system?

Assumption of authority is different for master key systems. Possession of a lock does not prove ownership of the entire system.

When someone presents you with a key to be duplicated, we generally assume that the fact that they have the key in their hand shows they have the authority to order duplicates. Likewise, when someone presents a lock to be rekeyed, we generally assume that the fact that they have access to the lock shows they have the authority to order a rekey or ask you to fit a key. This is not the case with master key systems. Access to, or even possession of, a lock from a master key system, does not show they have the authority to ask for additional keys or alterations to the master key system. More is required to show their authority. The general rule is to ask for “reasonable and appropriate” evidence, ask for ID, and get the customer’s signature on an authorization form.

If you do rekey a lock that was previously master keyed…

make sure you get all the old master pins out.



A master follower is handy for looking to see if there are any master pins. However, I have seen cases where a Pro-Lok master follower won't catch a Schlage #8 master pin. The way to be sure you get them all is to dump the entire cylinder, bottom pins, top pins, springs, and all.

MK decisions

Right vs Wrong ?

Correct vs Incorrect ?

Advantages vs Disadvantages

There is very little in master keying that is absolutely right or absolutely wrong. There are a few, such as when you need a #6 bottom pin in a lock cylinder and you accidentally use a #4 pin. That's incorrect. But mostly, master keying is about advantages and disadvantages. For example, using fewer master pins has the advantage of making the locks more secure, but it has the disadvantage of yielding fewer change keys.

8 Rules of Master Keying

#1 Before you start a new master key system, make sure the customer understands that master keying increases convenience but decreases security.

#2 Keep all your master keying records up-to-date.

#3 If the customer already has a master key system and they want you to take over the maintenance, you must have the paperwork.

#4 You, the locksmith, choose the bitting of the master key. Don't let the customer choose the key.

#5 Before you design a master key system, you have to find out what the customer needs.

#6 Choose a method which uses as few master pins as possible, while still meeting the customer's needs.

#7 Once you have decided how many constants each change key will have, make sure that all the change keys have the same number of constants.

#8 Use two-step progression for locks that have ten depths (like Schlage).

Here are my eight rules of master keying. These rules aren't set in stone. There are some rare circumstances where breaking the rules would be a good idea. But, following them will help keep you out of trouble. You don't have to memorize them right now. We'll talk about each one individually and then we'll come back to this list again.

Before we jump into the eight rules, we really should discuss what I call, "Rule Zero".

MK Rule zero

Don't be afraid to ask for help.

Call the factory.

Talk to another locksmith.

Send me an email.
locksmath@outlook.com

Don't be afraid to ask for help. Once you determine the requirements for the master key system, most lock manufacturers will be happy to help you with the development of the system. They can choose the TMK for you, progress all the bittings, write all the pinning charts, possibly even combinate all the cylinders and cut all the keys. They usually charge a fee for developing the system, maybe $40 or so, but they may throw it in for free, if you're buying hardware at the same time. Then you maintain the system, keeping the records up to date and making changes, as needed. I highly recommend asking the factory for help when master keying Medeco. Another option is to get some advice from another locksmith, or maybe just ask them to look over your work for mistakes before you start cutting keys and combinating cylinders. If you don't know who to ask, you can always email me, locks math at outlook dot com.

Now, let's look at rule number one.

MK Rule #1

Before you start a new master key system, make sure the customer understands that master keying increases convenience but decreases security.

Many people have the mistaken impression that master keying increases security. Often, the customer really shouldn't have a master key system and it's your job to try to talk them out of it. Always begin by discussing the risks and the benefits. The main advantage of master keying is convenience. For an office building with several offices which are all cleaned at night by a cleaning crew, it's easier to give the crew a master key instead of a ring of keys. For a school which does fire drills twice a year, a master key makes it much easier to evacuate the building quickly. For an assisted living facility whose residents have serious health problems, a master key can help the nursing staff respond quickly to a medical emergency. But master keyed locks are more likely to get jammed. They can be bumped or picked more easily than single-keyed locks. They are also more vulnerable to key interchange.

Master Keying is a balancing act, advantages vs. disadvantages.

Master Keyed Locks

- are easier to pick and bump
- take more time to rekey
- get jammed more frequently
- are more vulnerable to random keys
- can be hacked

Master Key Systems

- are more convenient
- can provide quick access in emergencies
- allow multi-level authorization
- may reduce the scope of rekeying

Here is a summary of some advantages and disadvantages of master keying. We'll talk about these more in future classes, especially part twelve, Hacking and Decoding MK Systems

Residential vs. Commercial

Residential

- 5 pins
- ANSI grade 3
- 2 3/8 backset (60mm)
- 6,000 – 70,000 keys

Commercial

✓6 pins
✓ANSI grade 1 or 2
✓2 3/4 backset (70mm)
✓600,000 – 10,000,000 keys

With residences, such as an apartment building, the advantages rarely outweigh the disadvantages. However, if you do proceed with master keying a residence, consider upgrading the locks to commercial grade. Since master keying decreases the security of the locks, we want to start from a position of strength.

Commercial locks are generally more secure, not only because they are tougher, but because they have more pins, which means more possible keys and better pick resistance. We can use split-pin master keying with residential locks, but it's better to use commercial locks for master keying.

Alternatives to Master Keying

1. Keyed alike groups
2. Single keyed from a bitting list
3. Some locks master keyed, others not
   - Two locks on each door?

Suggest for the customer alternatives to master keying, such as single keyed locks in keyed alike groups. Another option is to make all the locks keyed different and keep a list of the keys for future reference. You can keep one copy of each key in a box, or just cut a key by code, as needed.

If each door has two locks on it, you might suggest master keying one lock but not the other. This is a popular option for a cleaning service that only comes once a week. On the day the service is expected, the tenant leaves one lock unlocked and the cleaning crew opens the other lock with a master key. But the tenant is still safe when both locks are secured.

MK Rule #2

Keep all your master keying records up-to-date.

There are several situations where you may need to go back and look at exactly what you did in a master key system. Eventually, the customer will want one of the locks rekeyed. They may want to expand the system. You might be handing the system over to another locksmith. This is especially true if you work in a shop with several employees. But even if you're on your own, don't rely on your memory. Keep good records. These records might include: notes from the keying conference, a map, a **key schematic**, a bitting list, pinning charts, a keying schedule, and a list of change orders. The most important record is the **bitting list**.

