ACCURACY AND PRECISION

by

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Outline of a talk to be presented at a Round Table Conference on the subject of accuracy, precision, and sensitivity to be held at the Waldorf-Astoria on Monday, June 28th, at 8 P.M. under the auspices of the American Society for Testing Materials Committee on Presentation and Interpretation of Data, 193[illegible]

I

SHOW WHY ASTM ENGINEERS SHOULD WORRY ABOUT ACCURACY AND PRECISION

> Thus in many directions the engineer of the future, in my judgment, must of necessity deal with a much more certain and more intimate knowledge of the materials with which he works than we have been wont to deal with in the past. As a result of this more intimate knowledge his structures will be more refined and his factors of safety in many directions are bound to be less because the old elements of uncertainty will have in large measure disappeared.

> The possibility of improving the economy of steel to the consumer is therefore largely a matter of improving its uniformity of quality, of fitting steels better for each of the multifarious uses, rather than of any direct lessening of its cost of production.

Engineer deals with

A. Physical constants C

B. Physical properties $Y = f(X)$

A fundamental requirement of efficient use of material in mass production is in general that we have sufficient knowledge to reduce to an economic minimum the tolerance range AB on each and every quality characteristic X

Quality X ——|——|—— (A, B)

To obtain this objective he must not simply learn to talk about accuracy and precision but he must also learn how to do things with accuracy and precision. In fact, he must go further in this direction than any one has apparently gone in the field of pure science, as we shall soon see. For example,

how measure	how use
how present	how specify
how interpret	how verify
	how judge

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2. Dr. John Johnston, Director of Research of the United States Steel Corporation, "Applications of Science to the Making and Finishing of Steel", *Mech. Eng.*, February, 1935.
1. Dr. F. B. Jewett, "Problems of the Engineer", *Science* March 4, 1932.

II

SHOW WHEREIN CUSTOMARY DEFINITIONS OF ACCURACY AND PRECISION BREAK DOWN IN PRACTICE

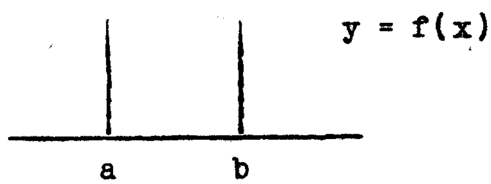
I assume that this audience would in general agree that the definition of accuracy and precision as synonymous terms is misleading. In other words, they will agree that

Accuracy $\neq$ Precision

Accuracy	observed value minus "true" value
	" " " "standard" value
	" " " "theoretical" value

Precision A characteristic of reproducibility

$$p = \int_a^b (x)dx$$



Fundamental Distinction

Accuracy is of nature of error and involves TWO operations

Precision is of nature of probability and involves one operation

HOW MEASURE - Customary answer.

Length	Psi		Drawings from bowl
25.06	34020		.5
25.09	31860		.1
25.15	31480		-.3
25.04	31230	Flat V	-.9
25.08	32880		.1
25.10	32040		-.1
25.09	34030		-.1
25.05	34340		.3
25.12	32340		-.6
25.12	30860		.7
25.11	34090	Round V	.4
	31230		
	34030		
	31030		

Length: $\bar{X} = 25.09$, $\sqrt{\frac{\sum v^2}{n-1}} = .0223$

Psi: $\bar{X} = 32532.86$, $\sqrt{\frac{\sum v^2}{n-1}} = 1324.23$

Drawings from bowl: $\bar{X} = .0091$, $\sqrt{\frac{\sum v^2}{n-1}} = .3226$

HOW INTERPRET SUCH A MEASURE - Customary answer

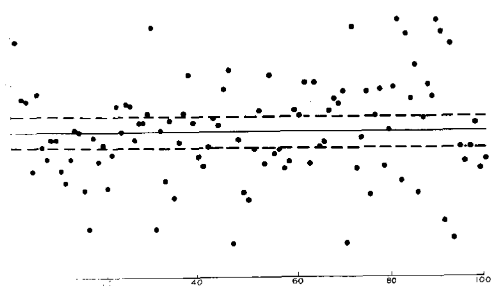


Fig. 1

Prediction 50%
Experiment 27% 100% mistake
Theory 25%

SUCH MISTAKES CANNOT BE TOLERATED BY INDUSTRY

OPERATION

SHOW THAT CONCEPT OF OPERATION IS FUNDAMENTAL

Type A - Mathematical or formal - Estimate π by infinite series
Type B - Experimental

a. Measure π from formula: circum. = $2\pi r$.
b. " Sum of angles of triangle.
c. Produce an alloy and measure a physical property such as tensile strength.
d. Measure a physical constant such as G or V.

Fundamental difference between two types

Type A - We always get the same result through the repetition of operation
Type B - We always get the following situation:

$X_1, X_2, \ldots X_i, \ldots X_n$	$X_{n+1}, X_{n+2}, \ldots X_{n+j}, \ldots X_{n+m} \ldots$

Past Present Future

Hence A is certain - B uncertain or probable

Hence in experimental work we must differentiate between

Observed accuracy and precision of past data	Predicted accuracy and precision of future set of data..

