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**PRODUCT
ENGINEERING**

SPECIAL REPORT

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VALUE . . .

the emerging emphasis in design

A study of present and future potentialities of specialist services in design engineering—reliability, value analysis, value engineering, quality assurance and the like, based on interviews with and comments from some 80 men, many of them engineering executives. Among the questions answered here: What do these services provide? How do they do it? At what cost? Why? How do these services differ and how do they interrelate? Why should I be interested? What can they do for me?

E J TANGERMAN, chief editor

THE RETURN TO VALUE

Ask an engineering executive today what worries him most and he'll say "Costs!" Ask the same question of a company executive or the head of the family and you'll get the same answer; costs are everybody's headache.

Even in missiles, the current "cost-is-no-object" field, federal pressures have resulted in what is called the area's "fastest-growing industry—unemployment." Cost reduction has resulted in slashing of engineering staffs as well as production forces, for massed engineers (some doing technician jobs) do not achieve efficiency; further, computers and other aids to calculation and analysis have reduced requirements for men.

Increasing foreign competition, using our methods, will force a continued searching examination of costs. Some elaborate R & D setups are being viewed with a critical eye, and some development is currently being imported. But now the paradox . . .

Specialist departments are being organized for reliability, value and engineering, expanded quality control, quality assurance and value research. Today, most engineers face a rise in "over-the-shoulder" advisers, an increase in organizational complication and costs—at the same time they

are asked to cut costs. They see added confusion and elaboration where the obvious need is for streamlining and simplification; they see pre-emption of their responsibilities by other groups which often include non-engineering personnel.

Why?

In some cases (too many, in fact), the pressure is for pure cost-cutting. In the enlightened cases, the effort is to achieve value—to hold costs down without sacrifice of quality—or more properly, to balance cost and performance, to attain the integrity that the customer now demands.

We have always had specialists within the engineering department, in materials, stresses, kinematics, even though every engineer has basic training in these fields. So we should expect specialists in reliability, value analysis, quality control, value assurance—areas where most engineers have limited training, if any. If one kind of specialist can improve the design and save money in the long run, why not the other?

The problem is not simple. Beyond the organizational difficulties, the irritation of “second-guessers” and “arm-chair admirals,” is the hard fact that these relatively new specialist services are paying their way. Value analysis in the Navy is currently paying out at 16:1. Reliability has gotten a much higher percentage of missiles off the launching pad. The armed services are so convinced of the value of value engineering that they offer their contractors 40% of first-year savings.

Beyond all that, the key to survival, of a nation or a company, is technological innovation; and the pressure of cost reduction encourages innovation. But no cost-cutter can ever pre-empt innovation—the basic function of the engineer.

THREE QUESTIONS

We asked engineering executives in 55 companies:

- 1. . . What changes are taking place in organization and responsibilities of engineering departments?*
- 2. . . Will Engineering have responsibility for quality control,, reliability, and value engineering?*
- 3. . . What organization is needed?*

ENGINEERING ORGANIZATION STILL IN TRANSITION

■ The last decade has brought a bewildering array of “scientific” management concepts that apply directly or indirectly to Engineering. Coupled with this has been a sharp increase in the amount of engineering in the product and faster development of new materials and processes. Along with the tendency of big companies to get bigger, these conditions are resulting in much larger engineering departments, with more complex functions and the necessity for new procedures in organization and cost control.

In Inspection, for example, the simple and straightforward process of comparing product with standard has changed radically. First, tolerances and dimensions became closer, so the instruments for inspection became more elaborate. Next, high-production machines were built to hold a setting or adjustment for long periods of time, so simple parts were more uniform. This led to statistical quality control with 100% inspection replaced by sampling.

Then, there were problems of dimensional drift and its causes, redesign to avoid inspection failures, and objective analysis of rejects that pushed Quality Control in the direction of Engineering.

In similar fashion, a number of other developments have had an impact on Engineering. Under such names as value analysis, value engineering, quality assurance, cost reduction, reliability, some have been championed by the military, others have ranged from vogue to value. Last May 16 we took a close look at Reliability.

To evaluate the importance of these continuing trends on Engineering, we more recently made both a mail and a person-call study among chief engineers and vice-presidents of engineering. We sampled both large and small companies, coast to coast; a few in the military and missile field but most in cost-sensitive industries—nearly 60 in all.

In the summaries that follow it is immediately

obvious that, in addition to differences created by size and individual organizations, there are also differences caused by type of product and volume of production.

We asked three questions:

1. How are engineering departments and their responsibilities changing? Where are they going?

2. Will Engineering have responsibility for reliability (R), Quality Control (QC), Value Analysis (VA), Value Engineering (VE) and similar specialty groups or programs?

3. If so, where will the responsibility be placed? What organization is needed?

Answers to the first question were basically the same we found two years ago, reported in "Engineering Organization in Transition" (*PE*—May 11 '59, p 47). There is no single preferred organizational structure; the form is secondary to many other factors, such as the people, products, policy and volume involved.

Within a company it often differs, product by product, plant by plant, or division by division. But the earlier trend of separating engineering effort into R & D and Product Design department is being modified by a further separation of product design and production design.

Product design grows in emphasis

We find increasing emphasis on a 3-part division such as Advanced Planning, Product Design, and Test; or Research, Development and Design, and Test; or Research, Development, and Design (really Redesign). In still other cases, the subdivision is into Research, Development, and Product Engineering, the latter meaning engineering for production. Sometimes, it includes functions previously considered as part of production engineering, such as tooling and programming; in other instances it includes all of production engineering. The objectives behind such organizational changes usually are optimum quality and cost.

What they tell us

Behind it is an evident change in emphasis—a shift which one engineer describes as from "product orientation" to "customer orientation"—a reawakening of a spirit of integrity, a reacceptance of the fact that the customer must be pleased with his purchase if the seller's long-term future is to be assured. There is a growing recognition of the importance of value.

Says another engineer, in a consumer-product plant: "Organization is irrelevant unless technological and social progress serves the needs and wants of the customer. Too often the tendency is to solve everything by organization, losing sight of the real objective, a satisfied and lasting customer."

In another instance, an over-grown "brain factory" that delivered more in ideas than in hardware, the products were excellently engineered and ideas were outstanding. But the engineering drive for perfection without regard for cost made complete reorganization necessary to impose proper controls and save the company from financial trouble.

One large company formerly had an R & D department to carry a development through the prototype stage, with tested models, manufacturing drawings and parts lists ready to release to Production. This has been re-oriented by establishing a plant-by-plant function called Product Engineering which handles:

1. Final development of the product—production design, tooling, methods of fabrication, assembly processing. However, R & D is required to make preliminary cost estimates.

