Colored Candies and Base SAS®: A Sweet Way to Produce Chi-Square Control Charts
Part 1: Tutorial
Sherri Joyce King, King Information Company, Rockville, MD
Melvin T. Alexander, Westinghouse, Baltimore, MD

ABSTRACT
Colored candies are easy-to-understand tools that can illustrate Statistical Quality Control principles. Candy companies want each bag to have about the same piece counts of each color as the other bags. The objective of this tutorial is to show how Base SAS® software can help to improve understanding of a manufacturing process where homogeneity of proportions is important, using candy color piece counts as input to SAS programs. Base SAS software will be used to produce a chi-square ($\chi^2$) control chart that checks the stability of piece counts for candy colors during the bag-filling operation.

$\chi^2$ is a statistical measure that compares actual values to specified values. $\chi^2$ has three principal uses; we concentrate here on its ability to measure homogeneity of proportions. This tutorial (Part 1 of the topic) teaches the use of the SAS DATA step and the PLOT procedure (among others) for this purpose. Part 2, in the Statistics section, explores more statistical aspects of the topic. A simulation is included in each Part, where attendees count (and subsequently consume) candies to collect data on color proportions in bags they are given.

AUDIENCE
The tutorial assumes some knowledge of process control and a basic knowledge of SAS software. Concepts on which the tutorial depends will be reviewed.

OVERVIEW
The first section of the tutorial introduces basic concepts that the attendees need in order to follow the session:

- Stability of the bag-filling process; color piece counts as the indicator of process control.
- Control charts and control chart anatomy.
- $\chi^2$.
- Analysis method.
- The data and what we need to do to prepare it and produce the $\chi^2$ control chart.

The second section of the tutorial is a step-by-step presentation of the program used to prepare the data and generate the $\chi^2$ control chart. The DATA step and the various procedures used (SORT, SUMMARY, TRANSPOSE, FREQ, PLOT) are explained. In overview, the program:

- Calculates $\chi^2$ for each bag of candies.
- Generates the $\chi^2$ control chart.

At the end of the tutorial, attendees are active participants in a simulation of the sampling inspection portion of the bag-filling operation. The simulation has these steps:

- Data is collected and entered on the counts of colors in candy bags the attendees are given.
- The program is then run on the data collected.
- The output is reviewed, interpreted, and explained, showing how it can be used to adjust variations in color proportion.
- Finally, the data is consumed.

Only Base SAS is required for Part 1 of this presentation. For additional information on more advanced statistical techniques (SAS/QC) applicable to homogeneity of proportion, the attendees are invited to attend Part 2.

THE BASICS
Stability of the bag-filling process; color piece counts as the indicator of process control

The bag-filling process must be stable and the resulting proportions consistent. Candy companies go to a great deal of trouble to find out which proportions would be pleasing to the consumer. It doesn't make sense to be sloppy about the bag-filling process.
When we talk about process control, we usually talk about stabilizing a process so that the number and causes of defects (variations) are minimized. Color is analogous to a defect, in that it is an observable attribute or characteristic of the product and can easily be measured.

Control charts and control chart anatomy

A control chart is a device that shows how stable, uniform, or consistent a specific aspect of a process is. A process is defined as a series of actions or operations performed for an identified purpose.

In 1924, Walter Shewhart introduced the first formal use of statistical control charts for process control. Part 2 of this paper includes a control chart diagram.

Figure 1-2 is a control chart:

```
\textbf{Figure 1-2}

\begin{center}
\begin{tikzpicture}
\node (n1) [draw,rectangle] {Value of Statistic};
\node (n2) [draw,rectangle,below=1cm of n1] {Upper Control Limit};
\node (n3) [draw,rectangle,below=1cm of n2] {Center Line};
\node (n4) [draw,rectangle,below=1cm of n3] {Lower Control Limit};
\node (n5) [draw,rectangle,below=1cm of n4] {Bag};
\node (n6) [draw,rectangle,below=1cm of n5] {Overfilled with one or more colors};
\node (n7) [draw,rectangle,below=1cm of n6] {Underfilled with one or more colors};
\end{tikzpicture}
\end{center}
```

The Center Line (CL) is a specified average, the expected value of the statistic under study.

The Upper Control Limit (UCL) is a line drawn at a specified distance above the Center Line, representing the largest acceptable average measurement (based on sample size) that the process should produce when it is operating in a stable manner.

