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A quarterly publication
for
the braiding artisan

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THE BRAIDER'S NOTEBOOK

In *The Braider*, Issue No. 29, we have seen on pg.682 that for a component of a cylindrical braid its number of sub-components, and hence its number of essential strings λ is equal to

$$\lambda = \text{g.c.d.} \left(\frac{\beta}{\alpha}, \frac{B_c}{\alpha} \right),$$

where α is the number of bights in the component's first-return string-run, β is the number of bights the first-return string-run spans in the component, and B_c is the component's number of bights.

Let's first illustrate with the aid of a few Examples this greatest common divisor of a component of a cylindrical braid.

Example 1.

Fig.554 depicts the string-run of a Nested Cylindrical Braid which has one first-return string-run only. Hence it consists of one component and consequently its number of bights is equal to $B_c = 16$.

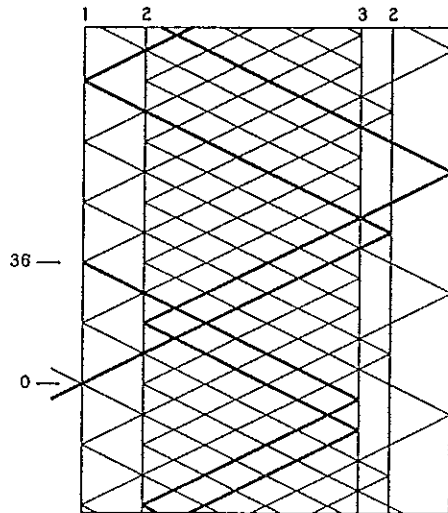


Fig. 554 — The Nested Cylindrical Braid $(2/7/12)\{12/2133\}16$.

The sequence of thick-lined half-cycles depicts the first-return string-run which has $\alpha = 4$ bights and spans $\beta = 36$ bights in the braid. Hence:

$$\lambda = \text{g.c.d.} \left(\frac{\beta}{\alpha}, \frac{B_c}{\alpha} \right) = \left(\frac{36}{4}, \frac{16}{4} \right) = (9, 4) = 1.$$

Thus Fig. 554 depicts the string-run of a single string Nested Cylindrical Braid.

Example 2.

Fig.555 depicts the string-run of a Nested Cylindrical Braid which has four first-return string-runs. Hence it consists of four components. Note that we have discussed this braid in *The Braider*, Issue No. 19, pp. 419-422.

The string-run of the first component, depicted at the left in Fig. 556, has the specification $(12/14/13)\{112222223/113312132\}18$. It is interbraided with the Nested Cylindrical Braid $(11/4/11)\{123/321\}6$, the string-run of which is depicted at upper right in Fig. 556, and which in turn consists of an interbraid of three Regular Cylindrical Braids with $p/b = 2/2$ each, the string-run of which is depicted at lower right in Fig. 556. The

two thick-lined half-cycle sequences depict the first-return string-runs in respectively the component $(12/14/13)\{112222223/113312132\}18$ and the component $p/b = 2/2$.

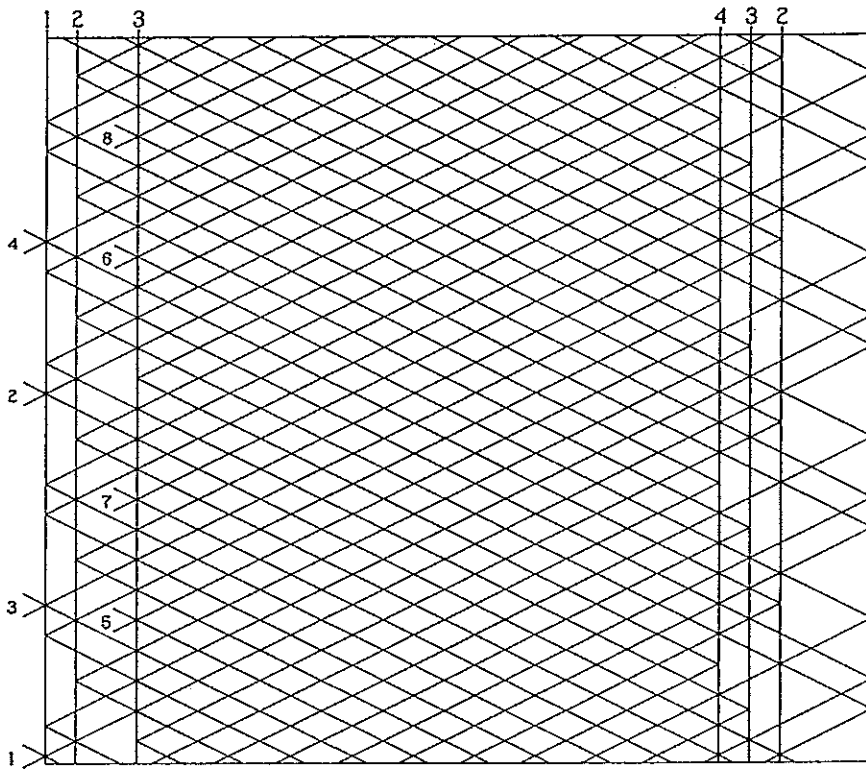


Fig. 555 — The Nested Cylindrical Braid $(12/19/113)\{1231/211314\}24$.

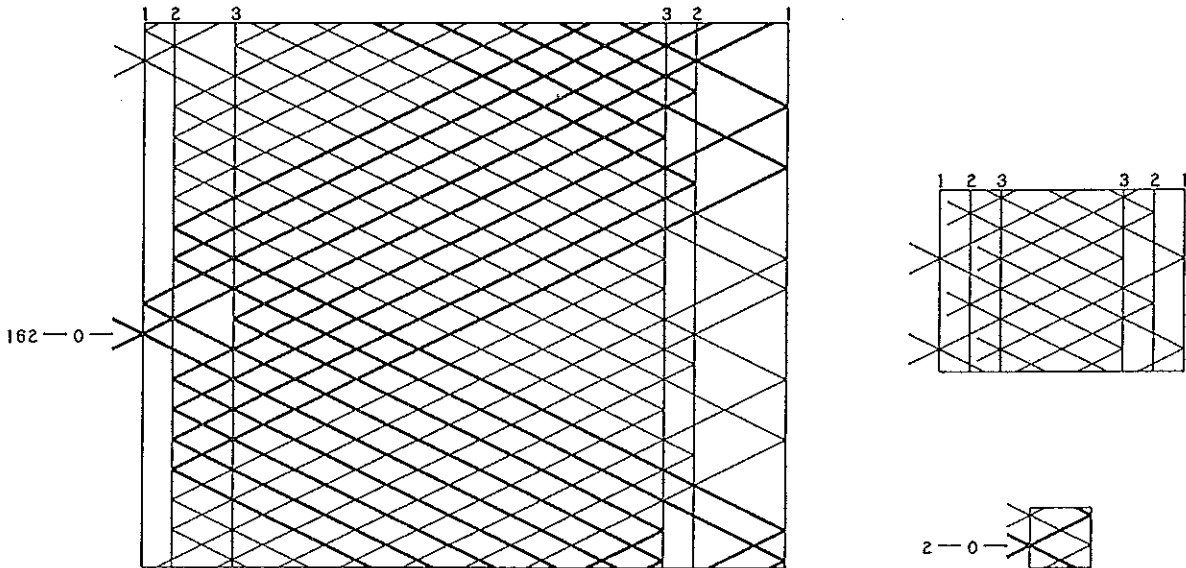


Fig. 556 — The interbraided components in Fig. 555.

For the component $(12/14/13)\{112222223/113312132\}18$, the first-return string-run spans $\beta = 162$ bights and has $\alpha = 9$ bights. Hence for this component

$$\lambda = \text{g.c.d.} \left(\frac{\beta}{\alpha}, \frac{B_c}{\alpha} \right) = \left(\frac{162}{9}, \frac{18}{9} \right) = (18, 2) = 2.$$

Thus this component consists of two sub-components and hence two essential strings are required in its construction.

For the component $p/b = 2/2$, the first-return string-run spans $\beta = 2$ bights and has $\alpha = 1$ bight. Hence for this component

$$\lambda = \text{g.c.d.} \left(\frac{\beta}{\alpha}, \frac{B_c}{\alpha} \right) = \left(\frac{2}{1}, \frac{2}{1} \right) = (2, 2) = 2.$$

Thus this component consists of two sub-components and hence two essential strings are required in its construction. The total of essential strings for the Nested Cylindrical Braid $(12/19/113)\{1231/211314\}24$ thus becomes $2 + 3 \times 2 = 2 + 6 = 8$.

Note that the β -value and the α -value of a component do not change with a change in its B_c -value. Hence a single string component is obtained by ensuring that its values $\frac{\beta}{\alpha}$ and $\frac{B_c}{\alpha}$ are coprime. Thus the Nested Cylindrical Braid $(12/19/113)\{1231/211314\}60$, for example, has four single string components ($B_{c_1} = 45; B_{c_2} = B_{c_3} = B_{c_4} = 5 \rightarrow 60 = 45 + 3 \times 5$); the string-run diagram of this braid is shown in Fig. 557.

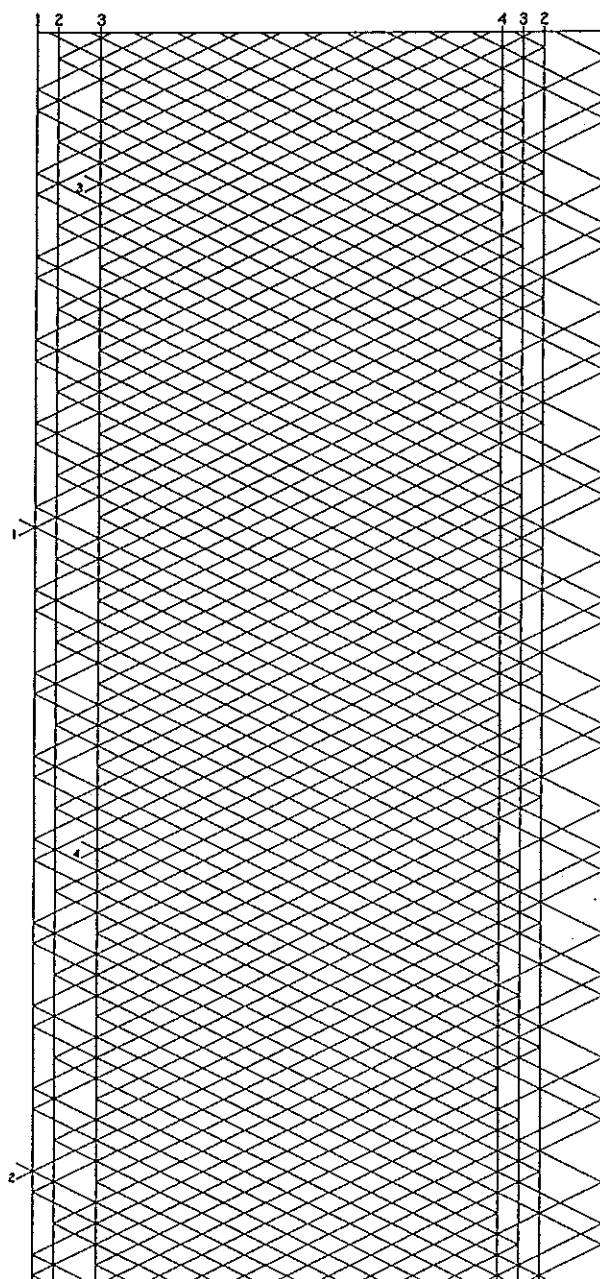


Fig. 557 — The Nested Cylindrical Braid $(12/19/113)\{1231/211314\}60$.

Thus Fig. 559 depicts the string-run of a single string Cylindrical Braid.

