CAUSATIVE MANAGEMENT FACTORS
RELATING TO INVENTIVENESS

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PREFACE

The work presented here was sparked by an amount of active participation in industrial research and invention which gradually convinced me that inventive genius is present in all, but in most the man-made environment totally squelches this ability. The real job of a director of research is not how to assign work to get requested work done, nor is it how to spot a genius to hire; the real job is how to release the inventive capacity of the people on hand so that the effort could be placed on "what they really should have been doing."

The attempt has been directed at presenting some specific courses of action whereby a director of research could release this squelched inventive genius in his subordinates. The value this study may have is due to the great help of the committee of professors who kept me on the track and headed into the material where fruitful investigation was possible. Drs. Earl J. Ferguson, James E. Shamblin, Thomas B. Auer, Ernest C. Fitch, and Clayton A. Morgan are responsible for what merit the work may have.

The initial encouragement and early guidance to attempt the work and to return to school came from the late Professor Wilson J. Bentley, under whom I had the privilege to study before his untimely passing.

The possibility for the attempt was, of course, created by my wife, Lucille E. and our children, Fredrich M., Lynne L., and Quentin C., who urged me to try and who carried on without husband and father for the necessary years. My brother, Dr. John M. Hilpert, and sister, Miss Myra E. Hilpert, also helped by "pushing little Connie along" as they have all my life.

Mr. John H. Batten, president of Twin Disc Incorporated, my employer, allowed a leave of absence so that I could return to school to study and learn so I could be reequipped with an amount of the advanced knowledge available in a modern college of engineering.

Mrs. Jean Lee has been able to decipher my terrible handwriting and translate it into perfect copy and with the help of Mrs. Portia Shea has eliminated my equally bad spelling and English.

Thank you each very much; it has been learning fun for me and I hope may be slightly worth while to others.

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CHAPTER I

BACKGROUND, OBJECT, AND ENGAGEMENT OF THE PROBLEM

Background

The mention of "Research Department" usually brings to mind an organization of people collected because of their unique inventive ability, applying their individual genius in a planned and directed attack on well defined obstacles in the path leading to a technological improvement in the health, happiness and general welfare of the people.

The mention of "Director of Research" usually brings to mind the guiding super brain who keeps the "Research Department" functioning as pictured above, is effective in leading the effort, and is responsible for selecting the creative geniuses who comprise the "Research Department."

The mention of "Research Scientist" or "Inventor" usually brings to mind a person who has decided his lot is to discover and create.

It is quite natural that a mental image such as this should be prevalent. The first establishment which had as its sole aim the creation of the new was Thomas Alva Edison's Menlo Park Laboratory (5). This institution originated the concept and was a supremely vivid example. As a first it was notable, and having as its head the greatest inventor of all time (1093 patents) it produced a fixed picture of the "Research Laboratory" or "Research Department" (41).

Today some great industrial corporations do strive to maintain a research department or laboratory in the image of Edison's Menlo Park, not as an imitation, but as the up-to-date result of 100 years improvement on an originally correct, basic idea. Bell Telephone Laboratories is perhaps the greatest and most obvious example of such a department. It nearly exactly supplies the prototypes for the pictures of the "Research Department," "Director of Research," and "Research Scientist" of the first three paragraphs.

The usual small company ($50,000,000.00 or less gross annual sales) research department, director of research, and research scientist are quite different in origin, organization, and real contribution to the corporate effort.

The following is a composite, perhaps more discouraging than any single real example, but with all factors taken from the experience of the author as a member of research departments, and as an involved observer of research departments of customer or supplier companies.

The beginning is not as a research department. The beginning is not with the research scientist or proven inventor. The beginning is not with the purpose to invent. The beginning is with a field service man or production assembler who is allowed to "rig up a test" in a corner of the production shop or in the company garage in place of the president's car.

The test is not to found or prove out an invention, but to determine a cure for some malperformance in a production design or to determine the characteristics of a new design. The service man rigged test might be to find a way to stop part X from breaking at 200 psi or to find the capacity of the fuel tank for an advertising brochure. An immediate result is that now sales can speak of "our test lab," hoping that a customer will visualize his purchase backed by a version of the paintings in paragraphs 1, 2, and 3.

The first "research scientist" in "our test lab" is a young engineer just out of school who is immediately quite useless in engineering design because he is totally ignorant of the company product. He is put under the guidance of the ex-service man in "our test lab" so he may become acquainted with the product. It is not even remotely considered that he could create or invent or even should while in "our test lab" as he was put there to "catch on," not "outstrip."

The real tangible result of this so called "test lab" is, of course, the cure to the breakage of part X or the correct capacity of the fuel tank. There is the more obvious useful value to the sales department, the ability to assure customers of the thorough research component of the product and an ability to show the facility to the customer. Knowing that no one expects creativity or invention from an educated novice and an ex-serviceman, the pressure is to run tests and provide a reasonable "research" appearance conforming to the sales department's concept of what will favorably stimulate the customer's confidence.

These beginnings are clearly the exact opposite of the first and correct industrial research laboratory and to an aggressive company management the fact becomes more and more obvious. Perhaps this realization takes place only after the pressure of field failure and specification fixing has enlarged "our test lab" to a few more people. It becomes known as the "Research and Development Laboratory" staffed with two "Research Engineers" and five "Research Technicians."

Actual selection of personnel is made as follows: one engineer is the young man above, the other an engineer who "just didn't work out on the board," one technician is the ex-serviceman above; two are service trainees and two are assemblers who took a cut in pay to gain the advantage of lighter work.

The realization by management of the necessity to convert from an impossible antithesis of a research and development laboratory to a real research and development laboratory puts the responsibility to do so squarely on the shoulders of some individual whom management decides should accomplish the mission. Call this man, the "Director of Research" and assume his job is to produce real creative invention with the facilities and personnel described above.

This is not intended to mean that the ideas, facts and resultant directions to move in are limited to the research department. Indeed, the president of the company, the chief engineer, the vice president of sales and any other manager should utilize what is herein to establish a higher level of creativity in their commands. The constant term director of research, will be used here only as a focal point not as a restriction.

There have been great amounts of investigation and discovery by psychologists in the field of creativity. A generous amount of this work has been aimed at the problem of recognizing and selecting inventive genius. Five good lists of characteristics of the creative person are found in Appendix A. Initially, this research is seen as of great aid to the director of research but unfortunately were he given the exact criteria of an ideal inventive genius and a test to locate this person it would be an academic exercise only. The director of research does not have the luxury of being able to obtain the people and facilities to do the assigned job but must do the assigned job with the people and facilities on hand. The change of facilities is possible as funds are made available. This is never very rapidly or copiously accomplished. The change of people is almost impossible and usually not fortunate when the change is forced, i.e., death, voluntary change of jobs, or gross incompetence causing dismissal.

Even with a vacancy to fill, the Director of Research, armed with the criteria of, and test for, genius is little better off than were he without these aids. The real fact of life is that the first fellow who looks like he might work out is hired; usually fewer than six applicants are necessary to find such a man.

The above very bleak picture is somewhat brightened by some observations of what has been the result of the great advancements in our knowledge of creativity. The "technology explosion," so often commented upon in the media, is mainly the mistaken idea that the existent mass production of similar things is the result of the mass production of new ideas, or invention. The number of patents granted per 1,000,000 population has not exploded. (See Table I)

The indication is that the recognition, selection, and utilization of genius is not in a marked manner better today than it was in the dawn of the industrial research laboratory, 100 years ago. The director of research who finds himself charged with the conversion of a department of seeming misfits in the field of creativity and invention is not truly left behind by a "creativity explosion." There appears to have been none.

TABLE I

PATENTS PER CAPITA (For U.S.A.)

YEAR	POPULATION (41)	PATENTS ISSUED (62)	PATENTS/1,000,000 PEOPLE
1870	39,818,449	13,986	350
1900	75,994,575	26,499	349
1930	122,775,046	45,342	369
1960	178,323,175	47,238	265
1970	203,184,772	64,439	318

When viewed alone, certain organizations appear to have had a creativity explosion, one such is the government. (See Table II)

This fantastic growth is not the result of an improvement in the management of creativity by the government but rather a change from a policy of doing nearly no research at all to one where government research labs are quite overwhelming in size. Of great interest and significance is the fact that in 1900 and 1930 the government did employ people but policy must have provided little opportunity to create and invent. Today, the govenment also employs people but also provides the opportunity to create and invent. The director of research could reasonably suspect that his five man crew, selected by a process not including a consideration of creative ability, could be changed from a non-creative group to a creative group by a change of opportunity. As a manager this he directly controls.

TABLE II

U. S. GOVERNMENT PATENTS

YEAR	PATENTS ASSIGNED TO U.S. GOVERNMENT (62)
1900	virtually none
1930	less than 10
1960	approximately 1600

The director of research can instantly change the incentives, opportunities, administration, formal and informal organization, and goals of the department. This he can do only if he has a clear picture of how to change these environmental factors in order to allow and encourage the creativity of his personnel to emerge.

The above statement may seem in direct contradiction to the deduction made from Table I. If, in general, country wide, modern psychology has not been able to accelerate invention, how can the director of research do so in his microscopically small department? In the small view this can be quite readily accomplished and might be explained as follows.

Assume two competing companies, A and B, who each build a form of product Z. The creativity effort in A is completely nullified, whereas in B it is encouraged. Company B's people invent an improved Z. Interestingly enough, had both companies had research efforts like B, it is very likely that still only one improved form of Z would result as one patent only is allowed per invention and that is the first to appear. The action is very similar to an automobile race. The number of entries does not affect the number of winners, nor does it directly affect the time from start to finish. Company A or B would have made the better Z and the other company would have wasted its time and money. The director of research by changing his department to one of creative production does not risk altering the whole inventive output in the country, he only risks beating out the competition.

The record of multiple invention is quite illustrative of this point. The Patent Office states that about 1% of the patent applications result in interferences (56). This means the unwitting race between inventors was so close that the result was almost a tie or a multiple tie. There are many more inventions which are not recorded where an inventor is totally surprised and disappointed to see "his invention" in the latest issue of the Patent Office Gazette invented by someone else.

Another great number of inventions are cancelled not because someone else has invented the same thing but because someone else has invented a better different solution to the problem. Only conjecture can be used to estimate the mass of inventions which were cancelled by the death of the steam locomotive and the vacuum tube.

The author, so far, has had only one patent which resulted in an interference but has had many "inventions" which were too late to be original, or while quite original were not nearly as good as some late patent by someone else.

The not so obvious result of the issue of nearly every patent is the nullification of an equal amount of work by an unknown number of other investigators. Thus, the director of research who decides to put his department into competition with other creative research departments only allows his company a chance of winning where previously it was a sure loser.

This investigation is not concerned with economic factors which might cause management to decide to compete or not compete in the research area but a hint of these is in order. There have been and are companies which compete commercially but invent nothing. Some of these are leaders in their field. The William S. Haynes Company of Boston, Massachusetts is an example. World renowned as the maker of the finest flutes and piccolos, their preeminence is not based on rapid development of the product based on research. Their product costs about as much as a large deluxe refrigerator or television set, but is not markedly different or better than one built fifty years ago, which is not similarly true of the refrigerator or television set.

The automobile industry is interesting. Their output of patents is seen in Table III.

TABLE III

AUTOMOBILE COMPANY PATENT RATES

COMPANY	SALES 1971 (9)	PATENTS ISSUED 1970 (62)	PATENTS/SALES 10^9 DOLLARS
General Motors	\$18.7 x 10^9	400	21.4
Ford	14.98 x 10^9	169	11.3
Chrysler	4.51 x 10^9	38	8.4
American Motors	1.09 x 10^9	5	4.6

The management of the companies appear to be satisfied to let GM be the leader and each apparently exerts only the effort needed to stay ahead of its follower. Looking at the "Research Race Track" none of the competitors appear to be "charging" hard enough to advance its place. Management of the lesser three appears to see it as not economically feasible to risk research competition with its superior. The far fewer product lines of the lesser three could allow any of them to outstrip GM with very little extra expense. The author's company believes a patent costs on the average of \$5000.00. Only 59 patents per year more, 0.65% of its sales dollar and Chrysler Research might equal GM, but instead made a decision for non-competition.

The present study will assume that management has decided to pursue aggressively creative research and invention. The director of research is commanded to produce useful inventions at the maximum rate company resources will allow and thus must establish.

Four Criteria of Inventive Environment

1. A technical environment equal to the state of the art;
2. True technical direction to the effort;
3. An effective motivation of creativity;
4. An administrative environment in which creativity is encouraged.

Object of This Investigation

The object of this investigation is to determine management controlled causative factors which allow the establishment of the four criteria above. Further, so that a company may benefit from the latent inventive genius inherent in its employees, specifically those in the research department, a defined course of action is presented for the director of research to follow.

Engagement of the Problem

Number one of the four criteria listed above is perhaps the easiest to provide and so is the one on which all resources are often spent. The knowledge to spend impressive amounts of money on even more impressive equipment is stored in the minds of all graduate engineers and technicians. The writer has seen tens of thousands of square feet of laboratories full of highly refined research equipment, the cost of which eliminated nearly all competent personnel. Finally, the parent company was forced to attempt to peddle its laboratory capacity to others and ultimately liquidate the facility. Until he too was "liquidated," the head of this research effort was enthusiastic about some new instrument which could determine some value more accurately.

