The development of an automatic rib transfer system for fully-fashioned knitwear manufacture

This item was submitted to Loughborough University's Institutional Repository by the/author.

Additional Information:


Metadata Record: [https://dspace.lboro.ac.uk/2134/27213](https://dspace.lboro.ac.uk/2134/27213)

Publisher: © Adrian Michael Woodward

Rights: This work is made available according to the conditions of the Creative Commons Attribution-NonCommercial-NoDerivatives 2.5 Generic (CC BY-NC-ND 2.5) licence. Full details of this licence are available at: [http://creativecommons.org/licenses/by-nc-nd/2.5/](http://creativecommons.org/licenses/by-nc-nd/2.5/)

Please cite the published version.
THE DEVELOPMENT OF AN AUTOMATIC RIB TRANSFER SYSTEM
FOR FULLY-FASHIONED KNITWEAR MANUFACTURE

BY

ADRIAN MICHAEL WOODWARD
B.Tech. (Loughborough)


© by Adrian Michael Woodward 1982
ACKNOWLEDGEMENTS

The candidate would like to express his sincere gratitude to Professor Gordon R. Wray, Mr. J.E. Baker and Dr. R. Vitols for their guidance and encouragement throughout the period in which this work was completed and to Professor Wray for his support during the preparation of this thesis.

The candidate also wishes to acknowledge the support provided by Messrs. T. Baker and L. Crawford on behalf of the firm of Corah Ltd. of Leicester and by Mr R. Bilson of the Department of Mechanical Engineering of Loughborough University of Technology.

In conclusion a final word of thanks must go to Mrs. D. Elks for typing this thesis and, in particular, to Dr. S.A. Bullivant for her continuing help and encouragement.
# TABLE OF CONTENTS

## Abstract

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
</table>
xvi   |

## Chapter 1. INTRODUCTION

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Knitted Outerwear Manufacture</td>
<td>1</td>
</tr>
<tr>
<td>1.1.1</td>
<td>Weft Knitting (general)</td>
<td>1</td>
</tr>
<tr>
<td>1.1.2</td>
<td>Fully-Fashioned Garment Manufacture</td>
<td>7</td>
</tr>
<tr>
<td>1.1.3</td>
<td>Cut and Sew Garment Manufacture</td>
<td>8</td>
</tr>
<tr>
<td>1.1.4</td>
<td>Assembly of Garment Pieces</td>
<td>8</td>
</tr>
<tr>
<td>1.1.5</td>
<td>Finishing and Packaging</td>
<td>9</td>
</tr>
<tr>
<td>1.2</td>
<td>Linking</td>
<td>9</td>
</tr>
<tr>
<td>1.2.1</td>
<td>Types of Linked Seams</td>
<td>11</td>
</tr>
<tr>
<td>1.2.2</td>
<td>Random or Mock Linking</td>
<td>12</td>
</tr>
<tr>
<td>1.2.3</td>
<td>Automatic Linking</td>
<td>12</td>
</tr>
<tr>
<td>1.3</td>
<td>Rib Transfer</td>
<td>13</td>
</tr>
<tr>
<td>1.3.1</td>
<td>Manual Rib Transfer</td>
<td>13</td>
</tr>
<tr>
<td>1.3.2</td>
<td>Automatic Rib Transfer</td>
<td>15</td>
</tr>
<tr>
<td>1.3.3</td>
<td>Doubling</td>
<td>15</td>
</tr>
<tr>
<td>1.4</td>
<td>Combined Rib and Plain Knitting</td>
<td>16</td>
</tr>
<tr>
<td>1.4.1</td>
<td>Bentley-Cotton Carrier Rib-to-Plain Machine</td>
<td>16</td>
</tr>
<tr>
<td>1.4.2</td>
<td>The Monk Ultramatic Rib-to-Plain Machine</td>
<td>16</td>
</tr>
<tr>
<td>1.5</td>
<td>Terms of Reference of the Present Work</td>
<td>17</td>
</tr>
</tbody>
</table>

## Chapter 2. THE COST OF CURRENT INDUSTRIAL PRACTICE

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Production Rates</td>
<td>18</td>
</tr>
<tr>
<td>2.2</td>
<td>Rejection and Faults</td>
<td>20</td>
</tr>
<tr>
<td>2.3</td>
<td>Recruitment and Training</td>
<td>21</td>
</tr>
<tr>
<td>Chapter 3.</td>
<td>LITERATURE SEARCH</td>
<td>Page</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>3.1 -</td>
<td>Patents</td>
<td>23</td>
</tr>
<tr>
<td>3.2 -</td>
<td>Publications</td>
<td>29</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 4.</th>
<th>CURRENT ALTERNATIVES TO THE CONVENTIONAL MANUAL RIB TRANSFER PROCESS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 -</td>
<td>The Fabrique Nationale Model R.A. System</td>
<td>32</td>
</tr>
<tr>
<td>4.2 -</td>
<td>The Bentley-Cotton Autorib 3 System</td>
<td>37</td>
</tr>
<tr>
<td>4.3 -</td>
<td>The Scheller Transrobot System</td>
<td>38</td>
</tr>
<tr>
<td>4.4 -</td>
<td>The Boehringer Ribomat 'V' &amp; 'P' Systems</td>
<td>38</td>
</tr>
<tr>
<td>4.5 -</td>
<td>The Bentley-Cotton C.R.P.</td>
<td>39</td>
</tr>
<tr>
<td>4.6 -</td>
<td>The Monk Ultramatic</td>
<td>42</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 5.</th>
<th>INDUSTRIAL INVESTMENT CONSIDERATIONS LEADING TO THE DEVELOPMENT OF AN ATTACHMENT FOR CONVERTING EXISTING MACHINES TO PERFORM AUTOMATIC RIB TRANSFER</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 - A</td>
<td>Survey of Currently Available Systems for Knitwear Manufacture from the Industrial Investment Viewpoint</td>
<td>44</td>
</tr>
<tr>
<td>5.1.1 -</td>
<td>Conventional Manual Rib Transfer</td>
<td>45</td>
</tr>
<tr>
<td>5.1.2 -</td>
<td>Alternative Processes</td>
<td>46</td>
</tr>
<tr>
<td>5.2 -</td>
<td>Evaluation of Currently Available Processes</td>
<td>46</td>
</tr>
<tr>
<td>5.2.1 -</td>
<td>Manual Rib Transfer</td>
<td>46</td>
</tr>
<tr>
<td>5.2.2 -</td>
<td>Automatic Rib Transfer</td>
<td>47</td>
</tr>
<tr>
<td>5.2.3 -</td>
<td>Rib-to-Plain Knitting Machines</td>
<td>47</td>
</tr>
<tr>
<td>5.3 - Proposals for Converting Existing 'V'-bed Machines to Facilitate Mechanised Rib Transfer Operations</td>
<td>48</td>
<td></td>
</tr>
</tbody>
</table>
### Chapter 6. THE FIRST (MARK I) LOUGHBOROUGH ART (AUTOMATIC RIB TRANSFER) SYSTEM

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>Elements</td>
<td>50</td>
</tr>
<tr>
<td>6.1.1</td>
<td>Take-down Elements</td>
<td>53</td>
</tr>
<tr>
<td>6.1.2</td>
<td>Take-off Elements</td>
<td>58</td>
</tr>
<tr>
<td>6.1.3</td>
<td>Knitting Elements</td>
<td>61</td>
</tr>
<tr>
<td>6.1.4</td>
<td>Magazine Bar Elements</td>
<td>63</td>
</tr>
<tr>
<td>6.2</td>
<td>Motions and Mechanisms</td>
<td>65</td>
</tr>
<tr>
<td>6.2.1</td>
<td>Take-down Mechanism</td>
<td>65</td>
</tr>
<tr>
<td>6.2.2</td>
<td>Take-off Mechanism</td>
<td>68</td>
</tr>
<tr>
<td>6.2.3</td>
<td>Knitting Element Operation</td>
<td>71</td>
</tr>
<tr>
<td>6.2.4</td>
<td>Magazine Bar Mechanism</td>
<td>74</td>
</tr>
<tr>
<td>6.2.5</td>
<td>Cut and Clamp Mechanism</td>
<td>74</td>
</tr>
<tr>
<td>6.2.6</td>
<td>Bed Drop Mechanism</td>
<td>76</td>
</tr>
<tr>
<td>6.3</td>
<td>Control System and Operating Cycle</td>
<td>79</td>
</tr>
<tr>
<td>6.4</td>
<td>Assessment of the Mark I System</td>
<td>82</td>
</tr>
</tbody>
</table>

### Chapter 7. THE UNIVERSITY PROTOTYPE ART SYSTEM (MARK II)

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1</td>
<td>Elements</td>
<td>83</td>
</tr>
<tr>
<td>7.1.1</td>
<td>Take-down Elements and Press-off Bar</td>
<td>84</td>
</tr>
<tr>
<td>7.1.2</td>
<td>Take-off Elements</td>
<td>88</td>
</tr>
<tr>
<td>7.1.3</td>
<td>Knitting Elements</td>
<td>94</td>
</tr>
<tr>
<td>7.1.4</td>
<td>Magazine Bar Elements</td>
<td>95</td>
</tr>
<tr>
<td>7.1.5</td>
<td>The Sweep-off Elements</td>
<td>98</td>
</tr>
</tbody>
</table>
7.2 - Motions and Mechanisms
7.2.1 - The Take-down Mechanism
7.2.2 - The Take-off Mechanism
7.2.3 - The Magazine Bar Mechanism
7.2.4 - The Sweep-off Mechanism
7.2.5 - The Cut and Clamp Mechanism
7.2.6 - The Bed-drop Mechanism
7.2.7 - Press-off Mechanism
7.3 - Control System and Operating Cycle
7.3.1 - The Control System
7.3.2 - The Operating Cycle
7.4 - Assessment of the Mark II System

Chapter 8  THE PRODUCTION PROTOTYPE ART SYSTEM
(MARK III)

8.1 - Elements
8.1.1 - Take-down Elements and Press-off Bar
8.1.2 - Take-off Elements
8.1.3 - Knitting Elements
8.1.4 - Magazine Bar Elements
8.1.5 - Sweep-off Elements
8.2 - Motions and Mechanisms
8.2.1 - The Take-down Mechanism (Incorporating the Press-off Mechanism)
8.2.2 - The Take-off Mechanism
8.2.3 - The Magazine Bar Mechanism
8.2.4 - The Sweep-off Mechanism
8.2.5 - The Cut and Clamp Mechanism
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.2.6 - The Bed-drop Mechanism</td>
<td>146</td>
</tr>
<tr>
<td>8.2.7 - The Press-off Mechanism</td>
<td>146</td>
</tr>
<tr>
<td>8.2.8 - The Yarn Tension Control Mechanism</td>
<td>149</td>
</tr>
<tr>
<td>8.3 - Control System and Operating Cycle</td>
<td>152</td>
</tr>
<tr>
<td>8.3.1 - The Control System</td>
<td>152</td>
</tr>
<tr>
<td>8.3.2 - The Operating Cycle</td>
<td>155</td>
</tr>
<tr>
<td>8.4 - Assessment of the Mark III Prototype Machine</td>
<td>161</td>
</tr>
<tr>
<td>Chapter 9 THE APPLICATIONS OF ART TO THE LINKING PROCESS</td>
<td>166</td>
</tr>
<tr>
<td>9.1 - The Relationship of the ART Research to the Complementary Studies on Linking</td>
<td>166</td>
</tr>
<tr>
<td>9.2 - Bar Feeding to Linking Machines</td>
<td>167</td>
</tr>
<tr>
<td>Chapter 10 PROPOSALS FOR FURTHER WORK</td>
<td>169</td>
</tr>
<tr>
<td>Chapter 11 THE NEED FOR GAUGE CHANGING</td>
<td>172</td>
</tr>
<tr>
<td>11.1 - Doubling, the Need and the Problem</td>
<td>173</td>
</tr>
<tr>
<td>11.2 - The Loughborough Gauge Changing Device</td>
<td>174</td>
</tr>
<tr>
<td>Chapter 12 SUMMARY AND CONCLUSIONS</td>
<td>179</td>
</tr>
<tr>
<td>12.1 - Summary of the ART System</td>
<td>179</td>
</tr>
<tr>
<td>12.2 - Conclusions</td>
<td>180</td>
</tr>
<tr>
<td>References and Bibliography</td>
<td>182</td>
</tr>
<tr>
<td>Glossary</td>
<td>184</td>
</tr>
<tr>
<td>APPENDIX A CRITICAL COMPARISON OF THE LOUGHBOURGH ART SYSTEM WITH OTHER CURRENTLY AVAILABLE SYSTEMS OF AUTOMATIC RIB TRANSFER</td>
<td>186</td>
</tr>
</tbody>
</table>
LIST OF FIGURES AND TABLES

Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Weft knitted structure</td>
<td>2</td>
</tr>
<tr>
<td>1.2</td>
<td>Warp knitted structure</td>
<td>2</td>
</tr>
<tr>
<td>1.3</td>
<td>The formation of weft knitted loops with a latch needle</td>
<td>3</td>
</tr>
<tr>
<td>1.4</td>
<td>The formation of weftknitted loops with a bearded needle</td>
<td>3</td>
</tr>
<tr>
<td>1.5</td>
<td>Cross-section of a 'V'-bed knitting machine</td>
<td>5</td>
</tr>
<tr>
<td>1.6</td>
<td>The action of a set of narrowing points</td>
<td>6</td>
</tr>
<tr>
<td>1.7</td>
<td>Types of linked seam</td>
<td>10</td>
</tr>
<tr>
<td>1.8</td>
<td>Loop doubling</td>
<td>14</td>
</tr>
</tbody>
</table>

Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>9-Gauge Manufacture</td>
<td>19</td>
</tr>
<tr>
<td>2.2</td>
<td>21-Gauge Manufacture</td>
<td>20</td>
</tr>
</tbody>
</table>

Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>F.N. model R.A. system of automatic rib transfer</td>
<td>33</td>
</tr>
<tr>
<td>4.2</td>
<td>Engagement of the transfer element</td>
<td>34</td>
</tr>
<tr>
<td>4.3</td>
<td>Loop transfer</td>
<td>34</td>
</tr>
<tr>
<td>4.4</td>
<td>Engagement of the transfer and magazine bar elements</td>
<td>35</td>
</tr>
<tr>
<td>4.5</td>
<td>Special transfer bar for doubling</td>
<td>35</td>
</tr>
<tr>
<td>4.6</td>
<td>The C.R.P. knitting elements</td>
<td>40</td>
</tr>
<tr>
<td>4.7</td>
<td>The C.R.P. compound needle bar</td>
<td>40</td>
</tr>
<tr>
<td>4.8</td>
<td>C.R.P. loop transfer</td>
<td>41</td>
</tr>
<tr>
<td>4.9</td>
<td>The Monk Ultramatic Knitting Elements</td>
<td>41</td>
</tr>
<tr>
<td>6.1</td>
<td>Take-down comb</td>
<td>51</td>
</tr>
<tr>
<td>6.2</td>
<td>Take-down comb with wire inserted</td>
<td>51</td>
</tr>
<tr>
<td>Section</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>6.3</td>
<td>Take-down hooks protruding between the beds</td>
<td>52</td>
</tr>
<tr>
<td>6.4</td>
<td>Hook-up course with take-down elements and knitting elements of one bed</td>
<td>52</td>
</tr>
<tr>
<td>6.5</td>
<td>Hook-up course with take-down hooks protruding between the beds</td>
<td>54</td>
</tr>
<tr>
<td>6.6</td>
<td>The knitting machine bed is shogged to engage the yarn loops with the take-down hooks</td>
<td>54</td>
</tr>
<tr>
<td>6.7</td>
<td>Press-off bar operation</td>
<td>55</td>
</tr>
<tr>
<td>6.8</td>
<td>Pivoting take-down hooks</td>
<td>55</td>
</tr>
<tr>
<td>6.9</td>
<td>The two types of take-down element</td>
<td>60</td>
</tr>
<tr>
<td>6.10</td>
<td>Transfer to a magazine bar element</td>
<td>60</td>
</tr>
<tr>
<td>6.11</td>
<td>The engagement of two narrowing points</td>
<td>60</td>
</tr>
<tr>
<td>6.12</td>
<td>Loop transfer to take-off element</td>
<td>62</td>
</tr>
<tr>
<td>6.13</td>
<td>Cross-section of the Mark I rig</td>
<td>64</td>
</tr>
<tr>
<td>6.14a</td>
<td>The take-off mechanism in its rest position</td>
<td>66</td>
</tr>
<tr>
<td>6.14b</td>
<td>The take-off mechanism in its operating position</td>
<td>67</td>
</tr>
<tr>
<td>6.15</td>
<td>Driving mechanism for the take-off elements</td>
<td>69</td>
</tr>
<tr>
<td>6.16</td>
<td>Standard and auxiliary cam boxes</td>
<td>70</td>
</tr>
<tr>
<td>6.17</td>
<td>Modified rear bed knitting element actuation</td>
<td>72</td>
</tr>
<tr>
<td>6.18</td>
<td>Take-off to magazine bar transfer</td>
<td>73</td>
</tr>
<tr>
<td>6.19</td>
<td>The cut and clamp mechanism</td>
<td>75</td>
</tr>
<tr>
<td>6.20</td>
<td>Control system</td>
<td>77</td>
</tr>
<tr>
<td>6.21</td>
<td>Operating cycle</td>
<td>78</td>
</tr>
<tr>
<td>7.1</td>
<td>Take-down bar and press-off bar</td>
<td>85</td>
</tr>
<tr>
<td>7.2</td>
<td>The drawthread course</td>
<td>85</td>
</tr>
<tr>
<td>7.3</td>
<td>The take-down hooks apply a light initial tension</td>
<td>86</td>
</tr>
<tr>
<td>7.4</td>
<td>The lower transfer position</td>
<td>86</td>
</tr>
<tr>
<td>7.5</td>
<td>Initial transfer system proposed for the Mark II machine</td>
<td>89</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>7.6 The front bed is dropped away from the knitting zone</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>7.7 Final transfer sequence</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>7.8 The take-off element</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>7.9 Take-off and magazine bar element interaction</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>7.10 The first sweep-off system</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>7.11 The final sweep-off system</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>7.12 The take-down mechanism</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>7.13 The collapsible link</td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>7.14 The Take-off mechanism</td>
<td>103</td>
<td></td>
</tr>
<tr>
<td>7.15 The magazine bar mechanism</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>7.16 The sweep-off mechanism</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td>7.17 Cross-section of the sweep-off mechanism</td>
<td>109</td>
<td></td>
</tr>
<tr>
<td>7.18 Path of sweep-off elements</td>
<td>109</td>
<td></td>
</tr>
<tr>
<td>7.19 Plan view of 'yarn gatherer'</td>
<td>111</td>
<td></td>
</tr>
<tr>
<td>7.20 Yarn trap and burner</td>
<td>111</td>
<td></td>
</tr>
<tr>
<td>7.21 'Scissors' type cut and clamp unit</td>
<td>113</td>
<td></td>
</tr>
<tr>
<td>7.22 Standard bed-drop mechanism</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>7.23 Modified bed-drop mechanism</td>
<td>117</td>
<td></td>
</tr>
<tr>
<td>7.24 Bed-drop mechanism</td>
<td>118</td>
<td></td>
</tr>
<tr>
<td>7.25 The press-off mechanism</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>7.26 The control system</td>
<td>121</td>
<td></td>
</tr>
<tr>
<td>7.27 The cycle of operation (Schematic)</td>
<td>124</td>
<td></td>
</tr>
<tr>
<td>8.1 The take-off element</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>8.2 The magazine bar element</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>8.3 The sweep-off element</td>
<td>136</td>
<td></td>
</tr>
<tr>
<td>8.4 The eight-section main frame</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>8.5 The revised bellcrank system</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>8.6</td>
<td>The press-off mechanism</td>
<td>141</td>
</tr>
<tr>
<td>8.7</td>
<td>The magazine bar mechanism</td>
<td>143</td>
</tr>
<tr>
<td>8.8</td>
<td>The sweep-off mechanism</td>
<td>145</td>
</tr>
<tr>
<td>8.9</td>
<td>The cut and clamp unit</td>
<td>147</td>
</tr>
<tr>
<td>8.10</td>
<td>The yarn 'burner' system</td>
<td>148</td>
</tr>
<tr>
<td>8.11</td>
<td>The effect of uncontrolled yarn tension</td>
<td>150</td>
</tr>
<tr>
<td>8.12</td>
<td>The yarn tension control mechanism</td>
<td>151</td>
</tr>
<tr>
<td>Table</td>
<td>Cycle of knitting operations</td>
<td>154</td>
</tr>
<tr>
<td>Figures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.13</td>
<td>The Cycle of Operation (Schematic)</td>
<td>157</td>
</tr>
<tr>
<td>8.14</td>
<td>The 'guide fingers'</td>
<td>163</td>
</tr>
<tr>
<td>10.1</td>
<td>Modified take-off element</td>
<td>171</td>
</tr>
<tr>
<td>11.1</td>
<td>The first regauging system</td>
<td>175</td>
</tr>
<tr>
<td>11.2</td>
<td>The Loughborough regauging system</td>
<td>177</td>
</tr>
</tbody>
</table>
LIST OF PLATES

Plate No.