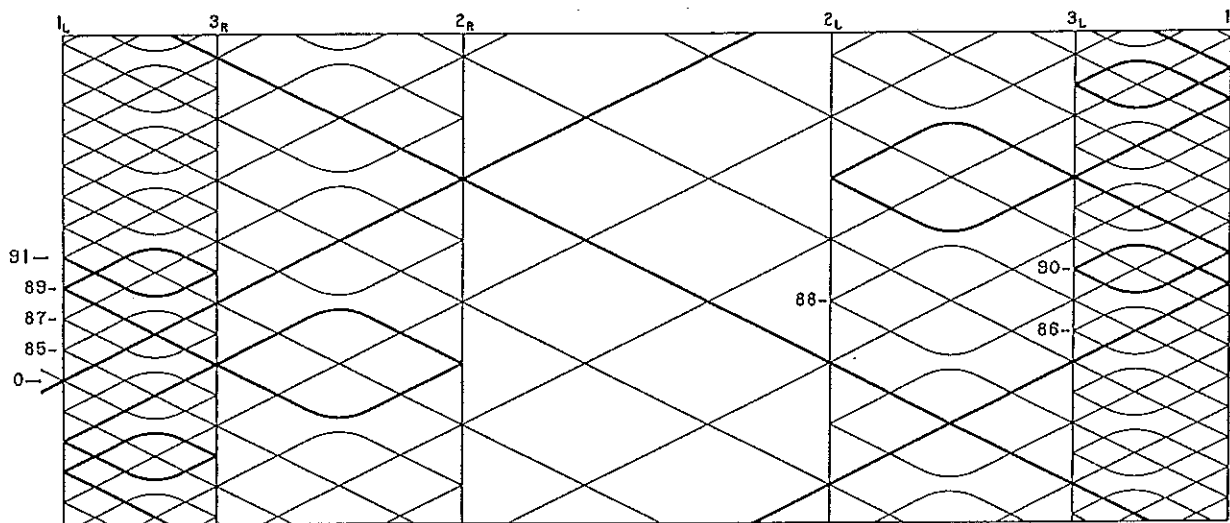


Fig. 560 — The span of bights β .

Example 5.

Fig. 561 depicts the string-run of a Cylindrical Braid which has only one first-return string-run. Hence it consists of one component with $B_c = 28$ (the bights on the sub-script L (or sub-script R) bight-boundaries).

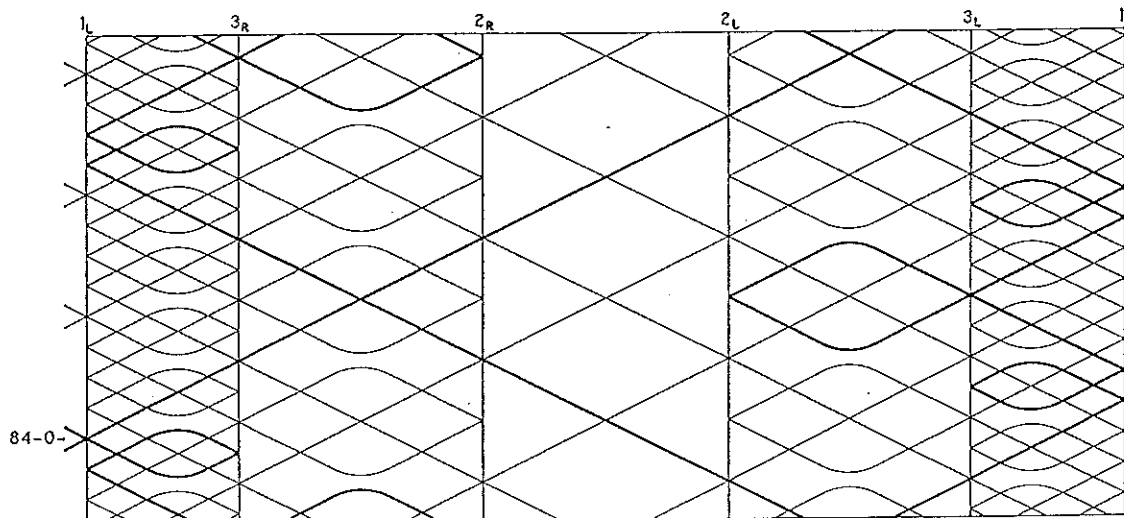


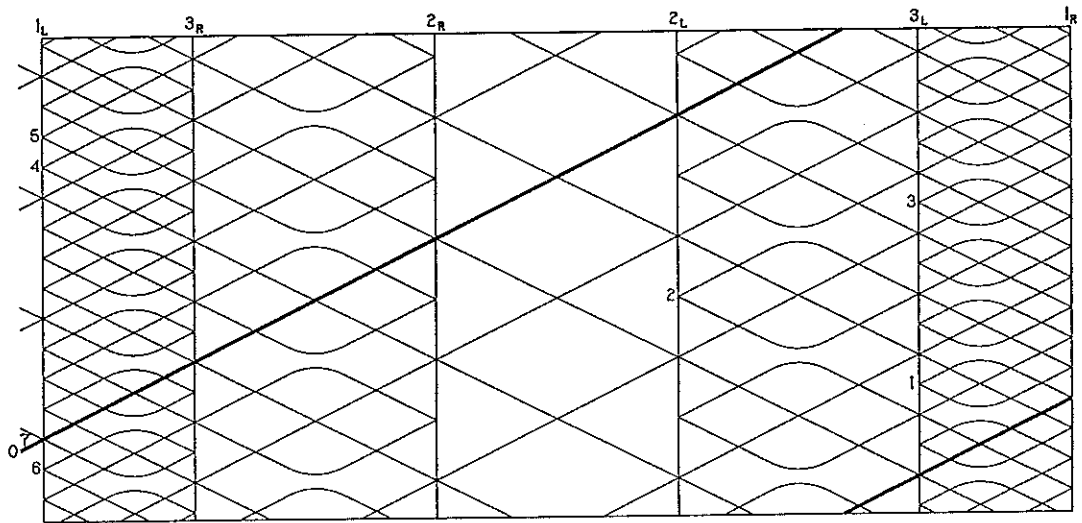
Fig. 561 — A one component Cylindrical Braid.

The sequence of thick-lined half-cycles depicts the first-return string-run which has $\alpha = 7$ bights and spans $\beta = 84$ bights in the braid. Hence:

$$\lambda = \text{g.c.d.} \left(\frac{\beta}{\alpha}, \frac{B_c}{\alpha} \right) = \left(\frac{84}{7}, \frac{28}{7} \right) = (12, 4) = 4.$$

Thus Fig. 561 depicts the string-run of a four string Cylindrical Braid.

From Fig. 562 we observe that a period consists of 7 consecutive bights, hence B_c must be a multiple of 7. Since the values of β and α of a component do not change with a change in the component's B_c -value, a single string component is obtained by ensuring that its values $\frac{\beta}{\alpha}$ and $\frac{B_c}{\alpha}$ are coprime. Thus for $B_c = 35$, for example, we obtain a single string Cylindrical Braid.



A PERIOD CONSISTS OF THE BIGHTS IN THE FIRST-RETURN STRING-RUN; HENCE CONSISTS OF α CONSECUTIVE BIGHTS

NI-563B. DWG line scale = 5 plot scale = 1.000

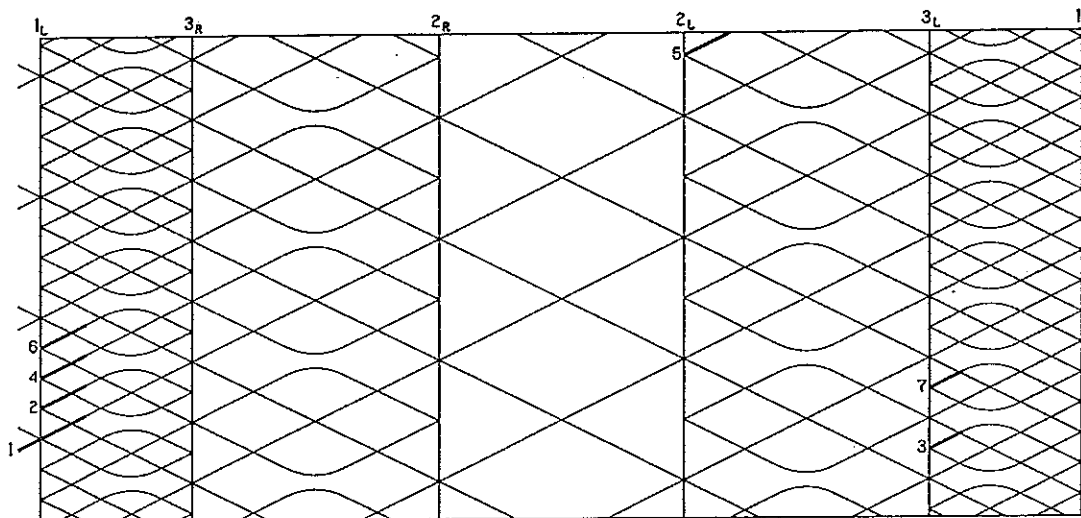


Fig. 562 — The number of bights in a period.

Example 6.

Fig. 563 depicts the string-run of a Cylindrical Braid which consists of two inter-braided components which are depicted by the two lower string-run diagrams. For both components $B_c = 10$.

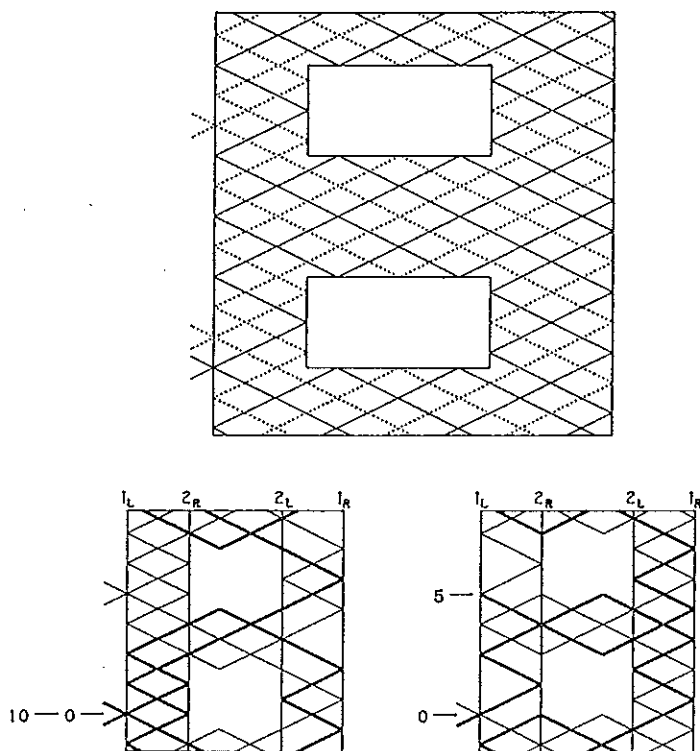


Fig. 563 — A Cylindrical Braid.

For the lower-left component $\beta = 10$ and $\alpha = 5$. Hence

$$\lambda = \text{g.c.d.} \left(\frac{\beta}{\alpha}, \frac{B_c}{\alpha} \right) = \left(\frac{10}{5}, \frac{10}{5} \right) = (2, 2) = 2.$$

Hence this component requires two strings in its construction.

For the lower-right component $\beta = 5$ and $\alpha = 5$. Hence

$$\lambda = \text{g.c.d.} \left(\frac{\beta}{\alpha}, \frac{B_c}{\alpha} \right) = \left(\frac{5}{5}, \frac{10}{5} \right) = (1, 2) = 1.$$

Hence this component requires one string in its construction.

Note that here the end-point of the first-return string-run lies **below** its starting-point.

A period in each component consists of 5 consecutive bights. Since the values of β and α of a component do not change with a change in the component's B_c -value, a single string component is also obtained for the lower-left component by ensuring that its values $\frac{\beta}{\alpha}$ and $\frac{B_c}{\alpha}$ are coprime. Thus for $B_c = 15$ (hence $B = 30$), for example, we obtain a single string component for each of the two interbraided components.

Note that for the lower-right component in Fig. 564 the end-point of the first-return string-run lies **below** its starting-point, which results again in $\beta = 5$.

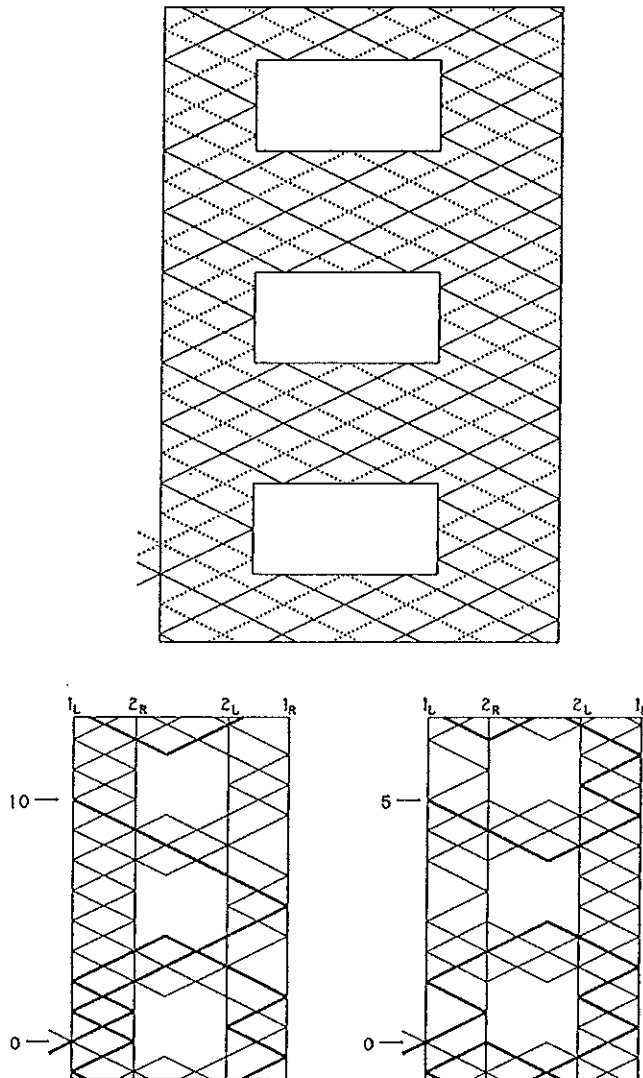


Fig. 564 — An interbraid of two single string components.