Example

Accuracy of test method is 10%;
Accuracy of the test method shall be 10%

Precision of Millikan's data $s = .0223$. Evidently s is merely a historical fact.

Density pure iron 7.86 gms. per cc at room temperature (U.S.)
7.87 ± .002 gms. per cc at 19° C. (G.B.)

V = 299,796 ± 4 km. per sec.*

Note that distinction between past and future is certainly not clear in customary practice. However, it is only the future knowledge we are interested in in practice.

IV

REPRODUCIBILITY

SHOW THAT SCIENTIST MERELY ASSUMES RANDOM REPRODUCIBILITY BUT THE ENGINEER MUST DO SOMETHING IN ORDER TO GET RANDOM REPRODUCIBILITY

All discussion of error theory based on the assumption of random conditions

BUT

The only way I know of to get a random operation is by defining some kind of physical operation such as drawing numbers from a bowl. Sets of numbers thus drawn satisfy Criterion I as I have shown elsewhere.

I think this criterion should be criterion of reproducibility, or, in other words, a criterion that data should satisfy if we are to place much faith in future predictions. See Fig. 2. Note that the available measurements on the two physical constants G and V do not satisfy this criterion.

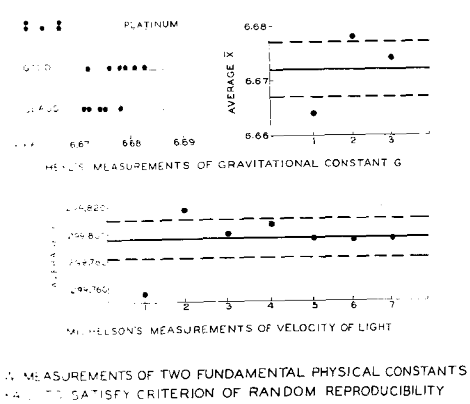


Fig. 2

<u>V</u>

DESCRIBE TWO KINDS OF PREDICTION OF IMPORTANCE IN ASTM WORK AND THE IDEAL POSSIBILITIES THAT MAY BE ATTAINED

Research

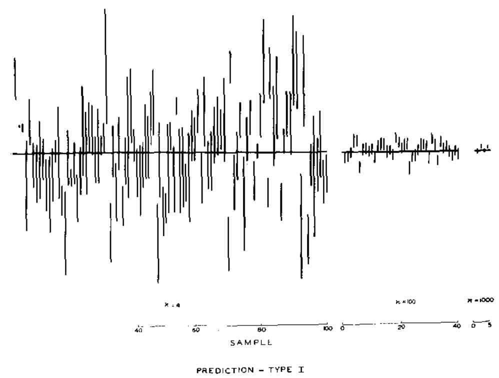


Fig. 3

"True" value; exploratory; separation of universes (alloys, processes, liquors, etc.)

Economic Mass Production

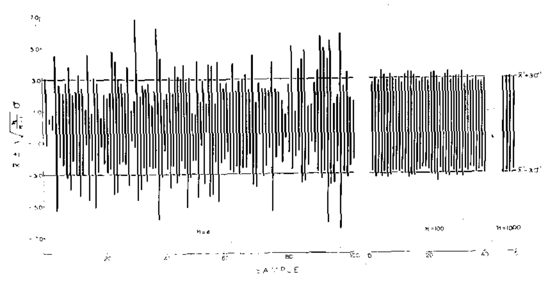


Fig. 4

Starting out to do the same thing again and again; trying to get on the straight and narrow path and stay there economically; making the best use of a given operation, alloy, material - THE FUNDAMENTAL PRACTICAL PROBLEM.

SHOW AN EXAMPLE OF ATTAINMENT OF THE SECOND KIND OF PREDICTION

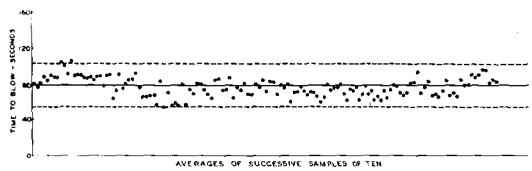


Fig. 5 - Blowing Time of Fuses.

Contrast, if you will, the attainment of reproducibility here under commercial conditions with the apparent lack of reproducibility in this refined sense in the "refined" measurements of Michelson and Heyl.

VII

SHOW HOW TO PRESENT DATA $(\bar{X}, \sigma, N)_{C,n}$

We have not time here to touch upon the problem of specifying and verifying accuracy and precision.

VIII

Real progress has been made in the field of industry toward attaining understanding of how to measure, tabulate, interpret, specify, verify, and use accuracy and precision - fundamental steps towards attainment of the goal set for the engineer of the future in the words of Drs. Jewett and Johnston.: