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A Modeling Approach To Address the Underlying Structure and Constraints of Thermal Mark Codes and Code Notation.

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ABSTRACT

The discussion presented here was prompted by a request of the NPAFC for establishing a code system for thermal marks which incorporates the country of origin. While on the surface the request appears quite simple and straightforward, accommodate that request is not nearly so straightforward, and in fact it may not be possible given how thermal marking is applied and currently being used in the United States. This point can be demonstrated in a number of different ways. The approach I will use here is to discuss thermal marking from the perspective of coding system, and the constraints that are in place which limit the total number of possible codes that are available. I do this by considering the two coding systems that are currently being used: the barcode approach presented by Volk et al. (1994), and the RBr code scheme described by Munk and Geiger (1998). I rely heavily on the information presented in those papers for this discussion.

In the first section, I provide a brief discussion about the constraints of marking that are common to both methods. These constraints include: the limited period that marks can be applied based on the particular constraints of each hatchery, the 'rules' that are built into both the RBr and barcode schemes which constrain the marks to have a particular appearance so they can be identified, and the use of thermal marking to meet local needs which has the highest priority and limits the amount of available marks for other uses. In the second section I develop a model approach for describing thermal mark patterns in terms of ring number and relative ring spacing. Patterns under RBr notation and barcodes can be described as subsets of this approach. A spreadsheet model is used to generate patterns under RBr guidelines to illustrate the relatively few base patterns that are available when ring number is limited. In addition, I present a formula that can be applied to the barcode approach for determining the number of patterns available for any fixed number of rings. In the final section I address the question of common terminology and suggest slight modifications to the RBr notation, and note how the barcode patterns can be described in a similar manner.

This discussion does not present information on how to produce good thermal marks, and it does not provide guidelines for choosing a particular code. Instead, its intent is to addresses the question of mark limitation and code structure, with some suggestions on nomenclature.

Mark Symbology and Marking Constraints

In their recent NPAFC document, Munk and Geiger (1998) introduce the "RBr" code symbology and discuss its rationalization for its development and application. "RBr" stands for Region: Band. ring. "Region" is the location on the otolith were the mark first appears – either prehatch or posthatch, "Band" is an index number that refers to the group of rings that appear close together with equal spacing, and "ring" is the number of thermal rings that appear in the band. Unique codes are created by grouping thermal rings into bands, and using band and ring numbers along with symbols that indicate relative spacing between them to describe thermal patterns. The paper should referenced for details on how this code system is constructed.

In addition to describing the RBr system, the Munk and Geiger paper details what type of patterns under this symbology produce suitable marks. In the summary section of the paper, cautionary statements are made regarding limitations on the overall number of discrete codes which could be produced. Though an upper limit on the number of possible codes is not provided, reference is made to the 37 discrete patterns applied to the 1998 releases.

The barcode symbology for inducing thermal marks was presented by Volk et al. (1994). The codes are based on six-ring thermal patterns in which two of the spaces between adjacent rings are wide and three are narrow. The order of the wide and narrow spacings produce unique patterns. Similar to the Munk and Geiger paper, the authors discuss the rationalization for use of the barcode symbology and provide cautionary statements regarding its application. The Volk et al. (1994) paper goes on to suggest that 1000 distinct codes are theoretically possible by imposing three six-ring barcode patterns on the otolith. But in practice that high number of codes have not been produced. Instead it appears that the number of discrete marks used in Washington each year, are similar to those that are used in Alaska. An example of those patterns are presented in (Volk and Hagen 1998).

While the RBr and barcode symbology may appear to be different, they are based on the same underlying concept where the codes are defined by the number of thermal rings and the relative spacing between rings. As a result there are common factors in both approaches which limit how many distinct codes are available to use.

The most important constraint is that imposed by the limitations of the hatcheries which are inducing the marks. Without going into much detail, a critical concept in understanding hatchery limitations is that of the 'marking window'. The marking window refers to the time during rearing that clear thermal patterns can be produced on the otoliths of a release group of salmon. Since hatching disrupts thermal marks, there are generally two windows available for marking, though they are not necessarily available for each hatchery facility. A pre-hatch window is constrained by the period of otolith fusion (near the eyed-egg stage) and when the first eggs begin to hatch. The post-hatch window takes place sometime after all the eggs have hatched and up to the point at which temperature manipulation fails to induce clear and easy to read thermal patterns. The post-hatch window is not well defined on its upper end but is generally constrained by other hatchery concerns and expenses that limit the ability to manipulate temperatures during late alevin or fry stages. Post-emergent marking generally does not produce good thermal patterns.

