C h a p t e r 1

Using This Book

1.1 Origins of This Book

In 1963 the National Bureau of Standards published the NBS Handbook 91 *Experimental Statistics*, which was "intended for the user with an engineering background who, although he has an occasional need for statistical techniques, does not have the time or inclination to become an expert on statistical theory and methodology" (Natrella 1963). Our years of experience teaching and working closely with engineers and scientists suggest that more than 45 years since these words were published they still ring true. So when the opportunity came to write a JMP book for engineers and scientists, the NBS Handbook 91 became our inspiration.

The NBS Handbook 91 *Experimental Statistics* brought together a series of five pamphlets that were commissioned by the Army Research Office. The handbook was prepared in the Statistical Engineering Laboratory (SEL) under the leadership of Mary Gibbons Natrella, and was written "as an aid to scientists and engineers in the Army Ordnance research and development programs and as a guide for military and civilian personnel who had responsibility for experimentation and tests for Army Ordnance equipment in the design and development stages of production" (Natrella 1963). Although intended for the army personnel, the NBS Handbook 91 became the National Bureau of Standards second best-selling publication because of its emphasis on solving practical problems using statistical techniques. The chapter headings are written in a language that points to a particular application or problem, rather than to a statistical technique. Within each chapter the user can find step-by-step instructions for how to carry out the analysis, including examples that have been worked out and discussions of the results.

Out of print for many years, the NBS Handbook 91 is still relevant and a highly regarded reference for many who work in industry. So much so that in the late 90s, SEMATECH (a consortium of major U.S. semiconductor manufacturers) approached the Statistical Engineering Division (SED) at the National Bureau of Standards and Technology (NIST, formerly known as the National Institute of Standards) with a "proposal for updating and recreating the book with examples directed towards the semiconductor industry" (Croarkin 2001). The result became a Web-based engineering statistics handbook (http://www.itl.nist.gov/div898/handbook/).

In writing this book we wanted to bring the spirit and usefulness of the NBS Handbook 91 to the countless engineers, scientists, and data analysts whose work requires them to transform data into useful and actionable information. In this book you will also discover how the ease and power of JMP make your statistical endeavors a lot easier than the hand calculations required when the NBS Handbook 91 was first published.

1.2 Purpose

In the spirit of NBS Handbook 91, our book is designed to serve as a ready-for-use reference for solving common problems in science and engineering using statistical techniques and JMP. Some examples of these types of problems include evaluating the performance of a new raw material supplier for an existing component, establishing a calibration curve for instrumentation, comparing the performance of several materials using a quality characteristic of interest, or troubleshooting a yield fall-out. These problems are not unique to a particular industry and can be found across industries as diverse as the semiconductor, automotive, chemical, aerospace, food, biological, or pharmaceutical industries. In addition, these problems might present themselves throughout the life cycle of a product or process, and therefore engineers and scientists focused on manufacturing, new product development, metrology, or quality assurance will benefit from using the statistical techniques described in this book.

1.3 Audience

As with the NBS Handbook 91, our main audience is *you* the engineer or scientist who needs to use or would like to use statistical techniques to help solve a particular problem. Each chapter is application driven, and is written with different objectives depending on your needs:

- For those of you who want a quick reference for how to solve common problems in engineering and science using statistical methods and JMP, each chapter includes step-by-step instructions for how to carry out the statistical techniques, interpret the results in the context of the problem statement, and draw the appropriate conclusions.

- For those of you who want a better understanding of the statistical underpinnings behind the techniques, each chapter provides a practical overview of the statistical concepts and appropriate references for further study.

- For those who want to learn how to benefit from the power of JMP in the context described previously, each chapter is loaded with general discussions, specific JMP step-by-step instructions, and tips and tricks.

1.4 Prerequisites

Although this book covers introductory topics in statistics, some familiarity with basic statistical concepts, such as average, standard deviation, and a random sample, is helpful. You should also have a basic working knowledge of JMP, including how to read and manipulate data in JMP, maneuver around the various menus and windows, and use the online help resources.

1.5 What's Unique About This Book?

We have spent many years as industrial statisticians working closely with, and developing and teaching courses for, engineers and scientists in the semiconductor, chemical, and manufacturing industries, and have focused on making statistics both accessible and effective in helping to solve common problems found in an industrial setting. Statistical techniques are introduced not as a collection of formulas to be followed, but as a catalyst to enhance and speed up the engineering and scientific problem-solving process. Each chapter uses a 7-step problem-solving framework to make sure that the right problem is being solved with an appropriate selection of tools.