From the above Examples the importance of the first-return string-run in a component will be evident. It appears that in the past its importance or even its existence has been totally overlooked as otherwise the general relationship:

$$\lambda_c = \text{g.c.d.} \left(\frac{\beta_c}{\alpha_c}, \frac{B_c}{\alpha_c} \right)$$

would have been known. It appears that in the past only the case for a single component Cylindrical Braid with $\alpha = 1$ was experimentally discovered (in fact it is still being discovered experimentally in more recent times, see the Newsletter of the International Guild of Knot Tyers, issue No. 56, pp. 39–40, and issue No. 57, pp. 22–25). When for a single component Cylindrical Braid $\alpha = 1$ the Cylindrical Braid is a Regular Cylindrical Braid and $\beta = p$ (the number of its parts), consequently:

$$\lambda = \text{g.c.d.} \left(\frac{\beta}{\alpha}, \frac{B_c}{\alpha} \right) = \text{g.c.d.} (p, b),$$

where b is the number of bights of the Regular Cylindrical Braid.

It is only a tiny step from the Regular Cylindrical Braids to the Perfect Nested Cylindrical Braids. A Perfect Nested Cylindrical Braid has also only one first-return string-run (consequently only one component) and hence its B_c -value is its B -value, while its $\frac{\beta}{\alpha}$ -value is its P -value (the number of its parts). Hence for a Perfect Nested Cylindrical Braid we obtain $\alpha = A^{**}$ and hence $\frac{B_c}{\alpha} = \frac{B}{A^{**}} = B^{**}$ with

$$\lambda = \text{g.c.d.} \left(\frac{\beta}{\alpha}, \frac{B_c}{\alpha} \right) = \text{g.c.d.} (P, B^{**}).$$

Another small step brings us to the Nested Cylindrical Braids with more than one type of first-return string-run, hence more than one component. For a component of such a Nested Cylindrical Braid we obtain:

$$\begin{aligned} \frac{\beta_c}{\alpha_c} &= \frac{\alpha \cdot x + \sum (\Delta l_i + \Delta r_i)}{A^{**}} = P_c, \\ \frac{B_c}{\alpha_c} &= \frac{B_{total}}{A^{**}} = B^{**}, \\ \lambda_c &= \text{g.c.d.} \left(\frac{\beta_c}{\alpha_c}, \frac{B_c}{\alpha_c} \right) = \text{g.c.d.} (P_c, B^{**}). \end{aligned}$$

Nested Cylindrical Braids

The string-runs of some Perfect Regular Nested Cylindrical Braids ($\text{g.c.d.}(\Delta, A) = 1$) can be enlarged to string-runs of bigger Perfect Regular Nested Cylindrical Braids. In the enlargement process any additional nests of bights can only be formed in the external valleys between the original nests of bights; in other words, they can on the left-hand bight-edge as well as on the right-hand bight-edge only be formed between half-cycles which start and end in adjacent nests at bight-boundary 1.

There are in essence two different enlargement processes:

Method I where the enlargement process starts with a lower-left to upper-right half-cycle **below** the Standing-End half-cycle.

Method II where the enlargement process starts with a lower-left to upper-right half-cycle **above** the Standing-End half-cycle.

Thus for enlargement process **Method I**, the first enlarging half-cycle (from lower-left to upper-right) must run:

1. either between the Standing-End half-cycle $1 \rightarrow 1$, and the half-cycle $2 \rightarrow A$ immediately **below** it,
2. or between half-cycle $A \rightarrow 1$ of the nest to which the Standing-End half-cycle $1 \rightarrow A$ belongs, and the half-cycle $1 \rightarrow A$ immediately **below** it.

While for enlargement process **Method II**, the first enlarging half-cycle (from lower-left to upper-right) must run:

1. either between the Standing-End half-cycle $A \rightarrow A$, and the half-cycle $(A-1) \rightarrow 1$ immediately **above** it,
2. or between half-cycle $1 \rightarrow A$ of the nest to which the Standing-End half-cycle $A \rightarrow 1$ belongs, and the half-cycle $A \rightarrow 1$ immediately **above** it.

Method I-1 : (See Fig. 565)

For enlargement **Method I-1** the second enlarging half-cycle (from lower-right to upper-left) could run between an $A \leftarrow 1$ half-cycle and the $1 \leftarrow A$ half-cycle immediately **above** it.

The final half-cycle in the enlargement process (from lower-right to upper-left) must run immediately **above** the $A \leftarrow 1$ half-cycle belonging to the nest to which the Standing-End half-cycle originally belonged. Hence in general, every even half-cycle in the enlargement process must run between an $A \leftarrow 1$ half-cycle and the $1 \leftarrow A$ half-cycle immediately **above** it. The earlier stated possible position of the second enlarging half-cycle fulfils this general requirement.

The string-run of the braid to be enlarged has thus a Δ -value of $A - 1$, hence is a string-run of a Perfect Regular Nested Cylindrical Braid.

Since the condition for the necessary position of the additionally created nests prevents the third enlarging half-cycle to run between an $1 \rightarrow 1$ half-cycle and the $A \rightarrow 2$ half-cycle immediately **above** it; it follows that the third enlarging half-cycle must run immediately **above** the first enlarging half-cycle. Hence the enlargement will create only one additional nest of bights on the left-hand bight-edge and one additional nest of bights on the right-hand bight-edge.

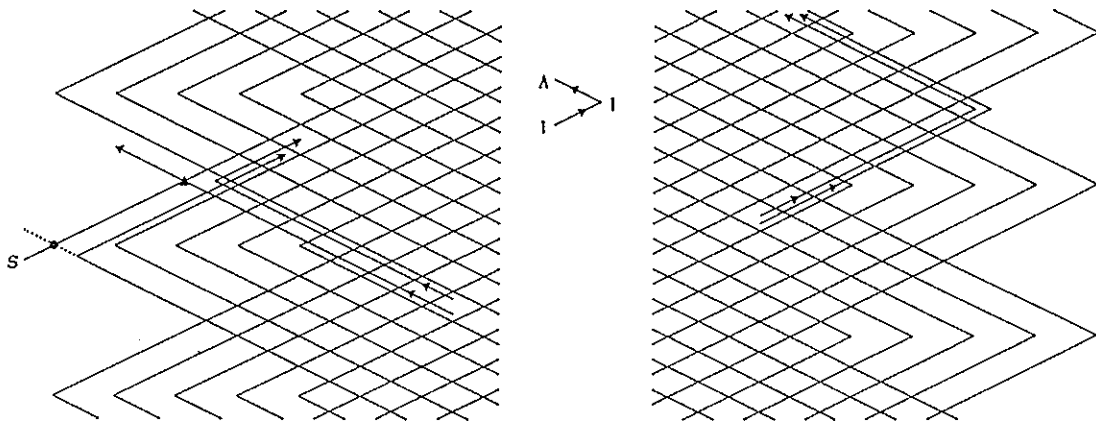


Fig. 565 — Method I-1 enlargement.

Method I-2 : (See Fig. 566)

For enlargement **Method I-2** the second enlarging half-cycle (from lower-right to upper-left) could run between an $A \leftarrow 1$ half-cycle and the $1 \leftarrow A$ half-cycle immediately **above** it.

The final half-cycle in the enlargement process (from lower-right to upper-left) must run immediately **below** the $2 \leftarrow A$ half-cycle belonging to the nest to which the

Standing-End half-cycle belongs. Hence in general, every even half-cycle in the enlargement process must run between an $1 \leftarrow 1$ half-cycle and the $2 \leftarrow A$ half-cycle immediately above it. The earlier stated possible position of the second enlarging half-cycle does not fulfil this general requirement. Hence the general requirement for the even half-cycles in the enlargement process only allows the creation of one additional nest of bights on the left-hand bight-edge and one additional nest of bights on the right-hand bight-edge.

The third half-cycle in the enlargement process runs immediately below the first enlarging half-cycle.

The string-run of the braid to be enlarged has thus a Δ -value of 1, hence is a string-run of a Perfect Regular Nested Cylindrical Braid.

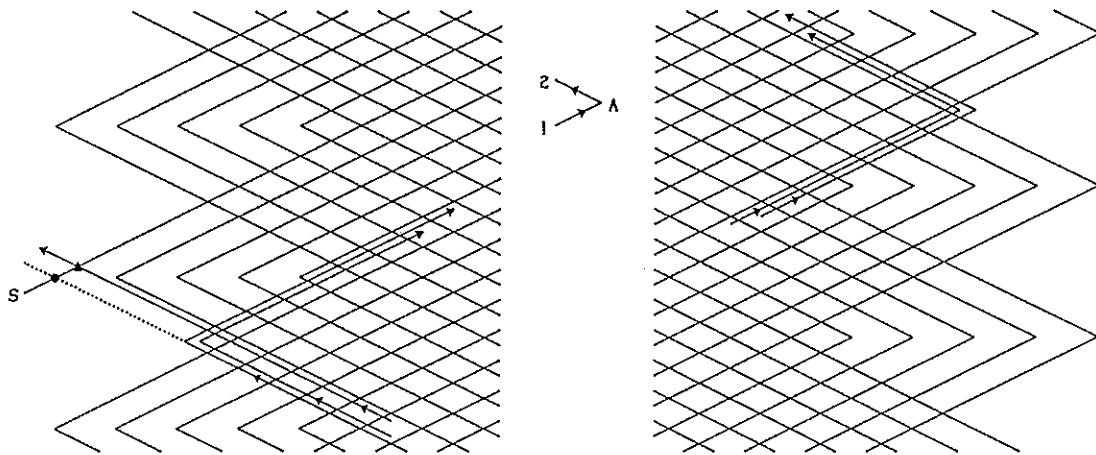


Fig. 566 — Method I-2 enlargement.

Method II-1 : (See Fig. 567)

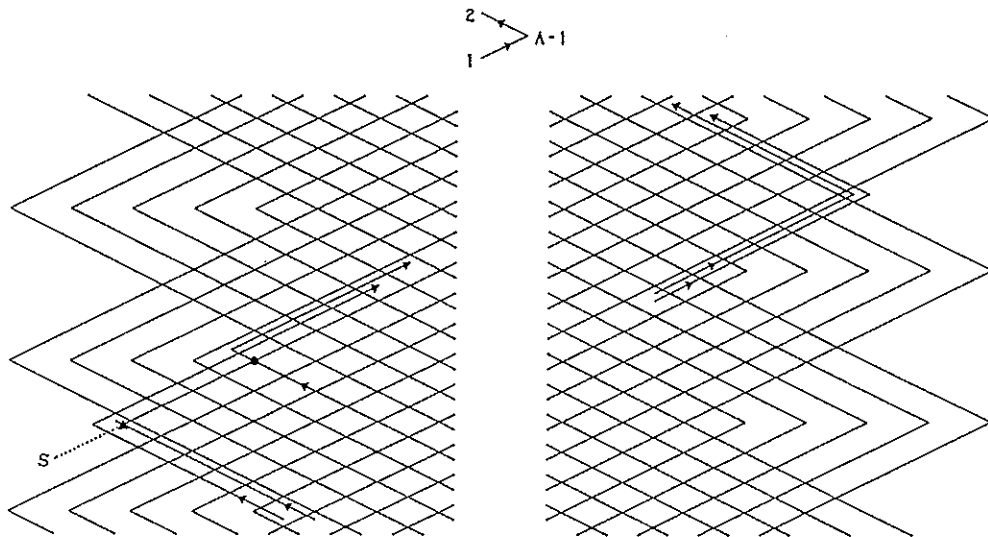


Fig. 567 — Method II-1 enlargement.

For enlargement Method II-1 the second enlarging half-cycle (from lower-right to upper-left) could run between an $A \leftarrow 1$ half-cycle and the $1 \leftarrow A$ half-cycle immediately above it.