This investigation will completely avoid a discussion of hardware. The author is technically familiar with the hardware pertaining to his past experience, and thus, could not intelligently discuss other. It is hopped that this investigation will produce some ways to accomplish 2, 3, and 4 of the above. The fundamental truth is that people invent and create; test hardware helps only if it is completely subordinated to the will of the inventor to solve his singular immediate problem. General instrumentation so impressive to "visiting firemen" only diverts the inventor from how to make his idea, to how to have a problem an on-hand facility can solve. The hardware which confronts the director of research as he begins to convert the department is already ill suited for the real creative research about to begin. The director of research should spend no money at all on hardware until he has effectively established 2, 3, and 4.

The statements of how the great geniuses invent are interestingly in support of this statement. Their statements are reminiscent of the powerful work Euclid did by scratching in the sand with his cane or Erasthenes did with a tower and a hole some distance apart. Joseph Rossman (48), has studied over 700 great inventors and has collected statements of their methods of inventing and their mental processes. The analysis of their replies he has reduced to the following distinct steps.

1. Observation of a need or difficulty.
2. Analysis of the need.
3. A survey of all available information.

4. A formulation of all objective solutions.

5. A critical analysis of these solutions for their advantages and disadvantages.

6. The birth of the new idea -- the invention.

7. Experimentation to test out the most promising solution, and the selection and perfection of the final embodiment by some or all of the previous steps.

Only in step 7 could one imagine the inventor to be hampered by lack of hardware SUITABLE "to test out the most promising solution." This is AFTER step 6, THE INVENTION. Thus, we see that even for the great inventors hardware is the last consideration and of course cannot be assembled ahead of time, unless someone can be ahead of first. Tube testers had to come after DeForest invented the tube.

A typical but short statement by A. Y. Dodge, as quoted in Rossman (48) is copied here.

ACTUAL METHODS OF INVENTING

> When working out a new device, mental pictures present themselves to my mind quite rapidly, more rapidly in fact than I can record them on paper. Therefore, the first step seems to be a process of eliminating the imaginary pictures to reduce the group to those most feasible. Another process of elimination follows after making freehand sketches, and a further process of elimination follows after laying the parts out to scale and studying the functions of the different parts in detail. This usually brings me to a lay-out (in complicated cases) which requires reinventing, or at any rate additional scheming in order to improve some of the objections of phases of the mechanism. (A. Y. Dodge)

A. Y. Dodge was a most prolific inventor of mechanical power transmission and control systems and devices. Nowhere in his statement of how he invents is a hardware requirement mentioned, yet a dynamometer installation to adequately put numbers on the performance of one of his inventions could easily cost $100,000.00 and be a source of just pride to its designer and an itinerary highlight of a "visiting fireman."

The great inventors studied by Rossman describe their mental processes and none emphasize the role of hardware or hardware generated mountains of data. A. D. Moore (41) quotes Einstein, Helmholtz, Edison, and Poincare briefly.

> EINSTEIN: I believe in intuition and inspiration. . . At times I feel certain I am right while not knowing the reason. . . Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution. It is, strictly speaking, a real factor in scientific research.

> HELMHOLTZ: [After previous investigations of a problem]. . . in all directions . . . happy ideas come unexpectedly without effort, like an inspiration. So far as I am concerned they have never come to me when my mind is fatigued or when I was at my working table. [Helmholtz got his inspirations when rested--often in the morning.]

> EDISON: The key to successful methods comes right out of the air. A real, new thing like an idea, a beautiful melody, is pulled out of space.

> POINCARE: . . . creative ideas did not come to him while he worked at his desk, but frequently flashed into his mind while engaged in other activities.

The author's experience has been quite in agreement with these sentiments. It is a firm conviction on the part of the author that a "researcher" taking data meticulously or instrumenting complexly is not functioning in a creative mode at all. He is a prisoner of no direction or misdirection and has retreated to a defensive position of exhibiting an obviously admirable quality of diligence and earnestness. The author has been guilty of all such sins and a typical example of a hardware blockage of creativity is useful here as illustration.

The company's clutches were suffering heat damage and research was asked to investigate. An immediate question was, "How hot is it inside the clutch?" This, for many reasons, is an instrumentation problem which has never been solved for reasons beyond the scope of this writing. The uninformed instantly wade in with confidence and the subtle problems show up one at a time. Each appears in a manner which allows optimism as to the effect of the new instrumentation innovation. Analysis of voluminous data shows that hours of work produced the conclusion that as yet there is no answer present to "How hot is it inside a clutch?" Progress continued to the point where data sheets were printed, on which the answering data would be printed, but still the instruments refused to produce the answer.

The problem was solved by subterfuge. A data sheet was filled out by the author with completely fictitious data as though success was actually on hand. The "answer" produced no suggestions at all which could prevent the heat damage. The entire test was stopped, the apparatus dismantled and the answer never found to "How hot is it inside a clutch?" but the research that started then allowed the company to market clutches which simply will not burn up or suffer any type of heat damage, even when operated by a malicious operator, and none has ever worn out.

This same fascination for hardware "pre-requirement" procured and its catastrophic uselessness is difficult to document in the case of industrial research and invention. The evidence of the error usually disappears with the effort which it has caused the demise. The pages of history, however, have some interesting records of the fascination with hardware development in anticipation of the need and its critical effect.

The records of Scott and Amundsen's race to the South Pole is interesting, and to the point (47). Amundsen is quoted, "My object was . . . to concentrate all our forces upon the one object--that of reaching the Pole." Traveling with only proven artic equipment and pulled by proven artic dogs, Amundsen accomplished his intended mission exactly as planned. It might be said Rossman's steps 1 through 6 indicated step 7 needed hardware of a very narrow assortment and of a type that would not become part of the problem rather than a means to the solution.

Scott, it seems, was more interested in hardware "perfection." His hardware included "motor sledges." "It was claimed that they could pull a two ton load over any surface." But they were not developed specifically for Rossman's step 7. These machines had such a record of aid to the effort that the early loss of one, which fell through the ice upon unloading, was commented upon as, ". . . a stroke of luck." Other seemingly odd motive power for artic use were nineteen ponies, also to prove unsuited for the environment of the Eskimo.

The effect of this hardware orientation rather than mission orientation is interestingly noted by Wally Herbert (20). "His [Amundsen] total climbing from the time he left the ice shelf to the time he returned from the Pole was 19,590 feet, as against 11,470 feet climbed by Scott's party."

It must be remembered, Amundsen was using only hardware developed by nomadic Eskimo tribes several thousand years previously. Scott was finally defeated by his modern hardware problems. Amundsen solved the larger problem much more quickly.

It could be demurred that being first to reach the South Pole is not quite like being first to make a phonograph but it is of striking similarity that the firsts in both cases moved directly, enencumbered by problems of hardware which was ill conceived for the task involved.

The above investigation has produced a definite, if half negative, course of action for the director of research in converting the department to do effective creative research resulting in invention. This is: "Buy no hardware until after someone has gone through Rossman's first six steps above and obtained the invention." The positive action then might be: "Buy only what the inventor needs for THAT invention to progress through step 7."

The background of the problems a director of research and development faces in the small company has been discussed and one of the problems, that of establishing, "a technical environment equal to the state of the art," has been dealt with.

CHAPTER II

THE INVENTION SEQUENCE

The purpose of this chapter is to describe in good detail and thoroughness the complete process of invention using as examples several of the author's inventions. These examples and discussion thereof will supply some evidence of direct courses of action a director of research should move in to establish creative research and invention in his sphere of influence.

Case One: The Omega Clutch

The first example is of a device marketed by Twin Disc, Incorporated as the "Omega Drive" and "Omega Clutch." The Greek letter "ω" in engineering usually refers to rotational speed; the clutch is sensitive to speed, thus the name "Omega."

The author was formerly in charge of the Hodgkins Test Facility of the Industrial Power and Equipment Division of the International Harvester Company. This was a proving ground for earth moving equipment. There the author became minutely familiar with the operation of all types of earth moving equipment, averaging twenty hours per week of actual "cat Skinning," grader, scraper and loader operation. This experience was as necessary to the later inventions as it was for Thomas Edison to be a skilled telegrapher in order for him to see the telegraphic deficiencies he was later to eliminate (5).

The many hours of operation gradually raised the skill to a level where the author no longer needed to think about what he was doing but could operate by reflex and apply his thoughts, as an engineer, to how to better design the equipment so it would allow an operator to do "what he really ought to be doing." Many such improvements, of course, were becoming more and more obvious with each added hour of operation and attempt to obtain higher and higher production, but here only the master clutch problem will be considered.

The I. H. C. TD-24 was at that time the largest and most powerful crawler tractor in the world. A unique steering system made it also the easiest to operate and thus it could be pushed by the operator to remarkable production (for that time, 1951). The limiting factor was the master clutch. A hard working TD-24 did not emit the familiar aroma of diesel exhaust but of Raybestos-Manhattan #1488 clutch facings operating far too hot and vaporizing.

When not operating, the author was submerged in all tests at the facility, the most important being the problem of the TD-24 clutch. The clutch was, commercially, barely economic. Every four hours the operator needed to adjust it to prevent slippage and complete failure.

An advanced TD-24 arrived at the facility which included a then novel hydrokinetic torque converter behind which was a new type master clutch of extremely high capacity. The author again was able to put in a major amount of time "skinning this cat" and found this new extremely large clutch to be a catastrophic failure, usually being completely destroyed in thirty minutes of normal operation.

Soon thereafter the writer found himself employed by Twin Disc, Incorporated, a company making clutches and torque converters. An immediate project for the research department was a crawler tractor transmission system then being tried by Allis Chalmers Company in an experimental HD-19. A design similar to the catastrophic failure in the TD-24 was a similar failure in the "almost as big as a TD-24" experimental HD-19. The author became an expert HD-19 operator at the Allis Chalmers proving grounds and was becoming quite aware of "what he really should be doing." One very startling observation was made after extensive operation of a standard production HD-19. The very low capacity, relatively crude master clutch in the standard production Allis Chalmers HD-19 almost never needed adjustment and rather than being the limit on production could not be damaged by anything which at that time was called severe operation.

At this point in the process of creativity, the conditions were as follows.

An individual who was in possession of the academic education gained by having earned three degrees in Mechanical Engineering had also become minutely familiar with the entire technical engineering and worker level aspects of the machine, its work, its operation, and its limitations. The author could look at it as a well trained engineer. The author could look at it as a skilled operator. The author could look at it as a service mechanic.

The significant point is that in one individual's mind, all of these views were multiplexed into a single thought function. Three individuals, each of superior abilities but with singular views, could not have produced this multiplex of views into a single thought function.

The support for this statement is by the logic that follows. It would only be gross conceit to opine that previous to the author's approach to the problem the engineering talent, operator skill, and mechanic's skill had been less competent. It is well known to the author that in both Twin Disc and Allis Chalmers, many engineers of superior ability, many superior operators, and superior mechanics, had all been concerned in concert about the very problem described, but the solution did not come for them.

A more well known example is that of Theobald Boehm's invention of the Boehm System Flute and the construction of the first silver flute. There were silversmiths of Boehm's competence, and flutists of Boehm's competence, and acoustical physicists of Boehm's competence. Boehm could, however, see the problem from all views of knowledge and experience so he did what none had before. Quite tritely, but quite rightly, had only one blind man been allowed to "see" the elephant from the "views of all six," his description might have been more accurate than the sum of the six independent views that it was a spear, a snake, a rope, a tree, a wall, and a leaf.

This multiplexed view, which was the author's only possible view and the other concerned engineers impossible only view, enabled the analysis to be made which is found in U. S. Patent No. 3,202,018 by the author (23). This analysis completely explained the clutch failures. But more valuable than that, it immediately indicated that it should be possible to make a master clutch which absolutely could not be damaged by intentional abuse or excessively severe operation. Intentional slipping of the clutch if ahead of the converter would cause no greater need of cooling than that already supplied to cool the converter.

Later the exact design of the initial field test report in its first application with no interim development made the most durable and successful power transmission system in the field from a former non-commercial catastrophic failure (23).

The fundamentals of this patent do not show any engineering beyond that which any graduate could accomplish were he set to it. The only reason the author could see to set himself to do it was because he had the description of the probelm forced upon him by seeing the conditions from the three mentioned views. The author invented and others did not because there simply were no other engineers either at Twin Disc or its customers or competitors who had such a vivid view of operation and mechanical service. It is a surprise to customers when a person titled "Chief Engineer Research" will climb on a crawler at 6:00 P.M. and off at 9:00 A.M., having done 15 hours productive bulldozing. This type of activity is what gave the added facts to enable their assembly into an invention.

Again, hundreds of hours of operation of these machines continuously pointed out that even though the system was thoroughly indestructible the master clutch lacked ideal control. Now the clutch can be slipped indefinitely, at all power levels without harm; thus, ideals of controlled continuous slipping operation are now possible should better control be inherent.