Sample Bitting List #1

TMK 1 2 5 1 2 A

3	4	7	3	4
5	6	9	5	6
7	8	1	7	8
9	0	3	9	0

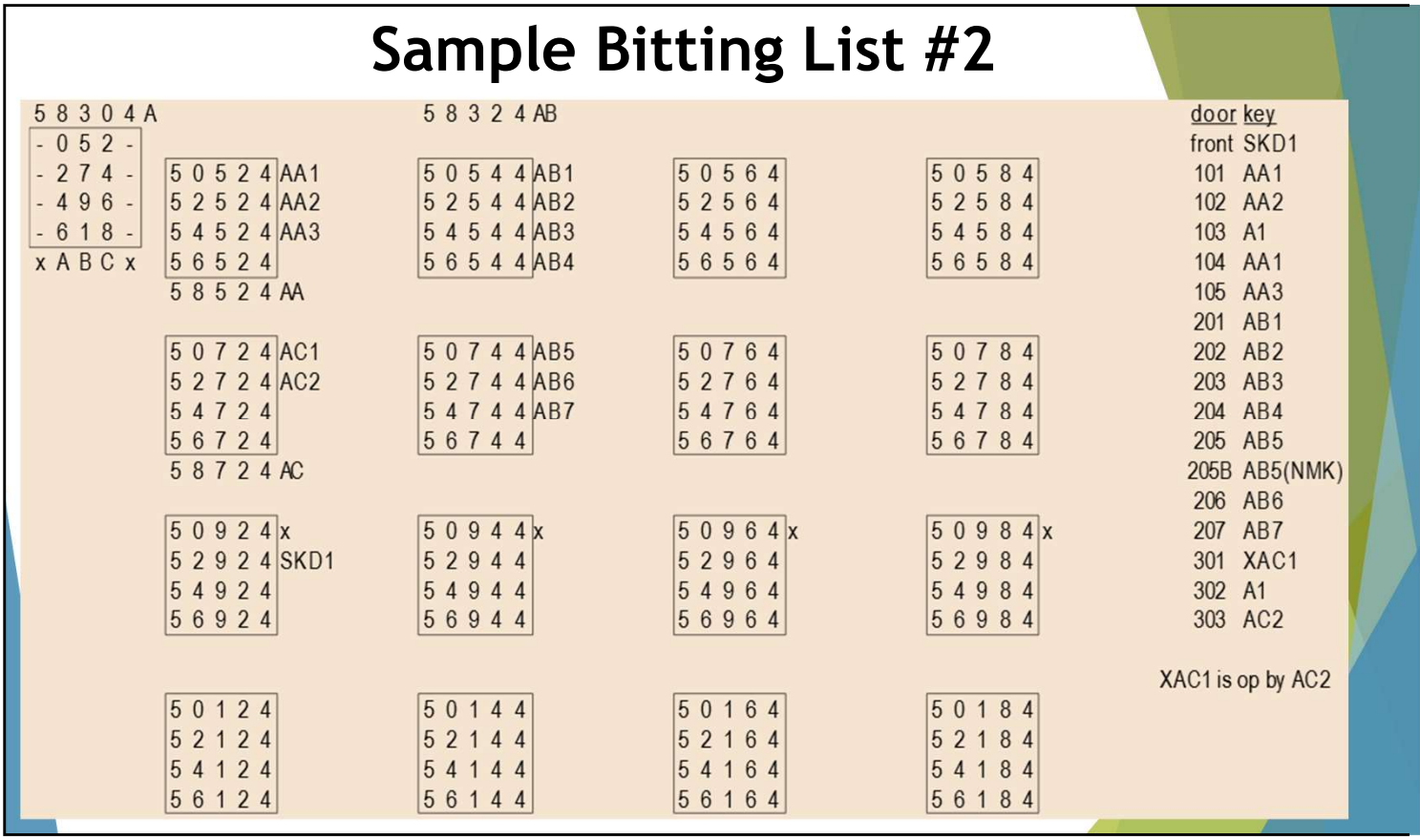
SOP E D C B A

3 4 5 1 2 AA

3 4 7 3 4 AA1	3 4 9 3 4	3 4 1 3 4	3 4 3 3 4
3 4 7 3 6 AA2	3 4 9 3 6	3 4 1 3 6	3 4 3 3 6
3 4 7 3 8 AA3	3 4 9 3 8	3 4 1 3 8	3 4 3 3 8
3 4 7 3 0 AA4	3 4 9 3 0	3 4 1 3 0	3 4 3 3 0
3 4 7 5 4 AA5	3 4 9 5 4	3 4 1 5 4	3 4 3 5 4
3 4 7 5 6 AA6	3 4 9 5 6	3 4 1 5 6	3 4 3 5 6
3 4 7 5 8	3 4 9 5 8	3 4 1 5 8	3 4 3 5 8
3 4 7 5 0	3 4 9 5 0	3 4 1 5 0	3 4 3 5 0
3 4 7 7 4	3 4 9 7 4	3 4 1 7 4	3 4 3 7 4
3 4 7 7 6	3 4 9 7 6	3 4 1 7 6	3 4 3 7 6
3 4 7 7 8 w	3 4 9 7 8	3 4 1 7 8	3 4 3 7 8
3 4 7 7 0	3 4 9 7 0	3 4 1 7 0	3 4 3 7 0
3 4 7 9 4	3 4 9 9 4	3 4 1 9 4 x	3 4 3 9 4
3 4 7 9 6	3 4 9 9 6	3 4 1 9 6 x	3 4 3 9 6
3 4 7 9 8	3 4 9 9 8	3 4 1 9 8 x	3 4 3 9 8
3 4 7 9 0 x	3 4 9 9 0 x	3 4 1 9 0 x	3 4 3 9 0 x

This is an example of a bitting list. The purpose is to show all the change key bittings in the system, indicating which ones are in use and which ones are available for future use. The bittings could be selected in a random order but they are not themselves random. This is actually page 1 of a 16-page system with 1024 change key bittings. That's obviously way too big if the customer only needed six change keys. The person who designed this system probably should have made it smaller.

Sample Bitting List #2



5 8 3 0 4 A

-	0	5	2	-
-	2	7	4	-
-	4	9	6	-
-	6	1	8	-
x	A	B	C	x

5 8 3 2 4 AB

5	0	5	2	4	AA1
5	2	5	2	4	AA2
5	4	5	2	4	AA3
5	6	5	2	4	

5 8 5 2 4 AA

5	0	5	4	4	AB1
5	2	5	4	4	AB2
5	4	5	4	4	AB3
5	6	5	4	4	AB4

5	0	5	6	4	
5	2	5	6	4	
5	4	5	6	4	
5	6	5	6	4	

5	0	5	8	4	
5	2	5	8	4	
5	4	5	8	4	
5	6	5	8	4	

5	0	7	2	4	AC1
5	2	7	2	4	AC2
5	4	7	2	4	
5	6	7	2	4	

5 8 7 2 4 AC

5	0	7	4	4	AB5
5	2	7	4	4	AB6
5	4	7	4	4	AB7
5	6	7	4	4	

5	0	7	6	4	
5	2	7	6	4	
5	4	7	6	4	
5	6	7	6	4	

5	0	7	8	4	
5	2	7	8	4	
5	4	7	8	4	
5	6	7	8	4	

5	0	9	2	4	x
5	2	9	2	4	SKD1
5	4	9	2	4	
5	6	9	2	4	

5	0	9	4	4	x
5	2	9	4	4	
5	4	9	4	4	
5	6	9	4	4	

5	0	9	6	4	x
5	2	9	6	4	
5	4	9	6	4	
5	6	9	6	4	

5	0	9	8	4	x
5	2	9	8	4	
5	4	9	8	4	
5	6	9	8	4	

5	0	1	2	4
5	2	1	2	4
5	4	1	2	4
5	6	1	2	4

5	0	1	4	4
5	2	1	4	4
5	4	1	4	4
5	6	1	4	4

5	0	1	6	4
5	2	1	6	4
5	4	1	6	4
5	6	1	6	4

5	0	1	8	4
5	2	1	8	4
5	4	1	8	4
5	6	1	8	4

door	key
front	SKD1
101	AA1
102	AA2
103	A1
104	AA1
105	AA3
201	AB1
202	AB2
203	AB3
204	AB4
205	AB5
205B	AB5(NMK)
206	AB6
207	AB7
301	XAC1
302	A1
303	AC2

XAC1 is op by AC2

Here is another example of a bitting list. This is a 3-level system. This one sheet of paper shows three important pieces of information. First is the Key Bitting Array, which explains how the key bittings are calculated. Second is the bitting list, where you can see which bittings have been used and which are available for future use. Third is the keying schedule, which describes exactly which keys should operate each lock. Of these three, the bitting list is the most important. Without an up-to-date bitting list, you could easily end up with two locks accidentally keyed alike.

