DETERMINATION OF THE BEST TECHNIQUES FOR
ACCOMPLISHING THE TRANSFER OF ORDNANCE PROJECTS
FROM THE DEVELOPMENT STAGE TO THE PRODUCTION STAGE

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Acknowledgments</th>
<th>iii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Discussion:</td>
<td></td>
</tr>
<tr>
<td>The German Way</td>
<td>5</td>
</tr>
<tr>
<td>Coping with Bigness</td>
<td>9</td>
</tr>
<tr>
<td>Freezing for Production</td>
<td>12</td>
</tr>
<tr>
<td>Establishing Contractual Relations</td>
<td>15</td>
</tr>
<tr>
<td>with the Using Agencies</td>
<td></td>
</tr>
<tr>
<td>Discussion of Industrial Survey</td>
<td>21</td>
</tr>
<tr>
<td>Conclusions</td>
<td>38</td>
</tr>
<tr>
<td>Bibliography</td>
<td>43</td>
</tr>
<tr>
<td>Appendix I, Composite of Industrial Survey</td>
<td>46</td>
</tr>
<tr>
<td>Appendix II, Standard Operating Procedures</td>
<td>50</td>
</tr>
<tr>
<td>Appendix III, Military Design Objectives</td>
<td>62</td>
</tr>
<tr>
<td>Appendix IV, Some Government Research Facilities</td>
<td>64</td>
</tr>
</tbody>
</table>
DETERMINATION OF THE BEST TECHNIQUES FOR ACCOMPLISHING THE TRANSFER OF ORDNANCE PROJECTS FROM THE DEVELOPMENT STAGE TO THE PRODUCTION STAGE

INTRODUCTION

A weapon, or any product for that matter, does not just happen into existence. Quite often ordnance products seem to appear from nowhere, and apparently are developed and produced overnight. Such is not the case with the usual ordnance product. Sometimes this mirage is the result of careful and successful security techniques. Often it so happens that the new weapon is overlooked until it becomes prevalent and eminent. Usually the weapon has weathered many processings before it goes into the field. The objective of this thesis is to delve into certain phases of such processings with the hope of arriving at some conclusion as to the best techniques of accomplishing the transfer of ordnance projects from development to production.

There is no standard procedure for developing a new product and finally producing it in quantity. The possible broad phases are as follows:

1. Fundamental Research - the search for new facts, with or without immediate application.
2. Applied Research - the search for specific facts for the purposes of immediate application.
3. Development - the application of the facts derived from research, resulting in the evolution of a tangible, refined article.
4. Design - the establishment of the physical form and characteristics of the developed product to be manufactured.

5. Production Engineering - providing the manufacturing facilities for making the article.

6. Production - the actual shaping of the article to its completed form, ready for use.

7. Distribution - getting the product to the right consumer at the right place at the right time.

8. Sales - securing buyers for the article.

9. Use - the consumption or employment of the article.

In the U. S. Army the usual new weapon goes through the following steps:¹ (See Table I) (Page 3)

1. The idea is conceived, military characteristics formulated and the project initiated by agreement of all concerned who hold membership on the Ordnance Technical Committee.

2. A preliminary design is made by Ordnance officers and engineers.

3. The project is assigned to an Ordnance Arsenal, a scientific agency either governmental or private, or to an industrial concern. (Today the majority go to private industry.) This facility completes the design and produces pilot models.

4. The pilots are first tested at the Ordnance Department's own Aberdeen proving Ground. It may be sent back to the developing agency several times before it proves satisfactory to Ordnance. Only then is it sent to the potential customer.

5. The Service Boards, which are tactical and technical testing grounds of the combat branches of the Army, then give the new development a thorough service test under field conditions. For instance, the Infantry Board at Fort Benning, Georgia will, among other tests, give the new item to troops on an exhaustive maneuver, or the Air Force will turn it over to returned combat flyers at its Elgin Field in Florida.

6. After being pronounced battle-worthy by the Service

¹Hoppoch, D. W. "How the Army Ordnance Develops Weapons for Its Customers". (Product Engineering, June, 1945)
BIRTHPLACE OF NEW WEAPONS – THE ORDNANCE TECHNICAL COMMITTEE

CHIEF OF ORDNANCE

ORDNANCE TECHNICAL COMMITTEE

Membership:
Using Arms, as shown below, plus Chiefs of Major Divisions and Branches of Ordnance Department.

General Function:
To consider and recommend technical action upon all matters affecting Ordnance material designed for the Armed Forces, and related matters.

INDUSTRIAL SERVICE:
Manufactures and procures items of Ordnance standardized by O.T.C.

RESEARCH & DEVELOPMENT SERVICE:
Conducts research and development programs upon recommended O.T.C.*

FIELD SERVICE:
Stores, issues, and maintains Ordnance items standardized by O.T.C.

ARMY GROUND FORCES
Anti-Aircraft
Armored Command
Coast Artillery
Infantry
Tank Destroyers
Electronics

ARMY AIR FORCES
Air Ordnance
Material Maintenance
Design

ARMY SERVICE FORCES
(Other Technical Services)
C. W. S.
Chaplains
Corps of Engineers
Medical
Provost Marshall
Quartermaster
Signal Corps
Transportation
W. S. C.

ALLIED AND OTHER U. S. USING ARMS
Navy
Marine Corps
British Army
R. A. F.
Canadian Army

TABLE I

Ibid

*Author's exact wording.
Boards, and after full approval by the various interested headquarters in Washington, the new weapon is placed before the Ordnance Technical Committee for standardization.

7. The new item is placed in mass production and issued to combat troops.

The above steps by no means constitute a complete picture of how a new ordnance product gets to the forces in the field. Some products have their inception at various steps along the way; others have to run the entire gamut. The rules in each stage are different for each product. Some products are difficult of design, but afterwards easily produced. Also, the chronology is not the same for each product. In fact, the multitude of product pathways gives this writer pause in the pursuit of the problem. This thesis shall try to see if there is a best pattern in the seeming jumble - or any order in the apparent chaos.

There must be some boundaries to the problem. The term Ordnance, itself, is quite broad, but it infers that the eventual customer is the U. S. Government in this case. It is the intention in this thesis to take up the product when it is well advanced in the development stage, and drop it off when it is put into routine production. Still there is no clear cut boundary, for a look ahead and a look behind is mandatory in such evolutions. The look behind is necessary to make sure the line of march is not a circular one traversing the same stretch of forest over and over; the look ahead is necessary to assure that the present efforts contribute to the ultimate goal.
THE GERMAN WAY

This writer had the opportunity and duty at one time of carefully studying and using a highly technical German weapon. Shortly after World War II a study was made of a German acoustic homing torpedo. This writer was assigned the job of Project Officer for this endeavor with the duty of making the torpedoes ready for firing, loading the torpedoes onto a German submarine, and advising the ship's officers in the firing of the torpedoes. Some observations were made at that time which, it is believed, would be pertinent to the problem at hand. The objectives of this thesis and the thesis itself were not even a gleam in the writer's eyes at that time, and it is felt that, accordingly, many worthwhile points went by unnoticed. Nevertheless, some relevant items of interest were noted and are passed on to the best of recollection.

The most striking thing about the torpedoes was the superior workmanship that was evident. The individual parts were of the highest quality and were assembled with a great deal of ingenuity. The over-all effectiveness of the weapon can be completely appreciated only with the realization that the Germans attained 51% hits in operational firings during World War II.

One very outstanding feature of these torpedoes was the arrangements for field repairs. Tests were easy to conduct in order to verify the proper functioning of the acoustic circuits. The acoustic panel was so arranged that, whenever a trouble developed, an entire section would be replaced instead of indi-
vidual leads, condensers, tubes, resistors, and other such individual electronic items. This feature greatly simplified maintenance, eased the inventory problems on board ship, and eased the training problems for maintenance personnel.

These accomplishments by the Germans were not attained without compromise elsewhere. The design problem probably was terrific, for the selection of parts for each replaceable unit must have been a tedious job. This writer did not determine how wisely the choices were made in these instances. The general impression received at the time was that the Germans' efforts with this particular weapon were directed toward making an excellent piece of machinery with little consideration given to arrangements for quantity production. Apparently the Germans neglected these manufacturing virtues in favor of superior manual workmanship.

A torpedo is not a highly competitive weapon. It does not compete tactically with another torpedo. The principal competition to a torpedo is torpedo countermeasures. There is usually an appreciable time lag before countermeasures become effective. In addition, the forces in the field gradually gain proficiency in the use of a torpedo, thus staying one jump ahead of the enemy's countermeasures. This particular torpedo was put to operational use early in the war. The impression is that the torpedo was the product of peacetime research.

The Germans had a wealth of such research products. Their research effort was quite successful, and just before the war broke out, Germany had a good sized inventory of research data with which to build successful weapons of war. The above com-
ments on one of her torpedoes indicate that Germany was highly successful in all phases of producing weapons, including the development stage. In general, however, her development efforts were a failure.\footnote{Simon, L. E. "German Research in World War II", (John Wiley and Sons, New York, 1947. P. 206} It was especially in the field of highly competitive development of rapidly changing weapons that she failed. 

**Combat aircraft is an example of what is meant by a highly competitive weapon.** It must compete with its own kind. The American fliers who had contact with German planes and returned to their bases reported the characteristics of the German planes to combat interrogators. The gleanings of these interrogations became the basis of re-design of existing planes, or the development of new ones. The Germans met their match in this see-saw game of development when they acquired America as an enemy.

