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A Proposal to Designate Specific Thermal Marks for Each Country by Species and Brood Year

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Abstract

As more countries have adopted thermal marking to identify Pacific salmon stocks, the duplication of marks throughout the Pacific Rim has increased. For many years, the Working Group on Salmon Marking has discussed the need for "country codes" or some similar method to determine the country of origin of a salmon otolith collected on the high seas. In Fall 2004, the United States Party agreed to examine this issue and to identify a solution to this problem. In this paper, we propose an approach that would reserve sets of thermal mark patterns for individual countries to minimize duplicate marks.

Introduction

Studies of oceanic salmon populations in the North Pacific Ocean and the Bering Sea by North Pacific Fish Anadromous Commission (NPAFC) member countries have included otolith mark recovery to determine the range and distribution of salmon. To confirm country of origin for thermal marks, it has become critical for member parties to coordinate thermal marking activities and avoid mark duplication. This has been a difficult task because of the increasing number of release groups marked by each country and the limited number of easily applied and discernable thermal mark patterns. Previous authors have discussed many of these problems in detail (Hagen 1999, Munk 1999).

Previously, the NPAFC Working Group on Salmon Marking (WGSM) discussed assigning each nation a "country code," but it was not able to resolve this issue (NPAFC 1998 and NPAFC 1999). Japan has been using a 2-ring band to preface most of their marks, and the other countries have avoided this format for chum salmon. As a result, Japan marks have been readily identified in high seas recovery efforts. Assigning similar codes to the other parties, however, has been challenging. If additional rings were used for other country codes, they would be more difficult to apply and result in increased financial costs.

The WGSM has invited the parties to propose country codes for several years without success. At the Fall 2004 meeting of the WGSM, the US Party agreed to examine this issue in greater detail.

To do this, we re-examined Hagen's (1999) model, which generated thermal mark patterns in terms of ring number and relative ring spacing while following the RBr guidelines defined by Munk and Geiger (1998). Hagen's (1999) model illustrated that relatively few base patterns were available when ring number was limited. Although Hagen (1999) did not resolve the issue of a "country code," he pointed out that the incorporation of "rules" into the thermal mark patterns greatly limited the number of patterns available. Relaxing these restrictions can increase the number of available patterns, but it could reduce the reliability of mark application and the accuracy of mark recovery and identification. The detection of a thermal mark relies upon human judgment and the ability to identify visual patterns; this limits the number of useful thermal marks.

These findings prompted us to re-evaluate our approach to the development of "country codes." The primary purpose behind developing a "country code" system was to avoid mark duplication and facilitate the identification of country of origin from thermally marked salmon recovered on the high seas. Thus, our goals regarding management of thermal mark assignments could be summarized as follows: (1) prevention of duplication of marks in any given species and brood year, and (2) the reliability of determination of country of origin based on the mark. We propose that if specific marks are assigned to specific countries, we can satisfy the above criteria with less cost and inconvenience to all the parties in the NPAFC.

THE PROCESS - IDENTIFICATION OF COMMON MARKS

To examine this issue, we needed to create a list of thermal marks that could be applied and identified. First we determined a set of simple mark combinations by modifying the Hagen (1999) modeling system to generate marks with 2 to 7 rings and 3 different spacings (Appendix 1). Using Hagen's (1999) terminology, "1" represented a normal ring space, "2" represented the band interval, and "3" represented the extra band interval. We created

graphical representations of the marks and gave each pattern an "Assigned Mark Code" (Appendix 1). A comma (,) was used to represent a band interval, and a dash (-) to represent the extra band interval. As an example, a four-ring mark with spacing of 123 had an "Assigned Hatch Code" of 2,1-1 and a graphic of **|| | |**. For marks with spacing 212, and 313, the respective "Assigned Hatch Codes" were 1,2,1 and 1-2-1. We assumed marks would be created before hatching occurred, so the 'H' representing the hatching event in the Hatch Code was not shown.

We identified 1,092 marks meeting our criteria; however some marks were very similar. As several authors have noted, thermal mark patterns are based on relative distances (Hagen 1999, Munk 1999). Munk and Geiger (1998) stipulated that spaces between bands should be relative to the previous rings. Marks with the same pattern, but differences in spacing would look the same. For example, the hatch code 2,1-1 listed above has a graphic of **|| | |**, but this mark appears to be two sets of two rings (2n,2). As another example, hatch codes 3,2 and 3-2 and 1,1,1-1-1 have the following graphics **||| || and ||| || and ||| ||**. Although these marks may be differentiated when viewed together or with careful measurements, each mark looks like 3 rings followed by 2 rings, or 3,2. When several marks look similar, we called the common mark the "Functional Hatch Code." We examined the graphic representations in our group of marks and assigned a "Functional Hatch Code" that would most closely resemble the graphic. We identified 159 "Functional Hatch Codes" (Appendix 1). This effort provided a group of thermal marks that would be readily distinguishable by most observers and that could be easily applied to otoliths.

Potential Mark Assignments

If certain marks were reserved for particular countries it would reduce the duplication of marks. This would make it easier to identify the source of marks recovered in ocean cruises. A table was created with the "Functional Hatch Codes" and we identified marks that were recently used by some countries for chum, sockeye, and pink salmon species (Table 1). We propose that only those countries could use those marks for the brood years specified.

This table of marks would need to be updated regularly, and countries would give up old marks and adopt new marks in response to changes in programs. Of course, there may still be inconsistencies in marking, and it would be important for countries to note how the actual thermal mark applied might differ from the intended mark. Digital images from voucher samples on the WGSM website would assist in the identification of individual marks.

There are some undeveloped parts to this proposal. The most obvious include marks with greater than 7-rings and post-hatch marks. We show current usage of some of these marks in Table 2. Using more than 7-rings greatly increases the number of available marks, and the WGSM would assign these marks as requested and with group consensus.

Most marks used by the State of Washington and Canada are missing from our example. These agencies tend to mark in the post-hatch region and we propose that another set of tables be created for post-hatch marks. The Alaskan delegation is willing to work with Washington Department of Fish and Wildlife and Canada to identify their marks and to develop a table of post-hatch marks with an appropriate listing of countries using those marks.

Summary

We recommend that the WGSM adopt this system of using a list of available marks by species and brood year. The list can be improved or altered once we agree to adopt this method of assigning marks. Once this system is adopted and a list of marks by country developed, then individual countries would allocate those specific marks to their hatcheries and release sites. These mark assignments would be re-evaluated each year.

References

Hagen, P. 1999. A modeling approach to address the underlying structure and constraints of thermal mark codes and code notation. (NPAFC Doc. 395). 12 p. Alaska Dept. Fish and Game, Juneau Alaska.

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Munk, K.M. 1999. Discrimination of multi-country thermal mark codes by augmentation of coding schemes or marking mechanisms. (NPAFC Doc. 396). 14 p. Alaska Dept. Fish and Game, Juneau, AK.

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North Pacific Anadromous Fish Commission. 1998. N. Pac. Anadr. Fish Comm. Annu. Rep. 1998: 49-50. Vancouver, Canada.

North Pacific Anadromous Fish Commission. 1999. N. Pac. Anadr. Fish Comm. Annu. Rep. 1999: 51. Vancouver, Canada.

Table 1. Proposed hatch code assignments for chum, sockeye, and pink salmon by country and brood year.

			CHUM SALMON PLANS Brood Year			SOCKEYE SALMON PLANS Brood Year			PINK SALMON PLANS Brood Year		
Rings	Hatch Code	Graphic	2006	2007	2008	2006	2007	2008	2006	2007	2008
2	2H	||	Japan	Japan	Japan	Alaska	Alaska	Alaska			
3	2,1H	|||	Japan	Japan	Japan	Alaska	Alaska	Alaska			
3	1,2H	|||									
3	3H	|||	Alaska	Alaska	Alaska	Canada	Canada	Canada	Alaska	Alaska	Alaska
4	3,1H	||||	Canada	Canada	Canada	Russia	Russia	Russia	Russia	Russia	Russia
4	2n,2H	||||	Japan	Japan	Japan						
4	2,2nH	||||	Japan	Japan	Japan						
4	2,2H	||||	Japan	Japan	Japan	Alaska	Alaska	Alaska			
4	1,3H	||||	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska			
4	1,2,1H	||||									
4	4H	||||	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska
5	4,1H	|||||	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska
5	3n,2H	|||||	Alaska	Alaska	Alaska						
5	3,2nH	|||||	Alaska	Alaska	Alaska						
5	3,2H	|||||	Russia	Russia	Russia	Alaska	Alaska	Alaska	Russia	Russia	Russia
5	2n,3H	|||||	Japan	Japan	Japan						
5	2n,2,1H	|||||	Japan	Japan	Japan						
5	2-1,2H	|||||	Japan	Japan	Japan						
5	2,3nH	|||||	Japan	Japan	Japan						
5	2,3H	|||||	Japan	Japan	Japan	Alaska	Alaska	Alaska			
5	2,2n,1H	|||||	Japan	Japan	Japan						
5	2,2,1H	|||||	Japan	Japan	Japan						
5	2,1-2H	|||||	Japan	Japan	Japan						

Table 1 (cont.). Proposed hatch code assignments for chum, sockeye, and pink salmon by country and brood year.

			CHUM SALMON PLANS Brood Year			SOCKEYE SALMON PLANS Brood Year			PINK SALMON PLANS Brood Year		
Rings	Hatch Code	Graphic	2006	2007	2008	2006	2007	2008	2006	2007	2008
5	2,1,2nH	|| | ||	Japan	Japan	Japan						
5	2,1,2H	|| | ||	Japan	Japan	Japan	Alaska	Alaska	Alaska			
5	1,4H	| |||	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska			
5	1,3,1H	| ||| |									
5	1,2n,2H	| || ||									
5	1,2,2nH	| || ||									
5	1,2,2H	| || ||									
5	5H	|||||	Russia	Russia	Russia	Alaska	Alaska	Alaska	Russia	Russia	Russia
6	5,1H	||||| |	Russia	Russia	Russia						
6	4n,2H	|||| ||				Alaska	Alaska	Alaska			
6	4,2H	|||| ||	Russia	Russia	Russia	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska
6	3n,3H	||| | | |									
6	3,3nH	||| |||	Korea	Korea	Korea	Alaska	Alaska	Alaska			
6	3,3H	||| |||	Russia	Russia	Russia	Russia	Russia	Russia	Alaska	Alaska	Alaska
6	3,2n,1H	||| || |									
6	3,2,1H	||| || |	Korea	Korea	Korea				Russia	Russia	Russia
6	3,1,2H	||| | ||	Korea	Korea	Korea	Russia	Russia	Russia	Russia	Russia	Russia
6	2n,4H	|| |||	Japan	Japan	Japan						
6	2n,3,1H	|| ||| |	Japan	Japan	Japan						
6	2n,2n,2H	|||| ||	Japan	Japan	Japan						
6	2n,2,2nH	|| | ||	Japan	Japan	Japan						
6	2n,2,2H	|| || ||	Japan	Japan	Japan						
6	2,4nH	|| ||||	Japan	Japan	Japan	Alaska	Alaska	Alaska			

Table 1 (cont.). Proposed hatch code assignments for chum, sockeye, and pink salmon by country and brood year.