2. Product improvement, even though this involves function of the product or parts.

3. Cost reduction on existing products.

4. Tool design, production engineering and process engineering.

In this setup, Quality Control remains in manufacturing and reports to the plant manager, but R & D has a department called Reliability Engineering that includes a testing lab for service to R & D and Product Engineering. It makes tests on materials and components, conducts Underwriters and government tests, R analysis and statistics, and quality assurance tests (on an auditing basis). A director of Quality, Products & Services reports to the president; he has no test labs or other physical setup; instead, he uses QC organizations in plants and R in the engineering dept to develop information, plus reports from field and service organizations.

The general effect is to assign out functions locally, with Engineering having responsibility for technical coordination, interpretation, standards and the like. Advanced design (or R & D) is corporate so it can coordinate the work of Product Engineering groups but is not responsible for control of production. It thus is a logical place for the R group.

An interest but contrasting opinion is presented by another engineer: "It is somewhat analogous to our form of government, in which we have a Congress (Engineering) to make the laws but other agencies to implement and enforce them. Some very desirable checks and balances are provided by having Purchasing, Manufacturing and Quality Control of an equal organizational stature with Engineering. These other functional elements have a responsibility to maintain and, through feedback, help improve the parameters established by Engineering; but the control and integration of these activities is the function of Management, not Engineering."

One company that makes portable tools has reoriented into a 5-part engineering setup:

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1. Engineering Research—really “Cloud 9” concepts, new ideas and products.
2. Advanced Design—three to four years ahead on potentially marketable products.
3. Production Engineering—design for production; includes human engineering.
4. Experimental Test Department—includes field and customer tests.
5. Administration Group—also handles drawing files, drafting section, library.

This company also has non-managerial premium jobs with titles like “layout engineer,” “test engineer,” “senior design engineer,” corresponding to General Electric’s system of “consultants”—high-ranking engineers with recognition and status, but no management responsibilities.

One engineer comments that he hadn’t thought of the growing need for close cooperation for what may be called Product Engineering and Production Engineering and thinks he may try a combination of the two.

A common relationship between Engineering, Reliability and Quality Control is summed up by a consultant on integrated design practices:

“The initial definition of the product which the business intends to design and manufacture, including the desired degree of perfection in terms of function and reliability and so forth, should come out of a product-planning process participated in by all the functions who will have a part in carrying out the plan. With the product requirements consistent with business goals such as the profit-investment ratio and product leadership, then Engineering and Manufacturing responsibilities for the new product are stated concisely.

“Engineering is responsible and accountable for designing a product which, if built in accordance with this design, will meet the product requirements. The design must be sufficiently complete and specific that Engineering is accountable if a product fails, unless it can show that failure is attributable to manufacturing.

“To achieve the degree of reliability called for, particularly in complex products or systems, a Reliability Engineering group has responsibility in one or more of these areas:

Engineering quality practices and standards—particularly as to life and environmental capabilities.

Engineering design reviews—to ensure use of past experience and proven procedures.

Product design evaluation—to determine if the product does meet requirements.

Mathematical techniques—for specifying, predicting and measuring product reliability.

“While these four areas are all normal responsibilities of Engineering, the Quality Control function may conduct the environmental and life tests for Engineering to conserve scarce competence or expensive facilities.

THREE INSPECTION FUNCTIONS RELATED TO RELIABILITY

1 . . . **Shop inspection.** Largely directed to determining conformity to prescribed methods, and the accuracy of human efforts. Statistical sampling may be used to reduce the amount of inspection effort.

2 . . . **Statistical quality control.** Analyzing and determining the adequacy of facilities and manufacturing methods, with the idea that it is “cheaper and quicker to do things right in the first place”; also that process checks should be provided at various stages to ensure that successive steps are properly taken. This is a manufacturing engineering function.

3 . . . **Quality assurance.** Examination of resultant manufacturing quality from the customer’s point of view. Involves check-inspection sampling, surveys of manufacturing information and methods, analysis of field complaints, and the like. This is inherently a design-engineering function, though it may be delegated in part to others for convenience.

4 . . . **Reliability, on this basis, is also a product-design function.** Establishment of reliability goals is an “advanced planning,” or “product planning,” or “systems engineering” subfunction. Embodiment of these goals into designs is obviously a design function, while verification of attainment is a quality-assurance function.

“To control the quality of manufacture using product design specifications as a standard, Manufacturing establishes a Quality Control program for measuring, analyzing and controlling the manufacturing work. This includes incoming inspection and test plus selective testing in the factory, although the personnel for routine testing may be a part of the production organization. Since the Quality Control organization becomes familiar with the strong points and weaknesses of the product, opinions of this group can be valuable to product planning as well as to Engineering.”

And there were a number of other comments with shades of meaning different in some respect from the ones we report here. But throughout, the emphasis was quite general on greater attention to value—along with an increase in the responsibility assigned to Engineering.

NEXT . . . VALUE RESEARCH

■ Search for value and quality must begin in research—with the initial concept for the product. Here are the thoughts of R. J. McCrory and Tom Trainer of Battelle Memorial Institute:

Value analysis is a process for finding the lowest cost for a product. Value engineering encompasses greater scope, to ensure the best performance and reliability consistent with product cost. "Value research" is the next step—the basic root of the value of a company's products.

"Value research is a diligent and systematic effort to discover facts and principles which will make a product more esteemed, more desirable, and more useful." Consideration of value must start well back in product conception and development. Research has the basic long-range responsibility for the value of a product.

Value research has three critical facets: create value in terms of function, performance, appearance, reliability, size, maintainability, and operating cost; explore alternative means having inherently higher value; apply science and technology to the development of product value.

Increased sales can no longer be stimulated to a satisfactory level by simple reductions in price. In the summer of 1960 refrigerator prices were cut to almost 50% of their normal value—yet sales continued slow. No longer, according to a study at the University of Michigan, can a merchant post a sale sign or place a few advertisements to move his merchandise. The time is fast approaching, and now exists in many industries, when the salesman must know the value of his merchandise so he can describe it in detail for the careful buyer. He must satisfy the customer that he is getting considerably more than price in his purchase.

You can no longer depend on the consumer to direct your design efforts. As explained by E. H. Land: "New products here at Polaroid are never developed because of market research or

questionnaires to customers. Industry must have insight into what are the deep needs of people that they don't know they have." Value research can provide the customer with the products which will fulfill his needs, both seen and unseen.

Primary consideration is the value to the customer, not the price to the customer. Major aspects of value are performance, appearance, reliability, size, maintainability, and, of course, first cost and operating cost. Performance itself includes several aspects of value: A product can perform a function better, it can perform more functions, or perform with fewer demands on the operator. Thus, value research requires a wide variety of technical decisions and compromises.

Secondary consideration of value research is the need for a product. In most product fields, one producer will reach a level of value beyond which competitors find it difficult to establish an increment of value. In the field of small engines for example, value analysis has resulted in a cost which has captured a huge consumer market. Value engineering has weighed the cost-reliability compromises of cast-in iron liner, a chrome-plated liner, or a bare aluminum cylinder wall. Value research, however, should take a look at the overall objective of providing shaft power. Would an engine employing the Stirling cycle (*PE*—April 11 '60, p 17) have greater value and provide a new stimulus to sales through safety, silence, and potential low cost?

Third element of value research is to cram as much value as possible into a given product by sophisticated technology rather than by cut-and-try methods of development. Demand for increased reliability has led to need for better understanding of the processes upon which the operation of a product depends, better methods of stress analysis, and use of mathematical reliability criteria to predict and control customer satisfaction and warranty costs.

ENGINEERING ASSUMES NEW RESPONSIBILITIES

■ The second of our three questions was:

"Is the Engineering Department likely eventually to have the over-all responsibility for reliability, including quality control, inspection and testing, and value analysis as well as value engineering?"

A majority of engineering executives said "no" for the over-all question but there were a surprising number of "yes" answers and many qualifications. There are obviously differences of definition and interpretation—which presented a major problem in preparing this summary.

Basically, reliability as a quantitative concept today is much more familiar, formal and advanced in companies having military contracts or

subcontracts, particularly those dealing with the Air Force. In fact, MIL Spec 58-10 specifically requires that the reliability function be separate.

Quality control, as a much older idea, is associated with Manufacturing, and tends to be tied in with Reliability only in terms of interchange of data and cooperation. The Reliability Group is most likely to be in or near Engineering.

Value Analysis is most often associated with Purchasing, as a cost-reduction function applied to the product after it is in production.

Value Engineering is often confused with VA, but where the distinction is clearly made, VE is considered part of Engineering, and has to do with **cost prevention**. Another definition: VA is

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a "second look" for value improvement, primarily cost-oriented; VE is cost assurance.

One authority goes so far as to say that VE at the design level may already be too late—that true value must be a key consideration in the research and development phase. So many characteristics of the design become fixed in the R & D phase that later VE and VA efforts are merely cost-cutting operations that injure quality more than they save in cost.

Personalities and relative abilities of individuals strongly affect any organization diagram, as do product complexity, precision and quantities. But the strongest factors are the amount of engineering and the rate of advance in development of the product. In products approaching stability or maturity—when the new model shows little advance over the old—the emphasis is on production and purchasing, hence VA and QC loom large. Presumably, reliability level has been well established during the development phase, so it is not a problem. A saving of a penny a unit can be a substantial, predictable sum.

Where the rate of advance is high, and the product is costly and incorporates a great deal of engineering, R is stressed far more heavily; this is reflected in executive thinking and in the organization diagram.

Differences in setup are reported at times as the result of differences in product. In one company, for example, a heavy-product department has QC and Inspection reporting to the chief engineer; in another department producing a similar but lighter product, QC and Inspection report to the works manager but take technical direction from the chief engineer—the technical direction being the stronger and more positive.

One company found it necessary to change its approach in shifting from a self-used to an outside-sale product. Quantity for the self-use product was small and QC had been "built in"—tacitly recognized but not singled out. But when the product was sold outside in larger quantities, cost became much more important, so specialist groups have been added.

VALUE ANALYSIS GROWS INTO VALUE ENGINEERING

Any design engineer will readily admit that value analysis is a good thing—in principle. But his enthusiasm often is tempered by experiences like these:

1. VA is often just an insurance program for something that the competent engineer does himself. He should have his own chance to modify designs for cost reduction—and will do it if given the chance.

2. The value analyst is second-guessing, which "anyone" can do, without full knowledge of the problem.

DEFINITIONS

One group of department managers, after several days of conference, agreed on these basic definitions:

- 1 . . **Inspection** is the process of comparing the product with applicable requirements and withholding discrepant material.

- 2 . . **Quality Control** is the function which plans, implements, and finally determines compliance with applicable criteria.

- 3 . . **Quality Assurance** is the proper integration of all functions directed toward achievement of a quality product which meets contractual requirements and any other applicable criteria.

- 4 . . **Reliability** is the probability of performing satisfactorily a specified function under given conditions for a specified period of time.

- 5 . . **Value Analysis** is a technique for determining cost of achieving a given function.

- 6 . . **Value Engineering** is an objective evaluation of all elements of a system for the purpose of achieving the required reliability at a minimum over-all cost.

- 7 . . **Production Engineering** is a major element of value engineering, primarily directed toward optimizing design for manufacturing.

Additional definitions for Items 2 and 6:

Quality Control is an effective system for coordinating the quality maintenance and quality-improvement efforts of the various groups in an organization to enable production at the most economical levels which allow for full customer satisfaction.—Armand Feigenbaum

Value Engineering is an objective appraisal of all elements of the design, construction, procurement, installation and maintenance of an equipment, including the specifications, to achieve necessary functions, maintainability and reliability at minimum cost.—BuShips

3. The value analyst may be the newest man in the department—or the one who doesn't fit in anywhere else—if the program is locally administered, or a non-engineer with no training with which to evaluate his ideas, if it is in an outside group.

4. A high percentage of VA suggestions are impractical, some even foolish, yet each must be checked through by Engineering, at enormous cost in time—and sometimes in delay. The cost of checking poor projects is often not assessed against the savings attained in successful ones.

5. VA is most useful in mass production, but is of progressively less value as quantities are reduced and engineering content of the product is increased.

6. Too often, VA becomes the symbol of quality reduction rather than cost reduction. The engineer feels that his design has been bastardized to save money.

The need to keep costs under control has led to some application of VA all through the design, by design review boards, test groups, or some other checking program within Engineering itself. Such a program, aimed at cost prevention rather than cost reduction, is particularly worthwhile where engineering content in the product is high and quantity low, so that normal processes of VA would be merely post-mortems.

Such a program is usually engineer-operated and is called "value engineering" to distinguish it from the Purchasing-supervised VA. A similar program within Manufacturing is on occasion called "value improvement," so some companies have VA, VE and VI, working in cooperation but separately administered.

With increasing frequency, men of all-round manufacturing experience and with some engineering experience are put in value engineering. They do excellent work, but the number of such men is small and the places where they can be used correspondingly great. As in other specialized services, the percentage of incompetents is high, as is the amount of smoke-screening. Sound principles of value engineering have been corrupted into a make-work, make-report technique that defeats its own purposes. At best the value engineer has a thankless job; he must have real competence if he is to balance his many opportunities to make himself unpopular.

Growth of specialist groups

A developing problem in authority is raised by several contributors. Responsibility for Reliability, for example, "is passed from department to department until it rests with the originating engineering department . . . Unfortunately, Engineering is rarely endowed with the authority commensurate with this responsibility. I believe that acceptable products are usually achieved through interdepartmental compromises and not through direct action by those in authority . . . The differences of opinion which arise when the subject of added authority for the Engineering Department is discussed need a thorough airing."

Another engineer wryly reports that in his company QC has been passed from Engineering to general management to manufacturing management—and has deteriorated at each step. Because the responsibility for quality comes back to Engineering, which specifies it in the first place, he feels that Engineering should decide whether it has been attained.

FUNCTIONS of QUALITY CONTROL

Quality Control, in the opinion of some advanced thinkers, should be divorced from routine inspection and test. Inspection must be an integral part of the Manufacturing Dept, so Quality Control can become a professional group serving both Engineering and Manufacturing. In this concept, Manufacturing is completely responsible (and accountable) for the quality of manufactured product. Engineering is held entirely responsible for the potential reliability of the design, while Manufacturing is held completely responsible for the reliability inherent in the product as delivered to the customer.

In this concept, Quality Control has three functions:

Quality Engineering—sets up, with Engineering, points of measurement and devises methods of measurement.

Quality Assurance—provides periodic but non-cyclical auditing of all test and inspection as conducted by Manufacturing to ensure good practices and adequate inspection.

Quality Analysis—assesses the costs of poor quality to motivate Manufacturing to do a better job.

Again and again, engineering executives reiterate that Reliability is primarily an engineering function: "If reliability isn't designed into a product, it cannot be created by production departments." Or again, "Say what you will responsibility for the design cannot be taken from the designer; the Reliability Group can only advise."

Thus there are Reliability Panels to administer and Reliability Coordinating Committees to develop policy, but the Reliability Group does the work, and more often than not, it is in Engineering. And, more often than not, Quality Control has the responsibility for maintaining reliability in Production.

Says one engineer: "Clearly, the product-development group should have the responsibility for resolving questions of reliability and performance specifications as the focal point for the entire company. The proper dividing line is probably at the point of specifications for performance, although in the more complex product areas it may be drawn at the point of process specification. Production of a product to meet these specifications is not a proper engineering function."

One large aircraft company has a production design group attached to the chief designer's

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office. This group is concerned with QC and VE as well as producibility. Their first question is always, "How producible is the design?" VA is done by tooling people in Industrial Engineering—an unusual placement.

Several aircraft companies are concerned about the growing multiplicity of R specs—they're trying to find a path through them. Simplification and avoidance of "boiler-plate" terminology are current needs.

Several companies—notably consumer-product ones—have developed an administrative or service engineering section in Engineering. It has responsibility for drafting, records, library, and often testing — and may incorporate whatever specialist functions are provided. Some make a sharp distinction between QC and Statistical QC and Inspection, the former being Engineering-oriented, the latter Manufacturing-oriented or independent.

One engineer comments that products tend to become less technical and more competitive as they mature, and this tends to transfer more

responsibility and control from Engineering to Manufacturing. This transfer is a hard pill for Engineering to swallow, but is inevitable and more profitable for the company. He consequently feels that most specialist groups will remain in Manufacturing, Purchasing or their equivalents. He also points out that trainees in Manufacturing tend to be recruited less frequently from available technically trained men.

In contrast, the chief engineers of several heavy-machinery makers feel that the trend to Engineering control is increasingly evident. One goes so far as to say that a truly objective appraisal

VE vs QC

Quality control must go beyond mere inspection. It should help prevent poor quality, not merely weed it out. This is done by watchdogging processes as it watches product through inspection. VE has no function in these areas except when excessive cost involves either.

QC emphasizes routine attention to such quality-influencing factors as: new designs which may cause excessive rejects, incoming-materials control and product control in conformance with specs, special process studies when they cause rejects, statistics for VE and R on frequency of failure and the like.

VE emphasizes special attention to all factors which affect costs. QC means primarily conformance to design, while VE means conformance to need. QC is a control function. VE is an advisory one.

Value engineering should not be limited by the specifications. It should examine specifications just as it questions the design. Big cost reductions start with elimination of unneeded functions or over-demands of too-elaborate specs.

Basically, a QC engineer learns how good quality is compared with how good it should be, and studies what to do about the difference. A VE engineer learns what the part is, what it does, whether something else will do the job, and how the cost and performance of two differing parts compare.

WHY SPECIALIST GROUPS?

The argument for separate organizations for reliability, and for value analysis or value engineering, is well stated by one interviewee in a precision-products plant. He says: "Over-all responsibility for reliability is a critical control function embodying the cradle-to-grave concept, thereby cutting across the lines of R&D, Design, Contracts, Planning, Manufacturing, Test and Service. Over-all reliability control must be unhampered by organizational alliance and independent of line organizations to achieve objectivity.

"But over-all control responsibility must not detract from one of the major line responsibilities of Engineering achievement of inherently reliable designs during the development and design phases. Responsibility cannot be split, the desired level of inherent reliability must be achieved during design. However, a reliable design must be followed by homogenous manufacture, compatible installation, and prescribed operation and maintenance to attain reliability in the field. Thus a master reliability plan continuously monitored and controlled throughout the life cycle of the product is essential for economical and early product maturity.

"The same thinking applies for a long-range program of value analysis and value engineering. However, getting a VA program started requires concentrated attention sustained over a period of time. In applying VA effectively in design, experience in manufacturing engineering is helpful. But additional engineering talent is needed in applying value engineering to determine system configuration having maximum effectiveness per unit of cost.

"The line engineer is under the burden of inventing on schedule to meet function alone, and will not always have the time and resource to meet VE requirements also."

would combine Engineering and Manufacturing so no responsibility-allocation problem would occur! Another says that they cannot use statistical methods in inspection—still find 100% inspection necessary in building heavy and special machinery.

One good question, often asked, is “Why spe-

cial groups in the first place?” A good answer is what Leslie Ball (R consultant now with Boeing) has defined as “memory retention”—a centralized gathering and storing place for information, so the company doesn’t make the same mistake twice. With high turnover of personnel, this is a very real need.

A LITTLE VA HISTORY

■ Back in the days when value analysis was young (L. D. Miles began it at GE in 1949), there was debate about whether it was an Engineering, Production or Purchasing function. As I understood it, it was essentially a technique for determining whether parts or subassemblies could be made more cheaply some other way or from other materials. It was a post-design (and often a redesign) operation, and for this reason ultimately became a Purchasing function, although performed by engineers.

A few years later, we began to hear of value engineering, basically the same idea, but applied as examination or evaluation by a special team during design of the product. VE thus was an engineering function.

The Navy was particularly interested in VA and pushed it strongly during the Korean War and after, but the idea never had so much popularity in industry as it has since the Reliability concept came in. This may, however, be coincidence because, as one value engineer put it: “Reliability is a roadblock to value analysis.” He meant, of course, that maximum reliability usually requires the best of every thing, even over-design, while VA seeks to achieve minimum cost, element by element.

The two can, however, have the emphasis and work hand in hand if the objective is maximum value, both to supplier and to user, with minimal maintenance and replacement. As the jokesmiths once put it, “It ain’t the first cost, it’s the up-keep” that determines real cost or value, so the real conflict is between VA on one side and planned or unplanned obsolescence on the other.

Perhaps an easier way to say this is to bring in the concept of total cost. Total cost is made up of initial cost, installation, operation, maintenance, replacement-parts cost and installation time, availability of replacement, value of lost time—all elements of cost straight through to failure.

Value analysis is a study of each operating function to determine its contribution to the over-all worth of the equipment. Value engineering, as the Navy expresses it: “an objective appraisal of all elements of the design, construction, procurement, installation and maintenance of an equip-

ment, including the applicable equipment specifications, in order to achieve the necessary functions, maintainability and reliability of an equipment at minimum cost (MIL-V-19858 Ships and Bu Ships Instruction 5450.33 Serial 741-861).”

VE compares function and cost

Thus VE is not just cost reduction, it is an analysis of function versus cost. Each characteristic of a design is evaluated to give optimum reliability, and is reviewed to see if modifications can be made that will reduce the cost of providing the required degree of operability and reliability. VE seeks simplification, which produces increased R as a natural byproduct.

SOME VALUE-IMPROVEMENT ACCOMPLISHMENTS

Bureau of Ships, Navy Dept, began its VA program in 1954, since that time has analyzed 2300 projects, of which 1650 were activated. These have saved \$35 million, counting savings on each project for only its first year. The program was made necessary by costs rising 500% in 20 years and the shift to much more expensive craft—one nuclear-powered carrier can cost a third of a year’s shipbuilding appropriation.

A number of Navy’s projects have shown startling savings. These bits and pieces show what can be done:

- Shifting from monel hatch bolts at \$5 each to high-tensile steel ones at 10 cents each.
- Redesign of a damper control cut cost from \$50 to 60 cents and redesign of insulation fasteners (1.5 million/carrier) saved \$100,000 per ship.
- A change in specs on gang-punched walkway plating cut costs from \$77,000 to \$17,000 on one carrier.
- Air test fittings for compartments were changed from custom at \$16 each to standard at 60 cents.
- A standard butterfly valve replaced a custom design to cut cost in half and space and weight four-fifths; annual saving is \$750,000.
- Photoengraved aluminum label plates at 14¢ each replaced engraved stainless steel at 27 cents, a saving of \$2500 per destroyer or \$750,000 a year Navy-wide.

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- Chafing guards for life lines were cut from \$3.50 to 25 cents.
- Off-the-shelf running blocks replaced custom ones to save \$8000 on two destroyers and \$1 million on all ships.

RCA

RCA has a "value improvement program" begun in 1957 which coordinates value analysis in Purchasing, value engineering in Engineering, and methods improvement in Production. They work together in cost reduction and in cost prevention. Cost prevention normally takes place in Engineering by determining the essential function and the simplest way to get it, and through reviewing designs regularly for performance, reliability, maintainability and cost. The "rightness" of a design can change with new materials, processes, field data, and also with the quantity that is being produced.

Each plant function at RCA is given equal responsibility in these six steps:

1. Help everyone concerned appreciate the need.
2. Organize to do the job.
3. Set goals.
4. Develop cost-prevention techniques and train to use them.
5. Develop price-prediction aids as a tool for meeting goals.
6. Continue to improve and use cost reduction techniques.

RCA uses both permanent VA and VE personnel and special teams. VA gets suggestions from vendors on how to cut purchase costs by design changes, and flags suspected high-cost items. VE concern itself with changes in technology that affect design and the like.

Considering all costs of change—including that of the study itself—the cost-reduction program has yielded about 15 times its cost in savings on items designed before cost prevention. **On equipment designed with full cost prevention (VE), returns from cost reduction (VA) are much lower.**

VE can aid R by locating over-designed or under-designed elements, highly stressed components, heat, nonessential refinements, duplicated functions or drafting inconsistencies. Here are examples:

In R & D design of a large radar, high flexibility was attained by using separate inter-bank cable connections. However, it was found that the radar would be housed in a standard building, so integral cabling could be used. Initial costs of \$2037 for materials and \$3600 for labor were cut to \$242 for material and \$36 for labor, saving \$5359. (Two soldering connections and two mating connectors per wire were eliminated—96 connector pairs per system—considerably increasing reliability.)

In another radar, over-all material costs were cut 11% by a cooperative VA. Here are examples: One selenium rectifier of a new type replaced two

RELIABILITY AND VE

Reliability, as we said a year ago, has various definitions, depending upon plant and industry. Basically, however, it is the probability that a product will perform satisfactorily a specified function under given conditions for a specified period of time. Thus it incorporates a probability, function, environment and time. It can be enhanced by many efforts, including:

1. Simplification.
2. Reduction of the number of parts.
3. Use of supporting or secondary circuits or devices ("redundancy").
4. Addition of standby.
5. Marginal checkout techniques.
6. Modularization, easy location of test or maintenance points.
7. Increased component life.
8. Improved use of components.
9. Standardizations.
10. Environmental controls.
11. Feedback of service and test data.
12. Skilled and preventive maintenance.

Each of these involves costs; some decrease cost automatically, others increase them initially, so added value must be equated to cost as well as Reliability (R). There is also a direct tie-in between R and Value Engineering (VE) in many of these items, notably 1, 2, 5, and 9.

These similarities, as well as practical considerations, suggest an educational program in R and VE for all designers including advance information on pitfalls to be avoided. In no case, should either R or VE programs take the responsibility from the designer; they are merely advisory.

old ones to save \$53.80, also increasing R by cutting out solder joints and possible human error. A standard potentiometer and gear train replaced a complex special pot to save \$44 to \$75 cost, gave a smaller, less complex, easier replaced unit of higher R. A knob to control hand rotation of the antenna was changed from a \$22 special to a \$2.20 standard already stocked by the military, increasing system availability, hence R.

A boresight target assembly was designed with special castings and a rectangular boxbeam. By substituting standard castings and a tube, a VA team cut cost from \$3672 to \$1412 and improved R by cutting complexity.

Sometimes, specs are unrealistic. In one instance, VA suggested cutting a "no flicker" spec to "no flicker 99.5% of the time." This slight reduction cut cost from \$12,000 to \$7000 with no appreciable loss in R.

New Holland

New Holland Machine Co established a VA program in 1954, broadened it to include VE in

1956: The Value Engineering Group is in Purchasing, but undertakes projects for everyone on request. Included in projects: Over-design in a gearbox cover was detected through a study on the high cost of dowel pins used in it. A power takeoff was similarly over-designed. A household window fastener replaced a bolt and wingnut for removable panels, cutting costs and simplifying design and maintenance. In a critical spring, lower-cost material, pre-set, saved costs. Redesign to eliminate an external grease line and fittings saved \$1700, cold-formed parts on a disk assembly saved \$5000.

Hughes

Hughes Aircraft saved \$21-million in a typical year through a program stressing:

1. Conserve materials, equipment, time, energy.
2. Improve methods, facilities, product quality.
3. Simplify operations, product.
4. Substitute lower-cost materials.
5. Eliminate waste, error, hazards.