The Lower Control Limit (LCL) is a line drawn at a specified distance below the Center Line, representing the smallest acceptable average measurement (based on sample size) that the process should produce when it is operating in a stable manner.

The larger the sample size, the narrower the control limits can be, providing for a greater amount of precision.

By convention, the horizontal axis shows the temporal order of production (date, shift, or time). The vertical axis shows the values being measured or counted.

Interpreting the process control chart involves examining it for points outside the control limits. When the measurement goes outside control limits, it is probable that something unexpected is happening in production.

Analysis will show whether the process is stable, whether it is operating within specification.

Chi-square ($\chi^2$)

$\chi^2$ is a test statistic or decision indicator serving three basic functions: goodness of fit; independence of two or more (crosstabulated) variables; homogeneity of proportions of counts to the whole. The last aspect is our focus.

$\chi^2$ gives you a single measure to help you decide whether the difference between specified and observed is statistically larger or smaller than expected. More specifically, it indicates the degree to which the difference between expected (specified) and observed counts is larger than can be explained by sampling variation alone.

$\chi^2$ is a discrepancy statistic. The calculation is based on the discrepancy between expected and observed; the larger the discrepancy, the larger the $\chi^2$. Its size depends on the size of the difference between expected and actual and on the number of differences involved.

An important piece of information you need to use $\chi^2$ is degrees of freedom (called df). This is the amount of essential information you need without redundancy.

Degrees of freedom is the number of categories under analysis minus one.

Analysis Method

Pearson is the classical analysis method. It suffers in validity when it is applied to data with small or zero call counts. It tends to produce inconsistent measures because it depends on bin sizes. To use Pearson's, all expected call frequencies should be more than 0 and fewer than 20% of them should be less than 5. Part 2 of this paper covers the more statistical aspects of this issue. There will be more about Pearson analysis in Part 2 of this paper. Also, Part 2 will discuss likelihood ratio and Neyman's statistics as ways to calculate $\chi^2$.

The data and what we need to do to prepare it and produce the $\chi^2$ control chart

Table 1-1 shows the data as it appears when we receive it. This is the kind of data collected during the bag-filling operation. Each observation represents one bag and contains a variable for each color. The value for each of those color variables is the piece count for that color for that bag.

```
\textbf{Table 1-1}

\begin{center}
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|}
\hline
\textbf{COLOR} & \textbf{BAGG.} & \textbf{RED} & \textbf{YELLOW} & \textbf{GREEN} & \textbf{ORANGE} & \textbf{PINK} & \textbf{BROWN} & \textbf{RANDOM} \\
\hline
1 & 1 & 6 & 12 & 1 & 1 & 6 & 0 & 26 \\
2 & 2 & 5 & 13 & 4 & 2 & 1 & 3 & 27 \\
3 & 3 & 2 & 6 & 8 & 5 & 1 & 2 & 24 \\
4 & 4 & 4 & 8 & 10 & 3 & 4 & 2 & 26 \\
5 & 5 & 5 & 10 & 7 & 1 & 3 & 2 & 28 \\
6 & 6 & 7 & 6 & 6 & 3 & 2 & 1 & 25 \\
7 & 7 & 7 & 9 & 8 & 4 & 1 & 1 & 27 \\
8 & 8 & 3 & 8 & 6 & 3 & 0 & 5 & 25 \\
9 & 9 & 8 & 8 & 5 & 1 & 3 & 1 & 26 \\
10 & 10 & 9 & 9 & 3 & 3 & 3 & 0 & 27 \\
11 & 11 & 4 & 8 & 7 & 3 & 4 & 1 & 27 \\
12 & 12 & 5 & 9 & 4 & 3 & 2 & 3 & 26 \\
13 & 13 & 6 & 5 & 12 & 2 & 1 & 2 & 27 \\
14 & 14 & 6 & 7 & 7 & 3 & 2 & 2 & 27 \\
15 & 15 & 5 & 6 & 8 & 3 & 1 & 3 & 26 \\
16 & 16 & 7 & 7 & 6 & 2 & 2 & 3 & 27 \\
17 & 17 & 8 & 3 & 4 & 3 & 4 & 4 & 26 \\
18 & 18 & 3 & 15 & 3 & 2 & 2 & 1 & 26 \\
19 & 19 & 5 & 12 & 5 & 1 & 2 & 2 & 27 \\
20 & 20 & 11 & 6 & 2 & 2 & 2 & 4 & 27 \\
\hline
\end{tabular}
\end{center}
```

1471
The program in this tutorial needs to do three things:

- Manipulate the data so that it is prepared to produce the control chart. When we collect the data, it comes to us one observation per bag, one variable per color, showing the piece count for that color. In order for us to calculate the bag $\chi^2$, the data needs to be organized differently.