In order to facilitate the learning process, numerous examples are used throughout the book that are relevant, realistic, and thoroughly explained. The step-by-step instructions show how to use JMP and the appropriate statistical techniques to solve a particular problem, putting emphasis on how to interpret and translate the output in the context of the problem being solved. You will find this book to be a useful reference when faced with similar situations in your day-to-day work.

Throughout the book we try to demystify concepts like *p*-values, confidence level, the difference between the null (H_0) and alternative hypothesis (H_1), and tests of significance. In addition, emphasis is placed on analyzing not only the average measured performance of a characteristic of interest, which is normally the case, but also the standard deviation of the characteristic of interest. This is crucial because most practitioners in an industrial setting quickly realize that the variation in a measured performance characteristic is as important, and sometimes more important, than focusing solely on the average performance characteristic in order to meet performance goals.

As in the NBS Handbook 91, each chapter heading reflects a practical situation rather than a statistical technique. This makes it easier for you, the user, to focus on the situation at hand rather than trying to figure out if a particular statistical technique is applicable to your situation. Section 1.6 describes the chapters in more detail.

1.6 Chapter Contents

The statistical concepts and techniques are divided into six chapters in this book, although some are repeated in all chapters. The chapter headings provide insight into what is being compared or studied, as opposed to using the name of the statistical technique used in the chapter. What follows is a brief description of each chapter.

Chapter 2
Overview of Statistical Concepts and Ideas

This chapter serves as the foundation of the many topics presented in Chapters 3 through 7, including the 7-step problem-solving framework. In this chapter you will learn the language of statistics, and how statistics and statistical thinking can help you solve engineering and scientific problems.

Descriptive statistics, such as the mean and standard deviation, and visualization tools, such as a histogram and box plots, are described, along with instructions on how to access them using the different platforms in JMP. Tests of significance as a signal-to-noise ratio, statistical intervals, the different measurement scales (nominal, ordinal, interval, and ratio), and how to set these appropriately in JMP are also discussed.

Chapter 3
Characterizing the Measured Performance of a Material, Process, or Product

Many situations call for the characterization of the measured performance of a material, process, or product. For example, if we have collected data on the performance of a particular product you may want to know, what is the average performance of the product, and what level of performance variation should we expect? It is important then to be able to use summary measures that efficiently represent the overall performance of the sampled population, and graphics that highlight key information, such as trends or different sources of variation. Once the data is summarized, statistical intervals, such as a confidence interval for the mean, or a tolerance interval to contain a proportion of the individual values in a population, are used to make performance claims about our data.

The industrial example presented in this chapter involves the qualification and characterization of a second source raw material that is used to make sockets in an injection molding operation. A four-cavity injection molder is used in the qualification, and the effective thickness of the sockets is the key quality characteristic. This data includes different sources of variation often found in manufacturing, and lends itself well to slicing and dicing the data in a variety of ways using different statistical techniques

and graphs. Three JMP platforms are used to explore the industrial example: the **Analyze > Distribution**, **Graph > Control Chart**, and **Graph > Variability / Gage Chart** platforms.

Chapter 4
Comparing the Measured Performance of a Material, Process, or Product to a Standard

This chapter shows how one-sample tests of significance for the mean and standard deviation can be used to address the common engineering problem of comparing a quality characteristic to a standard. We show you how to use the Student's *t*-test to compare the average performance to a standard, and how to use the Chi-square test to compare the average variation to a standard. We also discuss how to set up the null and alternative hypothesis to answer the question of interest, and highlight the difference between a one- and two-sided alternative hypothesis.

We use a semiconductor industry example involving the qualification of a new three-zone, temperature-controlled vertical furnace used for thin film deposition on wafers. The goal of the qualification is to show that the thickness of the silicon dioxide layer, a key fitness-for-use parameter, meets the target value of 90 Angstrom, and to predict how much product will be made below the lower specification limit of 87 Angstrom. The 7-step problem-solving framework is applied to this situation using several JMP platforms. The **Analyze > Distribution** platform provides the required Student's *t*-test and Chi-Square test for the comparisons.