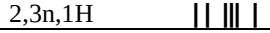
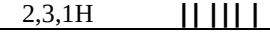
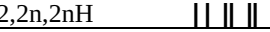
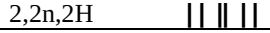
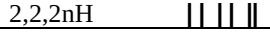
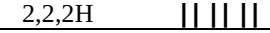
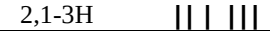
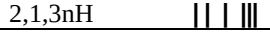
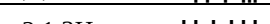
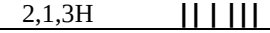
			CHUM SALMON PLANS Brood Year			SOCKEYE SALMON PLANS Brood Year			PINK SALMON PLANS Brood Year		
Rings	Hatch Code	Graphic	2006	2007	2008	2006	2007	2008	2006	2007	2008
6	2,4H		Japan	Japan	Japan	Alaska	Alaska	Alaska			
6	2,3n,1H		Japan	Japan	Japan						
6	2,3,1H		Japan	Japan	Japan						
6	2,2n,2nH		Japan	Japan	Japan						
6	2,2n,2H		Japan	Japan	Japan						
6	2,2,2nH		Japan	Japan	Japan						
6	2,2,2H		Japan	Japan	Japan	Alaska	Alaska	Alaska			
6	2,1-3H		Japan	Japan	Japan						
6	2,1,3nH		Japan	Japan	Japan						
6	2,1,3H		Japan	Japan	Japan						
6	2,1,2,1H		Japan	Japan	Japan						
6	1,5H		Russia	Russia	Russia						
6	1,4,1H		Alaska	Alaska	Alaska						
6	1,3n,2H										
6	1,3,2nH										
6	1,3,2H		Alaska	Alaska	Alaska						
6	1,2n,3H		Alaska	Alaska	Alaska						
6	1,2n,2,1H										
6	1,2,3H		Alaska	Alaska	Alaska						
6	1,2,2n,1H										
6	1,2,2,1H										
6	1,2,1-2H										
6	1,2,1,2H		Alaska	Alaska	Alaska						

Table 1 (cont.). Proposed hatch code assignments for chum, sockeye, and pink salmon by country and brood year.

			CHUM SALMON PLANS Brood Year			SOCKEYE SALMON PLANS Brood Year			PINK SALMON PLANS Brood Year		
Rings	Hatch Code	Graphic	2006	2007	2008	2006	2007	2008	2006	2007	2008
6	6H	||||||	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska
7	6,1H	|||||| |	Alaska	Alaska	Alaska						
7	5,2nH	||||| ||									
7	5,2H	||||| ||				Alaska	Alaska	Alaska			
7	4n,3H	|||| |||				Alaska	Alaska	Alaska			
7	4n,2,1H	|||| || |									
7	4n,1,2H	|||| | ||									
7	4,3nH	|||| |||									
7	4,3H	|||| |||	Russia	Russia	Russia						
7	4,2n,1H	|||| || |	Alaska	Alaska	Alaska						
7	4,2,1H	|||| || |									
7	4,1,2H	|||| | ||									
7	3n,4H	||| ||||									
7	3n,3,1H	||| ||| |									
7	3n,2,2nH	||| || ||	Alaska	Alaska	Alaska						
7	3n,2,2H	||| || ||	Alaska	Alaska	Alaska						
7	3n,1,3H	||| | |||									
7	3,4nH	||| ||||				Alaska	Alaska	Alaska			
7	3,4H	||| ||||	Russia	Russia	Russia	Russia	Russia	Russia	Russia	Russia	Russia
7	3,3n,1H	||| ||| |	Alaska	Alaska	Alaska						
7	3,3,1H	||| ||| |	Alaska	Alaska	Alaska						
7	3,2n,2nH	||| || ||									
7	3,2n,2H	||| || ||									

Table 1 (cont.). Proposed hatch code assignments for chum, sockeye, and pink salmon by country and brood year.

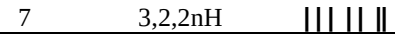
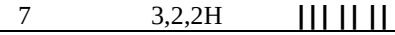
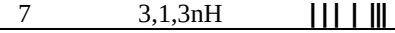
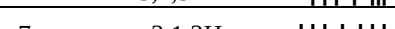
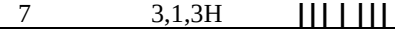
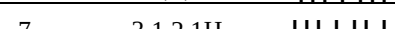
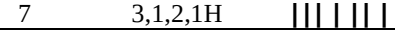
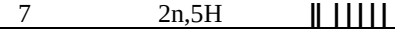
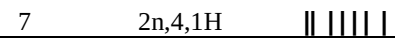
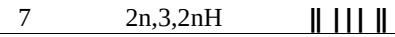
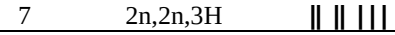
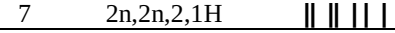
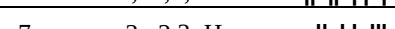
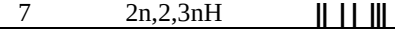
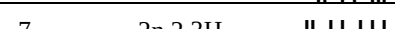
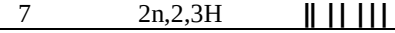
			CHUM SALMON PLANS Brood Year			SOCKEYE SALMON PLANS Brood Year			PINK SALMON PLANS Brood Year		
Rings	Hatch Code	Graphic	2006	2007	2008	2006	2007	2008	2006	2007	2008
7	3,2,2nH										
7	3,2,2H		Alaska	Alaska	Alaska	Russia	Russia	Russia			
7	3,1,3nH										
7	3,1,3H		Canada	Canada	Canada	Russia	Russia	Russia			
7	3,1,2,1H		Alaska	Alaska	Alaska						
7	2n,5H		Japan	Japan	Japan						
7	2n,4,1H		Japan	Japan	Japan						
7	2n,3,2nH		Japan	Japan	Japan						
7	2n,2n,3H		Japan	Japan	Japan						
7	2n,2n,2,1H		Japan	Japan	Japan						
7	2n,2,3nH		Japan	Japan	Japan						
7	2n,2,3H		Japan	Japan	Japan						
7	2n,2,2n,1H		Japan	Japan	Japan						
7	2n,2,1,2H		Japan	Japan	Japan						
7	2,5nH		Japan	Japan	Japan						
7	2,5H		Japan	Japan	Japan						
7	2,4n,1H		Japan	Japan	Japan						
7	2,4,1H		Japan	Japan	Japan						
7	2,3n,2nH		Japan	Japan	Japan	Alaska	Alaska	Alaska			
7	2,3n,2H		Japan	Japan	Japan						
7	2,3,2nH		Japan	Japan	Japan						
7	2,3,2H		Japan	Japan	Japan						
7	2,2n,3nH		Japan	Japan	Japan						

Table 1 (cont.). Proposed hatch code assignments for chum, sockeye, and pink salmon by country and brood year.

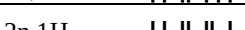
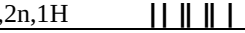
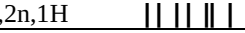
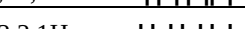
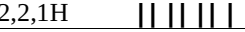
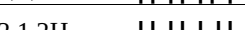
			CHUM SALMON PLANS Brood Year			SOCKEYE SALMON PLANS Brood Year			PINK SALMON PLANS Brood Year		
Rings	Hatch Code	Graphic	2006	2007	2008	2006	2007	2008	2006	2007	2008
7	2,2n,3H		Japan	Japan	Japan						
7	2,2n,2n,1H		Japan	Japan	Japan						
7	2,2n,2,1H		Japan	Japan	Japan						
7	2,2n,1,2H		Japan	Japan	Japan						
7	2,2,3nH		Japan	Japan	Japan						
7	2,2,3H		Japan	Japan	Japan						
7	2,2,2n,1H		Japan	Japan	Japan						
7	2,2,2,1H		Japan	Japan	Japan						
7	2,2,1,2H		Japan	Japan	Japan						
7	2,1,4nH		Japan	Japan	Japan						
7	2,1,4H		Japan	Japan	Japan						
7	2,1,3n,1H		Japan	Japan	Japan						
7	2,1,3,1H		Japan	Japan	Japan						
7	2,1,2n,2H		Japan	Japan	Japan						
7	2,1,2,2nH		Japan	Japan	Japan						
7	2,1,2,2H		Japan	Japan	Japan						
7	1,6H		Alaska	Alaska	Alaska						
7	1,5,1H		Alaska	Alaska	Alaska						
7	1,4n,2H										
7	1,4,2nH										
7	1,4,2H										
7	1,3n,3H		Alaska	Alaska	Alaska						
7	1,3n,2,1H										

Table 1 (cont.). Proposed hatch code assignments for chum, sockeye, and pink salmon by country and brood year.

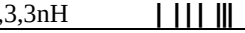
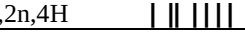
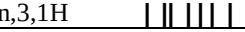
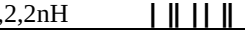
			CHUM SALMON PLANS Brood Year			SOCKEYE SALMON PLANS Brood Year			PINK SALMON PLANS Brood Year		
Rings	Hatch Code	Graphic	2006	2007	2008	2006	2007	2008	2006	2007	2008
7	1,3n,1,2H										
7	1,3,3nH										
7	1,3,3H		Alaska	Alaska	Alaska						
7	1,3,2n,1H										
7	1,3,2,1H		Alaska	Alaska	Alaska						
7	1,3,1,2H										
7	1,2n,4H		Alaska	Alaska	Alaska						
7	1,2n,3,1H										
7	1,2n,2,2nH										
7	1,2n,1,3H										
7	1,2,4nH										
7	1,2,4H										
7	1,2,3n,1H										
7	1,2,3,1H										
7	1,2,2n,2nH										
7	1,2,2,2nH										
7	1,2,2,2H		Alaska	Alaska	Alaska						
7	1,2,1,3nH										
7	1,2,1,3H		Alaska	Alaska	Alaska						
7	1,2,1,2,1H										
7	7H		Russia	Russia	Russia	Russia	Russia	Russia	Russia	Russia	Russia
8	8H		Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska

Table 2. Additional proposed mark assignments by country and brood year.

