Date: April 25, 1977

Project Title: A Study of Mill Conditions Affecting Weaving Room Operating Efficiency

Project No: E-27-653

Project Director: Dr. A. Tayebi

Sponsor: Rockwell International

Agreement Period: From 4/18/77 Until 6/30/77

Type Agreement: Standard Industrial Research Agreement dated 3/25/77

Amount: $6,964

Reports Required: Monthly Reports

Sponsor Contact Person(s):
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  - Mr. A. Krause
    Rockwell International
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    25 Hopedale Street
    Hopedale, Massachusetts 01747

- Contractual Matters (thru OCA)
  - (School/Laboratory)

Defense Priority Rating: none

Assigned to: TE

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- Project Code (GTRI)
- Other

CA-3 (3/76)
GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT TERMINATION

Date: OCTOBER 14, 1977

Project Title: A STUDY OF MILL CONDITIONS AFFECTING WEAVING ROOM OPERATING EFFICIENCY

Project No: E-27-653

Project Director: DR. A. TAYEBI

Sponsor: ROCKWELL INTERNATIONAL

Effective Termination Date: 9/16/77

Clearance of Accounting Charges: 9/16/77

Grant/Contract Closeout Actions Remaining:

X Final Invoice
- Final Fiscal Report
- Final Report of Inventions
- Govt. Property Inventory & Related Certificate
- Classified Material Certificate
- Other

Assigned to: TEXTILE ENGINEERING (School/Laboratory)

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Director, Physical Plant
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other

CA-4 (3/76)
A Study of Yarn-Loom Interactions Affecting Loom Operating Efficiency

A Sponsored Research Report Submitted to

The Rockwell International Corporation Draper Division
Hopedale, Massachusetts, 01747

By

Dr. Amad Tayebi
Associate Professor School of Textile Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

September 7, 1977
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CHAPTER I

OBJECTIVE OF RESEARCH

The objective of the conducted research has been to study mill factors involving fiber, yarn and loom and affecting the weaving room operating efficiency at the Hickman Plant of Graniteville Company.

Therefore, the major types of X-2 and DLG loom stops have been identified and their probable causes examined taking into consideration that a yarn-loom interaction is always the reason of any type of loom stop. Specific recommendations are made for minimization of the number of loom stops per loom running hour.
CHAPTER II
LOOM STOPS AND ANALYSIS

II.1. Location of Occurrence of Warp Body and Filling Stops

II.1.1. DLG Looms

The warp yarn length—extending from the loom beam to the fell of cloth—is divided into five zones, as shown in Figure (II.1.). The percentage of warp body stops per inch of warp width and the percentage of total warp body stops in the various zones are shown in Table (II.1.). As shown therein, approximately 75% of all warp body stops occur in zones 2, 3 and 4. Bearing in mind that the main cause of warp yarn breaks on most looms is insufficient yarn extensibility and that shed opening and beat-up impose a tensile strain on warp yarns, it becomes evident that in order to reduce the warp body stops in zones 2, 3 and 4, it is essential to maintain an adequate and uniform sized warp yarn breaking elongation.

On the other hand, the percentage of warp body breaks per inch of warp width is higher in the right hand 10 inch segment than in the middle and left hand segments. This could be attributed to the additional rubbing action and yarn bending and tensile strains imposed by the right hand carrier during its withdrawal from an almost closed shed, see Figure (II.2). These strains, and consequently their effect on number of warp body breaks in the right hand 10 inch segment can be significantly reduced by reducing the right hand carrier height (h) and coating its upper surface with a smooth low coefficient of friction hard
### Table (II.1) Location of Warp Body Stops (DLG Looms)

<table>
<thead>
<tr>
<th>Zone Number (See Fig.II.1)</th>
<th>Percent of Total Warp Body Stops</th>
<th>( \frac{N}{(T)\cdot(W)} \times 100 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>L.H. 10 Inch Segment</td>
</tr>
<tr>
<td>(1)</td>
<td>6.81%</td>
<td>1.848%</td>
</tr>
<tr>
<td>(2)</td>
<td>24.20%</td>
<td>1.804%</td>
</tr>
<tr>
<td>(3)</td>
<td>28.13%</td>
<td>1.184%</td>
</tr>
<tr>
<td>(4)</td>
<td>22.21%</td>
<td>1.167%</td>
</tr>
<tr>
<td>(5)</td>
<td>18.65%</td>
<td>1.190%</td>
</tr>
</tbody>
</table>

N = Number of Stops in Segment of Zone  
T = Total Number of Stops in Zone  
W = Width of Segment (inch).
material, (such as porcelain enamel).

II.1.2. X-2 Looms

Using the same presentation format and treatment of warp body stops data for the DLG looms, the X-2 looms data are presented in Table (II.2). As shown therein, over 85% of all warp body stops take place in zones 2, 3 and 4.

The data of percentage of occurrence of filling stops in the various quill zones are shown in Figure (II.3). The excessive rate of filling yarn breakage taking place in the quill end zone is attributable to the sharp increase in filling yarn unwinding tension developed in this zone. This sharp increase in tension is due to the small base diameter of quill - (for straight base quills) - causing the filling yarn to rub excessively against the quill surface and thus increasing the unwinding tension. Therefore, unwinding tension measurements have been carried out on a continuous unwinding set-up. These measurements have shown that the magnitude of filling yarn unwinding tension at quill base exceeds - by a factor of at least two times - that at quill top zone. Details of these measurements are given in section (II.3.2) of this report. Thus - on the basis of filling unwinding tension measurements presented in section (II.3.2) - it is suggested that the mill use conical base quills, See Figure (II.4). Experimental evidence of reduced quill end zone unwinding tension and thus reduced rate of filling yarn stops is provided here from measurements carried out by this author in an earlier study - (conducted in 1964) -, See Figure (II.5).
Table (II.2) Location of Warp Body Stops (X-2 Looms)

<table>
<thead>
<tr>
<th>Zone Number (See Fig.II.1)</th>
<th>Percent of Total Warp Body Stops</th>
<th>( \frac{N}{(T) \cdot (W)} \times 100 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>L.H. 10 Inch Segment</td>
</tr>
<tr>
<td>(1) 3.97%</td>
<td>2.143% 2.143%</td>
<td>1.429%</td>
</tr>
<tr>
<td>(2) 17.85%</td>
<td>2.118% 2.028%</td>
<td>1.800%</td>
</tr>
<tr>
<td>(3) 27.76%</td>
<td>1.259% 2.585%</td>
<td>0.986%</td>
</tr>
<tr>
<td>(4) 39.94%</td>
<td>0.993% 2.687%</td>
<td>0.945%</td>
</tr>
<tr>
<td>(5) 10.48%</td>
<td>1.710% 2.403%</td>
<td>1.080%</td>
</tr>
</tbody>
</table>

\( N \) = Number of Stops in Segment of Zone
\( T \) = Total Number of Stops in Zone
\( W \) = Width of Zone (inch).
Figure (II.3) Location of Filling Breaks (X-2 Looms)

Figure (II.4) Conical and Straight Base Quills
1 1/4" SHUTTLE WIDTH
1" EYE DISTANCE
COUNT: 30°/1
SPEED: 45 FT./SEC.