The final half-cycle in the enlargement process (from lower-right to upper-left) must run immediately below the $1 \leftarrow A$ half-cycle belonging to the nest to which the Standing-End half-cycle originally belonged. Hence in general, every even half-cycle in

the enlargement process must run between an $A \leftarrow 1$ half-cycle and the $1 \leftarrow A$ half-cycle immediately above it. The earlier stated possible position of the second enlarging half-cycle fulfils this general requirement.

The string-run of the braid to be enlarged has thus a Δ -value of 1, hence is a string-run of a Perfect Regular Nested Cylindrical Braid.

Since the condition for the necessary position of the additionally created nests prevents the third enlarging half-cycle to run between an $1 \rightarrow (A - 1)$ half-cycle and the $A \rightarrow A$ half-cycle immediately above it; it follows that the third enlarging half-cycle must run immediately below the first enlarging half-cycle. Hence the enlargement will create only one additional nest of bights on the left-hand bight-edge and one additional nest of bights on the right-hand bight-edge.

Method II-2 : (See Fig. 568)

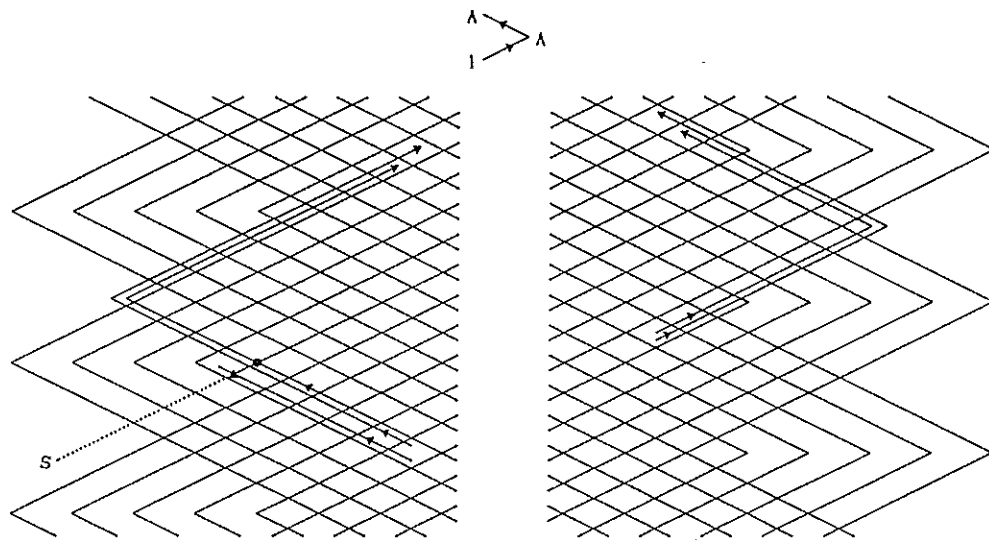


Fig. 568 — Method II-2 enlargement.

For enlargement Method II-2 the second enlarging half-cycle (from lower-right to upper-left) could run between an $A \leftarrow 1$ half-cycle and the $1 \leftarrow A$ half-cycle immediately above it.

The final half-cycle in the enlargement process (from lower-right to upper-left) must run immediately above the $(A - 1) \leftarrow 1$ half-cycle belonging to the nest to which the Standing-End half-cycle belongs. Hence in general, every even half-cycle in the enlargement process must run between an $(A - 1) \leftarrow 1$ half-cycle and the $A \leftarrow A$ half-cycle immediately above it. The earlier stated possible position of the second enlarging half-cycle does not fulfil this general requirement. Hence the general requirement for the even half-cycles in the enlargement process only allows the creation of one additional nest of bights on the left-hand bight-edge and one additional nest of bights on the right-hand bight-edge.

The third half-cycle in the enlargement process runs immediately above the first enlarging half-cycle.

The string-run of the braid to be enlarged has thus a Δ -value of $A - 1$, hence is a string-run of a Perfect Regular Nested Cylindrical Braid.

For the Perfect Regular Nested Cylindrical Braid to be enlarged according to enlargement Method I-1 :

i.) $\Delta = A - 1$; $y = A - 1$. Standing-End at left bight-boundary 1; Standing-End half-cycle $1 \rightarrow 1$.

$$x = (2n - 3)A + 3; B^* = \frac{2n - 1}{m}; P = (2n - 1)A + 1.$$

n and m are natural numbers; m divides into $2n - 1$.

For the resulting enlarged Perfect Regular Nested Cylindrical braid:

$$x_e = x + mA; y_e = |y + mA|_{2A} = |(m + 1)A - 1|_{2A}; B_e^* = B^* + 1; P_e = P + mA.$$

ii.) $\Delta = A - 1$; $y = 2A - 1$. Standing-End at left bight-boundary 1; Standing-End half-cycle $1 \rightarrow 1$.

$$x = (2n - 2)A + 3; B^* = \frac{2n}{m}; P = 2nA + 1.$$

n and m are natural numbers; m divides into $2n$.

For the resulting enlarged Perfect Regular Nested Cylindrical braid:

$$x_e = x + mA; y_e = |y + mA|_{2A} = |mA - 1|_{2A}; B_e^* = B^* + 1; P_e = P + mA.$$

For the Perfect Regular Nested Cylindrical Braid to be enlarged according to enlargement **Method I-2**:

i.) $\Delta = 1$; $y = A + 1$. Standing-End at left bight-boundary 1; Standing-End half-cycle $1 \rightarrow A$.

$$x = (2n - 3)A + 3; B^* = \frac{2n - 1}{m}; P = (2n - 1)A + 1.$$

n and m are natural numbers; m divides into $2n - 1$.

For the resulting enlarged Perfect Regular Nested Cylindrical braid:

$$x_e = x + mA; y_e = |y + mA|_{2A} = |(m + 1)A + 1|_{2A}; B_e^* = B^* + 1; P_e = P + mA.$$

ii.) $\Delta = 1$; $y = 1$. Standing-End at left bight-boundary 1; Standing-End half-cycle $1 \rightarrow A$.

$$x = (2n - 2)A + 3; B^* = \frac{2n}{m}; P = 2nA + 1.$$

n and m are natural numbers; m divides into $2n$.

For the resulting enlarged Perfect Regular Nested Cylindrical braid:

$$x_e = x + mA; y_e = |y + mA|_{2A} = |mA + 1|_{2A}; B_e^* = B^* + 1; P_e = P + mA.$$

For the Perfect Regular Nested Cylindrical Braid to be enlarged according to enlargement **Method II-1**:

i.) $\Delta = 1$; $y = A + 1$. Standing-End at left bight-boundary A ; Standing-End half-cycle $A \rightarrow A$.

$$x = (2n - 1)A + 1; B^* = \frac{2n + 1}{m}; P = (2n + 1)A - 1.$$

n and m are natural numbers; m divides into $2n + 1$.

For the resulting enlarged Perfect Regular Nested Cylindrical braid:

$$x_e = x + mA; y_e = |y + mA|_{2A} = |(m + 1)A + 1|_{2A}; B_e^* = B^* + 1; P_e = P + mA.$$

ii.) $\Delta = 1$; $y = 1$. Standing-End at left bight-boundary A ; Standing-End half-cycle $A \rightarrow A$.

$$x = (2n - 2)A + 1; B^* = \frac{2n}{m}; P = 2nA - 1.$$

n and m are natural numbers; m divides into $2n$.

For the resulting enlarged Perfect Regular Nested Cylindrical braid:

$$x_e = x + mA; y_e = |y + mA|_{2A} = |mA + 1|_{2A}; B_e^* = B^* + 1; P_e = P + mA.$$

For the Perfect Regular Nested Cylindrical Braid to be enlarged according to enlargement **Method II-2**:

i.) $\Delta = A - 1$; $y = A - 1$. Standing-End at left bight-boundary A ; Standing-End half-cycle $A \rightarrow 1$.

$$x = (2n - 1)A + 1; B^* = \frac{2n + 1}{m}; P = (2n + 1)A - 1.$$

n and m are natural numbers; m divides into $2n + 1$.

For the resulting enlarged Perfect Regular Nested Cylindrical braid:

$$x_e = x + mA; y_e = |y + mA|_{2A} = |(m + 1)A - 1|_{2A}; B_e^* = B^* + 1; P_e = P + mA.$$

ii.) $\Delta = A - 1$; $y = 2A - 1$. Standing-End at left bight-boundary A ; Standing-End half-cycle $A \rightarrow 1$.

$$x = (2n - 2)A + 1; B^* = \frac{2n}{m}; P = 2nA - 1.$$

n and m are natural numbers; m divides into $2n$.

For the resulting enlarged Perfect Regular Nested Cylindrical braid:

$$x_e = x + mA; y_e = |y + mA|_{2A} = |mA - 1|_{2A}; B_e^* = B^* + 1; P_e = P + mA.$$

The above formulae show that $\text{g.c.d.}(P, B^*) = 1$ and hence the above Perfect Regular Nested Cylindrical Braids are single string braids, hence are Perfect Regular Nested Knots.

★ ★ Prove the above formulae.

Recall from pp.644-645 (*The Braider*, Issue No.28) that for $y = A - 1$ and for $y = A + 1$ we are able to superimpose on the string-run of a Regular Nested Cylindrical Braid a **Herringbone Pineapple coding**. Thus the cases Method I-1(i), Method I-2(i), Method II-1(i), and Method II-2(i) fall within this category. It should be noted that in order to obtain an enlarged knot with a Herringbone Pineapple coding, we have to execute the selected enlarging method twice due to the A -over— A -under coding.

Example 1:

The Perfect Herringbone Pineapple Knot in Bruce Grant's *Encyclopedia of Rawhide and Leather Braiding*, pp.432-433.

The specification of the string-run of this Perfect Herringbone Pineapple Knot[†] is $(2/5/2)\{12/21\}6$.

$A = 2$; $x = 5$; $k = 2$ and $B^* = 3$, hence $y = |x - 2k - 2|_{2A} = |5 - 4 - 2|_4 = |-1|_4 = 3 = A + 1$ and $B = B^*A = 3 \times 2 = 6$. Its string-run diagram and grid-diagram are depicted in Fig. 569.

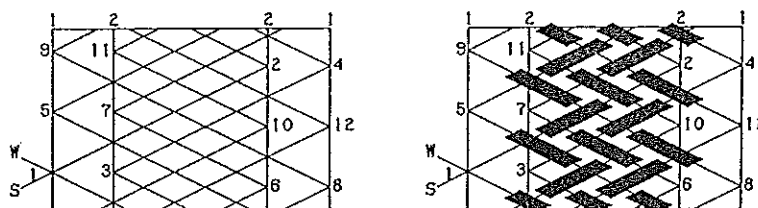


Fig. 569 — The Perfect Herringbone Pineapple Knot $(2/5/2)\{12/21\}6$.

[†] There are some errors on pp. 432-433 of Bruce Grant's *Encyclopedia of Rawhide and Leather Braiding*.

The half-cycle braiding algorithms are :

- | | | | | | |
|----|------------------|-----------|-----|------------------|------------------|
| 1. | $1 \nearrow 2$: | Free run. | 7. | $2 \nearrow 1$: | $o - u$. |
| 2. | $2 \searrow 2$: | Free run. | 8. | $1 \searrow 1$: | $2u - 2o$. |
| 3. | $2 \nearrow 1$: | Free run. | 9. | $1 \nearrow 2$: | $2o - 2u$. |
| 4. | $1 \searrow 1$: | $2o$. | 10. | $2 \searrow 2$: | $u - 2o - u$. |
| 5. | $1 \nearrow 2$: | $2u$. | 11. | $2 \nearrow 1$: | $u - 2o - u$. |
| 6. | $2 \searrow 2$: | $o - u$. | 12. | $1 \searrow 1$: | $2o - 2u - 2o$. |

This Perfect Herringbone Pineapple Knot can be enlarged in accordance with Method I-2(i) where $A = 2$; $y = A + 1$; $n = 2$; $m = 1$. Standing-End at left bight-boundary 1; Standing-End half-cycle $1 \rightarrow A$.

Thus $x = A + 3 = 5$; $B^* = 3$; $P = 2A + x - 2 = 4 + 5 - 2 = 7$.

After the first enlargement process has been completed we obtain a Perfect Regular Nested Knot (see Fig. 570) with $x_{e_1} = x + mA = 5 + 2 = 7$; $B_{e_1}^* = B^* + 1 = 3 + 1 = 4$; $P_{e_1} = P + mA = 7 + 2 = 9$; it has, however, **not** a Herringbone Pineapple coding.