Frontispiece  THE LOUGHBOROUGH ART PRODUCTION PROTOTYPE MACHINE
1.1 - Fully-fashioned garment showing fashioning marks
1.2 - Straight bar fully-fashioned machine
1.3 - A Dubied DRC-2 'V'-bed knitting machine
1.4 - A cup seaming machine
1.5 - The cup seaming operation
1.6 - Cup seaming
1.7 - Body linking
1.8 - Neck or collar linking
1.9 - Neck or collar linking
1.10 - Draw-thread removal
1.11 - Running-on area
1.12 - Running-on
1.13 - Ribs being transferred from a magazine bar to a machine bar
1.14 - Rib being automatically fed on to knitting elements of a straight bar machine

6.1 - Pivoting take-down hooks and carriage, initial position
6.2 - Pivoting take-down hooks, engaged position
6.3 - The take-off elements penetrating the front-bed knitted loops
6.4 - Back-bed knitting elements in raised transfer position (actuation by auxiliary cam box)
6.5 - Back-bed knitting elements raised to their transfer height by the operating plate
6.6 - Rear elevation of machine showing camshaft, spool valves, operating plate mechanism and take-down cylinder
6.7 - Swinging link assembly of the take-down mechanism
6.8 - Knitted loops on take-off elements
6.9 - Front elevation of machine showing camshaft and take-off cams
6.10 - Front elevation of machine showing bed-drop cylinders and cut and clamp mechanism

7.1 - The elements of the Mark II machine
7.2 - Front elevation of Mark II machine showing cam box (on the left)
7.3 - Rear elevation of cam box showing control disc, 'flags' and photoswitch
7.4 - Front elevation of cam box showing by-pass switch on front timing disc
7.5 - Loops set up on front-bed knitting elements prior to transfer to take-off elements
7.6 - Take-off elements adjacent to front-bed knitting elements
7.7 - Take-off elements engaged with knitting elements ready for transfer
7.8 - Schematic layout of elements at upper transfer position
7.9 - Schematic layout of elements at lower transfer position
7.10 - Engagement of magazine bar elements and take-off elements
7.11 - The completed rib following transfer to the magazine bar

11.1 - Trimming the excess trailing yarns
11.2 - Removing the hook-up yarns
11.3 - The ART machine bar elements are engaged with those of the regauging device
11.4 - The transfer of the ribs to the regauging device elements
11.5 - The regauging elements are moved to their upper position
11.6 - The engagement of the straight bar machine magazine bar with the regauging device elements

11.7 - The transfer of the ribs to the straight magazine bar

11.8 - The straight bar magazine bar is disengaged on completion of the transfer
ABSTRACT

In the manufacture of fully-fashioned knitted outerwear, it is usual for the garment sections to be constructed with a lower rib portion on to which is knitted a fashioned section of plain knitting. The majority of fully-fashioned knitting machines are capable of producing only the plain fabric section, the rib portion being knitted separately on 'V'-bed machines. In order to knit the plain section of the garment pieces on to the rib, each loop of the rib must be transferred to a corresponding knitting element on the fully-fashioned knitting machine. It is common practice within the knitwear industry to perform this transfer manually, each loop of a slack course in the rib being impaled on to a point of a magazine bar, the excess courses of knitting being unroved as waste. The loops are then transferred from this bar, via a feeding bar on to the knitting elements of the fully-fashioned machine. This manual transfer of the loops is both tedious and expensive in terms of labour.

However, there are recently developed machines on the market which will knit the rib and transfer it automatically to a magazine bar but they are both expensive and also render the existing plant obsolete.

This thesis describes the concept, design and development of a novel patented automatic rib transfer system which relies on the relatively inexpensive modification of existing 'V'-bed knitting machines. The modifications are aimed
at providing a sub-assembly attachment suitable for a variety of 'V'-bed knitting machines. Bars loaded automatically by these modified machines may be fed to any fully-fashioned knitting machine via a specially developed "gauge-changing" device to alter the pitch of the loops from that of the 'V'-bed machine to that of the fully-fashioned machine. These automatically loaded bars may also be used to feed either a modern semi-automatic "linking system", such as the Boehringer Autolinker, or, in certain cases, a conventional linking dial.

NOTE.

The term 'rib transfer' is used in the context of this thesis to describe the operation of transferring a knitted rib from a 'V'-bed knitting machine to a straight bar knitting machine.
CHAPTER 1

INTRODUCTION

In order to put into perspective the work undertaken in this thesis, it is necessary to describe the processes involved in the manufacture of knitted garments such as jumpers, pullovers, cardigans, and similar knitted outerwear.

1.1 Knitted Outerwear Manufacture

Traditional knitted outerwear garments are formed by the assembly of shaped knitted panels. These panels may be shaped at the knitting stage, as in the higher quality "fully-fashioned" garment, or after knitting, as in the cheaper "cut-and-sew" garment. The fashioned garment panels may be knitted on three basic types of knitting machines, i.e. 'V'-bed machines, straight bar "fully-fashioned" machines (See Section 1.1.1), or circular single-jersey or double-jersey machines.

1.1.1 Weft Knitting (general)

Knitting is a process in which rows or courses of yarn loops are formed into a fabric structure. Two basic methods of knitting exist; (i) weft knitting (Fig 1.1) where one or more single yarns are looped as they are laid across a row of needles in the weft (transverse) direction; and (ii) warp knitting (Fig 1.2) where parallel multiple warp yarns are looped together as they are drawn from a beam or yarn store in the warp (longitudinal) direction. In this present work, only weft knitting will be considered.

There are two fundamental types of weft knitting machine, namely those using "latch" needles (See Fig 1.3) to form the yarn loops and those using "bearded" needles (See Fig 1.4). Latch needles are used
Fig. 1.1 Weft knitted structure

Fig. 1.2 Warp knitted structure
Fig. 1.3 The formation of weft knitted loops with a latch needle

Fig. 1.4 The formation of weft knitted loops with a bearded needle
mainly in 'V'-bed and circular machines, bearded needles being used in straight bar fully-fashioned machines.

The latch needle is normally located in a slot or trick in which it may slide (Fig 1.3). In 'V'-bed machines each needle is raised and lowered by a linear cam mounted in a carriage which moves along the machine just above the beds and acts upon the needle butt. To form a knitted loop with a latch needle, the needle is raised in the trick so that the loop around the needle falls behind the latch. This loop is held in position by the verge (See Fig 1.3a) and by the tension applied to the fabric. With the needle in the knitting position a yarn is laid into the knitting zone (Fig 1.3b) such that, as the needle is lowered by the cam profile, the loop around the shank of the needle closes the latch thereby trapping the yarn into the hook. The verge, fabric tension and adjacent needles cause the previous loop to be cast off the needle, whilst forming the laid-in yarn into a loop (Fig 1.3c). The process is then repeated, the knitting elements being operated by the linear cam in the cam box of the machine. Raising and lowering the various cams in the cam box selects the path travelled by the butts of the elements and thus the action of the element. (See Section 6.2.3).

Fully-fashioned knitting machines are referred to as straight bar machines because their bearded needles are located in a straight needle bar. To form a knitted loop, the needle bar is raised, the fabric tension retaining the previous loops against the knocking-over bits, whilst yarn is laid along the whole needle bank, being kinked around the needles by the sinkers (Fig 1.4a) to provide sufficient yarn to form a loop. The needle bar is lowered with respect to the knocking-over bits until the previous loops are
Fig. 1.5 Cross-section of a 'V'-bed knitting machine
Fig. 1.6 The action of a set of narrowing points
almost at the beards of the needles; at this point the lower leading edge of the sinker bed reaches a position such that it closes the beards around the newly kinked yarn (Fig 1.4b). The needle bar continues to fall slipping the previously formed loops over the newly kinked yarn to form a new course (Fig 1.4c) and the elements return to their starting positions.

The previous descriptions refer to the knitting of plain fabric, which has a different appearance on each side. A rib fabric is formed by two sets of knitting elements and appears identical on both sides. An example of a rib knitting machine is the 'V'-bed machine, the knitting elements being carried in two beds positioned in an inverted 'V' (See Fig 1.5).

1.1.2 "Fully-Fashioned" Garment Manufacture

The term "fully-fashioned" or "full-fashioned" refers to the shaping of the garment pieces at the knitting stage (See Plate 1.1). "Fashioning" is accomplished on straight bar machines by either widening or narrowing the width of knitting every few courses; this involves transferring the edge or selvedge loops of the fabric either outwards or inwards by one needle pitch. In practice the last six or so loops of a course on each side of a fabric piece are transferred from the knitting elements onto a set of narrowing points (See Fig 1.6a,b,c&d & Plate 1.2). The points are then moved in or out by one or two pitches (Fig 1.6c) and the loops then returned to the adjacent needles (Fig 1.6d). Thus, knitted panels may be shaped as required (See Plate 1.1).

It is usual to knit the garment pieces with a border or rib fabric i.e. the cuff and waist-band of the garment, the remainder of the piece being in plain knitting. The majority of straight bar
knitting machines knit only plain fabric (there are rib knitting versions (See Section 4.5) but these are both more expensive, more complex and slower than the plain machine) and so the rib portion of the garment is usually knitted on a flat 'V'-bed knitting machine (Plate 1.3). This rib border is then transferred from the 'V'-bed knitting machine to the straight bar machine by one of two processes (See Section 1.3).

1.1.3 Cut and Sew Garment Manufacture

With this simpler type of garment, the individual panels are shaped by cutting rather than by fashioning. Generally the styles are simpler and garments made by this method are aimed at the lower end of the market. The process is cheaper than "fully-fashioned" manufacture because there are no time consuming fashioning motions during the knitting stage; moreover during the making up operations; simple sewing techniques are used rather than the expensive linking processes (See Section 1.2). The majority of underwear is also made by this process, many layers of fabric being cut to shape simultaneously from one pattern before the pieces are sewn together.

1.1.4 Assembly of Garment Pieces

Once the garment pieces have been knitted they have to be joined together to form a complete garment. There are several methods of joining, the choice of method depending on the type of garment, seam type and yarn type. The majority of "fully-fashioned" garments are linked (See Section 1.2) both along the body seams (body linking) and for the attachment of the neck piece or trim (neck linking). It is usual for "fully-fashioned" garments to be assembled along the body seams and finished before the neck trim is attached, thereby preventing unnecessary distortion of the neck seam during the finishing process.
Garments aimed at the lower end of the market, such as cut and sew garments, are assembled on cup seaming machines (See Plates 1.4, 1.5 & 1.6). With this type of machine the seam is fed into a sewing head by a pair of contra-rotating wheels or cups (See Plate 1.4). When assembly is complete the garment is inspected for faults in both the knitting and making up and is then ready for finishing and packaging.

1.1.5 Finishing and Packaging

By the time the garments have been assembled all of the components have, at some stage, been scoured to remove unwanted organic oils present in the fibres and mineral oil collected during the knitting process. Before the garments are packaged they are sized and set. The garments are knitted in basic sizes and during assembly the pieces are positioned to give the correct measurements at the neck, chest and sleeves. However minor adjustments may be made by steam setting. The garment is positioned on a wire frame and compressed on a table whilst steam is applied. This 'sets' the yarn and as it cools, the garment takes up the size and shape of the frame.

Once sized, the garment is folded and wrapped. It is important that the garment is presented to the customer in an attractive manner.

1.2 Linking

Linking is the name given to the process in which each individual loop of a knitted trim is stitched to the body of a garment. This method of assembly provides a very neat edge to the trim once assembled and also forms a very elastic seam, necessary around the neckline of a jumper.

The linking operation requires considerable skill from the operative for, if one of the loops is missed, it requires expensive manual repair and the garment becomes second quality.
Fig. 1.7 Types of linked seam
There are two basic types of linking. Body linking (See Plate 1.7), which is the joining of the body seams of a garment using a linking machine, requires a lesser degree of skill than neck linking as it is the joining of two selvedge seams with no "raw" edges that can run back. These seams can be cup seamed (See Section 1.1.4) but the linked seam is neater and blends with the knitted loops better. Neck linking (See Plate 1.8) requires a high degree of skill as it is here that the individual loops must each be caught by the stitching to complete the seam.

As may be seen from Plate 1.9 the operator impales each loop of a slackly knitted course of the trim on the points of a linking dial. The body of the garment is then positioned on the dial and the assembly passed through the stitching head of the linking machine. In the case of a round neckline it is necessary to sew part of the seam before the rest can be completed to allow the completed part to be removed from the dial (See Plate 1.8).

1.2.1 Types of Linked Seam

There are three basic types of linked seam construction:

Single Linking

The lower edge of the trim only is attached to the body (See Fig 1.7a).

Sandwich Linking

The lower edge is linked to the body along with the upper edge of the trim which is brought over the top of the seam to form a sandwich (See Fig 1.7b).

Tubular Linking

During the knitting of the trim a bifurcation of the trim is developed. The body is placed between the bifurcations in a similar
manner to the sandwich linked trim. This is the most costly of the linked seams as it requires both sides of the bifurcation to be linked perfectly to prevent a dropped loop and thus a fault (See Fig 1.7c).

1.2.2 Random or Mock Linking

Because of the increased cost of the linking process in recent years and the competition from cheaper imported garments from low-labour cost countries, several "mock" linking processes have been developed. These give the appearance of a traditional true linked garment but do not require such a high degree of operator skill.

The Mathbirk system looks very similar to a conventional linking machine but relies on a twin needle sewing system to insert a multiple seam along the garment. This makes the loops secure by covering each loop zone with the stitch pattern, so that at least one stitch passes through each loop.

The Arndt system relies on a special knitting technique to provide a rolled edge of fine yarn on the trim. This is then manipulated and sewn as a single "linked" trim (See Section 1.2.1) by a purpose built machine.

1.2.3 Automatic linking

There also exists at least one automatic linking system, namely the Boehringer Autolinker. Trims are produced on a special 'V'-bed knitting machine which transfers the loops of the trim to a comb-like point bar. The garment body is then positioned on this bar against the trim and the whole assembly passed through a sewing head. This process has the limitation that the assembly of the body panels must be altered from the normal method to allow the body panels to be applied to the bar in a straight form.

A more detailed account of linking and its problems may be found in the M.Tech thesis to be submitted by Mr. J. E. Baker (1).
1.3 Rib Transfer

As mentioned in Section 1.1.2, in the manufacture of "fully-fashioned" garment pieces it is usual to knit a rib border on a 'V'-bed machine, transfer this rib to the fully-fashioned straight bar machine, and continue the piece in plain "fashioned" knitting.

This transfer of the rib border is achieved in one of two ways, either manually or automatically.

1.3.1 Manual Rib Transfer

The rib borders are produced in lengths on 'V'-bed machines, joined by draw-threads, i.e. two courses of yarn that are removed to separate the trims (See Plate 1.10). Once separated, the trims are stacked and taken to the running-on area (See Plate 1.11). Here skilled operatives impale the individual loops of a slackly knitted course of the rib on the points of a comb-like magazine bar (See Plate 1.12), in a similar manner to linking (Section 1.2). Several trims are applied to each bar, the number depending upon the number of heads on the "fully-fashioned" machine, usually 8, 12, or 16. When the correct number of trims are on the bar, the waste courses above the slack course, knitted to allow ease of handling of the rib, are removed or unroved. The bar is then taken to the "fully-fashioned" machine where individual trims are transferred from the magazine bar to the machine bars, one trim for each knitting head (See Plate 1.13). The machine bars are then fed by conveyor to each knitting head and the "fully-fashioned" frame transfers the ribs onto the knitting elements ready to continue knitting (See Plate 1.14).

The manual loading of ribs onto bars is expensive in terms of both labour and yarn wastage; therefore attempts have been made to automate the process.
Fig. 1.8 Loop Doubling
1.3.2 Automatic Rib Transfer

There are on the market several commercial systems for automatic rib transfer (See Chapter 4). With these machines the rib is knitted on a "V"-bed machine, all loops transferred to one bed and then transferred from the knitting elements to a magazine bar. Because the loops of the rib are transferred at a fixed gauge or pitch, these special machines have to be of the same gauge as the "fully-fashioned" machines. This limits the types of yarn that may be used for the rib border as, for manual transfer, production is on coarser gauges than the "fully-fashioned" machine.

In addition to the limitations caused by the gauge of these machines, problems also occur where doubling is required on certain ribs.

1.3.3 Doubling

To improve the elasticity of rib borders on "fully-fashioned" garments it is a common practice to "double" loops up, i.e. to transfer one loop onto a needle which already possesses another loop (See Fig 1.8); this is performed at the knitting stage or sometimes at the running-on stage.

The number of doublings in a rib depends upon the gauge of the rib and the type of yarn used, e.g. a 9-gauge rib may have doublings every 3rd loop whereas a 21 gauge rib may be doubled every 7th or 9th loop.

With manual rib transfer, doublings present no problem as the operative is able to ensure that every point on the magazine bar carries a loop. However, if no loop is present when the rib is transferred to the "fully-fashioned" machine a "hole" will appear in the junction between the rib and the body of the panel.
Consequently, automatic rib transfer requires a doubling correction to ensure that adjacent needles each carry a loop. These devices are described in Chapters 4 and 11.

1.4 Combined Rib and Plain Knitting

From the earliest days of fully fashioned garment manufacture, rib and plain garment pieces have been produced on different machines. Recent developments in machine design have now made it possible to produce a fully-fashioned rib and plain garment pieces on a single machine, eliminating the rib transfer stage completely. These machines fall into two categories, the first based on the straight bar fully fashioned knitting frame and the second on the 'V'-bed machine. Both types represent a sizable capital investment and this has so far limited their use.

1.4.1 Bentley-Cotton Carrier Rib-to-Plain (CRP) Machine

This machine is based on the "fully-fashioned" straight bar knitting frame but has an additional set of knitting elements introduced to enable rib fabric to be produced. The increased complexity of the operating mechanisms over the standard frame both limits its rate of production and requires frequent adjustment to maintain a suitable quality of product.

1.4.2 The Monk Ultramatic Rib-to-Plain Machine

This machine is similar to the Bentley-Cotton CRP in that it is a straight bar knitting machine capable of knitting both rib and plain fabric on the same garment piece. It differs from the CRP in detail (see Section 4.6) but suffers from the same drawbacks of high capital cost and mechanical complexity.
1.5 Terms of Reference of the Present Work

The initial aims of the current research were to improve and automate the linking process. It gradually became obvious that the first step towards such a process would be to locate the individual loops of a rib or trim on a magazine bar and that the most suitable stage at which to perform this operation would be on the knitting machine itself. Other systems existed for automatic transfer of knitted ribs but they had limitations of gauge, were expensive, and rendered the existing plant obsolete.

The objective was therefore limited to the provision of a system of automatic rib transfer by the inexpensive and simple modification of existing machinery. A colleague, J. E. Baker, was to investigate the running-on of trims in the linking process as a complimentary research project (1).
Fashioning marks

Plate 1.1

Fully-fashioned garment showing fashioning marks.
A Dubied DRC-2 V-bed knitting machine.
Plate 1·8

Neck or collar linking.
Ribs being transferred from a magazine bar to a machine bar.
Plate 1·14

Rib being automatically fed onto knitting elements of a straight bar machine.
CHAPTER 2

THE COST OF CURRENT INDUSTRIAL PRACTICE

The terms of reference (Section 1.5) indicate the broad outlines of the research but to predict the target performance of any proposed system it is necessary to consider the present production processes in terms of specific output.

Fully-fashioned knitwear manufacture has already been described in Chapter 1 (Sections 1.1.2 and 1.1.4). By studying the present processes used within the industry the suitability of any proposed system may be evaluated in terms of production rates and methods of operation. For this exercise only manual rib transfer is considered, current automatic rib transfer systems being dealt with in Chapter 4. The actual figures quoted were obtained from Corah Ltd. of Leicester, a large company employing a total of 4,000 people, but the principles described equally apply to the majority of firms within the fully-fashioned knitwear sector; in the case of smaller firms however, the detailed systems used could vary due to the reduced number of staff employed.

2.1 Production Rates

Because of the large capital investment in knitting plants, it is usual to operate on a three shift system to obtain maximum plant utilisation. Thus at the Corah factory in Leicester, three shifts, each of 40 hours weekly duration, are run for five days per week. Machine and operator performance is judged on a percentage basis, i.e. if a machine runs continuously for five days, then, over all shifts, its maximum running time is 7,200 minutes assuming 100% performance. However, in practice, because of breaks for operators, routine maintenance, machine down time, etc., a more realistic
performance is about 90%. Taking into account operator efficiency and unbooked down-time, the overall figure for a machine/operator efficiency on such a knitting plant is about 80% to 85%.

Shown below (Tables 2.1 and 2.2) are typical production figures for knitwear production at the Corah factory assuming an overall 80% efficiency. Typical rates of pay are also shown along with production figures for the related labour-intensive processes of draw-threading and running-on (these two processes are single shift because of the high proportion of female labour employed).

Table 2.1

9-Gauge Manufacture

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>'V'-bed knitting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ribs</td>
<td>20 mins/doz (2 per machine)</td>
<td>£120 per week</td>
</tr>
<tr>
<td>cuffs</td>
<td>14 mins/doz (4 per machine)</td>
<td>+ £11 shift pay</td>
</tr>
<tr>
<td>collars:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>polo</td>
<td>20 mins/doz</td>
<td></td>
</tr>
<tr>
<td>crew &amp; 'V'</td>
<td>6 mins/doz</td>
<td></td>
</tr>
<tr>
<td>Draw-threading</td>
<td>6.1 mins/doz</td>
<td>£75 per week</td>
</tr>
<tr>
<td>Running-on</td>
<td>17.4 mins/doz (ribs and cuffs)</td>
<td>£80 per week</td>
</tr>
<tr>
<td>Fully-fashioned knitting</td>
<td>One 16 section machine produces 370 doz garments per 3 shift week</td>
<td>£120 per week</td>
</tr>
<tr>
<td></td>
<td>One 8 section machine produces 140 doz garments per 3 shift week</td>
<td>+ £11 shift pay</td>
</tr>
</tbody>
</table>
Table 2.2
21-Gauge Manufacture

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>'V'-bed knitting</td>
<td>Ribs and Cuffs 36 mins/doz (2 ribs and 2 cuffs per machine)</td>
<td>As per 9-gauge manufacture</td>
</tr>
<tr>
<td></td>
<td>Collars: polo 38 mins/doz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>crew &amp; 'V' 8 mins/doz</td>
<td></td>
</tr>
<tr>
<td>Draw-threading</td>
<td>4.1 mins/doz</td>
<td>As per 9-gauge manufacture</td>
</tr>
<tr>
<td>Running-on</td>
<td>25.9 mins/doz (ribs and cuffs)</td>
<td>As per 9-gauge manufacture</td>
</tr>
<tr>
<td>Fully-fashioned knitting</td>
<td>One 16 section machine produces 185 doz garments per 3 shift week</td>
<td>As per 9-gauge manufacture</td>
</tr>
</tbody>
</table>

2.2 Rejection and Faults

Knitting is a very precise process and faults such as broken needles are easily detected and rectified. Many faults such as dropped loops on transfer can be repaired manually, and edge or selvedge faults may be hidden in the seam of the garment. Because of the high yarn cost per garment, it is usual practice that all such minor faults should be repaired; therefore only major faults, such as a faulty needle causing an unsightly wale in the piece, would cause a garment to be totally rejected.

Visual inspection occurs at the end of each process and any faults detected are rectified manually by a skilled mender. The total loss of production due to faults is in the region of 7% to 10%.
2.3 Recruitment and Training

The direct labour force falls into two main categories; the male knitters and mechanics who work on a three-shift basis and the making-up operators, most of whom are female.