Figure (II.5)
II.2. Types and Frequencies of Occurrence of Loom Stops

In order to identify the most frequently occurring types of stops, the loom stop test data was treated in such a way that the number of loom stops per running loom hour—(i.e. 60 minutes of continuous loom operation)—be calculated for each stop type. This is a measure which is independent of loom-down time. The results of these calculations for the various fabric styles woven on the X-2 and the DLG looms are shown in Figures (II.6) to (II.27). The total duration of loom stop test—(i.e. number of loom hours)—and the average loom operating efficiency for the various fabric styles are shown in Table (II.3).

From the data shown in Figures (II.6) to (II.27), the major types of stops occurring consistently and with significant magnitudes in most fabric styles are identified as follows:

X-2 Looms:

(1) Warp
   Weak Thread Body
   Gouts
   Knots

(2) Mechanical
   Break on Transfer

(3) Filling
   Weak Filling
   Bad Filling
NUMBER OF LOOM STOPS/RUNNING LOOM HOUR

- WEAK THREAD BODY
- WEAK THREAD SELV.
- LOOSE ENDS BODY
- LOOSE ENDS SELV.
- KNOTS
- GOUTS
- SLACK THREAD BODY
- SLACK THREAD SELV.
- CROSSED ENDS
- SLIP KNOTS
- LINT ON YARN
- WILD YARN
- MAT UP
- SOFT YARN
- SPINNER PIECE
- STUCK END
- BROKE AT FILLING
- SELV. BOBBIN RUN OUT
- SELV. BOBBIN BREAK
- END
- TZ SIZING
- TIE IN OR MISDRAW

- MISS. LOOM REPAIR
- LOOM DRAGS
- STOP ON TRANS.
- BREAK ON TRANS.
- WARP RUN OUT
- THIN PLACES
- NO FILL IN BATTERY
- BOBBIN RUN OUT
- MISSED BOBBIN
- UNKNOWN STOPS
- CUT ENDS
- STOP ON FORK
- CUT ON DROP WIRE
- BOBBIN BROKE IN SHUTTLE
- ELECTRIC WIRE
- BREAK BEFORE CHANG

- FILLING BREAKS
- BAD QUILLS
- BAD BUNCH
- FILL SHELL OFF
- BAD FILLING
- MISS. FILLING
- IN FILLING

Figure (11.6)
Figure (II.7)
Figure (II.8)
Figure (II.10)

NUMBER OF LOOM STOPS/RUNNING LOOM HOUR

- Weak Thread Bobbin
- Weak Thread Selv.
- Loose Ends Bobbin
- Loose Ends Selv.
- Knots
- Gouts
- Slack Thread Bobbin
- Slack Thread Selv.
- Crossed Ends
- Slip Knots
- Lint on Yarn
- Wild Yarn
- Mat Up
- Soft Yarn
- Spinner Piece
- Stuck End
- Broke at Fell LAN
- Selv. Bobbin Run Out
- Selv. Bobbin Break
- Big End
- Hard Sizing
- Missed or Misdraw
- Misc. Loom Repair
- Loom Change
- Stop on Trans.
- Break on Trans.
- Warp Run Out
- Thin Places
- No Fill in Battery
- Bobbin Run Out
- Missed Bobbin
- Unknown Stops
- Cut Ends
- Stop on Fork
- Cut on Drop Wire
- Bobbin Broke in Machine
- Electric Wire
- Break Before Change

Filling Breaks
- Bad Quills
- Bad Bunch
- Fill Shell Off
- Bad Filling
- Weak Filling
- Waste in Filling

X-2 Loom Stops: Style No. O8-08
Figure (II.11)
<table>
<thead>
<tr>
<th>Category</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>Filling Breaks, Bad Quills, Bad Bunch, Fill Shell Off, Bad Filling, Weak Filling, Waste in Filling</td>
</tr>
<tr>
<td>Loom</td>
<td>Unknown Causes</td>
</tr>
<tr>
<td>Style No. 7024</td>
<td>X-2 Loom Stops</td>
</tr>
</tbody>
</table>
Figure (II.14)
<table>
<thead>
<tr>
<th>Condition</th>
<th>O</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak thread body</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weak thread selv.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loose ends body</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loose ends selv.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knots</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gouge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slack thread body</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slack thread selv.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crossed ends</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slip knot</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lint on yarn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wild yarn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mat up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft yarn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinner piece</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stuck end</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broke at fell cloth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selv. bobbin run out</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selv. bobbin break</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big end</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard sizing</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missed or medram</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misc. loom repair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loom change</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop on trans.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Break on trans.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warp run out</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thin places</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No fill in battery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bobbin run out</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missed bobbin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unknown stops</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut ends</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop on fork</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut on drop wire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bobbin broke in shuttle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric wire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Break before change</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure (11.15)**

**X-2 Loom Stops, Style No. 08080**
Figure (II.16)

X-2 LOOM STOPS. STYLE No. 8081

- B stops
- A stops
B stops

A stops

Figure (II.17)
Figure (II.18)
NUMBER OF LOOM STOPS/RUNNING LOOM HOUR

WEAK THREAD BODY
LOOSE ENDS
KNOTS
GOUTS
SLIP KNOTS
MAT-UP
WILD YARN
LINT BALL
CROSSED ENDS
SLACK THREAD
MISSED OR MISDRAW
BIG END
STUCK END
BROKE AT FELL OF CLOTH
HARD SIZING
THREAD OUT

BINDER BREAK
6 END SPOOL BREAK
FALSE SELVAGE BRK
BINDER RUN OUT
FALSE SELVAGE RUNOUT
WEAK THREAD SELVAGE
SLACK THREAD
6 END SPOOL RUNOUT

CAR. DROPS FIL. R.H.
GRIP. DROPS FIL. LH.
TRANSFER FAILURE
BINDER STOP (LEND)
6 END SPOOL SLACK
FALSE SELVAGE SLK
WARP OUT
LINT UNDER TEMPLATE
MISC. LOOM REPAIRS
UNKNOWN
CUT ENDS
BLOWER
FILLING CONE OUT OF HARNESS BROKE
SLACK WARP

WINDING DEFECT
BREAK AT FEEDER
BREAK AT CONE
SLIP KNOTS
CONE RUN OUT
WEAK YARN
LINT ON FIL.
EL. FIL.

FABRIC BODY 1-+-BINDER
SELVAGE
WARP - - - MECHANICAL

Figure (II.22)

DLG LOOM STOPS. STYLE NO. 4691
Figure (II.23)

- WEAK THREAD BODY
- LOOSE ENDS
- KNOTS
- GOUTS
- SLIP KNOTS
- MAT-UP
- WILD YARN
- LINT BALL
- CROSSED ENDS
- SLACK THREAD
- MISSED OR MISDRAW
- BIG END
- STUCK END
- BROKE AT FELL OF CLOTH
- HARD SIZING
- THREAD OUT

- BINDER BREAK
- 6 END SPOOL BREAK
- FALSE SELVAGE BRK
- BINDER RUN OUT
- FALSE SELVAGE RUNOUT
- WEAK THREAD SELVAGE
- SLACK THREAD
- 6 END SPOOL RUNOUT

- CAR. DROPS FIL. R.H.
- GRIP. DROPS FIL. L.H.
- TRANSFER FAILURE
- BINDER STOP (LEN)
- 6 END SPOOL SLACK
- FALSE SELVAGE SLK
- WARP OUT
- LINT UNDER TEN. PLATE
- MISC. LOOM REPAIRS
- UNKNOWN
- CUT ENDS
- BLOWER
- FILLING CONE OUT OF
- HARNES BROKE
- SLACK WARP

- WINDING DEFECT
- BREAK AT FEEDER
- BREAK AT COME
- SLIP KNOTS
- CONE RUN OUT
- WEAK YARN
- LINT ON FILLING
- BAI FILLING
Figure (II.24)
<table>
<thead>
<tr>
<th>Category</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak Thread Body</td>
<td>1</td>
</tr>
<tr>
<td>Loose Ends</td>
<td></td>
</tr>
<tr>
<td>Knots</td>
<td></td>
</tr>
<tr>
<td>Gouts</td>
<td></td>
</tr>
<tr>
<td>Slip Knots</td>
<td></td>
</tr>
<tr>
<td>Mat-Up</td>
<td></td>
</tr>
<tr>
<td>Wild Yarn</td>
<td></td>
</tr>
<tr>
<td>Lint Ball</td>
<td></td>
</tr>
<tr>
<td>Crossed Ends</td>
<td></td>
</tr>
<tr>
<td>Slack Thread</td>
<td></td>
</tr>
<tr>
<td>Missed Or Missed Hawk</td>
<td></td>
</tr>
<tr>
<td>Big End</td>
<td></td>
</tr>
<tr>
<td>Stuck End</td>
<td></td>
</tr>
<tr>
<td>Broke at Fell of Loom</td>
<td></td>
</tr>
<tr>
<td>Hard Sizing</td>
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<tr>
<td>Thread Out</td>
<td></td>
</tr>
<tr>
<td>Binder Break</td>
<td></td>
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<tr>
<td>6 End Spool Break</td>
<td></td>
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<tr>
<td>False Selvage Front</td>
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<tr>
<td>Binder Run Out</td>
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<td>False Selvage Runout</td>
<td></td>
</tr>
<tr>
<td>Weak Thread Selvage</td>
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</tr>
<tr>
<td>Slack Thread</td>
<td></td>
</tr>
<tr>
<td>6 End Spool Runout</td>
<td></td>
</tr>
<tr>
<td>Fabric Body Warp</td>
<td></td>
</tr>
<tr>
<td>Binder &amp; Selvage</td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td></td>
</tr>
<tr>
<td>Filling</td>
<td></td>
</tr>
</tbody>
</table>

**Figure (II.25)**
### DLG Loom Stops

**Style No. 9728**

<table>
<thead>
<tr>
<th>Category</th>
<th>Stops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabric Body</td>
<td></td>
</tr>
<tr>
<td>Warp</td>
<td></td>
</tr>
<tr>
<td>Binder &amp; Selvage</td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td></td>
</tr>
<tr>
<td>Filling</td>
<td></td>
</tr>
</tbody>
</table>

- **B stops**
- **A stops**

**Figure (II.26)**
Figure (II.27)
Table (II.3)

<table>
<thead>
<tr>
<th>Fabric Style Number</th>
<th>Loom Type</th>
<th>Duration of Loom Stop Test (Loom Hours)</th>
<th>Average Operating Efficiency (%)</th>
<th>Weighted Average Efficiency</th>
<th>Percent Cotton/Polyester in Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>1030</td>
<td>X-2</td>
<td>160</td>
<td>86%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1750</td>
<td>X-2</td>
<td>55</td>
<td>88%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2440</td>
<td>X-2</td>
<td>400</td>
<td>81%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3550</td>
<td>X-2</td>
<td>545</td>
<td>86%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4602</td>
<td>X-2</td>
<td>4705</td>
<td>89%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7020</td>
<td>X-2</td>
<td>1509</td>
<td>85%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7024</td>
<td>X-2</td>
<td>4395</td>
<td>83%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8020</td>
<td>X-2</td>
<td>60</td>
<td>85%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8021</td>
<td>X-2</td>
<td>140</td>
<td>90%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8080</td>
<td>X-2</td>
<td>465</td>
<td>87%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8081</td>
<td>X-2</td>
<td>1210</td>
<td>90%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8190</td>
<td>X-2</td>
<td>215</td>
<td>82%</td>
<td></td>
<td></td>
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<tr>
<td>8191</td>
<td>X-2</td>
<td>105</td>
<td>92%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8200</td>
<td>X-2</td>
<td>160</td>
<td>89%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9791</td>
<td>X-2</td>
<td>735</td>
<td>93%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4690</td>
<td>DLG</td>
<td>595</td>
<td>85%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4691</td>
<td>DLG</td>
<td>90</td>
<td>76%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7520</td>
<td>DLG</td>
<td>1305</td>
<td>81%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7521</td>
<td>DLG</td>
<td>212</td>
<td>79%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8140</td>
<td>DLG</td>
<td>1670</td>
<td>86%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9728</td>
<td>DLG</td>
<td>105</td>
<td>86%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9789</td>
<td>DLG</td>
<td>5</td>
<td>85%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

86.59% 83.61
II.3 Analysis of the Causes of Major Loom Stops

II.3.1 Warp Stops

In order to identify the parameters responsible for warp yarn related loom stops, the tensile characteristics of warp yarns before and after sizing were evaluated. The average breaking load and elongation were measured for warp yarns of several fabric styles, as shown in Table (II.4). In addition, certain measures of distribution spread have been calculated in order to assess the extent of variability of warp yarn tensile characteristics.

The testing apparatus used in the single-end tensile strength and elongation measurements is the Uster-Zellweger Automatic
<table>
<thead>
<tr>
<th>Style Number</th>
<th>Average (Gms)</th>
<th>Highest Value</th>
<th>Lowest Value</th>
<th>Range x100 Average (%)</th>
<th>Average (%)</th>
<th>Highest Value</th>
<th>Lowest Value</th>
<th>Coefficient of Variation (%)</th>
<th>Percent Size on Yarn</th>
</tr>
</thead>
<tbody>
<tr>
<td>3550</td>
<td>855</td>
<td>1079</td>
<td>1080</td>
<td>1320</td>
<td>150</td>
<td>150</td>
<td>109 108</td>
<td>7.7 7.4 12.0 9.8 2.6 4.0</td>
<td>16.13 12.43</td>
</tr>
<tr>
<td>4602</td>
<td>692</td>
<td>688</td>
<td>1000</td>
<td>960</td>
<td>404</td>
<td>100</td>
<td>86 125</td>
<td>18.0 14.9 36.0 34.4 6.5 2.8</td>
<td>18.34 32.13</td>
</tr>
<tr>
<td>4690</td>
<td>678</td>
<td>682</td>
<td>1290</td>
<td>870</td>
<td>180</td>
<td>510</td>
<td>164 53</td>
<td>19.1 14.2 29.4 21.4 5.2 4.8</td>
<td>16.48 31.1</td>
</tr>
<tr>
<td>7024</td>
<td>618</td>
<td>723</td>
<td>870</td>
<td>870</td>
<td>150</td>
<td>156</td>
<td>117 99</td>
<td>7.24 5.7 19.6 15.6 5.44 4.88</td>
<td>11.93 12.71</td>
</tr>
<tr>
<td>7521</td>
<td>575</td>
<td>701</td>
<td>675</td>
<td>870</td>
<td>360</td>
<td>480</td>
<td>55 56</td>
<td>6.75 5.15 12.2 9.0 4.8 4.0</td>
<td>12.44 13.98</td>
</tr>
<tr>
<td>8081</td>
<td>794</td>
<td>938</td>
<td>1065</td>
<td>1260</td>
<td>429</td>
<td>510</td>
<td>80 80</td>
<td>7.66 6.1 11.0 9.3 4.8 2.8</td>
<td>10.44 11.15</td>
</tr>
<tr>
<td>8140</td>
<td>855</td>
<td>1047</td>
<td>1059</td>
<td>1290</td>
<td>159</td>
<td>396</td>
<td>105 85</td>
<td>7.8 6.1 16.0 10.0 3.0 4.0</td>
<td>12.31 14.10</td>
</tr>
</tbody>
</table>

B = Before Sizing
A = After Sizing
Tensile Tester. Among the unique features of this apparatus are the graphic records produced showing the tensile strength and elongation at break for each tested specimen, and the simplified techniques developed for evaluation of coefficient of variation of strength and elongation data. However, when the scatter of data is high, these techniques cease to give an accurate evaluation of the coefficient of variation. Accordingly for fabric styles showing an excessive variation(*) in breaking elongation (such as fabric styles number 4602 and 4690 with blend ratio of [65P/35C]) the coefficient of variation has been calculated using individual-end elongation data and the familiar formula:

\[
\text{Coefficient of variation (C.V.\%)} = \frac{\sqrt{\sum (x - \bar{x})^2 / (n - 1)}}{\bar{x}} \times 100
\]

where \(x\) = individual end breaking elongation

\(\bar{x}\) = average breaking elongation

\(n\) = number of test specimens

The coefficient of variation of yarn elongation is a most important parameter with a significant influence on weaving room efficiency since individual warp ends break when their breaking elongation is exceeded by the loom-imposed shed formation tensile strain and not when the latter exceeds the average sized yarn breaking elongation.

(*) For comparative evaluation, see Figures (II.28) to (II.34) for graphic records of warp yarn strength and elongation data for fabric styles number 4602, 4690, 7521, 8081 and 8140 with blend ratios of (65P/35C) (80C/20P) and (100C/OP).
Figure (II.28):
Uster-Zellweger Single-End Tensile Strength and Elongation Chart
Fabric Style Number: 4602 (Before Sizing)
Figure (II.29):
Uster-Zellweger Single-End Tensile Strength and Elongation Chart
Fabric Style Number = 4602 (After Sizing)
Figure (II.30):
Uster-Zellweger Single-End Tensile Strength and Elongation Chart
Fabric Style Number = 4690  (Before and After Sizing)
Figure (II.31):
Uster-Zellweger Single-End Tensile Strength and Elongation Chart
Fabric Style Number = 7521  (Before and After Sizing)
Figure (II.32):
Uster-Zellweger Single-End Tensile Strength and Elongation Chart
Fabric Style Number = 8081  (Before Sizing)
Figure (II.33):

Uster-Zellweger Single-End Tensile Strength and Elongation Chart
Fabric Style Number = 8081  (After Sizing)
Figure (II.34):
Uster-Zellweger Single-End Tensile Strength and Elongation Chart
Fabric Style Number = 8140    (Before and After Sizing)
From the data shown in Table (II.4) and Figures (II.28 to (II.34), it is evident that the variability of breaking elongation of polyester/cotton blended yarns with (65P/35C) blend ratio is excessively high in the sized state - (the loom state). This excessively high coefficient of variation is attributable to:

(1) Nonuniform distribution of cotton and polyester fibers, (i.e., variation in blend ratio), along the yarn length resulting in nonuniform absorption of sizing solution. This blend ratio nonuniformity is ascertained by a selective dyeing intimacy of blend test in which a reactive dye - (ICI Procion Navy MX-RB, 4% depth, which has affinity only to the cotton fibers) - was used to dye single feed jersey knitted tubes made of the blended yarns. The obtained color depth was very light indicating that the proportion of polyester fibers on the yarn surface was high. Furthermore, visual examination of the knitted tubes showed segments of courses with almost no dye uptake - (indicating all-polyester fibers yarn segments) - and others with heavy dye uptake that corresponds to the presence of a high proportion of dyeable cotton fibers on yarn surface.

(2) The relatively high warp cover factor(*) resulting in nonuniform size solution pick-up and thus accentuating the irregularity of sized warp yarn elongation.

(*) For fabric styles number 4602 and 4690 with 106 warp ends per inch and warp yarn count = 14.75/1 the warp cover factor = 106/\sqrt[14.75]{1} = 27.60. It is worth noting that a cover factor of 28 corresponds to the limiting case where all adjacent warp ends touch each other.
The shielding effect exhibited by the polyester fibers on the yarn surface resulting from the fact that the polyester fibers used in this blend have—in comparison to the cotton fibers—a lower modulus. This mismatch in fiber moduli forces any undamaged long cotton fibers to migrate to the core of yarn.