This first enlargement process consists of the following half-cycle steps :

- | | | |
|-----|------------------|-----------------------|
| 13. | $1 \nearrow 2$: | $2u - 2o - 2u$. |
| 14. | $2 \searrow 2$: | $o - 2u - 2o - u$. |
| 15. | $2 \nearrow 1$: | $o - 2u - 2o - u$. |
| 16. | $1 \searrow 1$: | $2u - 2o - 2u - 2o$. |

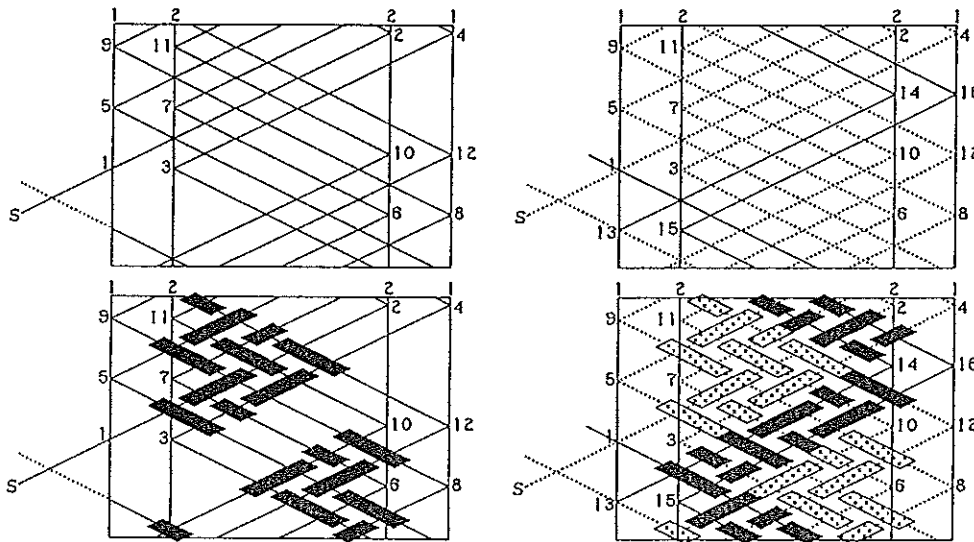


Fig. 570 — The first enlargement.

After the second enlargement process has been completed we obtain again a Perfect Regular Nested Knot (see Fig. 571), now with $x_{e_2} = x_{e_1} + mA = 7 + 2 = 9$; $B_{e_2}^* = B_{e_1}^* + 1 = 4 + 1 = 5$; $P_{e_2} = P_{e_1} + mA = 9 + 2 = 11$; it can now have a Herringbone Pineapple coding.

This second enlargement process consists of the following half-cycle steps :

- | | | |
|-----|------------------|----------------------------|
| 17. | $1 \nearrow 2$: | $2o - 2u - 2o - 2u$. |
| 18. | $2 \searrow 2$: | $u - 2o - 2u - 2o - u$. |
| 19. | $2 \nearrow 1$: | $u - 2o - 2u - 2o - u$. |
| 20. | $1 \searrow 1$: | $2o - 2u - 2o - 2u - 2o$. |

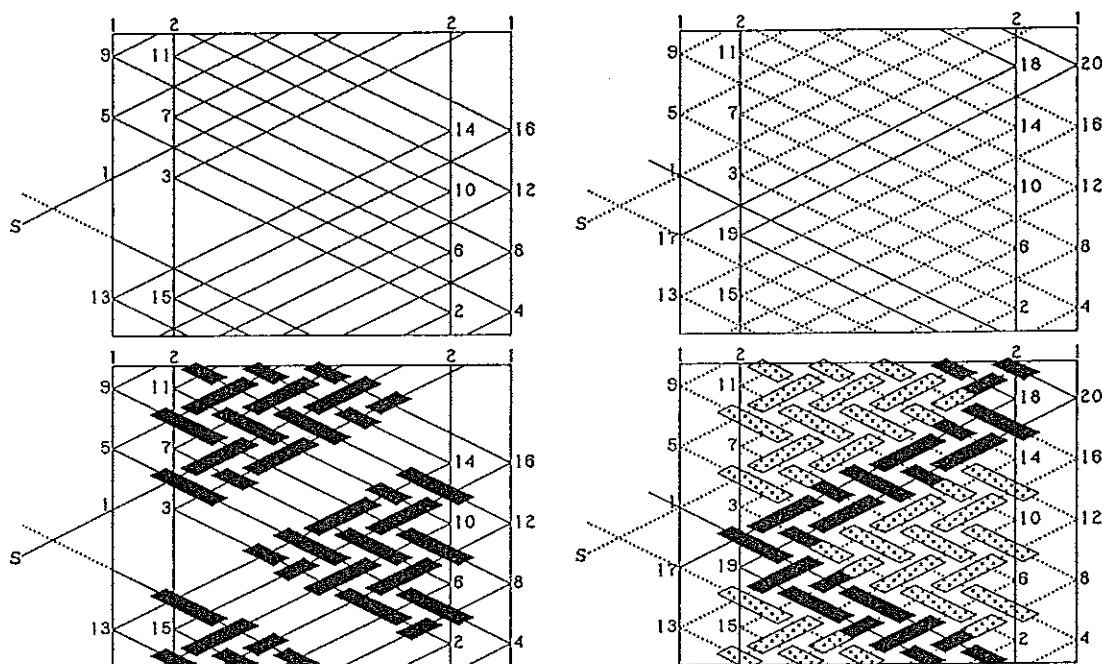


Fig. 571 — The second enlargement.

Notice that $A = 2$ is a special case due to being the lower limit value of A . Hence let's take a Perfect Herringbone Pineapple Knot example with $A > 2$.

Example 2:

$A = 3$; $x = 10$; $k = 3$ and $B^* = 5$, hence $y = |x - 2k - 2|_{2A} = |10 - 6 - 2|_6 = |2|_6 = 2 = A - 1$ and $B = B^*A = 5 \times 3 = 15$. Its string-run diagram and grid-diagram are depicted in Fig. 572.

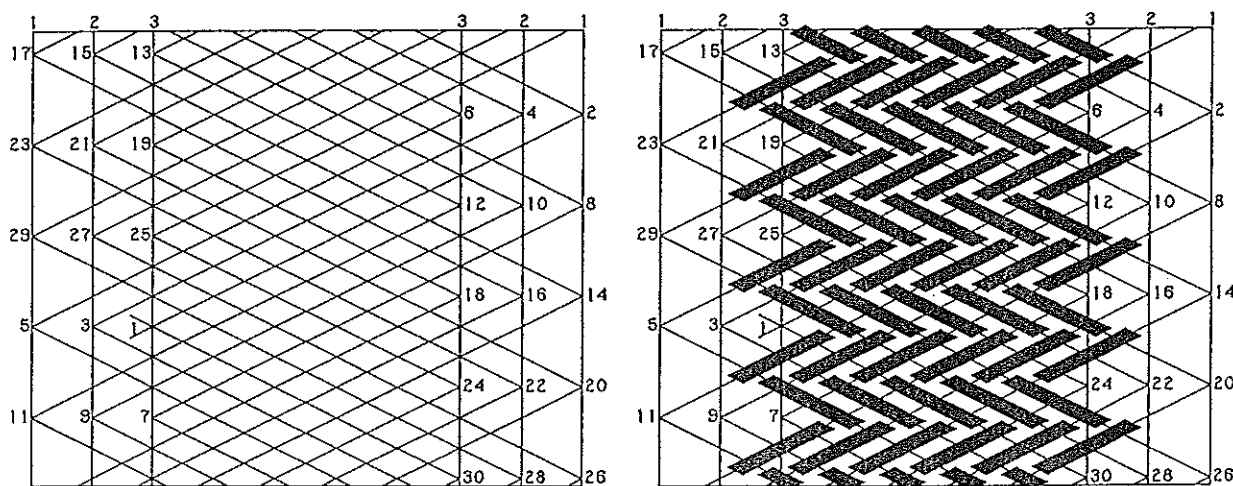


Fig. 572 — The Perfect Herringbone Pineapple Knot $(22/10/22)\{132/312\}15$.

The half-cycle braiding algorithms are:

- | | | | | | |
|----|------------------|-----------|-----|------------------|----------------------|
| 1. | $3 \nearrow 1$: | Free run. | 16. | $1 \searrow 2$: | $2u - 3o - u$. |
| 2. | $2 \searrow 1$: | Free run. | 17. | $1 \nearrow 3$: | $3o - 2u$. |
| 3. | $2 \nearrow 2$: | Free run. | 18. | $3 \searrow 3$: | $3u - 3o$. |
| 4. | $1 \searrow 2$: | Free run. | 19. | $3 \nearrow 1$: | $2u - 3o - 3u$. |
| 5. | $1 \nearrow 3$: | Free run. | 20. | $2 \searrow 1$: | $u - 3o - 3u - 2o$. |

6.	$3 \searrow 3$:	Free run.	21.	$2 \nearrow 2$:	$u - 3o - 3u - o$.
7.	$3 \nearrow 1$:	$2u$.	22.	$1 \searrow 2$:	$2u - 3o - 3u - o$.
8.	$2 \searrow 1$:	$u - 2o$.	23.	$1 \nearrow 3$:	$3o - 3u - 2o$.
9.	$2 \nearrow 2$:	$u - o$.	24.	$3 \searrow 3$:	$3u - 3o - 3u$.
10.	$1 \searrow 2$:	$2u - o$.	25.	$3 \nearrow 1$:	$2u - 3o - 3u - 3o$.
11.	$1 \nearrow 3$:	$2o$.	26.	$2 \searrow 1$:	$u - 3o - 3u - 3o - 2u$.
12.	$3 \searrow 3$:	$3u$.	27.	$2 \nearrow 2$:	$u - 3o - 3u - 3o - u$.
13.	$3 \nearrow 1$:	$2u - 3o$.	28.	$1 \searrow 2$:	$2u - 3o - 3u - 3o - u$.
14.	$2 \searrow 1$:	$u - 3o - 2u$.	29.	$1 \nearrow 3$:	$3o - 3u - 3o - 2u$.
15.	$2 \nearrow 2$:	$u - 3o - u$.	30.	$3 \searrow 3$:	$3u - 3o - 3u$.

This Perfect Herringbone Pineapple Knot can be enlarged in accordance with Method II-2(i) where $A = 3$; $y = A - 1$; $n = 2$; $m = 1$. Standing-End at left bight-boundary $A = 3$; Standing-End half-cycle $A \rightarrow 1$.

Thus $x = 3A + 1 = 10$; $B^* = 5$; $P = 2A + x - 2 = 6 + 10 - 2 = 14$.

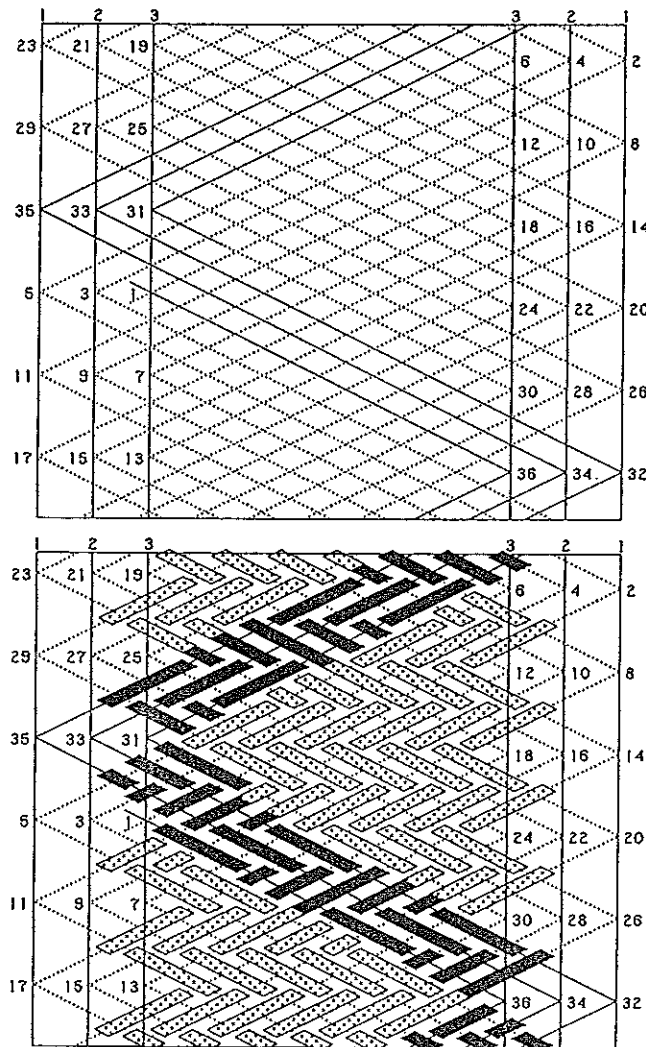


Fig. 573 — The first enlargement.

