

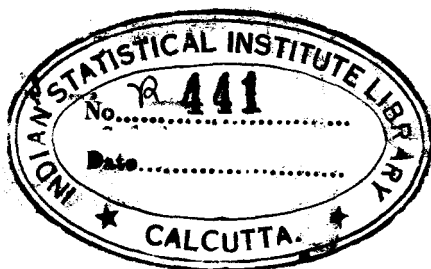
R 441
- WMS

Potential Opportunities
for
Statisticians

by

Walter A. Shewhart

Bell Telephone Laboratories



Informal talk to be given at joint meeting of American Mathematical Society and Institute of Mathematical Statistics at Wellesley, August 12, 1944.

W. A. SHEWHART'S COLLECTION

Teachers

Wanted

Men looking for jobs

Gov. Depts —
Industrial Executives

WHO WANTS
TO KNOW?

Professional statisticians
and officers of statisti-
cal societies interested
in organizing for the
future.

Prospective Students

INTRO DUCTI0N

1. It is assumed that all of you are familiar with the applications of statistics in such pure and applied sciences as the following:

- 1.1 Agriculture
- 1.2 Economics
- 1.3 Sociology
- 1.4 Education
- 1.5 Physics
- 1.6 Chemistry
- 1.7 Theory of measurement
- 1.8 Biology
- 1.9 Medicine
- 1.10 Psychology
- 1.11 Meteorology
- 1.12 Literary vocabulary
- 1.13 Consumer research - poling
- 1.14 Quality control
- 1.15 Research
- 1.16 Actuarial science
- 1.17 Astronomy

2. What is a Statistician?

The following definitions are given simply for the sake of clarity in this discussion.

2.1 Descriptive statistician.

Collects, summarizes, and interprets numerical results without special reference to questions of sampling or the problems of representativeness associated with the theory of probability.

2.2 Mathematical statistician.

One capable of developing new theory acceptable to the editor of the Annals.

2.2.1 Confidence in conclusions reached by careful reasoning.

2.2.2 Critical attitude toward detail of demonstration.

2.2.3 Idealizes any situation.

2.2.4 Desire for generality.

Consumer and producer risk generalized into errors of first and second kind.

2.3 Applied mathematical statistician.

One who can use intelligently material in a book like that of S. S. Wilks and in such publications as the Annals.

2.4 Statistical scientist or engineer.

Scientist + a knowledge of the material in Wilks book and the Annals.

2.4.1 Assumes project responsibility.

2.4.2 Must know his subject matter field, and know when his data are good.

2.4.3 Must deal with practical as well as ideal situations.

2.4.4 Must deal with concrete data and situations, as well as be able to think in terms of abstract principles.

2.4.5 Must assume responsibility for content as well as abstract form of his conclusions.

2.4.6 Must know from experiences his errors of 2nd kind. Must know from experience the best clues to such errors.

2.4.7 Must know the abstract statistical models that may be used as approximations and must know how unknown causes of deviations from such models may cause observed data to deviate from that expected upon assumption of a given model.

Part I

Application of Mathematical Statistics
in Industry

A. Industrial problem:

To make the most efficient use of raw materials from the earth, sea, and air and of human abilities in producing goods to satisfy human wants.

B. Management:

"Management is the art and science of preparing, organizing, and directing human effort applied to control the forces and to utilize the materials of nature for the benefit of man."

(Trans. ASME, 1913)

Management is in a sense a grand industrial experiment.

C. Statistical Design of this grand industrial experiment.

This is my subject.

1. Note that this experiment involves the control of the

1.1 Physical surroundings

1.2 Human element - About 8,000,000
in manufacturing alone (1939)

to satisfy wants of 130,000,000
people.

There were 184,230 manufacturing
establishments in 1939.

2. Raw materials.

The earth	{	Beneath surface	{ Coal
		Surface	{ Iron, etc.
		Above Surface	{ Agricultural Products
			{ Air

2.1 Use of statistics in agriculture
assumed known.

2.2 Sampling problems

Coal, etc.

Toxic gases in air.

Both of these have already at-
tracted wide attention. Hundreds
of pages written on the first and there
is ASA committee on the second.

3. Step 2 - Fabrication of Raw Materials into Useful Materials.
 - 3.1 Chemical elements.
 - 3.2 Chemical compounds.
 - 3.2.1 Rubber
 - 3.2.2 Alloys
 - 3.2.3 Drugs
 - 3.2.4 Insulating materials.
 - 3.3 Metallurgical products.
 - 3.3.1 Steel sheet and tubing
 - 3.3.2 Wire
 -
 - 3.4
4. Step 3 - Research, Design, Development and Specification of Useful Devices.
 - 4.1 Automobiles
 - 4.2 Radios
 - 4.3
5. Step 4 - Purchasing
6. Step 5 - Manufacturing
7. Step 6 - Inspection
8. Step 7 - Sales and distribution.