You may notice that there is a mistake in this example. The keying schedule says doors 103 and 302 are operated by key A1, which does not appear anywhere in the bitting list. This mistake should be corrected before attempting to assign any new keys. Disassemble the lock from 103 or 302 (or both), measure the pins, and determine the bitting of the A1 key. Then find it in the bitting list and mark it “A1”.

Also, there is an ambiguity. Door 301 has a cross-keyed lock, operated by AC1 and AC2. But, do the AC master and the A grand master also operate there? Try the A and AC keys in that lock to find out. If they work, update the records to indicate that fact. We’ll learn more about cross keying in part seven, Cross Keying without Key Interchange.

MK Rule #3

If the customer already has a master key system and they want you to take over the maintenance, you must have the paperwork.

If the customer doesn't have copies of this paperwork, you might be able to contact the previous locksmith. If the paperwork is not available, you might be able to reverse engineer it, but it's safer to just start a new master key system and rekey the entire property.

Let’s see what the ALOA Technical Standards have to say about this.

ALOA Technical Standard #11

11. Master Keyed System Integrity: No attempt will be made to expand any master keyed system without first obtaining a valid key bitting array and a list of all key bittings currently in use. If this is not possible, the lock shall be keyed SKD or a new master key system generated.

This is an excerpt from the ALOA Technical Standards. Like the ANSI standards, it doesn't have the force of law, and it's not even part of the ALOA Code of Ethics. But following the Technical Standards will help keep you out of trouble.

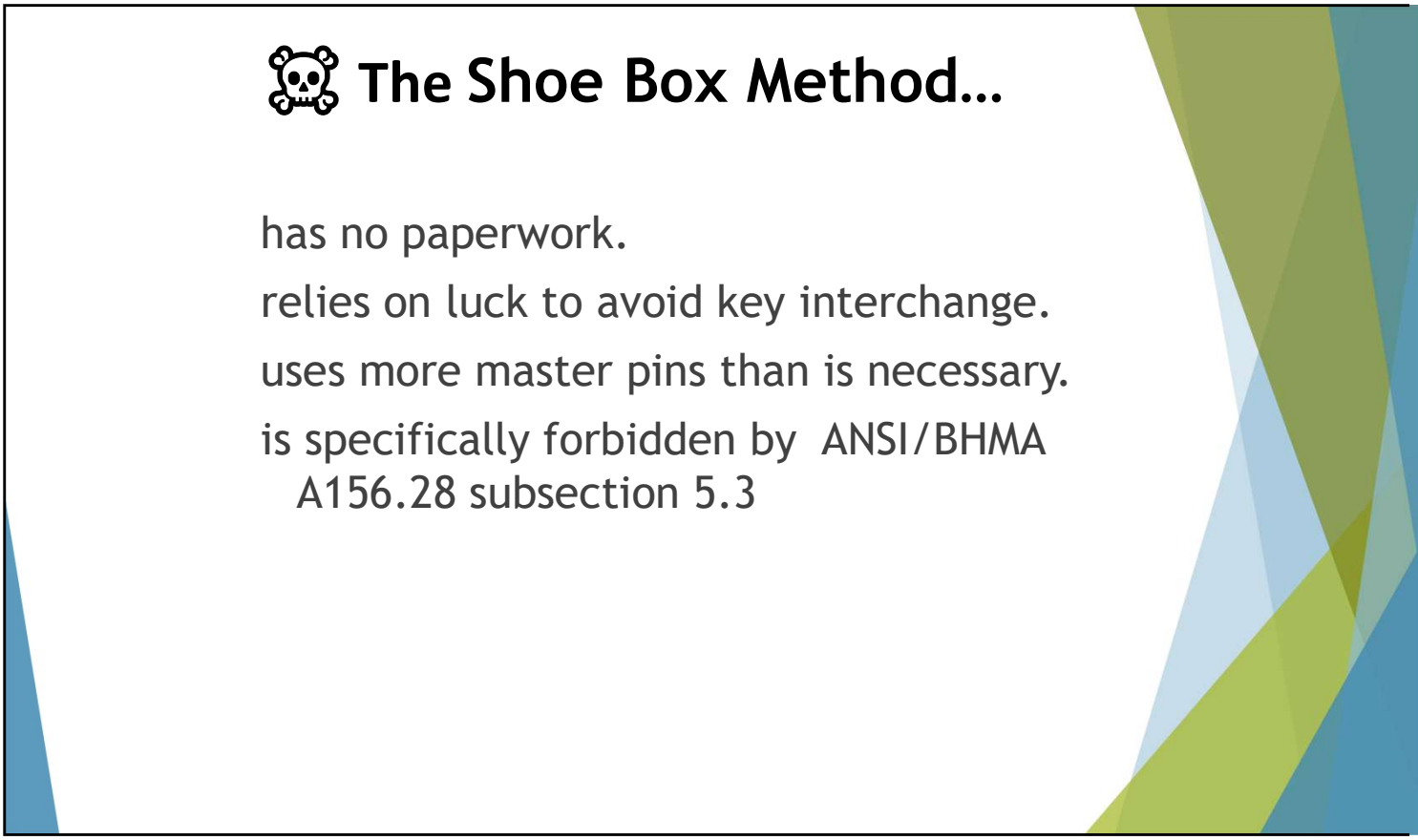
When a customer asks you to take over the maintenance of their master key system, even temporarily (even for just one lock!), you need to have the records. Hopefully, you'll receive a whole file folder full of documents. But the bare minimum is that you need to have the KBA and an up-to-date bitting list. If the customer can't provide those documents, you might obtain them from the previous locksmith, or you might be able to reverse engineer them. Otherwise, you have two good options: single key the lock, or create a brand new master key system, with a new master key that you choose yourself.

We'll talk more about this in part nine, Working on Master Key Systems Created by Others.

MK Rule #4

You, the locksmith, choose
the bitting of the master key.
Don't let the customer choose the key.

This actually follows from rule #3 but the reason isn't immediately obvious. Sometimes you'll find a customer who insists on getting locks master keyed with a master key which they already have, plus change keys which they want you to provide. The tricky part here is *why do they already have a master key?* It's probably because they already have a master key system in place. They are, in effect, asking you to do maintenance on their master key system without any paperwork. You have no way of knowing how many other locksmiths they have visited with this same master key, getting locks master keyed all over town, with no KBA and no up-to-date bitting list. This is a trap. Don't fall for it. Insist on picking the master key yourself. If you let the customer choose the master key, there is no way to know if the customer takes that same key to a dozen locksmiths, all over town, for a dozen locks. Essentially, they could be building a Shoebox master key system, one lock at a time. That's bad.



Master keying should not be random. We should choose a good bitting for the Top Master Key, decide where to put constants in the system, write a progression list, and choose change key bittings from that list. The precise order of the list is not important and it's fine to jump around within the list. But the items on the list are not random at all. They follow logically from the decisions we made about the TMK and the constants. When this is done properly, there should be zero chance of internal key interchange.

The Shoe Box method is very different from what we just described. Typically, you pick a random pattern key out of a box of pattern keys and call it the master, or you take two locks off the shelf which are keyed different, copy both keys onto the same blank, and call that the master. Then, for each lock, you pick another pattern key out of the box (or use the pattern keys which came with the lock) and combinate the lock so it will be operated by that random key and also the master key. The Shoe Box method has no bitting list, no plan for avoiding key interchange, no structure for multiple levels of master keying. For multiple keys under the same master, it would be prudent to test every change key in every lock to see if there is any internal key interchange. In practice, this usually doesn't happen. You often find Shoe Box systems on apartments.

It's usually not a good idea to master key residences at all. But if the customer insists, we should at least do it right and minimize the risks.

ANSI/BHMA A156.28 subsection 5.3

5.3 Progression Master keying progression varies widely when different cylinder mechanisms are used. The method of master keying progression should be selected to create the minimum number of incidental master keys, while still reaching the desired system expansion. Correct progression results in no duplication of key combinations and no key interchange. Random key bittings must never be used in a key system. In a conventional pin tumbler cylinder this is accomplished by using the fewest possible master pins per cylinder.

Here is an excerpt from ANSI/BHMA A156.28, which is the industry standard for master keying. It says random key bittings must never be used in a key system. In other words, Shoe Box master keying is expressly forbidden. You are not allowed to use it, period. ANSI standards do not have the force of law. You would never get a ticket or a citation for failure to follow them. But, in a lawsuit, you do not want it to come out that you knowingly violated the industry standards.

MK Rule #5

Before you design a master key system, you have to find out what the customer needs.

Usually, this involves a meeting called a keying conference. Make sure you're meeting with the r

Key control basically means strategies to keep track of who has keys and how to prevent unauth

Topics for the keying conference

- Who makes decisions
- Who hands out keys
- Levels of key control
- Future expansion and turnover
- Who needs access to what areas
- Vulnerabilities and threats
- Master keying decreases security.

Here are some topics for the keying conference. There is more about this in in ANSI/BHMA A156.28, sub

Goals for the site survey

Get a map of the facility.

- Blueprints? Evacuation plan?

Locate exterior doors.

Identify code violations.

Begin the hardware schedule

Note: every opening gets a label.

MK Rule #6

Choose a method which uses as few master pins as possible, while still meeting the customer's needs.

This is how you avoid too many incidental keys.

“constants”

The master key and change have the same cuts.

The chamber has no master pins in it.

Fewer master pins = more constants.

Constants are your friends.

Before we get to Rule #7, we need to know this vocabulary term. A constant is a place where a particular change key has the same cut as the master key. The lock has no master pin in that chamber. Notice this isn’t the same as saying, “it never changes.” If there’s a constant on one change key and a constant on another change key, they could be in different positions. Constants can move around.

Putting master pins into more than one chamber leads to incidental keys. The more incidental keys in the system, the greater the risk of key interchange. To reduce the risk, use fewer master pins, i.e. more constants. Constants are your friends.

MK Rule #7

Once you have decided how many constants each change key will have, make sure that all the change keys have the same number of constants.

How many constants?

34512 ← master

34531

31532

31535

Remember, a constant is a place where the cut on the change key is the same as the cut on the master key. It doesn't mean the change keys are the same as each other. The easy way to find the constants is to look at the master key, one cut at a time. The first cut is a 3. Let's find all the change keys that have a 3 for their first cut.

How many constants?

34512 ← master

34531

31532

31535

There. Now look at the second cut on the master. It's a 4.
Look for change keys that have a 4 in the second position.

How many constants?

34512 ← master

34531

31532

31535

Only that first one has a 4. Next, the third cut is a five.
Look for change keys that have a 5 in the third cut.

How many constants?

34512 ← master

34531

31**5**32

31**5**35

All of them do.

Next, look at the fourth cut, a 1. What change keys have a 1 for their fourth cut?

How many constants?

34512 ← master

34531

31**5**32

31**5**35

None of them do.

Finally, look at the fifth cut, a 2. What change keys have a 2 for their fifth cut?

How many constants?

34512 ← master

34531

31**5**3**2**

31**5**35

Just that one.

All our constants are in green. Let's count the constants for each key.

How many constants?

34512 ← master

34531 three constants

31**5**3**2** three constants

31**5**35 two constants

Every change key should have the same number of constants. This breaks the rule.

How many constants?

378425 ← master

370625

370025

358485

Here's another example. Find the constants.

How many constants?

378425 ← master

370625

370025

358485

Then count to see how many each key has.

How many constants?

378425 ← master

370**625** four constants

370**0**25 four constants

35**84**8**5** four constants

This follows the rule. All the change keys have the same number of constants.

MK Rule #8

A) Extremely short master pins are unreliable. Don't use master pins shorter than .023 inches.

Most locks either use six depths (like Corbin-Russwin, Kwikset, and Medeco) or ten depths (like Sargent, Schlage, and Yale). The vast majority of six-depth locks have an increment of .023 inches or more. This means that a #1 master pin is at least .023 inches long, and it's considered safe to use it in master keying. The factory pin kit for six-depth locks will contain a very short #1 master pin (which resembles a round wafer). On the other hand, the vast majority of ten-depth locks have an increment of less than .023 inches and there is no #1 master pin in the factory pin kit. This means that, with ten-depth locks, every change key needs to differ from the master key by at least two depths (or, in a constant position, be the same as the master key).