After the first enlargement process has been completed we obtain a Perfect Regular Nested Knot (see Fig. 573) with $x_{e_1} = x + mA = 10 + 3 = 13$; $B_{e_1}^* = B^* + 1 = 5 + 1 = 6$; $P_{e_1} = P + mA = 14 + 3 = 17$; it has, however, not a Herringbone Pineapple coding.

This first enlargement process consists of the following half-cycle steps:

Continue half-cycle 30 with 3o.

- 31. $3 \nearrow 1$: $2u - 3o - 3u - 3o - 3u$.
- 32. $2 \nwarrow 1$: $u - 3o - 3u - 3o - 3u - 2o$.
- 33. $2 \nearrow 2$: $u - 3o - 3u - 3o - 3u - o$.
- 34. $1 \nwarrow 2$: $2u - 3o - 3u - 3o - 3u - o$.
- 35. $1 \nearrow 3$: $3o - 3u - 3o - 3u - 2o$.
- 36. $3 \nwarrow 3$: $3u - 3o - 3u - 3o$.

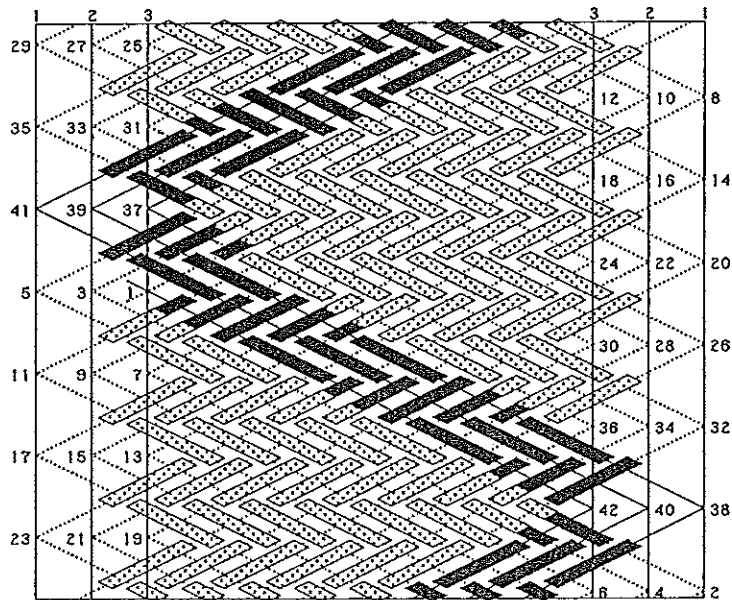
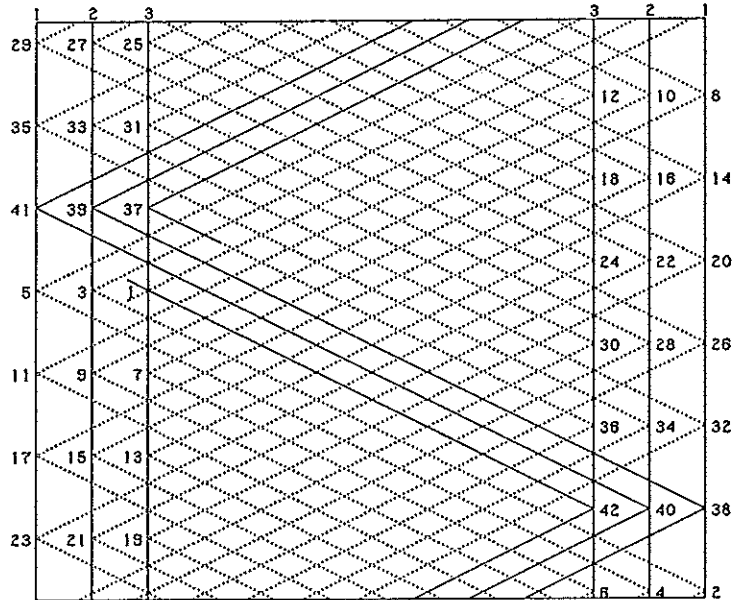


Fig. 574 — The second enlargement.

After the second enlargement process has been completed we obtain again a Perfect Regular Nested Knot (see Fig. 574), now with $x_{e_2} = x_{e_1} + mA = 13 + 3 = 16$; $B_{e_2}^* = B_{e_1}^* + 1 = 6 + 1 = 7$; $P_{e_2} = P_{e_1} + mA = 17 + 3 = 20$; it can now have a Herringbone Pineapple coding.

This second enlargement process consists of the following half-cycle steps:

Continue half-cycle 36 with 3u.

- 37. $3 \nearrow 1$: $2u - 3o - 3u - 3o - 3u - 3o$.

- 38. $2 \searrow 1$: $u - 3o - 3u - 3o - 3u - 3o - 2u$.
- 39. $2 \nearrow 2$: $u - 3o - 3u - 3o - 3u - 3o - u$.
- 40. $1 \searrow 2$: $2u - 3o - 3u - 3o - 3u - 3o - u$.
- 41. $1 \nearrow 3$: $3o - 3u - 3o - 3u - 3o - 2u$.
- 42. $3 \searrow 3$: $3u - 3o - 3u - 3o - 3u$.

Example 3:

$A = 4$; $x = 31$; $k = 1$ and $B^* = 3$, hence $y = |x - 2k - 2|_{2A} = |31 - 2 - 2|_8 = |27|_8 = 3 = A - 1$ and $B = B^*A = 3 \times 4 = 12$.

The string-run diagram and the grid-diagram of this Perfect Herringbone Pineapple Knot is depicted in Fig. 575.

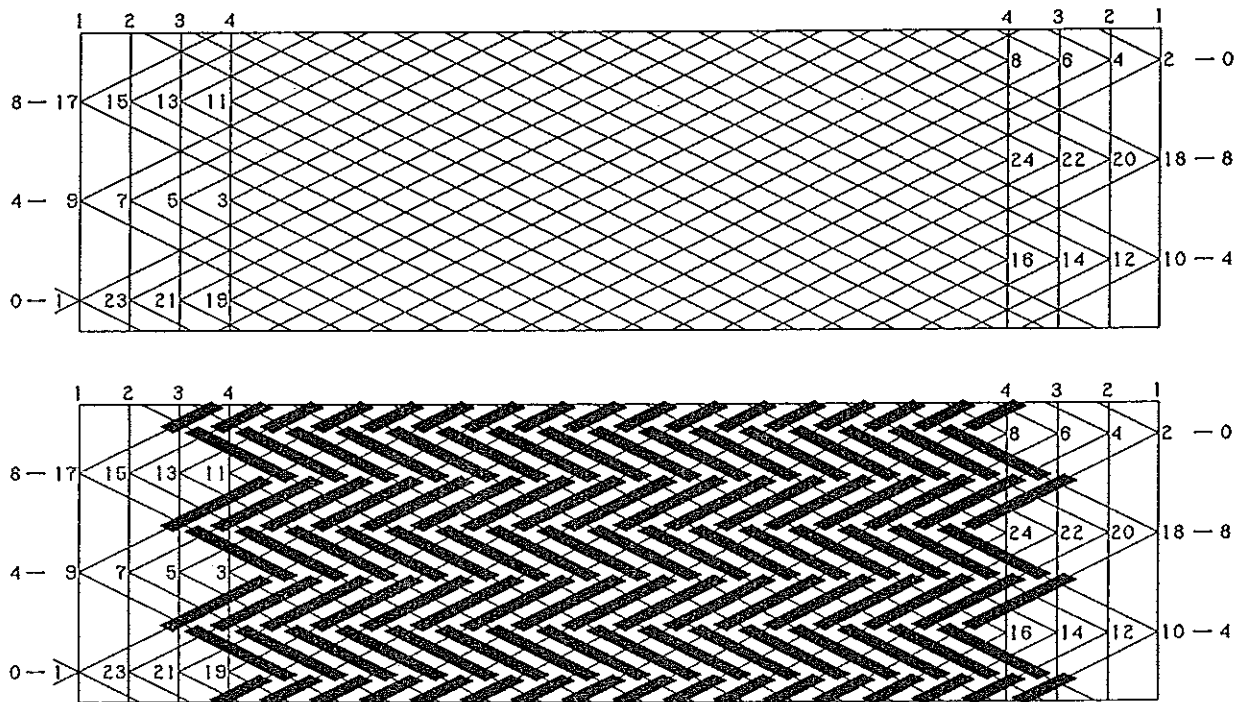


Fig. 575 — The Perfect Herringbone Pineapple Knot $(22/31/22)\{1432/1234\}12$.

The first-return string-run is drawn up again first, and from the information it contains we can draw up the half-cycle pattern as shown in Fig. 576. Then from this half-cycle pattern we assemble the half-cycle tables shown in Fig. 577. Finally, from these half-cycle tables we can read off the following half-cycle braiding algorithms:

- 1. $1 \nearrow 1$: Free run.
- 2. $4 \searrow 1$: $u - o - u$.
- 3. $4 \nearrow 2$: $o - u$.
- 4. $3 \searrow 2$: $2u - 2o - u$.
- 5. $3 \nearrow 3$: $2o - 2u$.
- 6. $2 \searrow 3$: $3u - 3o - u$.
- 7. $2 \nearrow 4$: $3o - 3u$.
- 8. $1 \searrow 4$: $4u - 4o - u$.
- 9. $1 \nearrow 1$: $4o - 4u - 4o$.
- 10. $4 \searrow 1$: $o - 5u - 5o - 4u$.
- 11. $4 \nearrow 2$: $3o - u - o - 3u - o - u - 3o - u$.
- 12. $3 \searrow 2$: $2o - 6u - 6o - 3u$.

- 13. $3 \nearrow 3$: $2o - 2u - 2o - 2u - 2o - 2u - 2o - 2u$.
- 14. $2 \searrow 3$: $3o - 7u - 7o - 2u$.
- 15. $2 \nearrow 4$: $o - 3u - 3o - u - 3o - 3u - o - 3u$.
- 16. $1 \searrow 4$: $4o - 8u - 8o - u$.
- 17. $1 \nearrow 1$: $4u - 8o - 8u - 4o$.
- 18. $4 \searrow 1$: $u - 4o - 4u - o - 4u - 4o - u - 4o - 4u$.
- 19. $4 \nearrow 2$: $3u - 4o - u - 4o - 4u - o - 4u - 4o - u$.
- 20. $3 \searrow 2$: $2u - 4o - 4u - 2o - 4u - 4o - 2u - 4o - 3u$.
- 21. $3 \nearrow 3$: $2u - 4o - 2u - 4o - 4u - 2o - 4u - 4o - 2u$.
- 22. $2 \searrow 3$: $3u - 4o - 4u - 3o - 4u - 4o - 3u - 4o - 2u$.
- 23. $2 \nearrow 4$: $u - 4o - 3u - 4o - 4u - 3o - 4u - 4o - 3u$.
- 24. $1 \searrow 4$: $4u - 4o - 4u - 4o - 4u - 4o - 4u - 4o - u$.

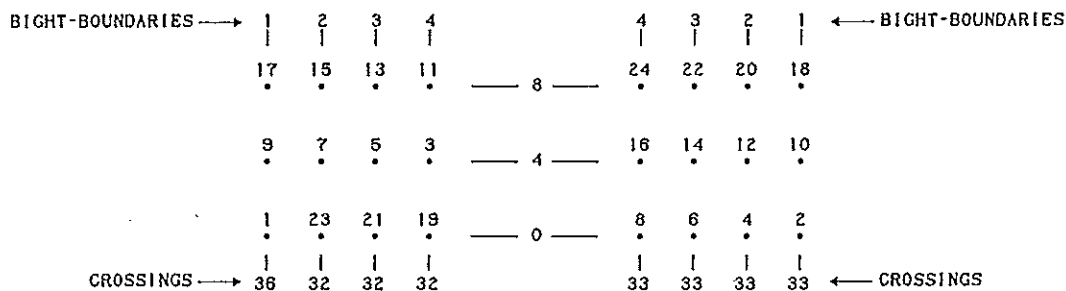
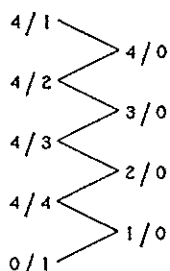


Fig. 576 — First-return string-run and half-cycle pattern.