These ideals of operation could only be seen by an engineer who also was an operator or by an operator who was an engineer. The dichotomy presented by singularizing the abilities of the one involved is an effective block to innovation. The operator <u>only</u> has one problem to solve in a more and more effective manner; that is, how to become a greater and greater virtuoso on the equipment he is afflicted with, making it perform to, but within, its limits. The engineer <u>only</u> has one problem to solve in a more and more effective manner; that is, how to make the equipment so that the operator can more continuously perform at his best virtuosity. This division of singular purposeful excellence produces a better what-has-always-been, but cannot initiate a feeble try of the grossly different.

Many methods of how to obtain control were conceived and studied, and continued operation continuously re-enforced the knowledge and conviction of the benefits available were good control possible. The result, after much engineering effort, was that control would be possible if a friction clutch were made which could operate independently of the coefficient of friction. The design applicable in this case is explained in the author's U. S. Patent No. 3,352,395 (24) and U. S. Patent No. 3,358,796 (25). These inventions contain only knowledge which any competent mechanical engineer would consider quite mundane and, indeed, the production versions of these designs are much more ideal by virtue of the work of many brilliant mechanical engineers who need be engineers only, their problem being to improve on an already is.

Any person who is only an engineer could have accomplished these inventions had someone asked him to solve each of the problems, the combined solution of which is the invention. Any operator could have directed any engineer to do so, had the operator the benefit of the engineering insight to see that what was of advantage was also technically possible. Any engineer could have established these operational ideals were he able to ask the correct questions of any operator.

An engineering department or research department which is organized so that this "complete experience" is not possible has effectively stopped all creative research and invention. Visualizing the whole organization and process of creativity as a system and comparing it to an animal system, such a disconnection in the creativity system is exactly that of the starving toad. It is common knowledge that a toad will starve to death in a cage when supplied with freshly killed bugs, of which the toad's diet consists. All conditions are present for the toad to grow fat. Unfortunately, the toad's body system asks, "Is there something here that looks like and moves like a bug?" It gets the correct answer, "Nothing here looks and moves like a bug." The correct question, "Is there food?" is not asked.

This entire line of thought on the management of creativity is epitomized by Peter Drucker's (8) poignant statement, "For there are few things as useless -- if not as dangerous -- as the right answer to the wrong question." "Toad like" research management is sure to get exactly what Drucker cautions against.

Case Two: Clutch Flutter

The path of investigation leading to the relevant facts of a phenomenon known as "clutch flutter" and the invention of its cures is further illustration of the necessity for the investigator to be possessed not only of the technical knowledge which will ultimately solve the problem, but also the most minute, detailed, first-hand experience with the problem. The startling part of this invention is that the whole phenomenon of "clutch flutter" is one in which the simple application of pure academic theory taught in every basic dynamics course is completely explanatory. The terminal destruction of transmisions from this phenomenon of flutter had been an unpleasant fact for years. It was described by voluminous data which was analyzed by the most brilliant minds available. The unfortunate and usual system of applied research organization caused the mind containing the powerful theoretical knowledge to be the most remote mind from the instances of failure. This mind was set at solving the problem by remote control, his time conserved by having delivered to him only cleaned up data reduced to manageable quantities.

The absoluteness of the impossibility for creativity is completely obscured by the obvious amount of work this powerful analytical mind could do with the data given. He produced the maximum of theoretical analysis and deductions and conclusions and recommendations based on data collected by minds which could not recognize the problem to be solved. It is like using the finest color film available to photograph the colors of a beautiful afghan but illuminated by pure monochromatic light. Perfect pictures of exactly what is illuminated by the light come forth every time the shutter is clicked. Brilliant analysis will come forth hour by hour from the powerful analytical mind based on what was illuminated by the data.

In the case of clutch flutter, the author was fortunate to have possessed the technical knowledge needed and was not "helped" by others "cleaning up and reducing the data to a manageable size." The author was in physical contact with the field and laboratory machinery every minute it was run or being modified. The test was not considered in progress unless this were true.

It must be pointed out that the engineering and research departments of at least two competitors, three customers, one independent research institute and two other divisions of the author's company were simultaneously and intensely pursuing the solution. All of these other efforts were led by engineers easily capable of the correct analysis but who were depending on data cleaned up and reduced to manageable size by lesser minds. This data reduction allowed the fundamental observations which indicated the solution to be missed by these other investigators.

These were:

1. A disengaged and never previously engaged clutch could flutter to destruction. (A forced observation of the author's since he not only built the clutch and transmission in the shop but also completely checked it and completely destroyed it in 2000 yards of operation).

2. The plates could run slanted and thus possess gyroscopic precession. (Again, an observation forced on the author since he built each clutch tested in the laboratory, disassembled and inspected each one and reconstructed each catastrophic failure.)

The first observation enabled the instant elimination of all further field testing as there was no field operation where the unique condition was never to engage the clutches. The other investigators missed this point. True, any of them could have asked the question, but any clutch theory up to then "proved" clutches burn up because of slipping under load or partial release or engagement; the theoretical mind using second hand data was free to make the assumption that for some reason the clutch must have improperly released or incompletely engaged. The author's theoretical mind had a new but correct problem forced on it. "Why did a clutch which had never been engaged and completely released burn up?"

The second observation was missed by other investigators because they looked at the meticulous data collected by laboratory and proving ground personnel who knew nothing of gyroscopic precession or Euler's equation of motion and thus could not record an evidence of the presence of such for the knowledgeable reader to recognize. SAE Paper No. 6990066 by the author (22) is an analytical discussion of the problem showing the startlingly straight-forward application of Euler's equation of motion for the complete explanation of the phenomenon. The author's U. S. Patent No. 3,446,323 (26), U. S. Patent No. 3,472,348 (27), and U. S. Patent No. 3,482,668 (28) cover the cures invented by the author. Evidence supported the fact that engineering as taught in a normal mechanical engineering course, when combined with complete experience with the problem, made the solution quite obvious.

It was revealingly true that in discussions of the author's explanation and cures with other investigators of clutch flutter the engineers easily saw the fundamentals and could see answers to questions in their minds, questions which had been raised by their studies of "cleaned up data reduced to manageable size." A typical comment was, "Oh, that explains why . . . . . . could be true."

Discussions with the engineering managements of the organizations which did not find the answer brought forth a uniform and interesting remark, "We can't have our analytical minds wasting time playing in the grease in the lab or in the mud in the field. We have mechanics and operators for that. We must keep the technical minds on the technical work." This attitude remained in spite of the obvious fact that all of the efforts of not only their technical minds but operators and mechanics and hardware were totally wasted. Their research management policy insured that their technical minds were ideally able to concentrate only on the higher level knowledge demanding solutions to the wrong problem. Research management had each person diligently working at tasks exactly suited to his skills producing a maximum of answers to irrelevant problems.

The management of creative research and development is thus critically different from the management of mass production or other commercial enterprises. The mass production of a commercial product is most efficiently accomplished by breaking its manufacture into parts which are made by specialists doing the same thing over and over but each doing as per a master plan previously delineated. The end product is clearly known before anybody starts work. Creative research starts and must ever continue with no similar plan or end defined.

The transfer of the conditions surrounding research to a production shop would have the plan of the shop work as follows. Each man make his machine produce something it does well as fast as possible from what is delivered by truckers traveling the shortest route between machines. Raw material will be whatever purchasing can obtain most economically. Assembly will put finished parts together in the most expedient manner. It is sincerely hoped hard work by all will produce whatever it is going to be, such that the company will prosper.

One of the research organizations studying clutch flutter so efficiently concentrated their efforts, as the absurd example above describes, that a "cure" which they recommended was, in fact, the worst thing possible which could be done to a standard clutch if the elimination of flutter was sought. The research which resulted in this was as sincere but also as erroneous as the "bleeding" done by medical doctors of the 1700's.

A very clear discussion of a similar facilitation or impediment to creativity is done by A. D. Moore (41). Moore shows very clearly how the ancient Greeks could have advanced mankind nearly 2000 years had they not almost completely isolated the theoretical mind from the real and practical.

The policy was for the thinkers to think and argue theory, practical application was beneath them. The doers did only the commonplace as advanced theory was beyond them intellectually and by policy.

The ingredient of creativity which the "toad system" of research management loses is called "insight" by Haefele (17). His eleven types of insight are as follows:

(1) The response is to sudden chance stimulation on a problem not under active attack, perhaps even never considered. This kind of thing may happen quite often, as when one looks up a journal article in the library. The attention strays to the article following. It stimulates an idea remote from the initial purpose in going to the library.

(2) The idea arrives as a "side thought" analogous to Hadamard's "thinking aside." It is the sudden realization of the answer to a problem while doing something else.

(3) An unexpected event, perhaps in experimentation, is correctly interpreted, as when Perkin said, "'If this color is so intense, it can be a dye.'" The unexpected result may be in the form of a very slender clue. Assume that some experiments are made, even without strong expectations. One result triggers the mind to progress, even though its relation to the direction of progress may be most tenuous.

The next four types of insight possess a large element of deliberate effort.

(4) The answer comes from a continuous sequence. There is the problem, and the work on it, and the solution.

(5) The answer comes on resumption of effort. Having done preparative work, and allowed time for incubation, some free time is taken for deliberate exploration for the answer. Soon, the fruitful idea comes.

(6) In this case, following preparation and due incubation, a train of thought directed to solution is initiated from the unconscious. This differs from (5) in the impetus of reattack, and from (2) in that one is not suddenly surprised with the answer, but starts thinking and quickly develops it. It is as if the solution were nearly ready, and the unconscious wished to gain rapport to finish the job most expeditiously, needing, perhaps, conscious aid to put the last stitches in the tapestry.

(7) Insight is by total coverage. A deliberate plan is made to cover all of a certain area and obtain the answer. Here, another and different insight preceded the planning. That was to perceive and delimit the area of study, and specify the methods to be used.

Four other types of insight are of special nature.

(8) A relay insight recognized as such. Here, some material is discovered which is at once recognized as especially pertinent. In scientific work, for example, one determines what would be a good experiment to try. It may or may not work. This insight differs in being an especially happy combination rather than the answer itself. The type is particularly prominent in literature and the arts. Tissot, in his mind's eye, saw figures moving in the ruins of a cathedral, and explicated the idea: That should be a good subject to paint. A lyric poet may be impressed by a scene, and feel that his description of the locale will make a good poem, after he has modified the details so . . . and so . . . and so. A writer may become acquainted with a strong or unusual character, and decide that he should be put in a story. Such occurrences and decisions have been vividly described by Richard Wilbur and Dorothy Canfield.

(9) A very common kind of insight occurs when a mass of material suddenly emerges as a pattern, or several ideas fall together into a unit or orderly arrangement. The new thing is the *ordering* of the ideas.

(10) In this type, one obtains as an insight a particular aspect of a more general case. But only gradually, as effort continues and the particular insight is worked with, does it dawn that "the general case of which this is a particular example is true, too, and it may be stated in this way . . .

(11) In this case, an insight is utilized in the progressive work for some time before it is consciously explicated as the principle upon which one is operating. The occurrence of this phenomenon in concept formation studies has already been mentioned (pp. 76-79).

It can be seen that each of these insights quite reasonably requires all facets of the final answer to have been present in the inventor's mind before whatever stimulii or "key bit" of knowledge allowed an assembled answer to be conceived. A policy which prevents the presence of any piece of this knowledge in the inventor's mind precludes insight.

Research Work Assignment Policy

The director of research must insist that every person who it is hoped will invent or create must study, participate in, and experiment with a whole problem, not "his knowledge level or most pleasant specialty." The delegation of a man to "his specialty" or "his level" in the organized attack on a problem effectively removes him from a creative role.

A. The ability specialization organization of a research department insures:

1. Continuous, orderly, efficient production of the highest level of totally useless recorded knowledge possible for the group.

2. The intentional segregation of knowledge in individual brains, so that no brain contains enough facts so that a solution or invention can be assembled.

B. The whole problem assignment organization of a research department insures:

1. Sporadic production of solutions and invention, average rate limited by the relation of educational level required by solutions to the educational level of the person assigned and his inspiration to diligent work.

2. Production of useless invention or infrequent invention curable by redistribution of people and problems.

The above directions and information if followed by a director of research will not assure that invention will happen but will assure that invention can happen.

A word of warning: much of top management is production oriented and will be favorably impressed by A., 1. above. If this penchant for continuous, orderly, efficient, high level, useless report production is extremely strong, no cure is possible. The director of research should leave this employer and move to one where reason is used.

The question, "Can this philosophy produce results if applied by a research director to his department?" will be answered in a following chapter.

The above states the results produced when a chief engineer of research applied these principles to himself. Each of the author's thirty patents is the result of exactly this process.

CHAPTER III

INVENTION ON DEMAND

The next to last paragraph of the preceding chapter asked, "Can this philosophy produce results if applied by a research director to his department?" The answer, pointed affirmative is presented in this chapter.

"Invention on Demand" is not intended to mean that invention comes forth because the boss has said, "I want an invention." This produces no results. No one told Edison, "Invent the phonograph, think of all the records we could sell." Invention comes about because the boss has "voiced" his demand by setting up the conditions where invention of some kind could take place and by putting people in these situations and keeping them working on solution to the obvious problems to which the inventions will not be the solutions. Shockley, Brattain, and Bardeen invented the transistor from just such a situation, related in the original case history by Jewkes, Sawers, and Stillerman (32) pages 317-318. While studying the specific problem these three inventors saw a totally different problem and the solution became the transistor.