Rings	Hatch Code	Graphic	Brood Year 2006	2007	2008
CHUM SALMON PLANS					
8	4n,4H	▮▮▮▮ ▮▮▮▮	Alaska	Alaska	Alaska
8	4n,2n,2H	▮▮▮▮ ▮▮ ▮▮	Alaska	Alaska	Alaska
8	4,4H	▮▮▮▮ ▮▮▮▮	Russia	Russia	Russia
8	4,3,1H	▮▮▮▮ ▮▮▮ ▮	Alaska	Alaska	Alaska
8	4,2,2H	▮▮▮▮ ▮▮ ▮▮	Alaska	Alaska	Alaska
8	4,1,3H	▮▮▮▮ ▮ ▮▮▮	Alaska	Alaska	Alaska
8	4,1,2,1H	▮▮▮▮ ▮ ▮▮ ▮	Alaska	Alaska	Alaska
8	3,4,1H	▮▮▮ ▮▮▮▮ ▮	Alaska	Alaska	Alaska
8	3,2,3H	▮▮▮ ▮▮ ▮▮▮	Alaska	Alaska	Alaska
8	3,1,4H	▮▮▮ ▮ ▮▮▮▮	Alaska	Alaska	Alaska
8	1,6,1H	▮ ▮▮▮▮▮▮ ▮	Alaska	Alaska	Alaska
8	1,5,2H	▮ ▮▮▮▮▮ ▮▮	Alaska	Alaska	Alaska
8	1,4,3H	▮ ▮▮▮▮ ▮▮▮	Alaska	Alaska	Alaska
8	1,4,2,1H	▮ ▮▮▮▮ ▮▮ ▮	Alaska	Alaska	Alaska
8	1,3,4H	▮ ▮▮▮ ▮▮▮▮	Alaska	Alaska	Alaska
8	1,3,3,1H	▮ ▮▮▮ ▮▮▮ ▮	Alaska	Alaska	Alaska
8	1,3,1,3H	▮ ▮▮▮ ▮ ▮▮▮	Alaska	Alaska	Alaska
8	1,2,5H	▮ ▮▮ ▮▮▮▮▮	Alaska	Alaska	Alaska
8	1,2,3,2H	▮ ▮▮ ▮▮▮ ▮▮	Alaska	Alaska	Alaska
SOCKEYE SALMON PLANS					
8	5n3H	▮▮▮▮▮ ▮▮▮	Alaska	Alaska	Alaska
8	5,3Nh	▮▮▮▮▮ ▮▮▮▮	Alaska	Alaska	Alaska
8	3,5H	▮▮▮ ▮▮▮▮▮	Canada	Canada	Canada
8	2,6H	▮▮ ▮▮▮▮▮▮	Japan	Japan	Japan
post hatch	H6	**H** ▮▮▮▮▮▮	Alaska	Alaska	Alaska
post hatch	H5	**H** ▮▮▮▮▮	Alaska	Alaska	Alaska
post hatch	H4,4	**H** ▮▮▮▮ ▮▮▮▮	Canada	Canada	Canada
post hatch	H4,2	**H** ▮▮▮▮ ▮▮	Canada	Canada	Canada
post hatch	H4	**H** ▮▮▮▮	Alaska	Alaska	Alaska
post hatch	H3,3	**H** ▮▮▮ ▮▮	Canada	Canada	Canada
post hatch	H3,2	**H** ▮▮▮ ▮▮	Alaska	Alaska	Alaska
post hatch	H3,1	**H** ▮▮▮ ▮	Alaska	Alaska	Alaska
post hatch	H2,4	**H** ▮▮ ▮▮▮▮	Alaska	Alaska	Alaska
post hatch	H2,2,2	**H** ▮▮ ▮▮ ▮▮	Alaska	Alaska	Alaska
post hatch	H1,6	**H** ▮ ▮▮▮▮▮▮	Alaska	Alaska	Alaska
post hatch	H1,5	**H** ▮ ▮▮▮▮▮	Alaska	Alaska	Alaska
post hatch	H1,4	**H** ▮ ▮▮▮▮	Alaska	Alaska	Alaska

Appendix 1. Summary of possible thermal marks using the modeling system developed by Hagen (1999) and the functional hatch code for each mark.

Mark Number	Rings	Hagen Code	Graphic	Assigned Hatch Code	Functional Hatch Code
1	2	1		2	2
2	2	2		1,1	2
3	2	3		1-1	2
4	3	11		3	3
5	3	12		2,1	2,1
6	3	13		2-1	2,1
7	3	21		1,2	1,2
8	3	22		1,1,1	3
9	3	23		1,1-1	2,1
10	3	31		1-2	1,2
11	3	32		1-1,1	1,2
12	3	33		1-1-1	3
13	4	111		4	4
14	4	112		3,1	3,1
15	4	113		3-1	3,1
16	4	121		2,2	2,2
17	4	122		2,1,1	2n,2
18	4	123		2,1-1	2n,2
19	4	131		2-2	2,2
20	4	132		2-1,1	2n,2
21	4	133		2-1-1	2n,2
22	4	211		1,3	1,3
23	4	212		1,2,1	1,2,1
24	4	213		1,2-1	1,2,1
25	4	221		1,1,2	2,2n
26	4	222		1,1,1,1	4
27	4	223		1,1,1-1	3,1
28	4	231		1,1-2	2,2n
29	4	232		1,1-1,1	2,2
30	4	233		1,1-1-1	2n,2
31	4	311		1-3	1,3
32	4	312		1-2,1	1,2,1
33	4	313		1-2-1	1,2,1
34	4	321		1-1,2	2,2n
35	4	322		1-1,1,1	1,3
36	4	323		1-1,1-1	1,2,1
37	4	331		1-1-2	2,2n
38	4	332		1-1-1,1	2,2n
39	4	333		1-1-1-1	4
40	5	1111		5	5
41	5	1112		4,1	4,1
42	5	1113		4-1	4,1
43	5	1121		3,2	3,2
44	5	1122		3,1,1	3,1,1
45	5	1123		3,1-1	3n,2
46	5	1131		3-2	3,2
47	5	1132		3-1,1	3n,2
48	5	1133		3-1-1	3n,2
49	5	1211		2,3	2,3
50	5	1212		2,2,1	2,2,1
51	5	1213		2,2-1	2,2,1
52	5	1221		2,1,2	2,1,2
53	5	1222		2,1,1,1	2n,3
54	5	1223		2,1,1-1	2n,2,1
55	5	1231		2,1-2	2,1-2
56	5	1232		2,1-1,1	2,1-2
57	5	1233		2,1-1-1	2n,3
58	5	1311		2-3	2,3
59	5	1312		2-2,1	2,2,1
60	5	1313		2-2-1	2,2,1
61	5	1321		2-1,2	2-1,2
62	5	1322		2-1,1,1	2n,3
63	5	1323		2-1,1-1	2n,2,1
64	5	1331		2-1-2	2,1,2
65	5	1332		2-1-1,1	2,1,2
66	5	1333		2-1-1-1	2n,3
67	5	2111		1,4	1,4
68	5	2112		1,3,1	1,3,1
69	5	2113		1,3-1	1,3,1
70	5	2121		1,2,2	1,2,2
71	5	2122		1,2,1,1	1,2n,2
72	5	2123		1,2,1-1	1,2n,2
73	5	2131		1,2-2	1,2,2
74	5	2132		1,2-1,1	1,2n,2
75	5	2133		1,2-1-1	1,2n,2
76	5	2211		1,1,3	2,3n
77	5	2212		1,1,2,1	2,2n,1
78	5	2213		1,1,2-1	2,2n,1
79	5	2221		1,1,1,2	3,2n
80	5	2222		1,1,1,1,1	5
81	5	2223		1,1,1,1-1	4,1
82	5	2231		1,1,1-2	3,2n
83	5	2232		1,1,1-1,1	3,2n
84	5	2233		1,1,1-1-1	3n,2
85	5	2311		1,1-3	2,3n
86	5	2312		1,1-2,1	2,2n,1
87	5	2313		1,1-2-1	2,2n,1
88	5	2321		1,1-1,2	2,1,2n
89	5	2322		1,1-1,1,1	2,3
90	5	2323		1,1-1,1-1	2,2,1
91	5	2331		1,1-1-2	2,1,2n
92	5	2332		1,1-1-1,1	2,1,2
93	5	2333		1,1-1-1-1	2n,3
94	5	3111		1-4	1,4
95	5	3112		1-3,1	1,3,1
96	5	3113		1-3-1	1,3,1
97	5	3121		1-2,2	1,2,2
98	5	3122		1-2,1,1	1,2n,2
99	5	3123		1-2,1-1	1,2n,2
100	5	3131		1-2-2	1,2,2

Mark Number	Rings	Hagen Code	Graphic	Assigned Hatch Code	Functional Hatch Code
101	5	3132		1-2-1,1	1,2n,2
102	5	3133		1-2-1-1	1,2n,2
103	5	3211		1-1,3	2,3n
104	5	3212		1-1,2,1	2,2n,1
105	5	3213		1-1,2-1	1,3,1
106	5	3221		1-1,1,2	1,2,2n
107	5	3222		1-1,1,1,1	1,4
108	5	3223		1-1,1,1-1	1,3,1
109	5	3231		1-1,1-2	1,2,2n
110	5	3232		1-1,1-1,1	1,2,2
111	5	3233		1-1,1-1-1	1,2n,2
112	5	3311		1-1-3	2,3n
113	5	3312		1-1-2,1	2,2n,1
114	5	3313		1-1-2-1	2,2n,1
115	5	3321		1-1-1,2	2,3
116	5	3322		1-1-1,1,1	2,3n
117	5	3323		1-1-1,1-1	2,2,1
118	5	3331		1-1-1-2	3,2n
119	5	3332		1-1-1-1,1	3,2n
120	5	3333		1-1-1-1-1	5
121	6	11111		6	6
122	6	11112		5,1	5,1
123	6	11113		5-1	5,1
124	6	11121		4,2	4,2
125	6	11122		4,1,1	4n,2
126	6	11123		4,1-1	4n,2
127	6	11131		4-2	4,2
128	6	11132		4-1,1	4n,2
129	6	11133		4-1-1	4n,2
130	6	11211		3,3	3,3
131	6	11212		3,2,1	3,2,1
132	6	11213		3,2-1	3,2,1
133	6	11221		3,1,2	3,1,2
134	6	11222		3,1,1,1	3n,3
135	6	11223		3,1,1-1	3n,2,1
136	6	11231		3,1-2	3,1,2
137	6	11232		3,1-1,1	3n,1,2
138	6	11233		3,1-1-1	3n,1,2
139	6	11311		3-3	3,3
140	6	11312		3-2,1	3,2,1
141	6	11313		3-2-1	3,2,1
142	6	11321		3-1,2	3,1,2
143	6	11322		3-1,1,1	3n,3
144	6	11323		3-1,1-1	3n,2,1
145	6	11331		3-1-2	3,1,2
146	6	11332		3-1-1,1	3,1,2
147	6	11333		3-1-1-1	3n,1,2
148	6	12111		2,4	2,4
149	6	12112		2,3,1	2,3,1
150	6	12113		2,3-1	2,3,1
151	6	12121		2,2,2	2,2,2
152	6	12122		2,2,1,1	2n,2n,2
153	6	12123		2,2,1-1	2n,2n,2
154	6	12131		2,2-2	2,2,2
155	6	12132		2,2-1,1	2n,2n,2
156	6	12133		2,2-1-1	2n,2n,2
157	6	12211		2,1,3	2,1,3
158	6	12212		2,1,2,1	2,1,2,1
159	6	12213		2,1,2-1	2,1,2,1
160	6	12221		2,1,1,2	2n,2,2n
161	6	12222		2,1,1,1,1	2n,4
162	6	12223		2,1,1,1-1	2n,3,1
163	6	12231		2,1,1-2	2n,2,2n
164	6	12232		2,1,1-1,1	2n,2,2
165	6	12233		2,1,1-1-1	2n,2,2
166	6	12311		2,1-3	2,1-3
167	6	12312		2,1-2,1	2,1,2,1
168	6	12313		2,1-2-1	2,1,2,1
169	6	12321		2,1-1,2	2,2n,2
170	6	12322		2,1-1,1,1	2,1,3
171	6	12323		2,1-1,1-1	2,1,2,1
172	6	12331		2,1-1-2	2n,2,2n
173	6	12332		2,1-1-1,1	2n,2,2n
174	6	12333		2,1-1-1-1	2n,4
175	6	13111		2-4	2,4
176	6	13112		2-3,1	2,3,1
177	6	13113		2-3-1	2,3,1
178	6	13121		2-2,2	2,2,2
179	6	13122		2-2,1,1	2n,2n,2
180	6	13123		2-2,1-1	2n,2n,2
181	6	13131		2-2-2	2,2,2
182	6	13132		2-2-1,1	2,2,2
183	6	13133		2-2-1-1	2n,2n,2
184	6	13211		2-1,3	2,1,3
185	6	13212		2-1,2,1	2,1,2,1
186	6	13213		2-1,2-1	2,1,2,1
187	6	13221		2-1,1,2	2n,2,2n
188	6	13222		2-1,1,1,1	2n,4
189	6	13223		2-1,1,1-1	2n,3,1
190	6	13231		2-1,1-2	2n,2,2n
191	6	13232		2-1,1-1,1	2n,2,2
192	6	13233		2-1,1-1-1	2n,2,2
193	6	13311		2-1-3	2,1,3
194	6	13312		2-1-2,1	2,1,2,1
195	6	13313		2-1-2-1	2,1,2,1
196	6	13321		2-1-1,2	2n,2,2n
197	6	13322		2-1-1,1,1	2,1,3
198	6	13323		2-1-1,1-1	2,1,2,1
199	6	13331		2-1-1-2	2n,2,2n
200	6	13332		2-1-1-1,1	2n,2,2n

Appendix 1. Summary of possible thermal marks using the modeling system developed by Hagen (1999) and the functional hatch code for each mark (continued).