L → R																																								
	23	21	19	9	7	5	3	17	15	13	11		23	21	19	9	7	5	3	17	15	13	11		23	21	19	9	7	5	3	17	15	13	11					
	17	15	13	11		23	21	19	9	7	5	3	17	15	13	11		23	21	19	9	7	5	3	17	15	13	11		23	21	19	9	7	5	3				
	9	7	5	3	17	15	13	11		23	21	19	9	7	5	3	17	15	13	11		23	21	19	9	7	5	3	17	15	13	11		23	21	19				
	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o				
	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u			23	7	15		
	u	u	o	o	o	o	u	u	u	u	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u			21	5	13		
	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u			19	3	11

R → L																																						
2	4	6	8	10	12	14	16	18	20	22	24	2	4	6	8	10	12	14	16	18	20	22	24	2	4	6	8	10	12	14	16	18						
18	20	22	24	2	4	6	8	10	12	14	16	18	20	22	24	2	4	6	8	10	12	14	16	18	20	22	24	2	4	6	8	10						
10	12	14	16	18	20	22	24	2	4	6	8	10	12	14	16	18	20	22	24	2	4	6	8	10	12	14	16	18	20	22	24	2						
u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	8	16	24
u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	6	14	22	
u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	4	12	20		
u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	o	o	o	o	u	u	u	u	2	10	18			

Fig. 577 — The half-cycle tables for the knot in Example 3.

This Perfect Herringbone Pineapple Knot can be enlarged in accordance with Method I-1(i) where $A = 4$; $y = A - 1$; $n = 5$; $m = 3$. Standing-End at left bight-boundary 1; Standing-End half-cycle $1 \rightarrow 1$.

Thus $x = 7A + 3 = 31$; $B^* = 3$; $P = 2A + x - 2 = 8 + 31 - 2 = 37$.

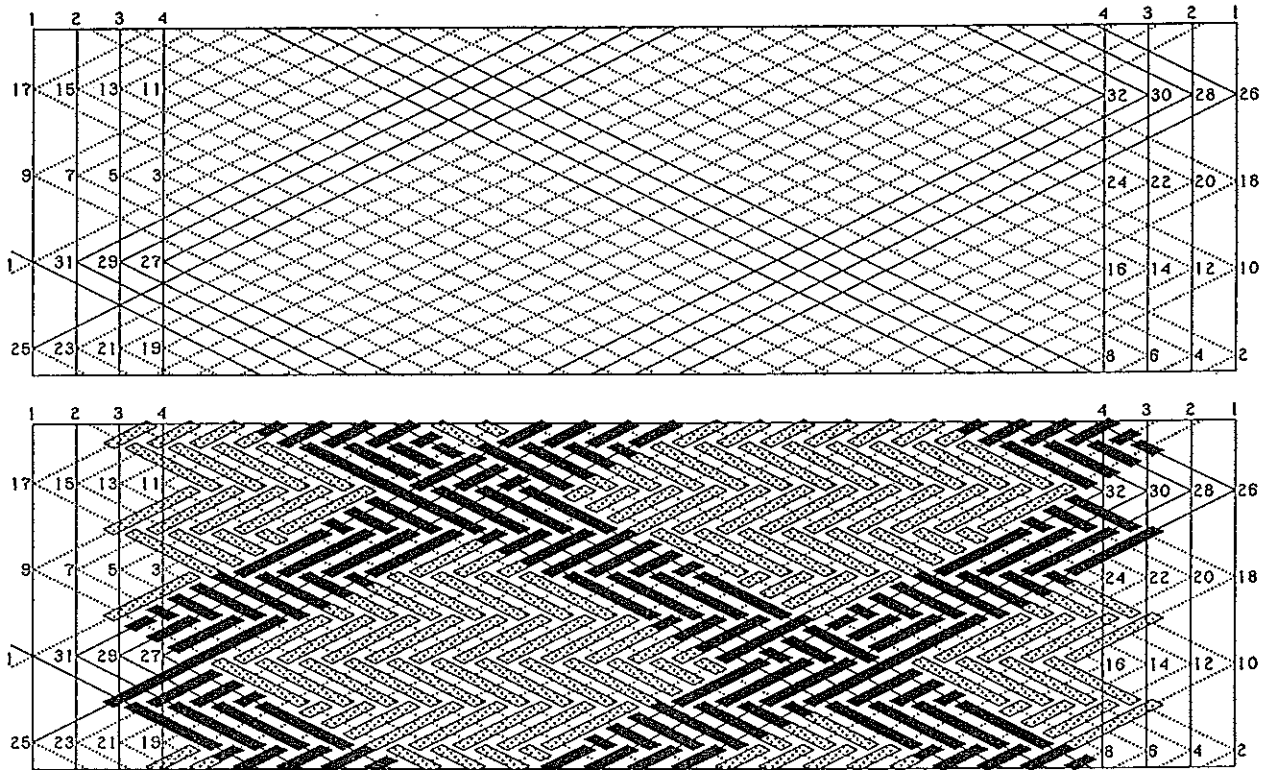


Fig. 578 — The first enlargement.

After the first enlargement process has been completed we obtain a Perfect Regular Nested Knot (see Fig. 578) with $x_{e_1} = x + mA = 31 + 3 \times 4 = 43$; $B_{e_1}^* = B^* + 1 = 3 + 1 = 4$; $P_{e_1} = P + mA = 37 + 3 \times 4 = 49$; it has, however, not a Herringbone Pineapple coding.

This first enlargement process consists of the following half-cycle steps:

25. $1 \nearrow 1$: $4o - 4u - 4o - 4u - 4o - 4u - 4o - 4u - 4o$.
26. $4 \searrow 1$: $o - 4u - 4o - 5u - 4o - 4u - 5o - 4u - 4o - 4u$.
27. $4 \nearrow 2$: $3o - 4u - 4o - u - o - 3u - 4o - 4u - o - u - 3o - 4u - 4o - u$.
28. $3 \searrow 2$: $2o - 4u - 4o - 6u - 4o - 4u - 6o - 4u - 4o - 3u$.
29. $3 \nearrow 3$: $2o - 4u - 4o - 2u - 2o - 2u - 4o - 4u - 2o - 2u - 2o - 4u - 4o - 2u$.
30. $2 \searrow 3$: $3o - 4u - 4o - 7u - 4o - 4u - 7o - 4u - 4o - 2u$.
31. $2 \nearrow 4$: $o - 4u - 4o - 3u - 3o - u - 4o - 4u - 3o - 3u - o - 4u - 4o - 3u$.
32. $1 \searrow 4$: $4o - 4u - 4o - 8u - 4o - 4u - 8o - 4u - 4o - u$.

After the second enlargement process has been completed we obtain again a Perfect Regular Nested Knot (see Fig. 579), now with $x_{e_2} = x_{e_1} + mA = 43 + 3 \times 4 = 55$; $B_{e_2}^* = B_{e_1}^* + 1 = 4 + 1 = 5$; $P_{e_2} = P_{e_1} + mA = 49 + 3 \times 4 = 61$; it can now have a Herringbone Pineapple coding.

This second enlargement process consists of the following half-cycle steps:

33. $1 \nearrow 1$: $4o - 4u - 4o - 4u - 8o - 4u - 4o - 8u - 4o - 4u - 4o$.
34. $4 \searrow 1$: $u - 4o - 4u - 4o - 4u - o - 4u - 4o - 4u - 4o - u - 4o - 4u - 4o - 4u$.
35. $4 \nearrow 2$: $3u - 4o - 4u - 4o - u - 4o - 4u - 4o - 4u - o - 4u - 4o - 4u - 4o - u$.

- 36. $3 \searrow 2$: $2u - 4o - 4u - 4o - 4u - 2o - 4u - 4o - 4u - 4o - 2u - 4o - 4u - 4o - 3u$.
- 37. $3 \nearrow 3$: $2u - 4o - 4u - 4o - 2u - 4o - 4u - 4o - 4u - 2o - 4u - 4o - 4u - 4o - 2u$.
- 38. $2 \searrow 3$: $3u - 4o - 4u - 4o - 4u - 3o - 4u - 4o - 4u - 4o - 3u - 4o - 4u - 4o - 2u$.
- 39. $2 \nearrow 4$: $u - 4o - 4u - 4o - 3u - 4o - 4u - 4o - 4u - 3o - 4u - 4o - 4u - 4o - 3u$.
- 40. $1 \searrow 4$: $4u - 4o - 4u - 4o - 4u - 4o - 4u - 4o - 4u - 4o - 4u - 4o - 4u - 4o - u$.

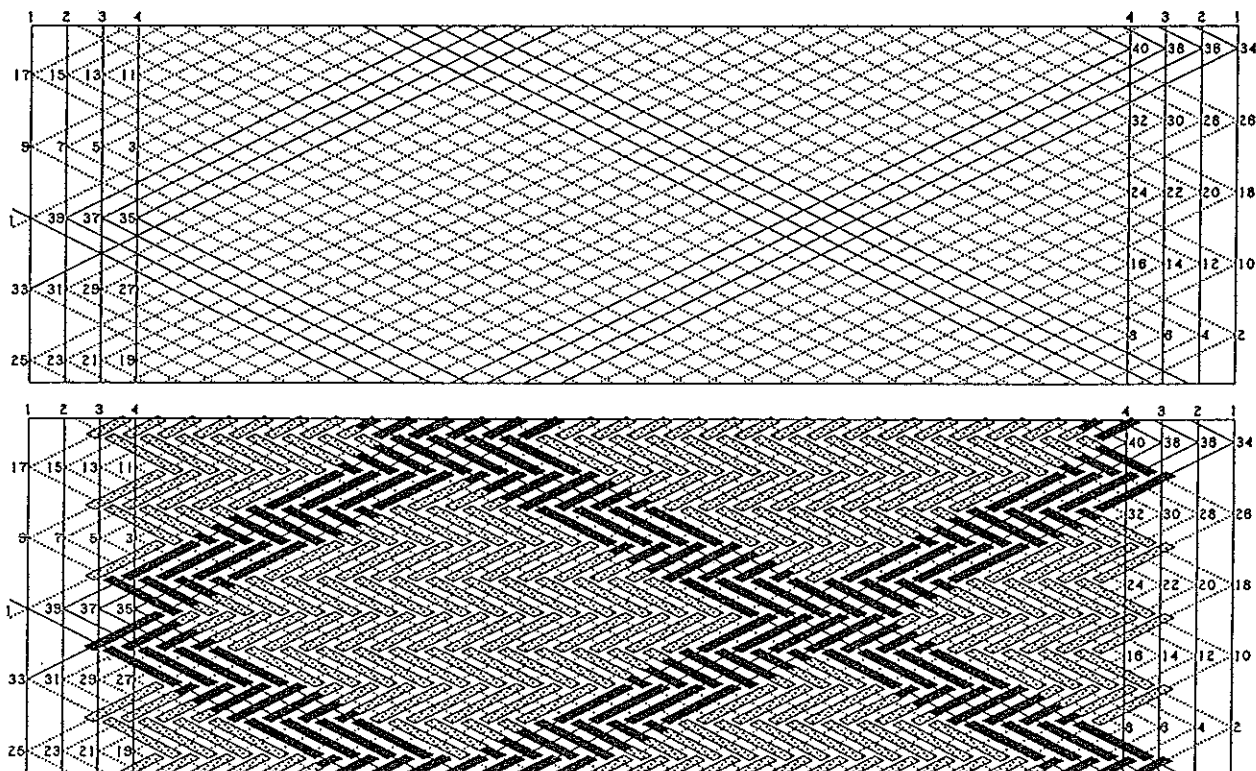


Fig. 579 — The second enlargement.

The Perfect Herringbone Pineapple Knots we began with in Examples 1, 2 and 3 could have been obtained by two successive enlargements of the respective method used from respectively the Perfect Herringbone Pineapple Knots with $x = 1, B^* = 1, P = 3$; $x = 4, B^* = 3, P = 8$; and $x = 7, B^* = 1, P = 13$.

The half-cycle braiding algorithms of the Perfect Herringbone Pineapple Knot we start with must be known or determined. They can be obtained from its half-cycle tables, which are assembled from its half-cycle pattern derived from its first-return string-run. Since two successive enlarging methods of the same type are required in order to enlarge the initial Perfect Herringbone Pineapple Knot to the next larger Perfect Herringbone Pineapple Knot, the two required sets of successive enlarging half-cycle braiding algorithms must be known or determined. Furthermore, only some Perfect Herringbone Pineapple Knots can be enlarged to bigger Perfect Herringbone Pineapple Knots. Hence in practice it is much more convenient to braid the final required Perfect Herringbone Pineapple Knot from its half-cycle braiding algorithms, which are read from its half-cycle tables obtained from its first-return string-run via the half-cycle pattern.

Pitfalls in knot design

With respect to the braiding-patterns of knots, we discussed in *The Braider*, Issue No. 3, pp. 39–41, the vital importance of balance and symmetry, and in *The Braider*, Issue No. 6, pp. 127–132, we discussed the aspect of orientation. There are unfortunately some non-orientational knots in which the designer neglected the important aspects of balance and symmetry. Some of those knots we shall discuss under the above heading.

The Small Pampas Button Knot :

This $p/b = 10/9$ knot, devised by Bruce Grant, is described in his book *Encyclopedia of Rawhide and Leather Braiding* on pg. 437. Its grid-diagram, path-formula, path in the RKT and half-cycle tables are shown in Fig. 580. In a half-cycle table, the i -values are indicated above the thick horizontal line and the half-cycles associated with a half-cycle coding-sequence are indicated in line with this coding-sequence to the right of the thick vertical line.

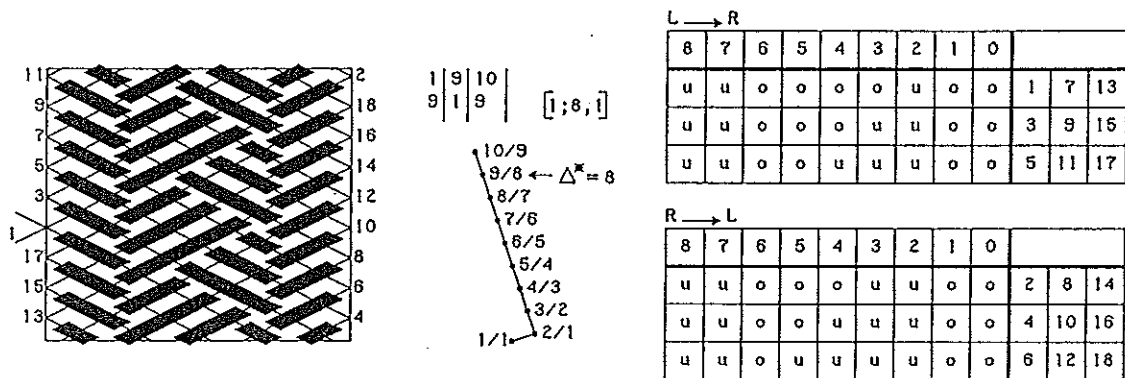


Fig. 580 — The small Pampas knot in the *Encyclopedia of Rawhide and Leather Braiding*.

From the half-cycle tables we read, from left to right, the following half-cycle braiding algorithms :

- | | | | | | | | |
|----|------------|-----------|-------------|------------|------------|-------------|----------------------|
| 1. | : | Free run. | 10. | $i \leq 4$ | : | $3u - 2o$. | |
| 2. | $i = 0$ | : | o . | 11. | $i \leq 4$ | : | $3u - 2o$. |
| 3. | $i = 0$ | : | o . | 12. | $i \leq 5$ | : | $4u - 2o$. |
| 4. | $i \leq 1$ | : | $2o$. | 13. | $i \leq 5$ | : | $3o - u - 2o$. |
| 5. | $i \leq 1$ | : | $2o$. | 14. | $i \leq 6$ | : | $3o - 2u - 2o$. |
| 6. | $i \leq 2$ | : | $u - 2o$. | 15. | $i \leq 6$ | : | $3o - 2u - 2o$. |
| 7. | $i \leq 2$ | : | $u - 2o$. | 16. | $i \leq 7$ | : | $u - 2o - 3u - 2o$. |
| 8. | $i \leq 3$ | : | $2u - 2o$. | 17. | $i \leq 7$ | : | $u - 2o - 3u - 2o$. |
| 9. | $i \leq 3$ | : | $2u - 2o$. | 18. | $i \leq 8$ | : | $2u - o - 4u - 2o$. |

The grid-diagram clearly shows the undesirable lopsided coding of the central section. The coding of the central section can made symmetric and balanced in either of the two ways depicted in Fig. 581.

The solution depicted on the left-hand side gives the knot 9 parts, but since the period of the braiding-pattern is equal to 3 bights, and hence b has to be a multiple of 3, it is not possible to create a single string knot with this coding-pattern.

The solution depicted on the right-hand side gives the knot 11 parts, and since the period of the braiding-pattern is equal to 3 bights, and hence b has to be a multiple of 3, all such b -values, except the values $33n$ where n is a natural number, will create a single string knot with this coding-pattern.

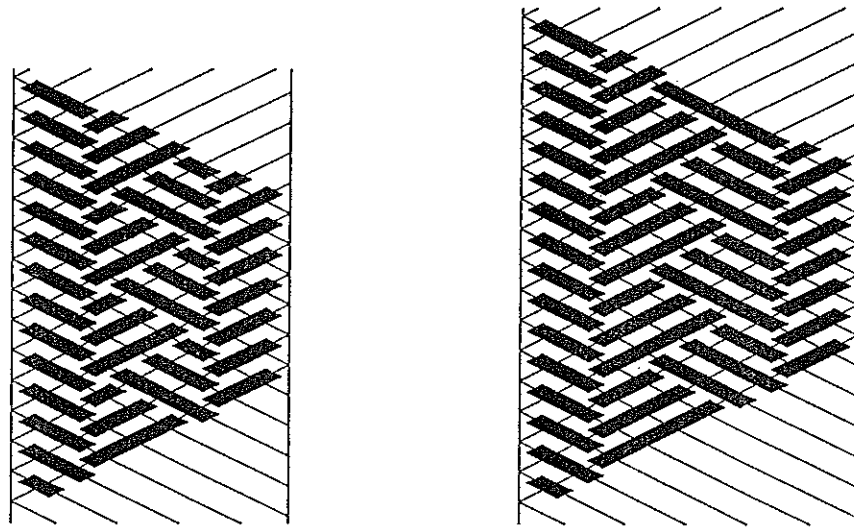


Fig. 581 — Balanced and symmetric coding arrangements.

Especially in the past when apparently no simple general design procedures for Regular Cylindrical Braids were known, many braiders restricted themselves to what Bruce Grant calls “the running method of making woven knots”. This entails that the braiding-pattern of Regular Cylindrical Braids is successively being built up during the braiding process wherein the successive odd-numbered half-cycles, and hence also the successive even-numbered half-cycles, are adjacent to each other. We now know that this means that Δ^* is either 1 (hence $p = (n + 1)b - 1$) or $b - 1$ (hence $p = nb + 1$).

★★ Prove these relationships.

Most braiders do unfortunately restrict themselves to the case $\Delta^* = b - 1$, hence to $p = nb + 1$.[†] It should thus be clear that in this case for a braiding-pattern period of 3 bights, hence for $b = 3m$ where m is a natural number, the braider requires for p the value of $3mn + 1$. For $m = 3$ and $n = 1$, the braider will require $p = 10$. However, the only viable balanced and symmetric braiding-pattern on the right in Fig. 581 requires $p = 11$. The obvious solution is to increase in the left-hand braiding-pattern the number of parts by 1 (or in the right-hand braiding-pattern to decrease the number of parts by 1) and so to create the braiding-pattern of the Small Pampas Button Knot in Fig. 580. Another and better solution would have been to retain the central coding of the left-hand braiding-pattern and to increase the p -value of the left-hand braiding-pattern with 1 part at the right bight-boundary, then to give all the intersections on the three rightmost intersection-columns an over-coding from lower-left to upper-right. Although of a weak nature, this would give the braiding-pattern and hence the knot some form of orientation and could give it at least some usefulness.

The so-called “running method of making woven knots” can also be used with $\Delta^* = 1$, hence with $p = (n + 1)b - 1$. Thus for $b = 3m$ where m is a natural number, the braider would require for p the value of $3(n + 1)m - 1$. For $m = 2$ and $n = 1$, or for $m = 4$ and $n = 0$, the braider would require $p = 11$. This is the p -value of the balanced and symmetric braiding-pattern on the right in Fig. 581. In order to make

[†] It is no doubt the more ‘natural’ one since the braiding-pattern builds up in the circumferential braiding direction. Thus for an upwards braiding direction (cycles from lower-left to upper-left) the braiding-pattern builds up in the upwards direction.

the braiding procedure for the knot easier, we rotate the right-hand braiding-pattern in Fig. 581 through an angle of 180°. The grid-diagram, path-formula, path in the RKT and half-cycle tables of the knot with $p/b = 11/12$ are shown in Fig. 582.

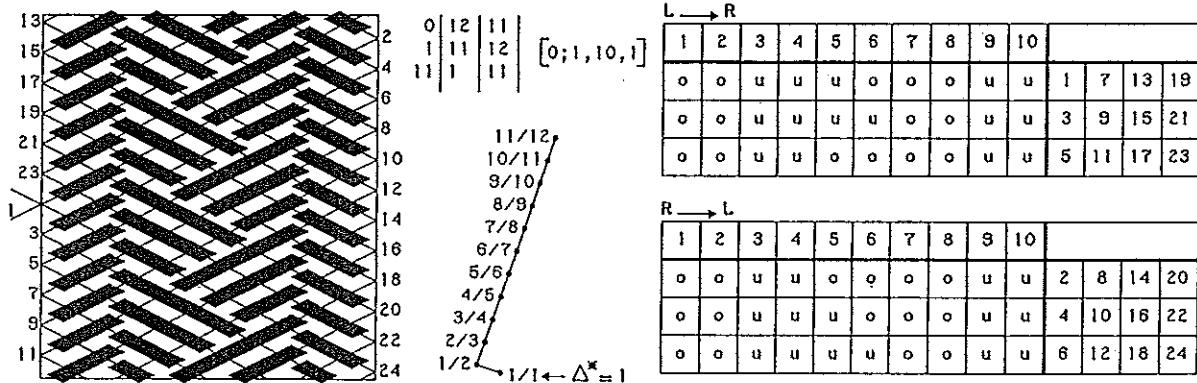


Fig. 582 — $p/b = 11/12$ small Pampas knot with balanced and symmetric pattern.

From the half-cycle tables we read the following half-cycle braiding algorithms:

- | | |
|------------------------------|---|
| 1. : Free run. | 13. $i \leq 5$: $2o - 3u$. |
| 2. $i = 0$: Free run. | 14. $i \leq 6$: $2o - 2u - 2o$. |
| 3. $i = 0$: Free run. | 15. $i \leq 6$: $2o - 4u$. |
| 4. $i \leq 1$: o . | 16. $i \leq 7$: $2o - 3u - 2o$. |
| 5. $i \leq 1$: o . | 17. $i \leq 7$: $2o - 2u - 3o$. |
| 6. $i \leq 2$: $2o$. | 18. $i \leq 8$: $2o - 4u - 2o$. |
| 7. $i \leq 2$: $2o$. | 19. $i \leq 8$: $2o - 3u - 3o$. |
| 8. $i \leq 3$: $2o - u$. | 20. $i \leq 9$: $2o - 2u - 4o - u$. |
| 9. $i \leq 3$: $2o - u$. | 21. $i \leq 9$: $2o - 4u - 2o - u$. |
| 10. $i \leq 4$: $2o - 2u$. | 22. $i \leq 10$: $2o - 3u - 3o - 2u$. |
| 11. $i \leq 4$: $2o - 2u$. | 23. $i \leq 10$: $2o - 2u - 4o - 2u$. |
| 12. $i \leq 5$: $2o - 3u$. | 24. $i \leq 11$: $2o - 4u - 2o - 2u$. |

There is no reason why a braider should be restricted to p/b values which are associated with the "running method of making woven knots"; in fact it is much easier to braid with the aid of half-cycle braiding algorithms which readily can be written down from the algorithm tables concerned, or to braid directly from these tables. If, for example, a 9-bight knot is required with the balanced and symmetric braiding-pattern depicted on the right in Fig. 581 (hence $p/b = 11/9$), then its grid-diagram, path-formula, path in the RKT and algorithm tables are those shown in Fig. 583.

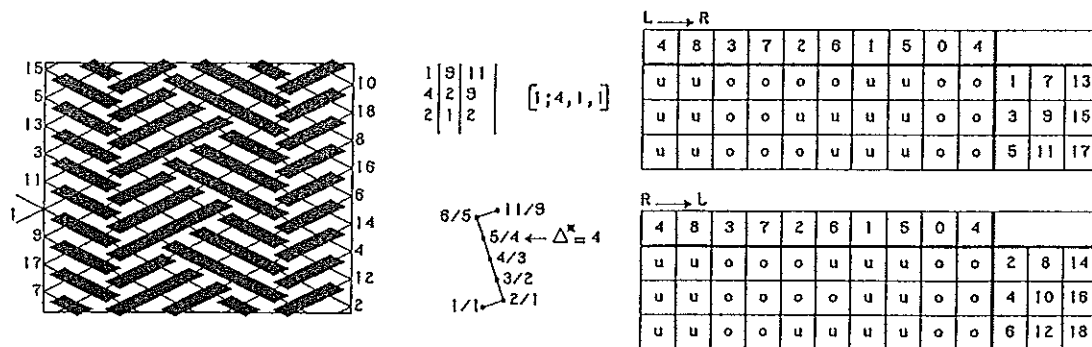


Fig. 583 — $p/b = 11/9$ small Pampas knot with balanced and symmetric pattern.