Case One--Invention on Demand

The first case of "Invention on Demand" is the invention which was granted U. S. Patent No. 3,417,845, December 24, 1968, to J. P. Swanson (53) "Actuating System for Multi-ratio Transmission."

At the time of this work Mr. James P. Swanson was a research engineer in the research department of Twin Disc, Incorporated which was headed by the author. Mr. Swanson was put in the position of being encouraged to do constructive thought on the control systems used on the company's multispeed, powershift transmissions. These units with up to six speeds forward and backward automatically shifted under loads of 100 H. P. to 1500 H. P., were attendant with a complicated hydraulic and/or electrical control system best described by an observant mechanic with a naturalist's view as a "Mess O Worms." Mr. Swanson was continuously forced, by the need to know all, to operate, and build, to repair and modify the systems in the customer's shops, proving grounds, and the "customer's customer's" stone quarries, mines, lumber camps and boats. Being a graduate Mechanical Engineer from Iowa State and thoroughly versed in the most up to date solid state electronic circuitry and application and with facilities to work with Mr. Swanson did not invent an improved "Mess O Worms" that worked as desired.

Patent No. 3,417,845 (53) was a quite radical approach to the system. The change was so radical that much resistance to it occurred immediately. This is usually a good sign to the experienced inventor, as it means that it is really a worth while innovation, or an unworkable misconception sure to fail the first test. The latter is, of course, not the product of any but the most naive innovator. One chief engineer was heard to remark, "That will never be used as long as I'm chief engineer." Today, he is still a chief engineer, is using the device and, in fact, is proud of his amplifications of the original idea.

This was not an "accidental" discovery while pursuing some other work. It was, rather, recognizing a fundamental problem that needed solving and then coming up with a novel solution. This solution could not have come forth unless the inventor had been in a position to see the problem. The author did not issue any instruction such as, "Jim, invent an end of shaft unitized valve and manifold system and electrical control circuitry which will allow electrical control, and reduce the pipes and hoses by a factor of seven to one and supply higher flow rates and quicker clutch action with fewer valves, making the whole thing as impervious to the environment as a blacksmith's anvil." The directions were that Mr. Swanson should apply himself mainly to the system from the operator's hand to the clutch shaft end and do the job he found would be satisfactory.

This type of originality is usually inspiration for dissatisfaction with the inventor's work by many who asked for the problems to be solved in the first place! The attitude is "We didn't ask for a major change, just a little something to get it working." An attitude almost like telling an M. D., "Doctor, I didn't want you to take out my appendix, just to stop that awful paid I had."

The director of research has a large protection duty to perform in nearly every instance where an innovation is made. This was not satisfactorily accomplished for had a questionnaire (described in Chapter V) been sent to Twin Disc, Incorporated, re Mr. Swanson, it would have been returned marked "No longer employed by Twin Disc."

Mr. Swanson, while becoming completely knowledgeable about the product, its uses, its desired performance, its service problems, its production problems, its application problems, was not reading reports written by lesser powered minds who cleaned up, ordered, and reduced the data to manageable size and uniformity. Mr. Swanson, for instance, was at a customer's proving ground for one week of every four for about a year during which time he operated every test machine a knowledgeable length of time every eight hour shift, twenty-four hours a day, seven days a week. On call at all time in the motel, he was instantly available to observe hints of trouble by the personnel and being a good operator himself could duplicate the malfunction in its most obscure form.

The other three weeks of the time were used in the laboratory and office, trying to find solutions or better ways. The upshot was that the "Mess O Worms" should not be put in order at all but a different approach entirely should be sought; the patent (53) covers this real cure.

The following is the response from Mr. Swanson to a request from the author to tell what he thinks allowed him to invent.

April 15, 1972

Conrad R. Hilpert
1301 West 3rd Ave.
Stillwater, Oklahoma
74074

Dear Conrad:

In reply to your inquiry regarding the actual and ideal background associated with a product development program, I trust the following comments shed a useful light on the subject.

By way of introduction, it should be noted that the discussion applies to the development of a valve system (resulting in the issuance of a patent) applicable to Power-Shift-Off-Highway Transmissions. The device was the happy combination of features which while enhancing the overall power train operational characteristics it also provided a substantial cost reduction to the OEM user. The device, furthermore, passed the ultimate test for its veracity in that the valve system ultimately found its way into production.

I shall not discuss the obvious requirements of an invention, i.e., the realization of the problem and its development, but rather concern myself with the environment provided by management. My opinion does not coincide with the commonly expressed one to the effect that inventions are merely the outgrowths of personal inspirations of the moment.

Quite the contrary, it is mandatory that the potential inventor be placed in an environment where a total realization of the "present" is possible. The classic story of the blindmen inspecting the elephant and drawing, for them, the obvious conclusions that an elephant is like a snake, etc., applies to the inventor, if he does not have the total situation in view.

With my invention, the Collector Valve, this formula for success was applied. I had the opportunity to become involved not only with my own company's product line, but also had free access to the customer's product. Hence I was allowed and encouraged to view the whole elephant, of which the collector-valves predecessor was only a very small part by comparison. The ultimate customer could see some rather irritating problems with the "predecessor" including service problems and the like. The OEM was aware of still other undesirable features, but in both cases the overall picture was an unknown, and the "predecessor" did function and had for years. In retrospect, the collector-valve was an obvious solution to the problem and in fact did enhance the performance of the vehicle, but it was obvious only when it could be viewed in the whole. In order for the inventor to function, management must encourage, or at least tolerate, the involvement of personnel in the total overall picture.

Obviously, from an economic standpoint, all people cannot be involved in all of the product line. Hence the necessity of creating an invention team for a specific product area. On the hardware level this means that the responsibility must rest with an individual, supported by a group comprised of specialists, i.e., mathematicians, technicians, designers, mechanics, operators, etc. It should be clearly understood that the operation is centered around an individual. This individual must in turn understand that a successful operation cannot be run from afar, nor will inspiration come out of the slide rule.

The Director of Research has the responsibility, to the inventor designee, to keep him properly supplied and supported. The successful creation of the Collector Valve followed this pattern. I was given total freedom of investigation on one hand while on the other, physical hardware and detail support was to be had for the asking. The director's initial selection of the inventor obviously has a distinct bearing on the project outcome.

The world's greatest mind could not create a useful product without a good deal of elbow grease, nor can the world's hardest worker create a useful product without having trained his mind and acquired some practical experience.

As a director of research, I would look for an individual with average intelligence or above, who has demonstrated his ability to work with diligence, who has been or can be made knowledgeable in the product area. The formal education background must be viewed from the standpoint that the potential inventor has been given a reasonable background in "read'n, rit'n and rithmatic" preferably through or beyond the B. S. level.

The basic college, or graduate college education is fundamentally associated with a very broad historical view. The inventor will be concerned ultimately with the future and in a very limited area of interest. As an inventor, I was concerned only with the off-highway vehicle as a whole, aiding to lead me in a direction to improve a very specific item in a manner that was most compatible, i.e., required response times, rugged, etc.

Every rule has its exception of course, but with the inventor an adequate academic background is a necessity. There is always the possibility that the drill press operator will drill a hole wrong and solve the stability problem, but one can hardly rely, nor wait for such a happy occurrence. The level of the background, formal or otherwise, required is reflected in the time required to achieve a useful solution. In other words, a man could be taken off the street, who is willing to work, and become an inventor providing the time can be spared to accumulate the necessary background knowledge. This is basically where the university has its responsibility. To produce a reasonably well organized learning environment where the individual can broaden himself.

There is, of course, a practical limit to how much background is necessary, both in the area of formal education and in experimentation and investigation. Sooner or later each potential inventor has to stop preparing, and simply try it out with the hope that it will work. We now come to an area where the Director of Research, again, comes into the act, this time as "judge and jury."

A hard-working-creative individual can always improve the concept "just a little bit more." The director of research must have a strong technical background to enable him to function as "judge and jury." If the director is lacking in this area, communication is virtually impossible and there is little likelihood of a proper go-no-go decision. Without technical competence the director's job becomes little more than a secretarial function, taking the minutes of the meeting, etc.

With the reassurance of knowing that the Collector Valve has been in successful production for some time (in a second generation version), it is reasonable to assume that the development program was a success, also. With all matters considered the success of the endeavor is directly traced to getting at the real iron, working on the vehicle, servicing the vehicle, operating the vehicle and realizing what went wrong and digging until it was understood as to why. An "ivory tower" invention was not likely to come about.

The valves were originally far removed from the transmission packs, hard to work on, sluggish in cold weather, and were subject to damage and in the road of other vehicle components. These are items everyone "on the job site" knew and could have possibly fixed, but the added feature of enhancing response times and to the proper degree, could not have been known. To make the valve operate, with a reasonable design, when the temperature varied from 50°F below to 150°F above zero required considerable "high theory" investigation.

All of this is obvious when looking back, and really quite simple. However, the real key to success is working in an environment created by management that supports rather than delays the progress, and focusing the responsibility in a single person while providing adequate technical support in all areas.

It is my hope that I have answered your questions, or at least aided in clarifying them. If I can be of further assistance, please feel free to call on me.

Sincerely yours,

(Signed) James P. Swanson

James P. Swanson
Chief Engineer
Research and Development
W. A. Whiteney Corp.

Beyond Jim's discussion of the environment provided by management, it is noteworthy that he points out, "the obvious requirements of an invention, i.e., the realization of the problem and its development." This is the real point of conflict the inventor has with the "other people." The inventor realizes the problem and moves to solve that problem, not the problem presented. This must evoke the most severe criticism from the "other people" as they were not at all bothered by an "infected appendix," just "that awful pain." The director of research who pays heed will expediently be pleasing the bosses and may impress much high management by such obvious data and report production on the symptoms everyone is aware of. The director of research must disregard this easy road to an appearance of diligence and production. He must keep his subordinates in the situation such as Jim describes and have faith.

Case Two--Invention on Demand

Gordon C. Olson, a member of Twin Disc's Research Department, was essentially exposed to the exact conditions Mr. Swanson was exposed. During one of the three weeks Jim was "at home" Gordy was "in the mud." (Two others were "in the mud" the remaining two weeks of each four week period.) The author directed Gordy to apply himself to solving the obvious problems that occurred "from the shaft end inward." It must be noted, also, that both Jim and Gordy were minutely involved in the other's work and problems because each was afflicted with the total project when "in the mud," and "at home" in the lab.

Mr. Olson was not instructed to invent a new clutch but to eliminate the "main irritating problems" of the then production clutch. The author did not have the opportunity to suggest the invention Mr. Olson came up with as the author had only then just been granted a patent on a new clutch mechanism of superior (to the production clutch) performance. Had a shift to something new been in order, this would have been the obvious suggestion of Mr. Olson's boss, the author. U. S. Patent No. 3,537,557 (42), "Hydraulically Actuated Clutch Having a Feedback Dump Valve," granted November 3, 1970 to G. C. Olson, covers a clutch of extreme simplicity which completely nullified the "superior" clutch of the author's. This is a good illustration of the fact that the inventor alone can be the one to "see the need to be filled." Mr. Olson's boss had already "seen the need and filled it," so was not even looking for a better clutch from Gordy, just for him to fix the irritating problems with the production clutch.

Mr. Olson, a graduate Mechanical Engineer from the University of Wisconsin, with experience in the aircraft industry as a designer, had the most rounded experience in Twin Disc. He was in application engineering and hydraulic design which in Twin Disc means, not valves but hydrokinetic torque converter design, turbo-machinery. He also was in mechanical design and the research department. Gordy was encouraged to look mainly at the shaft end inward because of his near perfect knowledge of power transmission uses and demands involving the torque converter. All of this enabled him to see a need and neatly fill it.

The following is a reply from him about the environment in which he invented. Unfortunately, in the author's view, Gordy is no longer in the research department but has been promoted upward and is manager of application engineering for torque converters and couplings.

3805 Crosby St.
Rockford, Ill.
April 25, 1972

Dear Connie,

I hope the enclosed is what you are seeking--a lot of words expanding on one theme--"You have to know the territory." Of course, encouragement from the upper echelon helps.

I regret the delay in getting this to you. We were away on vacation until April 13 and then got tied up with price increase notices to our customers and engineering meetings.

Best wishes on your thesis. I hope the information you got is what you wanted. I am honored to have been considered for your thesis and look forward to discussing the outcome with you this summer.

Best regards,

(Signed) Gordy

INVENTIVE ENVIRONMENT

Patentable invention of most products that are functional and marketable originates with an understanding of the operation or characteristics of the overall vehicle involved.

To gain this understanding requires active participation in the motivation of the vehicle as well as the foresight of its purpose and application. A great amount of this requirement is gained through the efforts of a Complete Research and Development Group. This is a group that will not only analyze a situation analytically, but will involve itself in the application in the field. This is known as experience which is a prolific teacher. No matter how well an invention performs "on paper" or in the "lab," if it does not perform in the "field," then what good is it?

In one of my own particular inventions, the design of a dump valve type oil actuated clutch for transmissions in the propulsion of motorized vehicles, such as trucks, tractors, and loaders, the above approach proved valuable. This is true of most inventions patented for Twin Disc, Inc.

The invention is seldom the complete thoughts of one person but originates after discussions with various knowledgeable people who offer their experience and suggestions toward the requirement of a new or improved device. This information is channeled into a group such as R & D through the supervisor and generally assigned to a specific person or group leader for investigation.

To be effective, the supervisor must be completely knowledgeable and understanding of the situation. Engineering oriented companies of which Twin Disc is classified generally have this type of supervisor. These people will offer their ideas to the requirement and are weighed accordingly by the person responsible for the project. Good supervisory assistance or direction facilitates the completion of the goal which is to develop a desirable or improved product. Patents or recognition are merely outcrops of the real goal.

In my case the supervisory quality was exceptional as they were as close to the realistic situation any any member of their staff. Their suggestions and advice were weighed strongly because of their analytical and actual field experience. Other members of the organization were technically capable also, as management strongly supports the involvement of R & D and design engineers with actual field experience. This means "living" with the program in the field as well as in the lab and on the drawing board. Overall involvement is the key to recognizing the situation. A person in order to be more effective must be able to conglomerate the conditions of the "field," research and design in an effort to produce the necessary product. A design engineer without the field experience requires more guidance and assistance since his scope is limited. The same virtually is true for the "field" engineer with no design experience. He understands the requirement but readily can't project it to the design engineer or offer direction with reference to the design.

In discussions with other engineers, the application of educational background pertains only to the basics learned. Generally, the engineers' profession is not in the realm of his major. My background after two years of basics was in the heating and air conditioning field. This was applicable somewhat in the phase of pneumatics in the aircraft industry. However, in my present employment it had little bearing; so the real education relating to the present position was learned "on the job." Good basic education is a valuable tool that can be applied universally in engineering a new product; however, to recognize the requirement of a new product comes from the actual experience gained in that area. Not until we gained that experience could we offer a new and better design clutch pack assembly. The new clutch is faster acting, smoother shifting and contains

> fewer parts than previous designs. The new design idea originated after substantial hours of operation of crawler tractors and realizing that the old style clutches were harsh during shift engagements and required excessive time to complete a shift. Group discussion of the short comings of the old style clutches encouraged the supervisor, who was aware of the necessity, to seek support from the management. A good supervisor, such as we had, directed each of us to work on special projects not necessarily originated by the individual but all discussed by the group. The projects are surveyed and those that receive favorable support within the group are presented to management for independent backing. An individual then is responsible for the project including design, analysis, manufacture, lab test, installation and field test. Each person in the group has his opportunity to work on a project. Each member had field experience in the areas where most of our products apply, making it easier to recognize shortcomings.
>
> I believe this concept offers more opportunity for inventiveness. It has proven to be effective for the company and creates self-satisfaction for the individual knowing that he is working on something that could be of benefit to his fellow man.

The magnitude of the improvement made possible by Mr. Olson's clutch is of interest. ". . .realizing that the old style clutches were harsh during shift engagements and required excessive time to complete a shift." It may be said Mr. Olson went on to make a clutch which instead of requiring 0.5 seconds to shift from one gear to another, will shift so fast that a shaft capable of accelerating over 20,000 RPM per second will move only 90° between gears. Gordy's clutch is cheaper and contains thirty-four fewer moving parts.

Case Three--Invention on Demand

The third example of "Invention on Demand" resulted in U. S. Patent No. 3,613,469, October 19, 1971, granted to R. C. McRoberts and Bruce C. Arnold (40). A graduate in General Engineering, Mr. McRoberts has been more than thirty years with Twin Disc. He has been through

Twin Disc from top to bottom and has, perhaps, more experience in the application of the company's products than anyone else. Several years ago his attention was directed to the marine market to determine what should be done there. The controllable pitch propeller was a very high sales item, especially in Europe, and all present production types as well as new inventions came under close analysis. The advantages and disadvantages of each was thoroughly investigated and the utility of the CRP propeller was so great that serious thought was given to developing such a device at Twin Disc or obtaining license for such from outside inventors.

Mr. McRoberts then "went to sea" with the shrimp fleet (a large Twin Disc market) and remained at sea for considerable periods transferring from shrimper to shrimper. This experience resulted in a manual on the requirements of marine gears and power auxiliaries on ship board which is a text of such operations.

It became obvious to Mr. McRoberts that what was really needed was not a new better CRP propeller but a better way to do more of what really ought to be done. Twin Disc was already producing the Omega clutch, (the invention of which is described in Chapter II) and Dick knew from first hand operation and application exactly what were its capabilities in allowing controlled power division and speed on the input side of torque converters. This was seen as being very nearly ideal control for a propeller enabling the ship's engine to operate at any speed above propeller speed and be continuously varied while the Omega clutch held the propeller at constant speed.

Mr. Arnold, a Mechanical Engineer graduate from Iowa State and a marine gear design engineer for many years, then designed it into a marine gear in a novel manner such that the new "Omega Power Control" Marine gear was interchangeable with standard gears. Mr. McRoberts describes the environment which allowed this invention as follows:

May 3, 1972

Mr. Conrad R. Hilpert
1301 West Third Avenue
Stillwater, Oklahoma 74074

Subject: History of An Invention

Dear Connie:

Here is a brief history of my Omega Power Control Marine Gear work which you may wish to include in your thesis.

In it I just mention the many varied and stimulating lunch discussions we often shared at the Smoke Shop in Rockford. Thinking back, this opportunity for self-expression may have been a vital ingredient in our search for new ideas.

Kindest regards,

TWIN DISC, INCORPORATED

(Signed) Dick

R. C. McRoberts
Development Engineer-
Marine Products

slw
Enclosure

HISTORY OF AN INVENTION

By R. C. McRoberts, P.E.
Development Engineer,
Marine Products
Twin Disc, Incorporated
Racine, Wisconsin

An "outside" inventor offered a new controllable reversible pitch propeller design to Twin Disc management and I was selected to make the market study. The objective agreed on for the market study was as follows:

First, to acquire the knowledge necessary to determine whether or not Twin Disc should enter the controllable reversible pitch propeller market.

Secondly, provide within this study sufficient evidence to carry on with a CRP Propeller project or discontinue the effort.

Prior to this, my work involved the sale and application of Twin Disc marine gears, clutches, universal joints and especially hydraulic torque converters for a variety of industrial and some marine applications.

With this background, I was given a free-hand as to where I would look for information and started by gathering in all the readily available printed material on CRP propellers. Marine magazines at the John Crear Library, Chicago, were helpful.

The market study was actually done on a part time basis starting in July, 1967 and completed in April, 1968 with a 50 page final report supplemented with 700 pages of indexed reference material.

An abstract of a 12 page summary report on this market study is attached. This paper was presented at a midwest SNAME meeting held 7 May, 1970, in St. Louis.

Over half of the information used in the market study came from the visit I made to the sea coasts of North America and Canada including on the spot opinions obtained from vessel operators and owners. Discussions with a number of Naval Architects and shipbuilders also brought out their reasons for using, or not using, CRP propellers. Several visits included opportunities to board ships and inspect CRP propeller installations.

In the third month of the study, on board discussions of CRP propeller bridge and engine room control gave me the insight that a "<u>controllable fixed pitch propeller</u>" could satisfy many of the vessel functions requiring a CRP propeller.

By mid-November, 1967, I became reasonably sure of this conclusion. Noon luncheon discussions with Conrad Hilpert assured me that his recently invented Omega Clutch could provide the propeller thrust control I was not in a position to define.

After completing the market study and formal report I made additional visits to the Gulf Coast and several sea trips on shrimp trawlers to further define:

A. Design objectives for a marine gear with Omega Clutch control of propeller thrust.
B. Ownership advantages of such a marine gear.
C. Requirements for field test installations.

The additional sea trips gave me deeper insight and better understanding of what we should achieve with the new marine gear capabilities. It enabled me to successfully target our first Omega Power Control Marine Gear at Shrimp Trawler Service.

Also, I was privileged to obtain a U. S. patent with Mr. B. C. Arnold, who supervised the actual design work, on the Omega Power Control Marine Gear which several knowledgeable people consider to be a "breakthrough in marine gear capability."

(Signed) R. C. McRoberts

Racine, Wisconsin
3 May, 1972

MARKET STUDY CONCERNING CONTROLLABLE PITCH PROPELLER DRIVE SYSTEMS

By

Richard C. McRoberts, P.E.
Development Engineer - Marine Products
Twin Disc, Incorporated
Racine, Wisconsin

ABSTRACT

This paper states the major objectives related to new product market investigation and by use of slides reviews a number of controllable reversible pitch propeller designs currently in use.

Additional slides illustrate the pattern and tooling requirements for typical forward and reverse marine gear volume manufacturing in the 100 to 1,000 horsepower size range.

The question of forecasting profitable manufacturing of various sizes of CRP propeller drive systems was negatively answered from market research data evaluating current usage of CRP propellers in Europe.

PRESENTED AT
THE SPRING MEETING, MAY 7, 1970 OF

THE SOCIETY OF NAVAL ARCHITECTS & MARINE ENGINEERS
GREAT LAKES AND GREAT RIVERS SECTION

Stouffer's Riverfront Inn
St. Louis, Missouri

An Invention, Not "The" Invention

The above three examples are of real commercially practical "Invention on Demand." In none of the three cases was the result the "Demanded Invention" nor was the resultant invention a happy mistake. In each case the invention was actually in opposition to a solution of the problem presented. In each case the very people who (much later became enthusiasts) were closest to the systems in use were disappointed that "their problem" was not solved and were quite insistent that the invention be ignored and "their problem" be solved. They were unable to grasp the fact that while "their problem" was not solved it certainly had been eliminated.

It has thus been shown that invention can be produced on demand but it will not be the demanded invention, it will be the solution to a problem which had not been recognized.

The above are three interesting yes answers to the question posed at the end of Chapter II. The negative side of this question cannot be documented because of the nature of the inquiry. That would resolve into a search for a proof of the non-existance of an unknown. Not only could it not be determined why someone who did not invent the phonograph did not, but it would be difficult to find the most likely non-inventor of the phonograph to ask.

The environmental, motivational and encouragement factors will be studied in Chapters IV and V.

CHAPTER IV

INVENTION AND COLLEGE OVER THE YEARS

As shown in Chapter I, Table I, the rate of invention has not exploded since 1900, but has actually dipped slightly. The number of college graduates has literally exploded since 1900, as seen in Table IV.

TABLE IV

THE GRADUATE EXPLOSION

YEAR	ALL GRADUATES	Ph.D. ONLY	U. S. POPULATION (41)	GRAD PER 10^4 PEOPLE	Ph.D. PER 10^6 PEOPLE
1900	15,549(11)	126(11)	39,818,449	3.9	3.2
1931	160,302(11)	2,900(11)	122,775,046*	12.3	22.6
1970	1,072,581(29)	29,872(29)	203,184,772	52.9	147.5

*1930 Population

Table I, Chapter I, shows a slight dip in patent rate and with the above might mean that the modern college graduate is a poorer inventor than his grandfather. Thus it appears college could actually impede invention. Writers and students of invention lend support to this view. Non-college educated people often negate the value of a college education. Some authoritative references are quoted below which indicate that for creativity this may be fact.

A Case for Education Stifled Creativity

A. D. Moore (41) states on page 20, "In fact, I suspect that the taking of a degree in engineering or science may, in many cases do more to stifle creativity than stimulate it."

DeSimone (6), page 2, has two paragraphs which are quoted below and are in good support of the Moore quote above.

> Consider the typical measure of a student's performance. It is often enough to stamp out whatever inventive and innovative qualities of mind and spirit he may have possessed when he entered school. By and large, his performance is measured by the fidelity with which he feeds back the information he has absorbed from lectures and texts. Perfect feed-back occurs when he gives the right answers to problems that have been assembled for him. These problems are solved through analysis based on unassailable principles of science and engineering.
>
> Creative individuals are oppressed by this regime, and the real world of invention and innovation is foreign to it. Although in school one must never fail, an inventor fails all the time, and is elated in those rare instances when he succeeds. 'An inventor' Charles Kettering therefore once remarked, 'is simply a fellow who doesn't take his education too seriously.' Indeed, Marshall McLuhan has observed that going to school interrupts the education of students, that the outside world is far richer in information than is the schoolroom.

Von Fange (63), page 19, describes another reason college graduates might be low on a creativity scale.

> "FOLLOW THE LEADER"
>
> Progressing to the usual college training, we find assignments that might be likened to a foot bridge swinging

> and swaying across a rather wide and deep chasm. The problem is the bridge. At the other end of the bridge lies the solution. Strong and sturdy guide rails are formed by such things as the detailed definition, boundary conditions, and the applicable formulas or procedures given in the text or by the instructor.
>
> As the student goes through his years of education, he is sent across progressively longer bridges, although each is still adequately protected by guard rails, and so he has little difficulty. Upon graduation, the guard rails are removed and he is told that his sheepskin equips him to start across the bridge alone.
>
> Small wonder that college graduates, new to industry, are a bit hesitant and undecided about what to do and how to go about doing it. And small wonder, too, that they learn to use the safely guarded bridges of the conventional in their careers. They refuse to cross a free swinging creativity bridge even if they see it, simply because it has no guard rails to guide them.

Moving for the support of the contention that education may harm creativity, Von Fange (63) quotes two of the all time greats, Einstein on page 21, and Kettering on page 224.