Paul Wooton quite correctly deduced this German weakness as early as 1942 when he stated:\footnote{Wooton, Paul, "Engineering in Washington". (Product Engineering, February, 1942). Page 114}

"Fortunes of war have put Germany in an awkward position regarding aircraft. The Nazis developed some fine airplanes up to 1936 and 1937, and they put them into production for a quick victory. The victory didn't come. Meanwhile, the United States, and other countries to a lesser degree, went from Germany's freeze point forward with the result that Germany is now desperately working on development of new models to meet the threat of ours. They have a few new ships, but not enough good ones to meet Boeing and Consolidated heavy bombers, our Airacobras and Republic fighters for low and high altitude respectively, our Martin and North American medium bombers, and others - some fifteen top-notch planes in all. Meanwhile, the United States, with its vast manpower, can spare enough engineers to go right
ahead with full-scale development of new planes."

There are two comments to be made regarding Wooton's statement above. First, he mentions the fact that Americans went forward from Germany's freeze point. It must be recognized that somewhere along the pathway a weapon must travel in going into production a decision must be made as to when to stop trying to improve the weapon and put it into production. This firming of the product for production is what Wooton was speaking of. The subject of freezing for production is discussed elsewhere in this thesis.

The other point of comment is in regard to the inference that America beat Germany in the development race because of the sheer number of development engineers available in America. This implication is not true, for the Germans were not lacking in development personnel. The principal failure was improper allocation of effort. High command decisions, political and military, inhibited development effort by diverting personnel and funds from development activity to other activities such as production. These decisions resulted in insufficient and inadequate development accomplishments.
COPING WITH BIGNESS

Leslie E. Simon, in a discussion of a German Air Force Research Organization Chart, stated: 1

"If the Air forces chart appears enormous and confused by lines of partial and overlapping authority, then it is truly representative of the organization. It is not at all unlikely that the chart contains some omissions and minor errors, since the information was obtained from the interrogation of a considerable number of persons. Very few people knew much about the organization. Only those at the very top, like the members of the Forschungsführung were permitted to know such broad matters, and persons who were that high in the organization were rather hazy about details."

The above points out the opportunities for inefficiencies within the individual segments working on a particular problem. For security reasons the segments may be prevented from close exchange of ideas and information. The man who does have access to the panorama of the problem is usually, as stated above, "hazy on details". The usual practice is to have a very eminent man in this position. His time is usually absorbed in many enterprises of his parent and other organizations. He is involved in conferences, committees, reports to higher-ups and other such drags of time. These nuisances prevent absorbing the details of the over-all picture of which he has cognizance. (I am assuming the particular person in mind is made aware of the over-all organization for action and not just for information purposes.)

A similar situation is frequently encountered in de-

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1 Simon, L. E. "German Research in World War II". (John Wiley and Sons, New York, 1947), p.69
velopment of new products not involving security considerations. Here the problem is mainly a matter of time available. The men in or in charge of the various segments evolving a new product, although uninhibited by security regulations in the exchange of information with other segments, are necessarily prevented from full absorption of all details available from these segments by the element of time. As in the previous security consideration, the man charged with following the over-all picture is frequently a VIP in the organization, and consequently "hazy on details".

A good over-all picture of the details - not a hazy knowledge of them, would undoubtedly pay dividends. Within each segment of the enterprise some details are neglected; others are uselessly pursued. Within that organizational segment the action with respect to such details may seem to be fruitful and applicable to the enterprise, but a man with the over-all picture in mind who "closely" follows details would be able to spot these inefficiencies and correct them. To have a man who is fully aware of the over-all problem and is able to closely follow all the details would be the ideal solution. As the enterprise becomes extensive, however, such men become increasingly difficult to find.

This discussion now seems to approach a more academic dissertation, for one question comes to mind: What shall be done when the organization becomes so large that it becomes impossible for the man in charge to closely follow details? He naturally becomes "hazy on details". The only course of action which approaches a solution in this case is to accept the fact
that the problem exists. The logical choice for the saturated executive is to be selective in considering details and to delegate remaining details to competent subordinates. A little of the philosophy of Quality Control is in order.

An additional balm for the aches of bigness is the formulation of a suitable organization and the selection of suitable men to complete the organization. This problem is approached from two directions - forming the organization, then choosing the men, or vice versa. The usual practice involves a little of both. Tasks involving routine or common talents permit the selection of men to suit the organization. Unique talents usually demand that the organization be oriented about its personnel. Frequently this trait can be recognized by observing organization charts. The stature of certain persons in the organization becomes evident. The organization of the KOPPERS Company for developing a new product is a pertinent example. In that company the Director of Research is the dominant man in the entire organization. As mentioned on page 24 of this thesis, he follows and has authority over a new product until production becomes routine.

Coping with bigness is principally a problem of organization. Each echelon of authority must organize its own time and efforts, maximizing the important details and minimizing the unimportant ones. The organization formed must be a balance between the assigned objectives and the personnel available.
FREEZING FOR PRODUCTION

In the evolution of a new product, progress and improvement are the goals of the entire endeavor. Were this not so there would be no need for new products. Contentment with the old product or the old production methods would override any such urge for progress. Commendable as this progressive urge may be, it has a point of diminishing returns. With every new product effort there must be some point in the evolution where someone in authority says, "All right, we've got to produce this thing. There's still room for improvement, but the delay in production is not justified by the expected improvements. Start production now."

That decision is easily uttered, but not easily reached. The person making the decision is caught between two fires. On one side is the demand for the product and the demand for economy of development and design effort. On the other flank is professional pride and zeal for perfection, if the man is conscientious. The decision is usually a compromise between these demands. Let us look into the possibilities of making this decision an easier one.

A wise commander strives to have an available retreat, just in case. The burden would be lessened somewhat if the decision to start producing were not a point of no return. If the decision is completely, inalterably final, it has to be very carefully considered. But, if it can be hedged on, it can be entered with a little lighter heart. One way of accomplishing this facet of the problem is to set up production ma-
chinery that can be changed without too much effort, and without too much loss in production during the changeover. Let us consider G. F. Nordenholt's words on this subject.

"Referring to the statement that airplane designs are frozen, the number of design engineers now engaged in improving American military planes refutes that statement forcibly. Mr. J. L. Atwood, in his above quoted speech, (J. L. Atwood, Executive Vice-President of North American Aviation, Inc., in his talk at spring meeting, 1942, of American Society of Mechanical Engineers) stated that, 'now there are actually more designers working on improvements than were required to produce the original design.' Exclusive of clerks, blueprint boys and secretaries, the number of design engineers ranging from draftsmen to engineering executives now employed by the major aircraft companies ranges from 800 to 1,500 in each company.

"As a conservative estimate, considerably more than 12,000 engineers are now engaged in the continuous improvements of the design of the American military planes. In addition to these engineers, there are those that are engaged in the continuous improvement of the airplane engines, the propellers, and the hundreds of accessories that enter into a complete ship. The sweat and brains of these thousands of engineers will maintain the supremacy of the designs of American military planes. But this manpower cannot produce effective results unless the production methods in aircraft manufacture continue to be such that design changes can be made without seriously interfering with production schedules. That is why steel dies have limited use in aircraft manufacture, and why rubber pads, wooden die blocks, zinc dies, router boards, and similar methods sometimes derided by the uninformed, must continue to be used. And that is why the American aircraft industry has been able to build up to its present large production in spite of the fact that at the same time it developed and put into production a succession of new models, thus attaining air supremacy in both numbers and quality of planes."

It must be kept in mind that die-casting is not always prohibitively expensive and permanent in the manufacture of weapons. Do not arbitrarily eliminate die-casting, for it may be the most economical compared with sand casting, forging, or stamping. One outstanding case in kind is encountered.

1Nordenholt, G. F., "Aircraft are Different", (Product Engineering, July, 1942), p. 371
in the manufacture of link trainers. In one set of parts the cost of machining sand castings was so high that a die would amortize itself (with relation to sand castings) after 211 sets had been cast. It should be kept in mind when striving for flexibility of production methods that mass production techniques do not always require production on a big scale for economic justification.

Freezing for action also permits the pooling of efforts by several industries and the concomitant liaison between them, which, if properly pursued, promotes the exchange of ideas to the mutual advantage of all.

As a rule the product of one company is accepted as "the model" to be produced and a combination of companies produces that particular model. The models that are shelved or laid aside are not necessarily bad. They are merely the victims of a standardization effort. The model selected usually comes closer to meeting all the requirements than do the others. The necessity for flexibility of production methods with such a combine is obvious.

Freezing for production is a paradox. It is necessary to freeze the design long enough to put the weapon into production, enough production to overpower the enemy. Yet, improvements must continually be made if the weapons that are produced are going to be on equal or better footing with those of the enemy. Flexibility of production methods is the apparent answer.

1 "Link Trainer Saves with Die-Castings", (Product Engineering, October, 1942), p. 576
ESTABLISHING CONTRACTURAL RELATIONS WITH THE USING AGENCIES

The manufacture of Ordnance equipment infers that the potential customer is the United States Government. Knowing the government is the customer eliminates certain problems and introduces certain others. In the ordinary course of the manufacture of items to be sold to the general public, the potential sales volume is, in the final analysis, unknown. The acumen and experience of sales representatives often make possible a close estimate of potential sales, but even then considerable tolerance must be allowed in utilizing this estimate. Commercial history reveals many instances where great production was foreseen and planned for, only to be met by unexpected consumer resistance which quite effectively cancelled out the anticipated amortization of a steep investment in production machinery and equipment. Similarly, many enterprises have been caught totally unprepared for the great demand by the general public for the new product. The production equipment provided in such instances is pitifully inadequate, and customers go begging. Herein, losses are incurred by either not satisfying the demand, or, in some cases, by losing production time in re-tooling for greater production. In extreme cases losses are realized when it is decided that the machinery originally provided is incompatible with the proposed machinery and has to be junked. In addition these re-estimates of production rate versus consumer demand might prove to be just as
erroneous as the original estimate, for the will o' the wisp of a product's popularity frequently disappears just as rapidly as it comes forth.

Such is not usually the case in meeting government demand. Federal contracts, as a rule, are quite definite in regard to quantity desired. Whenever the amount desired is indefinite, guaranteed minimums, graduated pricings, and other conditional clauses are included to soothe the uncertainties.