We also show how to use a test of equivalence for those situations where we want to show that the average performance is equivalent to a standard, within given performance parameters. Equivalence tests combine practical significance with statistical significance in order to produce a more targeted result. A JMP script is provided for this test.

Chapter 5
Comparing the Measured Performance of Two Materials, Processes, or Products

Many simple experiments are carried out in industry to compare the performance of two different things such as two suppliers, two temperature settings on a piece of equipment, or two gauges. We show how the two-sample Student's *t*-test and the *F*-test can be used for comparing the average performance and the performance variation of two groups of samples coming from normally distributed populations, as well as how to interpret them and make sense of the JMP output.

Guidance is also provided on how to set up a two-sample study, including how to determine how many samples to include, as well as how to sample them from the population. As was the case in Chapter 4, equivalence tests are introduced as an

alternative way to show that two populations are equivalent within some pre specified performance window.

The comparison of a newly purchased mass spectrometer to an existing mass spectrometer in an analytical laboratory serves as the case study for this chapter. These instruments are used to determine the isotopic ratio composition of a variety of elements with high precision. Since a key customer in the chemical industry is using silver as a catalyst in an oxidation reaction, the atomic weight of silver is used to compare the performance of the two instruments using the 7-step problem-solving framework and JMP.

Chapter 6
Comparing the Measured Performance of Several Materials, Processes, or Products

In this chapter, the simple experiments discussed in Chapter 5 that involve the comparison of two means or standard deviations are extended to include the comparison of the measured performance of three or more materials, processes, or products. Analysis of variance (ANOVA), the statistical technique at the heart of the analysis of experimental studies, is introduced, as well as the assumptions required for its use. Using the 7-step problem-solving framework, we walk through the JMP ANOVA output and review its key components, including the variation and degrees of freedom contributed by the factor (the signal), and by the experimental error (the noise).

We use an example from the home building industry in connection with a housing development of 100 semi-custom homes built in four phases. Shortly after the fourth and last phase of the development was completed, the residential developer responsible for its construction started to receive a number of complaints about premature cracking in the cement sidewalks leading from the driveways to the front doors. The compressive strength for the cement used in the different phases of construction, which is a key performance characteristic related to cement cracking, is used to compare the cements used in the four phases of construction.

Chapter 7
Characterizing Linear Relationships between Two Variables

When both the performance characteristic and the explanatory variable are measured on a continuous scale, we can fit a simple linear regression model, of the form $Y = \beta_0 + \beta_1 x + \varepsilon$, to examine the relationship between them. This simple model forms the basis of linear models, and can be easily expanded to include higher order terms, such as a quadratic term; that is, models of the form $Y = \beta_0 + \beta_1 x + \beta_2 x^2 + \varepsilon$.

Simple linear regression methods are used in the generation of calibration curves in engineering and science. We focus on an example for the development of a calibration curve for a canister-style load cell design that is used in cargo truck weighing systems. We walk through all of the necessary steps needed to produce the calibration curve, including collecting the measurements and specifying the model, with emphasis placed on checking the adequacy of the model using diagnostic statistics and plots. In addition, inverse prediction is used to demonstrate how the calibration curves are used in practice.

In addition, to show the power of regression techniques we look at the analysis presented in 1901 by a young Albert Einstein in his first published paper "Conclusions Drawn from the Phenomena of Capillarity," in which he investigated the nature of intermolecular forces.

1.7 Chapter Layout

The layout of Chapters 3 through 7 contains the same basic elements, as described in Table 1.1, to make it easier for you to find the information you need when solving a specific problem. Each chapter starts with the chapter goals followed by a description of the problem, or practical situation, that the chapter focuses on. A table with key questions, concepts, and tools is provided for easy reference.

The descriptions, examples, and discussion of the statistical underpinnings provide a "behind the scenes" look at tools for those of you who want to deepen your understanding of statistics. Note that the chapter sections that address the statistical underpinnings of a technique might have slightly different headings to reflect the particular technique. For example, in Chapter 5 the statistical underpinnings are presented in sections titled "5.3.2 Comparing Average Performance of Two Materials, Processes, or Products," "5.3.3 What to Do When We Have Matched Pairs," "5.3.4 Comparing the Performance Variation of Two Materials, Processes, or Products," and "5.3.5 Sample Size Calculations."