In order to assess the effectiveness of the sizing formula in bonding polyester fibers in the high polyester ratio blended yarns, the tensile strength data before and after sizing are expressed in gm/denier units and presented in Table (II.5). As shown therein, the change after sizing in high polyester ratio blend yarn strength is insignificant as compared to the other blend ratio and cotton yarns. This indicates that the sizing formula does not bond the polyester fibers. It also confirms the conclusion—drawn above from the selective dyeing intimacy of blend test—that the polyester fibers lie on the surface of yarn and shield the core of yarn where most of the undamaged long cotton fibers lie.

II.3.2. Filling Stops

In order to investigate the possibility that excessive unwinding tension is applied on the yarn during tape travel thus causing yarn breakage, measurements of yarn tension were carried out. Using a Rothschild tension meter transducer placed at point A, shown in Figure (II.35), measurements of maximum filling yarn tension were obtained for fabric styles number 8140, 7520 and 7521 as shown in Table (II.6). These measurements were carried out on looms equipped with automatic feeders as well as on looms
<table>
<thead>
<tr>
<th>Style Number</th>
<th>Percent Cotton/ Polyester in Blend</th>
<th>Average Measured Warp Yarn Count (Unsized)</th>
<th>Warp Yarn Tenacity (Gm/Denier)</th>
<th>Percent Change in Yarn Tenacity After Sizing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Before Sizing</td>
<td>After Sizing</td>
</tr>
<tr>
<td>3550</td>
<td>100 C</td>
<td>8.83/1</td>
<td>1.420</td>
<td>1.792</td>
</tr>
<tr>
<td>4602</td>
<td>35C/65P</td>
<td>14.30/1</td>
<td>1.862</td>
<td>1.851</td>
</tr>
<tr>
<td>4690</td>
<td>35C/65P</td>
<td>14.77/1</td>
<td>1.883</td>
<td>1.894</td>
</tr>
<tr>
<td>7024</td>
<td>80C/20P</td>
<td>11.93</td>
<td>1.387</td>
<td>1.623</td>
</tr>
<tr>
<td>7521</td>
<td>80C/20P</td>
<td>12.28/1</td>
<td>1.329</td>
<td>1.620</td>
</tr>
<tr>
<td>8081</td>
<td>80C/20P</td>
<td>9.22/1</td>
<td>1.377</td>
<td>1.627</td>
</tr>
<tr>
<td>8140</td>
<td>100C</td>
<td>9.16/1</td>
<td>1.474</td>
<td>1.805</td>
</tr>
</tbody>
</table>
Figure (II.35): Filling Yarn Path Using Automatic Feeder and Location of Rothschild Tension Meter Transducer (At Point A)

Figure (II.36): Filling Yarn Path (Using 2 Pairs of Tension Plates)
Table (II.6): Filling Unwinding Tension Measurements (DLG Looms).

<table>
<thead>
<tr>
<th>Number of Pairs of Tension Plates in Yarn Path</th>
<th>Automatic Yarn Feeder Used?</th>
<th>Fabric Style Number</th>
<th>Nominal Filling Count Cotton (Denier)</th>
<th>Average Maximum Yarn Unwinding Tension Gms. (gm/denier)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>8140 (100% Cotton)</td>
<td>9 (590.6)</td>
<td>54 (0.0914)</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>7521 (80%C/20%P)</td>
<td>8.6 (618.0)</td>
<td>58 (0.0939)</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>7520 (80%C/20%P)</td>
<td>9 (590.6)</td>
<td>54 (0.0914)</td>
</tr>
</tbody>
</table>
using two pairs of friction plates for tension control in lieu of an automatic feeder, (See Figure (II.36)).

As shown in Table (II.6), the unwinding tension—expressed in gm/denier units—is extremely low and should not subject the yarns to excessive stress nor result in a significant loom stops occurrence level. It is worth noting, however, that excessive lint accumulation under the tension plates was observed, See Figure (II.37). And, in looms where two pairs of tension plates were used, it was observed that the lint accumulation takes place at the first pair of friction plates—(the pair closer to the filling yarn packages)—even though the yarn tension is lower than at the second pair. This indicates that the filling yarns are hairy and carry a significant proportion of short loosely held fibers on their surfaces that can be pulled out easily and accumulated when the yarn is passed through such converging surroundings as the tension plates.

In order to make the loom more tolerant to yarn hairiness and minimize the accumulation of lint along the filling yarn path, it is suggested that tension control on filling yarn be achieved by an intermittently acting air jet pointed in the direction opposite to yarn travel. The jet would be actuated during tape travel period and a continuous self cleaning action of the filling yarn path would be achieved by enclosing the jet into a low vacuum head continuous suction box, as shown in Figure (II.38).

Unwinding tension measurements were also carried out on a specially built unwinding set-up in which the yarn wrap angles
Figure (II.37) Lint Accumulation Under Tension Plates
TO FILTER

LOW HEAD CONTINUOUS VACUUM

Suction Box

COMPRESSED AIR

AIRJET

COMPRESSED AIR

LARGE PORCELAIN YARN GUIDE

FILLING YARN

CONCEPT OF A SELF-CLEANING FILLING YARN TENSION CONTROL UNIT

Figure (II.38)
around the yarn guides on the DLG loom were duplicated and which is equipped with a Rothschild tension meter, as shown in Figure (II.39). The unwinding speed used in this test was 53.7 ft/sec. The selection of this speed is based on tape speed calculation from measurements of tape displacement vs. crankshaft rotation angle—made at Graniteville Company. The data of tape displacement vs. crankshaft angle of rotation are shown in Table (II.7) and Figure (II.40).

Continuous yarn unwinding was carried out for a period of 1 minute* per package. Table (II.8) shows the unwinding tension and occurrence of yarn breaks during unwinding. It has been observed that the amount of flying fibers given off by the yarns in this continuous unwinding test was excessive and—as also observed under mill operating conditions—lint accumulated under the first pair of tension plates. The accumulated lint was mostly cotton fibers as evidenced by a selective dyeing test and by a burning test.

Continuous unwinding tests were also carried out on filling yarn quills used on the X-2 looms. In these tests shuttles lined with light as well as with heavy nylon looping were held stationary and the filling yarn was continuously unwound at a speed of 38.35 ft./sec. As shown in Figure (II.41), the yarn unwinding tension

(*) In terms of filling yarn consumption, one minute of continuous unwinding at the speed of 53.7 ft./sec is the equivalent of 2.43 minutes of loom operation at a speed of 238 picks per minute.
Figure (II.39): Continuous Filling Yarn Unwinding Set-Up (Simulating DLG Loom Filling Line).
<table>
<thead>
<tr>
<th>Angle of Rotation of Crankshaft (Degrees)</th>
<th>Displacement of Tape (Inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>3/8</td>
</tr>
<tr>
<td>20</td>
<td>7/8</td>
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<tr>
<td>30</td>
<td>21/8</td>
</tr>
<tr>
<td>40</td>
<td>7/8</td>
</tr>
<tr>
<td>50</td>
<td>3/4</td>
</tr>
<tr>
<td>60</td>
<td>8/16</td>
</tr>
<tr>
<td>70</td>
<td>7/8</td>
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<tr>
<td>80</td>
<td>15</td>
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<td>90</td>
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<td>353/8</td>
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</tr>
<tr>
<td>150</td>
<td>42</td>
</tr>
<tr>
<td>170</td>
<td>451/2</td>
</tr>
<tr>
<td>180</td>
<td>457/8</td>
</tr>
</tbody>
</table>
Figure (II.40): Tape Displacement vs - Crankshaft Rotation Angle

MAXIMUM SLOPE TANGENT
(MAX. SPEED = 54.03 FT/SEC)

CARRIERS JUST ABOUT TO TOUCH

(0.126 SEC.)

