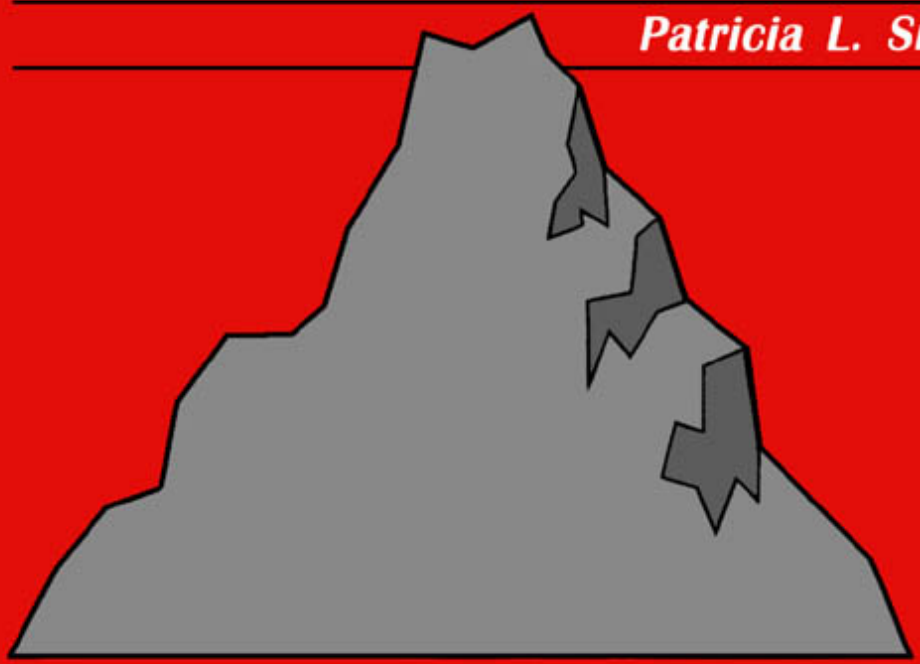
A Primer for Sampling Solids, Liquids, and Gases

Based on the Seven Sampling Errors of Pierre Gy

Patricia L. Smith



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Library of Congress Cataloging-in-Publication Data

Smith, Patricia L.
A primer for sampling solids, liquids, and gases : based on the seven sampling errors of Pierre Gy / Patricia L. Smith.
p. cm. – (ASA-SIAM series on statistics and applied probability)
Includes bibliographical references and index.
ISBN 0-89871-473-7
1. Bulk solids—Sampling. 2. Sampling. 3. Gases—Analysis. 4. Liquids—Analysis. I. Title. II. Series.

TA418.78 .S65 2000
620'.001'51952—dc21

00-061250

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To Phil
for support and encouragement

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Preface

In a 1962 paper in *Technometrics* (p. 330), Duncan states, "Randomness in the selection of original increments is indeed the number one problem in the sampling of bulk material." In my work as an industrial statistician, I certainly found this to be true. In fact, I was often at a loss in many practical sampling situations. I knew I needed help, and fortunately, I got it.

I was first introduced to the sampling theory of Pierre Gy by Francis Pitard, a student and practitioner of Gy's work. I was at once excited and overwhelmed. I was excited because I was exposed to a new and structured approach to sampling that would help me solve the practical problems I encountered in my work. At the same time, I was overwhelmed by the theory, the terminology, and the scope. The theory was totally different from, but not in conflict with, my formal statistical training. My graduate education in sampling theory addressed only situations in which the sampling units were well defined (people, manufactured parts, etc.). I did not learn in these statistics courses how to sample bulk materials (soils from the ground or in piles, powders, liquids, etc.), nor how much to sample. *Gy's theory, however, provided me with*

1. *a* ***structured approach*** *from which I could break down a sampling problem into component parts and*

2. ***basic principles*** *that I could apply to any sampling situation.*

Every subject area uses words in a specialized way, and sometimes the language is a stumbling block. To minimize possible confusion, I have used synonyms for some of Gy's words. I hope to convey his intuitive meaning while at the same time preserving his original ideas. I do not wish to trivialize or even oversimplify this complicated area, but I want to present the ideas in lay terms so that the *concepts and principles* are easily grasped and therefore more likely to be *applied.* Consequently, I also sacrifice technical correctness at times to convey the essentials.

Pierre Gy has written a number of papers and consolidated his work in several books. For simplicity, I quote mainly from his most recent books, one in 1992, consolidating his theory in its entirety, and his latest one in 1998, an abbreviated version that highlights the major elements. Francis Pitard has presented the essence of Gy's theory in a recent book and examined the idea of

chronostatistics, applying part of Gy's theory to control charting. With his publications in the area of spatial statistics, Noel Cressie has "legitimized," from a statistical viewpoint, the variogram, one of Gy's key tools for studying process variation. All of these works are sophisticated and require time and effort to understand and apply. In addition to these books and papers in technical journals, there is a wealth of articles in trade journals addressing specific sampling situations. Advertisements for sampling equipment abound. A search on the Internet can locate sampling information, documents, and vendors.

For the sampling practitioner, I saw the need for a short and useable handbook that would concentrate on the "how to's" and rely on intuitive explanations for the "why's." If intuitive explanations fall short, the inquisitive reader should go to Gy (1992, 1998) or Pitard (1993) to fill in the details. *This book is an introduction only.* It is designed for people in the field to serve as a guide that presents Gy's principles for use in day-to-day applications. It is also designed to serve as an overview and introduction to Gy's theory from which a more detailed study can be launched. The focus is on representative sampling in industrial, process, and lab settings. I do not address special situations, such as environmental contamination, which may require judgmental sampling or location sample selection based on existing data. However, some of the principles in Chapter 3 can be used to help characterize spatial distributions. While many examples reflect my industrial background, Gy's principles apply to any sampling situation in which representative sampling is desired.

Footnotes serve two purposes. In some cases, they provide theoretical details. These might be of interest to readers who want more technical information. Other footnotes provide expanded explanations of words or phrases to clarify the text. These should be useful to all readers. Appendix A provides a brief overview of the material and can actually be read first to get an idea of the type of thinking involved in this approach to sampling. Chapter 1 has a brief introduction, which provides background and motivation for the rest of the book. Chapters 2–4 give detail, and each has a summary section that can be used as a quick reference once the ideas are understood. I like Chapter 3 the best because it discusses the practical details of physical sampling and the difficulty of getting random samples from solid, liquid, or gas lots. The material in this chapter is what was most fascinating to me in my initial exposure to this subject. It is also the easiest to understand and apply. Chapter 5 suggests an overall strategy for implementing the ideas presented. Appendices B and D expand the technical detail from earlier chapters and are fairly specialized. Appendix C gives a practical way to obtain a random sample from a sequential set of items. Appendix E describes some simple experiments that can be performed with commonplace materials. I strongly encourage readers to try these because they illustrate in a straightforward way the difficulties of sampling bulk materials and certain liquids. While trying to reduce sampling errors, theoretical principles must sometimes be compromised in practice to ensure the safety of the person taking the samples. Thus, I include some information on safety in Appendix F. While the environmental impact of sampling should always be considered, I do not discuss this specialized subject.

Several people reviewed drafts in various stages of development. I am especially grateful to Francis Pitard. From his carefully crafted remarks and the detailed discussions I had with him, I was able to clarify ambiguous ideas and present them in a more complete framework. His support and encouragement throughout are very much appreciated. Lynn Charney and Greg Stenback provided valuable comments. Lynn furnished an overall perspective on organization and readability. Greg examined details including definitions and formulas. He made suggestions for rewording to clarify intended meanings and help avoid misinterpretations. I even found a way to put him in the references. Tom Welker contributed his expertise on liquid and gas sampling. I would also like to thank the reviewers of the final manuscript for their helpful comments, enabling further refinements and improvements.

Patricia L. Smith

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