- Calculate the $\chi^2$ for each bag. The $\chi^2$ calculation requires the number of pieces for each color by bag (we are calling the intersection of a color and a bag a cell), the total pieces per bag, and the ratio each color represents of the total number of pieces for all bags. The calculation for cell $\chi^2$ looks like this:

  \[
  \text{cell } \chi^2 = \frac{(\text{cell piece count} - (\text{bag total} \times \text{ratio}))^2}{(\text{bag total} \times \text{ratio})}
  \]

  The bag $\chi^2$ is simply the sum of the cell $\chi^2$s for the bag.

- Produce the control chart. The control chart requires a specification for the Center Line (CL), the Upper Control Limit (UCL) and the Lower Control Limit (LCL).

THE PROGRAM

The first DATA step in the program prefixes the bag number with the string "BAG" so that it will merge properly later on. It also separates the BAGTOTAL variable into a different data set called BAGTOTAL:

```sql
data eachbag(drop=bagtotal);
  bagtotal(keep=bagid bagtotal);
set original;
length bagid $5;
drop bagnum;
if bagnum<10 then
  bagid="BAGO"||put(bagnum,$1.);
else
  bagid="BAG"||put(bagnum,$2.);
run;
```

This next PROC TRANSPOSE reverses the variables and the observations in the data set. The result is the COLORS data set, where each observation represents a color and there are 20 variables in each observation showing how many pieces for that color in each bag:

```sql
proc transpose data=eachbag out=colors name=bagid prefix=pieces;
  var bag1-bag20;
  by color;
run;
```

This DATA step renames the bag indicators:

```sql
data colors;
set colors;
if length(trim{bagid)}=4 then
  bagid=substr{bagid,1,3}||"0"||substr(bagid,4,1);
run;
```

Partial results are shown in Table 1-3.
This PROC SUMMARY calculates the color totals. These will be used in the divisor in the ratio needed for the \( x^2 \) formula.

```sas
proc summary data=cells;
  class color;
  var pieces;
  output out=cellsum sum=;
run;
```

This DATA step calculates the ratio each color represents of the total number of pieces.

```sas
data ratio (drop=_freq_ _type_);
  set cellsum;
  (rename=pieces=cellpieces);
  retain bigtotal;
  if _type_ = 0 then do;
    bigtotal=cellpieces;
    delete;
  end;
  else ratio=cellpieces/bigtotals;
run;
```

This PROC SUMMARY calculates the color totals. These will be used in the divisor in the ratio needed for the \( x^2 \) formula.

```sas
proc summary data=cells;
  class color;
  var pieces;
  output out=cellsum sum=;
run;
```

This DATA step calculates the ratio each color represents of the total number of pieces.

```sas
data ratio (drop=_freq_ _type_);
  set cellsum;
  (rename=pieces=cellpieces);
  retain bigtotal;
  if _type_ = 0 then do;
    bigtotal=cellpieces;
    delete;
  end;
  else ratio=cellpieces/bigtotals;
run;
```
Table 1-7

<table>
<thead>
<tr>
<th>C1</th>
<th>INCLTOTL</th>
<th>BAGID</th>
<th>COLOR</th>
<th>CELLPIE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BPO01</td>
<td>BROWN</td>
<td>0</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>BPO02</td>
<td>BROWN</td>
<td>1</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>BPO03</td>
<td>BROWN</td>
<td>2</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>BPO04</td>
<td>BROWN</td>
<td>3</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>BPO05</td>
<td>BROWN</td>
<td>4</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>BPO06</td>
<td>BROWN</td>
<td>5</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>BPO07</td>
<td>BROWN</td>
<td>6</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>BPO08</td>
<td>BROWN</td>
<td>7</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>BPO09</td>
<td>BROWN</td>
<td>8</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>BPO10</td>
<td>BROWN</td>
<td>9</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>BPO11</td>
<td>BROWN</td>
<td>10</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>BPO12</td>
<td>BROWN</td>
<td>11</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>BPO13</td>
<td>BROWN</td>
<td>12</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>BPO14</td>
<td>BROWN</td>
<td>13</td>
<td>0.07211</td>
<td>1.61746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This next DATA step performs the calculation of the cell 
\( \chi^2 \) after merging the INCLTOTL and RATIO data sets. 
The two data sets must both be sorted by COLOR 
for the MERGE to be successful.

```plaintext
proc sort data=ratio;by color;run;
proc sort data=incltotl;by color;run;
data cellchi2;
merge incltotl ratio;
by color;
cellchi2 = (cellpiec - (bagtotal*ratio))**2 / (bagtotal*ratio);
run;
```

Table 1-8

<table>
<thead>
<tr>
<th>C1</th>
<th>BPO01</th>
<th>BPO02</th>
<th>BPO03</th>
<th>BPO04</th>
<th>BPO05</th>
<th>BPO06</th>
<th>BPO07</th>
<th>BPO08</th>
<th>BPO09</th>
<th>BPO10</th>
<th>BPO11</th>
<th>BPO12</th>
<th>BPO13</th>
<th>BPO14</th>
<th>BPO15</th>
<th>BPO16</th>
<th>BPO17</th>
<th>BPO18</th>
<th>BPO19</th>
<th>BPO20</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>BPO01</td>
<td>BPO02</td>
<td>BPO03</td>
<td>BPO04</td>
<td>BPO05</td>
<td>BPO06</td>
<td>BPO07</td>
<td>BPO08</td>
<td>BPO09</td>
<td>BPO10</td>
<td>BPO11</td>
<td>BPO12</td>
<td>BPO13</td>
<td>BPO14</td>
<td>BPO15</td>
<td>BPO16</td>
<td>BPO17</td>
<td>BPO18</td>
<td>BPO19</td>
<td>BPO20</td>
</tr>
<tr>
<td>3</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
<td>0.07211</td>
</tr>
</tbody>
</table>

To get the bag \( \chi^2 \), we need to add up the cell \( \chi^2 \) for all 
colors within each bag. We do this easily with the 
SUMMARY procedure.

```plaintext
proc summary data=cellchi2 nway;
output out=bagchi2 sum=bagchi2;
var cellchi2;
class bagid;
run;
```

Table 1-9

<table>
<thead>
<tr>
<th>C1</th>
<th>BAGID</th>
<th>TYPE</th>
<th><em>FREQ</em></th>
<th>BAGID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BAG1</td>
<td>1</td>
<td>6</td>
<td>BAG1</td>
</tr>
<tr>
<td>2</td>
<td>BAG2</td>
<td>1</td>
<td>6</td>
<td>BAG2</td>
</tr>
<tr>
<td>3</td>
<td>BAG3</td>
<td>1</td>
<td>6</td>
<td>BAG3</td>
</tr>
<tr>
<td>4</td>
<td>BAG4</td>
<td>1</td>
<td>6</td>
<td>BAG4</td>
</tr>
<tr>
<td>5</td>
<td>BAG5</td>
<td>1</td>
<td>6</td>
<td>BAG5</td>
</tr>
<tr>
<td>6</td>
<td>BAG6</td>
<td>1</td>
<td>6</td>
<td>BAG6</td>
</tr>
<tr>
<td>7</td>
<td>BAG7</td>
<td>1</td>
<td>6</td>
<td>BAG7</td>
</tr>
<tr>
<td>8</td>
<td>BAG8</td>
<td>1</td>
<td>6</td>
<td>BAG8</td>
</tr>
<tr>
<td>9</td>
<td>BAG9</td>
<td>1</td>
<td>6</td>
<td>BAG9</td>
</tr>
<tr>
<td>10</td>
<td>BAG10</td>
<td>1</td>
<td>6</td>
<td>BAG10</td>
</tr>
<tr>
<td>11</td>
<td>BAG11</td>
<td>1</td>
<td>6</td>
<td>BAG11</td>
</tr>
<tr>
<td>12</td>
<td>BAG12</td>
<td>1</td>
<td>6</td>
<td>BAG12</td>
</tr>
<tr>
<td>13</td>
<td>BAG13</td>
<td>1</td>
<td>6</td>
<td>BAG13</td>
</tr>
<tr>
<td>14</td>
<td>BAG14</td>
<td>1</td>
<td>6</td>
<td>BAG14</td>
</tr>
</tbody>
</table>

The next DATA step calculates the upper and lower 
control limits and the center line using the CINV 
(chi-square inverse) function. This will prepare 
the control limits for the control chart.
- The upper control limit (UCL) is set to 97.5% 
  (+2 sigma).
- The lower control limit (LCL) is set to 2.5% 
  (-2 sigma).
- The center line (CL) is set to 50%.

UCL, LCL, and CL are all calculated with 5 degrees of 
freedom for the six colors (6 - 1 = 5).

(These variables have special names because of the way 
we use them in Part 2.)

```plaintext
data ctrllims;
set bagchi2;
  drop _type_ _freq_; 
  %ucl = cinv(.975,5); 
  %lcl = cinv(.025,5); 
  %mean = cinv(5,5); 
run;
```
Table 1-10

<table>
<thead>
<tr>
<th>CBS</th>
<th>BAGID</th>
<th>BAGCODE</th>
<th>UCL</th>
<th>CLP</th>
<th>LCL</th>
<th>MEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NC01</td>
<td>13.6164</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>NC02</td>
<td>3.7811</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>NC03</td>
<td>6.3053</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>NC04</td>
<td>1.6515</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>NC05</td>
<td>1.6331</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>NC06</td>
<td>1.6539</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>NC07</td>
<td>7.7449</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>NC08</td>
<td>9.3192</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>NC09</td>
<td>2.5161</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>NC10</td>
<td>1.6451</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>NC11</td>
<td>1.3563</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>NC12</td>
<td>1.3563</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>NC13</td>
<td>7.6250</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>NC14</td>
<td>8.3912</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>NC15</td>
<td>5.1536</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>NC16</td>
<td>8.3912</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>NC17</td>
<td>2.3388</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>NC18</td>
<td>1.3675</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>NC19</td>
<td>7.6250</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>NC20</td>
<td>0.8012</td>
<td>12.8325</td>
<td>0.83121</td>
<td>4.35146</td>
<td></td>
</tr>
</tbody>
</table>

Now we plot the control chart. In Base SAS, this is done with the PLOT procedure. In the PLOT statement of that procedure, we request four plots, one for each control limit, one for the center line, and one for the bag chi square; then we present them all in one plot using the OVERLAY option of the PLOT statement. In Base SAS, we are operating without graphic capability, so we need to assign a meaningful text character to each plot so that we can tell them apart when they are overlaid.

```
proc plot data=ctrllims;
plot ucle_bagid=U / overlay;
title 'Chi Square Control Chart';
gtitle 'U';
quit;
run;
```

Table 1-11

<table>
<thead>
<tr>
<th>CBS</th>
<th>BAGID</th>
<th>BAGCODE</th>
<th>UCL</th>
<th>CLP</th>
<th>LCL</th>
<th>MEM</th>
</tr>
</thead>
</table>

Now we plot the control chart. In Base SAS, this is done with the PLOT procedure. In the PLOT statement of that procedure, we request four plots, one for each control limit, one for the center line, and one for the bag chi square; then we present them all in one plot using the OVERLAY option of the PLOT statement. In Base SAS, we are operating without graphic capability, so we need to assign a meaningful text character to each plot so that we can tell them apart when they are overlaid.

```
proc plot data=ctrllims;
plot ucle_bagid=U / overlay;
title 'Chi Square Control Chart';
gtitle 'U';
quit;
run;
```

AUTHOR CONTACT

Sherri Joyce King
King Information Company
16 Scotch Mist Court
Rockville, MD 20854-2929
Voice: (301) 251-7777
Fax: (301) 738-6873
Internet: 72764.164@compuserve.com

Mel Alexander
Integrated Product Development
Westinghouse Electronic Systems Group
7323 Aviation Boulevard
PO Box 746, MS G16
Baltimore, MD 21203-0746
Voice: (410) 993-1478
Fax: (410) 765-1485
Internet: 71006.1534@compuserve.com

REFERENCES


Base SAS is a registered trademark of SAS Institute, Inc. in the USA and other countries. ® indicates USA registration. Other brand and product names are registered trademarks or trademarks of their respective companies.