The male labour force is fairly stable, most operatives having served an apprenticeship of some description and often having family commitments. Recruitment is either from school leavers, who are trained up through a recognised training scheme, or from other firms in the area. Because the rates of pay and facilities within the area are relatively uniform, turnover is only in the region of 5% to 10% per annum.

In the making-up areas, including running-on, linking and draw-threading, the labour force, largely female, is much more changeable. Recruitment is from school leavers and from married women returning to the industry after child-bearing. With the higher skilled operation such as running-on and linking, training takes up to three months and often full production speeds are not achieved until after the first year. With many of the women leaving work in their late teens or early twenties due to pregnancies, it is rare for the younger operators to be employed for more than 3 years. However, older women returning to the industry to assist the family budget tend to be a far more stable workforce. This situation gives rise to a very high turnover of labour, in the region of 25% to 50% per annum.

In the areas where skills take long periods to acquire, considerable attention has been paid to deskilling the operations and this has led to the development of random linking, sewing techniques such as the Arndt process, and automatic rib transfer systems. With
these deskillled processes, training time has been cut by up to 75% and production rates have increased.
CHAPTER 3

LITERATURE SEARCH

Several literature searches have been conducted by the author at various stages of the work. Initial searches revealed several patents and publications on the subject and periodically these searches have been updated to monitor "the state of the art". More thorough patent searches were required when preparing the application for the Letters Patent for the Loughborough System.

3.1 Patents

The earliest patents found by the author on the topic of automatic rib transfer date from the early 1960s. Two patents, each filed in their countries of origin in the first few months of 1963, describe the two possible methods of transferring a knitted rib from a 'V'-bed knitting machine to a magazine bar. Jean Borne (2) claims:-

"a method of transferring stitches of a French welt knitted on a double bed flat knitting machine to a magazine-comb, comprising the steps of transferring the stitches of the last course to the needles of one of the beds, eliminating the tension exerted by the (take-down) comb of the machine, presenting the points of the magazine-comb to said stitches suspended from said needles of one of the beds, and transferring all of said stitches directly and simultaneously to said magazine comb."
The machine described transfers the rib to a magazine bar situated above the beds of the knitting machine. This patent appears to have established the trend in commercially developed automatic rib transfer machines. All of the systems commercially available today use the basic principle set out by this patent.

Further patents relating to rib take-off from above the bed of the knitting machine are held by Fabrique Nationale D'Armes de Guerre of Belgium (3), (4), (5). The method described in these patents is a more sophisticated version of that described by Borne (2). British Patent 1,165781 (3) claims:

"an automatic device for transferring a rib end from a needle row of a flat bed knitting machine to a magazine reed, comprising in combination a rotatably and translatory movable loop transfer reed having a length equal to that of the needle rows of the machine being equipped, means for holding said loop transfer reed in a waiting position, means operable to shift the loop transfer reed to the needle row supporting the last loop row of the rib end being transferred in such a manner that each hook of said reed grasps the loop carried by the corresponding needle of said needle row, means for bringing then the said loops transfer reed in front of the teeth of a magazine reed located above the needle beds of the machine and a transfer member providing for the hooking-up of the loops carried by the said loop transfer reed on the said magazine reed".
British patent 1,299,221 (4) describes a more sophisticated version of the above machine but still operating on the same principles. Neither of the machines described in (3) and (4) are able to perform doubling (as defined in Section 1.3.3). In British Patent 1,399,579 (5) Fabrique Nationale describe a system of doubling for use with their machine (3) and this is the method used on all commercially available machines today. They claim:

"a method of loop doubling on a double needle bed rib end knitting machine equipped with a transfer device for transferring a knitted rib end on to a magazine comb from a transfer comb, wherein, after a rib end has been knitted on some of the needles of each of the needle beds some of the loops on a first needle bed are simultaneously transferred on to free needles of the second needle bed; one needle bed is racked in relation to the other; the remaining loops on the first needle bed are transferred on to already laden needles of the second needle bed, thus forming groups of loops separated by spaces; all the loops on the second needle bed are picked up simultaneously on the transfer comb; the groups of loops thus picked up are brought closer together to provide a distance of one needle spacing between each two adjacent loops; and the uniformly spaced loops are transferred on to the magazine comb".

The other method of removing a knitted rib from a 'V'-bed machine is from below the beds. A system for performing this transfer is described in a patent by Rainer Stovhase (6). In this patent Stovhase
describes a system of introducing a bar of bearded needles, similar
to those found in a fully-fashioned machine, into the knitting zone
and engaging the same with the loops of the last knitted course, all
loops having been transferred to one bed of the machine. Stovhase
claims:-

"a method of automatically transferring a rib
border knitted on a rib machine to a transfer
bar of a full-fashioning machine, with the use
of a draw-off device which engages with the
first run-on course automatically and draws
the rib border off during subsequent knitting,
wherein individual rib borders are knitted and
drawn off and the last course of each rib border
is transferred to one of two needle beds and
brought thereon into the transfer position by
the knitting needles being pushed out together,
whereafter the points of the transfer bar are
introduced into the loops of the said last course
for transfer and the rib border is retained after
the transfer until the running-on comb has become
detached from the first run-on course, whereafter
the transfer bar with the rib border on it is
removed from the rib machine."

A German company, Universal Maschinenfabrik, also hold patents
on below-bed rib transfer mechanisms for 'V'-bed knitting machines.
Their first application, made in 1964 (7), is similar to the Stovhase
machine (6) in that it uses a bar of bearded needles situated below
the beds to collect the last course of loops of the knitted rib. The Universal machine however has an additional device situated above the beds of the knitting machine which performs an intermediate transfer operation allowing the doubling of loops in the rib but still maintaining loops on adjacent needles without a space.

Universal claim:

"A flat knitting machine having apparatus for receiving a course of stitches from the needles, comprising a point bar including a plurality of transfer points which are elongated in a common direction, are juxtaposed on said point bar in a direction transverse of said common direction and are arranged so as to constitute a plurality of juxtaposed groups, the spacing of the transfer points of each group in said transverse direction being uniform; and comprising moving means for moving said groups in said transverse direction toward and away from a closely packed position in which the spacing of said groups from each other is equal to said uniform spacing."

In a later patent Universal again use a transfer mechanism situated below the beds of a 'V'-bed knitting machine (8) and again the device is able to perform the doubling of loops. This machine however also allows for the gauge or pitch of the loops to be varied allowing the rib to be knitted at a different gauge to the rest of the garment piece.
Universal claim:

"A flat knitting machine having a frame on which are mounted two straight needle beds which are elongated in a common, horizontally extending direction and transversely spaced so as to define a knitting space therebetween, a set of knitting needles juxtaposed in said common direction in substantially uniformly spaced relationship, each knitting needle being movable on the associated needle bed into and out of the knitting space, and operating means for moving the needles in timed sequence, said operating means including a carriage mounted on said frame for reciprocating movement in the common direction wherein an elongated transfer member releasably mounted on said frame in a position in which it is elongated in said common direction and downwardly spaced from said needle beds, carries a set of point members in longitudinally and substantially uniformly spaced relationship and wherein guide means are further provided for guiding respective stitches of a fabric knitted on said needle beds to said transfer member, said guide means including a set of elongated guide members dimensioned to be received in the stitches, each guide member having an upper terminal portion adjacent to a respective point member on said transfer member, said guide
members being spaced from each other in said common direction and wherein stitch-transfer means responsive to the movement of said carriage are arranged for transferring stitches from the needles on said one needle bed to the adjacent upper terminal portions of said guide members."

Of the methods described above, it would appear that only the Fabrique Nationale(3), (4), (5) inventions have been applied commercially, in that all currently available machinery systems are based on the methods described in these patents which are apparently improvements on that by Jean Borne (2). As will be seen in Chapter 4, the Boehringer, Bentley Cotton and Scheller machines are each based on the Fabrique Nationale methods.

3.2 Publications

Although patents for automatic rib transfer machines date back at least to the early 1960s, it was not until 1969 that commercially available machines were first publicised in the textile journals. Fabrique Nationale d'Armes de Guerre S.A. of Belgium introduced their Model R.A. machine in 1969 having reacted to comments voiced by the textile industry 18 months previously when a prototype system was demonstrated at Basle. An article in the Hosiery Trade Journal (9) briefly outlines the features of the two-section and four-section 'V'-bed Model R.A. machines. A more detailed description is given in a later article (10) and the author has summarised the essential features of the F.N. Machine in Section 4.1.
In 1970, the French firm Rene Bordier also introduced an automatic rib transfer machine known as the Borcoto 70 which is described in the April 1970 edition of the Hosiery Trade Journal (11). This machine used the same transfer principle as the F.N. System, i.e. with "eyed" needles engaging with the hooks of the knitting elements (3), but this was only a single-section machine. The machine was never a commercial success and now the only commercially available automatic rib transfer machines are those offered by Bentley Cotton, Scheller and Boehringer.

Bentley Cotton first introduced their model VOR/M at the International Textile Machinery Exhibition, ITMA, in 1971 at Paris. This single-section 'V'-bed machine automatically loaded up to 16 ribs on to a magazine bar located above the beds of the machine (12). Later developments led to the introduction of a doubling system for this machine known as the "Doublarib". The VOR/M is now known as the Autorib 3 (13).

Two other commercially available machines utilise the same method of operation as the Fabrique Nationale RA models and the Bentley Cotton Autorib 3. The Scheller Transrobot (14) is a single-section 'V'-bed machine fitted with a rib transfer mechanism above the beds and, like the Bentley Cotton Doublarib, it incorporates doubling facilities. Boehringer aimed their Ribomat P automatic rib transfer 'V'-bed machine at a different market. By combining the rib transfer bar loading of the Ribomat P with a straight bar linking system known as the Autolinker they offered not only a capability to load magazine bars automatically but also the feature of automatically linking trims onto fully-fashioned garments (15), (16).
Fuller descriptions of all the above-mentioned machines are given in Chapter 4.
CHAPTER 4

CURRENT ALTERNATIVES TO THE CONVENTIONAL MANUAL RIB TRANSFER PROCESS

There are four commercially available automatic rib transfer systems; each is marketed as a machine 'package', that is to say a complete knitting machine equipped with an automatic rib transfer mechanism. At the time of writing these machines cost in the region of £18,000 to £25,000 per knitting head or section. (Some machines have more than one knitting head or section and are similar in layout to the fully-fashioned straight bar machines).

4.1 The Fabrique Nationale Model R.A. System

This machine was first shown at Basle in prototype form in 1967 but it was not until 1969 that the model RA was launched commercially. The machine is either of 2-section or 4-section single knitting system, four carrier 'V'-bed design equipped with the Fabrique Nationale patented system of rib transfer (3)(4)(5), operating above the beds of the machine.

Following the last knitted course all loops on the front bed of the machine are transferred to the back bed. A transfer bar consisting of a row of eyed elements is brought down towards the knitting elements; simultaneously, all of the knitting elements are raised by a lifting bar (see Fig 4.1). Each eyed element is caused to engage with the hook of the knitting element (as shown in Fig 4.2). The lifting bar raises the knitting elements to their knitting height such that the knitted loops are behind the latches and the latches are open to facilitate the engagement of the transfer elements. Once the two sets of elements are positioned
Fig. 4.1 F.N. Model R.A. System of Automatic Rib Transfer
Fig. 4.2 Engagement of the Transfer Element

Fig. 4.3 Loop Transfer
Fig. 4.4 Engagement of the Transfer and Magazine Bar Elements

Fig. 4.5 Special Transfer Bar for Doubling
as shown in Fig 4.2 they move together in a manner such that each loop slides up the knitting element, thereby closing the latch, and on to the transfer element (see Fig 4.3). The transfer elements are then disengaged from the knitting elements and raised to engage with the magazine bar (dotted line in Fig 4.1). Eyes formed in the transfer elements receive the points of the magazine as shown in Fig 4.4. The rib is then swept onto the magazine bar by a comb-like bar. When the required number of ribs have been transferred to the magazine bar, the full bar is removed and replaced with an empty one.

Doubling (see Section 1.3.3) may be performed on the model RA machine by the attachment of a special transfer bar (5). The eyed transfer points are mounted in blocks or leads, the number of elements per lead depending on the doubling frequency. Each lead is connected to the adjoining lead in a manner that allows the leads either to move apart by one pitch or to be compressed together so that the elements are all equispaced (see Fig 4.5).

When a rib with doublings is knitted, the appropriate leads are selected so that when the leads are "expanded" the "missing" transfer elements align with the empty knitting elements left by the doubling of the loops. After the knitted loops have been transferred to the transfer elements, in the manner described above, the leads are closed up so that all the elements are of a uniform pitch for transfer to the magazine bar as previously described.

The gauge of the machine must be chosen to match the gauge of the fully-fashioned machine, e.g. to knit a rib for a Cotton's 21 gauge (i.e. 21 needles per 1½ inches) machine, the Model RA must be fitted with needle beds of 14 needles per inch.
Fabrique Nationale claim that provided there is no great difference between the number of courses in the cuff ribs and body rib, the output of a two section Model R2RA making two cuffs simultaneously on each section can balance that of a four section model R4RA making one body rib per section; the production of the two machines together (with a pitch of 14 needles per inch) will meet the requirements of four modern 12-section 21-gauge fully-fashioned machines, making the rib ends for about five dozen garments per hour (10).

4.2 The Bentley-Cotton Autorib 3 System

The Bentley-Cotton VOR/M was introduced in the early 1970s as a single section, single knitting system automatic rib transfer 'V'-bed knitting machine. Following problems with reliability, the machine was redesigned, facilities for doubling added, and is now known as the Bentley-Cotton Autorib 3.

The method of rib transfer is exactly as described in Section 4.1 using eyed transfer elements to engage with the hooks of the knitting elements. Early VOR/M models used an auxiliary transfer cam box, normally stationed outside the knitting zone, but the transfer cams are now incorporated in the main cambox. With the Autorib 3, all loops are transferred to the back bed, as with the Fabrique Nationale System, before the eyed transfer elements engage with the hooks of the knitting elements to effect the transfer. The ribs are then transferred from the transfer elements to a stationary magazine bar above the rear of the machine, where up to 16 ribs may be stored.

Bentley-Cotton claim running speeds in excess of 50 courses per minute for full-width knitting (12) but the earlier machines suffered from a weakness in the drive system at these speeds. The carriage was driven by a split, reciprocating belt but because of
the high forces generated when the carriage reached the end of its stroke and started the return stroke, belt life was a problem.

The recent acquisition by Bentley-Cotton of the Fabrique Nationale textile machinery division (13) means that Bentley-Cotton can now offer two complementary types of rib transfer machine, the model RA and the Autorib 3.

4.3 The Scheller Transrobot System

The transrobot is like the Autorib 3, a single section, single system 'V'-bed machine and uses an identical method of rib transfer and doubling with 'eyed' transfer elements set in sliding leads. With a 40inch bed length, the Transrobot is longer than the Autorib 3 but the production speeds with full-width knitting are claimed to be similar (14) at more than 50 courses per minute. It is stated that under average conditions one machine can feed 8 sections of fully-fashioned equipment. Again it is necessary for the gauge of the machine to match that of the fully-fashioned plant that it is intended to feed.

4.4 The Boehringer Ribomat 'V' & 'P' Systems

The Boehringer system incorporating the Autolinker differs slightly from the previous machines in that it is truly an automated fully-fashioned garment manufacturing system. It not only automatically transfers rib borders on to magazine bars but the Autolinker machine also automatically links rib trims onto the garment pieces. Both the Autolinker and the fully-fashioned plant are fed with ribs automatically loaded onto bars by the Ribomat 'V'-bed single section single system knitting machine.
The Ribomat operates in exactly the same way as the described machines above, i.e. with 'eyed' transfer elements. Production rates are also similar with a maximum full-width knitting speed of about 50 courses per minute \(^{(15)(16)}\) and one machine on average can feed 8 sections of fully-fashioned plant.

### 4.5 The Bentley Cotton C.R.P.

The Bentley Cotton Carrier Rib-to-Plain is a machine capable of knitting both rib and plain fabric on the same knitting section thus making rib transfer unnecessary. It is an adaptation of the standard Cotton's Patent Straight bar knitting frame, modified in such a way as to facilitate the knitting of a rib fabric. This is achieved by introducing a second set of knitting elements, in the form of a set of latch needles, which operate in a plane at right angles to the main bearded knitting elements (see Fig 4.6). The bearded knitting elements are mounted in a compound bar such that alternate elements can be lowered (see Fig 4.7) out of action during the rib knitting phase of the cycle.

The rib section of a garment segment is formed between the latch needle bar and alternate bearded needles on the compound bar. Unlike a standard 'V'-bed knitting machine, the latch needles are operated in unison not in sequence, thus in order to ensure that sufficient yarn is available to correctly form each stitch, the yarn is laid between both sets of elements with a standard Cotton's Patent slurcock. Adjustment of the amount of yarn fed in is very critical as roughly twice the amount of yarn has to be provided to form a rib structure as is needed for a plain structure. This is one of the major operational problems with the CRP system.
Fig. 4.6 The C.R.P. Knitting Elements

Fig. 4.7 The C.R.P. Compound Needle Bar
Fig. 4.8 C.R.P. Loop Transfer

The Ultramatic Compound Knitting Element

Fig. 4.9 The Monk Ultramatic Knitting Elements
Once the rib portion of the garment piece has been knitted, the yarn loops held by the latch needles are transferred to the compound needle bar. This is achieved by engaging the so far inoperative alternate bearded needles in the compound bar, with the yarn loops on the latch needle bar. To facilitate this transfer 'pelereens' are provided on the side of the latch needles to support the yarn loop in such a way that it can be pierced by the bearded needle (see Fig. 4.8). The latch needles are then withdrawn from the yarn loops and retracted to a rest position, leaving all loops on the compound bar. The plain knitted portion of the garment segment is now formed by the compound bearded needle bar, with all elements knitting, in an identical manner to a standard straight bar knitting frame.

The main drawbacks of the CRP machines are their cost (almost twice the price of a standard straight bar knitting frame - £350,000 against £180,000) and their complexity. The numerous mechanisms of the CRP require frequent resetting by skilled operators to maintain an acceptable standard of production.

4.6 The Monk Ultramatic

The Monk Ultramatic is a straight bar knitting machine capable of knitting both rib and plain fabric on the same knitting section. Like the CRP machine manufactured by Bentley Cotton, the knitting of rib fabric is achieved by adding a second set of knitting elements which act perpendicular to the standard straight bar knitting elements. These secondary elements take the form of a set of compound needles (see Fig. 4.9).
and may be regarded as positively driven latch needles. Instead of a normal pivoting latch, the latch of each compound element acts axially along the element, controlled by a butt protruding from the element. The latch is positively opened and closed by a mechanism acting upon this butt (see Fig. 4.9).

The bearded needle bar is similar to that of the CRP, having the facility to take alternate elements out of action during the rib knitting operation (see Fig. 4.7).

The operating sequence of the Ultramatic is very similar to that of the CRP. The rib portion of the garment piece is formed by the two sets of elements. All loops are then transferred from the compound knitting elements to the previously deactivated bearded needles and the plain fabric portion of the garment piece is then formed on the bearded needles.

The Monk Ultramatic, like the CRP, is mechanically complex and suffers from similar operational problems. This, combined with its high initial price of over £300,000, limits the use of this machine to the larger knitwear manufacturers.
CHAPTER 5

INDUSTRIAL INVESTMENT CONSIDERATIONS LEADING TO THE DEVELOPMENT
OF AN ATTACHMENT FOR CONVERTING EXISTING MACHINES TO PERFORM
AUTOMATIC RIB TRANSFER

Automatic rib transfer, as a process, is already being used to a
limited extent within the fully-fashioned knitwear industry. Therefore
the following assessment concentrates on the details of the process
rather than the overall concept.

5.1 A Survey of Currently Available Systems for Knitwear Manufacture
from the Industrial Investment Viewpoint

The need to reduce the cost of fully-fashioned knitted outerwear
garments has, for at least a century, attracted the attention of many
people from the machinery designer to the knitter on the shop floor.
In the early stages of the development of the fully-fashioned knitting
process, a great deal of effort was given to improving the actual
method of knitting the garment. Modern fully-fashioned machines
represent many years of development and therefore leave little room
for improvements in performance without an expensive and fundamental
redesign, but considerable potential remains for improving the other
processes associated with fully-fashioned garment manufacture.

Currently the majority of manufacturers knit rib borders on
'V'-bed machines, transferring these ribs to the fully-fashioned
knitting machines either manually (See Section 1.3.1 and Chapter 2)
or automatically (See Section 1.3.2, and 4.1 to 4.4). The Bentley-
Cotton company manufacture a straight bar rib-to-plain machine,
known as the C.R.P. (carrier rib-to-plain) which is able to knit the rib border followed by the plain, fashioned section of the garment on the same machine (See Sections 1.4.1 and 4.5). The main drawback of this system, apart from its complexity, is the enormous capital cost, in the region of £250,000 to £350,000 depending upon the extra options provided.

5.1.1 Conventional Manual Rib Transfer

This process (See Section 1.3.1) is extremely labour intensive. It also results in a considerable wastage of yarn which is knitted as waste courses or unroving courses on each rib to enable the operator to manipulate the rib for running-on. With the increasing cost of both labour and raw materials, knitting manufacturers are looking to automatic rib transfer as a means of increasing production rates whilst reducing garment costs to compete with cheaper imports from lower labour cost countries. However, small companies often have insufficient capital to invest in automatic rib transfer machines and have no option but to retain their "runners-on".

Nevertheless, the manual process has one major advantage over automatic rib transfer and that is its versatility and adaptability. Skilled "runners-on" are able to cope with changes in yarn type and styles that prove difficult to achieve with the automatic machines. Moreover, for sampling and small batch production, where frequent changes are made, manual rib transfer is often superior.
5.1.2 Alternative Processes

The alternative processes to manual rib transfer fall into two categories. Firstly there are the machines that knit the complete garment segment such as the Bentley-Cotton C.R.P. (See Sections 1.4.1 and 4.5) and the Monk Ultramatic automatic rib-to-plain machine developed more recently (See Sections 1.4.2 and 4.6). Both of these types of machine involve large capital investment and limit the gauge of knitting, the types of yarn used and the style of the garment.

Automatic rib transfer machines (See Section 1.3.2) such as those described in Sections 4.1 and 4.4 offer a 'half-way' stage between the complete garment segment machines and the manual process. These machines still represent a sizable capital investment and at a time when the knitting industry of the western world is facing fierce competition from cheaper imports, it is only the larger companies that are able to make such investments.

5.2 Evaluation of Currently Available Processes

There are then three alternatives to be considered here, each involving different degrees of capital investment.

5.2.1 Manual Rib Transfer

Manual rib transfer requires very little in terms of capital investment, merely the cost of a bench mounted fixture to take the magazine bars to be loaded, a stool, and suitable illumination. The main cost of this process is labour, both as direct production cost and as training costs; it can take up to a year to train an operative to a reasonable standard, and labour turnover is high (See Section 2.1.3). Manual rib transfer is often the only means of feeding ribs to a fully-fashioned machine available to small firms, who cannot afford to invest in expensive automatic machinery.
Versatility is also an asset of manual rib transfer enabling the smaller firms to offer the facility of small batch production. It also provides for the manufacture of new sample designs for approval prior to production.

5.2.2 Automatic Rib Transfer

This provides a means of considerably reducing the labour content of manufacturing a fully-fashioned garment piece. The high capital cost of the presently available systems confines their use to major firms who produce large batches of similar garments, thus offsetting the reduced versatility of these systems over manual rib transfer techniques.

5.2.3 Rib-to-Plain Knitting Machines

Rib-to-plain knitting machines might be thought of as the ideal answer to the problem of reducing the cost of fully-fashioned knitwear. The whole process takes place on one machine, thereby reducing transportation and storage costs between stages, and providing no possibility of different batches of yarn being used for the body of the garment and the rib. Each machine requires only one or, at the most, two operators against the three or four operatives required even with automatic rib transfer systems. The plant can also be run for 24 hours per day. Nevertheless, such is the complexity of machines like the Bentley-Cotton C.R.P. that a great deal of lost production time occurs due to the need to reset the machine and to maintain its precise settings. Moreover, the principal drawback is that of capital cost; at well over £250,000 per machine, few companies can afford such rib-to-plain machines.
5.3 Proposals for Converting Existing 'V'-Bed Knitting Machines to Facilitate Mechanised Rib Transfer Operations

From the preceding Sections (5.1, 5.2) it has been argued that there is a need for a reliable but reasonable priced machine capable of automatic rib transfer. It was with this need in mind that the first proposals for a test rig were drawn up.

The aim was to design and develop a mechanism for loop transfer that was capable of being attached, as a conversion unit, to any of the common makes of 'V'-bed knitting machines. If this machine was to knit individual ribs, and transfer them to another machine, then certain basic motions would be needed for the conversion unit, whatever the final method of transfer decided upon. In order that the latch needles should operate satisfactorily, tension must be applied to the knitted loops. Some method of introducing the transfer elements into the knitting zone was also needed, and thus the following basic motions were proposed.

5.3.1 "Take-down" Motion

In normal 'V'-bed knitting, the ribs are knitted in a continuous roll separated by waste courses and draw threads. Each rib then exerts a sufficient "take-down" tension on its successor to allow the latch needles to function. In order to replace this effect, a linear, vertical motion was proposed to introduce elements into the knitting zone to apply tension to the knitted loops of a single rib. The elements had to be able to exert a constant force on the fabric as it was knitted and to cater for a reasonable length of rib.
5.3.2 "Take-off" Motion

The "take-off" motion was required to place suitably designed transfer elements accurately adjacent to the knitting elements; it also had to effect the transfer of the knitted loops from the knitting elements on to these transfer elements and to withdraw these to a suitable rest position.

Chapter 6 describes these motions, elements and auxiliary motions in detail, as embodied in the first Loughborough ART (mark I) System.
The first research rig for automatic rib transfer (conveniently named the Loughborough ART system) was based on a Dubied hand-operated 'V'-bed knitting machine. Being of simple construction and operation it provided a means of knitting a rib fabric, and could be suitably modified for researches into automatic methods for transfer of such ribs.

The requirements of the mechanisms and elements to be fitted to the knitting machine were thought to be:

(i) to apply take-down tension to the welt edge of the rib;
(ii) to position the transfer elements in the knitting zone adjacent to the knitting elements carrying the last course of knitted loops of the rib;
(iii) to operate the knitting elements in such a way as to transfer the knitted loops from the knitting elements to the transfer elements; and
(iv) to remove the transfer bar, complete with rib, clear of the knitting zone to a lower position to enable the cycle to recommence.

6.1 Elements

In the operations described previously as constituting the basic rib transfer procedure, the following four elements are required:

(a) elements to apply take-down tension to the welt edges of individual trims;
(b) knitting elements;
(c) elements to transfer the last course of knitted loops away from the knitting elements; and
Fig. 6.1 Take-down Comb

Fig. 6.2 Take-down Comb With Wire Inserted
Fig. 6.3 Take-down Hooks Protruding Between the Beds

Fig. 6.4 Hook-up Course with Take-down Elements and Knitting Elements of One Bed
(d) magazine bar elements upon which to store the completed ribs prior to removal from the machine.

Although co-operation between each set of elements is essential to the cycle of operation of a fully automatic rib transfer system, their functions can be considered individually as below.

6.1.1 Take-down Elements

The function of a set of take-down elements is basic to any knitting process in that it is necessary to apply a force to the welt edge, i.e. first course of knitting, to enable the knitting elements to function correctly (See Section 1.1.1). Over the years several alternative types of element have been used for applying this force, one of the earliest being the take-down comb still in use today for the knitting of design samples on hand-operated machines. This comprises a series of wire loops which are inserted between the beds of a 'V'-bed machine from below, so that the wire loops protrude between the loops of the first course of yarn (See Fig 6.1). A thin retaining wire is then inserted through the wire loops so as to trap the yarn loops. Weights are then added to the comb to obtain the required take-down force (See Fig 6.2). To release the comb from the completed fabric the retaining wire is withdrawn. A disadvantage of this method is that it requires an awkward manipulation of the comb and wire to attach it to the loops of the set-up or welt course.

Another common method of applying take-down force to the set-up course is to use welt hooks. With this method, a bar of hooked elements is introduced into the knitting zone, the hooks of the elements being positioned just through the gap of beds of the knitting machine (See Fig 6.3). The set-up course can either be laid around
Take-down Hooks

Set-up Course

Fig. 6.5 Hook-up Course with Take-down Hooks Protruding Between the Beds

Direction of Shogg

Fig. 6.6 The Knitting Machine Bed is Shogged to Engage the Yarn Loops with the Take-down Hooks
Fig. 6.7 Press-off Bar Operation

Fig. 6.8 Pivoting Take-down Hooks
the welt hooks and the knitting elements of one bed, (See Fig 6.4) or the welt course may be laid between both beds in the normal manner; the welt hooks are then introduced as before, and one bed moved relative to the other, or shogged, to engage the yarns with the elements (See Fig 6.5 and 6.6). The hook at the end of the element can cause difficulties in cleanly disengaging all of the loops. One solution to this problem is to bring a bar over the top of the hooks, thus forcing the loops off the hook (See Fig 6.7a & b) and this is typically used on the Bentley Cotton Doublarib machine.

For the Loughborough ART (Mark I) research rig an element was finally devised that was a combination of the better features of the two take-down systems described above.

The final element was basically a shallow hook shape to provide loop retention and easy disengagement. This was mounted in a bar so that it could be pivoted, i.e. rotated about its vertical axis, through $90^\circ$. (See Fig 6.8a & b and Plates 6.1 & 6.2). This enabled the elements to be passed through the loops of a welt course set up between the beds of the machine and then pivoted to engage the loops. Once the take-down weight was applied to the loops, the hooks could again be pivoted to retain the loops during knitting. Because of this pivoting action of the elements, and the shallow angle of the hooks, the loops could be retained at the hook-up stage and yet be released readily when the fabric was removed from the machine. The other advantage of this system was that it was not necessary to traverse the carriage or cam-box of the machine during engagement, as with the welt hook system described in connection with Figs 6.3 to 6.6.
6.1.2 Take-off Elements

The take-off elements were required to perform two different functions. Firstly they needed to engage with and receive loops from the knitting elements, and subsequently they needed to engage with and transfer to the elements of a magazine bar. Initially the research priority was directed towards achieving a reliable transfer from the knitting elements since, if this was not realised, then any research directed to the second stage would be useless.

At the end of the knitting cycle the loops of the last course were held between the beds of the knitting machine by the hooks of the knitting elements of each bed. It was in this position that the take-off elements had to engage with the loops, and, because the hand-flat knitting machine had no provision for transferring knitted loops from one bed to another, the take-off elements had to accept loops simultaneously from both back and front beds. The knitted loops were retained and positioned between the beds by the knitting elements which in turn were located in the 'tricks' or slots of the beds and by the cams of the knitting carriage. Thus the spatial location of the loops was predictable and repeatable. It was therefore necessary to research into means for penetrating these loops by suitably formed and operated elements.

Initial trials were made with hand-made elements formed from latch needles which had been modified by partly removing and reversing the hooks (Fig 6.9a & b). Two types of elements were eventually evolved, a shorter one to engage with the loops on the front bed of the machine and a longer one to engage with those on the back bed. Such use of modified latch needles enabled the latch to form a "bridge" between the take-off elements and the magazine bar elements for the second stage transfer (See Fig 6.10) the latch return being by magnetic means.
The front-bed loops were engaged by raising the take-off elements to a position adjacent to the hooks of the front bed knitting elements (Plate 6.3), whereby the points of front-bed transfer elements penetrated the front-bed loops whilst, during the same raising action, the back-bed transfer elements had also risen through the spaces between these loops. By raising the elements just through the gap of the beds of the machine it was possible to raise, and hold in the raised position, the back-bed knitting elements (this was achieved by a specially designed auxiliary cam box, See Section 6.2) so that the back-bed take-off elements were held against the side of the back-bed knitting elements (See Plate 6.4). The auxiliary cam box was later replaced by a presser plate which raised all of the back-bed knitting elements in unison (See Plate 6.5). Modifications were made to the back-bed knitting elements (See Section 6.1.3) so that the loops held on these elements were raised to a position over the points of the back-bed take-off elements. At this point the take-off elements were again raised so that the back-bed take-off elements were able to pierce the loops held on the back-bed knitting elements. With all of the loops held thus, the back bed knitting elements were withdrawn from the loops by traversing the auxiliary cam box. The front bed knitting elements were then disengaged from the knitted loops by a subsequent traverse of the cam box, with front bed needles performing a knitting action but without yarn, thus serving to "press-off" the loops.

At this stage the loops of the last knitted course were retained on the take-off elements. The take-off bar could then be withdrawn from the knitting zone to its lower position, ready to engage with the magazine bar to which the ribs were to be transferred and stored.
Fig. 6.9 The Two Types of Take-off Element

Fig. 6.10 Transfer to a Magazine Bar Element

Fig. 6.11 The Engagement of Two Narrowing Points
The take-off elements, formed from modified latch needles, adequately received the knitted loops from the knitting elements. However, for the second stage, i.e. transfer to the magazine bar; they proved inadequate due to the latches tending to stick in the forward position (Fig 6.10) rather than being satisfactorily returned to the rearward position by magnetic means as had been intended.

It was for this reason that a new take-off element was sought. The shape of the tips of the modified latch needles was found to be similar to that of the narrowing points used in fully-fashioned knitting frames (See Section 1.1.3) and therefore a set of narrowing elements (See fig 6.11) was obtained and evaluated. Their performance was found to be superior to that of the latched elements for two principal reasons. Firstly, it was possible to use a single type of element for both back and front bed loops, and secondly, the shape of the narrowing point was designed for ease of loop transfer from one element to another thus making the transfer from the take-off bar to the magazine bar very similar to the operation regularly performed in fully-fashioned manual rib transfer (See Plate 1.13 in Section 1.3.1). It was therefore possible to use standard narrowing points in both the take-off and magazine-bars.

6.1.3 Knitting Elements

In Section 6.1.2 it was stated that modifications to the knitting elements of one bed of the machine were required. Because of the simple nature of the hand-flat knitting machine used for the system, no facility for loop transfer from bed to bed was available. However, many 'V'-bed knitting machines used in rib production have a transfer facility and have specially designed elements for this purpose. For example, one construction of transfer knitting elements is shown
A Standard Knitting Element With Bed-to-bed Transfer Facility

Loop on Rear Knitting Element

Rear Knitting Element Raised to Engage Loop With Take-off Element

Fig. 6.12 Loop Transfer to Take-off Element
Fig 6.12. Each loop to be transferred is raised by lifting its knitting element higher than its normal knitting height by an auxiliary transfer cam in the cam box of the machine so that the loop is engaged against a notch in the element and is forced upwards. The underside of the element is scalloped so that the opposing element on the other bed of the machine may pass between the element and one leg of the loop.

A similar "notch and scallop" modification was therefore made to the elements of one bed of the hand-flat machine. This enabled the loops retained on the elements to be penetrated by the take-off elements as described in Section 6.1.2 rather than by the elements of the opposing bed as described in the preceding paragraph.

6.1.4 Magazine Bar Elements

The most exacting area of the loop transfer system described in Sections 6.1.1 to 6.1.3 was the interaction between the take-off elements and the knitting elements. Transferring the loops from the take-off bar to a magazine bar for storage was a simpler task, in that such transfers are regularly performed in the feeding of knitted ribs to fully-fashioned knitting frames (See Section 1.3).

With the adoption of standard narrowing points for both take-off and magazine elements the accuracy of their interaction and transfer ability was guaranteed. The magazine elements were to be brought into engagement with the take-off elements for the transfer to take place as shown in Fig 6.11. This transfer mechanism, although designed, was never fitted to the Mark I machine but was used as a basis for the later Mark II machine (See Chapter 7).
Fig. 6.13 Cross-section of the Mark I Rig
6.2 Motions and Mechanisms

The elements described in Section 6.1 would have been completely useless without mechanisms capable of positioning those elements reliably and accurately relative to one another. Although the hand-flat knitting machine offered simplicity of operation it also imposed limitations of size upon the mechanisms and their means of operation. The mechanisms, although interacting with each other, are best considered separately.

6.2.1 Take-down Mechanism

The function of this mechanism was to deliver the take-down bar and elements into the knitting zone, operate the elements, and then apply a take-down force via the elements to the welt edge of the rib. The elements, although needing precise positioning in the knitting zone and in their lower position, did not need such critical control during the knitting cycle as the bar was effectively "suspended" from the beds of the knitting machine by the fabric. The stroke of this motion was of the order of 300mm and so a carriage system was designed with guide rollers mounted on the carriage and running on vertical guide bars (See Fig 6.13). As shown in Fig 6.8, and Plates 6.1 and 6.2, on top of the carriage was mounted the take-down bar with its operating cylinders to pivot the take-down hooks (See Section 6.1.1). The upper and lower positions of the carriage and bar assembly were controlled by stops. Motive power for the take-down assembly came from a double-acting pneumatic cylinder controlled by a 5-port spool valve (See Section 6.3) driving from a base plate on the machine to the base of the carriage assembly (See plate 6.6).
Fig 6.14a The Take-off Mechanism in its Rest Position
Fig. 6.14b The Take-off Mechanism in its Operating Position
The use of a double-acting air cylinder to drive the take-down system enabled a small back-pressure to be applied to the cylinder during knitting to provide additional take-down force, this being adjusted by a pressure regulator, eliminating the need to add extra weights to the carriage.

6.2.2 Take-off Mechanism

The limited space available on the hand-flat knitting machine necessitated the development of a compound linkage mechanism to operate the take-off elements. In order to clear the take-down carriage as it was raised into the knitting zone, the take-off mechanism had to be withdrawn from that area. This led to the design of the swinging action shown in Fig 6.14 and Plate 6.7.

At the end of the knitting cycle the take-off mechanism was swung from its rest position (Fig 6.14a) to its operating position (Fig 6.14b) by a pneumatic cylinder. In this latter position the 4-bar linkage supporting the take-off bar and elements was operated by a cam and push rod system to drive the elements up into the knitting zone. The four bar linkage was designed to provide the elements with the motion shown in Fig 6.14b such that, at the top of the stroke, the elements had not only been driven upwards through the loops on the front-bed elements, thus collecting them, but had also moved towards the back-bed of the machine, to further collect the loops from that bed (See Plate 6.8).

The actual take-off motion was operated mechanically rather than pneumatically to provide the precise control necessary for accurate positioning of the elements, this motion being derived from a cam and camshaft mounted on the base plate of the machine (See Plates 6.6 & 6.9). Two matched cams were used, one for each
Fig. 6.15 Driving Mechanism for the Take-off Elements
Fig. 6.16 Standard and Auxiliary Cam Boxes
71

end of the take-off bar, with pivoting follower arms driving push-rod linkages attached to the driver arm of each four-bar linkage (See Fig 6.15).

6.2.3 Knitting Element Operation

The transfer of loops from the front bed elements to the take-off points was effected by use of the knitting machine carriage, as described in Section 6.1.3. Transfer from the rear-bed knitting elements to the take-off points, however, required an additional operation not provided by the simple standard knitting machine cam box. The action required to achieve the rear-bed transfer was to position the take-off elements so that, as the rear-bed knitting elements were raised, the point of each take-off element ran against the side of its associated knitting element and entered the scallop, thus penetrating the loop as shown in Fig 6.12.

Initially an auxiliary cam box was designed and built to lift the rear-bed knitting elements to the transfer position (See Fig 6.16). By operating this cam box, the rear knitting elements were raised and held in the transfer position whilst the take-off elements were raised to their maximum position, penetrating the knitted loops. Reversal of the auxiliary cam box retracted the rear-bed knitting elements, casting off the knitted loops and leaving the loops on the take-off elements.

This method of operation was later modified to enable the rear-bed knitting elements to be operated by a separate operating plate, or presser plate, rather than by the auxiliary cam box, thus reducing the time taken to effect the transfer (See Fig 6.17 and Plate 6.5). The operating plate was controlled in a slide-way by linear bearings.
Fig. 6.17 Modified Rear Bed Knitting Element Actuation
Fig. 6.16 Take-off to Magazine Bar Transfer
and powered by a double-acting pneumatic cylinder. Once lifted to
the transfer position, the take-off elements being raised through
the knitted loops, the rear-bed knitting elements were lowered by
retracting the operating plate and traversing the main knitting
carriage across the beds of the machine.

6.2.4 Magazine Bar Mechanism

The operating mechanism of the magazine bar, although designed,
was never fitted to the Mark I machine rig. This mechanism was
designed to use standard narrowing elements as described in Sections
6.1.2 and 6.1.4 and would have been the last of the mechanisms to be
tested on this research rig. Because of the success of the initial
transfer from the knitting elements to the take-off elements, it was
decided that the magazine bar transfer system should be subsequently
tested on a powered 'V'-bed machine of the type used industrially
to produce knitted ribs which eventually became the basis of the
Mark II ART System (See Chapter 7).

The basic design of this mechanism is shown in Fig 6.18 and
consists of two motions, one to drive the magazine bar in and out of
engagement with the take-off elements and the other to sweep the rib
off the take-off elements to the magazine bar elements.

6.2.5 Cut and Clamp Mechanism

In order that the individual ribs could be separated from one
another it was necessary to cut the yarn which still attached the
rib to the yarn carriers of the machine. The cut end attached to
the rib needed to be released but the end still attached to the
carrier had to be retained to enable the next rib to be knitted.
If this latter yarn end was accidentally released, there would be
insufficient tension to operate the latches of the knitting elements
when the yarn was laid across the machine bed to form the welt course.
Fig. 6.19 The Cut and Clamp Mechanism
A device was developed that would both cut and clamp this "umbilical" yarn as the rib was lowered away from the knitting zone. The device (shown in Fig 6.19) consisted of a double-edged blade operating in a slot, the lower edge being sharp and performing the cutting operation and the upper edge being chamfered to clamp the yarn. As the take-off bar and rib reached their lower position the cut and clamp jaw was extended by the main air cylinder, thus opening the jaw, and releasing the previously held yarn as the retaining collar reached the front support, the stroke of the blade being greater than the stroke of the blade carrier. Once in its fully forward position, the auxiliary cylinder swept the mechanism across the yarn path to collect the yarn into the jaw. The main cylinder was then retracted, closing the cutting unit to cut and clamp the yarn and retain it clear of the path of the take-down and take-off mechanisms.

6.2.6 Bed Drop Mechanism

Although this mechanism was not essential to the functioning of the elements involved with the transfer operations, lowering the front bed of the knitting machine did provide a little extra clearance at various stages in the transfer cycle (See Section 6.3). The original hand-flat 'V'-bed machine had the facility to lower the front bed by operating a hand lever. This lever turned a shaft running across the front of the machine just below the bottom of the front bed and actuated a cam at either end of the shaft which lowered and raised the front bed. A simple modification to this system, consisting of an extra operating link at each extremity of the shaft, allowed the shaft to be operated by a pneumatic cylinder at each end of the machine (See Plate 6.10).
Needle Lift

Take-off Swinging Cylinders

Take-down Drive

Bed Drop

Cut and Clamp

Take-down Hook Pivot

Fig. 6.20 Control System
Fig. 6.21 Operating Cycle
6.3 Control System and Operating Cycle

The concept of the Mark I research-rig was to produce a simple, versatile system for evaluating various types of element and mechanism for performing rib transfer. The rig therefore required a simple and versatile control system and it was for this reason that a mechanical/pneumatic control-and-drive system was chosen. Control of the operating cycle was provided by a single camshaft upon which were mounted the cams for operating pneumatic valves and for powering the main take-off mechanism (See Plate 6.6). The camshaft was driven by a variable-speed d.c. motor which was controlled by microswitches positioned at each end of the bed of the knitting machine and by a microswitch operated by the camshaft (See Fig 6.20).

The system is best described by considering a single cycle of operation, in the numerical sequence shown in Fig 6.21, as follows:

**Position 1** At the start, the knitting machine carriage was parked at the right hand end of the beds as were the yarn carriers. The mechanisms were all withdrawn from the knitting zone and all mechanism actions were instigated by the cams on the camshaft. The carriage traversed to the left, laying in the first course of yarn between all the knitting elements in the knitting zone of both back and front beds.

**Position 2** The carriage reached the extreme left of the bed and started the camshaft rotation. The take-down cam operated the pneumatic valve to raise the take-down bar to the knitting zone, with the hooks through the beds and pointing across the axis of the machine between the
yarn loops of the first course. The hooks pivoted so as to be aligned along the axis of the machine and the take-down carriage was lowered to apply weight to the first course. The camshaft operated microswitch then stopped the camshaft motor.