Recently, value engineering has been added to the program. VE at Hughes differs from straight-forward cost improvement which is an extra-curricular program for everybody, while VE is a concentrated effort by specially trained, value-oriented personnel on a full-time basis. They appraise a system or a product to attain performance, reliability and maintainability at lowest cost. Through VE, one division saved \$2.4 million in one year, Engineering attained 126% of its half-year cost-improvement bogey, with 54% attributable directly to VE.

VA vs QUALITY

Value analysis can easily be downgraded into cost reduction only, and that in turn corrupted into *quality* reduction. Many designs are initially too elaborate and too costly, and the alert analyst can find and remove these elements—material, process, or component—without affecting the value of the product to the user. But the temptation is everpresent to shade quality or make a price (or both). What the engineer must do always is to approach analyst suggestions (or his own design) with an open mind, asking such questions as these:

1. What parts of this unit were designed on the basis of custom or habit, rather than on function or need?
2. Is this part really necessary?
3. How versatile must the product really be?
4. Will a change of process reduce the material quality or gage required? Can beading, contouring or ridging, for example, replace mere weight to give needed rigidity?
5. Is my special component really only a "Chinese copy" of a standard component costing less?

TEN QUESTIONS

RCA has these 10 questions as tests for a design.

Have you:

- 1 . . . Challenged specification requirements?
- 2 . . . Eliminated unnecessary parts or functions?
- 3 . . . Simplified the design as much as possible?
- 4 . . . Made maximum use of standard items?
- 5 . . . Used least-costly materials?
- 6 . . . Designed for lowest mfg cost?
- 7 . . . Relaxed tolerances as much as possible?
- 8 . . . Used lowest-cost finishes?
- 9 . . . Used company Materials & Component Specialists?
- 10 . . . Fully utilized Purchasing's assistance to gain supplier's "know-how"?

Obviously, items 1, 2, 3 and 4 are sound Reliability procedures too. But 5, 6, 7 and 8 may be working against R and must be equated with it if both R and VE are important.

A lever latch for a Falcon shipping container cost \$17 and four were required. Substitution of a small quarter-turn latch raised requirements to eight per container, but cost was cut to 30 cents each. Net saving per container was \$62.40, or \$61,152 per year. When a standard bolt was substituted for a special to secure a box of etched circuit cards and simplify design, cost was cut from \$1.50 to 30 cents. A synthesizer chassis was shifted from a casting to a dip-brazed sheetmetal assembly. Tolerances difficult to maintain in the casting were attained and cost cut 78%.

Boeing

Patterned after GE's original value-analysis system, that at Boeing Aero-Space is only three years old. It differs from the GE plan, however, in that it is directly under Management (as is the Reliability Group), rather than under Purchasing. There has been some feeling there that the limited-production character of Aero-Space operations, as contrasted to typical GE quantity production, might well put the VA Group in Engineering—operating as a value-engineering group. However, on such a problem as the Dyna-Soar missile, the emphasis must be on *quality* rather than cost during development. It embodies several avant-garde ideas, one being particularly interesting because it turns the clock back to the structural practice on earliest planes—a core structure to carry load, with the skin carrying no stress, but just involved with heat.

The present VA Group is not engineer-oriented; it includes specialists in packaging, fabrication and electronics. Experience thus far has been that the value analyst who is not an engineer does not anticipate, or is not stopped by, engineering problems, thus provides a good contrast. Problems

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thus far have included locating a source for René 41 forgings and for special seamless tubing.

Among VA savings at Boeing are these: Redesign of a dado strip for the 707 that cut material and handling as well as fabrication costs 84% . . . Replacement of a special thermal-relief valve by an off-the shelf unit, saving 76% . . . Almost \$100,000 were saved by working out a procedure for reuse of Bomarc dust caps and plugs . . . Redesign of a missile battery so only cells and rubber components are discarded each six months, saving annual costs of \$700,000 . . . Change from a weldment to a casting on antenna coupler assemblies saved 62% . . . Reducing excess grip-length on pieces to be stretchformed

saved \$56,000 per year . . . A stump-type T1 fastener replacing a pull-up type on one section of the B-52 saved \$100,000 . . . A corrosion-resistant steel washer replaced a stainless one on the Minuteman, cutting cost from \$1.51 to \$0.005 each—a 99.8% saving.

ABMA

Brig Gen Richard M. Hurst, commander of the Army Ballistic Missile Agency, Huntsville, Ala, said recently that he hoped, through VA, to increase by 25% the number of missiles produced. He feels more effective communications are major answers in achieving economy, just as they are in achieving reliability.

HOW ARE SPECIALIST GROUPS ORGANIZED?

■ In coordinating reliability, quality control, value engineering and other special functions, how do you set them up? This is the third question in our survey, and the least important in the opinion of engineers who have been through the experience of setting up such groups. **They point out that the first problem is to establish and agree that these functions have merit, can be used, and will result in gain for the organization.** The concept is the same for every organization, regardless of size, complexity or product. How important is quality or integrity compared with price? What is management's attitude?

Next comes the function. This may differ because of product, personnel, quantity to be produced, and like factors. A simple, traditional product, on which design is changed infrequently, suggests emphasis on VA and QC; a complex, limited-production, costly item shifts emphasis to Reliability and VE. Is the function to monitor, to advise, to audit, to control? Which factors are to dominate if trade-offs are necessary? What authority will be granted the group?

Finally, the organization itself, which differs widely from plant to plant, even from division to division or department to department within a company, just as Engineering itself does. It varies with product, with quantity, with complexity, with manufacturing method, and particularly with personnel. And it will vary markedly with management's definition of the function being discussed.

A Quality Control Group will not do the same work in every company; reliability does not mean the same thing in any two plants. Even the semantics are a problem; there are no standard definitions. One large company spent three days of conference time to arrive at acceptable definitions of basic terms. These are shown here (page 84)—and will be challenged immediately by everyone.

But there are certain broad areas of agreement.

Most engineers agree that value analysis is part of Purchasing, that quality control is Manufacturing-oriented. But some companies have Reliability Groups or Quality Control Groups reporting to general management, some have QC reporting to the head of Engineering and monitoring production, and so on.

Where Reliability fits in

While VE and R are generally engineering-oriented, there are exceptions. One maker of missile components has the R group as part of Quality Control, so the emphasis is on production and testing (quality assurance) rather than on design. The group conducts a tight receiving inspection and makes sampling tests of incoming items, obtains and analyzes failure data and test information from facilities and subcontractors, but has virtually no contact with Engineering. Incidentally, its submergence in Quality Control has led to a high turnover of men as they attain competence.

Several companies combine Reliability with Standards, an apparently sound combination. In one large setup, such a group acts in a checking and advisory capacity, while actual R testing on new products is done by a product-testing laboratory. This well-equipped group is independent of Engineering, monitors all new designs in the breadboard or prototype stage.

To an increasing extent, Reliability Groups are in Engineering and report to the chief engineer. The parallel function of acquiring data in procurement and manufacturing is performed by Quality Control. Failure reports feed R data to QC and other groups. This is in line with the Navy approach, although the Air Force prefers (AF 375-5) to have R report at the top—to division or general manager.

Quality vs Reliability

Reliability and quality are being linked increas-

ingly in industry, with each word having a special meaning. Reliability is the newer concept covering the probability that the product will perform satisfactorily a specified function under given conditions for a specified period of time. Quality is perhaps more properly "quality assurance"—the integration of all functions to achieve a product that meets all requirements—thus somewhat parallel to reliability. This "quality" covers the analytical and preventive aspects of quality control, as well as quality control itself.

In a major missile producer, R is given top priority, the Group reporting to the general manager. Data from Engineering, QC and Product Support (field engineering) are combined in

THE COST OF RELIABILITY

"It isn't reliability that costs money, but unreliability." This slogan has been prominently displayed by some companies, supported by evidence that the less-reliable product requires larger inventories of spare parts, increased maintenance and costly repairs. It is of course obvious in the case of non-maintainable assemblies like missiles, rockets and satellites, almost as true in the case of critical products like airplanes, safety devices, warning devices—even automobiles—where failure may result in total loss accompanied by loss of life. But it is none the less true in products where the results of unreliability are less evident.

Reliability often also increases the cost of engineering design—something that chief engineers are guarding against these days. But the over-all result may be a saving as a result of lower costs in testing. Similarly the apparent conflict between reliability and value analysis may not exist in actuality because the simplification of design that results from value analysis usually also increases reliability.

The Minuteman missile, for example, offers no greater performance than its predecessors. Its major advance is in reliability—to two orders of magnitude. Reliability in missiles is characterized by one R head as "nit-picking meticulousness", which must involve itself even with the infrequently occurring causes of failure, to maintain a reliability that cannot be measured. The real question is whether the popular "permissive management" system is good enough; at least one missile maker has gone back to authoritarian methods, because the only controllable factor in missile production actually is labor.

A curious offshoot of current emphasis on reliability occurs in connection with fuel cells. Battery reliability is extremely high—one failure in 100,000 is considered unusual and almost disastrous. The fuel cell and other new power sources must approximate that reliability before they can go very far.

the Reliability Group. Mathematical data from Engineering are monitored there, and close liaison is maintained by R men assigned to Engrg and QC.

Reliability is still basically a "dependability" program in non-defense industry, with data and techniques being added to give mean-life-to-failure data and the like. A typical setup places test or prototype units in the hands of selected customers at the same time the company does its own testing. Statistics from both groups can be transferred to punch cards and data collated for study by a product-improvement committee.

Experience in one plant during the past three years indicates that infant mortality occurs within 25 hr, and that 100 hr of use in test or in customers' hands corresponds to about three months of service use. In regular production, four of each 100 units produced are tested; one failure stops shipments until the difficulty is corrected. This company, incidentally, makes styling changes only when tools or dies wear out—usually 1½ to 2 years.

HOW TO SET UP VALUE ENGINEERING

Before there can be a VE unit, management must understand what the VE unit can do and be willing to support it to the hilt. This means that management must be willing to admit that unnecessary costs can exist, and why they are there. Management must have a "constructive discontent."

VE is not purely a "big-company" operation; it can be handled by one competent man if necessary, or even by a part-time consultant, if the atmosphere is right and proper indoctrination is provided for decision-making people. It can also be applied regardless of product quantity or complexity because it is essentially a review or advisory operation, asking the questions about the trees when the designer and production man are preoccupied with the forest.

If we accept the increasingly common designation of value analysis as cost reduction, value engineering as cost prevention, there must be two operations: VA in Purchasing, and VE in Engineering. Or an over-all department or group can be set up.

Where does VE report?

Of 20 companies polled by Electronic Industries Assn, VE reported to Manufacturing in three, Manufacturing Engrg in four, Engineering in five, Purchasing in five, top management in two and Industrial Engineering in one. There is no single "best location"—it will vary somewhat with personnel and organization of a particular company and with the ability or bent of the man who heads it up.

Experienced value engineers are hard to find; the idea is still relatively new and has been growing slowly. The successful man must get along

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with line executives, yet retain his ability to pry into problems. In a way he must be an anomaly—a well-rounded experienced man with an active curiosity.

The value engineer's job

He should be able to set up and operate training programs, lead and operate cost-reduction committees, act as value specialist in design reviews, handle depth studies on product evaluation, direct and train special task groups, and suggest basic cost-control efforts. Above all, he must not be given other responsibilities "part time" or the whole effort will collapse.

Given a man, goals must be established—usually in terms of ratio of cost to return. A good VE department should return from 10 to 20 times its cost. (The Navy started in 1954 with 10:1, is now at 16:1.) It must of course start slowly and be content with less initially—working with simple parts and simple problems until the skills of its members and outsiders working with it mature. Unless skills and interest are built up outside the group; unless the cooperation of the line organization is built up, the effort is almost certain to fail.

Obviously, proper facilities must be provided and the relative authority and responsibility of the group must be clearly defined. It must have access to data and records so its effects can be shown.

Some companies have simply designated men from their own staffs as "value engineers," and in effect use them only when they have a competitive problem. This achieves some results, but is by no means as effective as constant attention to VE by a man or men trained to look for savings. **It is important that someone (preferably trained) be given long-term responsibility for cost savings, with no other assignment to split his loyalties or interest.**

Training of value specialists is an essential step toward maintenance of a program, far better than the pirating that has been practiced. Specialized training is of the workshop type ranging from 40 to 120 hr. Most training plans use vendor specialists, and have teams from all departments evaluate proposals developed in training.

Sources of information

Programs can be conducted by outsiders within a plant or for a local group. Among organizations doing such work are Value Analysis Inc; Industrial Education Institute; University of California. Northeastern University is developing a program, as is Electronic Industries Assn.

Training courses must be followed by periodic refreshers. GE, for example, follows basic training by six months of experience, then a refresher, another six months of work, and another refresher.

Papers of the VE Symposium of the EIA in 1959 are available from Engrg Publishers, Box 2,

Elizabeth 2, NJ, at \$6 per hard-backed copy. Papers of the 1960 symposium will be available soon at \$7.50. Industrial Education Institute has a VE and VA Reference Manual at \$15, Industry Reports Inc, 1327 F St, Washington 4, DC, has Value Engineering Weekly at \$75/year. L. D. Miles has written a book on the subject, to be published by McGraw-Hill in August.

WHAT'S "PRODUCT ASSURANCE"?

As product complexity has grown, retained engineering experience has declined with personnel turnover, shortage of engineers, and other factors. Consequently, design time has increased, while time to product obsolescence has decreased. Within adequate development, the design may become obsolete before it has matured. Thus the traditional method of basing final design on user data is now too slow.

This situation has given rise to the new function known as product or quality assurance, which combines performance, reliability and economy. This is often handled by a separate group, collecting data from design, production and the user, evaluating it and feeding it back to Engineering. Essentially, Product Assurance combines reliability and value analysis.