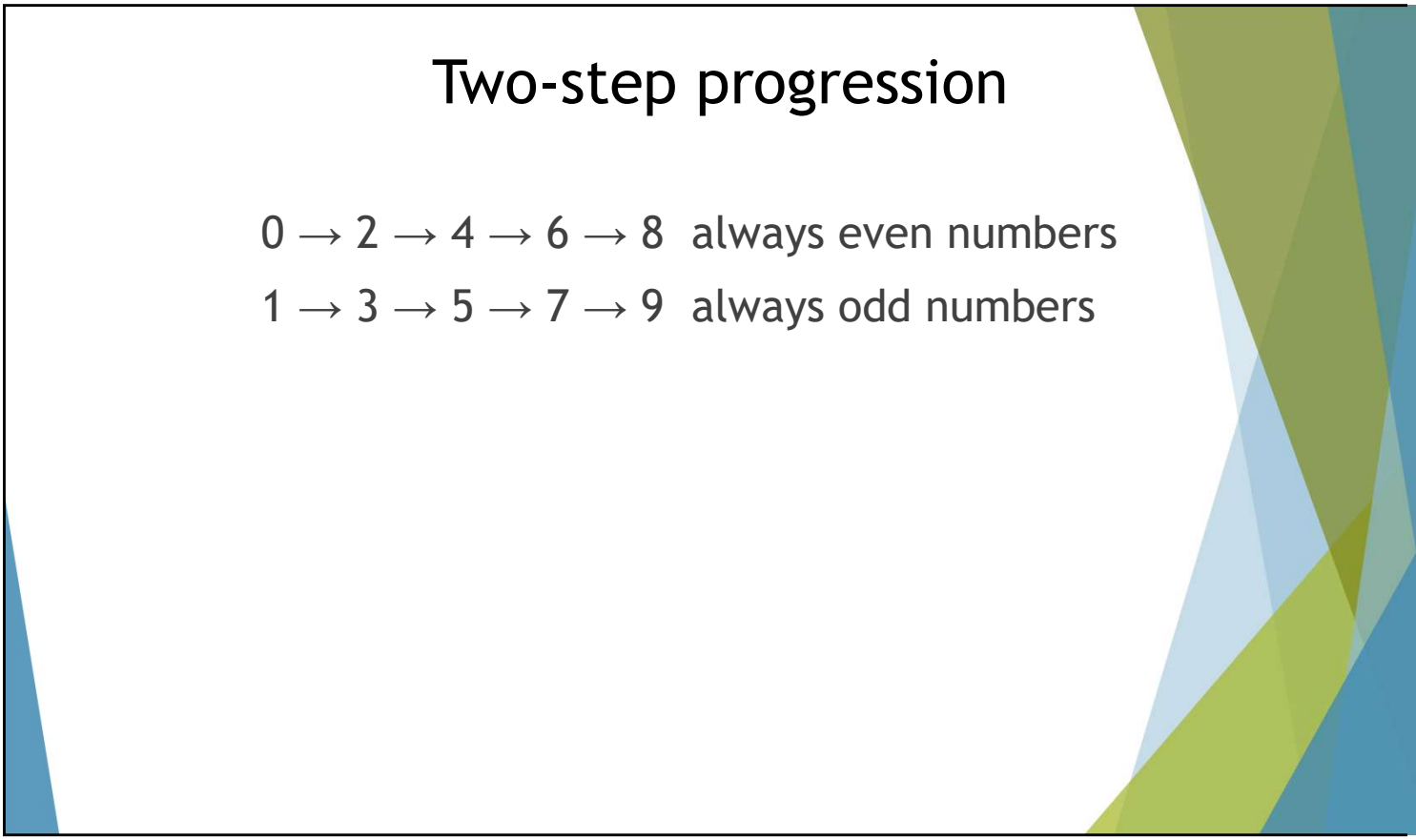
For example, if the master key is a Schlage 45723, the change key 45741 is allowed but 45744 isn't because the 4 in the 5th position differs from the master by just one depth, requiring a #1 master pin which is only .015 inches. Make the bitting 45745 instead and that would be acceptable.

MK Rule #8

A) Extremely short master pins are unreliable. Don't use master pins shorter than .023 inches.

B) Similar keys can cause key interchange. Make sure each key is different from the others by at least .023 inches in at least one position.

With six-depth locks, you're allowed to have change keys that differ from each other by just one depth (or any number of depths) because the increment is .023 or more. But with ten-depth locks, we want to avoid situations where one change key differs from another by just one depth. It's okay for them to be identical to each other in some places and it's okay for them to differ from each other by two depths or more. Example: Master key 358314 (Yale). Change keys are 351014, 352014, 355014. Ignore the master key; just focus on the change keys. They are all the same in the 1st and 2nd positions. In the 3rd position, the cuts are 1, 2, and 5. The 1 cut and the 2 cut are too close together. We can fix this by changing the 2 cut to a 3. Now we have change keys 351014, 353014, 355014. That fixed it.



Two-step progression is standard procedure for locks which use ten depths (like Schlage). For any two keys, and in any position, either the cuts will be the same or they will differ by a multiple of 2. This applies to both change keys and master keys. The result is this: if the master key has an odd number in a certain position, all the keys will have odd numbers in that position. If the master key has an even number, all the keys will have even numbers in that position. Odds go with odds and evens go with evens. For example: The master key is 594166 (Schlage). The cuts are odd-odd-even-odd-even-even (which we could abbreviate OOEOEE). Every change key should follow the same pattern of odds and evens. For example, the change key 596302 follows two-step progression, but 596844 doesn't because it has an even number in the 4th position, where all the other keys have an odd number. For locks which use six depths, you don't need to use two-step progression; you can use **single step progression**.

Two-step progression

0 → 2 → 4 → 6 → 8 always even numbers

1 → 3 → 5 → 7 → 9 always odd numbers

594166 ← master

596302

596844

The last change key is incorrect. It doesn't follow the pattern of odds and evens. The 8 in the fourth position needs to be an odd number.

Two-step progression

0 → 2 → 4 → 6 → 8 always even numbers

1 → 3 → 5 → 7 → 9 always odd numbers

594166 ← master

596302

596744

After changing the 8 to a 7, both change keys are following two-step progression.

MK Rule #8

A) Extremely short master pins are unreliable. Don't use master pins shorter than .023 inches.

B) Similar keys can cause key interchange. Make sure each key is different from the others by at least .023 inches in at least one position.

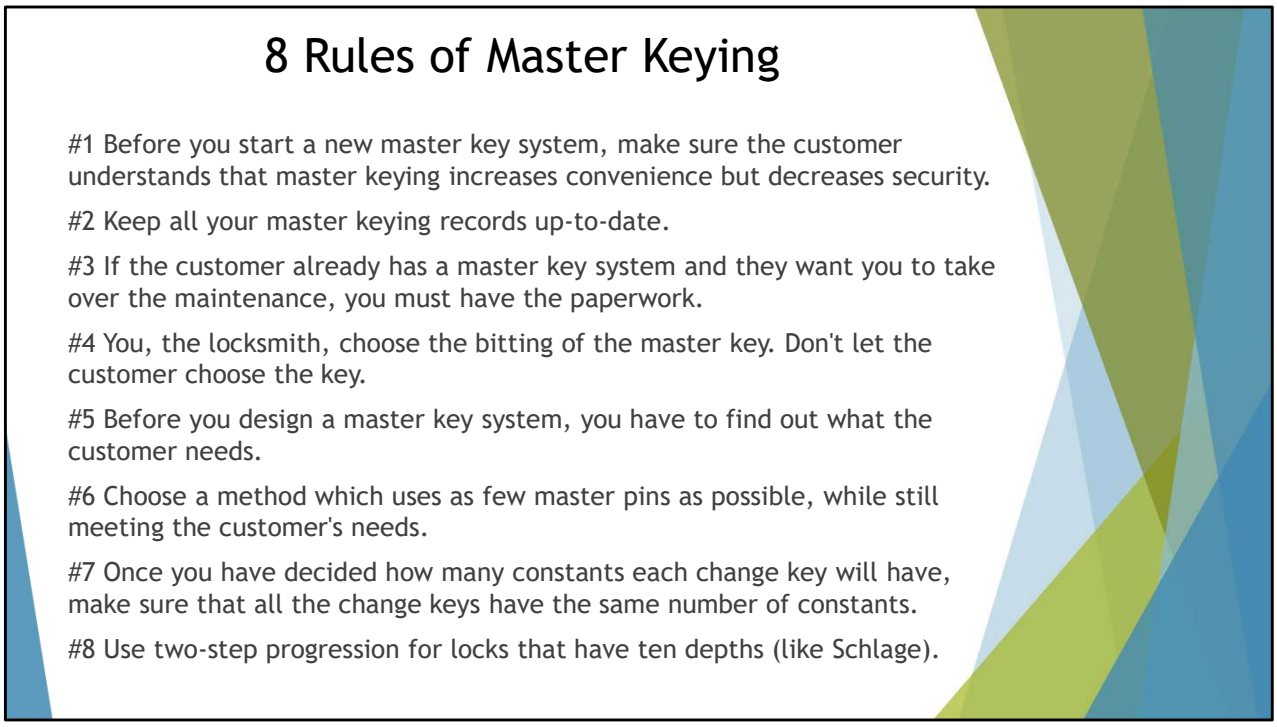
Use two-step progression for locks that have ten depths (like Schlage).

Two-step progression automatically enforces Rules 8A and 8B. We don't bother examining each key individually to make sure. We just use two-step progression for ten depth locks and the keys will take care of themselves. Likewise, we don't bother examining each key individually to make sure they follow rule #6 and rule #7. If the KBA was written properly and progressed properly, you don't have to check the progression list for constants or odds and evens, (but you do have to check for MACS violations and undesirable keys). After that, you add key symbols for the bittings of the keys you actually cut. Once the key symbols are added, it's called a bitting list.

Some common locks

	depths	MACS
Best SFIC (A2)	0-9	9
Best SFIC (A4)	0-5	5
Corbin-Russwin (system 70)	1-6	4
Kwikset	1-6*	4
Medeco	1-6	varies 2-4
Sargent	1-10†	7
Schlage	0-9	7
Yale	0-9	6

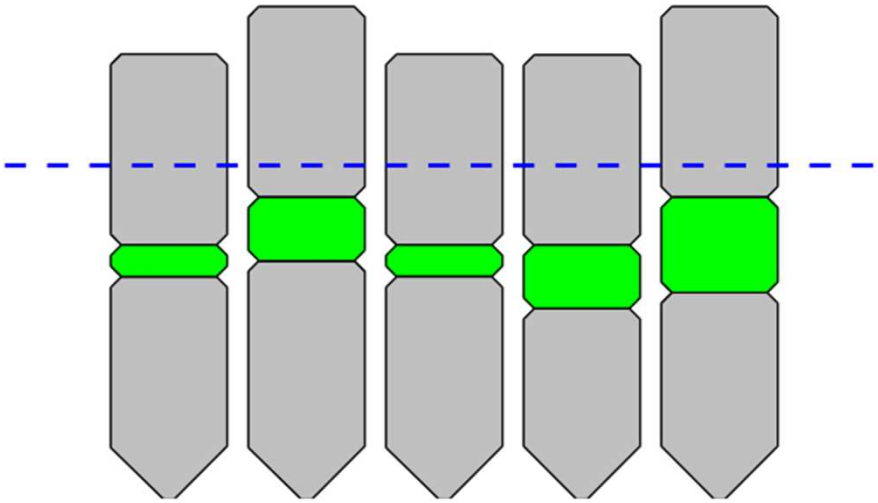
Here are some common locks that we'll talk about in master keying. Notice that they fall into two categories. The ones in yellow have ten depths (usually zero to nine). The ones in blue have six depths (usually one to six). This makes a difference in master keying, as we'll see later on, when we get to rule number eight.



That's all eight rules of master keying.

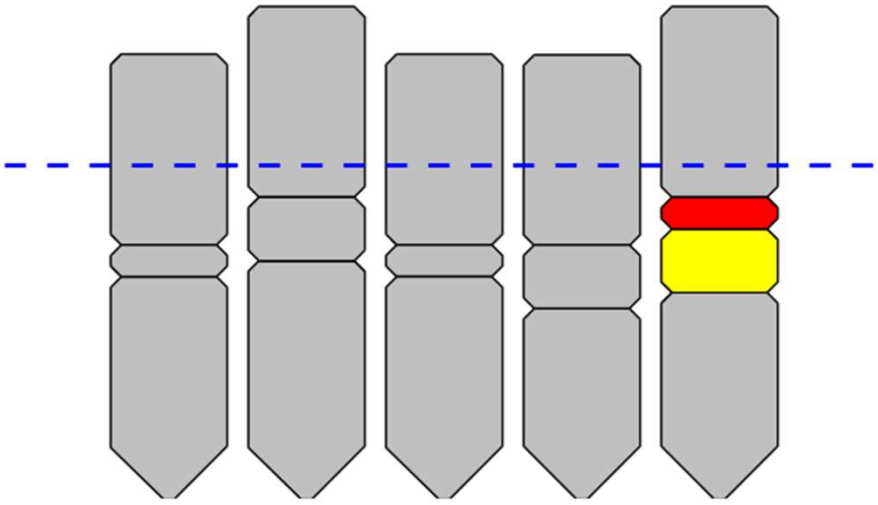
There are circumstances where it may be safe to break each of these rules. But this is where we start. If you follow these rules, they will help keep you safe. If you break the rules, proceed with caution.

Master pins in 5 chambers



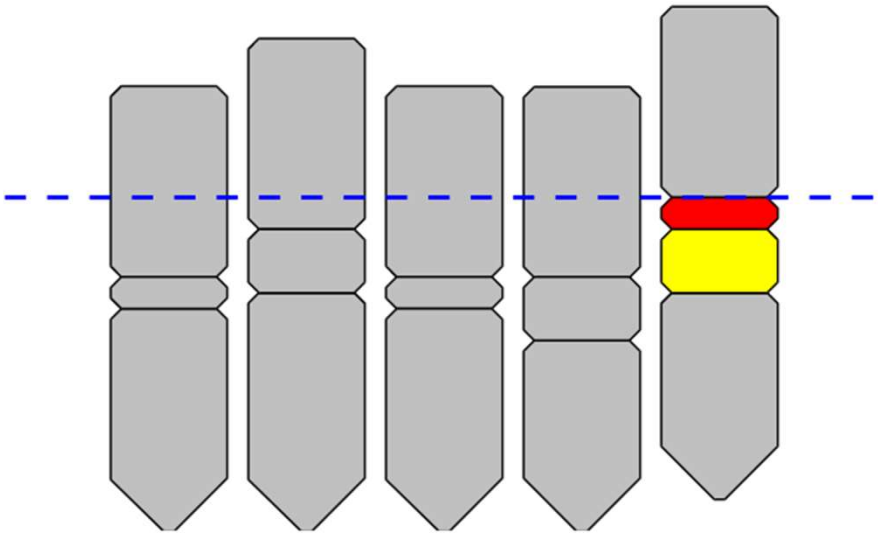
With master pins in all five chambers, there are 32 keys that can operate this lock. 2x2x2x2x2=32.

2 Master pins in 1 chamber



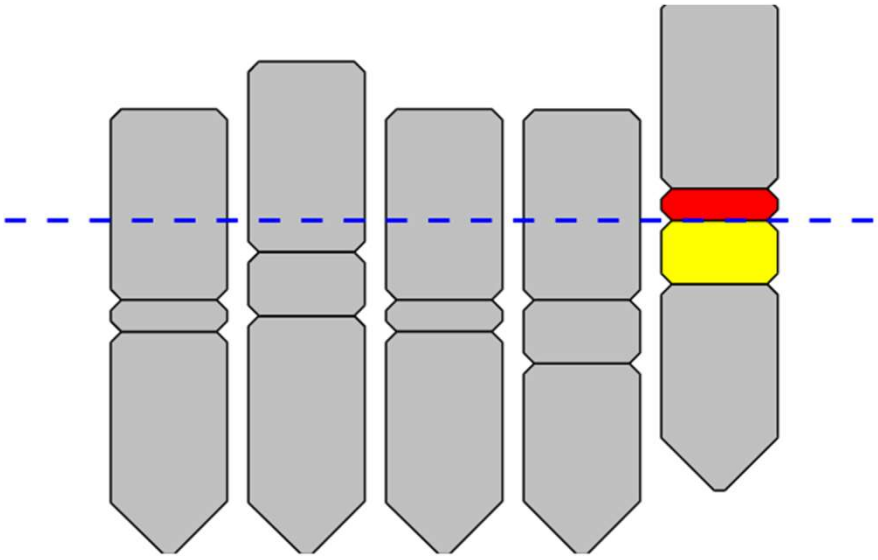
This lock can be operated by 2x2x2x2x3=48 keys.