Each chapter also includes a 7-step problem-solving framework to guide you through the different stages of problem solving in the context of engineering and science.

Table 1.1 Chapter Sections and Descriptions

Section	Description
Chapter Goals	These goals reflect what we hope you will be able to accomplish when you complete the chapter. In essence, you will become familiar with the technique, and will be able to follow along using JMP to solve the practical problem presented.
Problem Description	A real problem from engineering, science, or both is used in each chapter to illustrate how statistics and JMP can be used to solve the problem. The chapter starts with what we know about the problem, clarifies the main questions that need to be answered or the uncertainty that needs to be resolved, and reveals the statistical technique that will be used to solve the problem. This sets the stage for what comes next.
Key Questions, Concepts, and Tools	A table outlines the key statistical questions, concepts, and tools that are highlighted in each chapter and how they relate to the practical problem outlined in the Problem Description section. This provides you with a quick preview of the concepts that will be discussed throughout the chapter.
Description and Some Applications	An introduction to the statistical techniques used in the chapter is provided in this section, including why we would want to use it, and some of the common statistical nomenclature and terminology surrounding it. We also provide you with several examples of common questions from engineering and science that could be answered using the technique described in each chapter.
Statistical Underpinnings of Technique	These sections provide a more in-depth review of the statistical techniques and concepts that are featured in the chapter. Examples include: specifying the null and alternative hypothesis, calculating and interpreting the test statistic, obtaining and interpreting the p-value, checking model assumptions, and determining sample sizes. In addition, relevant JMP output is included in discussions of key concepts.
Step-by-Step Analysis Instructions	A 7-step problem-solving approach is used to solve the practical problem described at the beginning of the chapter using both the statistical techniques presented in the chapter, and the appropriate JMP platforms, functions, and, in some cases, scripts. The steps begin with a clear statement of the question and end with practical recommendations for next steps. These steps are shown in Section 1.10.
Summary	The techniques and concepts discussed in the chapter are summarized and key practical points are outlined.
References	A list of books and technical papers that support or further develop the ideas presented in the chapter.

Because Chapter 2 is a foundation chapter, it does not follow the layout in Table 1.1. However, it provides an overview of many statistical concepts used throughout the book, and introduces the 7-step problem-solving framework.

1.8 Step-by-Step Analysis Instructions

We realize that some of you might have no experience or limited experience with applying statistical methods, and that even those of you who use statistical methods on a more regular basis might not be fluent in all situations. For this reason, we have included a 7-step problem-solving framework to facilitate the application of statistical methods and JMP, and for solving the practical engineering and scientific problems that are presented in Chapters 3 through 7.

Table 1.2 gives an example of how the 7-step problem-solving framework is used in the context of solving the practical problem in Chapter 3 "Characterizing the Measured Performance of a Material, Process, or Product." This framework helps us to follow the scientific method in our investigations by clearly defining the questions, or uncertainties, of interest (Step 1), by making sure those questions are carefully translated into key hypotheses to be examined (Step 2), by conducting our studies using relevant data and adequate samples sizes (Steps 3 and 4), by using appropriate statistical techniques that help us answer our questions (Step 5), by not getting lost in the statistical output (Step 6), and by interpreting the results within the context of the problem and the original questions (Steps 7). In our investigations we want to prevent key ideas from being overlooked or omitted all together, and having a structured approach helps. A structured approach also gives us the ability to critically review our studies and those of others.

The third column in Table 1.2 shows the different JMP platforms that are needed to carry out the sample size calculations, the analysis, and the visualization of relevant relationships and information. As you will discover throughout the book, JMP is an integral part of the analysis, making it easy to generate the necessary output and graphs that help trigger insights, answer our questions, suggest future paths, and support our conclusions.