(AT 238 PICKS/MIN.)
Table (II.8)

<table>
<thead>
<tr>
<th>Fabric Style Number</th>
<th>Package Number</th>
<th>Nominal Filling Count (Denier) (Gms/denier)</th>
<th>Average Unwinding Tension Gms (Gms/denier)</th>
<th>Number of Yarn Breaks (in one minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 51 (0.132)</td>
<td>51 (0.132)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 53 (0.137)</td>
<td>53 (0.137)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 13.75/1 (386.54)</td>
<td>53 (0.137)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 52 (0.135)</td>
<td>52 (0.135)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 54 (0.140)</td>
<td>54 (0.140)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fabric Style Number</th>
<th>Package Number</th>
<th>Nominal Filling Count (Denier) (Gms/denier)</th>
<th>Average Unwinding Tension Gms (Gms/denier)</th>
<th>Number of Yarn Breaks (in one minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 62 (0.100)</td>
<td>62 (0.100)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 64 (0.104)</td>
<td>64 (0.104)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 8.6/1 (618.0)</td>
<td>63 (0.102)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 63 (0.102)</td>
<td>63 (0.102)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 62 (0.100)</td>
<td>62 (0.100)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>terial Style Number</th>
<th>Package Number</th>
<th>Nominal Filling Count (Denier) (Gms/denier)</th>
<th>Average Unwinding Tension Gms (Gms/denier)</th>
<th>Number of Yarn Breaks (in one minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 61 (0.103)</td>
<td>61 (0.103)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 64 (0.108)</td>
<td>64 (0.108)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 9/1 (590.6)</td>
<td>62 (0.105)</td>
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</tr>
<tr>
<td>4 62 (0.105)</td>
<td>62 (0.105)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5 64 (0.108)</td>
<td>64 (0.108)</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure (II.41): Continuous Filling Unwinding Set-Up
(Simulating Shuttle Flight on X-2 Loom)
was measured using a Rothschild tension meter transducer threaded in the yarn path between the shuttle eye and the yarn take-up drum.

Plots of unwinding tension as a function of amount of filling yarn on quill are shown in Figures (II.42) to (II.45). As shown therein, the unwinding tension rises sharply near the end of quill. This explains the data presented earlier in section (II.1.2) showing the majority of filling yarn break stops to occur in the quill end zone.

11.3.3 Mechanical Stops:

Before analyzing the causes of the major reported loom stops classified as mechanical stops, it is essential to first recognize that a loom mechanical stop is one that results from the unsatisfactory performance of a loom component or components properly set and timed, provided environmental conditions and/or deficient yarn qualities did not lead to nor accelerate the occurrence of such a stop.

In this section, the reported mechanical loom stops with the highest occurrence frequency, namely; R.H. carrier drops filling, transfer failure and lint under tension plate are analyzed with special emphasis placed on the fiber–yarn–loom interactions that cause and affect the rate of occurrence of these loom stops. Furthermore, suggestions are made for loom components modifications to make the loom more capable of tolerating certain yarn irregularities.
SHUTTLE WALL LINED WITH LIGHT NYLON LOOPS

SHUTTLE WALL LINED WITH HEAVY NYLON LOOPS.

FABRIC STYLE: 8081
YARN COUNT: 5.5/1
BLEND RATIO: 80C/20P

AMOUNT OF YARN ON QUILL

Figure (II.42)
SHUTTLE WALL LINED WITH LIGHT NYLON LOOPS

SHUTTLE WALL LINED WITH HEAVY NYLON LOOPS.

FABRIC STYLE: 8200
YARN COUNT: 7/1
BLEND RATIO: 80C/20P

Figure (II.43)
SHUTTLE WALL LINED WITH LIGHT NYLON LOOPS

SHUTTLE WALL LINED WITH HEAVY NYLON LOOPS.

FABRIC STYLE: 7024
YARN COUNT: 8.6/1
BLEND RATIO: 80C/20P

Figure (II.44)
SHUTTLE WALL LINED WITH LIGHT NYLON LOOPS

SHUTTLE WALL LINED WITH HEAVY NYLON LOOPS.

FABRIC STYLE: 4602
YARN COUNT: 13.75/1
BLEND RATIO: 65 P/35 C

FULL QUILL  3/4 FULL  1/2 FULL  1/4 FULL  NEAR BUNCH

AMOUNT OF YARN ON QUILL

Figure (II.45)
(A) R.H. Carrier Drops Filling:

Before examining the conditions that may result into loom stops classified as "R.H. Carrier Drops Filling", it is worth noting that two critical fast-occurring steps must be achieved in order for the R.H. carrier to carry the filling yarn from the R.H. side to the center of loom. These steps are:

1. While the yarn segment on side A of the R.H. carrier—See Figure (II.46)—is held the carrier advances in direction S and the yarn segment located between sides A and B of the carrier is thus pulled under the carrier gripper starting at point C and advancing to point D.

2. The cutter acts at point E and the carrier continues to advance in direction S drawing the filling yarn from side B—the filling yarn package side.

In light of these steps, a loom stop classified as "R.H. carrier drops filling" stop may take place because of one or more of the following conditions:

(i) Yarn or yarn segment(*) exhibits low friction and cutter acts too late: In this case the yarn slips at rear end (F) of holding zone of R.H. carrier gripper and the filling is dropped since the yarn tension on side B exceeds the yarn loose end resistance to slippage through the carrier slot on side B. The

(*) Such as a high percent cotton fiber yarn segment in a polyester/cotton blend yarn.
Figure (II.46)
possibility of yarn slippage at rear end (F) can be eliminated when the carrier finger is fitted with a carrier stop located at the middle of the holding zone. The carriers received from the Graniteville Company for examination were either not fitted with such carrier finger stop or had the latter ground off.

(ii) **Thick slub, large knot, or snarled yarn segment at point C:**

This makes the yarn slide around point C, instead of being pulled under the carrier gripper into the holding zone. When the cutter cuts the yarn at the right time and the carrier continues to advance the yarn cut end will slide back from side A to side B, thus resulting in carrier dropping filling. This analysis—(which is based on the assumption that the yarn tension, required to pull the yarn under the carrier gripper into the holding zone or to cause the yarn to slip out of the holding zone, is excessively high for a snarled or thick yarn segment)—is confirmed by measurements of increase in yarn tension during slippage through the holding zone developed because of yarn snarls. These measurements are reported in part (D) of section (II.3.3).

(iii) **Too Low Yarn Tension:** In this case, instead of being pulled under the carrier gripper into the holding zone, the yarn will slide from side B over point C to side A, where the yarn is held and the tension is relatively higher. As the carrier continues to advance and the yarn is cut at point E the relatively higher tension side becomes side B and the cut yarn end slides from side A to side B resulting in carrier dropping filling.
(iv) Too High Yarn Tension: An excessively high filling tension that may be caused by snarled yarn segments, large knots, accumulated lint in filling yarn path or thick slubs can force the filling yarn loose end to slide from side A to side B as the carrier advances. If the loose yarn end clears the holding zone before the R.H. carrier reaches the loom center the filling will be dropped.

(v) Too early cutter timing: When the cutter acts too early the yarn may not get pulled adequately under the carrier gripper into the holding zone. Thus, as the carrier advances the filling is dropped when the loose yarn end slides over point C to the relatively higher yarn tension side B.

(B) Transfer Failure:

In order to make evident the yarn-loom interactions causing transfer failure, diagrammatic sketches of the R.H. and L.H. carriers are shown in Figure (II.47). Upon examination of the carriers and the kinematics of the filling transfer process the following condition that could result in transfer failure is deduced:

Large Knots, gouts, and warp yarn irregularities or crossing ends resulting in unclear shed: Under such condition, the R.H. carrier may receive a vertical displacement thus causing the yarn segment stretching between points H and D, (see Figure (II.47)), to escape the L.H. carrier hook and a transfer failure takes place. Kinematic models have been developed to determine the minimum vertical displacement the right hand carrier must receive in
Figure (II.47)

Figure (II.48)
order for the filling yarn segment located between sides A and B to clear the L.H. carrier hook tip (G). This minimum displacement has been calculated, and found to be 0.26 cm, and experimentally verified in a slow motion filling transfer test simulating the actions that take place on the loom. Such a R.H. carrier vertical displacement can - in actual practice - happen if the warp shed is unclear or if large knots or gouts exist in the warp sheet causing deflection of R.H. tape and carrier.

In order to make the loom more tolerant to shed irregularities and knots and gouts in the warp sheet, it is suggested that the R.H. carrier be modified as follows:

(i) reduce height (M) of holding zone (See Figure II.48).

(ii) reduce height (Q) of the yarn threading point by cutting a narrow slot in side (B) of the R.H. carrier, as shown in Figure (II.48).

These changes would lower the level of yarn segment in the R.H. carrier and thus reduce its probability of clearing the L.H. carrier hook tip (G) and enhance the reliability of the filling transfer process.

(C) Lint Under Tension Plate:

Observations concerning lint accumulation under tension plates and a suggestion for making the loom more tolerant to yarns carrying excessive amounts of short fibers have been presented briefly in section (II.3.2) of this report.

Upon examination of accumulated lint generated from 65P/35C blended yarn rubbing action against the tension plates, it is found
to be mostly cotton fibers. This has been verified by a selective (reactive) dye test and a burning test.

The presence of a high proportion of cotton fibers in the accumulated lint is attributable to the fact that the cotton fibers in the yarn are of a short staple length. The average length of cotton fibers removed from untwisted fabric style number 4690 filling yarn has been measured and found to be 18.7 mm. The average length of polyester fibers taken out of the same yarn was found to be 37.5 mm. Furthermore, the ranges of length variation were from 7 to 28 mm and from 34 to 38 mm for the cotton and polyester fibers respectively. This indicates that a high percentage of cotton fibers was damaged whereas the polyester fibers were practically undamaged during the yarn formation processes.

The short cotton fibers are held into the yarn by minute frictional forces that act over short distances along the fiber length. Therefore, any rubbing action against guides located in the yarn path results in the release and accumulation of these short fibers.

It is most likely that the cotton fibers damage takes place in the carding process. In order to test the validity of this hypothesis, it is suggested that the number of teeth/fiber in the licker-in zone be calculated. If this ratio is found to be less than 1.0, the carding process results in severe damage and incomplete opening of fibers. The ratio can be computed from the following equation:
Number of teeth/fiber = 1.172 \left( \frac{D \cdot W \cdot N \cdot d}{P} \right) \times 10^{-6}

where, 
- D is the licker-in diameter (inch)
- t is the number of clothing teeth/square inch
- W is the width of card (inch)
- N is the R.P.M. of licker-in
- d is the fiber denier
- \lambda is the average fiber length (inch)
- P is the card output rate (lb/hr).

When the ratio is less than 1.0, the licker-in pulls fiber tufts instead of individual fibers. The fiber tufts are then delivered to the cylinder and a grinding action resulting in a severe fiber damage takes place between the cylinder and flats, instead of a carding action. What makes the cotton fibers more vulnerable than the polyester fibers during this grinding action is their lower extensibility and thus lower toughness. (The breaking strain of a cotton fiber is approximately one third of that of a polyester fiber).

Such severe fiber damage will not only increase the rate of generation of short fibers and lint accumulation, but also result into the formation of a greater number of nepes. In fact, all fiber nepes observed on yarn surface are formed of short cotton fibers as identified by their dark color developed in a selective dyeing test.

The fiber damage and difference in average fiber length of cotton and polyester fibers will also result in drafting waves.
during the process of drawing due to lack of control on the relatively shorter cotton fibers. The development of drafting waves, on the other hand, causes the blend ratio along the yarn length to fluctuate thus varying its frictional characteristics too.

(D) Interactions Involving Fiber, Yarn and Loom Components Resulting into Stops Classified as Mechanical Stops.

The difference in frictional characteristics of cotton and polyester fibers and the blend ratio variability along the yarn length make the yarn frictional behavior in the holding zone of the R.H. carrier erratic, i.e., the yarn resistance to slippage varies over a wide range. And, as mentioned earlier in part (A) of section (11.3.3), this variation results in loom stops that are not caused by unsatisfactory performance of loom components, yet are classified as mechanical stops.

This erratic frictional behavior has become evident from the results of a special test developed for measurement of magnitude and variability of yarn resistance to slippage in the holding zone. This test consists of threading the yarn through the carrier in the same fashion in which it is carried on the loom. As shown in Figure (11.49), yarn end (M) is clamped by the upper jaw which is attached to the Instron tensile tester load cell. The Instron tester lower jaw carries the yarn carrier and moves down, thus forcing the yarn to slip from side A to side B of the R.H. carrier.