2 Master pins in 1 chamber



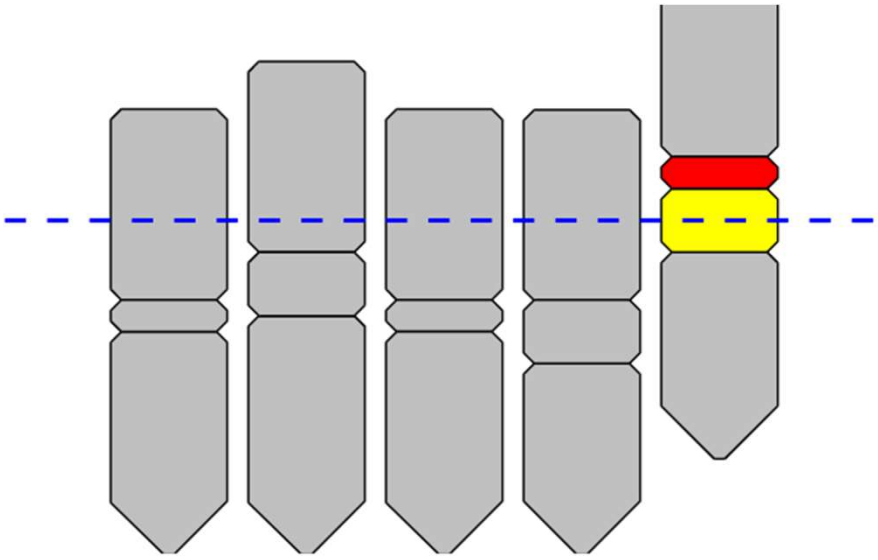
If the fifth cut is an 8, it could lift the pin stack like this and the plug could turn (if the other chambers also shear up).

2 Master pins in 1 chamber



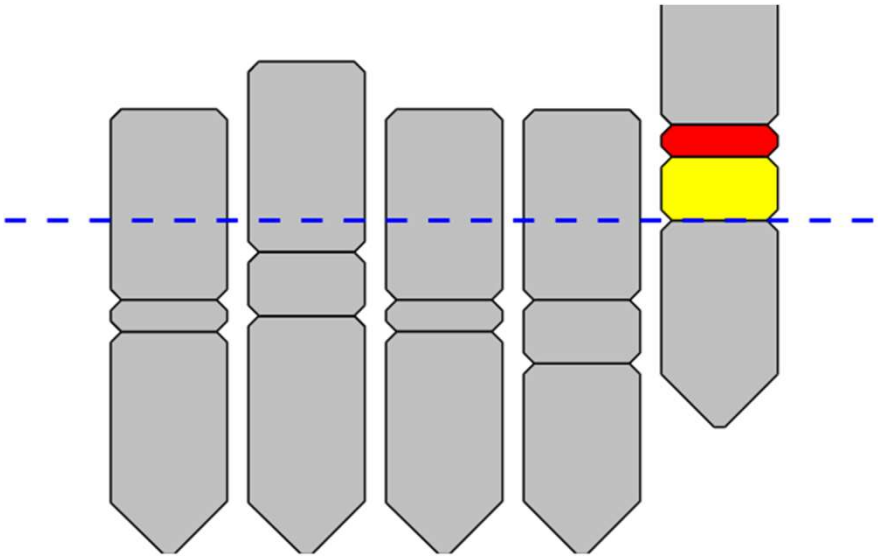
If the fifth cut is a 6, it could lift the pin stack like this and the plug could turn.

2 Master pins in 1 chamber

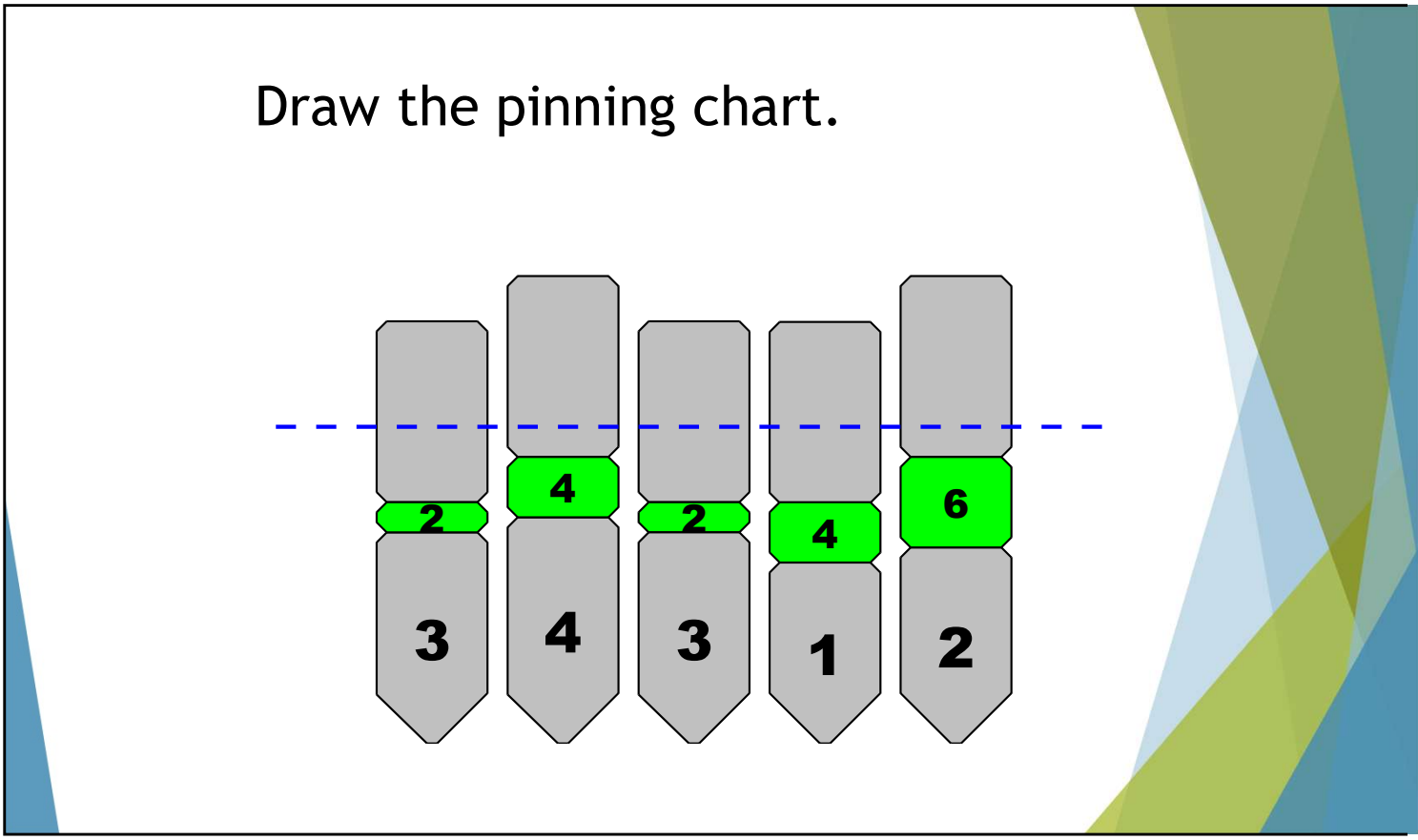


If the fifth cut is a 4, it could lift the pin stack like this and the plug would **NOT** turn.