Table 1.2 Step-by-Step Analysis for Socket Qualification

Step	Objectives	JMP Platform
1. Clearly state the question or uncertainty.	Make sure that we are attempting to answer the right question with the right data.	Not applicable.
2. Specify the expected performance of a material, product, or process.	Cleary state the performance criteria for the socket qualification, using the existing raw material performance as a baseline.	Not applicable.
3. Determine the appropriate sampling plan and collect the data.	Identify how many sockets will be manufactured with the new raw material and what sources of variation should be included in the study. How well do we want to estimate μ and σ?	• **DOE > Sample Size and Power**
4. Prepare the data for analysis and conduct exploratory data analysis.	Make sure all stratification factors (sources of variation) are included in the JMP table, along with the measured response. Set column properties as needed. Check for any outliers or discrepancies with the data.	• **Cols > Column Info** • **Analyze > Distribution** • **Graph > Variability/Gage Chart**
5. Characterize your data and answer the questions of interest.	Calculate appropriate descriptive statistics and statistical intervals and understand sources of variation in the data. Check the analysis assumptions to make sure your results are valid.	• **Analyze > Distribution** • **Graph > Variability/Gage Chart** • **Graph > Control Chart**
6. Summarize the results with key graphs and summary statistics.	Find the best summary measures and graphical representations of the results that give us insight into our uncertainty. Select key output for reports and presentations.	• **Analyze > Distribution** • **Graph > Variability/Gage Chart**
7. Interpret the results and make recommendations.	Translate the statistical jargon into the problem context. Assess the practical significance of your findings.	Not applicable.

1.9 JMP Software

Several JMP platforms are used in the analyses presented in this book, and are highlighted in the corresponding chapters. Since we are primarily dealing with studies involving one response and up to one factor, the **Fit Y by X** platform will be our primary focus. However, we will also demonstrate other JMP platforms and functionality that are essential for studying the measured performance of a material, product, or process. The JMP platforms used in this book are shown in Table 1.3.

Table 1.3 JMP Platforms Used in This Book

JMP Platform	Purpose	Chapters
Analyze > Distribution	Study the distribution of data using a histogram, normal quantile plot, and descriptive statistics.	2 through 7
	Calculate process capability indices and percentage of samples outside of specification limits.	3
	Calculate confidence, prediction, and tolerance intervals.	2 and 3
	Conduct one-sample tests of significance for determining if the mean or standard deviation is equal to a standard value.	4
Analyze > Fit Y by X	Conduct two-sample tests of significance for comparing means and variances from two populations, including tests of equivalence.	5
	Carry out a one-way ANOVA for comparing three or more populations, conduct multiple comparison tests, and check for equal variances.	6
	Fit a simple linear regression model, or quadratic model, to study the linear correlation among two variables.	7
Analyze > Matched Pairs	Use to examine the difference between two populations when the observations are sampled in matched pairs.	4
Analyze > Fit Model	Fit a simple linear regression model or quadratic model to obtain additional row diagnostics to study residuals and influential observations, and conduct inverse prediction.	7

(*continued*)

Table 1.3 (*continued*)

JMP Platform	Purpose	Chapters
DOE > Sample Size and Power	Derive sample sizes for estimating the sample mean for one population.	3 and 4
	Derive sample sizes for estimating the sample variance for one population.	4
	Determine sample sizes for estimating the difference between two sample means.	5
	Determine sample sizes for estimating the difference among k sample means.	6
Graph > Overlay Plot	Study patterns in residuals to check for violations in model assumptions or trends in performance measures.	3 through 7
Graph > Bubble Plot	Enables information to be displayed for up to four variables. Used to examine influential observations or outliers in simple linear regression.	7
Graph > Control Chart	Used to examine process stability over time for performance measures or homogeneity assumption for residuals.	2, 3, 6, and 7
Graph > Variability/Gauge	Examine the different sources of variation and systematic patterns in the data, and estimate variance components.	3 and 4

In addition to the platforms listed in Table 1.3, there are illustrations of table functions and manipulations interspersed throughout the chapters. We show, for example, how to add columns to JMP tables, use some functionality in the Formula editor, set row states, summarize data tables, stack columns, sort tables, exclude or hide rows, and set column properties.

Although the analyses presented in this book were done using JMP 7, where appropriate we have included information about the differences in JMP 8.

1.9.1 JMP Help and Resources

If you are not familiar with the basic functionality of JMP, we encourage you to take advantage of the information available in the JMP **Help** menu, in particular the **Tutorials** and **Books**, as well as the different resources such as podcasts, JMP blog, JMP data

stories, newsletters, and so on that are provided at the JMP.com Web site. These resources will definitively increase your level of expertise using JMP.

JMP Tutorials

The JMP tutorials are intended for you to learn how to do common tasks in JMP. You can access the tutorials from the **JMP Help** menu. These tutorials use a combination of textual references and demo tables to guide you through a hands-on activity. The tutorials that are directly applicable to this book include the Beginners, One Mean, Two Means, Many Means, and Paired Means tutorials.