8. Statistical problems arise at each step.
- 8.1 Sampling for quantity and quality of raw materials.
 - 8.2 Sampling to determine human wants in terms of quantity and quality.
 - 8.3 Research
Development
Design
Specification
 - 8.4 Purchase of raw and fabricated materials.
 - 8.5 Manufacturing control.
 - 8.6 Inspection.
 - 8.7 Sales and distribution.
 - 8.8 Operational research.

10. Some observations.

- 10.1 Generally speaking, the application of statistics is no stronger than the weakest link.

Example 1 - If a producer cannot buy statistically controlled product on the open market, he may be limited in the reduction of variability in the quality of a given device in which this material is used. That is to say, suppliers must see the economic advantages in producing statistically controlled product and purchasing agents must likewise know the added value of statistical control of product. Advertising departments also must be able to see the advantages of control of the product they sell in order to sell their product to the highest bidder.

- 10.2 To get fabricators of a material to cooperate usually means that the majority of the suppliers must adopt control methods.
- 10.3 One cannot build quality into product by sampling but one can find causes of variability that some other prior department may eliminate.
- 10.4 To see the maximum potential contribution, the statistician should keep in mind the over-all problem - should try in so far as possible to keep improving each link in the chain at the same rate.
- 10.5 For a corporation to maximize the contribution of statistics, there should be a statistical control consultant on its staff.

11. How many statisticians?

For each of 241 corporations employing more than 2500

1. Statistical control consultant to top management.
2. Mathematical statistical project men in each of the following
 - 2.1 Consumer research
 - 2.2 Production
 - 2.3 Inspection
 - 2.4 Purchasing and sales.
 - 2.5 Research.

For each of 6308 corporations employing from 250-2500.

1. One statistical consultant.

12. Need for committees - the following have been set up (see attached page)

Committee on statistical control needed in each of several large societies.

AIEE may set one up in August.

13. Need for students who have worked in cooperation with industrial leaders on important problems.

Examples - see attached sheets.

14. Need for National Organization of Statisticians in Special Fields

Example: Statistical quality control.
At least 1000 potential members now.
At least 5000-8000 potential members in ten years.

15. Need for special journals for statistical specialists.

Example: National Journal of Statistical Control.
.....

16. Need for survey and special articles in such journals as

- 16.1 Journal of Applied Physics.
- 16.2 Industrial Chemistry
- 16.3 AIEE Journal
- 16.4 Civil Engineering
- 16.5 Mining and Metallurgical Engineering
- 16.6 ASTM Journal.

These articles should not be simply a rehash of tests of significance and the like but should show what the applied scientist in the specific field has done and can do that the special scientist wants to do.

Example: a) article on sampling of coal.
b) physical constants
c) rubber, plastics, etc.
d) resistors, vacuum tubes, etc.

The kind of an article that a statistical student could write under guidance of an expert mathematical statistician and a scientist in the special field in question.



17. Research

17.1 New Processes.

17.1.1 Testing methods

- Ex. 1 - Spectrographic analysis
- " 2 - Microanalytical.

17.1.2 Corrosion tests.

17.1.3 Materials

- Ex. 1 - Rubber
- " 2 - Plastics
- " 3 - New contact materials
- " 4 - Special steels & alloys.

17.2 New Designs.

17.2.1 Pieceparts

- Ex. 1 - New relays, i.e. Hg type
- Ex. 2 - Resistors
- " 3 - Vacuum tubes
- " 4 -

17.2.2. Theoretical models to minimize cost of over-all variability of given magnitude.

17.3 Human reaction to new product.

17.3.1 Tests on hearing aids.

17.3.2 Articulation tests.

Color tolerance.

17.4 Operational Research to determine cause of failure.

17.4.1 Make one hoss shay.

18. Organization Needs

- 18.1 Should have opportunity to review all proposed new projects internal to the research department of an organization.
- 18.2 Should have broad acquaintance with research men in the materials field (ASTM)
- 18.3 Should have broad acquaintance with leaders in the specification and control of quality.
- 18.4 Should have contact with leaders in fields of research.
- 18.5 Should have contact with statisticians in I.M.S., Econ. Soc., Psychometric Soc., etc.

ILLUSTRATIVE ORGANIZATION CHART
OF A
MANUFACTURING ENTERPRISE

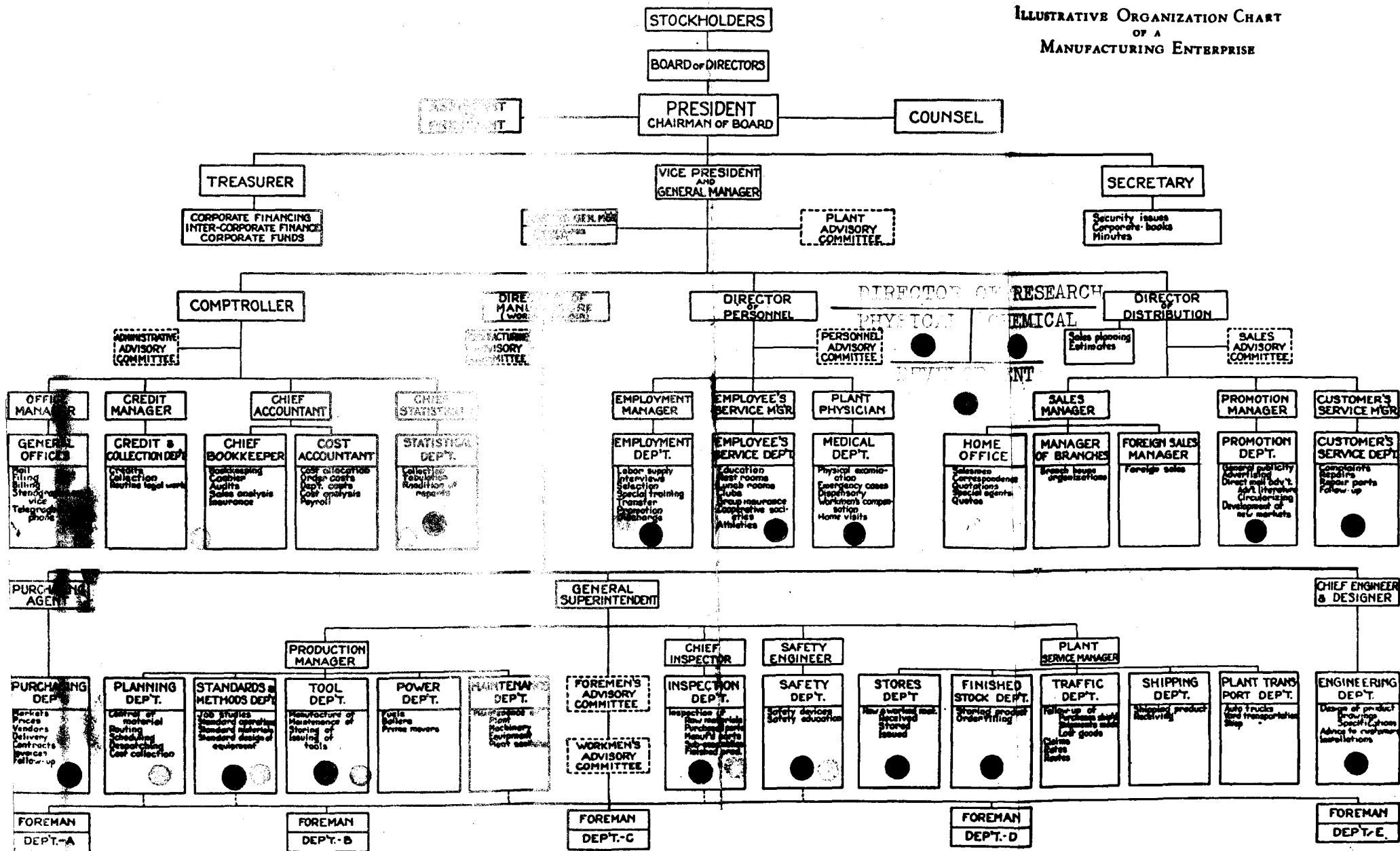
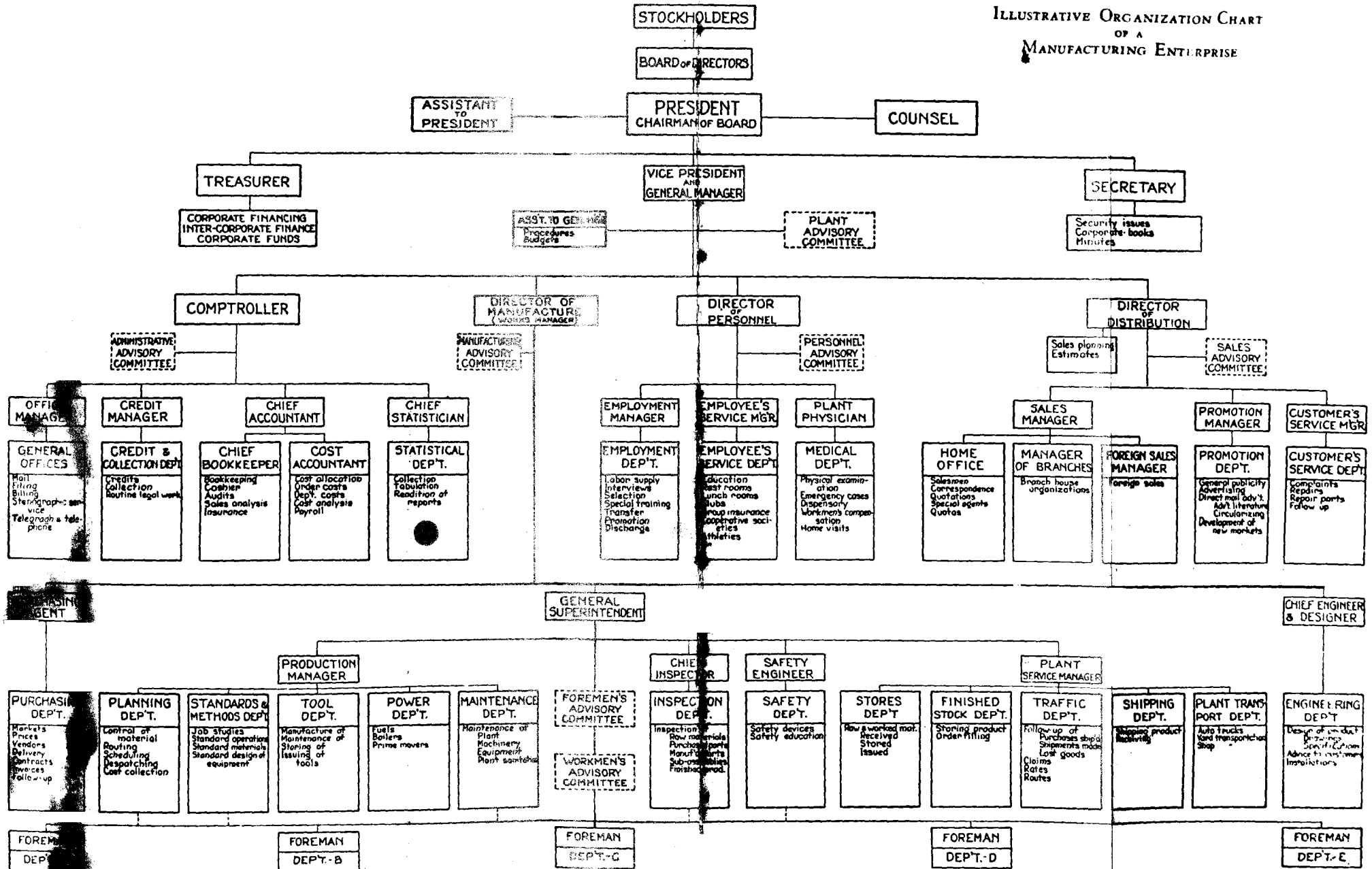