2 Master pins in 1 chamber



If the fifth cut is a 2, it could lift the pin stack like this and the plug could turn.



There are 32 keys that can operate this lock. In each chamber, you can determine what the cut on the key has to be, by looking at the numbers and adding them together. The first cut must either be a 3 or 3+2=5. The second cut must either be a 4 or 4+4=8. The third cut must either be a 3 or 3+2=5. The fourth cut must either be a 1 or 1+4=5. The fifth cut must either be a 2 or 2+6=8.

There is no way that a #6 cut could work in the fifth chamber. The master pin can be above the shear line (in which case the cut on the key has to match the bottom pin) or the master pin can be below the shear line (in which case the cut on the key has to match the bottom pin plus the master pin) but the bottom pin can never be above the shear line. The master pin and bottom pin can't just change places with each other. There's no way the master pin can be below the shear line by itself.

This diagram is helpful but it takes too much time to draw. We only need the numbers themselves. That will be our "pinning chart". It tells us exactly what pins we need for the lock. The left side is the front of the lock. The pins are listed in order from bow to tip, with very few exceptions.

Draw the pinning chart.

1st key: 247835
2nd key: 463237

Answers in the following slides.

Draw the pinning chart.

1st key: 247835
2nd key: 463237

2
2

The shallowest cut in the first chamber is a 2. That's our bottom pin.
The distance from 2 to the next cut (4) is 2. That's our master pin.

Draw the pinning chart.

1st key: 247835
2nd key: 463237

22
24

The shallowest cut in the second chamber is 4. That's the bottom pin. The distance from 4 to 6 is 2. That's the master pin.

Draw the pinning chart.

1st key: 247835
2nd key: 463237

224
243

Shallowest cut is 3. Distance from 3 to 7 is 4.

Draw the pinning chart.

1st key: 247835
2nd key: 463237

2246
2432

Shallowest cut is 2. Distance from 2 to 8 is 6.

Draw the pinning chart.

1st key: 247835
2nd key: 463237

2246-
24323

Since 3=3, we don't need a master pin at all.

Draw the pinning chart.

1st key: 247835
2nd key: 463237

2246-2
243235

Shallowest cut is 5. Distance from 5 to 7 is 2

Notice that all the master pins are even numbers. This is a natural consequence of two-step progression..

Draw the pinning chart.

1st key: 384212
2nd key: 544058

Draw the pinning chart.

1st key: 384212
2nd key: 544058

24-246
344012

The top row is the top pins and the bottom row is the bottom pins. Some people like to do it the other way around. Once again, notice that all the master pins are even numbers.

Draw the pinning chart.

1st key: 384212
2nd key: 544058
3rd key: 344654

In each chamber, find the shallowest cut. That's the bottom pin. Then find the distance from that number to the next shallowest. That's the master pin. If you're not done, find the distance from there to the next shallowest. That's the next master pin.

Draw the pinning chart.

1st key: 384212
2nd key: 544058
3rd key: 344654

```
---4-4
24-242
344012
```

Incidental Master Keys

master key: 333333
change key: 555555

222222
333333

64 keys operate this lock.

333333	333355	353535
555555	333535	353553
	333553	355335
	335335	355353
333335	335353	355533
333353	335533	533555
333533	353335	535355
335333	353353	535535
353333	353533	535553
533333	355333	553355
	533335	553535
	533353	553553
	533533	555335
555553	535333	555353
555535	553333	555533
555355	333555	335555
553555	335355	353555
535555	335535	355355
355555	335553	355535
	353355	355553

This is a rather silly example, just to illustrate a point. The master key is all threes, and the change key is all fives. In every chamber, a three cut will lift the bottom pin to the shear line, with the master pin above the shear line, and a five cut will lift the bottom pin plus the master pin, together, to the shear line. Any key which is a combination of threes and fives will operate this lock. There are 64 such keys, 2x2x2x2x2x2. Of course, 333333 will work; that's the master key. Of course, 555555 will work, that's the change key. Any key that has some combination of 3s and 5s will work.

ANSI/BHMA A156.28 subsection 5.3

5.3 Progression Master keying progression varies widely when different cylinder mechanisms are used. The method of master keying progression should be selected to create the minimum number of incidental master keys, while still reaching the desired system expansion. Correct progression results in no duplication of key combinations and no key interchange. Random key bittings must never be used in a key system. In a conventional pin tumbler cylinder this is accomplished by using the fewest possible master pins per cylinder.

This illustrates why too many incidental master keys is a bad thing. Each additional key is an opportunity for an outside key to operate the lock, or an opportunity for the lock to be picked.

Which is not an incidental key?

Master key: 384212
change key: 544058

24-246
344012

a) 584258 b) 548258 c) 384012 d) 384042

With that in mind, look at this pinning chart and tell me which of the following is not an incidental key.

Which is not an incidental key?

Master key: 384212
change key: 544058

24-246
344012

a) 584258 b) 548258 c) 384012 d) 384042

The answer is d). The fifth cut needs to be either 1 or 5, not 4.

Finding an incidental master key

Master key A:	384212
change key AA1:	546812
change key AA2:	766812
change key AB1:	568412
change key AB2:	748412

But, there's some good news. We can take advantage of this to create master keys. Suppose we want a three level system with change keys AA1 and AA2 under a master AA, and AB1, AB2 under a master AB, with grand master key A.

Finding an incidental master key

Master key A:	384212
change key AA1:	546812
change key AA2:	766812
change key AB1:	568412
change key AB2:	748412

AA1 and AA2 xx6812

Look for the places where AA1 and AA2 are the same.

Finding an incidental master key

Master key A:	384212
change key AA1:	546812
change key AA2:	766812
change key AB1:	568412
change key AB2:	748412

AA1 and AA2	xx6812
master key A	38xxxx

Where they are different, steal the value from the TMK.

Finding an incidental master key

Master key A: 384212
change key AA1: 546812
change key AA2: 766812
change key AB1: 568412
change key AB2: 748412

AA1 and AA2 xx6812
master key A 38xxxx

Incidental master 386812 will be AA.

We can use this incidental master key as our AA key and we won't need any additional master pins to do it.

We can do the same for AB.

Finding an incidental master key

Master key A: 384212
change key AA1: 546812
change key AA2: 766812
change key AB1: 568412
change key AB2: 748412

AA1 and AA2 xx6812
master key A 38xxxx

Incidental master 386812 will be AA.

Incidental master 388412 will be AB.

Next Topic

Key Schematics and Keying Schedules

Master Keying Schematics and Keying Schedules, described in ANSI A156.28, are the foundation of good record keeping and communication in master keying. Learn how to draw schematics using a computer or with paper and pen, and how to use keying schedules to create records and submittal documents.

Homework Assignment

(You should receive a copy of this by email.)

Visit https://locksmath.github.io/aloa_main.html .

Click on settings .

Enter a display name, so we can recognize you.

Go back to the main page.

Click on Lesson 1.

Take the quiz. Repeat, if necessary.

Once you get a passing score (70% or more), click “submit” to send your score to us.

Click on Show Homework part 2 .

Write your answers and email them to aloamkhomework@protonmail.com.