JMP Books

You can access a list of books that are available within the **JMP Help** menu. These books provide a comprehensive overview of the features and functionalities of the software and often use different JMP tables to illustrate some of these points. However, these books are not geared towards interpretation of the output and describing the statistical underpinnings of the approaches. Some of the JMP data sets used in these books might be located under the Sample Data folder where the installation resides.

The **JMP User Guide** is an appropriate reference for learning about data manipulation. Important concepts, such as creating and opening files, editing data tables, selecting rows and columns, and assigning properties to columns are included in this user guide. You can print the **JMP Menu Card** to have easy access to the options available in the main JMP menus: **File**, **Edit**, **Tables**, **Rows**, **Cols**, **Analyze**, and **Graph**. Similarly, the **JMP Quick Reference Card** has tips on using the **Formula Editor**, **JMP Tools**, Working with Files and Editing Files, for example. Finally, selecting **Help > Contents** in JMP pulls up all of the books into one frame.

JMP.com Resources

The JMP Web site, http://www.jmp.com/about/resources.shtml, has a wealth of resources to help increase your knowledge of JMP, acquire new skills, learn about new features and events, and connect with the JMP community worldwide. These resources include the following:

- Podcasts
  Hear from who's who in the world of statistics, what they're doing, and what's on their minds.

- JMP Demos
  Demos of the new capabilities of JMP.

- JMP Blog
  A Web log devoted to all things related to data visualization, visual Six Sigma, design of experiments and other statistical topics.

- JMP Data Stories
  JMP Data Stories show you how you can use the advanced data visualization techniques in JMP software to explore your data, answer your questions, and find out what your data is trying to tell you.

- *JMP Foreword* Magazine
  The statistical discovery magazine from SAS, which is available in PDF.

- *JMPer Cable* Newsletter
  A technical publication for JMP users.

- JMP Scripting Library
  The JMP Scripting Language (JSL) enables JMP users to program JMP to repeat analyses, write custom programs to manipulate data in complex ways (including full matrix algebra support), and even extend the graphical and analytical capabilities of JMP.

- JMP File Exchange
  The JMP Community File Exchange contains files contributed by users and includes sample data files, JMP Scripting Language (JSL) files, and SAS stored processes.

- Seminars
  Because there's no substitute for hands-on learning, JMP offers seminars featuring world-renowned leaders in statistical thought.

- White Papers

1.10 Scope

The statistical analyses presented in this book are appropriate when the performance characteristic of interest is measured on a continuous scale. The variables used to explain the behavior of the performance characteristic can be either categorical or continuous. This, we believe, covers a large number of applications that you might encounter in industry and science. A companion book dealing with categorical performance characteristics will be published at a future date.

The following statistical techniques and concepts are covered in this book:

- descriptive statistics such as the mean, median, mode, standard deviation, range, and process capability indices
- graphics including histograms, trend plots, control charts, normal quantile plot, box plots, scatter plots, and residual plots
- tests of significance
  - one-sample tests for the mean and standard deviation
  - two-sample tests for means and standard deviations
  - paired *t*-test
  - equivalence tests for the mean
  - analysis of variance (ANOVA)
  - multiple comparison tests
  - Brown-Forsythe test for comparing variances
  - simple linear regression
- measurement scales: nominal, ordinal, interval, and ratio
- experimental and observational units
- response vs. factor
- signal-to-noise ratio
- statistical intervals: confidence, prediction, and tolerance
- Type I and Type II errors
- *p*-value and confidence level
- degrees of freedom
- randomization
- stratification factors
- statistical inference
- sampling plans, including random and stratified random samples
- sample size calculations
- probability distributions, for example, normal, Student's *t*, *F*, and Chi-square
- variance components

1.11 Typographical Conventions

Several typographical conventions are used in this book to point you to important information related to both statistical content and JMP software usage.

Statistics Typographical Conventions

Two different types of typographical conventions are used throughout this book to highlight important statistical content. This was done to draw your attention to key concepts that are important when applying statistics to engineering and science problems. The first statistical convention is the use of statistics notes. These are numbered according to the chapter they are in, and their order of appearance. Statistics notes appear throughout a chapter to emphasize main points and things worth remembering. An example of a statistics note (Statistics Note 4.2) from Chapter 4, "Comparing the Measured Performance of a Material, Process, or Product to a Standard," summarizes the three main assumptions that are required in many statistical analyses.
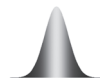
Statistics Note 4.2: The validity of this procedure (for determining if the average performance is equal to a standard) depends upon the assumptions that were discussed in Chapter 2 and are reiterated here. The underlying population must be normally distributed, or close to normally distributed, the data are homogeneous, and the experimental units must be independent from each other.

The second type of statistics typographical convention that the reader will encounter is a callout box, like the one below. The information in the callout box is a snippet of a key point that is presented in the main text of the chapter. They are intended to be short and memorable.

A p-value is an area under a probability density curve that quantifies the likelihood of observing a test statistic as large as, or larger than, the one obtained from the data.

JMP Typographical Conventions

In each chapter, JMP software is discussed in a general sense in order to highlight the various elements that support the statistical techniques and analyses used to solve a practical problem. In addition, specific instructions are provided so the reader can reproduce the JMP analysis using the data showcased in each chapter. The following typographical conventions are used in reference to JMP software in this book.

- *JMP platforms* will be displayed using a bold Arial font and platform paths will be shown using an '>' to distinguish the individual selections needed. For example, the Distribution platform is labeled as **Analyze > Distribution**.

- *JMP dialog boxes* that get launched after selecting a JMP platform and require user input are also shown in bold Arial font. For example, to create a histogram the user must highlight a response variable in the **Select Columns** window, and then click **Y, Response**.

- *JMP column names,* which are unique to a JMP data table and are used to populate JMP dialog boxes, are shown in unbolded Arial font. For example, we must highlight Effective Thickness, which is the name of the response of interest in our JMP table.

When these elements come together to provide instructions for creating, for example, a histogram for a response in JMP, it will look like the following: "We use the **Analyze > Distribution** platform to generate the histogram and the descriptive statistics for the data. In the Distribution dialog box, select Effective Thickness, click **Y, Columns**, and then click **OK**."

Similar to statistics notes, JMP notes are scattered throughout the chapters to highlight information that is relevant to using JMP but that might not be obvious. The reader will find that they are numbered according to the chapter number they are in and the order in which they appear. Shown below is a JMP note from Chapter 7 "Characterizing Linear Relationships between Two Variables."

> **JMP Note 7.2:** In JMP raw residuals can be saved to the data table from the **Analyze > Fit Y by X** platform, but the studentized residuals must be saved from the **Analyze > Fit Model** platform.

We also include notes pertaining to JMP 8 usage when there is a significant difference between how something is handled in JMP 8 as compared with JMP 7. Below is an example from Chapter 7.

> **JMP 8 Note:** To get the same output in JMP 8 from within the **Distribution** platform, we select **Continuous Fit > Normal**.

JMP Figure Annotations

Each chapter has numerous figures that capture the JMP instructions for the analyses together with the corresponding output. At times, these figures are annotated with additional information for ease of use or interpretation. Most of the time these annotations are presented to the left- and right-hand side of the output. Figure 7.12 below shows an example of an annotation outside of the output.

Figure 7.12 Example of Annotation Outside of JMP Output
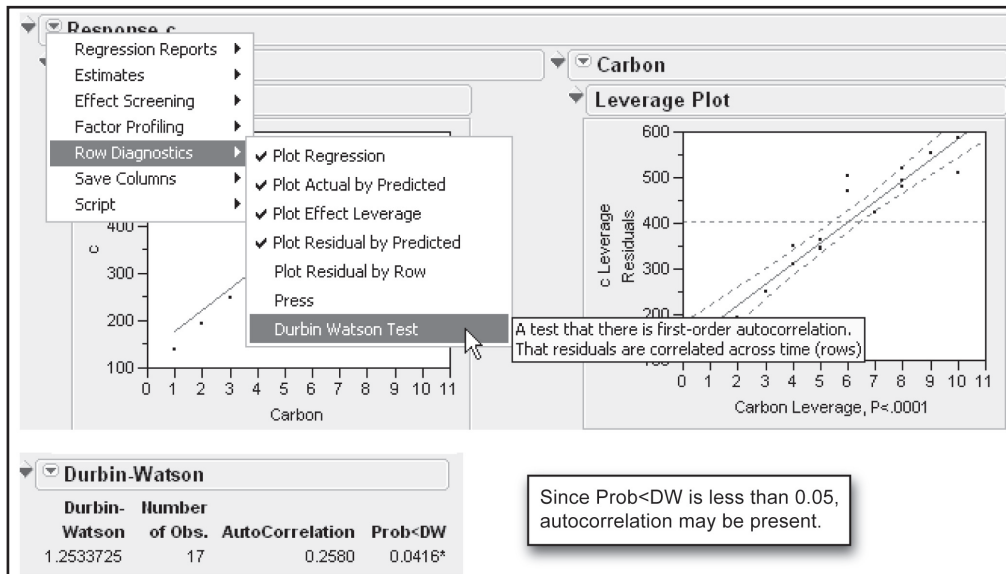
There are a few instances, however, where the annotations are included within the JMP input window or the JMP output window. These annotations are not generated by JMP and cannot be reproduced by the user, but they have been added to facilitate the understanding of the inputs needed in a particular analysis or the interpretation of the output. Figure 4.8 shows an example identifying the inputs required in the **Sample Size and Power** calculator, while Figure 5.23 shows the annotated output for the **Unequal Variances** test.