FIG. 9.

ILLUSTRATIVE ORGANIZATION CHART
OF A
MANUFACTURING ENTERPRISE



For Princeton meeting:

Phillips Lamps

Bristol Aeroplane Company

U. S. Rubber Company (reprinted by
Frankford Arsenal)

General Electric Company (Fort Wayne Works)

Australian Report

Aircraft War Production Council

Sun, rain, cosmic rays, etc.

radio transmission

Forests

Mines

Agriculture

Consumer research

Research

Purchasing

Design

Development

Specification

Production

Inspection

Sales

Operational

research

130,000,000

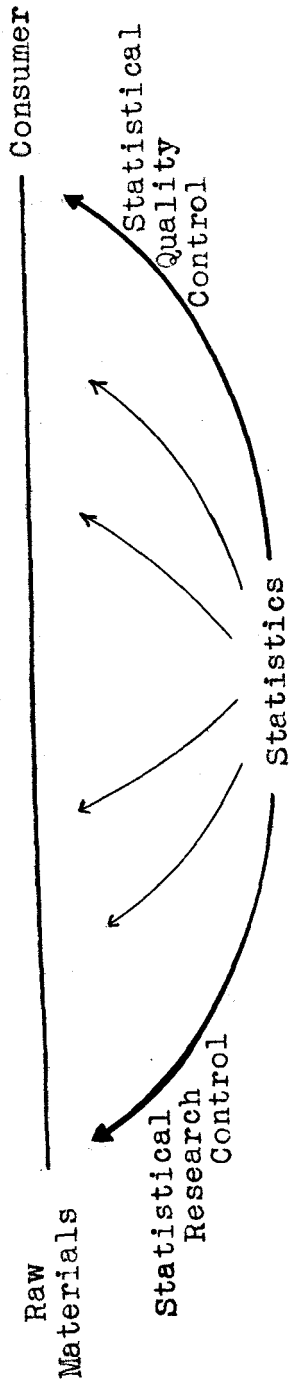
people

8,000,000

employees in

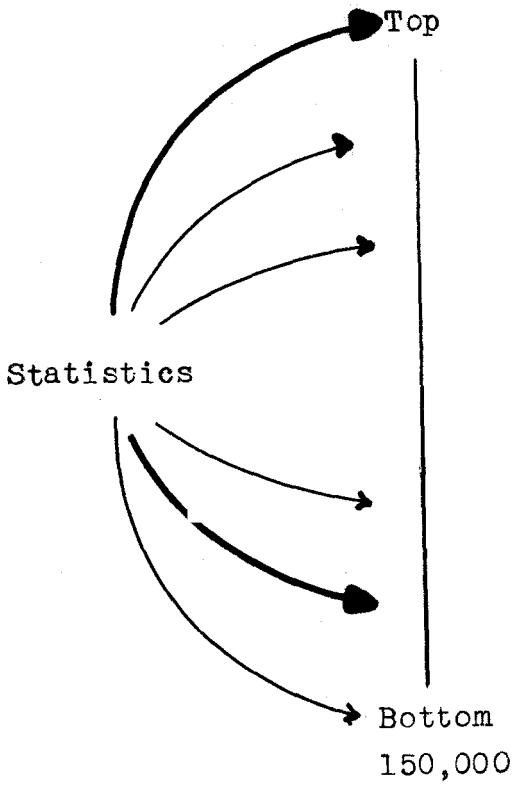
manufacturing

"Management is the art and science of preparing, organizing, and directing human effort applied to control the forces and to utilize the materials of nature for the benefit of man."



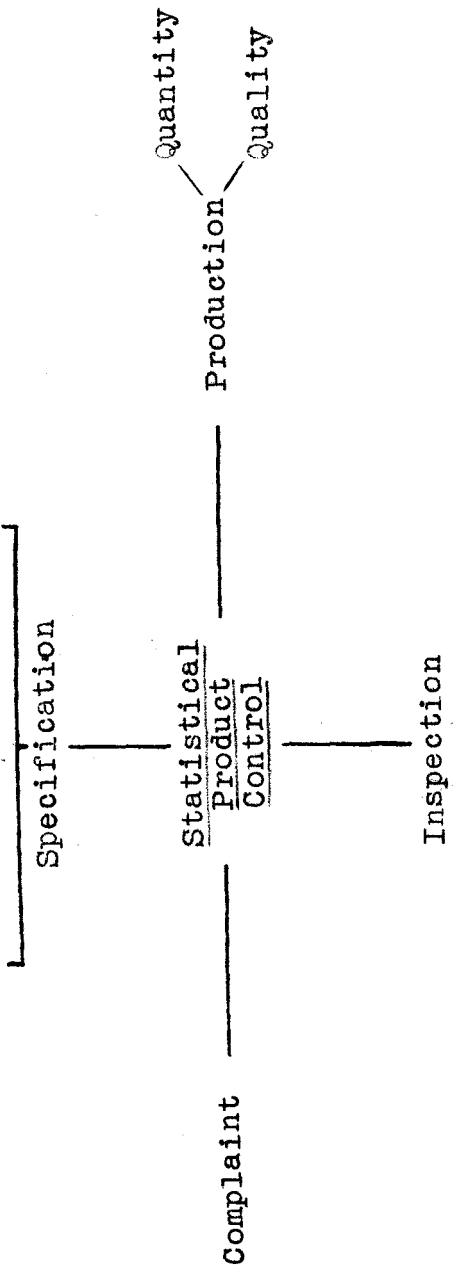
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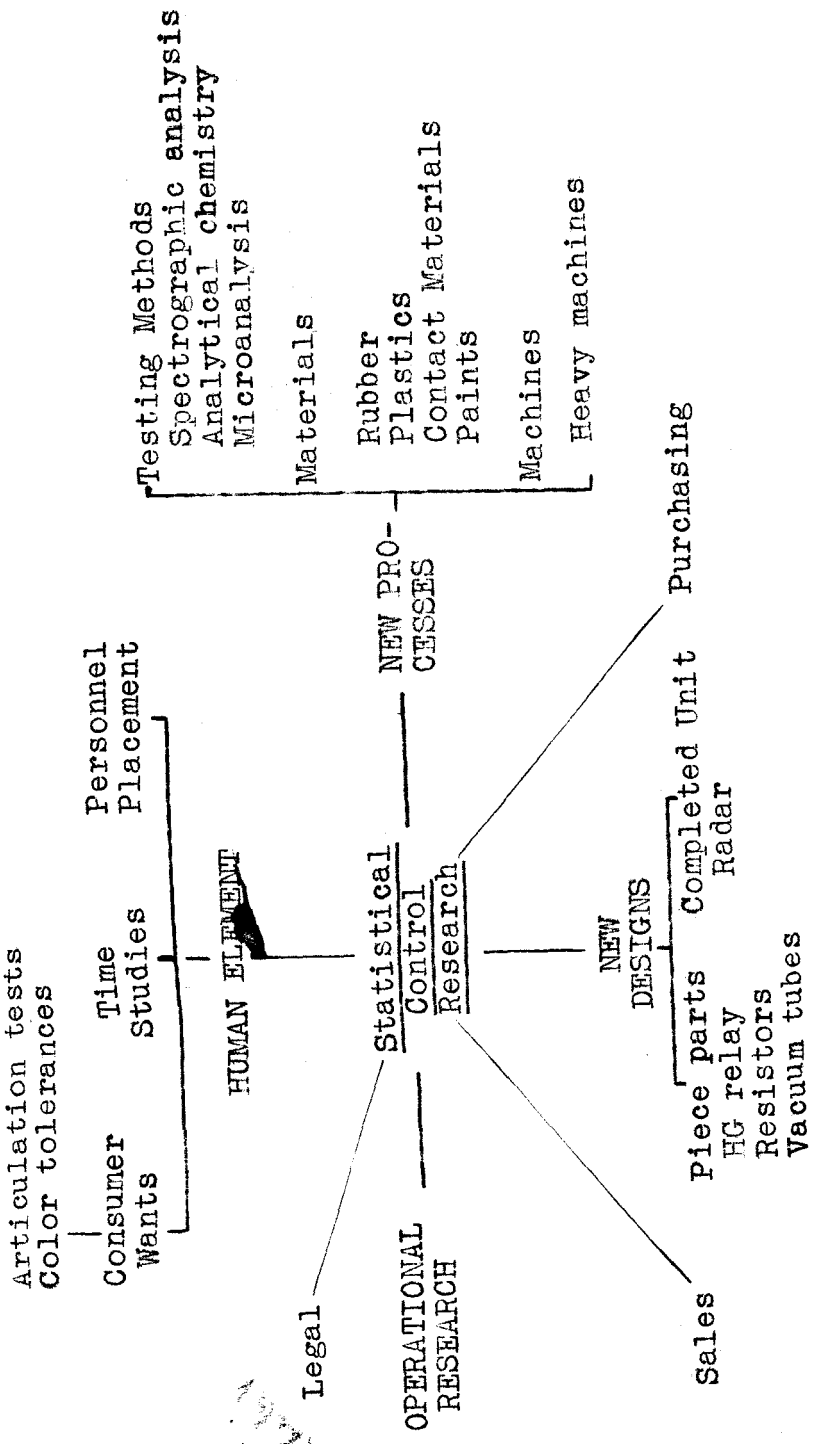
FEEDBACK BY STATISTICS



*CONTROL
of
HUMAN EFFORT*

Standards for units Standards for product





Articulation tests
Color tolerances

Consumer Wants
Time Studies
Personnel Placement

HUMAN ELEMENT

Legal

Statistical Control Research

OPERATIONAL RESEARCH

NEW PRO-CESSSES

Testing Methods
Spectrographic analysis
Analytical chemistry
Microanalysis

Materials

Rubber
Plastics
Contact Materials
Paints

Machines
Heavy machines

NEW DESIGNS

Piece parts
HG relay
Resistors
Vacuum tubes

Purchasing

Completed Unit
Radar

Engineering
and
Manufacturing



Joint
Committee



Statistical
Control

Science ← NRC
Committee



ASTM and ASA
Committees



Standards

Howkins mem. ... Sept 1932

British Ministry of Commerce

APL - April 1935

British Standards Institution
Ad hoc committee on statistical Methods in Mechanical
and Industrial Standardization
Great Britain
Organized 5/11/1932

<u>Name of Committee</u>	<u>Sponsor</u>	<u>Date of Organization</u>	<u>When Initiated</u>
Committee on Interpretation and Presentation of Data <i>Approved by the Board of Directors 5/24</i>	A.S.T.M.	3/18/30	Oct. 1929
Joint Committee for the Development of Statistical Applications in Engineering and Manufacturing	A.S.M.E.	12/5/29	7/1/28
	A.S.T.M.		
	I.M.S.		
	A.S.A. A.M.S.		
Committee on Applied Mathematical Statistics	N.R.C.	1/15/43	4/4/42
Emergency Technical Committee on Quality Control <i>SA 4265/1072 (Rev. 5/5/41)</i>	A.S.A.	12/11/40	June, 1940
Committee to advise on scope and content of statistical information which government might make available for use of business	Working with Govt. through Advisory Committee on Govt. questionnaires	May, 1944	

Leaders in Great Britain

C. C. Paterson, Director of Research,
General Electric Company, Ltd.

Sir Charles Darwin, Director,
National Physical Laboratory

Sir Frank Gill, Director
Intl. Standard Electric Corp.