Each release group in a hatchery has its own marking window based on ambient water temperature, the capabilities of the thermal mark system for heating or chilling, the holding facilities for the eggs and fry, and the range of developmental stages which are held together and marked as one group. In practice there are few facilities in Alaska that have been able to accommodate more than 10 rings for a thermal pattern. In addition most hatcheries in Alaska must expend fuel for heating and/or chilling the water to create thermal marks and there is a natural inclination by the hatcheries to keep costs low and use as few as rings as is practical.

A second constraints in available patterns is imposed by the requirement that a thermal pattern be easy to distinguished from natural patterns found in wild stocks and from other thermal patterns likely to be encountered in mixed stock fisheries. A key component in these constraints is the method by which the patterns are recognized, and the need to incorporate 'rules' on what patterns to expect. The 'RBr' symbology of Munk and Geiger (1998) is explicitly built upon the assumption that human vision is the primary means for identifying thermally marked otoliths and that background patterns found in both wild and hatchery otoliths can mimic some thermal patterns. The document provides rules which define what are acceptable patterns which will create a strong visual impact and avoid conflicting or ambiguous marks. In contrast, the barcode symbology of Volk et al. (1994) is based on a code structure used in machine vision. The 'rules' embedded in that code are based on error checking protocols that are built into barcode scanning systems. The primary protocols as they apply to thermal marking is that same number of rings is used for each pattern, and each pattern contains the same number of narrow and wide spaces, but in different order. In that manner each pattern covers a similar amount of area on the otolith, though in practice that may not always be the case. Volk et al. (1994) discusses the differences between thermal marks and barcodes and the difficulties in applying machine vision to automate the detection of thermal rings. As far as I'm aware the method of barcode scanning has not successfully been applied to thermal mark detection. The recent NPAFC document by Hickenbotham et al. (1998), presents a texture analysis approach using machine vision which is more directly analogous to the human vision approach embedded in the RBr code. However the texture analysis method is still exploratory and at least in the near future as long as otoliths are handled manually to expose the otolith center, human vision will be the primary method for identifying thermal marked fish.

A final constraint on the assignment of thermal patterns is based on the 'expectations' of encountering those marks during sampling. In Washington thermal marking has been used extensively for in-river studies of fry and returning adults. While in Alaska, considerable sampling takes place in commercial fisheries in near-shore areas and the information from that sampling is used in the management of those fisheries. In both applications, the recovery of the marks is based on the assumption that in the vast majority of cases only the marked fish which are expected to come back to those areas are likely to be encountered. Thermal patterns in fish from distant areas are not likely to seen.

Under this constraint an important concept to note is that of 'base marks', which applies more directly to the assignment of marks in Alaska. A base mark is a thermal pattern that is clear and can be readily identified. In contrast, an accessory mark is more difficult to detect and is used to separate marked groups which may have a common base pattern. The concept of base marks and accessory marks has been incorporated into the RBr code structure where a '+' symbol is used to identify its presence. If the basemark is prehatch, the accessory mark is placed posthatch or separated by at least five ring spacings. Details are given in the Munk and Geiger (1998) paper. Accessory codes are not part of the barcode symbology, however its use may not be incompatible with the design. In Volk and Hagen (1998), reference is made to pre-hatch 'toggle codes' which are used pre-hatch, while the barcodes which require a larger marking window are placed posthatch. In these applications, the toggle codes could serve as the base mark, with the barcode as the accessory mark.

In Alaska, different base marks are assigned to hatchery releases in areas in which there is a high expectation of encountering those marks during management of the mixed stock fisheries. In assigning thermal marks, near-shore management concerns are given the highest priority since it is critical to have clear and distinctive base marks to rapidly distinguish between release groups. As a result of this prioritizing, it is not uncommon to have groups released with the same base mark if the management areas are separated by wide geographic distances. It is only recently with the advent of projects focused on high seas sampling, that fish with the same base marks are now being recovered together.

While it would be desirable to have unique base marks for all release groups in Alaska, limitations on the marking window and the requirement that the marks be clear and easy to recover in areas of highest priority has resulted in cases where there are duplicate base marks. This is likely to unavoidable at times and is an indication that there are practical limits on the number of thermal mark patterns available for use.

Modeling approach to describe Thermal Mark codes

There are various ways to approach thermal marks from a modeling perspective. The approach I use here is one based strictly on code structure. It was done for the purpose of helping to determine the number of discrete thermal patterns available for use under the RBr guidelines for marking presented by Munk and Geiger (1998). The model can also be used to illustrate the underlying similarity between the barcode and RBr approaches.

I constructed this model based on the observation that in both the RBr and barcode systems, it is ring number and relative ring spacing which define the patterns. The codes available for use in each system are just subsets of all possible patterns based on a set of rules. For this model, I used three categories of relative ring spacing based on the RBr system. More categories than this can be accommodated, though with base mark codes it appears that only three are commonly used. In the barcode system only two spacings are used as part of that protocol. It should be noted that with a set number of thermal rings n, there are $n - 1$ spaces between those rings. The total number of thermal patterns possible using the three types of spacing is $N = 3^{(n-1)}$. For example, given a six ring code and three space classifications an upper limit on the total number of patterns possible would be $3^5 = 243$.

As discussed in Munk and Geiger (1998) most of those patterns generated this way would be difficult to identify so rules are used to determining how the rings should be grouped together into bands for making a strong visual impact. I incorporated these rules into a set of 8 functions and encoded it into visual basic code as a means to filter out unacceptable patterns. Table 1 shows a print out of this model with the 8 filters applied to patterns containing up to 9 rings. In the table I used a code system for the ring spacings to generate the patterns. Normal ring spacing, which serves as the reference for measuring other spaces is given the numeric code 2. Narrow ring spacing, which is used only in the RBr system for spacing within bands that also have normal spacing, is assigned the numeric code 1. And the space that is used to separate bands of rings is given the code 3. For a six-ring pattern, only 3 distinct codes are possible following the RBr guidelines. However since the model does not distinguish between the 'Region' on the otolith where the mark is located (the "R" in the RBr code) the number of codes could be doubled that presented in Table 1. In addition the model does not include additional band width categories which is discussed in Munk and Geiger (1998). However the table does illustrate in general, how the incorporation of 'rules' to produce thermal patterns greatly limits the number of patterns that would be available without such restrictions. For contrast, table 2 shows the printout of the model with a relaxation of two of the filter rules. This slightly increases the number of patterns though at the expense of some patterns not being as easy to recover.

Table 1. Graphic representation of thermal mark codes based on Munk and Geiger (1998) criteria for designing acceptable base mark patterns. The patterns are generated from three discrete ring spacings. 1= narrow, 2= normal, 3= band interval. The space combination which generates the grahics are shown. Rules coded into Visual Basic are used as filter to remove 'unacceptable' patterns from all possible combinations (e.g 3^n where n = no. spaces). The number of codes could be doubled when distinquishing between otolith 'Regions' (prehatch verses posthatch patterns). In addition, using additional discrete band interval would also increase number of codes.

	4 rings	5 Rings	6 Rings	7 Rings	8 Rings	9 Rings
1	222 IIII	2222 IIIII	22222 IIIIII	222222 IIIIIII	2222222 IIIIIIII	22222222 IIIIIIIII
2			22311 III III	222311 IIII III	2222311 IIIII III	22222311 IIIIII III
3			22322 III III	222322 IIII III	2222322 IIIII III	22222322 IIIIII III
4				223111 III IIII	2223111 IIII IIII	22223111 IIIII IIII
5				223222 III IIII	2223222 IIII IIII	22223222 IIIII IIII
6					2231111 III IIIII	22231111 IIII IIIII
7					2231311 III II III	22231311 IIII II III
8					2231322 III II III	22231322 IIII II III
9					2232222 III IIIII	22232222 IIII IIIII
10					2232311 III II III	22232311 IIII II III
11					2232322 III II III	22232322 IIII II III
12						22311111 III IIIIII
13						22311311 III III III
14						22311322 III III III
15						22313111 III II IIII
16						22313222 III II IIII
17						22322222 III IIIIII
18						22322311 III III III
19						22322322 III III III
20						22323111 III II IIII
21						22323222 III II IIII
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						
35						
36						

Number of codes using RBr 'rule set'	
4 rings	1
5 rings	1
6 rings	3
7 rings	5
8 rings	11
9 rings	21
Total	42

Number of codes without 'rules'	
4 rings	27
5 rings	81
6 rings	243
7 rings	729
8 rings	2187
9 rings	6561
Total	9828

Filter Rules

- ☑ 1. No single ring band in middle
- ☑ 2. No single ring band at start
- ☑ 3. No single ring band at end
- ☑ 4. No two ring band at start
- ☑ 5. No two ring band at end
- ☑ 6. No codes that start w/ space 1 bands
- ☑ 7. No space 1 & 2 adjacent w/in bands
- ☑ 8. No codes with just space 1 bands

Clear codes

Run Filter!

Table 2. Graphic representation of thermal mark codes based on Munk and Geiger (1998) criteria for designing acceptable base mark patterns. The patterns are generated from three discrete ring spacings. 1= narrow, 2= normal, 3= band interval. The space combination which generates the grahics are shown. Rules coded into Visual Basic are used as filter to remove 'unacceptable' patterns from all possible combinations (e.g 3^n where n = no. spaces). The number of codes could be doubled when distinguishing between otolith 'Regions' (prehatch verses posthatch patterns). In addition, using additional discrete band interval would also increase number of codes.

	4 rings	5 Rings	6 Rings	7 Rings	8 Rings	9 Rings
1	222 ||||	2222 |||||	22222 ||||||	222222 |||||||	2222222 ||||||||	22222222 |||||||||
2	231 || ||	2231 ||| ||	22231 |||| ||	222231 ||||| ||	2222231 |||||| ||	22222231 ||||||| ||
3	232 || ||	2232 ||| ||	22232 |||| ||	222232 ||||| ||	2222232 |||||| ||	22222232 ||||||| ||
4		2311 || |||	22311 ||| |||	222311 |||| |||	2222311 ||||| |||	22222311 |||||| |||
5		2322 || |||	22322 ||| |||	222322 |||| |||	2222322 ||||| |||	22222322 |||||| |||
6			23111 || ||||	223111 ||| ||||	2223111 |||| ||||	22223111 ||||| ||||
7			23131 || || ||	223131 ||| || ||	2223131 |||| || ||	22223131 ||||| || ||
8			23132 || || ||	223132 ||| || ||	2223132 |||| || ||	22223132 ||||| || ||
9			23222 || ||||	223222 ||| ||||	2223222 |||| ||||	22223222 ||||| ||||
10			23231 || || ||	223231 ||| || ||	2223231 |||| || ||	22223231 ||||| || ||
11			23232 || || ||	223232 ||| || ||	2223232 |||| || ||	22223232 ||||| || ||
12				231111 || |||||	2231111 ||| |||||	22231111 |||| |||||
13				231131 || ||| ||	2231131 ||| ||| ||	22231131 |||| ||| ||
14				231132 || ||| ||	2231132 ||| ||| ||	22231132 |||| ||| ||
15				231311 || || |||	2231311 ||| || |||	22231311 |||| || |||
16				231322 || || |||	2231322 ||| || |||	22231322 |||| || |||
17				232222 || |||||	2232222 ||| |||||	22232222 |||| |||||
18				232231 || ||| ||	2232231 ||| ||| ||	22232231 |||| ||| ||
19				232232 || ||| ||	2232232 ||| ||| ||	22232232 |||| ||| ||
20				232311 || || |||	2232311 ||| || |||	22232311 |||| || |||
21				232322 || || |||	2232322 ||| || |||	22232322 |||| || |||
22					2311111 || ||||||	22311111 ||| ||||||
23					2311131 || |||| ||	22311131 ||| |||| ||
24					2311132 || |||| ||	22311132 ||| |||| ||
25					2311311 || ||| |||	22311311 ||| ||| |||
26					2311322 || ||| |||	22311322 ||| ||| |||
27					2313111 || || ||||	22313111 ||| || ||||
28					2313131 || || || ||	22313131 ||| || || ||
29					2313132 || || || ||	22313132 ||| || || ||
30					2313222 || || ||||	22313222 ||| || ||||
31					2313231 || || || ||	22313231 ||| || || ||
32					2313232 || || || ||	22313232 ||| || || ||
33					2322222 || ||||||	22322222 ||| ||||||
34					2322231 || |||| ||	22322231 ||| |||| ||
35					2322232 || |||| ||	22322232 ||| |||| ||
36					2322311 || ||| |||	22322311 ||| ||| |||

Number of codes using RBr 'rule set'	
4 rings	3
5 rings	5
6 rings	11
7 rings	21
8 rings	43
9 rings	85
Total	168

Number of codes without 'rules'	
4 rings	27
5 rings	81
6 rings	243
7 rings	729
8 rings	2187
9 rings	6561
Total	9828

Filter Rules

- [x] 1. No single ring band in middle
- [x] 2. No single ring band at start
- [x] 3. No single ring band at end
- [ ] 4. No two ring band at start
- [ ] 5. No two ring band at end
- [x] 6. No codes that start w/ space 1 bands
- [x] 7. No space 1 & 2 adjacent w/in bands
- [x] 8. No codes with just space 1 bands

Clear codes   Run Filter!

For the barcode systems, a different set of rules are used to generate those patterns. The number of these patterns can be determine directly by the use of the combination function which is commonly used in probability calculations. In these cases, the number of codes available for use can be determined by taking the number of spaces, *s*, available and calculating the ways that a set number of wide spaces, *k*, can be arranged in the code without regard to order, using the formula;

$$N = \binom{s}{k} = \frac{s!}{k!(s-k)!}$$

For example, the number of codes available from the 2 in 5 barcode symbology based on a six ring pattern as discussed in Volk et al. (1994) would be determined by the expression

$$\binom{5}{2} = \frac{5!}{2!(5-2)!} = \frac{5\times4\times3\times2\times1}{2\times1\times(3\times2\times1)} = 10$$

Similarly, other barcode type patterns could be generated if the marking windows allowed a greater or fewer number of rings.

Developing a Common Mark symbology

Both the RBr symbology and the barcode scheme are based on the number of rings and relative spacing between rings to define code structure. As mentioned above, the barcode approach is based on a fixed ring number with a binary pattern composed of narrow and wide spacing, where the order of the wide and narrow spacing defines the code. As discussed in Volk et al. (1994), the wide spacing should be at least 2 and preferable 3 times the distance of the narrow spaces. Its representation as binary code consisting of a series of 0's and 1's. For instance if 1 is narrow and 0 is wide, a typical code and its visual representation would be 11010 = ||| || |.

As shown in the construction of table 1, the RBr scheme is also based on an underlying symbology of ring spacing. Using the notation in Table 1, a code can be represented by a sequence of 1,2, and 3. The RBr notation presented by Munk and Geiger (1998), however makes only partial use of ring spacing in the code structure. The ring numbers are grouped together into bands with implicit understanding that the bands contain rings of equal spacing. Extra notation is used to describe the relative spacing between the bands and when there are multiple bands with more than one type of spacing. As recommended in the paper, band spacing should be at least 2 to 2.5 times the common ring spacing.

The barcode pattern while based on an underlying pattern of spaces can also be described in terms of the RBr notation, in this case wide spacing would represent

the separation of a bands of rings. For example if the mark occurs prehatch, the numeric representation of the spacing (using the definitions in Table 1), with the equivalent visual representation and Rbr code would be:
22323 = ||| || | = 1:1.3,2.2,3.1

In the case of the RBr code, the position of the band number could be dropped without loss of information, thus reducing the code to 1:3,2,1.

Table 3 shows the equivalent notation of ring spacing, visual representation and RBr code applied to common base patterns which for purposes of simplification are presumed to be prehatch patterns. In Table 3, the RBr code is slightly modified from that presented by Munk and Geiger (1998). In this case the letter 'n' following a band.ring number is used to indicate that it is a narrow spaced band. In the Munk and Geiger (1998) document, narrow ring bands are represented by an underline. Unfortunately underlines are generally not amenable to most email communication and database protocol. In addition, Table 2 also shows a shortened version of the RBr code, illustrated with the barcode examples. The modification here is to drop the Band number in the code, since that can be inferred directly by position.

Because detecting thermal patterns will continue to rely on human judgement and visual methods. It is important that how the thermal marks are reported is dealt with in a straightforward manner. While variation in ring spacing is the underlying basis of the thermal codes, we generally think of thermal marks in terms of the number rings and not the number of spaces. For that reason using graphical representation along with the RBr symbology with appropriate modifications for electronic communication should be used. The primary modification from that presented in Munk and Geiger (1998) is to replace the underline symbol denoting narrow rings with the letter 'n'. In cases where more rapid and communication is needed or where there is space limitations due to the length of the code, dropping the Band position from the RBr code can be done without loss of information. However when discussing particular characteristics of a pattern, reference to band.ring position becomes a useful means of identifying location on the thermal mark. The RBr approach also appears to accommodate patterns based on the barcode symbology. However it is possible that additional modifications will be needed. These modifications should be discussed and the nature of the modification considered in terms of the underlying code structure.

It is very important to mention that the particular symbology used to describe thermal mark codes is not nearly as important as seeing the mark itself. In order of preference, the best way to exchange information on thermal patterns is to examine example otoliths from reference collections. This would be followed by digital images of example patterns, then graphic representation of the pattern using hash marks, with the RBr code to provide shorthand notation of the mark pattern.

Table 3. Representation of common thermal mark patterns, showing relative ring spacing (1= narrow, 2= normal, 3= band width) with graphic representation, and RBr code. Patterns are assumed to be prehatch (R=1). The letter 'n' following a Band.ring indicates narrow spacing between rings. Barcodes are based on six-ring patterns. A short RBr code is used in which band number is inferred by position.

<table>
<tr><th colspan="3">4 Ring codes</th></tr>
<tr><th>Spacing</th><th>Graphic</th><th>RBr</th></tr>
<tr><td>222</td><td>||||</td><td>1:1.4</td></tr>
</table>

<table>
<tr><th colspan="3">5 Ring codes</th></tr>
<tr><th>Spacing</th><th>Graphic</th><th>RBr</th></tr>
<tr><td>2222</td><td>|||||</td><td>1:1.5</td></tr>
</table>

<table>
<tr><th colspan="3">6 Ring codes</th></tr>
<tr><th>Spacing</th><th>Graphic</th><th>RBr</th></tr>
<tr><td>22222</td><td>||||||</td><td>1:1.6</td></tr>
<tr><td>22311</td><td>||| |||</td><td>1:1.3,2.3n</td></tr>
<tr><td>22322</td><td>||| |||</td><td>1:1.3,2.3</td></tr>
</table>

<table>
<tr><th colspan="3">Barcodes</th></tr>
<tr><th>Spacing</th><th>Graphic</th><th>short RBr</th></tr>
<tr><td>22233</td><td>|||| | |</td><td>1:4,1,1</td></tr>
<tr><td>22323</td><td>||| || |</td><td>1:3,2,1</td></tr>
<tr><td>23223</td><td>|| ||| |</td><td>1:2,3,1</td></tr>
<tr><td>32223</td><td>| |||| |</td><td>1:1,4,1</td></tr>
<tr><td>32232</td><td>| ||| ||</td><td>1:1,3,2</td></tr>
<tr><td>32322</td><td>| || |||</td><td>1:1,2,3</td></tr>
<tr><td>33222</td><td>| | ||||</td><td>1:1,1,4</td></tr>
<tr><td>23322</td><td>|| | |||</td><td>1:2,1,3</td></tr>
<tr><td>22332</td><td>||| | ||</td><td>1:3,1,2</td></tr>
<tr><td>23232</td><td>|| || ||</td><td>1:2,2,2</td></tr>
</table>

<table>
<tr><th colspan="3">7 Ring codes</th></tr>
<tr><th>Spacing</th><th>Graphic</th><th>RBr</th></tr>
<tr><td>222222</td><td>|||||||</td><td>1:1.7</td></tr>
<tr><td>222311</td><td>|||| |||</td><td>1:1.4,2.3n</td></tr>
<tr><td>222322</td><td>|||| |||</td><td>1:1.4,2.3</td></tr>
<tr><td>223111</td><td>||| ||||</td><td>1:1.3,2.4n</td></tr>
<tr><td>223222</td><td>||| ||||</td><td>1:1.3,2.4</td></tr>
</table>

<table>
<tr><th colspan="3">8 Ring codes</th></tr>
<tr><th>Spacing</th><th>Graphic</th><th>RBr</th></tr>
<tr><td>2222222</td><td>||||||||</td><td>1:1.8</td></tr>
<tr><td>2222311</td><td>||||| |||</td><td>1:1.5,2.3n</td></tr>
<tr><td>2222322</td><td>||||| |||</td><td>1:1.5,2.3</td></tr>
<tr><td>2223111</td><td>|||| ||||</td><td>1:1.4,2.4n</td></tr>
<tr><td>2223222</td><td>|||| ||||</td><td>1:1.4,2.4</td></tr>
<tr><td>2231111</td><td>||| |||||</td><td>1:1.3,2.5n</td></tr>
<tr><td>2231311</td><td>||| || |||</td><td>1:1.3,2.2n,3.3n</td></tr>
<tr><td>2231322</td><td>||| || |||</td><td>1:1.3,2.2n,3.3</td></tr>
<tr><td>2232222</td><td>||| |||||</td><td>1:1.3,2.5</td></tr>
<tr><td>2232311</td><td>||| || |||</td><td>1:1.3,2.2,3.3n</td></tr>
<tr><td>2232322</td><td>||| || |||</td><td>1:1.3,2.2,3.3</td></tr>
</table>

References

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