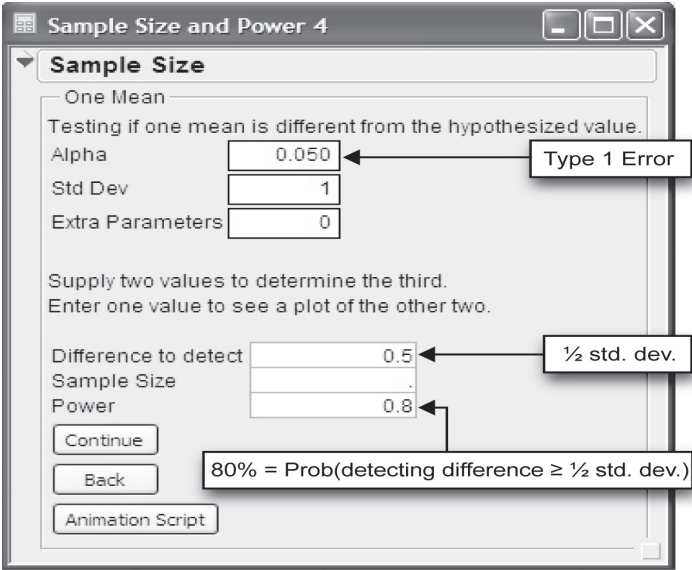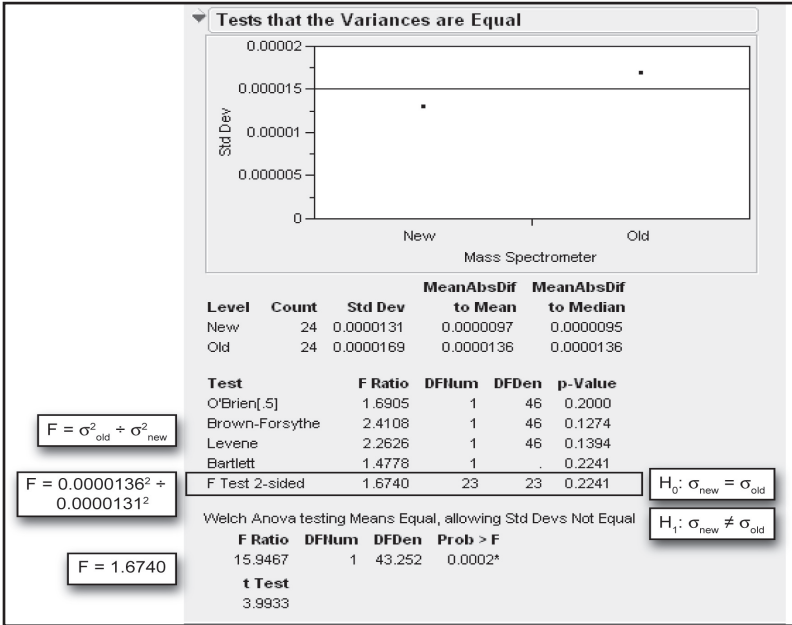**Figure 4.8** Sample Size Calculation for One Sample Mean

Figure 5.23 Output for Unequal Variances Test

1.12 References

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