Unfortunately, however, there is one big disadvantage encountered when the U. S. Government is the customer - RED TAPE. Of late much has been said in newspapers of "five percenters" in and around the Washington scene. "Influence peddling" has been the usual charge, and probably not without justification in many cases. Many times, however, the "five percenters" were merely men who had the knack and know-how of cutting government red tape. It might be economically wise in some negotiations to engage the aid of such an individual, but it is not always necessary or advantageous. The government would like to cut out these middle men just as much as would industry. Accordingly the federal government puts out many pamphlets which undermine the lucrative five percent business. Some of these pamphlets pertinent to this study are as follows:

1. Selling to the Government covers all government agencies. It includes a summary of who buys for the government; where to get information; how to obtain government business and how the government buys. Obtainable from the

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1 "Designing for Military Requirements". (Product Engineering, January, 1951), P.90
2. How to Sell to the United States Army describes where and how Army purchasing is accomplished. It explains also the general form of government contracts and defines some standard clauses and terms. Major portion of the booklet consists of a list of purchased items and the appropriate purchasing offices. For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price is 30 cents.

3. Selling to the Navy discusses military procurement in greater detail than either of the foregoing. Among topics covered are: specific differences between government and civilian purchases; detailed description of the Navy's procurement organization; how to get a Navy contract; discussion of contract clauses and execution of same; inspection; addresses of purchasing offices and inspectors. For sale by the U. S. Government Printing Office, Washington 25, D. C. Price is 15 cents.

4. A Guide for Selling to the United States Air Force tells who buys Air Force equipment; what items are purchased; where Air Force procurement offices are located, and how material is purchased. Obtainable from Procurement Information Center, Office of the Assistant Secretary of the Army, Room 3-D, 749 The Pentagon, Washington 25, D. C. No charge.

5. An Introduction to Planning for Emergency Production is a brief resume of the Munitions Board production allocation program. The aim of this program was to decide which firms were to produce what equipment in the event of a national emergency. Available from Central Military Procurement Information Office, Room 3-D, 760 The Pentagon, Washington 25, D. C. Free.


7. Consolidated Synopsis of Department of Defense and General Service Administration Procurement Information is a list of proposed purchases. Specific information is given on type of equipment, quantities and originating office. Issued daily - no charge. Available at U. S. Department of Commerce Field Offices, and at the Central Military Procurement Information Office, Room 3-D, 760 The Pentagon, Washington 25, D.C.

The foregoing bibliography should be of some use as background material in getting a contract from the government. Often it will be found that the government agency which wants the research product will be a tyro in the field of negotiating a contract. The foregoing bibliography should help some in such a case. This bibliography is not a compendium, however, and will in no wise take the place of experience.

Of additional interest is a general knowledge of the scheme of government specifications. There are two classifications of specifications:

(a) Performance Specifications which prescribe the functions an item must perform and what tests it must meet.

(b) Detail Specifications which give complete information including design drawings and data on manufacturing processes. Most ordnance material is covered by detail specifications.

The last statement about ordnance material implies many things. It implies that complete drawings and data on the manufacturing processes have to be worked out. It also implies that the company which works out the detailed specifications is not necessarily the company which will manufacture the item. This is true.

Developmental contracts are frequently let in cases where the desired item has no commercial counterpart. The originating branch of the service draws up appropriate military characteristics desired and submits them to the other military services which incorporate their own ideas or requirements which would make the item suitable for that service.

\[2\] Ibid
The proposal then goes to the Joint Chiefs of Staff which issues them forth as "Joint Military Characteristics". These are ideal objectives being sought and not specifications. The military characteristics then go to the Munitions Board which designates one of the military departments as the preparing activity. If it is determined that Performance Specifications are in order, the pertinent military department, after consultation with engineers of other departments, technical societies such as ASME, SAE, AIEE, and AIIE, and with members of private industry, would produce a preliminary draft of the specifications. This draft would go back to other departments for further comment, then to the Munitions Board which publishes the final specifications.

If, however, it is determined that developmental work will be necessary, the service branch designated by the Munitions Board carries out the development or awards a developmental contract. These contracts are awarded on both bid and negotiated bases. The Joint Military Characteristics are presented to pertinent firms and contracts are negotiated in the usual government pattern - sometimes going to the lowest acceptable bidder, sometimes going in segments to various bidders. This developmental contract calls for the delivery of a certain number of production models for test purposes. It is definitely not a quantity order.

At this point the government's control of the project is relegated to liaison rather than direct supervision. The contracted firm assumes authority and responsibility for the project. The coordinating military activity does keep close
contact with the project, lends technical assistance where needed, and helps work out revisions of requirements whenever portions of the military characteristics are impractical to accomplish.

When production models are completed, testing begins. Testing is done by various governmental agencies. Sometimes the coordinating military activity does the testing; sometimes the using arm tries out the product; and sometimes the Bureau of Standards contributes to the testing phase. During this phase "bugs" are eliminated and the design is finalized. Specifications are evolved from the final approved models. These specifications are always of the "detail" type and include complete assembly and parts drawings, tooling information and other manufacturing data. Such a procedure prevents the developing firm from having exclusive control of the project. It will have to compete with other firms for the production contract as distinguished from the developmental contract. It is quite obvious, however, that the developing firm will have a head start on its competitors when bids for quantity contracts are advertised.
DISCUSSION OF INDUSTRIAL SURVEY

In the pursuit of the will o' the wisp of best procedure of transferring research products into production a questionnaire was sent to various industries with research laboratories. (See Appendix I for questionnaire and composite replies.) The questionnaire was intentionally somewhat vague, for it was hoped that the various company representatives would be goaded into giving additional comment, thus yielding more information than any questionnaire could possibly give.

Each of these companies, knowingly or unknowingly, has made an analysis to determine the best method of accomplishing the transition from research to production. They do accomplish the transition. Some do it in a heterogeneous, inconsistent fashion; some follow standard operating procedures. The standard operating procedures themselves may be the result of disorganized trial and error, or they may be efficiently and shrewdly deduced plans. But each company has analyzed the problem and has a solution, whether good or bad. The questionnaires permit an analysis of the companies' analyses.

The first question on the questionnaire was asked to determine the source of research products in each case. The actual details of the administration of research were not asked. The inception point of the analysis is the research result, itself, with no deeper thought on the problems of the administration of research than is necessary or pertinent to the problem at hand. (The other cut-off point of the problem is "routine production".) The breakdown indicates that the survey was taken on companies that do practically all their own re-
search. That means that the company's control of the procedure is very direct, right from the inception of the idea. There seems to be little use made of other sources of research. (It is to be noted that the questionnaire was sent to companies which were known or believed to have research laboratories of their own.) One large aircraft corporation conducts 64% of its research with own facilities and 23% in government laboratories. This arrangement is logical inasmuch as the government is one of its biggest customers. The distribution of the research by the various companies is not particularly significant within itself, but the composite shows that the companies have direct control of over 90% of their products right from the very beginning of the research. This fact introduces the possibility that some of the problems of the transition from the development stage to the production stage originate in the research phase.

If a company could acquire its desired research product from without its own organization, it would be much better off in many ways. Empire builders within the research organization frequently do not want to yield any of their prerogatives over the research product and in some cases exert considerable influence and control over the evolution of a new product - in some instances even in the production phase. To a certain degree this situation is desirable. The research man has acquired knowledge about what will and what will not work with a particular research item. His comment and ideas are quite beneficial so long as they remain unbiased, but research men have the unfortunate characteristic of being
human beings, and their judgment is frequently colored with prestige considerations - personal, professional, or otherwise. This frailty is one of the main nemises introduced by a company doing its own research, but unfortunately the uncertainties of research make it expedient that companies conduct their own research. The objectives of research are nebulous enough within the research organization itself. These objectives are clouded even more when the over-all point of view of the company itself is brought into play. The situation becomes quite complicated when, in the case of farmed out research, the whims and desires of two separate organizations are involved. These considerations make the previously mentioned problems of a company conducting its own research amount to a calculated risk. But let us keep in mind the fact that the problem exists.

The next question on the questionnaire is concerned with the criteria on which the decision to transfer projects from development to the production stage is based. The predominant factor governing this decision seems to be "acceptance by the production group". Jumping ahead to question 8 we see that a good majority of the companies do not permit revisions of any kind to be made by the production department without the design engineer's approval. The inference is that the production engineering effort is forced into the development (and design) stage by the fact that the production department does not accept the project until it is ready for production inasmuch as the production department cannot revise the product
without approval of the development group.

This question of overlapping controls and cut-off points for authority is a point of primary importance to the over-all problem at hand. One company replying to the questionnaires (KOPPERS COMPANY) sent a copy of its standard procedure for developing new products. (See Appendix II) The procedure was broken down into six basic steps: (1) Preliminary investigation (2) Decision to proceed with research (3) Laboratory research (4) Pilot plant evaluation (5) Decision to proceed with the project, and (6) Commercial Plant. These basic steps, of course, have various sub-steps included under them. The manager of the Research Department of this company had the following direct responsibilities in regard to developing new projects: He makes a general appraisal of the preliminary investigations; he makes an evaluation of the laboratory investigation and reports his findings to top management; he makes a report and evaluation of pilot plant operation; he must approve the design of the product for production; he has to approve the design of the commercial plant itself; and, finally, he has a direct voice in the determination of when the plant is ready for production.

It would seem that this is an extreme case of research department authority, and that this authority is carried over much too far along the evolution. For a decision to be worthwhile it must at least be well considered. It must take a long time for the research manager to follow a project completely through into production. Why not let him spend his time on
research instead of production problems? Also, if he is a research man, of what value is his opinion regarding the readiness of a plant for production? There is possibly an uneconomical use of talent here.