Experiments have been carried out to show the frictional behavior of the 100%C, 80C/20P and 65P/35C yarns. The main emphasis
Table (II.9)

<table>
<thead>
<tr>
<th>Yarn Count</th>
<th>Blend Ratio</th>
<th>Angle of Wale Spirality (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.75/1</td>
<td>65P/35C</td>
<td>24.5</td>
</tr>
<tr>
<td>8.6/1</td>
<td>20P/80C</td>
<td>20</td>
</tr>
<tr>
<td>9/1</td>
<td>0P/100C</td>
<td>18</td>
</tr>
</tbody>
</table>
of these experiments has been placed on assessing the magnitude and variability of yarn tensile load required to overcome the frictional resistance in the carrier holding zone.

Figure (II.50) shows an Instron tensile tester recorder chart exhibiting the load against time or length of yarn slipping under the carrier gripper in the holding zone. As shown therein, as the Instron lower jaw moves down the yarn tension rises until slippage takes place. The tension required for slippage varies as the Instron lower jaw continues to move down indicating a variation in friction coefficient between the yarn and the carrier gripper surface. Such a variation in friction coefficient is caused by blend ratio variability since the cotton fibers have a lower coefficient of friction than the polyester fibers.

The behavior of a 100% cotton yarn threaded through the same carrier is shown in Figure (II.51). As shown therein, the variability in frictional resistance to slippage is considerably lower than that for the case of 65P/35C blend yarn shown in Figure (II.50).

The average loads required for slippage for the 65/35 blend yarn and for the 100% cotton yarn are 102 and 118 gms respectively. In order to obtain a normalized measure of the frictional behavior of the above mentioned yarns, the tensile load required for slippage is expressed in gm/denier units. The 65P/35C blend yarn has a resistance to slippage load of 0.264 gm/denier vs. 0.20 gm/denier for the 100% cotton yarn.
Figure (II.50)
Figure (II.51)
Bearing in mind that the 65P/35C blend yarn count is 13.75/1 and the 100% cotton yarn count is 9/1, and that the gripper pressure setting used for both yarns is the same; one may conclude that the difference in slippage resistance would further be accentuated if a finer (13.75/1) 100% cotton yarn or a coarser (9/1) 65P/35C blend yarn were used in this test.

The 80P/20C blend yarn frictional behavior is shown in Figure (II.52). In this test, however, the Instron lower jaw was moved at a faster rate. The variability in yarn frictional behavior is considerably less than that of the 65P/35C blend yarn. In addition, on a gm/denier basis, the average tensile load required for slippage is 0.206, which is considerably lower than that for the 65P/35C blend yarn.

From the above data, a conclusion may be drawn about the effect of blend ratio uniformity on loom performance as follows:

Since the exhibited yarn resistance to slippage varies with the variation in blend ratio for the same gripper pressure setting, it follows that the reliability of the process of pulling the yarn under the carrier into the holding zone and pulling it out of the holding zone can be adversely affected by blend ratio variability along the yarn length. This, in turn, results in carrier dropping filling stops that did not occur because of malfunction of carrier or incorrect cutter timing, but because of yarn variability.
Figure (II.52)

80/120 C

875/1

Gripper #2

80/120 yarn

875/1 yarn

Yarn Sliding Down

Starting Point: Middle of Finger

Load

Slipped Yarn

Length

X-head speed: 10" / min

Chart speed: 10" / min

Full Scale = 200 gms
In addition, other-apparently mechanical-loom stops may take place due to filling yarn size variability, twist liveliness resulting in yarn snarling or presence of large yarn knots. The presence of these yarn defects results in a sharp rise in load required to pull filling yarn under the carrier gripper thus causing carrier to drop filling. On the other hand, when such filling yarn irregularities or snarls caused by twist liveliness are located on side A of carrier—(see Figure (II.47))—the reliability of the filling yarn end transfer process may be adversely affected by the sharp rise in tensile load required for slippage, as shown in Figure (II.51).

With regard to yarn twist liveliness that may—as discussed above—result into snarl formation and such stops as R.H. carrier dropping filling or transfer failure, observations have been made on single feed jersey knitted tubes made of the 65P/35C, 80P/20C and 100% cotton yarns. The angle of wale spirality which is a measure of yarn residual torque has been measured for the knitted tubes. The results, shown in Table (II.9), indicate that the torque liveliness of the 65P/35C blend yarn is highest, signifying a high snarling(*) tendency, and suggest that an effective yarn torque relaxation (yarn conditioning) treatment for cotton/polyester blend yarns would only be effective if steam is used since the polyester fiber is hydrophobic and its residual stresses would be relaxed only by a heat treatment.

(*) Such yarn snarling and kinking tendency can best be observed during loom operation behind the first pair of friction plates at the instant the filling yarn is decelerated sharply, e.g. at transfer moment.
CHAPTER III
RECOMMENDATIONS

(1) Reduce overall height of right hand carrier to a minimum and coat its upper surface with a smooth low coefficient of friction hard material, (such as porcelain enamel).

(2) Use conical base quills.

(3) Assess cotton fiber damage in steps preceding the drawing process. If fiber damage is found to take place in the carding process, a reduction of feed roller and doffer speeds or an increase in licker-in and cylinder speeds may be essential to minimize the fiber damage.

(4) For high polyester/cotton ratio blends use high modulus polyester fibers.

(5) Blend cotton and polyester fibers in the drawing process in order to obtain a uniform ratio of cotton to polyester fibers along yarn length.

(6) Modify the filling yarn line on DLG loom to make it more tolerant to yarn hairiness and loosely held short fibers and to minimize lint accumulation. A conceptual outline of such modification is present in section (II.3.2).

(7) Raise the filling yarn tension level on DLG looms by a factor of at least 20% (but less than 50%) and reinstall carrier finger stops onto R.H. carriers.

(8) Improve warp yarn and sheet qualities, especially with regard to frequency of knots, gouts, and crossed ends.
(9) Modify right hand carrier as discussed in Part (B) of Section (II.3.3) of this report.

(10) Modify sizing formula to provide effective bonding of polyester fibers in the 65P/35C blend warp yarns.

(11) Filling yarn conditioning - in ring spinning bobbins form - is recommended to reduce yarn torque liveliness. For high polyester/cotton blend ratio yarns, low pressure steam yarn conditioning treatment for a period of 20 to 25 minutes is recommended since polyester fibers are of a hydrophobic nature.

(12) To minimize error in setting of gripper pressure on yarn in the holding zone, it is recommended that a simple mill-oriented procedure be developed for loom fixers to follow in setting appropriate gripper pressure levels for various fiber types, yarn counts and blend ratios.