Mark Number	Rings	Hagen Code	Graphic	Assigned Hatch Code	Functional Hatch Code
201	6	13333		2-1-1-1-1	2n,4
202	6	21111		1,5	1,5
203	6	21112		1,4,1	1,4,1
204	6	21113		1,4-1	1,4,1
205	6	21121		1,3,2	1,3,2
206	6	21122		1,3,1,1	1,3n,2
207	6	21123		1,3,1-1	1,3n,2
208	6	21131		1,3-2	1,3,2
209	6	21132		1,3-1,1	1,3n,2
210	6	21133		1,3-1-1	1,3n,2
211	6	21211		1,2,3	1,2,3
212	6	21212		1,2,2,1	1,2,2,1
213	6	21213		1,2,2-1	1,2,2,1
214	6	21221		1,2,1,2	1,2,1,2
215	6	21222		1,2,1,1,1	1,2n,3
216	6	21223		1,2,1,1-1	1,2n,2,1
217	6	21231		1,2,1-2	1,2,1-2
218	6	21232		1,2,1-1,1	1,2,1-2
219	6	21233		1,2,1-1-1	1,2n,3
220	6	21311		1,2-3	1,2,3
221	6	21312		1,2-2,1	1,2,2,1
222	6	21313		1,2-2-1	1,2,2,1
223	6	21321		1,2-1,2	1,2,1,2
224	6	21322		1,2-1,1,1	1,2n,3
225	6	21323		1,2-1,1-1	1,2n,2,1
226	6	21331		1,2-1-2	1,2,1,2
227	6	21332		1,2-1-1,1	1,2,1,2
228	6	21333		1,2-1-1-1	1,2n,3
229	6	22111		1,1,4	2,4n
230	6	22112		1,1,3,1	2,3n,1
231	6	22113		1,1,3-1	2,3n,1
232	6	22121		1,1,2,2	2,2n,2n
233	6	22122		1,1,2,1,1	2,2n,2
234	6	22123		1,1,2,1-1	2,2n,2
235	6	22131		1,1,2-2	2,2n,2n
236	6	22132		1,1,2-1,1	2,2n,2
237	6	22133		1,1,2-1-1	2,2n,2
238	6	22211		1,1,1,3	3,3n
239	6	22212		1,1,1,2,1	3,2n,1
240	6	22213		1,1,1,2-1	3,2,1
241	6	22221		1,1,1,1,2	4,2n
242	6	22222		1,1,1,1,1,1	6
243	6	22223		1,1,1,1,1-1	5,1
244	6	22231		1,1,1,1-2	4,2n
245	6	22232		1,1,1,1-1,1	4,2
246	6	22233		1,1,1,1-1-1	4n,2
247	6	22311		1,1,1-3	3,3n
248	6	22312		1,1,1-2,1	3,2n,1
249	6	22313		1,1,1-2-1	3,2n,1
250	6	22321		1,1,1-1,2	3,1,2
251	6	22322		1,1,1-1,1,1	3,3
252	6	22323		1,1,1-1,1-1	3,1,2,1
253	6	22331		1,1,1-1-2	3,1,2
254	6	22332		1,1,1-1-1,1	3,1,2
255	6	22333		1,1,1-1-1-1	3n,3
256	6	23111		1,1-4	2,4n
257	6	23112		1,1-3,1	2,3n,1
258	6	23113		1,1-3-1	2,3n,1
259	6	23121		1,1-2,2	2,2n,2n
260	6	23122		1,1-2,1,1	2,2n,2
261	6	23123		1,1-2,1-1	2,2n,2
262	6	23131		1,1-2-2	2,2n,2n
263	6	23132		1,1-2-1,1	2,2n,2
264	6	23133		1,1-2-1-1	2,2n,2
265	6	23211		1,1-1,3	2,1,3n
266	6	23212		1,1-1,2,1	2,1,2,1
267	6	23213		1,1-1,2-1	2,1,2,1
268	6	23221		1,1-1,1,2	2,2,2n
269	6	23222		1,1-1,1,1,1	2,4
270	6	23223		1,1-1,1,1-1	2,3,1
271	6	23231		1,1-1,1-2	2,2,2n
272	6	23232		1,1-1,1-1,1	2,2,2
273	6	23233		1,1-1,1-1-1	2n,2n,2
274	6	23311		1,1-1-3	2,1,3n
275	6	23312		1,1-1-2,1	2,1,2,1
276	6	23313		1,1-1-2-1	2,1,2,1
277	6	23321		1,1-1-1,2	2,2,2n
278	6	23322		1,1-1-1,1,1	2,1,3
279	6	23323		1,1-1-1,1-1	2,1,2,1
280	6	23331		1,1-1-1-2	2n,2,2n
281	6	23332		1,1-1-1-1,1	2n,2,2n
282	6	23333		1,1-1-1-1-1	2n,4
283	6	31111		1-5	1,5
284	6	31112		1-4,1	1,4,1
285	6	31113		1-4-1	1,4,1
286	6	31121		1-3,2	1,3,2
287	6	31122		1-3,1,1	1,3n,2
288	6	31123		1-3,1-1	1,3n,2
289	6	31131		1-3-2	1,3,2
290	6	31132		1-3-1,1	1,3n,2
291	6	31133		1-3-1-1	1,3n,2
292	6	31211		1-2,3	1,2,3
293	6	31212		1-2,2,1	1,2,2,1
294	6	31213		1-2,2-1	1,2,2,1
295	6	31221		1-2,1,2	1,2,1,2
296	6	31222		1-2,1,1,1	1,2n,3
297	6	31223		1-2,1,1-1	1,2n,2,1
298	6	31231		1-2,1-2	1,2,1,2
299	6	31232		1-2,1-1,1	1,2n,3
300	6	31233		1-2,1-1-1	1,2n,3

Mark Number	Rings	Hagen Code	Graphic	Assigned Hatch Code	Functional Hatch Code
301	6	31311		1-2-3	1,2,3
302	6	31312		1-2-2,1	1,2,3
303	6	31313		1-2-2-1	1,2,2,1
304	6	31321		1-2-1,2	1,2,1,2
305	6	31322		1-2-1,1,1	1,2n,3
306	6	31323		1-2-1,1-1	1,2n,2,1
307	6	31331		1-2-1-2	1,2,1,2
308	6	31332		1-2-1-1,1	1,2,1,2
309	6	31333		1-2-1-1-1	1,2n,3
310	6	32111		1-1,4	2,4n
311	6	32112		1-1,3,1	2,3n,1
312	6	32113		1-1,3-1	2,3n,1
313	6	32121		1-1,2,2	2,2n,2n
314	6	32122		1-1,2,1,1	2,2n,2
315	6	32123		1-1,2,1-1	2,2n,2
316	6	32131		1-1,2-2	2,2n,2n
317	6	32132		1-1,2-1,1	2,2n,2
318	6	32133		1-1,2-1-1	2,2n,2
319	6	32211		1-2,2,3	1,2,3n
320	6	32212		1-1,1,2,1	1,2,2n,1
321	6	32213		1-1,1,2-1	1,2,2n,1
322	6	32221		1-1,1,1,2	1,3,2n
323	6	32222		1-1,1,1,1,1	1,5
324	6	32223		1-1,1,1,1-1	1,4,1
325	6	32231		1-1,1,1-2	1,3,2n
326	6	32232		1-1,1-1,1	1,3,2
327	6	32233		1-1,1,1-1-1	1,3n,2
328	6	32311		1-1,1-3	1,2,3n
329	6	32312		1-1,1-2,1	3,2n,1
330	6	32313		1-1,1-2-1	1,2,2n,1
331	6	32321		1-1,1-1,2	3,1,2
332	6	32322		1-1,1-1,1,1	1,2,3
333	6	32323		1-1,1-1,1-1	1,2,2,1
334	6	32331		1-1,1-1-2	1,2,1,2
335	6	32332		1-1,1-1-1,1	1,2,1,2
336	6	32333		1-1,1-1-1-1	1,2n,3
337	6	33111		1-1-4	2,4n
338	6	33112		1-1-3,1	2,3n,1
339	6	33113		1-1-3-1	2,3n,1
340	6	33121		1-1-2,2	2,2n,2n
341	6	33122		1-1-2,1,1	2,2n,2
342	6	33123		1-1-2,1-1	2,2n,2
343	6	33131		1-1-2-2	2,2n,2n
344	6	33132		1-1-2-1,1	2,2n,2
345	6	33133		1-1-2-1-1	2,2n,2
346	6	33211		1-1-1,3	3,3n
347	6	33212		1-1-1,2,1	3,2n,1
348	6	33213		1-1-1,2-1	3,2n,1
349	6	33221		1-1-1,1,2	2,2,2n
350	6	33222		1-1-1,1,1,1	2,4n
351	6	33223		1-1-1,1,1-1	2,3n,1
352	6	33231		1-1-1,1-2	2,2,2n
353	6	33232		1-1-1,1-1,1	2,2,2
354	6	33233		1-1-1,1-1-1	2,2n,2
355	6	33311		1-1-1-3	3,3n
356	6	33312		1-1-1-2,1	3,2n,1
357	6	33313		1-1-1-2-1	3,2n,1
358	6	33321		1-1-1-1,2	4,2n
359	6	33322		1-1-1-1,1,1	3,3n
360	6	33323		1-1-1-1,1-1	3,2n,1
361	6	33331		1-1-1-1-2	4,2n
362	6	33332		1-1-1-1-1,1	4,2n
363	6	33333		1-1-1-1-1-1	6
364	7	111111		7	7
365	7	111112		6,1	6,1
366	7	111113		6-1	6,1
367	7	111121		5,2	5,2
368	7	111122		5,1,1	5n,2
369	7	111123		5,1-1	5n,2
370	7	111131		5-2	5,2
371	7	111132		5-1,1	5n,2
372	7	111133		5-1-1	5n,2
373	7	111211		4,3	4,3
374	7	111212		4,2,1	4,2,1
375	7	111213		4,2-1	4,2,1
376	7	111221		4,1,2	4,1,2
377	7	111222		4,1,1,1	4n,3
378	7	111223		4,1,1-1	4,2,1
379	7	111231		4,1-2	4,1,2
380	7	111232		4,1-1,1	4,1,2
381	7	111233		4,1-1-1	4n,1,2
382	7	111311		4-3	4,3
383	7	111312		4-2,1	4,2,1
384	7	111313		4-2-1	4,2,1
385	7	111321		4-1,2	4,1,2
386	7	111322		4-1,1,1	4n,3
387	7	111323		4-1,1-1	4n,2,1
388	7	111331		4-1-2	4,1,2
389	7	111332		4-1-1,1	4,1,2
390	7	111333		4-1-1-1	4n,1,2
391	7	112111		3,4	3,4
392	7	112112		3,3,1	3,3,1
393	7	112113		3,3-1	3,3,1
394	7	112121		3,2,2	3,2,2
395	7	112122		3,2,1,1	3,2,2
396	7	112123		3,2,1-1	3n,2n,2
397	7	112131		3,2-2	3,2,2
398	7	112132		3,2-1,1	3n,2n,2
399	7	112133		3,2-1-1	3n,2n,2
400	7	112211		3,1,3	3,1,3

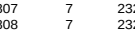
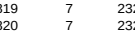
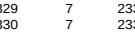
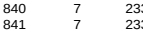
Appendix 1. Summary of possible thermal marks using the modeling system developed by Hagen (1999) and the functional hatch code for each mark (continued).