Getting back to the questionnaire, it is observed that one of the next factors controlling the transfer of projects from development is time schedules. Research is rather difficult to administer time-wise.\(^1\) Development is a little more susceptible to time scheduling, but is still difficult. There are many reasons for using time schedules for controlling the transfer of a process to its next stage. Time might be the very essence of the problem such as the demand that a new model be out by a certain date. In that case whatever has been developed is taken when the decisive date arrives. Other factors involved with time schedules arise when the company is forced into time commitments on development because of the dependence placed upon the completion of development at a certain time by other operating segments of the company. For instance, procurement commitments might force a time schedule. A violation of the time schedule might dislocate other operations to such an extent that the expected gain from additional development effort would not warrant the violation.

The next important factor affecting the transfer decision is voluntary release by the development group. This factor indicates that there are many companies with strong

development groups. Of interest was the comment sent by one company representative regarding voluntary release by development group. Alongside this line he put a huge "NEVER".

The next question concerns the stage at which the production engineering division is brought into collaboration with the development group. Amazingly, one of the most prevalent answers was upon completion of the first model, with design stage running second. Whether there is a lack of appreciation of the production engineering problems, or whether the production engineering effort fits in quite easily after the model stage is not shown. The question comes to mind, however. Should the production engineering group be brought into consultation sooner?

Questions 4 and 5 on the questionnaire concern control of the project by the development group after it has passed on to further stages. The statistics, when amplified by comments, give the impression that development as a rule retains only liaison or veto control after passing the project on to the next stage. One possible solution comes to mind, if it is not too soon to draw conclusions. At any stage of a project the segment in control at the time could have complete authority and would receive "forced" liaison from the division from which it derived the project and the division to which it will eventually deliver the project. Prior or subsequent divisions would be available for "request" liaison on the project. That means that while a project is in the division just preceding the development division in the chain, or the
Immediate succeeding division, development would be obligated to comment on the project from the development point of view. However, the development division would have no authority in the decisions until the project actually came under development control. This proposal, of course, is at variance with the survey results as shown by Question 5.

The next two questions, 6 and 7, concern the evaluation of the readiness of the project for production. High ranking committee action seems to be the overwhelming method employed. A project is evaluated upon its merits by the committee, and, if readiness is indicated, the "GO" sign is given. Whether the various committees described in the individual questionnaires were advisory bodies or deciding bodies was not always clearly indicated. The committee method seems to be the trend, however.

Results obtained from question 7 were somewhat disappointing. "Tests and predictions" is listed as the leading answer, but the tests described by industries were quite inconsistent. The usual procedure was for a committee to look at the proposed model critically as to suitability, feasibility of manufacture, acceptability as to cost, and probability of sales value.

Question 8 indicates that changes cannot be altered in most cases after leaving the design engineer. The answers to Question 10 tend to explain this arrangement. The indications are that the production engineering effort in a large majority

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2 Ibid, Section 4
of the cases is applied before the design drawings are made.

Question 9 yields neutral answers, so to speak. The margin between answers does not seem significant. The production department seems to hold the lead in the control of the production engineering effort.

Question 11 points out that design and development are combined in most companies.

As was previously pointed out, the survey questionnaire used in this thesis was broad and designed to induce more comment than simply checking off questions. Many companies, of course, no doubt fall right into the pattern of the questionnaire and were able to give the complete picture requested with brief answers. Some companies gave additional information in amplification in order to more clearly tell their story. Some companies were cooperative to the extent of sending copies of their standard operating procedures for bringing forth a new product. To leave out these additional comments, as would surely happen with a mere statistical summary of the questionnaire, would yield only a fragmentary picture of the survey results. Accordingly, let us look into these expoundings and consider them for what they are worth.

Many of the companies lend the impression that the procedures followed in bringing forth a new product vary greatly with each product and, hence, they follow no set procedure, or procedures for that matter. Policies are developed, but these are sometimes vague and nebulous. On the other hand, the companies which have forwarded their "standard Operating
procedures" indicate that they have given enough consideration to the problem to come forth with a definite plan which is committed to writing and publication for all concerned to observe and abide by in bringing forth a new product. It is considered by this writer that the mere existence of such a publication in an organization, notwithstanding the merits of the procedure it sets forth, is a great step forward toward solving the basic problem of this thesis. Admittedly there are a great number of ways of accomplishing any task, all with varying efficiencies. Theodore Roosevelt once said, "The best way to repeal a bad law is to enforce it." If, even after due and careful consideration, the standard operating procedure proves to be unworkable in some instances, trial and error will bring about the necessary improvements. If there is no plan, however, there is nothing to which improvements can be applied. (See Appendix II for examples of standard procedures.)

Where possible the names of the responding companies shall be identified with the statements given. Some companies have expressed a desire to keep the source confidential, and this trust shall not be violated in this report.

The first question in the survey which induces irregular answers is number 3: "At what stage in development is the production engineering division brought into collaboration on the project?" Some of the replies were as follows:

a. SERVEL, INC. - mass production of appliances. "Gradual increase in contact through conferences, becomes serious after completion of first operating model by development group."

b. ATLAS POWDER COMPANY "When the project goes into pilot plant."
c. GRINNELL CORK
"Early, late or not until completion of development, depending upon anticipated production difficulties or changes required in inventories of raw materials."

d. HARTFORD-EMPIRE COMPANY
"During the stage of designing for manufacture which normally occurs after development tests have been completed."

e. EAGLE-PICHER COMPANY - Zinc and lead products; home and industrial insulations.
"The Research Department through its Development Section and with whatever aid is required from the Engineering Section handles the transfer of projects to the Operating Departments. As operating complications decrease, Development gradually relinquishes control to Operations though Development may be called back for assistance if needed. Flexibility in procedure depending upon circumstances and a high degree of cooperation are major elements in our method of operation."

f. EMERSON RADIO AND PHONOGRAPH CORPORATION
"As soon as the first engineering models are built and before the release of specifications."

g. GAYLORD CONTAINER CORPORATION
"As near the beginning as seems feasible. Usually immediately after the technical group has decided a project has merit."

h. THE GLENN L. MARTIN COMPANY
"In general they are brought in at the time of the transfer. However, in many cases production engineering specialists are assigned to a development item at the time of its origin and transferred with the item to follow it through to completion."

i. A large typewriter manufacturer -
"Production engineering brought into collaboration upon completion of the first working model. Model and prints are examined by this department and the second group built from the combined recommendations."

j. "When development is complete production engineering, writes the production specifications based on recommendations made by the development group."

k. A prominent aircraft manufacturer -
"During development of experimental prototype."

l. A food processor -
"From its inception."

m. A prominent chemical producer -
"Usually in the semi-works stage, as it is in this stage that development begins to resemble production, i.e., as to
materials of construction, design, and operation."

n. An ordnance and fire-control equipment manufacturer -
"Production engineering is brought in on the project as soon as there is a definite plan for it to go into the production stage. This may be early in development in some cases where success appears to be easy, or at a later stage when a successful breadboard or prototype has been made and demonstrated."

o. A large electrical apparatus manufacturer -
"Either at the beginning of the project or very early. The production group are responsible for the design, compliance to specifications hence need to set the goals to be accomplished as well as planning of overall schedules."

p. A shoe manufacturer -
"On receipt of drawings from development department."

q. A safety appliance company -
"In our Company, the Methods Department, which is responsible for tooling and production setup, is brought into collaboration on the project at the time the initial breadboard model is built and participates through the Project Engineer in the design characteristics thereafter. Their purpose is to guide design in such a way that it will fit into our manufacturing facilities and that the manufacturing cost may be kept at a minimum."

r. A large automobile manufacturer -
"Whenever the production engineering group are interested in working with the project."

s. A photographic equipment manufacturer -
"- - They (production engineers) are expected to cooperate at all stages by calling attention to design details which might cause trouble in manufacture or will require new facilities. However, the principal responsibility of the Production Engineering Department starts after the drawings for a new product have been released."

It can be seen that there seems to be no set pattern as to when Production Engineers should be brought into the problem. Their initial contact varies from the inception within the company to the time the product is actually handed to them for action. To this writer the last three replies are the most appealing.

The next question calling for more than a check-off
answer is number 6: "Who evaluates the project in the design and development stage to determine whether the project is acceptable and ready for production?" Some answers were:

a. SERVEL
"Management group consisting of President and heads of sales, production engineering, and finance."

b. ATLAS POWDER
"Research committee."

c. GRINNELL CORK
"Representatives of development, production and sales subject to approval of company President, in major projects."

d. HARTFORD-EMPIRE
"Jointly between Development and Field Service Division of Sales Department."

e. EMERSON
"Management, development engineering, and Production Department."

f. GAYLORD CONTAINER
"A group composed of Manager, General Superintendent, Technical Director, Department Superintendent, and Chief Engineer."

g. GLENN L. MARTIN
"This evaluation is made by the production project engineer and the development group (this group consists of design specialists from all engineering departments)."

h. An electrical apparatus manufacturer.
"Project engineer or the production engineer responsible for meeting specifications and delivery dates."

i. A shoe manufacturer
"Qualified development personnel in conjunction with commercial department personnel. Commercial management has final say."

j. A safety appliance manufacturer
"Product development in our Company is under the direction of the Sales Planning Department. This department is comprised of a number of Product Line Managers, each of whom specializes in a specific group of related products. These Product Line Managers are the men who evaluate whether or not a developmental project requires further work or is ready for production and sale."

k. A rubber goods manufacturer
"Development cooperates with production until satis-
factory process or product performance has been achieved in the project which has been taken over by production."

1. A large powder company
"Project evaluation is done by the group conducting the active part of the program, usually the pilot plant - engineering group. Final evaluation is made by the section of management responsible for manufacturing the product, with the aid of the plant design engineer and technical people responsible for evaluation of the utility of the product."

m. An automobile manufacturer
"No one individual has the mental acumen to decide such a momentous matter. Must be a joint agreement of many people based on existing data."

It appears to this writer that the common practice is to have some sort of steering committee make this decision. It is difficult to determine from the survey just who "counts the votes" of the committee. As indicated in some of the above replies, the president of the company enters directly or indirectly into the decision. Committee opinion seems to be his main support, however.

The next pertinent question on the questionnaire is number 7: "How is the project evaluated in the design and development stage to determine whether the project is acceptable and ready for production?" Some answers ran:

a. SERVEL
"Preliminary cost estimates; sales research studies; factory facilities analysis; field tests experimental models."

b. ATLAS POWDER
"By analysis of costs, smoothness of operation, results of field evaluation and market survey."

c. HARTFORD-EMPIRE
"Preliminary tests are given whenever possible in our own Experimental Plant. After the usual corrections are made the device is sent to the field for further testing usually on a 'consignment trial' basis."

d. EMERSON
"1. By building additional engineering samples.
2. By laboratory and field tests."
3. By Production Department building and testing additional units.

e. GAYLORD CONTAINER
"Usually by a mill scale experimental run."

f. GLENN L. MARTIN
"In general the evaluation is based on compliance with existing specifications and acceptance of the mock-up."

g. A typewriter manufacturer -
"After extensive life and endurance tests plus operating tests by the Sales and Service Departments."

h. "By developmental runs on production equipment or the equivalent."

i. "No definite criterion - every case on its own merits, with broad consideration of all factors involved."

j. A prominent aircraft manufacturer -
"Acceptability of the project is determined on the basis of prototype performance, estimates of production cost and the available market. The final decision rests with higher management advised by the Development Group as to the product performance; the Production Group as to production cost and schedules; and the Sales or Military Liaison Groups as to the market potential."

k. Food processor -
"1. Can it be produced within the estimated cost? 2. Does it contain the features and meet the specifications previously established?"

l. A prominent chemical manufacturer -
"Evaluation is repetitive and progressively more refined. There are at least three evaluations: (1) following exploratory research but prior to extensive bench scale research; (2) following bench scale research but prior to semi-works development; (3) following semi-works development but before requesting funds for construction of commercial-scale plant."

m. Ordnance and fire-control equipment manufacturer -
"The group mentioned above considers the suitability of a product insofar as our Sales organization, type of customer, possible market, profitability, our probably ability to manufacture the type of product and the estimated market."

n. Electrical equipment manufacturer -
"Analysis of test data, experience on prior jobs and review of other items which may adversely affect the proper performance of equipment or failure of equipment to meet specifications."
There seems to be no general pattern to the above answers other than consideration of product on its merits. The usual determining factors seem to be meeting of specifications, cost, marketability, and ease of manufacture. This particular question was not fully understood by all companies apparently, for many statements were made which, however enlighening, did not answer the question.

The remaining questions were of the check-off variety and did not lend themselves to a great deal of aberration. It seems appropriate at this time to digest some of the expository statements sent by the various companies.

A prominent photographic equipment manufacturer in reply to questions 6 and 7 regarding the readiness of the product for production indicated that a steering committee made the decision on the basis of the merits of the product in complying with various requirements such as the cost-price problem, whether the need is being filled by some other product, availability of personnel and facilities, and other such pertinent requirements. Of particular interest in this instance was the use of a Manufacturing Approval Card which is circulated for endorsements. Some of the items included on the card are: name and description of product, patent approval information, estimated sales, unit cost, tool cost, initial production cost, number of units needed to amortize initial investment, list price, profit, and date available for trade announcement. Signatures are necessary on the card from as follows: Plant Approval, Inter-Plant Approval, Planning Department, Comp-
controller, Sales Department, Coordinator for Mechanical and Optical Products, Vice-President (Sales and Advertising), Assistant General Manager, and the General Manager.

Much of the above is accomplished in most companies by committee action, and this card's travels are no doubt expedited by some sort of committee action. The principal value of such a check-off card seems to be the fact that the card focuses attention on what data must be known and whose approval must be obtained before production can be effected.

LEEDS AND NORTHRUP COMPANY replied by letter as follows:

"When the production design is completed, the Engineering Department submits Technical Reports to the Development Committee giving tooling costs, inventory requirements, tooling and production schedules, and including a request for authorization to 'release for production'.

"Prior to submitting the Research Reports to the Development Committee, it is customary to build several 'Research Models', make several 'Field Trials' to obtain cost estimates on the Research Models so that the Research Reports may give assurance that there is at least one practical form of the apparatus. This does not commit the Engineering Department to the form developed in Research, but does enable the Engineering Department to undertake its work with the assurance that a practical form can be produced."

A prominent powder company sent the following comments:

"2. The initiation of the transfer of projects from development to production usually depends upon technical success gained in the development stage, and on the amount of pressure put on the development group by management.

"3. The engineers who design our plants for manufacture of chemicals are brought into the picture during what we call the pilot plant stage. This would probably correspond to the latter stages of prototype development in the case of mechanical devices.

"4. Control of the project always rests with the group actually doing the work. The laboratory chemist continues to work closely with the pilot plant group during the pilot plant phase. Likewise, the pilot plant engineer follows through to maintain close liaison with the plant when preliminary production is undertaken."
"5. Development personnel are directly responsible only for the stage of development. They have only advisory responsibilities in the production stage. They are available for consultation."
CONCLUSIONS

A MANUAL OF BEST TECHNIQUES FOR ACCOMPLISHING THE TRANSFER OF ORDNANCE RESEARCH PRODUCTS FROM DEVELOPMENT TO PRODUCTION

We have observed the development-production failure of Germany in World War II. In spite of the collective inventive genius rampant in Germany and in spite of her manufacturing deftness, she failed to effect efficient transfer of research products into production. It can happen here. We, in America, cannot assume that everything will come out all right in the end. We are not living a "fairy tale". We must make ordnance material, and we must make it of good quality, in appreciable quantity, soon.

It is quite evident in our study of American Industry that there is no set pattern for accomplishing the transfer. There are trends; there are "usual" methods; and there are unique methods well worthy of emulation. The findings derived in any thesis are necessarily tinctured with the opinion of the writer. Different people will quite often arrive at different conclusions from the same set of facts. In addition, in the process of acquiring information points are observed which, by themselves, seem insignificant and consequently are not recorded at the time. However, these points leave their mark on the mind and collectively induce opinions by a process best described as "mental osmosis". This statement is not intended as an excuse for failure to substantiate findings with facts. It merely avers that the reasoning process cannot be wholly explained. In the opinion of this writer, the following constitutes the findings of this thesis and are submitted for
consideration:

1. THE ESTABLISHMENT OF A WRITTEN STANDARD OPERATING PROCEDURE.

Policy written on a cloud soon blows away. The procedure should be recorded so that all departments and segments of the firm can read and comply. It should be as detailed as possible. A little experience should point out the errors in the procedure. Good examples are shown in Appendix II.

2. THE USE OF SOME SORT OF CHECK-OFF CARD REQUIRING DATA AND SIGNATURE APPROVALS FROM VARIOUS DEPARTMENTS IN THE FIRM.

This card will accomplish several things. It will focus attention on necessary information and requirements which must be complied with. It shows that various departments are satisfied with the project. Lastly, it makes for a more effective conference and committee action when decision time comes by insuring the presence of all the facts. The card mentioned in connection with the anonymous photographic company is an example.

3. THE USE OF COMMITTEE ACTION FOR ARRIVING AT THE DECISION TO EFFECT INTER-DEPARTMENT TRANSFER OF THE PROJECT.

This procedure is a direct result of the survey of the current practice of industry. This technique seems to be the overwhelming choice of industry. Committee action accomplishes the additional task of keeping all departments informed.

4. THE DEPARTMENT IN ACTIVE CONTROL OF THE PROJECT HAVING FULL AUTHORITY AND RESPONSIBILITY FOR CHANGES MADE TO THE PRODUCT.

The statistics of the survey are somewhat misleading in this point. Usually where a particular department is not
permitted to make changes, that department does not accept the project until it considers it ready for its endeavor. In effect, this is control over changes. The control is indirect. Inasmuch as committee action for accomplishing the transfer is advocated, each department should have authority to control that which is thrust upon it. This arrangement does not imply utter disregard of specifications. Sound and conscientious practice by individual departments will preclude such deleterious results. Besides, there is usually another committee to be pleased. This reckoning will stay departments from most radical or unwanted changes.

The policy used by the powder company mentioned at the end of the previous section concerning the survey is an example.

5. The use of a project manager to follow the progress of the project.

This man's function may be a staff or line responsibility. If a Project Task Force is formed for carrying the project through the various stages, the Project Manager would be in charge of this group and bear line responsibilities. If the project is passed on from one department to the next without the concomitant transfer of a project group, the Project Manager should have staff responsibilities. He should keep management informed of progress, assist in maintaining inter-departmental liaison insofar as the project is concerned, be available for advice to departments, and in general smooth the way and expedite the evolution of the project.

In some cases a small group headed by a Project Manager
moves from one department to the next in company with the project. This arrangement is somewhat of a blend of the other two systems. Which of the preceding is best is not readily ascertainable. The choice depends upon such factors as how radical a departure is the product from other presently manufactured products, how radical a departure in manufacturing technique, and how exacting are the needs for experts and specially trained personnel in processing the product.

6. DESIGN FOR SHORT TERM AMORTIZATION OF MANUFACTURING FACILITIES.

There is a common idea that in war production money is no object. Money expended, however, is usually a good measure of effort expended. If short-term amortization requirements are met, permanent dies, jigs, fixtures and other mass production embellishments "a la Detroit" will be dropped by the wayside. The result will be that unexpected changes in the product can be more readily effected, production can be started sooner, and the decision to freeze production can be made with a lighter heart.

7. THE USE OF STANDARD PARTS

If a unique part of a weapon in the field is broken, the weapon may be out of commission for an appreciable period until a replacement part can be obtained. In addition, unique parts place a burden on the spare parts system. Where possible some compromises should be made in order to use standard parts.¹

¹There was a concerted drive during World War II to induce industry to use standard parts. The periodical PRODUCT ENGINEERING ran a series of posters advocating such practice.
The recent combined British-American compromise on a standard screw thread is a stellar example.

Standardization of parts is a requirement of many government controls.²

The above is, of course, not a complete solution to the problem, for there is no "this is it" in this case. It is hoped that it is a worthwhile contribution.

²See Appendix III
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APPENDIX I

COMPOSITE

The Graduate School of Industrial Engineering, Georgia Institute of Technology, has joined forces with an important current project for determining the most effective techniques for transition of ordnance and similar products from the development into the production stage, based primarily upon a study of methods used in private industry.

Any help that you are willing to give will be in direct support of one of our major National Defense agencies. A summary of this study will be made available to those assisting if desirable and in so far as possible within the proper bounds of ethics and security. All information sent will be treated as confidential as to content and source until or unless cleared as otherwise by you.

Please furnish as much or as little help as you can or are willing to. Information on this problem may be furnished by:

a. Executing the enclosed questionnaire

or

b. A letter explaining how you handle similar problems

or

c. Copies of written procedures used by your organization

or

d. A combination of one or more of the above plans or in any other way you see fit.

Frank F. Groseclose, Director
School of Industrial Engineering

15 February 1951
APPENDIX I

COMPOSITE

QUESTIONS ON TECHNIQUES FOR TRANSFERRING PRODUCTS FROM
THE DEVELOPMENT STAGE TO THE PRODUCTION STAGE.

Please answer all or any questions and add comments as you see fit.

1. What percent of research projects conducted for your organi­
ization are through
   a) 93% own facilities
   b) 1.5 government laboratories
   c) 2 private industrial research associations or
      laboratories
   d) 1 technological research institutes, such as
      universities
   e) 2.5 other industrial laboratories

2. Which of the following factors have the greatest effect upon
initiating the transfer of projects from development to
production stage
   a) 16 time schedules
   b) 11 percentage complete - compliance with minimum re­
      quirements
   c) 7 cost (Budget control)
   d) 16 voluntary release by development group
   e) 23 acceptance by production group
   f) 6 controlled by project engineer
   g) 8 priority existing among various projects
   h) (other) acceptance by Sales
      7 acceptance by Sales
      4 acceptance by Customer
      1 planned program

3. At what stage in development is the production engineering
division brought into collaboration on the project?

Inception - 9  Prototype or Model - 17
Indication of Commercial  Pilot Plant - 2
possibilities - 9  Transfer to Production
Completion of Research - 1  Engineering - 8
Design - 13

4. When the project is passed on from the development group, does the control of the project remain with the development group?
   a) 24 yes
   b) 41 no

5. Does development maintain any control on the project after production has started on it?
   a) 38 yes
   b) 29 no

6. Who evaluates the project in the design and development stage to determine whether the project is acceptable and ready for production?
   Steering Committee - 43  Top Management - 4
   Sales - 8  Production - 4
   Chief Engineer - 5  Project Engineer - 3
   Development - 5

7. How is the project evaluated in the design and development stage to determine whether the project is acceptable and ready for production?
   Tests and Predictions - 35  Compliance with Specifications - 9
   Trial Run - 13  Demonstration - 1

8. May revisions of any kind be made by the production departments without the design engineer's approval, even after the drawing and specifications have been released by the design engineer to the production department?
   Yes - 20
   No - 46
9. Is the production engineering department in your organization under the
   a) 25 design (engineering dept.) Management
   b) 36 production department (manufacturing)
   c) 7 (other) Separate Department

10. At what stage is production engineering effort applied to the product design?
   a) 13 while product is in the engineering evaluation phase.
   b) 28 while product is in the development phase
   c) 25 during preparation of detailed drawings for production use
   d) 13 after drawings have been released to the production department.

11. Are your developmental engineering and end product design groups separated organizationally?
   a) 25 yes
   b) 39 no

   If so, please explain.
APPENDIX II
STANDARD PRACTICE INSTRUCTIONS

DEVELOPMENT OF PRODUCTS - POLICY
RESPONSIBILITY OF DIVISIONS AND PROCEDURE

This sets forth the policy, and responsibilities of the Divisions, and the procedure with reference to the development and manufacture of the products of Corporation.

Engineering and Manufacturing Divisions have direct responsibilities although the Sales Division and the Comptroller have indirect responsibilities, as does the New Products Committee.

The Sales Division working in cooperation with the Engineering Division and to the degree necessary with the Manufacturing Division, is responsible for comprehensive design objectives and also volume and price norms. Within the Sales Division, it is the responsibility of the Product Manager to formalize these objectives in the mutual interest of the customer and Corporation -- within the Product Policy of Corporation, and the New Products Committee Procedure -- for presentation to the New Products Committee.

Action by the New Products Committee fixes the design objectives and the production and profit aims for the direction and information of all Divisions.

The Sales Division, through its Service Department, is responsible for preparing, in cooperation with the Engineering and Manufacturing Divisions, installation and service instructions for the field so that all products will be maintained properly. The Service Department is also responsible for a continual and formalized reporting to the Engineering Division and Manufacturing Division of field experience with products new and old; and through the proper Product Manager for the obtaining of corrective action based on unsatisfactory product reports.

The Comptroller is responsible for the ascertaining of the cost of the product, and all other costs, and for the ascertaining of the margins and profit. Under the Pricing Policy it is also the responsibility of the Comptroller to issue warning notices of deterioration in costs or profits. This does not alter in any way the responsibilities of the Comptroller as expressed in the Pricing Policy.

The Engineering Division is responsible for the development, design and redesign of products and for their design quality and market suitability in keeping with the Product Policy of the Corporation and the design objectives, authorized by the New Products Committee.

This responsibility includes a continuous coopera-
tion with the proper Product Manager and the Service Department in diagnosing all complaints and correcting design faults, improving the product to maintain its sales suitability and reducing its cost.

The Manufacturing Division is responsible for the production of products in keeping with standards of quality and performance established by the Engineering Division, and at a minimum cost, not exceeding that approved by the New Products Committee. The Manufacturing Division should also cooperate with the proper Product Manager and Service Department in diagnosing all complaints and correcting manufacturing faults in products.

Accordingly, during the period that a product is being developed and designed, primary responsibility must rest in the Engineering Division.

However, the Engineering Division shall seek the advice of the Manufacturing Division, particularly the Factory Engineering Department and the Manufacturing Laboratory, with a view to designing products that can be made economically regardless of the character of the then existing manufacturing facilities. It may be necessary later to modify designs for manufacture on the existing equipment, but this should only be done after review by and approval of the New Products Committee.

THE RESPONSIBILITY OF THE ENGINEERING DIVISION DOES NOT CEASE WITH THE BEGINNING OF PRODUCTION. A continuous responsibility for product quality and for improvement and cost reduction, from a design standpoint, exists, requiring close collaboration with the Manufacturing Division, and with the Sales Division, including the Proper Product Manager, and the Service Department. In connection with these related responsibilities, the Engineering Change Procedure (SPI 8-5) and the Deviation Procedure (SPI 3-5) apply.

In this same connection, the written approval of the appropriate Director of Development is required to put into effect any deviation from product specifications.

With specific reference to new products or redesigned ones, the Engineering Division is to furnish to the Manufacturing Division a complete manual of instructions relative to design specifications, including performance requirements and pertinent test data. Hereinafter this will be referred to as Product Specification Manual. The Manufacturing Division must review said manual and accept (see procedure later) or reject its content. Assuming rejection, proper representatives of the two divisions are to confer and reconcile the differences. Should any differences not be reconciled, they shall be submitted to the
President of the Corporation for decision.

WHEN THE MANUAL IS ACCEPTED IN WRITING BY THE HEAD OF THE MANUFACTURING DIVISION, PRIMARY RESPONSIBILITY SHIFTS FROM THE ENGINEERING DIVISION TO THE MANUFACTURING DIVISION. Nevertheless, the Manufacturing Division is obligated to utilize to the fullest practical extent the talents and assistance of the Engineering Division, with a view to obtaining the best overall results. Toward this end, Manufacturing Division will furnish to Engineering Division a copy of the Manufacturing Specifications including all inspection procedure and the amount of inspection, for comment and criticism.

SUMMARIZING, THERE IS TO BE EARLY AND CONSTANT COLLABORATION BETWEEN THE ENGINEERING AND MANUFACTURING DIVISIONS, AND NO ABRUPT CUT-OFF. EACH SHALL SEEK AND ACCEPT THE ASSISTANCE OF THE OTHER DURING THEIR RESPECTIVE PERIODS OF PRIMARY RESPONSIBILITY AND BOTH DIVISIONS WILL BE HELD RESPONSIBLE FOR FAILURES IN ANY PRODUCT.

PROCEDURE

Implementing this broad policy of cooperation, the following procedure applies:

Product Specification Manual. This is required for every new or redesigned product, and a copy accepted in writing therein by the Head of Manufacturing Division must be sent to the Head of the Engineering Division. The manual consists of the following, all prepared by the Engineering Division:

- Drawings of the Product
- Engineering Bill of Material
- Painted Parts List
- Engineering Standards
- Performance Test Data

It is realized that under normal conditions this manual will be submitted to the Manufacturing Division in segments. Each segment must be approved and it is the responsibility of the Manufacturing Division to see that sufficient reviews of sample tests, general design, and other factors are made prior to approval of segments so that manufacturing difficulties will not be experienced, and approval of the design and specification can be given.

Engineering Requirements and Test Limits. The Engineering Division will be responsible for specifying only "what is required" type of performance limits on production parts, on tests and on inspection operations; while the Manufacturing Division will be responsible for the "method of doing it".
Manufacturing Specifications. These will be prepared by Manufacturing Division on Manufacturing Specifications Form No. P-53, and will include the following:

- Manufacturing Process
- Manufacturing Layout
- Inspection Procedure
- Inspection Equipment and Gages
- Detail Cost Estimates

Production and Testing Processes and Equipment. The Manufacturing Division shall specify the process, and design the equipment to be used in manufacturing, inspecting and production testing of all products of Corporation.

Sources of Supply. The Factory Engineering Department of the Manufacturing Division will establish approved sources for manufacturing supplies and materials (tools, cutting oils, etc.). Approvals on in-product materials and standard parts is the function of the Engineering Division. However, all in-product material and standard parts specifications are to be reviewed by Manufacturing Division for comments.

Note: In setting up all approved sources of both in-product and non-product materials, the Procurement Department will be given as much latitude as possible — at least two sources except where special single source items must be specified. The Manufacturing Division should keep the Engineering Division informed as to the quality of materials obtained from these sources as indicated by Receiving Inspection. If the material is consistently bad, it is the responsibility of the Manufacturing Division to recommend changing the specifications or sources.

Where material is purchased subject to approval, responsibility is as defined in the above paragraph.

Trial Production Runs. On all new and major redesigned products, trial production runs using production tools are to be made. The quantity of unit and/or parts made should be decided upon by both the Engineering and Manufacturing Divisions.

Production Sample Tests. As production begins, the Manufacturing Division shall deliver to the Engineering Division a quantity of first run new or redesigned products (as previously scheduled between the Divisions) for performance test and examination purposes. No release of production units for shipment (other than approved test units) shall be made until Engineering Division has completed its examination and the Head of the Engineering Division has written an approval of the samples as being
within the original or approved amended specifications, as accepted by the Head of the Manufacturing Division.

Subsequently, the Engineering Division shall from time to time, and by arrangement with the Manufacturing Division, select one or more sample units from the production line for examination and test. If such units are found deficient with reference to the specifications, the Head of the Engineering Division shall notify in writing the Head of the Manufacturing Division, the proper Product Manager, and the Assistant to the President.

The manufacturing Division shall see that inspection reports are prepared regularly in a formal and organized manner on all products and that these are submitted to the proper Product Manager and Director of Development. All special inspection reports should also be submitted to the proper product Manager and Director of Development.

The Sales Division, through the Service Department and proper Product Manager, is responsible for checking and reporting promptly and in an organized manner to both the Engineering and Manufacturing Divisions, field troubles found with all products. On first run production, special efforts are to be made to follow products into the field and report troubles promptly to the Engineering and Manufacturing Divisions.

**ACCEPTANCE OF PRODUCTS FOR PRODUCTION**

**PURPOSE**

This instruction outlines the procedure and policy to be followed in the acceptance of products for production.

This procedure and policy applies in its entirety to new models and major revisions of high production units. Its application to minor changes on high production units or major revisions on low production units may be modified by common agreement of the applicable Director of Development, the Production Control Manager, Factory Engineering Manager and the Director of Quality Control; such agreement being approved by the Coordinating Committee.

The instruction is intended, further, to implement Standard Practice Instructions #8-2, "Development of Products - Policy" which outlines the responsibility of the various corporate divisions and the authorities of the New Products Committee.

**DIRECTOR OF DEVELOPMENT**

1. The Director of Development in charge of the unit development, as the Engineering Division Representative, will have the final responsibility for and ap-
prove all changes made to the design, prior to the acceptance for production.

2. It will be the responsibility of the Development Director to keep all departments of the company, including the applicable Product Manager advised on changes made in design.

3. Working with Development personnel during unit development will be the Tool Engineer and Supervisor of Methods from Manufacturing and the Accounting Cost Estimate Supervisor. These individuals will assist the Project Engineer from a Manufacturing and Cost standpoint.

PRELIMINARY DRAWINGS

4. All preliminary drawings will be marked with an "EX" symbol for positive identification.

Preliminary drawings may be identified as follows:

1. Sample unit drawings -- includes drawings for laboratory samples and tool and method studies.
2. Trial production drawings -- drawings for Manufacturing Laboratory samples.

5. Trial Production run drawings will be released to the following department heads for necessary immediate action such as tooling and layout appropriations, equipment orders, preliminary bills, purchase commitments, etc.: 

A. Supervisor of Methods - Factory Engineering - two copies.
B. Tool Engineer - Factory Engineering - four copies.
C. Superintendent Manufacturing Laboratory - one copy.
D. Supervisor of Material Control - two copies.
E. Director of Quality Control - one copy.
F. Service Technical Section Supervisor - one copy.

ORDINATION

6. During the period between the release of trial production-run drawings and the final production drawings, the following individuals will confer, be kept currently advised of, and approve all changes being made.

A. Development Project Engineer
B. Tool Engineer - Manufacturing Division
7. It will be the responsibility of these individuals to coordinate all action within their departments being taken concurrently on the ordering of material, tools, etc.

8. The Supervisor of Methods is responsible for keeping Material Control (responsible for coordinating Procurement) and Quality Control advised of all changes affecting these departments. However, these departments may, on development of certain units, act as their own representatives in meetings concerning changes in the unit design.

9. All such changes made will be reported by the Project Engineer, in letter form, to all departments concerned immediately, and then recorded on revised drawings, clearly marked with revision number and identified as "EX".

10. Copies of revised drawings will be distributed together with a covering Engineering Change Record to the same personnel who received the initial trial production run drawings.

11. One extra copy of the Change Record, only, will be sent to the Accounting Cost Estimating Supervisor.

12. The Manufacturing Vice-President will signify his acceptance of the product for production by notifying all Division Heads to that effect in writing. (Refer to S.P.I. #8-2, Page 2.)

13. When a design is offered for acceptance, the Vice-President in Charge of Sales will signify the acceptance of the design from a marketing and service standpoint by writing his approval in a letter to the Engineering and Manufacturing Division Heads.

14. Upon receipt of acceptance from Sales and Manufacturing Divisions, the Engineering Division will issue final production drawings, clearly indicated by the wording "Final Production" being clearly marked or stamped in a conspicuous place.

15. Acceptance by Manufacturing and Engineering Division will be indicated by approval, on each drawing, in the space provided in the Title Block of the drawing.
16. As final production drawings are being prepared, it will also be the responsibility of the Development Director to issue new or revised Sample Price Page Notices in accordance with Standard Practice Instruction #8-14.

17. All engineering changes prior to production drawings will be made according to the above procedure.

18. All engineering changes originating after the issuance of production drawings are to be handled through the Engineering Change Request Committee.

19. Changes in design or specification shall not be made during the production year unless they are imperative from the viewpoint of quality or reliability or unless they are of extreme importance from the viewpoint of salability or cost reduction, otherwise, suggested changes will be accumulated and incorporated into the next year's model.

A group of changes may be considered important enough for a mid-season change but such a mid-season change should not be made without approval of the Coordinating Committee.
PROCEDURE

ORIGINATED BY: OFFICE OF THE PRESIDENT - KOPPERS COMPANY

SUBJECT: New Products and Processes - Research, Engineering, Plant Construction, Starting-up Operations, etc.

GENERAL:

The procedure set forth below is for the purpose of clarifying and outlining the assignment of responsibility for laboratory research, pilot plant development, engineering design, construction and starting-up operations of new plants and processes.

Accompanying and included in this procedure as Exhibit "A" is a flow chart. This details the various steps and the units of the organization involved in the various phases of developing a product from the idea stage to the completion and initial operation of a full scale plant.

Cooperation and compliance by all organizational units concerned is essential for proper functioning under this procedure.

PROCEDURE:

1. The Research Department, Central Staff, shall have full responsibility and shall be in active charge of new product or process projects through all the necessary development phases to the completion of any pilot plant work necessary for the design and operation of a full scale plant. The details of the various phases of work involved are set forth in the accompanying chart (Exhibit "A") under phases 1 to 4 inclusive.

2. Although actual responsibility and active charge of the project are vested in the Research Department during this period, it will be noted by reference to the chart that other units of the company concurrently participate. The Manager, Research Department, shall be responsible for presenting the project or otherwise advising these other units at the times when their assistance or participation is indicated on the chart. In this connection, participation by the Chemical Department and/or the Project Engineering Section of the Engineering and Construction Division and the interested operating division specifically calls for each of these units to assign one or more of their employees the responsibility for following the project, observing operations and becoming thoroughly familiar with the work.
PROCEDURE:
(Continued)

3. After a project passes the pilot plant stage, its advancement becomes the responsibility of the Engineering and Construction Division (see phase 5 on attached chart). The Chemical Department and/or the Project Engineering Section of this division shall have active charge and shall perform the project engineering work, including general specifications and design.

Through the engineering design phase, the interested operating division and the Research Department shall actively participate by each assigning one or more individuals the responsibility for following such design and assisting as necessary, in order to insure that design is not at variance with that indicated by pilot plant findings or other sound technological knowledge.

4. Upon completion of the project engineering phase (general specifications and design), the Manager, Central Staff Production Department, shall review the project design for plant lay-out and safety. Following this the General Manager, Engineering and Construction Division shall approve the design and shall secure the written approval of the Manager, Research Department and the General Manager of the interested division. Such approval should be noted in writing on the specifications or other appropriate papers (chart phase 5B).

5. Engineering and Construction Division's Estimating Section shall prepare an estimate of plant costs for the project (chart phase 5C) after which the interested operating division shall be in a position to make its estimate of production costs and earnings (chart phase 5D).

6. The interested operating division shall request a market survey to be made by the Central Staff Sales Department (chart phase 5E), except that market surveys are not required if the capital expenditures needed for plant facilities do not exceed $25,000. (See Executive Order No. 16).

7. An appraisal of the raw material supply (chart phase 5F) shall be made by the Central Staff Procurement Department at the request of the interested division.

8. The interested operating division shall at this point submit various data (estimated production costs and earnings, market survey and the appraisal of the raw material supply) to the New Products Committee.

9. If the project is approved by the New Products Committee, the interested division shall pursue standard existing procedures in effect for processing proposals for capital ex-
PROCEDURE:
(Continued)

penditures through the Appropriations Committee, Operating Committee, and the Board of Directors (chart phases 5H to 5J inclusive).

10. Following receipt of approval to construct a commercial size plant, the Chemical Department and/or the Project Engineering Section of Engineering and Construction Division shall complete the final specifications and design work (chart phase 6A). Following this, the General Manager of the Engineering and Construction Division shall approve the design and shall secure written approval thereto from the Manager, Research Department, and the General Manager of the interested operating division (chart phase 6B).

11. Engineering and Construction Division's Engineering Department shall then complete all necessary detailed engineering and design work required to construct the plant (chart phase 6C) and this division's Construction Department shall have active charge of plant construction work (chart phase 6D). Reference to the chart indicates that various other company units shall also follow the work in order to be familiar therewith during the final design and erection period.

12. When construction of the plant is completed, the Engineering and Construction Division shall have active charge of and responsibility for starting-up operations, and for turning the operating plant over to the interested division. The Engineering and Construction Division's Operating Department shall be in charge of this work, with operating personnel to be supplied as required by the Engineering and Construction Division and the division involved, and with assistance requested of the Research Department as necessary (chart phase 6E).

13. The acceptance of the plant shall be considered to be accomplished when the Manager, Research Department; General Manager, Engineering and Construction Division; and the General Manager of the interested operating division agree that the plant is capable of producing specification products at rated capacity. It shall be the responsibility of the General Manager, Engineering and Construction Division to secure written confirmation of such agreement from the General Manager of the interested division and the Manager, Research Department.

14. The procedure as outlined above covers methods to be followed when new product facilities are built for any of the Company's operating divisions. The same procedure, however, shall be followed when plants are built for outside customers except where expressly provided otherwise in contracts.
FLOW AND SEQUENCE OF THE DEVELOPMENT AND COMMERCIALIZATION OF A NEW PROCESS OR PRODUCT

**Flow and Sequence**

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**Notes:**
- JULY 5, 1949
- Exhibited by [Exhibit A]
APPENDIX III

MILITARY DESIGN OBJECTIVES

1. Performance 6. Durability
2. Ease of Operation and Safety 7. Multi-Job Versatility
3. Light Weight and Small Size 8. Military Job Suitability
4. Ease of Maintenance 9. Replacement Possibilities
5. Efficiency and Economy 10. Availability

REQUIREMENTS FOR WHICH THE MILITARY SERVICES ARE REPEATEDLY CALLING

Fungus Proofing. Tactical equipment as well as food and clothing. A prime object of fungus attack is the insulation of electrical wires and cable. In most cases, military specifications list the materials to be avoided or give instructions on how fungus proofing can be accomplished.

Radio Interference Suppression. For all rotating equipment. Static charges and commutator sparking are two sources of trouble. Remedies are proper grounding, shielding and secure electrical connections. Commutator-type electrical equipment must be carefully designed or eliminated altogether.

Light-Weight Construction. For ease of transporting. Services encourage use of the lighter materials - titanium, aluminum, magnesium, high-strength steel and plastics. Check the possibility of fabricated assemblies against castings.

Corrosion Resistance. All Navy equipment. Principally a problem of materials and finishes, although other topics such as flow lubrication or hermetic sealing may be involved.

Substitution for Critical Materials. Department of Defense will not disclose its list of critical materials on the grounds of security. From past experience the following materials might be in short supply: rubber, aluminum, copper, asbestos, mica, cerium alloys, cobalt, chromium, molybdenum, stainless steel, tantalum, cork, shellac, lead, zinc, manganese, antimony, tin and others. Equipment specifi-

"Designing for Military Requirements", PRODUCT ENGINEERING, January, 1951. Page 87
ations often recommend alternate materials to replace those that may be scarce. In new developments, a designer should try to recommend a substitute material. He should also get advice from the military agencies on what priority the equipment would rate in wartime to help him choose materials.

Waterproofing. Various graduations. Ability to operate under water is specified for many ordnance vehicles. Ordinarily solely the designer's problem. The military specification gives the performance standards that must be met and lets the product engineer proceed from there.

Air-cooled Engines. Main object is adaptability of such engines for operation in different climates.

Standardization of Parts - to simplify production, servicing and spare parts stocking. On developmental contracts, the government indicates any standard parts that are to be used.

Ease of Maintenance - access and serviceability.

Shockproofing - left entirely up to designers. Specifications describe tests to be passed.

Arctic Grade Lubricants will be specified for all military equipment. Designer not free to recommend the optimum lubricant. Lighter oils and greases may limit shaft speeds and necessitate special seals.

Ruggedization of electronic equipment is a combined government - industry program. Tubes. In infancy, but before specifying tubes for electronic equipment, check as to whether ruggedized versions are available.

Easy Disassembly for Shipment - especially for heavy or bulky equipment. When designer is unable to reduce weight and size, he may be able to make compensations by particular emphasis on features for rapid disassembly.

Miniaturization of Electronic Equipment. Printed circuits and sub-miniature tubes are becoming widely used in radio, radar, and all airborne electronic equipment. Will eventually be required of other military equipment, such as calculators and machine controls.

Cold-Weather Kits - accessories and auxiliaries used to enable operation of equipment in cold weather.
APPENDIX IV

SOME GOVERNMENT RESEARCH FACILITIES

DEPARTMENT OF THE TREASURY

Bureau of Engraving and Printing Research Laboratory
Printing equipment; paper making machines; collating; stitching and trimming equipment.

Bureau of the Mint Laboratory
Metallurgy; metal forming process, plastics.

DEPARTMENT OF AGRICULTURE

Northern Laboratory, Peoria, Ill.
Plastics, elastomers, resins, adhesives.

Beltsville Agriculture Center
Machinery research

DEFENSE DEPARTMENT - NAVY

Special Devices Center
Electronics, servomechanisms, computers.

Naval Research Laboratory
Synthetic crystals for sound transducers and oscillators; infra-red radiation devices; non-inflammable hydraulic fluids; electronics; miniaturization and ruggedization of vacuum tubes.

Bureau of Ships
Ship structures; turbines; gears; propellers; shafts; boilers and fuel systems; electric generators, motors, cable and equipment; internal combustion engines and gas turbines, materials and processes; tools; storage batteries; ultra-compact power plants; diesel engines; synthetic fuels; refrigerating equipment and refrigerants; searchlights and beacons; standardization of electronic components. Bureau of Ships research installations include:

(1) Daniel W. Taylor Model Basin, Carderock, Md.
Ship hull design.

(2) Naval Engineering Experiment Station, Annapolis, Md.
Power plants, piping, fuels.

(3) Material Laboratory, Naval Shipyard, New York.

(4) Industrial Test Laboratory, Naval Shipyard, Philadelphia.

(5) Naval Boiler and Turbine Laboratory, Philadelphia.

(6) Navy Electronics Laboratory, San Diego.

Bureau of Aeronautics. Aircraft; engines; electronics; buffers; fuels; photographic equipment. Specific research centers include:

(1) Naval Air Experiment Station, Patuxent, Maryland.

(2) Naval Air Material Center, Philadelphia.

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1 "Designing for Military Requirements", PRODUCT ENGINEERING, January, 1951. Page 97
Bureau of Ordnance. Main installation is
(1) Naval Ordnance Laboratory, White Oak, Maryland.
Ordnance equipment; environmental testing; plastics; electronics.

ARMY ORDNANCE DEPARTMENT
Aberdeen Proving Grounds. Tanks; trucks and ordnance equipment. Includes Paint and Chemical, Photographic, Physical Test and Instrumentation Laboratories.
Frankford Arsenal. Servo-mechanisms, mechanical and electrical computers.
Watertown Arsenal. Ferrous metallurgy stress analysis, welding.
Other Arsenals at Rock Island, Watervliet, Picatinny, and Springfield.

ARMY QUARTERMASTER CORPS
Climatic Research Lab at Lawrence, Mass.
Refrigeration, equipment for food preparation.
Quartermaster Food and Container Institute, Chicago.
Container design, molded plastics, finishes, materials handling and lighting equipment.

ARMY SIGNAL CORPS
Coles Signal Laboratory, Squier Signal Laboratory, and Evans Signal Laboratory. Electronic equipment; electronics physics; miniaturization, ruggedization, and standardization; plastics and insulating materials.

ARMY CORPS OF ENGINEERS
Engineer Research and Development Labs. Fort Belvoir, Va. (Center for Engineer research including construction equipment, power plants, transportation equipment, cargo and fuel handling equipment.) Fire-fighting equipment, pumps, compressors, materials, maintenance equipment.

AIR FORCES
Air Material Command Laboratory, Wright-Patterson Air Force Base. Aircraft; electronics; airplane power plants and accessories; metallurgy; vibration and fatigue studies; low temperature lubrication; instrumentation; photographic equipment.

NATIONAL ADVISORY COMMITTEE ON AERONAUTICS
Langley Memorial Aeronautical Laboratory (Langley Field, Va.); Flight Propulsion Research Laboratory (Cleveland Airport); Ames Aeronautical Laboratory (Moffett Field); Aircraft design studies; fuels and lubricants, compressors, turbines, high temperature materials.
FEDERAL COMMUNICATIONS COMMISSION

Engineering Department. Radio equipment; high frequency industrial heating.

MARITIME COMMISSION

Technical Division. Welding, structural aluminum, paints, electronics, lubricants, gas turbines.

COMMERCE DEPARTMENT

National Bureau of Standards. Electricity and optics; metrology; heat and power atomic physics; chemistry; mechanics; organic and fibrous materials; metallurgy; mineral products; building technology; applied mathematics; ordnance development; electronics.

Office of Technical Services. Fibers, plywood, powder metallurgy, gasoline powered generator sets, electronic filing and selecting equipment, air conditioning equipment.

Civil Aeronautics Administration. Aircraft instruments; airport equipment, electronics.

Weather Bureau. Electronics, instrument research.

DEPARTMENT OF INTERIOR