**Position 3** The carriage was traversed twice to knit two more courses, and after the second traverse it was again taken to the extreme left of the bed to initiate the camshaft rotation.

**Position 4** The camshaft started to rotate, thus pivoting the take-down hooks, again to face across the machine axis. Then the take-down pressure valve was operated to provide extra take-down weight. The camshaft operated microswitch then stopped the camshaft motor.

**Position 5** The carriage was then traversed across the knitting zone until the required number of courses had been completed. Before knitting the last course the quality cams, which controlled the amount of yarn drawn into each loop of the fabric, were changed to knit a slack course. This course was always knitted left to right across the machine to ensure that the yarn carriers were parked over the cut and clamp unit at the right-hand end of the knitting zone. On completion of this course the carriage was traversed to the extreme right of the bed to initiate the rotation of the camshaft.

**Position 6** The camshaft started to rotate, switching off the low pressure supply to the take-down carriage. The take-off mechanism was then swung into its vertical position and the main drive cams raised the take-off bar until the
take-off elements had just pierced the front bed loops. They were then in position to receive the back-bed loops, the mechanism being held by a dwell on the main cams. The back bed knitting elements were then raised and the take-off elements correspondingly raised to their maximum height to pierce the loops. The needle raising mechanism was then retracted and the camshaft operated microswitch then stopped the camshaft motor.

Position 7 The carriage was then traversed towards the left, having disengaged the yarn carriers, to lower the back-bed knitting elements. It was then traversed to the right to press off the front bed loops, the front bed knitting cams being set as though to knit, thereby transferring the remaining loops on to the take-off bar. On reaching the extreme right-hand bed position the carriage initiated the camshaft rotation.

Position 8 The camshaft started to rotate, thereby lowering the take-off bar, rib and take-down assembly. As the take-off bar reached its lower position, and was fully retracted, the cut-and-clamp unit was extended, swept across the machine to collect the yarns in the jaw, and then retracted to cut and clamp the yarns. The camshaft then rotated to its zero position and was stopped by the camshaft-operated microswitch.

This represented one complete cycle of operations. It must be noted that the carriage was only traversed to the extremes of the beds of the machine when the camshaft was to be initiated; otherwise, the carriage was traversed only the shorter distance necessary to perform its knitting function.
6.4 Assessment of the Mark I System

The concept of the Mark I system was to provide a simple, versatile test rig to evaluate various designs of element and mechanism regarding their suitability for automatic rib transfer. In this it succeeded insofar as loops of a knitted rib had been "automatically" transferred from the knitting elements of a 'V'-bed machine to a set of take-off elements suitable for transfer to other machines. However, because the test rig was small in comparison to the machines used for mass-production of ribs it was not possible to produce full-width ribs. Problems were foreseen in providing the accuracy required over the much longer bed lengths of any possible production machines using this system.

The control system had functioned effectively on the small-scale rig, but it was thought that, with a larger machine of bed lengths up to two metres, a mechanical rather than pneumatic control would be desirable.

It was proposed to proceed to the next research stage aimed at modifying a powered 'V'-bed knitting machine of the type used industrially for producing knitted ribs. This Mark II machine could usefully incorporate design modifications to the system in the light of experiences with the Mark I rig and thereby provide a basis for further research and development towards the ultimate pre-production prototype (Mark III) machine.
Pivoting take-down hooks and carriage, initial position.
Pivoting take-down hooks, engaged position.
Plate 6.3

The take-off elements penetrating the front-bed knitted loops.
Plate 6.4

Back-bed knitting elements in raised transfer position.
(actuation by auxiliary cam box)
Plate 6-5

Back-bed knitting elements raised to their transfer height by the operating plate.
Plate 6.6

Rear elevation of machine showing camshaft, spool valves, operating plate mechanism and take-down cylinder.
Plate 6·7

Swinging link assembly of the take-off mechanism.
Plate 6·9

Front elevation of machine showing camshaft and take-off cams.
Plate 6.10

Front elevation of machine showing bed-drop cylinders and cut and clamp mechanism.
CHAPTER 7

THE UNIVERSITY PROTOTYPE ART SYSTEM (MARK II)

The Mark I test-rig had been designed to provide a means of researching a simple system of automatic rib transfer. Success in this early work led to the proposal to modify, for fully automatic rib transfer, a powered 'V'-bed machine, typical of the type used in industry to produce rib borders.

It was at this stage of the research that the early results were shown to a local knitwear manufacturer, Corah Ltd. of Leicester. Such was their interest in the research that a production 'V'-bed machine was made available to the Department as a base for the prototype Mark II system. The aim was to research, design and develop an attachment that could be fitted to a standard, powered, 'V'-bed machine to facilitate the automatic transference of knitted ribs to a magazine bar.

7.1 Elements

The Mark I system had proved the feasibility of the Loughborough system of rib transfer under 'laboratory conditions'. For such a system to be industrially viable, 100 per cent reliability was essential, thus each element was analysed again to optimise its shape and method of operation (the final elements are shown in Plate 7.1). The machine used as a base for the Mark II system was a 2.5 mm pitch Dubied DRC 2 powered 'V'-bed machine. It was anticipated that the 2.5 mm pitch would present the greatest degree of difficulty in achieving automatic transfer compared with the coarser 5 mm pitch.
7.1.1 Take-down Elements and Press-off Bar

The take-down elements used in the Mark I system were designed to engage the first course loops by pivoting about their axes (see Section 6.1.1). This method, although successful on the relatively short bed length of the test rig, presented problems of operation over the much greater bed length of the Mark II machine. Location and operation of the special pivoting take-down elements were difficult in the confined space beneath the beds of the DRC 2 machine.

In order to simplify both the element and the mechanism, the 'welt hook' system of applying take-down tension was adopted (see Section 6.1.1 and Fig 6.3).

The main problem with a 'welt hook' system is the disengagement of the welt course loops from the hooks following the completion of the rib. The loops are normally disengaged by bringing a bar over the top of the hooks to force the loops down and off the hooks (see Fig 7.1). During this operation uniform tension must be maintained in the rib along its length to ensure that the loops are fully released. The take-down system of the Mark II machine was designed such that a light tension was maintained on the welt edge of the rib when the take-down bar and carriage reached its lower stops. The bar and operating mechanism of the disengaging bar was adjustable and mounted independently from the take-down carriage assembly. As the take-down carriage reached its lower stops, the disengaging bar was brought over the tops of the take-down elements, and well past the hooks, to disengage the welt course loops from the take-down hooks.
Fig. 7.1 Take-down Bar and Press-off Bar

Fig. 7.2 The Drawthread Course
Fig. 7.3 The Take-down Hooks Apply a Light Initial Tension

Fig. 7.4 The Lower Transfer Position
To ensure engagement of the welt course yarn loops with the hooks of the take-down elements, the yarn was laid between the take-down hooks and the front-bed knitting elements only (see Section 6.1.1). The take-down elements were introduced into the knitting zone by the take-down mechanism, the hooks protruding through the bed gap some 15 mm. The yarn was drawn around the hooks by traversing the knitting machine cam-box with front-bed knitting elements operating in the knitting mode. A drawthread, i.e. manually removable yarn, was used for the first course to avoid uneven tension distorting the main yarn welt course. The drawthread yarn carrier was slightly offset from the centre line of the bed to clear the take-down elements (see Fig 7.2).

The drawthread course having been laid, the take-down elements were lowered by the take-down mechanism to apply a light tension to the yarn loops (see Fig 7.3). Take-down tension at this stage of the cycle was critical; with too high a tension the yarn would break during the subsequent course; with too low a tension, the knitting elements would not function correctly. Application of the take-down tension was controlled by the movement of the take-down mechanism (see Section 7.2.1) and by the control system (see Section 7.3).

The control system gradually increased the take-down tension on each subsequent course for the first six courses of knitting, at which point full take-down tension was applied to the fabric.

On completion of the required number of courses of knitting, the knitted loops were transferred from the knitting elements to the take-off elements and the take-off bar. The take-off bar, fabric and take-down bar were lowered together to the lower transfer point (see Fig 7.4) which was set by stops on the take-down and
take-off mechanisms. The stops were positioned so as to provide a slight tension in the fabric to enable the press-off bar to disengage the drawthread course from the welt hooks. Again fabric tension was critical; a low tension could prevent some of the loops from disengaging; too high a tension would not allow the loops to be removed from the take-down hooks (see Section 6.1.1 for details of the operation of the press-off bar).

7.1.2 Take-off Elements

The Mark I system take-off element had been based upon a standard fully-fashioned narrowing point. Interaction with the knitted loops relied upon these loops being located by the knitting elements of the machine. A similar approach was adopted with the Mark II system. However, with the transfer facility of the DRC 2 machine, it was possible to perform loop doubling and to transfer all loops to one bed of the machine. The method of loop transfer used on the DRC 2 required that a knitting element should be capable of piercing a yarn loop on an opposing knitting element, in a similar manner to that of the loop transfer configuration used in the Mark I system of take-off. It was therefore possible to use this feature of the knitting elements (see Section 7.1.3) to effect a transfer of loops from the knitting elements to the take-off elements.

The method of transfer first envisaged for the Mark II system required that the yarn loops of the last knitted course were transferred to one bed of the machine. At this stage the take-off elements were raised in to the knitting zone (see Fig 7.5) adjacent to the knitting elements carrying the loops. The knitting elements were then raised, and held in unison at their transfer height,
Standard Dubied DRC 2' Latch Needle

Fig. 7.5 Initial Transfer System Proposed for the Mark II Machine
lifting the yarn loops over the points of the take-off elements. Full engagement of the yarn loops was ensured by raising the take-off elements a further 10 mm before retracting the knitting elements to disengage them from the yarn loops.

The system described above was based upon the Mark I transfer system but, as with the take-down system, the length of the DRC 2 machine required extreme precision from the mechanisms which was an undesirable feature for a 'bolt-on' system. Alternative methods of transfer were sought therefore in an attempt to reduce the precision required from the mechanisms.

The previous methods of transfer had all relied upon the knitting elements and the take-off elements being engaged directly. It was proposed that the take-off elements should be introduced into the space between the knitting elements, then moved axially along the machine to engage with the knitting elements.

To achieve this a novel method of elemental interaction was devised. Subsequent to the last course of knitting, all loops were transferred to the front bed of the DRC 2, the knitting elements of each bed being laid out to achieve the necessary doubling of loops during the transfer. A further single slack course was knitted on the front-bed only and then the front-bed was dropped away from the knitting zone (see Fig 7.6). The cambox of the machine was then traversed with no yarn being fed, an action which would normally 'press-off' the loops from the knitting elements. As the verge of the front bed was now below its normal position, the loops were retained on the knitting elements and not 'pressed-off' (see Fig 7.7a and Plate 7.5).
Fig. 7.6 The Front Bed is Dropped Away from the Knitting Zone

Fig. 7.7 Final Transfer Sequence
The new take-off elements consisted of a 'double curved' hook (see Fig 7.8) and were introduced by the take-off mechanism into the spaces between the knitting elements. An axial and upward motion of the knitting bed relative to the take-off elements engaged the hooks of the take-off elements with the 'eye' formed by the hooks and latches of the knitting elements, above the loops (see Fig 7.7b and Plate 7.6). The knitting machine carriage was then traversed across the knitting zone with the knitting cams disengaged such that the quality cams acted upon the butts of the needles pulling the hooks down to a height below that of the verge of the bed. This had the effect of 'pressing-off' the knitted loops from the knitting elements but, because the points of the take-off elements extended over the verge (see Fig 7.7b & c), the loops were slipped onto the take-off elements before being disengaged from the knitting elements, thus effecting the transfer. In order to ensure that all knitted loops had passed over the crests of the take-off elements and were retained against the barbs of these elements, an auxiliary transfer cam or plough was swept across the knitting zone. The plough, mounted upon a modified yarn carrier, traversed the knitting zone between the take-off elements and the rear-bed, forcing the take-off elements forward against the front-bed verge ensuring that the loops were brought over the crest of the elements and down to the barbs (see Fig 7.7d). Following this traverse, the front bed was lowered and the take-off and take-down carriages allowed to descend to the lower transfer position where the magazine bar elements were brought into engagement with the take-off elements as shown in Fig 7.9b. As the magazine bar elements approached the take-off elements, a brush mounted upon the magazine bar carriage above the magazine bar
Fig. 7.8 The Take-off Element

a. Modified Magazine Bar Element

b. Engagement of Take-off and Magazine Bar Element

Fig. 7.9 Take-off and Magazine Bar Element Interaction
elements swept any loops away from the crest of the take-off elements. This was found necessary to prevent the trapping of loops during the engagement of the two sets of elements. This could occur at the selvedge edges of the ribs where the reduced fabric tension was unable to pull the end loops sufficiently far over the crest of the take-off elements to avoid trapping. Once the two sets of elements were correctly engaged, the sweep-off elements were operated to lift the loops to the crest of the take-off elements then to drive the loops forward onto the magazine bar elements, completing the transfer (see Fig 7.9b).

In order to achieve the necessary uniformity between elements, the new take-off elements were manufactured to drawings, provided by the author, by a specialist knitting element firm (namely T. Grieve and Son Ltd. of Coalville Leicestershire).

7.1.3 The Knitting Elements

The Dubied DRC 2 knitting machine (see Plate 1.3) used as a basis for the Mark II machine was a double system machine (i.e. two sets of knitting cams and yarn carriers to enable two courses to be knitted with each traverse of the cambox) with front bed to rear bed and rear bed to front bed loop transfer facility.

The knitting elements of the Mark II machine were not modified in any way; however the Mark II system of rib transfer required all knitted loops to be on the front bed knitting elements prior to transfer to the take-off elements. This transfer from rear to front bed knitting elements was accomplished using the standard transfer facility of the DRC 2 cambox.
7.1.4 Magazine Bar Elements

The magazine bar elements had to be capable of both receiving loops from the take-off elements and transferring loops to the elements of another machine, such as a straight bar fully-fashioned machine. With the Mark I system this had not been a problem as standard, fully-fashioned narrowing points had been used for the take-off elements. However, the final Mark II take-off element was considerably different from the Mark I element and thus the interaction between it and the magazine bar element required a complete redesign.

The loop transfer from take-off to magazine bar elements was through an angle of 90 degrees rather than the normal linear transfer motion (see Fig 7.9). This also required the development of a special sweep-off motion (see Section 7.1.5) to transfer or sweep the loops from the take-off elements to the magazine bar elements. The basis for the new magazine bar element was a standard fully-fashioned magazine bar element.

To accommodate the hook of the take-off element, the eye of the magazine bar element was brought forward to 'run out' of the end of the element (see Fig 7.9). The hook of the take-off element was thus in a trailing orientation to the yarn path. An 'eye' in the take-off element accommodated the point of the new magazine bar element and assisted the alignment of the elements. In order to achieve the necessary uniformity between the elements, these new elements were made to drawings, provided by the author, by a specialist knitting element manufacturer (namely T. Grieve and Sons Ltd.).
Fig. 7.10 The First Sweep-off System
Fig. 7.11 The Final Sweep-off System
7.1.5 The Sweep-off Elements

The transfer of the loops from the take-off elements to the magazine bar elements required that the loops were first raised vertically from the barb or yarn stop of the take-off elements and then moved forward on to the magazine bar elements. In order to prevent distortion, all loops were required to be manipulated in unison.

The first sweep-off system consisted of a series of curved, plate-like elements (as shown in Fig 7.10) mounted on a bar. The transfer of the loops was accomplished by first engaging the comb-like sweep-off bar between the take-off elements. Rotation of the bar and sweep-off elements raised the loops up the take-off elements and then pushed them forward on to the magazine bar elements. In practice, these elements exhibited a tendency to trap the yarn loops against the magazine bar elements, causing the mechanism to jam.

An alternative method of transfer was therefore researched.

Two motions were required to transfer the loops from the take-off to the magazine bar elements, a vertical motion followed by a horizontal one. By keeping these two motions separate rather than combining them, as with the rotary transfer system, trapping of the yarn was eliminated. The final sweep-off system is shown in Fig 7.11, the elements being modified fully-fashioned dividing elements mounted, comb-like, in a bar.

The sweep-off elements were mounted on the sweep-off mechanism located to the rear of the lower transfer point. Once the take-off bar and mechanism had reached this point and the magazine bar elements had engaged with the take-off elements, the sweep-off elements were moved forward to engage with the loops of the rib between adjacent
End Plate
Follower
Camshaft
Cam
End Plate
Take-down Bars
Bellcranks
Fig. 7.12 The take-down Mechanism
take-off elements. The sweep-off elements and the loops were then raised until they aligned with the magazine bar elements and the loops pressed forward on to the magazine bar elements (see Fig 7.11a, b & c). The sweep-off mechanism was then retracted.

7.2 Motions and Mechanisms

The use of the Dubied DRC-2 'V'-bed machine required that all motions and mechanisms were re-examined with regard to the greater bed width of the Mark II system. It was essential that all elements should be controlled precisely in order to function correctly, as such elements could be almost 2m apart. Thus mechanisms were devised to provide this control, the motions being generated by cams.

Although the DRC-2 machine was much larger in size than the hand-flat 'V'-bed used for the Mark I system, space in which to accommodate mechanisms was still limited. It was essential that all mechanisms should be capable of simple adaptation to other makes of 'V'-bed machine in common use in the knitwear industry.

7.2.1 The Take-down Mechanism

The function of the take-down motion (see Fig 7.12) was to position the take-down elements accurately in the knitting zone, adjacent to the knitting elements and to maintain that position during the introduction of the drawthread yarn. Once the yarn had been engaged by the knitting elements and the take-down elements, a gradual lowering of the take-down elements was required to apply an initial tension to the yarn to ensure correct operation of the knitting elements. During the first six courses of knitting, the take-down elements were lowered incrementally, gradually applying a greater tension to the fabric at the end of each course. Following the

† see note on p. 132
completion of the sixth course, the mechanism was required to provide full take-down tension to the fabric and to allow the take-down elements, bar and carriage to descend with the fabric.

One of the major factors governing the design of the take-down mechanism was the length of rib to be knitted. The mechanism had to be capable of applying tension to the welt edge of the rib during the knitting cycle and also during the descent of the rib from the knitting zone to the lower transfer position. This position was determined by the distance that the take-off mechanism had to travel to clear the underside of the knitting beds of the machine (see Section 7.2.2). Enquiries in the knitwear industry revealed that a range of rib lengths from 20 to 150mm covered the vast majority of rib styles in current production. The stroke of the take-off mechanism was set at 180mm (see Section 7.2.2) and therefore the maximum stroke required from the take-down mechanism was 330mm.

To provide the necessary guidance for the elements, and their mounting bar, they were fixed to a carriage running on plain linear bearings attached to vertical end-plates at either end of the knitting machine. These end plates enabled the necessary relationship between the three main mechanisms, i.e. take-down, take-off and magazine bar, to be achieved. The guides on the end plates provided lateral location for the take-down mechanism, the axial location being obtained via a central guide bar. Vertical location of the take-down mechanism was provided by a system of cross-linked bellcranks and pushrods as shown in Fig 7.12 and Plate 7.2. The system was operated by a cam and follower mounted in a specially designed cam-box located at one end, outside the main frame of the knitting machine. The cam follower was connected to the take-down mechanism via a 'collapsible' link. This link was designed so as
Fig. 7.13 The Collapsible Link
Fig. 7.14 The Take-off Mechanism
to allow the follower to remain in constant contact with the cam, this being particularly important when the take-down mechanism was being raised and when subsequently attached to the fabric during the knitting and transfer cycles (see Fig 7.13). The cam profile was constructed with a dwell period at maximum lift to enable the mechanism to be held in the knitting zone during the laying of the drawthread yarn. Following this dwell, a period of gradual fall allowed the take-down tension to be increased steadily up to maximum tension. A detailed description of the cycle of operations is given in Section 7.3.

7.2.2 The Take-off Mechanism

The function of the take-off mechanism was to position the take-off elements adjacent to the knitting elements in the knitting zone, maintain that position during loop transfer, lower the elements to the lower transfer position and maintain that position during the transfer of the loops to the magazine bar elements. In operation and construction, the take-off mechanism was essentially identical to the take-down mechanism except that the bellcrank levers were connected to the cam follower by a rigid rather than a collapsable link. The vertical slides were however set at 4 degrees to the vertical to provide clearance between the take-down and take-off carriages in the knitting zone during the loop transfer sequence from the knitting elements to the take-off elements. Spatial location of the mechanism was accomplished in the same way as the take-down mechanism, i.e. laterally by the linear guides, axially by a central guide bar and vertically by a system of cross-linked bellcranks (see Fig 7.14).
During the sequence of loop transfer from the knitting elements to the take-off elements, it was necessary to provide a relative axial movement in order to engage the two sets of elements (see Sections 7.1.2 and 7.1.3). Initially it was anticipated that this motion would have to be incorporated in the take-off mechanism. However, experiments conducted to evaluate the practicality of moving (or 'shogging') the knitting elements rather than the take-off elements led to this motion being generated by specially designed bed location blocks; these imparted an axial movement to the front bed, and its knitting elements, as the bed was raised and lowered prior to the transfer sequence (see Section 7.2.6). It was therefore unnecessary to incorporate a 'shogging' motion in the take-off mechanism.

7.2.3 The Magazine Bar Mechanism

The magazine bar and its elements provided the link between the 'V'-bed knitting machine and the straight-bar fully-fashioned knitting system. Therefore the magazine bar elements were required to interact with both the take-off elements of the 'V'-bed machine and the standard elements used in fully-fashioned knitting via a gauge-changing device (see Chapter 11). The bar itself was detachably mounted to the magazine bar mechanism of the 'V'-bed machine and was also capable of being mounted remotely from the machine in order to interact with bars and elements from the fully-fashioned system.

The magazine bar mechanism consisted of a carriage mounted on plain linear bearings located on the two end plates of the machine. These bearings were inclined at 40 degrees to the horizontal to provide a suitable path for the magazine bar elements as they approached the take-off elements in their lower transfer position.
Fig. 7.15 The Magazine Bar Mechanism
This inclined path allowed the magazine bar elements to approach the take-off elements from below in order to enable the elements to engage correctly (Fig 7.15). The mechanism was operated by a cam and follower acting through a system of crosslinked bellcranks in a similar manner to both the take-down and take-off mechanisms. An extra set of bellcranks at each end of the magazine bar mechanism transferred the drive from the vertical mode to act at 40 degrees to the horizontal (see Fig 7.15). Axial location was provided by a centrally mounted guide plate attached to the frame of the machine and a 'shoe' attached to the mechanism. Central axial location was chosen for all of the major mechanisms in order to reduce errors due to differential thermal expansions of the aluminium carriage bars and the steel of the machine frame.

The magazine bars were required to locate on the magazine bar mechanism of the 'V'-bed machine and also on a "transfer frame" to transfer the ribs to the fully-fashioned system. Location for these bars was provided by dowel pegs on their undersides which located in holes on the carriage bar.

7.2.4 The Sweep-off Mechanism

Whereas all the mechanisms described in Sections 7.2.1 to 7.2.3 had required only straight line motion, to function correctly, the sweep-off elements required motion in two planes. The transfer of the loops from the take-off elements to the magazine bar elements necessitated the raising of the knitted loops from their rest position against the retaining barbs (see Fig 7.8) of the take-off elements to a position level with the magazine bar elements; this was then followed by a forward motion to transfer the loops onto the magazine bar elements. This sweep-off motion was split into three
Fig. 7.16 The Sweep-off Mechanism
Fig. 7.17 Cross-section of the Sweep-off Mechanism

Fig. 7.18 Path of the Sweep-off Elements
sequential movements (see Fig 7.18). The first (horizontal) movement brought the sweep-off elements forward from their rest position at the rear of the machine to engage the knitted loops just below the retaining barbs of the take-off elements. The second (vertical) movement raised the loops to align them with the magazine bar elements and the third (horizontal) movement transferred the loops forward from the take-off elements onto the magazine bar elements.

These three phases of the sweep-off motion were generated by a four-bar linkage and linear cam at each end of the mechanism. The linkage was designed with a cam follower attached to a trailing link and running on the linear cam (see Fig 7.17). The mechanism was set so that in the rearmost position the sweep-off elements were aligned below the level of the knitted loops held on the take-off elements. As the sweep-off mechanism was driven forwards (by a cam, follower and bellcrank system of similar design to that of the magazine bar mechanism, see Fig 7.16), the 'nebs' of the sweep-off elements entered the spaces between adjacent take-off elements below the knitted loops. The linear cams were set so that as the sweep-off elements penetrated these spaces, the followers on the linkage arrived at the point of lift on the cams. Further forward motion of the leading link caused the trailing link to rise, thus lifting the sweep-off bar and elements and causing the knitted loops to engage with the nebs of the sweep-off elements. Once the follower had reached the crest of the cam, the sweep-off bar continued its forward motion, driving the knitted loops onto the magazine bar elements. The sweep-off elements were then withdrawn, following in reverse their path on the forward stroke.
Fig. 7.19 Plan View of 'Yarn Gatherer'

Fig. 7.20 Yarn Trap and Burner
7.2.5 The Cut and Clamp Mechanism

The system of cutting and clamping yarns researched on the Mark I machine, although adequate for the purpose, had a number of drawbacks in the context of the university prototype machine (Mark II) in that the hardened cutting edges would require resharpening, the clamping action was not really positive and the method of operation was complex. It was therefore decided to research other methods of severing and retaining yarns.

On the Mark II machine it was possible to knit two body ribs or four cuff ribs at the same time. It was therefore necessary to be able to cut and clamp up to four different sets of yarns simultaneously across the width of the machine. Thus these mechanisms were required to be compact and self-contained, and be conveniently repositioned anywhere along the machine adjacent to the lower transfer zone. Because of the inclined motion of the magazine bar mechanism, it was possible to mount a device on this mechanism which would gather the sets of yarns to one point as the mechanism reached its upper position (see Fig 7.19). This yarn trap was positioned above and in front of the tips of the magazine bar elements and comprised three adjacent wires formed in the shape of a 'Y' (see Fig 7.20). The carbon steel wire provided a gripping action as well as serving to guide the yarns over an electrically heated wire 'burner' situated below the yarn trap. The heated wire severed the yarns and the yarn trap retained the 'live' yarns, i.e. the ends of the yarns passing through the yarn carriers of the knitting machine, ready for the start of the next rib. The system was simple in operation, requiring no extra mechanisms; however a microswitch was included in the 'burner' circuit so that the wire was only heated when the magazine bar mechanism was
Fig. 7.21 'Scissors' Type Cut and Clamp Unit
operated. Although this system retained the yarns after separation so that knitting could continue, a problem was found with the build-up of yarn ends which occasionally failed to be released from the trap. As the number of these ends increased, the wires were forced apart, allowing subsequently gathered yarns to be pulled from the trap during the first course of knitting. Provided that the trap was cleared every 20 or so ribs, the function was not impaired but this was an undesirable feature on a machine designed for production and therefore alternative systems were researched.

Further tests indicated that the only sure way of releasing the trapped yarns once the first courses of knitting had been completed was to mechanically disengage the yarns. The system used on the Mark I rig had this facility, but had not been used on the Mark II machine because of its need for a driving means and also because its construction was complex. A re-evaluation of this system was undertaken to reduce its complexity and to improve its durability. The basic principle of the system was that, as the yarn was trapped, it was severed by a cutting edge. With the Mark I rig the cutting and trapping edges had been on the same blade. By separating the two functions and providing a flexible 'blade' for each, the need for close manufacturing tolerances was removed. The mechanism itself was simplified by operating the 'blades' with a scissors action (see Fig 7.21), driven from a linkage on the magazine bar mechanism, through a Bowden cable. Being cable operated, the mechanism could be positioned along the magazine bar mechanism wherever the yarns required cutting and clamping.
Fig. 7.22 Standard Bed-drop Mechanism
7.2.6 The Bed-drop Mechanism

The bed-drop mechanism on the Mark I rig had been provided to give added clearance in the knitting zone for the transfer operation. On the Mark II machine the bed-drop mechanism formed an integral and fundamental part of the operating cycle. In order to prevent the last course of knitting from being 'pressed off' from the knitting elements and to retain the loops in a suitable orientation for transfer to the take-off elements, it was essential for the front bed to be lowered. The Dubied DHC 2 'V'-bed knitting machine used as a basis for the Mark II machine was fitted with a manually operated bed-drop mechanism as standard. It was therefore decided to use this standard mechanism to form the basis for the automatic bed-drop mechanism.

The front bed of the machine was retained by a tapered block at each end of the bed, fastened to the main bed-supporting casting. These blocks were fitted through elongated slots in the bed such that the bed could slide up and down (see Fig 7.22). To retain the bed in its raised position, a spring loaded, tapered wedge at each end of the bed was inserted between the bed and a fixed stop when the bed was raised. These wedges could be raised by small cams situated in the bed-support casting at each end of the machine, and operated by a lever which rotated a shaft running the length of the machine just below the bed. By rotating this shaft in the opposite sense, a lever at each end of the bed raised the bed until the sprung wedges could drop in behind the bed to retain it.
Fig. 7.23 Modified Bed-drop Mechanism
Fig. 7.24 Bed-drop Mechanism
An essential part of the transfer operation was the relative axial motion of the knitting elements and the take-off elements. This motion could be achieved by two methods; either the take-off bar and elements could be 'shogged' to engage the two sets of elements, or the knitting bed and elements could be 'shogged' towards the take-off elements. The Dubied DRC 2 machine was fitted with a 'shogging' mechanism as standard, but this operated only on the rear bed which was not fitted with a bed-drop facility. A graphic analysis of the interaction of the take-off and knitting elements revealed that it was possible to 'shog' the knitting elements as the front bed was raised, and so two special bed-retaining wedges were manufactured to test the principle. The wedges were designed to completely fill the elongated slots in the bed and had a slot cut in them at an angle in which ran the retaining bolt (see Fig 7.23). Thus as the bed was raised and lowered it was 'shogged' axially to engage and disengage the elements. This simple modification to the machine eliminated the need for the inclusion of a 'shogging' mechanism on the take-off mechanism.

The bed-drop mechanism was operated from the main cam-box, by a cam and follower system acting through a Bowden cable and lever at each end of the standard bed-drop operating shaft of the machine (see Fig 7.24).

7.2.7 Press-off Mechanism

In order to release the drawthread yarn loops from the hooks of the take-down elements, a press-off bar was pivoted over the top of the hooks (see Sections 6.1.1 and 7.1.1). The bar was carried on a rotating bar running axially along the machine below the
Fig. 7.25 The Press-off Mechanism
Fig. 7.26 The Control System
lower transfer position, which in turn was located at either end by plain bearings mounted on the end plates of the machine. Operation of the mechanism was by a cam in the main cam-box acting through a system of bellcrank levers and rods (see Fig 7.25).  

7.3 Control System and Operating Cycle

The preceding sections 7.1 and 7.2 have described the functions of the various elements and their operating mechanisms. This section will describe the method of control and the sequence of operations.  

7.3.1 The Control System

The major functions of the transfer system, i.e. the take-down, take-off and magazine bar mechanisms, all required precise control in order to function with the maximum reliability. It was for this reason that these mechanisms were cam-controlled (see Fig 7.26). The cams and camshaft were located at the left-hand end of the machine, outside the main frame (see Plate 7.2). All mechanisms used in the transfer operation were driven from this cam-box; thus the position of the cams relative to each other provided the necessary interrelationship between the mechanisms. Control of the transfer sequence was therefore simply a matter of controlling the position of the camshaft and initiating the knitting cycle at the appropriate time. Positional control of the camshaft was provided by 'flags' arranged around the periphery of a disc (see Plate 7.3). These 'flags' interrupted a photoswitch and stopped the camshaft at the desired position. In order to ensure that the knitting machine was not in operation whilst the transfer mechanism was functioning, an interlock, in the form of a changeover relay was used to initiate either the knitting cycle or the camshaft motor such that they could not operate simultaneously. The camshaft was driven by a threephase brake-motor, through a reduction gearbox, the camshaft being indexed by switching the motor.
In order to ensure that the knitting machine carriage was out of the knitting zone during the transfer operation, i.e. parked at one end of the bed or the other, photoswitches were positioned at either end of the knitting beds such that they were interrupted when the carriage was at the extremities of its travel. Only when either one of these switches was operated was it possible to operate the camshaft drive.

The Dubied DRC 2 used for the Mark II machine had a mechanical clutch and brake system fitted to interrupt the carriage drive from the main motor which, under normal circumstances, was constantly running. The clutch was operated by pulling out a tapered shaft running through the centre of the main drive wheel of the machine, thereby forcing the clutch shoes out into engagement with the inner surface of the main drive wheel to transmit the drive. The tapered shaft was latched in its outward position by a solenoid which, when operated, released the shaft and disengaged the drive to the machine carriage. In order to operate the machine automatically, modifications to this mechanical clutch were necessary to facilitate automatic control. The engagement of the clutch was achieved by actuating a pneumatic cylinder via a solenoid-operated valve triggered by the changeover relay of the main control system, thus mechanically operating the tapered shaft of the machine clutch mechanism. Disengagement of the clutch was achieved by operating the solenoid latch to release the tapered shaft and thus the clutch. The function of the solenoid release on the original machine was to stop the knitting cycle in the event of a yarn breakage. Microswitches operated by the yarn breakage detectors interrupted the solenoid circuit, releasing the clutch and thus stopping the carriage.
Fig. 7.27 The Cycle of Operation (Schematic)
The DRC 2 machine was equipped with a control card system to enable a series of knitting functions to be 'programmed'. A number of these plastic punched cards were assembled into a loop to provide the knitting instructions for the automatic cycle. The punched cards were indexed over a four-sided prism to be 'read' by a matrix of operating pins which, at the end of each course, could be indexed by either one or two cards backwards or forwards. It was possible to arrange the cards in such a way as to oscillate between two cards, enabling several similar courses to be knitted, without having to construct a long chain of identical cards. In order to exit from this 'closed loop' a card-saver drum was provided. This consisted of an indexing drum, controlled by the punched cards and having two rows of holes around its periphery into which could be placed pegs. Pegs placed in one set of holes enabled the machine to exit from the 'closed loop' by providing an additional index to the prism. A peg placed in the other set of holes actuated a micro-switch as the drum was indexed and this switched off the main motor of the knitting machine. This function was not required on the ART machine and so it was modified to initiate the transfer cycle by reactivating the extreme traverse sensors following the completion of the rib (see Section 7.3.2).

7.3.2 The Operating Cycle

All functions of the automatic cycle were initiated by the camshaft system, either by the cams themselves or by the 'flags' on the control disc. Thus the relationships between the various mechanisms and functions of the system could be set to provide optimum performance. Figure 7.27 is a graphical representation
of this interrelationship. The cycle of operations is best described by considering the production of one rib.

At the commencement of the machine cycle the following conditions were set:

1. All mechanisms were at zero displacement (camshaft at zero),
2. The knitting machine carriage was positioned at the right-hand end of the knitting beds at the start of a right-to-left traverse, the carriage being set to open the latches of the front-bed knitting elements, a standard feature of the DRC 2 machine,
3. The main and drawthread yarn carriers were set at the right-hand of the knitting zone,
4. The auxiliary transfer plough was set to the left-hand end of the knitting zone,
5. The card control system of the knitting machine was set to the correct card.

In order to start the automatic cycle, the machine clutch was engaged manually and the knitting carriage traversed from right-to-left, opening the latches of the front-bed knitting elements and then returned left-to-right to open the latches of the rear-bed knitting elements. During this part of the cycle, the left-hand extreme traverse sensor (e.t.s.) was bypassed by a microswitch on the camshaft front control disc (see Plate 7.4) so that two courses were completed before the camshaft motor was initiated. As the carriage reached the right-hand end of the bed, completing the left-to-right traverse, the right-hand extreme traverse sensor was triggered, the carriage stopped and the camshaft motor started. During the first 70 degrees of camshaft motion (see Fig 7.27) the take-down mechanism
was raised to its maximum position, so that the hooks of the take-down elements protruded through the gap between the two knitting beds. Once the take-down cam reached maximum lift, a flag located on the periphery of the control disc signalled the camshaft to stop and the machine carriage to start. When the carriage had reached the end of its previous stroke, at the right-hand end of the machine, the knitting functions had been selected for the next two courses; thus, traversing from right-to-left, the carriage picked up the drawthread yarn carrier and knitted on the front bed only using the first system of knitting cams. The yarn was thus drawn around the take-down elements by the front-bed knitting elements (see Section 7.1.1).

Reaching the left-hand end of the machine, the carriage operated the left-hand e.t.s., stopping the carriage and initiating the camshaft motor. The camshaft rotated through a few degrees, lowering the take-down elements to impart a slight tension in the drawthread yarn, until the next flag on the control disc signalled the camshaft motor to stop and the carriage to start. Traversing from left-to-right, the drawthread was knitted by the front-bed knitting elements, the drawthread yarn carrier being released at the right-hand end of the knitting zone, the carriage continuing to the right to operate the right-hand e.t.s. This stopped the carriage and indexed the camshaft to the next flag thereby adding to the take-down tension.

The drawthread courses had now been completed and, as the carriage was started again, the first main yarn carrier was collected and, knitting on all needles with the first system of knitting cams, the set-up course was formed. Reaching the left-hand end of the machine, the carriage again initiated an index of the camshaft via
the e.t.s. to apply further take-down tension to the fabric.

Returning from left-to-right, one course of the tubular welt of the rib was knitted on the front bed needles only followed by a further tension increase as the carriage again initiated an index of the camshaft via the right-hand e.t.s. As the carriage traversed to the left again a tubular course was knitted on the back bed elements only. Two more courses of tubular knitting were made, one on each bed, during the next two traverses of the carriage. At the left-hand end of the machine, the carriage initiated the final increment of the take-down weight and, as the carriage traversed to the right, the first rib course was knitted.

After the carriage reached the right-hand e.t.s., the carriage was again stopped and the camshaft indexed to exert full take-down tension to the rib. Once the take-down cam had reached its minimum displacement position, the camshaft was stopped and the carriage was started by a flag on the main control disc. A microswitch operated by the front control disc isolated the e.t.s. s' at this camshaft position, thereby enabling a multiplicity of courses to be knitted without indexing the camshaft. Control of the system at this stage of the cycle was passed to the knitting machine's card saver drum. This enabled the required number of courses to be set to produce a rib of the desired depth (see Section 7.3.1). On completion of the required number of courses, exit from this closed loop was made by the two pegs on the drum. The first peg indexed the machine control cards out of the loop and into the pre-transfer preparation courses. During these preparation courses, the loops formed on the rear-bed knitting elements were transferred
to the front-bed elements using the standard transfer facility of the DRC 2. The knitting was programmed so that a final slack course was knitted on the front-bed to leave one loop only on each knitting element for transfer to the take-off elements. This course was made with the carriage traversing to the right to leave all yarn carriers at the right-hand end of the knitting zone. The second peg of the card saver drum was set to place the e.t.s. s' back in circuit as the carriage reached the right-hand end of the machine, thus initiating the camshaft motor and stopping the carriage. The camshaft rotated to the next flag on the main control disc, allowing the front bed of the machine to drop and releasing the microswitch on the front control disc to reactivate the two e.t.s. s'. The carriage was then traversed to the left with the first system in the knitting mode but with no yarn carrier engaged, thus setting up the loops for transfer to the take-off elements (see Plate 7.5 and Section 7.1.2). On reaching the left-hand e.t.s. the carriage stopped and initiated the camshaft motor, causing the take-off mechanism to raise the take-off elements to their upper height adjacent to the front-bed knitting elements (see Plate 7.6), then operating the bed-drop mechanism to raise the front-bed to engage the knitting elements with the take-off elements (see Plate 7.7 and 7.8). A flag on the main control disc then stopped the camshaft motor and started the carriage. Traversing to the right, the carriage collected the auxiliary transfer cam, mounted on a yarn carrier, and transferred the loops to the take-off elements. On reaching the right-hand end of the machine, the e.t.s. stopped the carriage and initiated the camshaft motor to complete the rest of
the transfer cycle. The front-bed was dropped to allow the take-off mechanism to descend to the lower transfer position. The magazine bar and elements were then engaged with the take-off elements (see Plates 7.9 and 7.10) and the main yarns clamped and cut. Moving forward from the rear of the machine, the sweep-off mechanism transferred the loops from the take-off elements to the magazine bar elements. As the loops were pushed along the magazine bar elements, the press-off bar was pivoted over the top of the take-down hooks to disengage the drawthread yarn. The mechanisms were then all retracted to their waiting positions as the camshaft completed its cycle of operations (see Plate 7.11). When the flag at the zero position on the main cam control disc stopped the camshaft and restarted the carriage, the cycle of operations was repeated, starting with the two latch opening courses, the auxiliary transfer cam being returned to the left-hand end of the knitting zone as the carriage traversed left.

Rib length was controlled solely by the position of the pegs on the card saver drum of the DRC 2 and a range of rib lengths from 25 to 150mm was possible.

7.4 Assessment of the Mark II System

In comparison with the Mark I system, the Mark II represented a number of significant advances. The Mark I system had been a test rig upon which to test various elements and mechanisms but, because of the increased bed length of the Mark II machine, a considerable amount of redesign was necessary in order to achieve the required accuracy of motion. The development of an improved method of loop transfer greatly increased the reliability of the
system, even to the extent of allowing the machine to run on the automatic cycle virtually unattended. This enabled the machine to operate over an extended period under simulated production conditions, it being observed by a knitter provided by the co-operating firm, Corah Ltd.

The tests highlighted the high reliability of the system, the elements requiring little or no adjustment to achieve perfect transfer. However, one or two of the system's functions did appear to require further development in order to fulfil the rigorous demands of an industrial environment:

1) The sweep-off mechanism showed a tendency to jam as the loops were lifted around the hooks of the take-off elements. This was due to the design of the mechanism and it would have to be eliminated from any production machine (Mark III).

2) As the take-off elements descended, following the transfer from the knitting elements, the tension in the main yarns still attached to the machine occasionally caused the loops on the take-off bar to be pulled to the top of the take-off elements, thereby resulting in a poor transfer of these loops to the magazine bar elements. A method of preventing this would need to be devised for the production machine.

3) The control system, although causing no real problems, was not as simple to use as could be desired. The development of a more 'user-friendly' system would be preferable for a production machine. An improved method of controlling the knitting carriage was considered essential because the mechanical clutch system of the DRC 2 was not designed for continuous stop-start operation.
The overall success of this machine however prompted Corah Ltd. to enter into an agreement with a local firm of machine builders, Jordan, Lovatt and Jones Ltd., of Leicester, to develop the system, in conjunction with the university inventors, to the production prototype stage. The Prototype (Mark III) ART System is described in Chapter 8.

NOTE.

The slow rotational speed of the camshaft (4 r.p.m.) during the rib transfer sequence enabled simply generated cam profiles to be used in the ART machine. Complex cam laws are required to minimise the changes of acceleration in high-speed cam-operated systems, but in the case of the ART machine a simple sine law was used to generate the cam profiles.
Plate 7·1
The elements of the Mark II machine.
Plate 7.2

Front elevation of Mark II machine showing the cam box (on the left).
Plate 7.3

Rear elevation of cam box showing control disc, flags and photoswitch.
Front elevation of cam box showing by-pass switch on front timing disc.

Plate 7.4
Loops set up on front-bed knitting elements prior to transfer to take-off elements.
Take-off elements adjacent to front bed knitting elements.

Plate 7.6
Plate 7·8
Schematic layout of elements at upper transfer position.
Plate 7·9
Schematic layout of elements at lower transfer position.
CHAPTER 8

THE PRODUCTION PROTOTYPE ART SYSTEM (MARK III)

The development of the Mark II machine enabled the various elements and mechanisms of the ART system to be optimised to provide a reliable method of rib transfer. Although consideration was given to economy of design on the Mark II machine, the basic aim was to devise a workable system. Certain of the mechanisms, for example the sweep-off mechanism, required redesigning in order to improve their methods of operation and ease of adjustment whilst reducing production costs. The machine selected as a base for the Mark III system was again a Dubied DRC 2 provided by Corah Ltd., but with a pitch of 5mm rather than the 2.5mm of the Mark II machine. This pitch was chosen because it was the gauge of most of the fully-fashioned production machinery at the Corah factory.

The interaction of the elements was to be identical to the Mark II machine, but the mechanisms and control system were to be 'value engineered' to reduce costs wherever possible whilst retaining or improving reliability.

8.1 Elements

The elements developed for the Mark II system had proved their reliability during extensive tests and were therefore generally scaled-up to form the Mark III elements where an increase in size was required to match the larger knitting elements of the 5mm pitch machine. These elements, as with those for the Mark II machine, were made to the author's designs by a firm of specialist needle manufacturers, namely T. Grieve & Co. Ltd., Coalville, Leicestershire.
8.1.1 Take-down Elements and Press-off Bar

As with the Mark II system, the take-down hooks used for the Mark III machine were commercially available elements as used on automatic rib transfer machines of corresponding gauge. These elements were mounted in trick-cut bars at a pitch of 5mm, one bar being attached to the take-down carriage on either side of the central guide pillar. The mountings for the press-off bar and its operating mechanisms were incorporated in the end castings of the attachment, and the method of operation of the elements was identical to that described in Section 7.1.1.

8.1.2 Take-off Elements

The greater pitch of the Mark III machine required a scaling up of the take-off elements to match the 5mm gauge knitting elements. In order to aid location during their production, flats were provided on the shank of each element (See Fig 8.1), these also assisting the location of the elements in the take-off bar. The take-off bars and their elements were mounted on the take-off carriage, one being situated on either side of the central guide pillar. The method of operation of the take-off elements was identical to that described in Section 7.1.2.

8.1.3 Knitting Elements

As with the Mark II machine, the knitting elements used on the Mark III machine were standard Dubied latch needles incorporating a 'cut-out' to enable bed-to-bed loop transfer. No modifications were made up to these elements and the method of operation was again identical to that previously described in Section 7.1.2.
Fig. 8.1 The Take-off Element

Fig. 8.2 The Magazine Bar Element
Fig. 8.3 The Sweep-off Element
8.1.4 Magazine Bar Elements

The magazine bar elements, like the take-off elements of the Mark III machine were effectively scaled-up versions of the Mark II elements, these again being specially manufactured by T. Grieve and Co. Ltd. to the author's designs. Because of the increased sizes of both the take-off and magazine bar elements, it was necessary to offset the points of the magazine bar elements in order to ensure engagement of the two elements at the lower transfer position (See Fig 8.2).

8.1.5 Sweep-off Elements

Although the performance of the sweep-off elements of the Mark II machine had been satisfactory, problems with the reliability of the mechanism necessitated some redesign work on the Mark III machine. The opportunity was therefore taken to modify the profile of the sweep-off elements to gain maximum advantage from the new mechanism. Therefore, rather than modifying existing fully-fashioned dividing elements, elements were specially designed to be produced by Mitchell and Co. Ltd., Birmingham (See Fig 8.3).

8.2 Motions and Mechanisms

The aim of the work was to develop a 'bolt-on' mechanism suitable for fitment to a range of 'V'-bed knitting machines to facilitate the automatic transfer of rib trims to a magazine bar. In order to simplify the fitting of such a mechanism, the number of attachment points was reduced to a minimum. It was decided to mount all the mechanisms on a sub-frame which could then be attached to a variety of types of knitting machine. A simple eight-section frame
was devised to carry the main cam-box and the main mechanism (See Fig 8.4), thus fixing the interrelationships between the mechanisms and removing the need for precise adjustments and settings. Consideration of the possible simplification of the operating mechanisms led to the adoption of cable drives where practicable.

8.2.1 The Take-down Mechanism (Incorporating the Press-off Mechanism)

The Mark II take-down system had proved both accurate and reliable and therefore it formed the basis for the design of the Mark III system. Plain linear cast iron guides were provided at each end of the machine, these castings also incorporating the take-off guides and press-off bar mountings. The castings were attached to the upper and lower cross-beams situated at either end of the machine. The two main operating bellcrank links were repositioned, the right hand link being inverted to decrease the cross-link length (See Fig 8.5). As with the Mark II system, the motive power and control of the mechanism came from a cam/follower arrangement. Axial location was again obtained from a central guide bar incorporating an adjustable stop to take the weight of the take-down mechanism at the lower transfer point. A collapsible link was not incorporated in the Mark III machine because the gradual, controlled descent of the mechanism did not cause any severe impact by the follower on to the cam surface. The cycle of operation of the system is described in Section 8.3.

The press-off mechanism was identical to that of the Mark II machine and was operated by a cam and follower but the drive was transmitted via a cable and spring system (See Fig. 8.6).
Fig. 8.4 The Eight-section Main Frame
Fig. 8.5 The Revised Bellcrank System
Fig. 8.6 The Press-off Mechanism
8.2.2 The Take-off Mechanism

As with the mechanism for take-down, that for take-off remained virtually unchanged from the Mark II system. Lateral guidance was from the plain linear slideways in the special end-castings, the axial location being from a central guide pillar. Vertical location was by a system of cross-linked bellcranks similar to that used with the take-down mechanism. The rigidity of this cross-linking enabled a single lower stop to be provided on the central guide pillar, as with the take-down mechanism. Control was effected via a cam/follower system similar to the Mark II machine.

8.2.3 The Magazine Bar Mechanism

The linear slides and bellcrank system used on the Mark II machine had proved effective but these were complex and relatively costly to manufacture. Consideration was given to the essential characteristics of the required motion and it was found that these could be satisfied by the use of a four-bar linkage (See Fig 8.7). Motive power to operate the mechanism was transmitted from the follower of the controlling cam via a system of pulleys and control wires, the system being tensioned by a return spring.

The magazine bars themselves were again located by dowel pins and retained by 'quarter turn' 'Camloc' fastenings. Four bars were provided, two being located on the mechanism, so as to be filled by the machine, with two empty bars being held in reserve; as each machine-located bar was filled, it was replaced by its reserve. The ribs could then be transferred to fully-fashioned machine bars, the then empty bars being returned to the machine for reloading. The operating cycle is described in Section 8.3.
Fig. 8.7 The Magazine Bar Mechanism
8.2.4 The Sweep-off Mechanism

Some problems had been found with the operation of the sweep-off mechanism on the Mark II machine in that it required precise setting in order to function correctly. The Mark III sweep-off mechanism was redesigned to eliminate this shortcoming by providing two motion inputs, one for each axis of movement. A four-bar pivoting linkage was used to control the main component of motion laterally across the machine, with an eccentric bush in the lower front pivot providing a superimposed vertical motion component (See Fig 8.8). The sweep-off bars were supported at either end of the machine by the linkage systems and were driven by two cams, one for each component of the motion, through a system of control wires, pulleys and tensioning springs. Thus the elements could be moved forwards to engage the yarn loops of the rib below the 'barbs' on the take-off elements, actuated by the lateral motion cam. Then, during a dwell on this latter cam, the vertical motion cam raised the sweep-off elements to the level of the magazine bar elements, by rotating the eccentric bushes, in readiness to complete the transfer. A dwell period on the vertical control cam maintained the sweep-off elements at this height whilst the lateral motion cam drove the loops off the take-off elements and onto the magazine bar elements, thereby completing the transfer. The mechanism was then retracted to its start position.

8.2.5 The Cut-and-Clamp Mechanism

The method of clamping and cutting the yarn eventually devised for the Mark II machine was of the 'scissor' type as described in Section 7.2.5. This was the method adopted for the Mark III machine.
Fig. 8.8 The Sweep-off Mechanism
The 'scissors' were adjustably mounted on a bar attached to the magazine bar mechanism (See Fig 8.9) such that the 'umbilical' yarns, from the rib to the yarn carriers of the machine, were collected into the jaws of the device as the magazine bar elements came in to engagement with the take-off elements. The jaws were then closed, trapping and severing the yarns attached to the rib. These yarns were retained by the cut-and-clamp mechanism until the first few courses of the subsequent rib had been knitted. In order to prevent the ribs from having long 'tails' of yarn attached to the welt, 'burner' wires were mounted on the take-down bars. These were operated when the first six courses of the subsequent rib had been knitted, thereby trimming the yarn tails to an acceptable length (See Fig 8.10). The 'burner' was triggered by a microswitch activated from an auxiliary cam mounted on the side of the sweep-off cam, a timer being included in the circuit to prevent overheating of the wire. Once the yarns had been 'burned', the jaws of the cut-and-clamp units were opened to release the remainder of the yarn.

8.2.6 The Bed-drop Mechanism

The combined system of lowering and shogging the bed of the Mark II machine had proved its reliability and therefore an identical system was used for the Mark III machine. A cam/follower/cable system was used to control the front bed of the machine as described in Section 7.2.6.

8.2.7 The Press-off Mechanism

The construction of the press-off mechanism on the Mark III machine was similar to that of the Mark II machine. It comprised a steel sheet formed as shown in Fig 8.6 and mounted on a rotatable
Fig. 8.9 The Cut and Clamp Unit
Fig. 8.10 The Yarn 'Burner' System
bar. Pivots for the bar were adjustably attached at either end to
the castings which carried the take-down and take-off guides. The
mechanism was operated by a cam and follower acting through a bowden
cable against a return spring.

8.2.8 The Yarn Tension Control Mechanism

During the descent of the take-off mechanism subsequent to the
transfer of a rib to the take-off bar, there were occasions with the
Mark II machine when the yarn tension system pulled the last few
loops of the rib towards the top of the take-off elements (See
Fig 8.11). In order to prevent this occurrence with the Mark III
machine, a method of reducing the yarn tension immediately after
loop transfer was required. This was achieved by building an
additional yarn reservoir into the yarn feed system comprising
two auxiliary carriages mounted on rails, one being fixed at each
end of the yarn carrier rails. These were connected to the take-
down carriage by cables which were tensioned by a dead-weight
attached via other cables to the opposite ends of the auxiliary
carriages (See Fig 8.12). Thus, as the take-down carriage descended,
the two auxiliary carriages were drawn inwards towards the centre of
the machine, and, as the take-down carriage ascended, the auxiliary
carriages were drawn outwards by the weights. By suitably positioning
the yarn guides, it was possible to draw extra yarn into the system
as the take-down carriage ascended, and, to release this yarn as the
take-down carriage descended. This prevented the loops from being
pulled off the take-off elements by excessive yarn tension as the
take-off bar descended following rib transfer.
Fig. 8.11 The Effect of Uncontrolled Yarn Tension
Fig. 8.12 The Yarn Tension Control Mechanism
8.3 Control System and Operating Cycle

The basic control philosophy adopted on the Mark III machine was the same as that on the Mark II machine, namely a cam and camshaft system to control the transfer functions, this being interlocked with the standard controls of the knitting machine. Detailed modifications were made to the methods of sensing. The control system utilised solid state logic. An electromagnetic clutch and brake were used to control the knitting machine carriage with better reliability than the standard mechanical unit supplied with the Dubied DRC2 machine (See 8.3.1).

8.3.1 The Control System

The Mark II control system had proved adequate in performance (See Section 7.3) but the opportunity was taken to update and improve the control system during the design stage of the Mark III machine.

Although the optical sensors used on the Mark II machine had functioned faultlessly, it was thought desirable to eliminate the possibility of contamination of these devices by dust, oil and fluff, and therefore they were replaced by 'Hall effect' switches. These solid state semiconductor switches are actuated by the presence of a magnetic field and are therefore unaffected by such possible contaminants. The 'flags' on the main camshaft control disc were replaced by small adjustably mounted magnets actuating a 'Hall effect' device. An auxiliary device was provided as a datum mark in the machine cycle, operated by another magnet mounted offset on the control disc. In order to produce a variable, incremental take-down tension over the first few courses of knitting, a 'Hall effect' switch was mounted adjacent to the camshaft gearbox input shaft.
Two magnets attached to the shaft, 180° apart, triggered the device twice each revolution. By switching on the camshaft motor and counting a programmable number of pulses before stopping it, an accurate and adjustable increase in take-down tension could be achieved. A series of six such increments was provided for the first six courses of knitting.

The Mark II machine had used the mechanical clutch and brake unit of the Dubied DRC 2 knitting machine, a unit designed for intermittent operation only. Therefore the Mark III machine was fitted with an electromagnetic clutch and brake unit replacing the mechanical one of the DRC 2. This upgraded system enabled faster and more positive switching from camshaft to machine control and vice versa. In order to reduce the size of the unit needed, the knitting machine drive motor and associated clutch were combined as a single assembly and mounted at the right-hand end of the machine. The drive was transmitted through a speed-reducing 'V'-belt system to the main drive pulley of the knitting machine. An electromagnetic brake was mounted within the centre of this large diameter pulley.

Certain of the mechanisms of the Mark III machine were modified as described in Section 8.2 to improve their performance and to reduce manufacturing cost. The use of cable drives facilitated the simplification of some of the cumbersome bellcrank drive trains devised for the Mark II machine, bias springs being used to tension the cable systems.

The functioning of the control system is best described by considering the operating cycle of the machine. The basic transfer sequence is controlled from the timing disc on the camshaft. During
Table 8.1
Cycle of Knitting Operations

<table>
<thead>
<tr>
<th>Operation</th>
<th>Speed</th>
<th>Direction</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latch Opening Course</td>
<td>Slow†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latch Opening Course</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st. 'Hook-up' Course (Front Bed)</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd. 'Hook-up' Course (Back Bed)</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set-up Course (Both Beds)</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st. Tubular Course (Front Bed)</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd. Tubular Course (Back Bed)</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd. Tubular Course (Front Bed)</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th. Tubular Course (Back Bed)</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st. Rib Course Single System</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd. Rib Course Single System</td>
<td>Fast*</td>
<td></td>
<td>DRC 2</td>
</tr>
<tr>
<td>3rd. Rib Course Single System</td>
<td>Fast</td>
<td></td>
<td>Card-Saver Drum</td>
</tr>
<tr>
<td>4th. &amp; 5th. Rib Courses Double System</td>
<td>Fast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsequent Rib Courses Double System</td>
<td>Fast</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Rib Course Single System</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carriage Traverse ('Dummy Course')</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfer All Stitches to Front Bed</td>
<td>Slow</td>
<td></td>
<td>ART Cambox</td>
</tr>
<tr>
<td>Slack Course (Front Bed)</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set Needles For Rib Transfer</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfer Loops to Take-off Hooks</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traverse Auxiliary Transfer Cam</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traverse Auxiliary Transfer Cam</td>
<td>Slow</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† 10 courses per minute
* 28 courses per minute
the knitting of the bulk of the rib, following the completion of the first nine 'set-up' courses and prior to the transfer operations, the control is passed to the control drum of the knitting machine (See Section 7.3).

8.3.2 The Operating Cycle

The operating cycle of the Mark III machine was based on that of the Mark II machine (See Section 7.3). Control was derived from a timing disc located on the front end of the camshaft upon which were mounted adjustable magnetic triggers to operate the 'Hall effect' position sensors. The system is best described by considering one cycle of operation in conjunction with the cycle of operation (Fig 8.13) and the cycle of knitting operations (Table 8.1).

At the initiation of the machine cycle, the following conditions are set:

(i) All mechanisms at zero displacement (camshaft at zero);

(ii) the knitting machine carriage positioned at the right-hand end of the knitting beds at the start of a right-to-left traverse, the carriage being set to open the latches of the front-bed knitting elements, this being a standard feature of the DRC 2 machine;

(iii) the main and drawthread yarn carriers set at the right-hand end of the knitting zone;

(iv) the auxiliary transfer plough set to the left-hand end of the knitting zone; and

(v) the card control system of the knitting machine set to read the initial card of the sequence.
In order to start the automatic cycle, the knitting machine clutch is engaged by pressing the manual start button, thereby energising the electromagnetic clutch. The carriage traverses to the left-hand end of the machine opening the front bed needle latches, then returns from left-to-right to open the rear-bed needle latches. At this stage of the cycle, the left-hand extreme traverse sensor (e.t.s.) is isolated by the control system. At the start of each rib it is necessary to open the latches of all of the knitting elements after all the knitted loops of the previous rib have been transferred, thus leaving no yarn loops to operate the latches.

On reaching the right-hand e.t.s., the clutch is released, the brake is energised, and a signal is sent to start the camshaft motor. The camshaft rotates to raise the take-down carriage and elements into the knitting zone in preparation for the drawthread course. As the take-down carriage reaches maximum height, a timing disc 'flag' signals the camshaft motor to stop, activates the fine control sensor, and signals the carriage drive to start. The carriage then traverses from right-to-left, the carriage control cards of the DRC 2 having selected the drawthread yarn carrier and the front-bed knitting cams on the first knitting system. Reaching the left hand e.t.s., now activated by the control system, the carriage drive is disengaged and the camshaft motor started. The take-down carriage is lowered until the fine control sensor receives a preset number of pulses, this position being set to provide a slight tension on the yarn loops of the first drawthread course. For this index of the camshaft and the subsequent five indices, the degree of
Fig. 8.13 The Cycle of Operation (Schematic)
rotation is governed by the number of pulses counted by the fine control sensor. The number of pulses to be counted for each index is input into the control system via preset switches, up to a maximum of fifteen pulses per index. The take-down cam is profiled over this segment to give a gradual fall of the take-down carriage. Returning from left-to-right, the second drawthread course is knitted on the front-bed needles only. When the carriage reaches the right-hand e.t.s., the carriage drive is disengaged and the camshaft motor started, thereby applying further tension to the yarn loops via the fine control sensor.

The main yarn carrier is now selected by the DRC 2 control cards and knitted on both front and rear beds as the carriage traverses from right-to-left using one system of knitting cams. This forms the set-up or welt course of the rib. On reaching the left-hand end of the machine, the carriage is again stopped and the camshaft is indexed to maintain the tension on the rib. Having counted the correct number of pulses from the fine control sensor, the control system stops the camshaft motor and restarts the main drive system. The carriage returns from left-to-right, knitting the first of four tubular knitting courses, two on each of the beds, the camshaft being indexed by the fine control sensor after each course (See Table 8.1).

Following the fourth tubular course, the camshaft is indexed out of the fine control sequence, the take-down carriage being allowed to exert its full weight on the rib. During this index of the camshaft, the burners on the take-down carriage are operated to trim the excess yarn from the start of the rib. The control of
the machine is now switched to the card saver drum of the DRC 2 as described in Section 7.3, the number of courses being set to provide the required rib length. The first three courses of this sequence are knitted single system before engaging the second system of knitting cams and yarn carriers. The main drive motor of the DRC 2 machine has two output speeds, fast and slow. Slow speed is used for all set-up and transfer courses, the fast speed only being used for knitting the last two single system courses and all double system courses (See Table 8.1).

Once the required number of courses have been knitted to produce the correct length of rib, the first peg on the card saver drum indexes the card prism out of its repeat function and the transfer sequence is initiated (See Section 7.3.2).

The machine control cards are set to produce the following sequence of operations. A course of single-system knitting is formed with the carriage traversing from right-to-left. The yarn carrier is then parked at the left-hand end of the knitting zone whilst the carriage returns to the right-hand end without actuating the knitting elements. A 'dummy' course is necessary to position the yarn carrier in preparation for the knitting of the slack course. This follows the subsequent right-to-left traverse of the carriage during which the front bed is 'shogged' by a half-pitch to receive the knitted loops from the rear bed knitting elements. The slack course is then knitted as the carriage returns to the right-hand end of the machine where the right-hand e.t.s. has been activated by the second peg in the card saver drum. This stops the carriage
and initiates the camshaft motor. The camshaft indexes to the next stop on the control disc, lowering the front-bed ready to set-up the knitted loops for transfer to the take-off elements.

As the camshaft stops, the carriage is started and traverses from right-to-left with the first system front-bed knitting cams in the knit position, thereby positioning the yarn loops on the knitting elements ready for transfer to the take-off elements (See Section 7.2.2). The left-hand e.t.s. then stops the carriage and starts the camshaft motor, thereby causing the take-off mechanism to raise the take-off elements into position adjacent to the front-bed knitting elements in the knitting zone and raising the front-bed to engage the two sets of elements. The next position sensor on the camshaft control disc then stops the camshaft motor and starts the carriage moving from left-to-right, with the knitting cams out of action, thus causing the knitted loops to be transferred from the knitting elements to the take-off elements (See Section 7.2.2).

As the carriage traverses the machine for the transfer course, the auxiliary cam (or plough) is collected by the yarn carrier system to assist the movement of the yarn loops around the 'hook' of the take-off elements (See Fig. 7.7). In order to ensure that all of the loops have dropped to the retaining barbs of the take-off elements, two further passes of the carriage and transfer plough are made before the carriage is arrested at the right-hand end of the machine and the camshaft motor is started by the right-hand e.t.s.

As the camshaft rotates, the take-off and take-down carriages are lowered in unison to the lower transfer position and the yarn tension is reduced by the yarn tension control mechanism. There
the magazine bar mechanism brings the magazine bar elements into engagement with the take-off elements and positions the cut-and-clamp units over the trailing yarns as the press-off mechanism concurrently releases the welt edge of the rib from the take-down elements. The sweep-off elements are then sequentially advanced, raised, then advanced once more, to transfer the knitted loops on to the magazine bar elements. Simultaneously, the cut-and-clamp mechanism severs the yarns from the rib and retains the yarn ends attached to the knitting machine. The magazine bar mechanism is then returned to its rest position and the camshaft resets to its zero point with all mechanisms retracted. This cycle of operations is repeated until the required number of ribs has been knitted. When this has been attained, the cycle is stopped prior to the machine entering the main knitting phase and a 'bar full' indicator is activated.

The control cycle also has a 'single step' facility which allows the machine to be indexed through its cycle of operations one step at a time. Each time the 'single step' button is pressed the camshaft indexes to the next stop, thereby enabling the cycle to be checked and adjustments to be made.

8.4 Assessment of the Mark III Prototype Machine

The Mark III prototype was the first version of the Loughborough ART machine to be run on site in the factory by production personnel. As such it was subjected to the same operating conditions as the standard production 'V'-bed knitting machines and, subsequent to an initial period of familiarisation, it has been run on three shifts for five days per week.
Generally, the machine has run without fault, although an initial problem of magazine bar element engagement with the take-off elements at the selvedge edge of the ribs had to be overcome. It was found that following the transfer of a number of ribs to the magazine bar, the tension from the selvedge loops of the ribs had a tendency to deflect the last few magazine bar elements carrying the ribs. This caused the magazine bar elements to miss the eyes of the take-off elements and thus selvedge loops were not transferred correctly. The problem has been solved by attaching a series of guide fingers to the extreme ends of the sweep-off bars so that the sweep-off bars are now brought forward to the position shown in Fig 8.14 to engage these fingers between the take-off elements before the approach of the magazine bars to the take-off bars. When the magazine bar elements make their approach they are guided by the fingers into the eyes of the take-off elements irrespective of any deflections caused by the build-up of ribs on the magazine bar. This problem had not been encountered on the finer gauge Mark II machine and this is assumed to be because of the extra tension exerted by the coarser gauge of ribs knitted on the Mark III machine.