Activities of a Product Assurance Group encompass:

1. Collection and evaluation of performance, cost and reliability data.
2. Development of assurance tools—component and system indices, economy techniques, design-effort allocation, publications, reliability techniques, and a regular report.
3. Education and consultation—regular seminars are held for all engineering departments.
4. Design review—check user needs, system and component design, test and operating results, as design develops.

SLOGANRY

While there are violent objections to any such term as "idiotproof"—and sincere belief that no designer should be responsible for incompetent operation of his products, the expressions concerned with this element continue to grow. Some current ones:

- **Make the design GI-proof**
- **A design can be made foolproof, but not damfool proof.**

One company has developed this 4-step formula for reliability, called the "DMUF system:"

- **Design it to be reliable**
- **Make it like the design**
- **Use it as intended**
- **Feed back the results**

Some wag promptly dubbed this the "Damn Mess Unless Followed" system.

5. Test design and criteria—statistical techniques for determining minimum time and cost for tests by purchaser, design, and production.

6. Automatic model updating—collect and disseminate to Engineering information on design changes and how well model is meeting the design objectives.

7. Industry participation—exchange information and research literature and meeting reports.

Most useful of the PA Group's activities is the Product Assurance Report, basically a tool to locate components most deserving of extra effort

and to demonstrate attainment of results in dollar savings. It can also be used by management to monitor progress or slippage in competitive position, vendor selection, cost reduction, reliability and added value.

Each system or major component is listed and data recorded for time period, quantity, number of failures, life in hours, and the prevention, down and rerun percentages of time under load. Cost of failure in product performance can be computed for equipment, maintenance and user losses from equipment failure.

IS PRODUCTION LOSING ITS GRIP?

■ In the light of the long-term trend toward specification and control by Engineering (or Production Engineering) of such elements of operation as heats, heat-treats, solutions, feeds and speeds, method of manufacture and many other elements of processing, there seems to be a shift toward relieving Production of many of its responsibilities. In our interviews we suggested, therefore, that there might be a shift toward a three-section Engineering setup: (1) R & D or Advanced Design, (2) Product Engineering, (3) Testing, Value Engineering, Reliability and similar services. We further suggested that the first two sections might handle new and redesigned products straight through into production, leaving the Production Dept as primarily a labor-handling setup.

This generated much comment—for the most part that this would not happen. The general feeling was that Engineering and Production would remain separate, with present functions. Reliability, Value Engineering, and like groups will be in Engineering; quality control, production test, material supply, shipping, inventory, safety and like functions will remain in Production.

However, there are these two trends: (1) Addition of, or strengthening of, control groups reporting to top management to monitor and audit over-all effectiveness of production in adequately meeting customer requirements at minimum cost. (2) Increase in technical capability of the line organization for more scientific approach to production processes with increased use of machine programming, computers and analysis.

Here are typical opinions:

- "It depends on product, conditions and personnel, but, generally speaking, the technical functions should be in one department so the buck cannot be passed. Put all functions of manufacturing in Manufacturing; all design, performance and reliability in Engineering. Then make sure the two departments work together."
- "Product Engineering should report to the plant manager with Manufacturing, Assembly, Quality Control and the like. Closer association is necessary between Engineering and Manufac-

turing, with one senior vice-president in charge of the two functions."

- "We have noted a swing back to real manufacturing management in the last year."

- "Too many functions dilute the effectiveness of Engineering. Manufacturing needs to develop its own creative approach to processes, plant layout and materials handling and must move forward in step with development and product-design activities rather than resigning such future higher orders of capability to the development groups. This is necessary if the R & D and Product Design groups are to be kept free . . ."

"A production design group in Engineering Research can organize project designs for production, but should not take on tool engineering even though its members know how any part will probably be manufactured. Quality Control is growing in effectiveness so rapidly that it can be used in Research, Engineering and Manufacturing."

- "Product Engineering at the plant level should report to the plant manager with Assembly, Quality Control and similar services. This will need a better association between Manufacturing and Engineering."

- "Engineers should devote themselves to technical work and let others operate after things are spelled out. Also the motivations necessary to produce economy carefully and to schedule are different from design motivations. Product Engineering and Tool Engineering must be coordinated to get new models out on time, but this has been accomplished by liaison rather than by placing Tool Engineering in Product Engineering. Tool Engineering is a function of Manufacturing rather than of Product Development."

- "Product Engineering and Tool Engineering may or may not be a portion of the development responsibility, depending upon the plant environment. The principal function of production is to make a product according to schedule and costs, and add improvements that do not affect performance. Production is essentially a labor setup and management organization."

- "Product design, tool engineering and produc-

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tion engineering must be coordinated very carefully, but we do not expect control of one by the other."

- "Inspection responsibility has been largely taken from Production in recent years, and given independent status, reporting directly to management rather than to Engineering. Thus it has full responsibility for quality. The trend in the automobile industry is to separate Reliability and Quality Control functions."

- "We have kept tool design, process control, inspection and statistical quality control in Manufacturing, but have cost reduction, value analysis, quality control and reliability under the Product Improvement section of Engineering. Test facilities are individually controlled by the groups that need them, and are geographically separated."

- "We need engineers trained both in product engineering and production engineering—then we could have a single engineering management." (This is one of the few dissenters.)

A longer aircraft analysis

- "While our situation may not hold in general industry, the following pattern is common within the airframe, missile, space, and electronics industry. Advanced design groups generally work

with operation analysis and concepts. Preliminary design groups reduce a concept to a product with specifications for performance and evaluate aerodynamic and dynamic characteristics. Testing usually is a staff engineering function concerned with initial qualification and environmental testing of various types on components and elements of the design; it does not include production testing performed by Quality Control.

"Value Engineering, which includes Value Analysis and Reliability, is usually a staff engineering function reporting to a relatively high level of engineering management. Production Engineering is usually a Product Engineering function and reports to engineering management; it includes certain phases of value engineering such as evaluating design for ease of manufacture, low maintenance, cost and standard components. The tooling function consists of pre-planning, tool planning, tool design, and tool making, usually reporting to Manufacturing rather than Engineering. The pre-planning in tooling and production engineering work closely to make the design producible.

"In the missile and space field, much of this work is done under engineering management; however, quality control is usually a general management function."

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 Stromberg-Carlson, San Diego—E S Winlund, engineer; Ed Myer, applications engr
 Studebaker-Packard Corp, South Bend—M P de Blumenthal, chief des engr
 Stewart-Warner Corporation, Chicago—E G Wicklatz, manager of Engrg
 United Shoe Machinery Corp, Research Div, Beverly—W L Abel, Asst Director of Research
 Western Electric Company, Inc, NYC—T E Shea, vp-Engrg Division
 Westinghouse Electric Corp, Pittsburgh—J A Hutcheson, vice-president
 Whirlpool Corp, St Joseph—Wm E Mahaffay, vice-president