J. H. Gough, Director of Research,
Ministry of Supply.

P. Good, Director,
British Standards Institution.

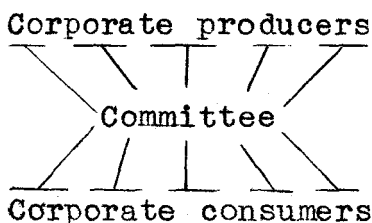
III

Training Problem

1. Mathematical Statisticians.
2. Statistical Scientists.
3. Statistical Research Control Scientists (in adequate number for 2254 industrial research laboratories in 1942).
4. Statistical Production Control Engineers (in adequate number for 184,230 manufacturing firms in 1939).

One or more of the three committees might assist in finding industrial research problems in statistical control for a few graduate students with outstanding personality and technical ability.

For example, each of the 1158 ASTM Standards must be a tailor-made job involving the following:



and often composed of

physicists
chemists
metallurgists
engineers
etc.

Portland Cement

Standard Methods of Sampling and Physical Testi
of Portland Cement

ASTM Designation: C 77-40 1942, II, 33-46

Quicklime and Lime Products

Standard Methods of Sampling, Inspection,
Packing, and Marking of Quicklime and Lime
Products

ASTM Designation: C 50-27

1942, Part II, pp. 77-80

Brick

Standard Methods of Sampling and Testing Brick

ASTM Designation: C 67-41

1942, Part II, pp. 145-150.

Salt Spray Test on Organic Coatings

Emergency Method for Conducting Salt Spray
Tests on Organic Protective Coatings

ASTM Designation: ES-3

1942, Part II, pp. 1020-25.

Coal

Standard Method of Sampling Coal for Analysis

ASTM Designation: D 21-40

1942, Part III, pp. 11-14.

Condenser Paper

Tentative Methods of Sampling and Testing
Untreated Paper used in Electrical Insulation

ASTM Designation: D 202-41T

1942, Part III, pp. 1187-1206.

Sampling Petroleum Products

Standard Methods of Sampling Petroleum and Petroleum Products

ASTM Designation : D 270-33
1942, Part III, pp. 199-214.

Sampling Soap and Soap Products

Standard Methods of Sampling and Chemical Analysis of Soaps and Soap Products

ASTM Designation: D 460-462
1942, Part III, pp. 743-765.

Plant Corrosion

Recommended Practice for Conducting Plant Corrosion Tests.

ASTM Designation: A 224-241.
1942, Part I, pp. 492-499.

Testing Machines

Standard Methods of Verification of Testing Machines.

ASTM Designation: E 4-36.
1942, Part I, pp. 889-897.

Metallic Materials

Standard Methods of Tension Testing of Metallic Materials.

ASTM Designation: E 8-42.
1942, Part I, pp. 898-908.

- - - - -

Vols. I, II, III

Total specifications	574
" methods	554
	<u>1128</u>
Emergency standards	30
	<u>1158</u>

Institute of Statistics - 19?

Statistical Societies

<u>Society</u>	<u>Organized</u>	<u>Membership</u>	
		<u>1941</u>	<u>1944</u>
American Statistical Association	1839	3000	
Econometric Society	1930	703	
Psychometric Society	1934	228	
Institute of Mathematical Statistics	1935	400	598
Society of Statistical Production Control		1944: 1000 1954: 5000-600	

ASA 3575

11/27/45

Inst 770

11/15/45

Econ 716

10/1/44

Psych.

ASME Income - 1942-43

Initiation and Promotion Fees	\$13,008.42
Membership dues	241,594.17
Student dues	26,715.35
Interest and discount	4,547.16
<u>Mech. Eng.</u> Advertising	178,457.30
Mechanical Catalog advertising	68,517.82
Publications sales	91,474.82
Contribution, Jour. Appl. Mech.	500.00
Engineering Index, Inc.	798.60
Registration fees.	405.00
Sale of equipment	35.00
Membership list advertising
Miscellaneous sales	1,684.79
Total income	\$ 614,730.01
To be added to surplus	59,329.72
Balance for expense	\$ <u>555,400.29</u>

Mechanical Engineering, August, 1944

Advertising total = 246,975.12

40%

Number of Members

Institute of Math. Statistics	598
American Mathematical Society	2,314
American Physical Society	3,800
American Chemical Society	27,860
A.A.A.S.	22,000
ASME	21,763
AIEE	17,886
AS Civil Engineers	17,047
American Society for Metals	12,500
Amer. Inst. Mining and Met. Eng.	
Institute of Radio Engineers	5,705
ASTM	6,250
American Ceramics	1,721

Publications

Pure Sciences

General Science

Applied Fields

So-called quality

Popular Industry Magazine

Annals Math. Stat.
766

Scientific Monthly
10, 171

Mech. Eng.
22, 457

Harper's
106, 733

Fortune
164, 359

Physical Review
2, 982

Science
15, 746

Ind. & Eng. Chemistry
23, 152

Atlantic Monthly
106, 989

Jour. Amer. Chem. Soc.
11, 500

Elec. Eng.
22, 945

Popular Journal:

Bull. Amer. Math. Soc.
2, 649

Mining and Metallurgy
10, 724

*SAE
6, 948*

Product Engineering
12, 449

Journal of Applied Physics
2, 487

Instruments, the magazine of measurement and control
5, 509

Life
3, 759, 0
Sat. Eve
3, 405, 5

Statistical Production Control
1944: 1000
1954: 12,000

Journal of Statistical Research

Possible Topics to be Covered in a journal on statistical quality control

In general, the journal might cover the fields of application of statistics in production, research engineering and manufacturing. It would be read by such practical men as ordinarily read

Product Engineering
Machine Design
Instruments
Factory Management

and similar journals.

Fields Covered

1. Specification

- 1.1 The three meanings of quality.
- 1.2 Specification of quality of type I.
 - 1.2.1 Specification of quality of materials.
 - 1.2.2 Specification of quality of pieceparts.
 - 1.2.3 Specification of quality of processes.
 - 1.2.4 Specification of over-all quality of a unit composed of thousands of pieceparts to provide chain type design.
 - 1.2.5 Specification of quality of a product.

- 1.3 The legal status of a specification.
- 1.4 The problem of testing human reaction to physical things to get at quality of Type III.

2. Production

- 2.1 Control of quantity and quality.
(Quantity is a quality of the production process).
 - 2.1.1 Control of quality of machines.
 - 2.1.2 " " " of methods of measurement.
 - 2.1.3 Control of quality of product.
 - 2.1.4 Control of quality of production processes.
- 2.2 Control of quality of human operations

3. Inspection

- 3.1 Inspection plans.
- 3.2 Inspection operations.

4. Testing Methods.

- 4.1 General theory of testing.
- 4.2 Round robin tests.
- 4.3 Routine tests.
- 4.4 Error of measurement of first and second kinds.
 - 4.4.1 General theory
 - 4.4.2 Errors of two kinds for special types of tests.

5. Machine Analysis

The use of IBM and other types of machines.

6. Q. C. from viewpoint of Management

"Management is the art and science of preparing, organizing, and directing human effort applied to control the forces and to utilize the materials of nature for the benefit of man."

Trans. ASME, 1913.

- 6.1 Organization for efficient control
- 6.2 Personnel requirements.
- 6.3 Problems of training.
- 6.4 Use of quality control information in design and development.
- 6.5 Use of quality control information in advertising.
- 6.6 Use of quality control information in purchasing.

Possible Organization as Section of
American Statistical Association

Section on Quality Control

(or some such title)

Chairman

The ASA to ask E. G. Olds to
serve as chairman.

Section Committee

Each quality control group to
be asked to appoint representative.

Duties of Committee

Organize meetings and publications;
effect an efficient organization as a
section.

Booklets

Philips Lamps, Ltd., "Statistics and Quality Control", by A. S. Wharton. Published for circulation amongst the Philips Group of Companies, 1943.

Bristol Aeroplane Company, Ltd., "Quality Control Handbook", resume of instructions issued on quality control, setting out the duties of all personnel connected with the system, 1943.

London and Southern District Junior Gas Association, "Standardization and Quality Control", by S. F. Dunkley, 1935.

Alexander Smith and Sons Carpet Company, "Statistical Methods of Quality Control in Textile Manufacturing", by A.G.Ashcroft and O. P. Beckwith, 1944.

U. S. Rubber Company (reprinted by Frankford Arsenal), "Methods in Quality Control", by L. W. Montreuil and Paul Peach; "The Chart Control Method of Inspection", by R. J. Hartmann, 1944.

General Electric Company, Fort Wayne Works, "Product Rejection Data", by K. E. Ross, 1944.

British Standards Institution

BSI 600:1935, "The Application of Statistical Methods to Industrial Standardization and Quality Control", by E. S. Pearson.

BSI 600R-1942, "Quality Control Charts", by B. P. Dudding and W. J. Jennett, 1942.

American Standards Association

Z1.1-1941, "Guide for Quality Control".

Z1.2-1941, "Control Chart Method of Analyzing Data.

Z1.3-1942, "Control Chart Method of Controlling Quality during Production".

Ministry of Supply

"A First Guide to Quality Control for Engineers", by E. H. Sealy, September, 1943.

Reports

Department of Munitions and Standards
Association, Australia

"Report on the Use of Statistical Quality Control in U.S.A.", by R. G. Moore and A. L. Stewart, 1944.

Aircraft War Production Council

"Statistical Control of Quality for the Aviation Industry", by D. D. Pettit and E. E. Bates, 1944.

Ordnance Department, U. S. Army

"Report of the Special Mission (Simon) on Ammunition, Chronographs, and Ballistics, in Eto and Nato", by Col. Leslie E. Simon, 1944.