Mark Number	Rings	Hagen Code	Graphic	Assigned Hatch Code	Functional Hatch Code
401	7	112212		3,1,2,1	3,1,2,1
402	7	112213		3,1,2-1	3,1,2,1
403	7	112221		3,1,1,2	3n,2,2n
404	7	112222		3,1,1,1,1	3n,4
405	7	112223		3,1,1,1-1	3n,3,1
406	7	112231		3,1,1-2	3n,2,2n
407	7	112232		3,1,1-1,1	3n,2,2
408	7	112233		3,1,1-1-1	3n,2,2
409	7	112311		3,1-3	3,1,3
410	7	112312		3,1-2,1	3,1,2,1
411	7	112313		3,1-2-1	3,1,2,1
412	7	112321		3,1-1,2	3n,2,2n
413	7	112322		3,1-1,1,1	3n,1,3
414	7	112323		3,1-1,1-1	3n,1,2,1
415	7	112331		3,1-1-2	3n,2,2n
416	7	112332		3,1-1-1,1	3n,2,2
417	7	112333		3,1-1-1-1	3n,4
418	7	113111		3-4	3,4
419	7	113112		3-3,1	3,3,1
420	7	113113		3-3-1	3,3,1
421	7	113121		3-2,2	3,2,2
422	7	113122		3-2,1,1	3n,2n,2
423	7	113123		3-2,1-1	3n,2n,2
424	7	113131		3-2-2	3,2,2
425	7	113132		3-2-1,1	3n,2n,2
426	7	113133		3-2-1-1	3n,2n,2
427	7	113211		3-1,3	3,1,3
428	7	113212		3-1,2,1	3,1,2,1
429	7	113213		3-1,2-1	3,1,2,1
430	7	113221		3-1,1,2	3n,2,2n
431	7	113222		3-1,1,1,1	3n,4
432	7	113223		3-1,1,1-1	3n,3,1
433	7	113231		3-1,1-2	3n,2,2n
434	7	113232		3-1,1-1,1	3n,2,2
435	7	113233		3-1,1-1-1	3n,2,2
436	7	113311		3-1-3	3,1,3
437	7	113312		3-1-2,1	3,1,2,1
438	7	113313		3-1-2-1	3,1,2,1
439	7	113321		3-1-1,2	3n,2,2n
440	7	113322		3-1-1,1,1	3n,1,3
441	7	113323		3-1-1,1-1	3n,1,2,1
442	7	113331		3-1-1-2	3n,2,2n
443	7	113332		3-1-1-1,1	3n,2,2n
444	7	113333		3-1-1-1-1	3n,4
445	7	121111		2,5	2,5
446	7	121112		2,4,1	2,4,1
447	7	121113		2,4-1	2,4,1
448	7	121121		2,3,2	2,3,2
449	7	121122		2,3,1,1	2n,3n,2
450	7	121123		2,3,1-1	2n,3n,2
451	7	121131		2,3-2	2,3,2
452	7	121132		2,3-1,1	2n,3n,2
453	7	121133		2,3-1-1	2n,3n,2
454	7	121211		2,2,3	2,2,3
455	7	121212		2,2,2,1	2,2,2,1
456	7	121213		2,2,2-1	2,2,2,1
457	7	121221		2,2,1,2	2,2,1,2
458	7	121222		2,2,1,1,1	2n,2n,3
459	7	121223		2,2,1,1-1	2n,2n,2,1
460	7	121231		2,2,1-2	2,2,1,2
461	7	121232		2,2,1-1,1	2,2,1,2
462	7	121233		2,2,1-1-1	2,2,1,2
463	7	121311		2,2-3	2,2,3
464	7	121312		2,2-2,1	2,2,2,1
465	7	121313		2,2-2-1	2,2,2,1
466	7	121321		2,2-1,2	2,2,1,2
467	7	121322		2,2-1,1,1	2n,2n,3
468	7	121323		2,2-1,1-1	2n,2n,2,1
469	7	121331		2,2-1-2	2,2,1,2
470	7	121332		2,2-1-1,1	2,2,1,2
471	7	121333		2,2-1-1-1	2n,2n,3
472	7	122111		2,1,4	2,1,4
473	7	122112		2,1,3,1	2,1,3,1
474	7	122113		2,1,3-1	2,1,3,1
475	7	122121		2,1,2,2	2,1,2,2
476	7	122122		2,1,2,1,1	2,1,2,2
477	7	122123		2,1,2,1-1	2,1,2,2
478	7	122131		2,1,2-2	2,1,2,2
479	7	122132		2,1,2-1,1	2,1,2,2
480	7	122133		2,1,2-1-1	2,1,2,2
481	7	122211		2,1,1,3	2n,2,3n
482	7	122212		2,1,1,2,1	2n,2,2n,1
483	7	122213		2,1,1,2-1	2n,2,2n,1
484	7	122221		2,1,1,1,2	2n,3,2n
485	7	122222		2,1,1,1,1,1	2n,5
486	7	122223		2,1,1,1,1-1	2n,4,1
487	7	122231		2,1,1,1-2	2n,3,2n
488	7	122232		2,1,1,1-1,1	2n,3,2
489	7	122233		2,1,1,1-1-1	2n,3,2
490	7	122311		2,1,1-3	2n,2,3n
491	7	122312		2,1,1-2,1	2n,2,2n,1
492	7	122313		2,1,1-2-1	2n,2,2n,1
493	7	122321		2,1,1-1,2	2n,2,1,2
494	7	122322		2,1,1-1,1,1	2n,2,3
495	7	122323		2,1,1-1,1-1	2n,2,2,1
496	7	122331		2,1,1-1-2	2n,2,1,2
497	7	122332		2,1,1-1-1,1	2n,2,1,2
498	7	122333		2,1,1-1-1-1	4,3
499	7	123111		2,1-4	2,1,4
500	7	123112		2,1-3,1	2,1,3,1
501	7	123113		2,1-3-1	2,1,3,1
502	7	123121		2,1-2,2	2,1,2,2
503	7	123122		2,1-2,1,1	2,1,2,2
504	7	123123		2,1-2,1-1	2,1,2,2
505	7	123131		2,1-2-2	2,1,2,2
506	7	123132		2,1-2-1,1	2,1,2,2
507	7	123133		2,1-2-1-1	2,1,2,2
508	7	123211		2,1-1,3	2n,2,3n
509	7	123212		2,1-1,2,1	2n,2,2n,1
510	7	123213		2,1-1,2-1	2n,2,2n,1
511	7	123221		2,1-1,1,2	2,1,2,2
512	7	123222		2,1-1,1,1,1	2,1,4
513	7	123223		2,1-1,1,1-1	2,1,3,1
514	7	123231		2,1-1,1-2	2,1,2,2
515	7	123232		2,1-1,1-1,1	2,1,2,2
516	7	123233		2,1-1,1-1-1	2,1,2,2
517	7	123311		2,1-1-3	2n,2,3n
518	7	123312		2,1-1-2,1	2n,2,2n,1
519	7	123313		2,1-1-2-1	2n,2,2n,1
520	7	123321		2,1-1-1,2	2n,3,2n
521	7	123322		2,1-1-1,1,1	2n,2,3n
522	7	123323		2,1-1-1,1-1	2n,2,2,1
523	7	123331		2,1-1-1-2	2n,3,2n
524	7	123332		2,1-1-1-1,1	2n,3,2n
525	7	123333		2,1-1-1-1-1	2n,5
526	7	131111		2-5	2,5
527	7	131112		2-4,1	2,4,1
528	7	131113		2-4-1	2,4,1
529	7	131121		2-3,2	2,3,2
530	7	131122		2-3,1,1	2,3,2
531	7	131123		2-3,1-1	2n,3n,2
532	7	131131		2-3-2	2,3,2
533	7	131132		2-3-1,1	2n,3n,2
534	7	131133		2-3-1-1	2n,3n,2
535	7	131211		2-2,3	2,2,3
536	7	131212		2-2,2,1	2,2,2,1
537	7	131213		2-2,2-1	2,2,2,1
538	7	131221		2-2,1,2	2,2,1,2
539	7	131222		2-2,1,1,1	2n,2n,3
540	7	131223		2-2,1,1-1	2n,2n,2,1
541	7	131231		2-2,1-2	2,2,1,2
542	7	131232		2-2,1-1,1	2,2,1,2
543	7	131233		2-2,1-1-1	2n,2n,3
544	7	131311		2-2-3	2,2,3
545	7	131312		2-2-2,1	2,2,2,1
546	7	131313		2-2-2-1	2,2,2,1
547	7	131321		2-2-1,2	2,2,1,2
548	7	131322		2-2-1,1,1	2n,2n,3
549	7	131323		2-2-1,1-1	2n,2n,2,1
550	7	131331		2-2-1-2	2,2,1,2
551	7	131332		2-2-1-1,1	2,2,1,2
552	7	131333		2-2-1-1-1	2n,2n,3
553	7	132111		2-1,4	2,1,4
554	7	132112		2-1,3,1	2,1,3,1
555	7	132113		2-1,3-1	2,1,3,1
556	7	132121		2-1,2,2	2,1,2,2
557	7	132122		2-1,2,1,1	2,1,2,2
558	7	132123		2-1,2,1-1	2,1,2,2
559	7	132131		2-1,2-2	2,3,2
560	7	132132		2-1,2-1,1	2,3,2
561	7	132133		2-1,2-1-1	2n,3n,2
562	7	132211		2-2,2,3	2n,2,3n
563	7	132212		2-1,1,2,1	2n,2,2n,1
564	7	132213		2-1,1,2-1	2n,4,1
565	7	132221		2-1,1,1,2	2n,3,2n
566	7	132222		2-1,1,1,1,1	2n,5
567	7	132223		2-1,1,1,1-1	2n,4,1
568	7	132231		2-1,1,1-2	2n,3,2n
569	7	132232		2-1,1-1,1	2n,3,2
570	7	132233		2-1,1,1-1-1	2n,3,2
571	7	132311		2-1,1-3	2n,3,2n
572	7	132312		2-1,1-2,1	2n,2,2n,1
573	7	132313		2-1,1-2-1	2n,2n,2,1
574	7	132321		2-1,1-1,2	2,2,1,2
575	7	132322		2-1,1-1,1,1	2n,2,3
576	7	132323		2-1,1-1,1-1	2n,2,2,1
577	7	132331		2-1,1-1-2	2n,2,1,2
578	7	132332		2-1,1-1-1,1	2n,2,1,2
579	7	132333		2-1,1-1-1-1	2n,2,3
580	7	133111		2-1-4	2,1,4
581	7	133112		2-1-3,1	2,1,3,1
582	7	133113		2-1-3-1	2,1,3,1
583	7	133121		2-1-2,2	2,1,2,2
584	7	133122		2-1-2,1,1	2,1,2,2
585	7	133123		2-1-2,1-1	2,1,2,2
586	7	133131		2-1-2-2	2,1,2,2
587	7	133132		2-1-2-1,1	2,1,2,2
588	7	133133		2-1-2-1-1	2,1,2,2
589	7	133211		2-1-1,3	2n,2,3n
590	7	133212		2-1-1,2,1	2n,2,2n,1
591	7	133213		2-1-1,2-1	2n,2,2n,1
592	7	133221		2-1-1,1,2	2,1,2,2n
593	7	133222		2-1-1,1,1,1	2,1,4
594	7	133223		2-1-1,1,1-1	2,1,3,1
595	7	133231		2-1-1,1-2	2,1,2,2n
596	7	133232		2-1-1,1-1,1	2,1,2,2
597	7	133233		2-1-1,1-1-1	2,1,2,2
598	7	133311		2-1-1-3	2n,2,3n
599	7	133312		2-1-1-2,1	2n,2,2n,1
600	7	133313		2-1-1-2-1	2n,2,2n,1

Appendix 1. Summary of possible thermal marks using the modeling system developed by Hagen (1999) and the functional hatch code for each mark (continued).

Mark Number	Rings	Hagen Code	Graphic	Assigned Hatch Code	Functional Hatch Code
601	7	133321		2-1-1-1,2	2n,3,2n
602	7	133322		2-1-1-1,1,1	2n,2,3
603	7	133323		2-1-1-1,1-1	2n,2,2,1
604	7	133331		2-1-1-1-2	2n,3,2n
605	7	133332		2-1-1-1-1,1	2n,3,2n
606	7	133333		2-1-1-1-1-1	2n,5
607	7	211111		1,6	1,6
608	7	211112		1,5,1	1,5,1
609	7	211113		1,5-1	1,5,1
610	7	211121		1,4,2	1,4,2
611	7	211122		1,4,1,1	1,4n,2
612	7	211123		1,4,1-1	1,4n,2
613	7	211131		1,4-2	1,4,2
614	7	211132		1,4-1,1	1,4n,2
615	7	211133		1,4-1-1	1,4n,2
616	7	211211		1,3,3	1,3,3
617	7	211212		1,3,2,1	1,3,2,1
618	7	211213		1,3,2-1	1,3,2,1
619	7	211221		1,3,1,2	1,3,1,2
620	7	211222		1,3,1,1,1	1,3n,3
621	7	211223		1,3,1,1-1	1,3n,2,1
622	7	211231		1,3,1-2	1,3,1,2
623	7	211232		1,3,1-1,1	1,3,1,2
624	7	211233		1,3,1-1-1	1,3n,3
625	7	211311		1,3-3	1,3,3
626	7	211312		1,3-2,1	1,3,2,1
627	7	211313		1,3-2-1	1,3,2,1
628	7	211321		1,3-1,2	1,3,1,2
629	7	211322		1,3-1,1,1	1,3n,3
630	7	211323		1,3-1,1-1	1,3n,2,1
631	7	211331		1,3-1-2	1,3,1,2
632	7	211332		1,3-1-1,1	1,3n,1,2
633	7	211333		1,3-1-1-1	1,3n,3
634	7	212111		1,2,4	1,2,4
635	7	212112		1,2,3,1	1,2,3,1
636	7	212113		1,2,3-1	1,2,3,1
637	7	212121		1,2,2,2	1,2,2,2
638	7	212122		1,2,2,1,1	1,2,2,2
639	7	212123		1,2,2,1-1	1,2n,2n,2
640	7	212131		1,2,2-2	1,2,2,2
641	7	212132		1,2,2-1,1	1,2n,2n,2
642	7	212133		1,2,2-1-1	1,2n,2n,2
643	7	212211		1,2,1,3	1,2,1,3
644	7	212212		1,2,1,2,1	1,2,1,2,1
645	7	212213		1,2,1,2-1	1,2,1,2,1
646	7	212221		1,2,1,1,2	1,2n,2,2n
647	7	212222		1,2,1,1,1,1	1,2n,4
648	7	212223		1,2,1,1,1-1	1,2n,3,1
649	7	212231		1,2,1,1-2	1,2n,2,2n
650	7	212232		1,2,1,1-1,1	1,2n,2,2
651	7	212233		1,2,1,1-1-1	1,2n,2n,2
652	7	212311		1,2,1-3	1,2,1,3
653	7	212312		1,2,1-2,1	1,2,1,2,1
654	7	212313		1,2,1-2-1	1,2,1,2,1
655	7	212321		1,2,1-1,2	1,2n,2,2n
656	7	212322		1,2,1-1,1,1	1,2n,1,3
657	7	212323		1,2,1-1,1-1	1,2,1,2,1
658	7	212331		1,2,1-1-2	1,2n,2,2n
659	7	212332		1,2,1-1-1,1	1,2n,2,2
660	7	212333		1,2,1-1-1-1	1,2n,1,3
661	7	213111		1,2-4	1,2,4
662	7	213112		1,2-3,1	1,2,3,1
663	7	213113		1,2-3-1	1,2,3,1
664	7	213121		1,2-2,2	1,2,2,2
665	7	213122		1,2-2,1,1	1,2,2,2
666	7	213123		1,2-2,1-1	1,2n,2n,2
667	7	213131		1,2-2-2	1,2,2,2
668	7	213132		1,2-2-1,1	1,2,2,2
669	7	213133		1,2-2-1-1	1,2n,2n,2
670	7	213211		1,2-1,3	1,2,1,3
671	7	213212		1,2-1,2,1	1,2,1,2,1
672	7	213213		1,2-1,2-1	1,2,1,2,1
673	7	213221		1,2-1,1,2	1,2,2,2
674	7	213222		1,2-1,1,1,1	1,2n,4
675	7	213223		1,2-1,1,1-1	1,2n,3,1
676	7	213231		1,2-1,1-2	1,2n,2,2n
677	7	213232		1,2-1,1-1,1	1,2n,2,2
678	7	213233		1,2-1,1-1-1	1,2n,2,2
679	7	213311		1,2-1-3	1,2,1,3
680	7	213312		1,2-1-2,1	1,2,1,2,1
681	7	213313		1,2-1-2-1	1,2,1,2,1
682	7	213321		1,2-1-1,2	1,2n,2,2n
683	7	213322		1,2-1-1,1,1	1,2n,1,3
684	7	213323		1,2-1-1,1-1	1,2,1,2,1
685	7	213331		1,2-1-1-2	1,2n,2,2n
686	7	213332		1,2-1-1-1,1	1,2n,2,2n
687	7	213333		1,2-1-1-1-1	1,2n,4
688	7	221111		1,1,5	2,5n
689	7	221112		1,1,4,1	2,4n,1
690	7	221113		1,1,4-1	2,4n,1
691	7	221121		1,1,3,2	2,3n,2n
692	7	221122		1,1,3,1,1	2,3n,2
693	7	221123		1,1,3,1-1	2,3n,2
694	7	221131		1,1,3-2	2,3n,2n
695	7	221132		1,1,3-1,1	2,3n,2
696	7	221133		1,1,3-1-1	2,3n,2
697	7	221211		1,1,2,3	2,2n,3n
698	7	221212		1,1,2,2,1	2,2n,2n,1
699	7	221213		1,1,2,2-1	2,2n,2n,1
700	7	221221		1,1,2,1,2	2,2n,1,2
701	7	221222		1,1,2,1,1,1	2,2n,3
702	7	221223		1,1,2,1,1-1	2,2n,2,1
703	7	221231		1,1,2,1-2	2,2n,1,2
704	7	221232		1,1,2,1-1,1	2,2n,1,2
705	7	221233		1,1,2,1-1-1	2,2n,3
706	7	221311		1,1,2-3	2,2n,3n
707	7	221312		1,1,2-2,1	2,2n,2n,1
708	7	221313		1,1,2-2-1	2,2n,2n,1
709	7	221321		1,1,2-1,2	2,2n,1,2
710	7	221322		1,1,2-1,1,1	2,2n,3
711	7	221323		1,1,2-1,1-1	2,2n,2,1
712	7	221331		1,1,2-1-2	2,2n,1,2
713	7	221332		1,1,2-1-1,1	2,2n,1,2
714	7	221333		1,1,2-1-1-1	2,2n,3
715	7	222111		1,1,1,4	3,4n
716	7	222112		1,1,1,3,1	3,3n,1
717	7	222113		1,1,1,3-1	3,3n,1
718	7	222121		1,1,1,2,2	3,2n,2n
719	7	222122		1,1,1,2,1,1	3,2n,2
720	7	222123		1,1,1,2,1-1	3,2n,2
721	7	222131		1,1,1,2-2	3,2n,2n
722	7	222132		1,1,1,2-1,1	3,2n,2
723	7	222133		1,1,1,2-1-1	3,2n,2
724	7	222211		1,1,1,1,3	4,3n
725	7	222212		1,1,1,1,2,1	4,2n,1
726	7	222213		1,1,1,1,2-1	4,2n,1
727	7	222221		1,1,1,1,1,2	5,2n
728	7	222222		1,1,1,1,1,1,1	7
729	7	222223		1,1,1,1,1,1-1	6,1
730	7	222231		1,1,1,1,1-2	5,2n
731	7	222232		1,1,1,1,1-1,1	5,2
732	7	222233		1,1,1,1,1-1-1	5n,2
733	7	222311		1,1,1,1-3	4,3n
734	7	222312		1,1,1,1-2,1	4,2n,1
735	7	222313		1,1,1,1-2-1	4,2n,1
736	7	222321		1,1,1,1-1,2	4,1,2
737	7	222322		1,1,1,1-1,1,1	4,3
738	7	222323		1,1,1,1-1,1-1	4,2,1
739	7	222331		1,1,1,1-1-2	4,1,2
740	7	222332		1,1,1,1-1-1,1	4,1,2
741	7	222333		1,1,1,1-1-1-1	4n,3
742	7	223111		1,1,1-4	3,4n
743	7	223112		1,1,1-3,1	3,3n,1
744	7	223113		1,1,1-3-1	3,3n,1
745	7	223121		1,1,1-2,2	3,2n,2n
746	7	223122		1,1,1-2,1,1	3,2n,2
747	7	223123		1,1,1-2,1-1	3,2n,2
748	7	223131		1,1,1-2-2	3,2n,2n
749	7	223132		1,1,1-2-1,1	3,2n,2
750	7	223133		1,1,1-2-1-1	3,2n,2
751	7	223211		1,1,1-1,3	3,1,3n
752	7	223212		1,1,1-1,2,1	3,1,2,1
753	7	223213		1,1,1-1,2-1	3,1,2,1
754	7	223221		1,1,1-1,1,2	3,2,2n
755	7	223222		1,1,1-1,1,1,1	3,4
756	7	223223		1,1,1-1,1,1-1	3,3,1
757	7	223231		1,1,1-1,1-2	3,2,2n
758	7	223232		1,1,1-1,1-1,1	3,2,2
759	7	223233		1,1,1-1,1-1-1	3,2,2
760	7	223311		1,1,1-1-3	3,1,3n
761	7	223312		1,1,1-1-2,1	3,1,2,1
762	7	223313		1,1,1-1-2-1	3,1,2,1
763	7	223321		1,1,1-1-1,2	3,2,2n
764	7	223322		1,1,1-1-1,1,1	3,1,3
765	7	223323		1,1,1-1-1,1-1	3,1,2,1
766	7	223331		1,1,1-1-1-2	3,2,2n
767	7	223332		1,1,1-1-1-1,1	3n,2,2n
768	7	223333		1,1,1-1-1-1-1	3n,4
769	7	231111		1,1-5	2,5n
770	7	231112		1,1-4,1	2,4n,1
771	7	231113		1,1-4-1	2,4n,1
772	7	231121		1,1-3,2	2,3n,2n
773	7	231122		1,1-3,1,1	2,3n,2
774	7	231123		1,1-3,1-1	2,3n,2
775	7	231131		1,1-3-2	2,3n,2n
776	7	231132		1,1-3-1,1	2,3n,2
777	7	231133		1,1-3-1-1	2,3n,2
778	7	231211		1,1-2,3	2,2n,3n
779	7	231212		1,1-2,2,1	2,2n,2n,1
780	7	231213		1,1-2,2-1	2,2n,2n,1
781	7	231221		1,1-2,1,2	2,2n,1,2
782	7	231222		1,1-2,1,1,1	2,2n,3
783	7	231223		1,1-2,1,1-1	2,2n,2,1
784	7	231231		1,1-2,1-2	2,2n,1,2
785	7	231232		1,1-2,1-1,1	2,2n,1,2
786	7	231233		1,1-2,1-1-1	2,2n,3
787	7	231311		1,1-2-3	2,2n,3n
788	7	231312		1,1-2-2,1	2,2n,2n,1
789	7	231313		1,1-2-2-1	2,2n,2n,1
790	7	231321		1,1-2-1,2	2,2n,1,2
791	7	231322		1,1-2-1,1,1	2,2n,3
792	7	231323		1,1-2-1,1-1	2,2n,2,1
793	7	231331		1,1-2-1-2	2,2n,1,2
794	7	231332		1,1-2-1-1,1	2,2n,1,2
795	7	231333		1,1-2-1-1-1	2,2n,3
796	7	232111		1,1-1,4	2,1,4n
797	7	232112		1,1-1,3,1	2,1,3n,1
798	7	232113		1,1-1,3-1	2,1,3n,1
799	7	232121		1,1-1,2,2	2,1,2,2
800	7	232122		1,1-1,2,1,1	2,1,2n,2

Appendix 1. Summary of possible thermal marks using the modeling system developed by Hagen (1999) and the functional hatch code for each mark (continued).

Mark Number	Rings	Hagen Code	Graphic	Assigned Hatch Code	Functional Hatch Code
801	7	232123		1,1-1,2,1-1	1,2,1,2n,2
802	7	232131		1,1-1,2-2	2,1,2,2
803	7	232132		1,1-1,2-1,1	2,1,2n,2
804	7	232133		1,1-1,2-1-1	2,1,2n,2
805	7	232211		1,1-2,2,3	2,2,3n
806	7	232212		1,1-1,1,2,1	2,2,2n,1
807	7	232213		1,1-1,1,2-1	2,2,2n,1
808	7	232221		1,1-1,1,1,2	2,3,2n
809	7	232222		1,1-1,1,1,1,1	2,5
810	7	232223		1,1-1,1,1,1-1	2,4,1
811	7	232231		1,1-1,1,1-2	2,3,2n
812	7	232232		1,1-1,1-1,1	2,3,2
813	7	232233		1,1-1,1,1-1-1	2n,3n,2
814	7	232311		1,1-1,1-3	2,2,3n
815	7	232312		1,1-1,1-2,1	2,2,2n,1
816	7	232313		1,1-1,1-2-1	2,2,2n,1
817	7	232321		1,1-1,1-1,2	2,2,1,2
818	7	232322		1,1-1,1-1,1,1	2,2,3
819	7	232323		1,1-1,1-1,1-1	2,2,2,1
820	7	232331		1,1-1,1-1-2	2,2,1,2
821	7	232332		1,1-1,1-1-1,1	2,2,1,2
822	7	232333		1,1-1,1-1-1-1	2n,2n,3
823	7	233111		1,1-1-4	2,1,4n
824	7	233112		1,1-1-3,1	2,1,3n,1
825	7	233113		1,1-1-3-1	2,1,3n,1
826	7	233121		1,1-1-2,2	2,1,2,2
827	7	233122		1,1-1-2,1,1	2,1,2n,2
828	7	233123		1,1-1-2,1-1	2,1,2n,2
829	7	233131		1,1-1-2-2	2,1,2,2
830	7	233132		1,1-1-2-1,1	2,1,2n,2
831	7	233133		1,1-1-2-1-1	2,1,2n,2
832	7	233211		1,1-1-1,3	2,2,3n
833	7	233212		1,1-1-1,2,1	2n,2,2n,1
834	7	233213		1,1-1-1,2-1	2n,2,2n,1
835	7	233221		1,1-1-1-1,1,2	2,1,2,2n
836	7	233222		1,1-1-1,1,1,1	2,1,4
837	7	233223		1,1-1-1,1,1-1	2,1,3,1
838	7	233231		1,1-1-1,1-2	2,1,2,2n
839	7	233232		1,1-1-1,1-1,1	2,1,2,2
840	7	233233		1,1-1-1,1-1-1	2,1,2,2
841	7	233311		1,1-1-1-3	2,2,3n
842	7	233312		1,1-1-1-2,1	2n,2,2n,1
843	7	233313		1,1-1-1-2-1	2n,2,2n,1
844	7	233321		1,1-1-1-1,2	2n,3,2n
845	7	233322		1,1-1-1-1,1,1	2n,3,2n
846	7	233323		1,1-1-1-1,1-1	2,2,2,1
847	7	233331		1,1-1-1-1-2	2n,3,2n
848	7	233332		1,1-1-1-1-1,1	2n,3,2n
849	7	233333		1,1-1-1-1-1-1	2n,5
850	7	311111		1-6	1,6
851	7	311112		1-5,1	1,5,1
852	7	311113		1-5-1	1,5,1
853	7	311121		1-4,2	1,4,2
854	7	311122		1-4,1,1	1,4n,2
855	7	311123		1-4,1-1	1,4n,2
856	7	311131		1-4-2	1,4,2
857	7	311132		1-4-1,1	1,4n,2
858	7	311133		1-4-1-1	1,4n,2
859	7	311211		1-3,3	1,3,3
860	7	311212		1-3,2,1	1,3,2,1
861	7	311213		1-3,2-1	1,3,2,1
862	7	311221		1-3,1,2	1,3,1,2
863	7	311222		1-3,1,1,1	1,3n,3
864	7	311223		1-3,1,1-1	1,3n,2,1
865	7	311231		1-3,1-2	1,3n,1,2
866	7	311232		1-3,1-1,1	1,3n,1,2
867	7	311233		1-3,1-1-1	1,3n,1,2
868	7	311311		1-3-3	1,3,3
869	7	311312		1-3-2,1	1,3,2,1
870	7	311313		1-3-2-1	1,3,2,1
871	7	311321		1-3-1,2	1,3,1,2
872	7	311322		1-3-1,1,1	1,3n,3
873	7	311323		1-3-1,1-1	1,3n,2,1
874	7	311331		1-3-1-2	1,3,1,2
875	7	311332		1-3-1-1,1	1,3,1,2
876	7	311333		1-3-1-1-1	1,3n,3
877	7	312111		1-2,4	1,2,4
878	7	312112		1-2,3,1	1,2,3,1
879	7	312113		1-2,3-1	1,2,3,1
880	7	312121		1-2,2,2	1,2,2,2
881	7	312122		1-2,2,1,1	1,2n,2n,2
882	7	312123		1-2,2,1-1	1,2n,2n,2
883	7	312131		1-2,2-2	1,2,2,2
884	7	312132		1-2,2-1,1	1,2n,2n,2
885	7	312133		1-2,2-1-1	1,2n,2n,2
886	7	312211		1-2,1,3	1,2,1,3
887	7	312212		1-2,1,2,1	1,2,1,2,1
888	7	312213		1-2,1,2-1	1,2,1,2,1
889	7	312221		1-2,1,1,2	1,2n,2,2n
890	7	312222		1-2,1,1,1,1	1,2n,4
891	7	312223		1-2,1,1,1-1	1,2n,3,1
892	7	312231		1-2,1,1-2	1,2n,2,2n
893	7	312232		1-2,1,1-1,1	1,2n,2,2
894	7	312233		1-2,1,1-1-1	1,2n,2,2
895	7	312311		1-2,1-3	1,2,1,3
896	7	312312		1-2,1-2,1	1,2,1,2,1
897	7	312313		1-2,1-2-1	1,2,1,2,1
898	7	312321		1-2,1-1,2	1,2n,2,2n
899	7	312322		1-2,1-1,1,1	1,2,1,3
900	7	312323		1-2,1-1,1-1	1,2,1,2,1

Mark Number	Rings	Hagen Code	Graphic	Assigned Hatch Code	Functional Hatch Code
901	7	312331		1-2,1-1-2	1,2n,2,2n
902	7	312332		1-2,1-1-1,1	1,2n,2,2
903	7	312333		1-2,1-1-1-1	1,2n,4
904	7	313111		1-2-4	1,2,4
905	7	313112		1-2-3,1	1,2,3,1
906	7	313113		1-2-3-1	1,2,3,1
907	7	313121		1-2-2,2	1,2,2,2
908	7	313122		1-2-2,1,1	1,2n,2n,2
909	7	313123		1-2-2,1-1	1,2n,2n,2
910	7	313131		1-2-2-2	1,2,2,2
911	7	313132		1-2-2-1,1	1,2n,2n,2
912	7	313133		1-2-2-1-1	1,2n,2n,2
913	7	313211		1-2-1,3	1,2,1,3
914	7	313212		1-2-1,2,1	1,2,1,2,1
915	7	313213		1-2-1,2-1	1,2,1,2,1
916	7	313221		1-2-1,1,2	1,2n,2,2n
917	7	313222		1-2-1,1,1,1	1,2n,4
918	7	313223		1-2-1,1,1-1	1,2n,3,1
919	7	313231		1-2-1,1-2	1,2n,2,2n
920	7	313232		1-2-1,1-1,1	1,2n,2,2
921	7	313233		1-2-1,1-1-1	1,2n,2,2
922	7	313311		1-2-1-3	1,2,1,3
923	7	313312		1-2-1-2,1	1,2,1,2,1
924	7	313313		1-2-1-2-1	1,2,1,2,1
925	7	313321		1-2-1-1,2	1,2,1,3
926	7	313322		1-2-1-1,1,1	1,2,1,3
927	7	313323		1-2-1-1,1-1	1,2,1,2,1
928	7	313331		1-2-1-1-2	1,2n,2,2n
929	7	313332		1-2-1-1-1,1	1,2n,2,2n
930	7	313333		1-2-1-1-1-1	1,2n,4
931	7	321111		1-1,5	2,5n
932	7	321112		1-1,4,1	2,4n,1
933	7	321113		1-1,4-1	2,4n,1
934	7	321121		1-1,3,2	2,3n,2n
935	7	321122		1-1,3,1,1	2,3n,2
936	7	321123		1-1,3,1-1	2,3n,2
937	7	321131		1-1,3-2	2,3n,2n
938	7	321132		1-1,3-1,1	2,3n,2
939	7	321133		1-1,3-1-1	2,3n,2
940	7	321211		1-1,2,3	2,2n,3
941	7	321212		1-1,2,2,1	2,2n,2n,1
942	7	321213		1-1,2,2-1	2,2n,2n,1
943	7	321221		1-1,2,1,2	2,2n,1,2
944	7	321222		1-1,2,1,1,1	2,2n,3
945	7	321223		1-1,2,1,1-1	2,2n,2,1
946	7	321231		1-1,2,1-2	2,2n,1,2
947	7	321232		1-1,2,1-1,1	2,2n,1,2
948	7	321233		1-1,2,1-1-1	2,2n,1,2
949	7	321311		1-1,2-3	2,2n,3n
950	7	321312		1-1,2-2,1	2,2n,2n,1
951	7	321313		1-1,2-2-1	2,2n,2n,1
952	7	321321		1-1,2-1,2	2,2n,1,2
953	7	321322		1-1,2-1,1,1	2,2n,3
954	7	321323		1-1,2-1,1-1	2,2n,2,1
955	7	321331		1-1,2-1-2	2,2n,1,2
956	7	321332		1-1,2-1-1,1	2,2n,1,2
957	7	321333		1-1,2-1-1-1	2,2n,3
958	7	322111		1-1,1,4	1,2,4n
959	7	322112		1-1,1,3,1	1,2,3n,1
960	7	322113		1-1,1,3-1	1,2,3n,1
961	7	322121		1-1,1,2,2	1,2,2n,2n
962	7	322122		1-1,1,2,1,1	1,2,2n,2
963	7	322123		1-1,1,2,1-1	1,2,2n,2
964	7	322131		1-1,1,2-2	1,2,2n,2n
965	7	322132		1-1,1,2-1,1	1,2,2n,2
966	7	322133		1-1,1,2-1-1	1,2,2n,2
967	7	322211		1-1,1,1,3	1,3,3n
968	7	322212		1-1,1,1,2,1	1,3,2n,1
969	7	322213		1-1,1,1,2-1	1,3,2n,1
970	7	322221		1-1,1,1,1,2	1,4,2n
971	7	322222		1-1,1,1,1,1,1	1,6
972	7	322223		1-1,1,1,1,1-1	1,5,1
973	7	322231		1-1,1,1,1-2	1,4,2
974	7	322232		1-1,1,1,1-1,1	1,4,2
975	7	322233		1-1,1,1,1-1-1	1,4,2
976	7	322311		1-1,1,1-3	1,3,3n
977	7	322312		1-1,1,1-2,1	1,3,2n,1
978	7	322313		1-1,1,1-2-1	1,3,2n,1
979	7	322321		1-1,1,1-1,2	1,3,1,2
980	7	322322		1-1,1,1-1,1,1	1,3,3
981	7	322323		1-1,1,1-1,1-1	1,3,2,1
982	7	322331		1-1,1,1-1-2	1,3,1,2
983	7	322332		1-1,1,1-1-1,1	1,3,1,2
984	7	322333		1-1,1,1-1-1-1	1,3n,3
985	7	323111		1-1,1-4	1,2,4n
986	7	323112		1-1,1-3,1	1,2,3n,1
987	7	323113		1-1,1-3-1	1,2,3n,1
988	7	323121		1-1,1-2,2	1,2,2n,2n
989	7	323122		1-1,1-2,1,1	1,2,2n,2
990	7	323123		1-1,1-2,1-1	1,2,2n,2
991	7	323131		1-1,1-2-2	1,2,2n,2n
992	7	323132		1-1,1-2-1,1	1,2,2n,2
993	7	323133		1-1,1-2-1-1	1,2,2n,2
994	7	323211		1-1,1-1,3	1,2,1,3n
995	7	323212		1-1,1-1,2,1	1,2,1,2,1
996	7	323213		1-1,1-1,2-1	1,2,1,2,1
997	7	323221		1-1,1-1,1,2	1,2,2,2n
998	7	323222		1-1,1-1,1,1,1	1,2,4
999	7	323223		1-1,1-1,1,1-1	1,2,3,1
1000	7	323231		1-1,1-1,1-2	1,2,2,2n

Appendix 1. Summary of possible thermal marks using the modeling system developed by Hagen (1999) and the functional hatch code for each mark (continued).

Mark Number	Rings	Hagen Code	Graphic	Assigned Hatch Code	Functional Hatch Code
1002	7	323233	| | | | | |	1-1,1-1,1-1-1	1,2n,2n,2
1003	7	323311	| | | |||	1-1,1-1-3	1,2,1,3n
1004	7	323312	| | | || |	1-1,1-1-2,1	1,2,1,2,1
1005	7	323313	| | | || |	1-1,1-1-2-1	1,2,1,2,1
1006	7	323321	| | | | ||	1-1,1-1-1,2	1,2n,2,2n
1007	7	323322	| | | | | |	1-1,1-1-1,1,1	1,2,1,3
1008	7	323323	| | | | | |	1-1,1-1-1,1-1	1,2,1,2,1
1009	7	323331	| | | | ||	1-1,1-1-1-2	1,2n,2,2n
1010	7	323332	| | | | | |	1-1,1-1-1-1,1	1,2n,2,2n
1011	7	323333	| | | | | |	1-1,1-1-1-1-1	1,2n,4
1012	7	331111	| | ||||	1-1-5	2,5n
1013	7	331112	| | ||| |	1-1-4,1	2,4n,1
1014	7	331113	| | ||| |	1-1-4-1	2,4n,1
1015	7	331121	| | ||| ||	1-1-3,2	2,3n,2n
1016	7	331122	| | ||| |	1-1-3,1,1	2,3n,2n
1017	7	331123	| | ||| |	1-1-3,1-1	2,3n,2
1018	7	331131	| | ||| ||	1-1-3-2	2,3n,2n
1019	7	331132	| | ||| |	1-1-3-1,1	2,3n,2
1020	7	331133	| | ||| |	1-1-3-1-1	2,3n,2
1021	7	331211	| | || |||	1-1-2,3	2,2n,3n
1022	7	331212	| | || ||	1-1-2,2,1	2,2n,2n,1
1023	7	331213	| | || | |	1-1-2,2-1	2,2n,2n,1
1024	7	331221	| | || | ||	1-1-2,1,2	2,2n,1,2
1025	7	331222	| | || | |	1-1-2,1,1,1	2,2n,3
1026	7	331223	| | || | |	1-1-2,1,1-1	2,2n,2,1
1027	7	331231	| | || | ||	1-1-2,1-2	2,2n,1,2
1028	7	331232	| | || | |	1-1-2,1-1,1	2,2n,1,2
1029	7	331233	| | || | |	1-1-2,1-1-1	2,2n,3
1030	7	331311	| | || |||	1-1-2-3	2,2n,3n
1031	7	331312	| | || || |	1-1-2-2,1	2,2n,2n,1
1032	7	331313	| | || || |	1-1-2-2-1	2,2n,2n,1
1033	7	331321	| | || | ||	1-1-2-1,2	2,2n,1,2
1034	7	331322	| | || | | |	1-1-2-1,1,1	2,2n,3
1035	7	331323	| | || | | |	1-1-2-1,1-1	2,2n,2,1
1036	7	331331	| | || | ||	1-1-2-1-2	2,2n,1,2
1037	7	331332	| | || | | |	1-1-2-1-1,1	2,2n,1,2
1038	7	331333	| | || | | |	1-1-2-1-1-1	2,2n,3
1039	7	332111	| | | ||||	1-1-1,4	3,4
1040	7	332112	| | | ||| |	1-1-1,3,1	3,3n,1
1041	7	332113	| | | ||| |	1-1-1,3-1	3,3n,1
1042	7	332121	| | | || ||	1-1-1,2,2	3,2n,2n
1043	7	332122	| | | || | |	1-1-1,2,1,1	3,2n,2
1044	7	332123	| | | || | |	1-1-1,2,1-1	3,2n,2
1045	7	332131	| | | || ||	1-1-1,2-2	3,2n,2n
1046	7	332132	| | | || | |	1-1-1,2-1,1	3,2n,2
1047	7	332133	| | | || | |	1-1-1,2-1-1	3,2n,2
1048	7	332211	| | | | |||	1-1-2,2,3	3,1,3n
1049	7	332212	| | | | || |	1-1-1,1,2,1	2,5n
1050	7	332213	| | | | || |	1-1-1,1,2-1	2,4n,1
1051	7	332221	| | | | | ||	1-1-1,1,1,2	2,5n
1052	7	332222	| | | | | |	1-1-1,1,1,1,1	2,5n
1053	7	332223	| | | | | |	1-1-1,1,1,1-1	2,4n,1
1054	7	332231	| | | | ||	1-1-1,1,1-2	2,3n,2n
1055	7	332232	| | | | | |	1-1-1,1-1,1	2,3n,2n
1056	7	332233	| | | | | |	1-1-1,1,1-1-1	2,3n,2
1057	7	332311	| | | |||	1-1-1,1-3	2,2,3n
1058	7	332312	| | | || |	1-1-1,1-2,1	2,2n,2n,1
1059	7	332313	| | | || |	1-1-1,1-2-1	2,2n,2n,1
1060	7	332321	| | | | ||	1-1-1,1-1,2	2,2n,1,2
1061	7	332322	| | | | | |	1-1-1,1-1,1,1	2,2n,3n
1062	7	332323	| | | | | |	1-1-1,1-1,1-1	2,2,2,1
1063	7	332331	| | | | ||	1-1-1,1-1-2	2,2n,1,2
1064	7	332332	| | | | | |	1-1-1,1-1-1,1	2,2n,1,2
1065	7	332333	| | | | | |	1-1-1,1-1-1-1	2,2n,3
1066	7	333111	| | | |||	1-1-1-4	3,4n
1067	7	333112	| | | |||	1-1-1-3,1	3,3n,1
1068	7	333113	| | | |||	1-1-1-3-1	3,3n,1
1069	7	333121	| | | || ||	1-1-1-2,2	3,2n,2n
1070	7	333122	| | | || | |	1-1-1-2,1,1	3,2n,2
1071	7	333123	| | | || | |	1-1-1-2,1-1	3,2n,2
1072	7	333131	| | | || ||	1-1-1-2-2	3,2n,2n
1073	7	333132	| | | || | |	1-1-1-2-1,1	3,2n,2
1074	7	333133	| | | || | |	1-1-1-2-1-1	3,2n,2
1075	7	333211	| | | | |||	1-1-1-1,3	4,3n
1076	7	333212	| | | | || |	1-1-1-1,2,1	4,2n,1
1077	7	333213	| | | | || |	1-1-1-1,2-1	4,2n,1
1078	7	333221	| | | | | ||	1-1-1-1,1,2	3,4n
1079	7	333222	| | | | | |	1-1-1-1,1,1,1	3,4n
1080	7	333223	| | | | | |	1-1-1-1,1,1-1	3,3n,1
1081	7	333231	| | | | ||	1-1-1-1,1-2	3,2,2n
1082	7	333232	| | | | | |	1-1-1-1,1-1,1	3,2,2
1083	7	333233	| | | | | |	1-1-1-1,1-1-1	3,2n,2
1084	7	333311	| | | |||	1-1-1-1-3	4,3n
1085	7	333312	| | | || |	1-1-1-1-2,1	4,2n,1
1086	7	333313	| | | || |	1-1-1-1-2-1	4,2n,1
1087	7	333321	| | | | ||	1-1-1-1-1,2	4,3n
1088	7	333322	| | | | | |	1-1-1-1-1,1,1	4,3n
1089	7	333323	| | | | | |	1-1-1-1-1,1-1	4,2n,1
1090	7	333331	| | | | ||	1-1-1-1-1-2	5,2n
1091	7	333332	| | | | | |	1-1-1-1-1-1,1	5,2n
1092	7	333333	| | | | | |	1-1-1-1-1-1-1	7