The elements of the Mark III machine have functioned well, needing little or no attention to maintain fault-free transfers. Investigations are still in progress to further improve the action of the take-off elements by altering the profile of the crest of the element to aid progress of the yarn loops down to the yarn stop. If this can be achieved, it will remove the need to make three passes of the transfer plough following loop transfer to the take-off elements (See Chapter 10).
Fig. 8.14 The 'Guide Fingers'
Although the price of the ART conversion has not yet been fixed, Corah Ltd. have predicted the production rates of the machine together with estimates of the likely labour savings. Taking as a base figure the production of 1000 dozen 9-gauge fully-fashioned garments per week, the production requirements in terms of machines and labour are as follows:-

**Manual Process:**

- 3 x 16-sections of fully-fashioned plant + 3 knitters;
- 4 DRC 2 'V'-bed machines + 1 knitter;
- 5 runners-on;
- 2 drawthreaders; and
- 1 service person

**ART Process:**

- 3 x 16-sections of fully-fashioned plant + 3 knitters;
- 5 ART 'V'-bed machines + 1 knitter; and
- 1 regauging unit (operated by the above-mentioned 'V'-bed machine knitter).

This represents a labour saving of 8 people. At an average cost to the firm of £5,000 per person per annum (including incidentals) the financial saving is approximately £40,000 per annum. The estimated cost of the conversion is £14,000 per machine and thus the amortisation period would be well under two years. Proposed future improvements to the system should increase its production rate to match that of the standard 'V'-bed machines, thus reducing the payback period to about one year.
The above savings are only in terms of labour and do not include the benefits of the system in terms of increased space utilisation and reduced yarn consumption. This latter point is highly significant since no waste courses are knitted by the ART machine, thus obviating the current high wastage of costly yarn which has been through all the protracted processes of opening, carding, combing, drawing, spinning, winding and often dying. Further advantages exist such as the ability of the ART/regauging combination to distribute the yarn loops to any desired position on the fully-fashioned machine bar. Thus on cable styles, a free fully-fashioned element can be left by suitably arranging the regauging elements in order to accentuate the cable feature. To perform this operation manually at the running-on stage of the production process takes an extra 7 minutes per dozen above the standard time.

The initial trials of the Mark III ART machine have proved its ability to improve the fully-fashioned process and to reduce production costs. Its nearest rivals cost 25% more to purchase and are some 35% to 45% less productive (See Chapter 4).
CHAPTER 9

THE APPLICATIONS OF ART TO THE LINKING PROCESS

During fully-fashioned garment manufacture, there are two stages involving loop transfer, the first being the transfer from rib-to-plain knitting and the second, the process of loop-for-loop linking (see Section 1.2). Loop-for-loop linking requires each knitted loop of a trim to be sewn or linked to the body of the garment. As the knitted trims are normally produced on a 'V'-bed machine the attachment of the Loughborough ART system to these machines allows such trims to be stored on a magazine bar, each loop being retained on a magazine bar element. It is then possible to transfer these loops from the magazine bar points to the points of a linking dial or to a machine such as the Boehringer Autolinker (see Section 4.4).

9.1 The Relationship of the ART Research to the Complementary Studies on Linking

It was from the early studies into knitted garment linking that the potential of a simple inexpensive automatic rib transfer machine was first brought to light. A feasibility study into improving the labour intensive linking process was undertaken by Mr. J. E. Baker of the Department of Mechanical Engineering, Loughborough University of Technology in 1971, and this highlighted three areas for further investigation namely:-

(a) An ergonomic study of the linking process;
(b) a study of the textile technology aspects of linking; and
(c) a study of methods of automating the linking process.
Under the auspices of a Science Research Council research grant the investigations progressed to a stage where it became evident that the automation of the linking process was totally dependent upon the development of a practical and inexpensive method of automatic rib transfer, and therefore resources were devoted to this task. It was with the automation of linking that the author was mainly involved and from which evolved the Loughborough ART System. The ergonomic study of linking and the later work on automating the linking process forms the basis of a research thesis presently being prepared for submission by Mr. J. E. Baker (1).

9.2 Bar Feeding to Linking Machines

The automatic feeding of trims to a linking dial has two distinct stages. Firstly the trim must be taken from the knitting elements of the knitting machine to a point or magazine bar. This may be accomplished by the use of the Loughborough ART system, or by any one of the automatic rib transfer systems on the market (see Sections 4.1 to 4.4). The second stage involves transferring the trim from the magazine bar to the points of the linking dial or to a linear linking system such as the Boehringer Autolinker. It was always the aim of the work at Loughborough to provide economic solutions to the problems and to use as much of the existing plant as possible. Thus the automation of the linking process concentrated upon the feeding of trims to existing linking machines using simple "bolt-on" attachments. A simple rack-and-pinion system was geared to the linking dial drive to power the magazine bar forward and a system of ploughs and guides transferred the trim from the magazine bar points to the points of the linking dial. Further details will be contained in the thesis being prepared by J. E. Baker (1).
An enquiry has already been received by the ART machine manufacturers Jordan, Lovatt and Jones Ltd. as to the possibility of providing ART machines to feed a linking system based on the Boehringer Autolinker principle.
CHAPTER 10

PROPOSALS FOR FURTHER WORK

The initial field trials of the Mark III production prototype ART system in the industrial environment have been most promising. Following the preliminary familiarisation period, the machine has run on three shifts for five days per week. However, as with any production machine, there is always the continuing quest for increased productivity. The ART machine is up to 25% less productive than the standard machine due to two undesirable features of the ART process, namely non-productive time due to the stopping of the knitting cycle during the periods of camshaft rotation and also due to the insertion of extra yarn-less "dummy" courses in the ART knitting cycle compared with the standard machine cycle.

It is proposed to control the final production machines with a microprocessor-based system which will increase the degree of control of the machine and enable the camshaft and the knitting carriage to be run simultaneously at various stages of the cycle. This feature would remove the need to stop and start the knitting cycle during the initial six set-up courses and thus reduce the overall cycle time. A further means of reducing the cycle time is to increase the speed of rotation of the camshaft to its maximum speed consistent with reliable transfer and this has yet to be determined.

The need to operate the auxiliary transfer plough for two extra courses adds to the number of non-productive courses. Suggestions for further work in this area are two-fold. Firstly,
alterations to the profile of the take-off elements to improve the yarn path (See Fig 10.1) by bringing the crest of the element over the top of the verge to allow the loops to slip more easily down to the retaining barbs. Alternatively, the front-bed could be raised above its normal position to force the loops over the crest of the take-off elements, thereby imitating the effect of the action of the auxiliary transfer plough.

Although the cut-and-clamp mechanism of the Mark III machine is effective in operation, it has been found to restrict access to the various mechanisms. Alternative methods of achieving this function should be investigated; one possibility would be to sweep all the yarns to a common point, thereby removing the need to mount the cut-and-clamp mechanism in an adjustable manner.
Fig. 10.1 Modified Take-off Element
CHAPTER 11

THE NEED FOR GAUGE CHANGING

The terms of reference for the Loughborough ART project required a system of automatic rib transfer to be developed around existing 'V'-bed knitting machines. Such a system, though providing an economic solution to the rib transfer problem, in itself required the development of an extra device capable of readily changing the gauge or pitch of ribs on a magazine bar, i.e. from that of the 'V'-bed knitting machine to that of the straight bar knitting frame. Existing commercially available automatic rib transfer systems are produced in gauges matching those of the straight bar machines (Sections 4.1 to 4.4) and so do not require such a regauging operation. This however does limit the type and bulk of yarn that may be knitted. Most knitwear manufacturers using manual rib transfer as a means of loading ribs on to straight bar machines produce these ribs on 'V'-bed machines of a coarser gauge than that of the straight bar machines. The coarser gauge 'V'-bed machines enable the use of a wider range of yarns and produce a more elastic rib than the fine gauge machines necessary for the automatic rib transfer systems described in Sections 4.1 to 4.4.

A gauge changing device is therefore not only a means of avoiding the need to change the beds of existing 'V'-beds to the gauge of the straight bar machines that they have to feed, but is also a method of retaining the advantages of being able to use a wide range of yarns and to produce a good, elastic rib.
11.1 Doubling, the Need and the Problems

The main reason for producing garments with rib borders is that the rib structure is inherently more elastic than a plain knitted fabric. Waist, cuff and neck bands of knitted garments require this elasticity to prevent the edges of the garment sagging and looking "baggy". Although the rib structure is naturally elastic this elasticity may be improved by doubling loops onto adjacent elements, either at the knitting stage or during manual rib transfer as described in Section 1.3.3.

During rib transfer it is necessary to correct the loop distribution so that adjacent elements each carry a loop or doubled loops. The existing automatic machines perform this function as part of their operating cycle (5) (see Sections 4.1 - 4.4). However, with the Loughborough ART system it was proposed that the loops would be rearranged on to adjacent elements at the same time that the elements and loops were "regauged", i.e. changed from the gauge of the 'V'-bed knitting machine to that of the straight bar knitting frame. It was therefore necessary to develop a machine, and method of work to enable the ribs (automatically transferred to a magazine bar on the 'V'-bed knitting machine at the gauge of that machine and with spaces caused by doublings) to be transferred to the magazine bar of the straight bar machine at the gauge of that machine and with each element carrying a knitted loop or doubled loops. These requirements set the terms of reference for a separate investigation carried out by colleagues in the Department of Mechanical Engineering at Loughborough University of Technology to design and manufacture a "regauging and doubling" device to complement the Loughborough ART system.
11.2 The Loughborough Gauge Changing Device

One of the major factors influencing the design of this device, apart from the requirements stated in the terms of reference, was the productivity of the system. A 'V'-bed knitting machine is capable of knitting and loading 16 ribs onto a magazine bar approximately every 30 minutes (using the Loughborough ART system) depending upon length of rib knitted. However it was envisaged that one operator should be able to run up to six machines at a time which would mean that at most he would have no more than five minutes to perform the following operations:-

(i) Unload the full magazine bars from 'V'-bed machine;
(ii) place empty magazine bars in 'V'-bed machine and reset that machine;
(iii) place the full bars, one at a time, on to the regauging device along with an empty fully-fashioned machine magazine bar;
(iv) operate the regauging device; and
(v) remove and stack both bars, and reset the device.

From the above list of operations, the actual time available for regauging is of the order of one to two minutes. Such a time factor immediately ruled out one of the early proposals for a device based upon the transfer of elements from a trick-slotted bar with the tricks at the gauge of the 'V'-bed machine to a trick bar at the gauge of the straight-bar machine. Doublings were to be accommodated by feeding the 'V'-bed bar two pitches whilst the straight-bar machine bar moved only one pitch (see Fig. 11.1).
Fig. 11.1 The First Regauging System
The device eventually adopted is shown in Fig 11.2 and in Plates 11.1 to 11.8. Prior to the regauging operation excess trailing yarns are trimmed (see Plate 11.1) and the drawthread or hook-up yarns are removed (see Plate 11.2). The magazine bar from the Loughborough ART machine is then placed on the regauging device such that the tips of the elements engage with the elements of the transfer device (see Plate 11.3). These elements are mounted in spring steel strips which in turn are located top and bottom in trick-cut bars of the gauge of the ART machine (lower) and of the gauge of the straight-bar machine (upper). The 16 ribs are then transferred from the ART magazine bar elements to the elements of the transfer machine by a comb-like set of elements (see Plate 11.4). The transfer elements are then moved upwards out of engagement with the ART magazine bar elements (see Plate 11.5). By arranging the strips such that they are in adjacent tricks in the upper bar of the device and only in the tricks of the lower bar corresponding to the ART magazine bar elements carrying loops, the "empty elements" are "lost" as the transfer elements move from the lower to the upper position. At the upper station (see Plate 11.5) the elements are set, by the upper trick bar, at a gauge corresponding to that of the "straight bar" magazine bar. The straight-bar machine magazine bar is then brought forward to engage with the transfer elements (see Plate 11.6). The ribs may then be transferred from the transfer elements to the "straight-bar" magazine bar (see Plate 11.7) and this can be removed from the transfer device, with each element carrying a loop, ready to feed to the straight-bar knitting machine (see Plate 11.8).
Fig. 11.2 The Loughborough Regauging System
The whole operation can be performed in under 30 seconds by the machine operator which is well inside the initial speed stated in the terms of reference. It is thus theoretically possible for one regauging device to service up to 12 'V'-bed machines providing that all machines are producing at the same gauge. Any number of different gauges can be handled by the device simply by changing the upper and lower trick-cut bars to suit the gauges of the 'V'-bed and straight-bar machines.
Plate 11.1
Trimming the excess trailing yarns.
Removing the hook-up yarns.
The ART machine bar elements are engaged with those of the regauging device.
Plate 11.4

The transfer of the ribs to the regauging device elements.
Plate 11.5
The regauging elements are moved to their upper position.
The engagement of the straight-bar machine magazine bar with the regauging device elements.
The straight-bar magazine bar is disengaged on completion of the transfer.
179

CHAPTER 12

SUMMARY AND CONCLUSIONS

12.1 Summary of the ART System

The research, design and development programme described in this thesis, has led to a novel, low cost conversion for standard 'V'-bed knitting machines, equipped with bed-to-bed stitch transfer facilities, to enable the loops of knitted rib fabric pieces to be automatically transferred to the elements of a standard fully-fashioned magazine bar. This has been termed the Loughborough Automatic Rib Transfer (ART) System. In order to perform this rib transfer function, eight specially developed cam-operated mechanisms have been attached to a standard 'V'-bed machine. These mechanisms perform the following functions:

(i) The take-down mechanism applies a downward force to the knitted loops to facilitate knitting.

(ii) The take-off mechanism removes the last course of knitted loops from the knitting elements, subsequently transferring these loops to the elements of the magazine bar.

(iii) The magazine bar mechanism collects the knitted loops from the take-off elements and stores the completed ribs.

(iv) The sweep-off mechanism sweeps the knitted loops from the take-off elements to the magazine bar elements.

(v) The cut-and-clamp mechanism clamps the umbilical yarns still attached to the machine and severs them from the rib.

(vi) The bed-drop mechanism provides the means of setting up the last course of knitted loops on the knitting elements prior to transfer and provides access to the knitting zone for the take-off elements.
(vii) The press-off mechanism releases the welt edge of the rib from the take-down hooks.

(viii) The yarn tension control mechanism reduces the yarn tension during the descent of the rib from the knitting zone to the lower transfer point.

The system allows for up to 24 ribs to be loaded on to each magazine bar for subsequent transfer, via a specially developed gauge-changing device, namely the Loughborough Regauging machine, to a standard fully-fashioned machine magazine bar and hence to the knitting heads of conventional fully-fashioned knitting machines.

12.2 Conclusions

The aim of this research, design and development project was to produce an economically priced 'bolt-on' attachment capable of being fitted to a standard powered 'V'-bed machine to facilitate the automatic transfer of the last course of knitted loops from the knitting elements of the machine to the elements of a magazine bar.

The embodiment of this conversion now exists in the form of the Mark III Loughborough ART machine and its associated Regauging machine. This system is capable of feeding knitted ribs to fully-fashioned knitting machines and is currently running on three shifts, for five days per week at the Leicester factory of Corah Ltd. (17). In terms of productivity, the ART system does not, as yet, match that of a standard, unconverted machine but has the potential to achieve this in the next generation of machines. However, the ART conversion is 25% cheaper than rival automatic rib transfer systems and is up to 45% more productive. In the present depressed economic climate, with severe competition from cheap foreign imports, the British knitwear industry could have the immediate opportunity to reduce its production costs and meet this challenge by economically converting existing 'V'-bed machines.
The concepts developed in the ART system are completely original; therefore the possibility exists for UK textile machinery companies to exploit the patents for a new range of complete machines embodying the ART principles of automatic rib transfer.

A critical comparison of the Loughborough ART system of automatic rib transfer with other currently available systems is made in the Appendix.
REFERENCES AND BIBLIOGRAPHY

1. Baker, J.E.
   M.Tech. thesis in preparation (Loughborough University of Technology)

2. Borne, J.
   British Patent 1,040,315 11 June 1963

3. Fabrique Nationale
   British Patent 1,165,781 1 October 1969

4. Fabrique Nationale
   British Patent 1,299,221 13 December 1972

5. Fabrique Nationale
   British Patent 1,399,579 2 July 1975

6. Støvhase, R.
   British Patent 1,002,386 10 June 1964

7. Universal Maschinenfabrik
   British Patent 1,050,500 15 June 1965

8. Universal Maschinenfabrik
   British Patent 1,291,788 4 October 1972

9. Fabrique Nationale
   Hosiery Trade Journal, 76, August 1969, p67

10. Fabrique Nationale
    Hosiery Trade Journal, 80, April 1973, p108-9

11. Bordier, R.
    Hosiery Trade Journal, 77, April 1970, p129-30

12. William Cotton Ltd.
    Hosiery Trade Journal, 72, April 1972, p86-8

13. William Cotton Ltd.
    Knitting International, 86, March 1979, p95-6

14. Scheller, Gebr., GMbH.
    Hosiery Trade Journal, 80, April 1973, p104-5
15. Goadby, D.R.
   Knitting International, 81, June 1974, p56-7

16. Reichman, C.
   Knitting Times, March 15 1976, p26-7

17. Jordan, Lovatt and Jones Ltd.
   Knitting International, 89, January 1982, p96-7

BIBLIOGRAPHY

Lancashire, J.B.
   'Jacquard Design and Knitting' (Knitted Outerwear
   Association, New York, 1969)

Miller, E.
   'Textile Properties and Behavior' (Batsford Ltd.,
   London, 1973)

Mills, R.W.
   'Fully-fashioned Garment Manufacture' (Cassell,
   London, 1965)

Reichman, C.
   'Advanced Knitting Principles' (Knitted Outerwear
   Association, New York, 1964)

Smirfitt, J.A.
   'Introduction to Weft Knitting' (Pitman, Bath, 1975)

Wignall, H.
   'Knitting' (Pitman, London, 1964)

Wray, G.R.
   'Textile Manufacture' (Vol. 13, Encyclopedia of
   Polymer Science and Technology, Wiley & Son Ltd.
   New York, 1970)

PATENTS PENDING ON THIS WORK

   'A Gauge Changing Device'

European Patent Application 10,982 2 November 1979
   'A System of Automatic Rib Transfer'
GLOSSARY

Cotton's Gauge. The number of elements in a 1\(\frac{1}{2}\) inch length

i.e. Cotton's 21 gauge \(\equiv\) 14 needles per inch (N.P.I.)

" 9 " \(\equiv\) 6 N.P.I.

Eye (of an element). An indentation or 'hole' through an element

Jacquard. A jacquard machine has the facility to independently select the operation of each element.

Knitting Heads or Sections. A fully-fashioned knitting machine is made up of several knitting heads or sections (usually 8, 12, or 16 in number) driven by a common camshaft and control system.

Neb. The nose or tip of an element.

Pelereen. A piece of spring steel secured to the side of a knitting element to hold open a yarn loop for transfer to another element.

Quality Cams. The cams in a knitting machine cam box which set the amount of yarn drawn in to a knitted loop.

Selection Jacks. The elements in a jacquard knitting machine which select the knitting elements.

Shogging. The relative sideways movement between two adjacent knitting beds or sets of elements.
**Slack Course.** A course of knitting where the loops contain a greater length of yarn than the loops of the adjacent courses to highlight the course and to assist loop transfer.

**Slurcock.** In a fully-fashioned knitting machine it is the slurcock that causes the required length of yarn to be drawn around the knitting elements by the sinker elements.

**System—Single or Double.** Certain 'V'-bed knitting machines have two sets of knitting cams and yarn carriers to enable two courses to be knitted with each traverse of the carriage (double system) rather than single system knitting where only one course is knitted with each traverse.

**Trick.** A slot in which elements are located.
APPENDIX

A CRITICAL COMPARISON OF THE LOUGHBOROUGH ART SYSTEM
WITH OTHER CURRENTLY AVAILABLE SYSTEMS OF AUTOMATIC RIB TRANSFER

The objective of the Loughborough ART programme of work was to produce a low-cost, 'bolt-on' attachment for existing 'V'-bed knitting machines to enable them to automatically transfer a knitted rib border from the knitting elements to a magazine bar for subsequent transfer on to a straight bar knitting machine. The Loughborough ART system of automatic rib transfer, in its latest form, has a number of advantages over other currently available systems:

1. The cost of the ART machine conversion is expected to be approximately £15,000 compared with £20,000 for machines such as the Bentley Cotton Autorib 3 or the Boehringer Ribomat.

2. The conversion utilises existing 'V'-bed machines, removing the need to 'scrap' or sell-off costly existing plant as would be necessary if a complete conventional automatic rib transfer machine were to be purchased.

3. The latest ART system is as productive as the unmodified 'V'-bed machine, thus enabling 4 cuff ribs or 2 body ribs to be knitted on a modified machine with 200cm wide beds. Systems such as the Autorib 3 and the Ribomat can only accommodate 2 cuff ribs or one body rib per machine. Therefore the ART system is potentially much more productive despite the slightly higher knitting speeds possible with the narrower bedded machines.

4. The nature of the ART rib transfer process makes the operation of loop transfer generally more tolerant of misaligned elements than the other systems of rib transfer. Systems such as the Autorib require the knitting elements to be engaged with a small eye in the opposing transfer element. This engagement is in the vertical sense,
thus any sideways misalignment between the two sets of elements may cause a loop to be 'dropped'. The ART process introduces the take-off elements into the knitting zone between the knitting elements and engagement is by a sideways movement of the knitting elements, eliminating any sideways misalignment between the two sets of elements.

5. The use of existing 'V'-bed machines by the ART system enables rib borders to be knitted at a coarser gauge than that of the straight bar machine. This permits a wide range of yarn types and counts to be knitted. Systems such as the Autorib 3 and Ribomat have beds that are of the same gauge as the straight bar machines and so limit the range of usable yarns.

6. The Loughborough Regauging device complements the ART system by allowing any combinations of doublings or changes of gauge to be performed. Operations such as moving a loop at the junction of the rib and plain fabric to highlight a cable stitch are vastly simplified by the use of this device (See Chapter 11).

7. The ART system may be used to feed automatic linking systems such as the Boehringer Autolinker.

The many benefits offered by the Loughborough ART system of automatic rib transfer now enable the smaller knitwear manufacturer, threatened by the increasing importation of cheap knitwear, to enter the field of automatic rib transfer to reduce production costs and to compete in terms of price and quality with these imports.