> *Einstein was outspoken against the preparation that his college afforded:*
>
> I soon learned to scent out that which was able to lead to fundamentals and to turn aside from everything else, from the multitude of things which clutter up the mind and divert it from the essential. The hitch in this was, of course, the fact that one had to cram all this stuff into one's mind for the examinations, whether one likes it or not. This coercion had such a deterring effect [upon me] that, after I had passed the final examination, I found the consideration of any scientific problems distasteful to me for an entire year. . . It is, in fact, nothing short of a miracle that the modern methods of instruction have not yet entirely strangled the holy curiosity of inquiry; for this delicate little plant, aside from stimulation, stands mainly in need of freedom; without this it goes to wreck and ruin without fail.
>
> Some years ago a survey was made in which it was shown that if a person had an engineering or scientific education, the probability of his making an invention was only about half as great as if he did not have the specialized training.
>
> Now that is very interesting, and I have spent a great deal of time wondering why it is so. As a result, I have

> arrived at a definition of what an inventor is. An inventor is simply a fellow who doesn't take his education too seriously.
>
> You see, from the time a boy is six years old until he graduates from college he has to take three or four examinations a year. If he flunks once, he is out. But an inventor is almost always failing. He tries and fails maybe a thousand times. If he succeeds once, he is in. These two things are diametrically opposite.

Haefele (17), page 258, further shows the creativity squelching power of school.

> From the home background of firm support, the child goes forth to school. There he is met with the insidious, creativity-throttling tentacles of formal education which takes away his time for dissociated thought and instead gives him "activities;" which is a factory for the reproduction of facts; which makes him forget that a problem may have more than one, unique answer; which teaches him in solving to use all the given, no more and no less; which teaches him to judge and judge and criticize and analyze, with never a *chance* to create.
>
> Of course, the obverse side of this is that there is so much to learn and so much to do. Weisskopf writes, 'The constant activity enforced by many educators does not give young people the leisure which is an essential prerequisite for intellectual or artistic creation.
>
> . . .We keep the secret of biological creation from small children, and the secret of intellectual creation from youth.' And so the creative spirit is weakened -- a significant falling off appearing in the fourth grade. Meanwhile, the stern conformity pressures of our culture begin to operate: from peer groups; from the need to conform to win acceptance of the opposite sex; from the over-riding educational philosophy of adjustment, to teach not subjects but girls and boys. The easy way to obtain adjustment is to teach conformity.

Jack W. Taylor (55) has a chapter titled "What's Holding Us Back?" a section of which is "VI. Repressive Training and Education." The reasons he gives are most understandable to one who has existed in the educational system as a student for some time.

George J. Seidel (50) also berates education as a significant stifler of creativity on page 137,

> And certainly when the educational process degenerates into a mere supplying of answers to the student -- these to be repeated by the student for the examination -- genuine learning is simply obviated, and the opportunity for the development of creative thought lost.

This nearly overwhelming evidence could indicate to a director of research that education produces human encyclopedias which might have their greatest value in being on hand to supply the technically intricate answers to well defined problems some "uneducated creative mind" is stumped by. A situation so greatly negated in Chapter II, where research must be accomplished by ability specialization might actually be correct. The highly educated mind applied to the whole problem will not invent. Creativity is probably not within the still functional capacity of the highly educated mind.

A Case for the Positive Value of Education

Having been exposed to industrial research for some time and having the opportunity to be close to an inventor of some ability, and finally, having invented by himself, the author was not prepared to agree with the premises of the above authorities or the statistics. The late Meier George Hilpert continuously admonished,

> Con, get all the education you can if you want to invent. You've got to know what's in the books if you want to invent what's not in the books. When you grow up there will be so much already done, if you aren't educated, you will only do it again. Nobody gets patents for being second.

The gentleman had degrees in Civil Engineering and Mechanical Engineering from Iowa State and Cornell pre 1900 and was granted the first of many patents in 1904.

The author's thirty patents are felt to be absolutely dependent upon the college education he received prior to the granting of the patents. They could not have been invented had the author been ignorant of what he learned in college. Of course, had he, like Edison, learned it all by himself, the result would have been the same; but not having a mind like Edison, the author needed college.

A useful piece of information to a research manager would be whether this stifling of creativity by engineering schools has been getting worse over the years or is disappearing. The general level of technical education is increasing steadily. It is quite true that the B. S. in engineering today is representative of an exposure to, and an absorbtion of a level of scientific knowledge which an M. S. or Ph.D. of some years back could lay claim to.

Evidence of a stifling increase on top of the 7000% increase in college graduates would instruct the director of research to operate contra to the availability of degreed persons and shed people with degrees. The 29800% increase in availability of Ph.D.'s coupled with the eight to twelve years of high level creativity stifling they have absorbed would mean a real surplus of these exists.

A by-product of this would be to sound warning to engineering educators that they are creating the polished pianist rather than the composer they had hoped for, or it might tell them that they are doing very well and should keep it up.

Daniel V. DeSimone (6), on page 1, observes,

> Engineering is a profession, and art of action and synthesis and not simply a body of knowledge. Its highest calling is to invent and innovate . . . in the absence of deliberate counter-measures, it is an educational system that stifles creativity.

It is believed that evidence of the progress or regression in engineering education systems in stifling invention (to use the words of two experts) could be found by comparing the patented inventions of a group of graduates of 1900, 1925, and 1950 for a period of years following their graduation. This has been approached by sending the letter, Exhibit 1, Appendix B, to forty of the oldest Engineering Universities in the country. The research required to produce results was extremely voluminous but could well be worth it.

It can, of course, be pointed out that patented inventions are not the only sign of creativity and a patent does not assure worth. These and other criticisms are valid if these criteria are to be considered, but for this part of the study, it is not so intended. There simply is no way seen to determine whether a man in 1900 had more unrecorded new ideas than a man in 1950 had unrecorded ideas. There is some evidence that the encouragement to patent has increased over the years and that the difficulty of getting a patent has also increased. Thus, the chances that recent patents "generally" are more or less valuable than the earlier ones is ambiguous.

DeSimone's statement will be assumed true that the highest calling of engineers is to invent and innovate. Patented inventions are concrete evidence of invention. Should graduate engineers today show less patented invention than in former years, it must be assumed that the education is not enlarging the ability of these graduates to reach their highest calling under the conditions that exist today.

A very gratifying response was the result of the letter of request for aid. The universities responding with similar data, which could allow selection of engineering graduates for the years to be studied, were as follows:

1. Worcester Polytechnic Institute
2. Georgia Institute of Technology
3. Ohio State University
4. University of Illinois
5. University of Kentucky
6. University of Notre Dame
7. University of Delaware
8. North Carolina State University
9. University of Maine
10. University of Pennsylvania
11. Rutgers University
12. University of Michigan

About as many more also responded but some had no engineering graduates for 1900, some had listed graduates only by last name and initials, and some did not define the various segments of engineering. Appendix B, Exhibit 1, is the original letter of request reproduced and it may be seen that these omissions are not a fault of the responding universities but a reasonable variation in the interpretation of the requesting letter. An interesting observation was that a letter would come from one university saying what was asked for was totally beyond reason to ask of anyone, (Appendix B, Exhibit 2), and another letter from a different university with the exact data requested and a nice letter more detailed than expected, (Appendix B, Exhibit 3). This "put upon" attitude did not follow the big schools, little schools, private or public, but it allows the observation that what is impossible for some is easily and cheerfully done by others.

One response was a bit wry. The dean of engineering said that normally such information should come from the registrar, but "he would spare me this" and get the information to me quickly. His school's data is used.

The names on the graduate lists were reduced in total number as will be explained, but as predicted by one responding dean, (Appendix B, Exhibit 4), the task was formidable. The job required approximately 8000 individual references to specific patentees in the Index of Patents of the U. S. Patent Office (62).

Namesakes or Graduate Patentees

The question arises, "Is the John S. Smith, who graduated from the University of XYZ in 19XX, THE John S. Smith, who was granted patent No. 1,234,567 in 19YY?" It is possible that they are only namesakes. The study was intended to include the graduates from the years 1900, 1925, and 1950, so it is quite obvious that "writing and asking" would be quite futile. Many from the classes of 1900 would be among the deceased and even for the classes of 1950, the twenty-two year old addresses in the patent files are not always current. Of course, the universities could very likely produce the last known address of the individuals. These difficulties indicate that it would be more useful to try to utilize a statistical method of determining if the college graduates and patentees of similar names are perhaps only namesakes.

The probabilities of the occurrence of names in the U. S. population is necessary data to the calculation. A useful possible source of this information is the telephone books. Inaccuracies could arise because the frequency of names vary as to locale across the nation. Elsdon C. Smith (51), on page 299, shows Sullivan to be most common in Boston; whereas, it is not among the first twenty most common names in New York. Cohen, the second most common name in New York, is not among the first twenty in Chicago, Milwaukee, Minneapolis, or San Francisco.

In order to obtain a good source for the needed statistics, the following were contacted: the FBI, the U. S. Bureau of Census, American Telephone and Telegraph Company, the American Name Society, and Dr. Elsdon C. Smith. The references not available in our library were searched for in others. The statistics found indicate the probability that the graduates are the patentees if their names are identical. The most accurate reference was first located by a response from a Mr. Darrol Haug of A. T. and T. He called from New York and stated that A. T. and T. had often run such statistics on certain cities but the only known country-wide and generally applicable statistics on names was compiled by the Social Security Administration (60). This work gives the frequency of names which occurs down to about one per 16,000. The most common name is Smith which occurs about one per 100.

The Bureau of the Census (58) was able to contribute some information on the relative frequency of first names which also had its origin in lists received from Mrs. Charlott Crenson of the Social Security Administration in Baltimore, Maryland (60). Further information was obtained from The Dictionary of Given Names with Origins and Meanings (37). Additional information was also sought from the publisher of this work. Since the above reference does not enable the "least common" name statistics, several large city telephone companies were contacted to enable a reasonable statistic to be developed from their directories.

To get a "feel" for the problem, a three point calculation was tried using a hypothetical most common name and a similarly constructed least common name listed by the Social Security Adminsitration (60) and from Loughead (37), and an uncommon name from a telephone directory. Let,

LN = probability of the Last Name

MI = probability of the Middle Initial

FN = probability of the First Name

TN = probability of the Total Name

TN = LN * MI * FN (* means multiplication).

From the "Report of Distribution of Surnames in the Social Security Account Number File," (60) and Loughead (37), the following is shown for the names "John S. Smith" and Richard X. Breen."

Smith	LN = 0.101E-01
S.	MI = 0.996E-01
John	FN = 0.920E-01
	TN = 0.927E-04
Breen	LN = 0.603E-04
X.	MI = 0.468E-03
Richard	FN = 0.921E-01
	TN = 0.260E-08

"Keith D. Zwickl" TN = 0.100E-5. The name, Keith D. Zwickl was selected as "one in a million" name from the Chicago, 1972, Telephone

Directory which has about 1,000,000 private listings, and only one Keith D. Zwickl appears.

The terms LN, MI, and FN, are the probabilities that the name element they represent might be selected at random from the Social Security Account Rosters.

Except for "Keith D. Zwickl," TN is the calculated probability that the total name would be selected at random from the same list. In the case of Keith D. Zwickl it is the probability the total name might be selected from the names listed in the Chicago Telephone Directory.

It is reasonable to assume that the Social Security list might be representative of the U. S. population in general, and surely, is quite close to the workers' population which is, of course, the group where the inventors belong.

Since both the patent list and graduate list are on hand, the coincidence of names is found easily. Should the name John S. Smith be found on the patent list X times and graduate list Y times, the probability of these occurrences by pure chance can be found as can the probability that it occurs on both lists by pure chance.

Of all the names looked up on the study, only one appeared on a list more than once, so for simplicity, it will be assumed that X and Y above both equal 1.

Let, np = total number of names on the patent lists used

ng = total number of names on the graduate lists used

npg = number of names on both lists

Pp = probability that the name in question will occur by chance once on the patent list

Pg = probability that the name in question will occur by chance once on the graduate list

Pb = probability that the name in question will occur by chance on both lists

Pt = probability that all names on both lists are there by chance.

Then, Pp = np * TN * (1-TN) ** (np-1)

Pg = ng * TN * (1-TN) ** (np-1)

Pb = Pp * Pg

$Pt = Pb_{name\ 1} * Pb_{name\ 2} * Pb_{name\ 3} \cdot \cdot \cdot \cdot * Pb_{name\ npg}$

(* means multiplication, ** means exponetiation)

The number of graduates was 119 for the year 1900 for the schools 2 through 11 on the list of responding schools. The total number of patents issued for the years 1911 through 1915 was 186,243.

Using the above calculations and the three example names, it may be seen,

John S. Smith	Pp = 0.548E-06	
	Pg = 0.109E-01	
	$Pb = Pb_1$ = 0.598E-08	
Richard X. Breen	Pp = 0.484E-03	
	Pg = 0.309E-06	
	$Pb = Pb_2$ = 0.149E-09	
Keith D. Zwickl	Pp = 0.155	
	Pg = 0.119E-03	
	$Pb = Pb_3$ = 0.184E-04	

$Pt = Pb_1 * Pb_2 * Pb_3$

Pt = 0.164E-22

Thus, it may be seen that the chance is small that the names appearing on both lists are indicative of merely namesakes and not indicative of graduates who are patentees.

The name "Keith D. Zwickl" presents a problem when using the Social Security lists as neither Keith nor Zwickl appear on the lists. It appears that if the FN and LN "just off" the list was used the probabilities would not only be on the conservative side but also still be indicative of a small chance of namesakes. Using these values for Keith D. Zwickl,

LN = 0.603E-04

MI = 0.469E-03

FN = 0.920E-01

TN = 0.260E-08

it will be noted that the name has much less probability than the telephone directory derived TN. Thus, this "just off the list" calculation should not produce unrealistically high probabilities, even though it very possibly produces higher than actual probabilities in the case of some names.

This calculation was made for the actual names of the class of 1900 and in the Index of Patents of 1911 through 1915. The results using a CPS Pℓ/1 program showed essentially zero chance that the coincidence of the names represented only namesakes, not graduates who were patentees. This latter assumption was proven quite correct by the relationship of other attributes of the graduates to numbers of patents as will be seen and which could be only a random relation between namesakes and these attributes.

It has been determined by means discussed elsewhere that a five year period beginning eleven years after graduation would be selected. The years, 1911 through 1915, 1936 through 1940, and 1961 through 1966, are of interest for the classes of 1900, 1925, and 1950. The U. S. Patent Office (62) lists the total patents for these years as follows:

YEARS	TOTAL PATENTS
1911 through 1915	186,243
1936 through 1940	201,177
1961 through 1965	259,971

This period may be looked at as a single list of patentees for the period of five years,--and set np for the class of 1900 at 186,243; np for the class of 1925 at 201,177; and np for the class of 1950 at 259,971.

The particular years were selected as they represent a five year period which falls across the normally most productive time of life for inventors. Lehman (34) shows the most inventive years of age are between thirty and forty for inventors, the peak occurring from 32 to 37 years of age. This is quite evident even for all time greats like Thomas Alva Edison (1093 patents). Of course, exceptions are in existence but the statistics Lehman presents are quite definitive of the most likely years of age for invention.

This present study is not an attempt to equate three men with three patents each from 1900 with nine men with one each from 1950, but rather a representative incidence of an invention during a significant period. A man with one invention is considered equivalent to a man with four. This is not as invalid as might appear. Many times a "single invention" produces several patents (discussed in more length elsewhere) and examples are U. S. Patents by the author (26), (27), and (28). Unless each inventor's patents were studied by one thoroughly familiar with the subject, this "single invention" origin of multiple patents could not be determined in any reasonable manner. The term "single invention" is in quotes because actually A patent is issued for an invention. Thus, in the eyes of the patent office five patents cover five inventions but in the inventor's eyes, he did them all in one.

Why Only Male Name Statistics?

The nearly 1500 patents referred to for the questionnaire in Chapter V of this study yielded only two names which most likely were women. The truth is that few women take out patents. A random scan of the 1969 List of Patentees (34) for twenty pages resulted in no obvious names of women. The lists of engineering graduates received from the universities does not show a significant number of women; thus, excluding these statistics is not damaging to the inferences which may be made. Statistics are available for first names of women; thus, if encountered, "Mary S. Smith" can be handled as "John S. Smith" in an undiscriminatory manner (60). The middle initial and last name statistics would not be affected. No attempt will be made to discuss the reasons few women obtain patents but the observation is interesting since the patent law is one which has had from the beginning no sex discrimination.

Also, the many references seem not to dwell upon the sex issue nor indicate any importance as to whether an inventor is male or female. It might be conjectured that this is: (1) an assumption that "of course only men invent," or (2) it is quite unimportant if "Marion Jean Richeleux-Schmidt" wore a dress or pants, but was the invention worth while?

The author's father, the late Meier George Hilpert, holder of many patents, when asked many years ago, "How come Mama doesn't have any patents?" stated, "Well, Con, perhaps Mama is too good, women give birth to men, men can only give birth to things, Mama lets me do what I can."

The probability calcualtions make one fact clear which at first appears at odds with "common sense." The probability of a graduate's name appearing on the patentee list is not affected by the size of the list of graduates. Of course, the probability that some graduate listed will actually have a patent increases as the list of graduates is increased. The question of class size was illuminated when it was apparent that in 1900 few graduates were seen on campuses that are very large today. For example, Georgia Tech sent class lists showing eight in 1900 and 1170 in 1950, a 14000% increase when the state population increased only 155% (65). However, a totaling of the 1900 classes of several of the colleges from whom useful information was obtained will provide a graduate list of reasonable size.

The fields of engineering have multiplied over the years. Disciplines such as "Ceramic Engineering," possible in 1950, were absent in 1900. Thus, a question comes up, "Should all fields be included or should only a select few?"

Engineering disciplines today could all be traced to the Military Engineer who did non-military construction and finally wanted a name and decided on "Civil Engineer" to set him apart from his military brother. Thus, it could be reasoned that the engineering mind in those days was only civil; today, it covers a range of names. This study will look more specifically at two disciplines, Mechanical and Electrical, for the reason that these fields produce a high incidence of invention and were established by 1900. Further, the Electrical Engineering discipline was a branching away from Mechanical Engineering, there having been an "Electrical Option" in Mechanical Engineering and a discipline of "Electromechanical" Engineering (still given in some foreign universities). The combination of these two should thus produce a uniformity of course over the years. This will technically restrict the results to these two disciplines. However, should great differences in the inventive output of the graduates appear for the years selected, broader applications could be assumed with confidence. Slight differences are meaningless even for the two disciplines selected.

The Procedure, Search, and Results

1. Collect a list of graduates for the years 1900, 1925, and 1950 in Electrical and Mechanical Engineering.
2. Look up each name on the graduate list in the patentee list for the years as follows: 1900-1911 through 1915; 1925-1936 through 1940; and 1950-1961 through 1965 (62).
3. Perform the previously described probability calculations on the names found on both lists.
4. Tabulate, compare, and discuss the results.

It was decided that a trial should be made with only one university so a large one was selected which had a sizeable class in 1900 such that a similar sample from later classes might be representative. The

University of Michigan was selected as a 100% sample for the year 1900 of Civil Engineers, Electrical Engineers, and Mechanical Engineers, produced a forty-six graduate list; Civil 15, Electrical 9, Mechanical 22. Civil Engineers were included in this sample to determine if a great error in invention rate would be caused by eliminating this discipline. Were there a great superiority in the invention rate of Civil Engineers over the other two for certain years, it might indicate that a comparison of invention rate was rather a comparison of discipline popularity.

The lists for years other than 1900 were not 100% samples but were selected by picking random numbers or by just selecting every second (or third or fourth) name as needed and letting the randomness of individuals and their name spelling give a random distribution (most graduation lists are alphabetical).

The only biases intentionally put on the lists where these. The individuals with home addresses listed as outside the United States were eliminated and where the parent lists were large compared to the sample, individuals with the most common names were eliminated (60). This seemed not too warped a procedure as the study only included a perusal of U. S. Patent files not Foreign Patent Files. No evidence could be found indicating the Smiths (most common name) were more or less inventive than the Breens (least common name) or that inventiveness was a function of alphabetical order of names (60). The results appear in Tables V, VI, VII, and VIII.

The patentee totals for five years appear at first not to equal the sum of individual years because very often an inventor appears in each year; thus, he can only be counted once in the grand totals. The data presented for this single university required nearly three thousand referrals to the Index of Patents (62).

The calculations possible which seem interesting are in Table VI and for this single university seem informative about the inventiveness of the university engineering graduate compared to the average for the nation.

Referring to page 10, Lehman (34), Figure 6, it is seen that approximately 18.5% of the average inventors total output is between the ages of 32 and 37. A statement may be made that given an inventor's patent, the probability is 0.185 that he invented it between the ages of 32 and 37. The Index of Patents (62) is just a given list of inventor's patents. It may thus be observed that approximately 0.185 of this list of patents are expected to be by inventors between the ages of 32 and 37.

The number of patents issued during the years of 1961 and 1965 was 259,971 and by the above reasoning it may be calculated 18.5 x 259,971 = 48,100 patents may be expected to be by 32 to 37 year old inventors (62).

The male population between the ages of 32 and 37 is approximately 5,700,000 (63). This, then, is the population from which the inventors of 48,100 of the patents come from. Thus, we see that a ratio of 48,100/5,700,000 = 0.00845 or a patent incidence of about nine patents per 1000 males 32 to 37 years old during a five year period.

The previously cited dismal view of the effects of education might be expected to place the patents per 32 to 37 year old graduate at far less perhaps only 5 or fewer per 1000.

The class of 1950 for the University of Michigan shows an interesting rate. Between the years of 1961 and 1965 a sample of 348 graduate engineers between the ages of 32 and 37 produced 93 patents from 43 inventors from that group. These are ratios of 93/348 = 0.267 and 43/348 = 0.123. This group of graduate engineers produced patents at the rate of 267 per 1000 graduates, ages 32 to 37, and patentees of 123 per 1000 graduates, ages 32 to 37, during the five year period.

This, compared to the 9 patents per 1000 males, ages 32 to 37, from the entire population including the graduates, seems to be significantly at odds with the dismal prediction of the previously quoted authors. The rate of production of inventions by graduate engineers is thus more than thirty times that of the average population including graduates of all kinds.

It could be conjectured about the actual rate of invention for non-college graduates, perhaps it is quite high because there are so many non-engineering graduates who have been taught very effectively to invent nothing by their schools.

Approximately 7.7% of the population over 25 years of age had been graduated from college in 1960 (59). If these are removed from the 5,700,000 males 32 to 37 years of age calculated above, there are left 5,250,000 non-graduates to whom the 48,100 patents calculated above might conservatively be attributed. Thus, it is seen 48,100/5,250,000 = 0.00916, or again approximately 9 patents per 1000 could be attributed to the non-college graduate population if it is arbitrarily assumed that no college graduate invents anything.

There appears to be very little basis for the fears expressed that education stifles invention, at least in the case of engineers. The comparisons made here are reasonable as the patents are on technological inventions, not creations in the arts. It is reasonable to expect that graduate engineers would invent in these fields unless thoroughly dissuaded from doing so by their education.

A thought could cause the question, "What of the inventiveness of the individual who learned everything by himself that another man learned in college compared to that college educated man?" This academic question is beyond the scope of this investigation and deemed best manipulated by philosophical treatment.

Table VI is similar to Table V but includes the entire list of the universities above less the University of Michigan and Worcester Polytechnic Institute. Worcester is treated as a 100% sample for all years as it is of manageable size and had a good number of graduates in 1900 and not too many in 1950. Worcester also sent the complete alumni directory which includes all who attended even those who did not graduate, which gives a small insight to the inventiveness of people who for some reason did not get a degree. Table VII is also similar to Table V but for Worcester Polytechnic Institute.

Table VI is of some interesting ratios calculated from the previous tables. The data placed in Table VIII is on a per 1000 graduate scale so comparison is easy. Tables V, VI, and VII, of course, show less than 1000 graduate samples used but in many cases 100% of the population was used so the sampling was as accurate as possible for that population, but of course, suffers from still being only a few.

It is of great interest that in no case does the rate of invention of engineering graduates get within the same magnitude as the invention for the same age group, general population of males 32 to 37 years old.

TABLE V

UNIVERSITY OF MICHIGAN DEGREES-PATENTS-PATENTEES

CLASS	1900 TOTAL	1900 SAMPLE	1925 TOTAL	1925 SAMPLE	1950 TOTAL	1950 SAMPLE
BSCE	15	15	74	74	111	111
BSEE	9	9	41	41	112	93
BSME	22	22	78	41	213	92
BS TOTAL	46	46	193	156	436	296
MS			15	15	45	45
PhD					7	7
TOTAL	46	46	208	171	488	348

STUDY YEAR		1911	1912	1913	1914	1915	1936	1937	1938	1939	1940	1961	1962	1963	1964	1965
Patentees	BSCE		1(1)	1(2)		1(1)	4(5)	2(6)		2(3)	4(4)		2(2)		2(4)	
X	BSEE			1(2)		1(1)	1(1)	1(1)		1(1)		6(11)	1(1)	5(7)	2(3)	4(5)
Patents	BSME		1(3)	2(5)		1(1)			2(2)			6(10)	8(10)	5(6)	3(5)	6(7)
(X)	MS						3(8)	2(2)				2(3)	6(9)	3(3)	2(2)	2(2)
	PhD												1(1)		1(1)	1(1)

		1900	1925	1950
5 YR. TOTALS	BSCE	1(4)	5(18)	4(6)
	BSEE	2(3)	1(3)	11(27)
	BSME	2(9)	2(2)	17(38)
By Degree	BS	5(16)	8(23)	32(71)
	MS		4(10)	9(19)
	PhD			2(3)
GRAND TOTALS		5(16)	12(33)	43(93)

TABLE VI

SEVERAL UNIVERSITIES DEGREES-PATENTS-PATENTEES

CLASS	1900 TOTAL	1900 SAMPLE	1925 TOTAL	1925 SAMPLE	1950 TOTAL	1950 SAMPLE
BSEE	49	49	186	68	189	68
BSME	59	59	176	64	1001	74
BSEE & ME	108	108	362	132	1790	142
MSEE			10	10	55	48
MSME	*non "specified MSEng."		14	14	110	21
MSEE & ME	11*	11*	24	24	165	69
PhD					10	6
TOTAL	119	119	386	156	1965	217

STUDY YEAR		1911	1912	1913	1914	1915	1936	1937	1938	1939	1940	1961	1962	1963	1964	1965
Patentees	BSEE			4(5)	2(3)	1(2)	3(6)	3(5)	4(13)	4(4)	7(18)	1(1)	2(3)	4(4)	4(4)	
X	BSME	4(5)	2(2)	5(6)	6(7)	4(8)	1(1)	3(3)	5(7)	2(3)	1(1)	8(9)	3(4)	7(7)	2(2)	7(9)
Patents	MSEE	1(1)*				1(1)*				1(2)	1(2)	4(6)	7(9)	6(7)	6(7)	4(6)
(X)	MSME						1(1)			1(1)	1(3)	1(4)	1(2)	1(1)		3(3)
	PhD											1(2)	1(2)		1(1)	

		1900	1925	1950
5YR.TOTALS	BSEE	6(10)	10(46)	9(11)
	BSME	12(28)	8(15)	17(31)
	MSEE	2(2)*	1(4)	15(35)
	MSME		1(5)	3(10)
	PhD			2(5)
By Degree	BS	18(38)	18(61)	26(42)
	MS	2(2)	2(9)	18(45)
	PhD			2(5)
GRAND TOTALS		20(40)	20(70)	46(92)

TABLE VII

WORCESTER POLYTECHNIC INSTITUTE
DEGREES, PATENTS, AND PATENTEES

CLASS		1900	1925	1950
	BSEE	15	34	52
	BSME	17	23	85
OTHER	BS	12	15	59
TOTAL	BS	44	72	196
NONGRADUATE		17	24	22

STUDY YEAR		1911	1912	1913	1914	1915	1936	1937	1938	1939	1940	1961	1962	1963	1964	1965
Patentees X	BSEE	1(1)		2(2)	1(2)	1(4)						3(5)	2(2)	3(3)	3(3)	4(6)
Patents (X)	BSME	1(1)		1(1)		2(2)	2(6)	4(6)	1(2)	3(3)	3(4)	2(3)	5(6)	5(6)	5(6)	3(4)
Other	BS	2(3)				2(2)		1(1)	2(6)	2(5)	1(3)	2(2)	2(2)	2(3)	2(2)	4(5)
Nongraduate		3(3)	1(2)	1(2)	1(2)	1(2)	2(2)	1(1)	1(1)	1(1)		1(1)		1(1)	1(1)	1(1)

5 YR.TOTALS	BSEE	3(9)		10(19)
	BSME	3(4)	6(21)	13(25)
Other	BS	4(5)	2(15)	9(14)
Nongraduate		3(11)	3(3)	2(4)
By Degree	BS	10(18)	8(36)	32(58)
Nongraduate		3(11)	3(3)	2(4)

TABLE VIII

PATENTEES AND PATENTS/1000 GRADUATES DURING
11TH THROUGH 15TH YEAR AFTER GRADUATION

Patentees/1000 X
Patents/1000 (X)

Line	University	Degree and Discipline	Graduation Year 1900	1925	1950
1	University	BSCE	67(266)	68(243)	36(54)
2	of	BSEE	212(333)	24(73)	118(290)
3	Michigan	BSME	91(409)	48(48)	185(414)
4		BSCE+EE+ME	109(348)	51(148)	108(240)
5		MS		267(667)	200(420)
6		PhD			286(428)
7		ALL ABOVE	109(348)	70(193)	123(267)
8	Several	BSEE	123(204)	147(676)	132(162)
9	Universities	BSME	204(475)	125(234)	229(409)
10	*non-specified	BSEE+ME	167(352)	136(449)	183(296)
11	"MSEng"	MSEE		100(400)	313(730)
12		MSME		72(357)	143(476)
13		MSEE+ME	182(182)*	83(375)	261(652)
14		PhD			333(834)
15		ALL ABOVE	168(336)	128(449)	222(424)
16	Worcester	BSEE	200(600)	0 for 34 Grads.	192(365)
17	Polytechnic	BSME	176(235)	261(912)	153(294)
18	Institute	Other BS	333(416)	133(1000)	153(237)
19		All BS	237(409)	111(500)	163(296)
20		Non Grads	177(647)	125(125)	91(182)
21	All Above	Grads. Above	167(354)	100(348)	159(319)

The calculations above show for the years near 1962 the inventiveness of the general population of males 32 to 37 to be nine patents per 1000 persons. The study shows the inventiveness of graduate engineers to be 319 patents per 1000. Schooling has apparently not stifled creativity in these persons to any marked degree.

It is interesting that persons who never graduated but attended a purely technical school showed inventiveness far above the general population of males 32 to 37 years of age.

The invention rates shown by BS, MS and PhD compared in Table VIII show that a director of research should definitely place the most educated personnel at his disposal in situations as per Chapters II and III and they will invent more than the non-educated. Of course, it may be said that individuals are individuals and a bad apple is a bad apple no matter how good other apples are from the same tree. Thus, these results should be looked on as a buoyancy to the expectations and a basis for policy. The policy should be:

1. Place your best educated engineers where the greatest opportunity for invention exists.
2. Give them the broadest experience.
3. Other things equal, hire the man with the highest engineering degree.

What were the somewhat emotional statements of the authors quoted based on? It is difficult to determine, but it could be that the following facts start the belief off.

1. The thought of the uneducated clod springing forth and revolutionizing the world with a brilliant invention is something all would like to believe.

2. Some of the most brilliant men accomplished things never equaled without the advantage of any real formal education.
3. Many, upon finding that some person has a college degree, immediately begin a biased comparison of the college man being baffled by a problem the unschooled solved.
4. The study shows that even among college men the degree does not mean he is an inventor more than about 10% of the time. The logic "Since you are a graduate have you invented something?" is not applied to the non-graduate, so, the nine to one yes allows the thought to develope that invention is not helped by education.

Of general interest to engineering educators is the fact that colleges are NOT doing BETTER than the schools which graduated the present educators' grandfathers. Perhaps technological advances give colleges more knowledge to impart to a student before he can invent.

It is the view of the author that great improvement in the inventiveness of college graduates could be made by suitable courses in creativity and suitable changes in present courses. The specific recommendations are beyond the scope of this writing, but it must surely be that modern education utilizing present knowledge should be able to do better than schools of seventy years ago.

This chapter has shown some definite courses for a director of research to follow when confronted with decisions of how to utilize the educational levels of his technical subordinates.

CHAPTER V

INDUSTRIAL ENVIRONMENT AND MOTIVATION

OF PRACTICAL ECONOMIC INVENTION

The previous chapters have enabled some straight forward directions the director of research should follow in the procurement of facilities (Chapter I), the division and assignment of work to those expected to be creative (Chapter II and Chapter III), and the educational level to be sought and applied in work where creativity is to be expected (Chapter IV).

The present attack will be on the problem of defining the directions which should be taken by the director of research in producing items three and four of page 11, Chapter 1.

3. An effective motivation of creativity.
4. An administrative environment in which creativity is encouraged.

There has been an amount of work done studying the environments and motivation which existed for the great inventors, such as done by Rossman (48). The director of research described in Chapter I is, however, not confronted by the problem of how to motivate and environmentalize for the true genius. The director of research has the problem of motivating and obtaining a creative environment for the, perhaps, quite mundane people already on hand; thus, what worked well for the genius of a Steinmetz at General Electric might be totally misplaced in what is termed "our test lab" of Chapter I.

The observation is made that most products on the market are in some facet covered by patents and a glance at the list of patentees for any year quickly reveals that almost all are by different people. The 1970 List of Patentees (62) lists 64,439 patents. A random selection from five pages shows two inventors with five patents, four with three, twenty-one with two in approximately 330 patentees. Thus, it may be seen that the majority of inventions are by inventors with low production rates, certainly averaging less than one per year. Chapter IV shows that the incidence of invention was in the vicinity of 0.41 patents per year per inventor for engineering college graduates during the five years of their probable peak production. Also shown, was that this production was far in excess of the invention rate for the similar average American male. It is thus seen that what would be of good use would be the motivation and administrative environment that surrounds these "average" inventors and allows them to produce.

Approximately seventy companies responded to a request for a list of twenty-five numbers of patents under which they manufacture commercial products of use in manufacturing processes. Nearly 1500 such numbers were referenced in the complete files of the Patent Office Gazette (57) in the O. S. U. Library. The inventors were then contacted by means of a questionnaire to be described shortly. These names were of inventors who had produced not just patents of questionable worth but patents of proven commercial value, exactly the type of patent the director of research desires should come forth from his department, or exactly what the company president desires should come from anywhere in his company. This group of inventors it was hoped would not turn out to be 1029 (the mail out number) "great inventors" each with hundreds of patents to their names, but inventors with several patents to date, the inventor type most patents are issued to.

Should the director of research be able to change his department from the present zero creativity to an invention production approaching the graduates of Chapter IV, a significant improvement would take place. It is a firm conviction of the author from his previously described association with many antitheses of research departments, that creativity present in them is completely hidden, neutralized, destroyed, and reversed. Unfortunately, the observation has been that these tragedies are not "the exception that proves the rule" but "the rule looking for an exception." It was hoped that these "meat and potatoes" inventors could shed light on what was necessary for them to invent the commercially practical and economic.

The approximately 1500 patent numbers reduced to 1029 by eliminating duplicate inventors, foreign inventors, and inventors with addresses which could not be found, Thus, with 1029 people to question the problem arises what to ask, and how?

What to Ask

The what to ask was determined not only by searching past personal experiences, but by studying the literature available on creativity and an indication of what to ask was found.

Previously herein, the amount of work defining the characteristics of creative people and the methods of invention has been noted. It is interesting that there should be a less amount done on the environment which has allowed or caused invention, but so it appears. Taylor and Barron (54) have a few pointed paragraphs on this which are copied here.

ENVIRONMENTAL CONDITIONS AND EDUCATIONAL METHODS

> We are perhaps more in the dark about the environmental conditions which facilitate creativity than we are about any other aspect of the problem. Beyond obvious conditions, such as the need for ample time in which to work freely on problems of one's choice, little is known.
>
> There are, it is true, several useful discussions of the socioeconomic conditions that promoted the scientific and industrial revolutions, as well as a few recent studies of working conditions, morale, and productivity in individual industrial and government laboratories. But almost no other guideposts exist. The man who wishes to understand, for example, why some countries, like our own until the very recent past, have been particularly productive of technological innovation but somewhat backward in contributions to basic science, can scarcely find grounds for even an educated guess. The same is true for the man who wishes to discriminate between the sorts of scientific work effectively undertaken by a group and those which are better left to concentrated individual work. Yet the ability to answer questions like these will inevitably affect the nation's ability fully to utilize its creative scientific potential.
>
> Research, then, on the *general environmental conditions*--cultural, professional, and institutional--conducive to first-rate scientific research needs major encouragement. We are aware of no area in the social sciences where research is simultaneously so vitally needed and so sadly neglected. The joint efforts of sociologists and social psychologists, of economic historians and historians of science, will be required. Research on creativity will certainly benefit from an increased understanding of the role of the environment in the effective utilization of potential scientific talent.

The environment which a director of research could exercise some control over is what is of interest in this study, national origin of the inventor, his family situation, past education, religion, etc., all make up his environment but are not in the control of the director of research.

The major areas which are controllable to a degree by the director of research are seen as:

1. Superiors
2. Subordinates
3. Equals (Horizontal Associates)
4. Facilities
5. Incentives
6. Organization policy

A number of references have been researched and the following list of subjects appear which could be viewed as environment dependent. These come from Haefele (17), pages 18-19, 24-25, 180-183, 186-187, 192-194; Harrisberger (19), pages 44-48; Von Fange (63), pages 21, 32, 33; and Rossman (48), pages 162, 163, 173, 152. This list is in no particular order but the attempt was made to associate the listed subjects with the above six environmental factors.

It appears that of 77 total subjects: 65, or about 85%, appear to be superior related; 33, or about 43%, appear to be equal related; 31, or about 40% appear to be organization policy related; 19, or about 25%, appear to be subordinate related; 2, or about 3%, appear incentive related; and 1, or about 1%, appear facility related. These all add to more than 100% because some of the subjects appear to be related to more than one area.

These proportions do not seem unreasonable. Some discussion might be aimed toward the low proportion of facility and incentive related but facilities actually are not the big problem in invention as at all times in invention, the inventor must make do with his knowledge and facilities. The mere presence of facilities and knowledge does not sprout invention and no investigator ever has an excess of either knowledge or facilities. Incentives also must be adequate but high pay alone cannot bring forth invention either.

The Questionnaire might, therefore, be proportioned with the heaviest weight of questions towards superiors, equals, and organization policy. It is believed that the attitude of one's equals is very liable to be a mirror image of the attitude of one's superiors. Thus, the heavy weight should be on superiors and company policy.

Subjects Considered

Related Area (See list of six major controllable areas above)	
5	The practical 3 F's (food, family, fame)
1	Freedom from frustration
1	Identification with own name
1	Alternative goal
1	Recognition
1	Use
1	Freedom
4	Services
1	Selection and training
1	Over planning
1	Over reporting
1,3	Tolerance of non-conformities
1	We will let you try in your own way
1	We will recognize and credit your work
1	We will use your work
1	We will provide a satisfying goal to reward your creativity
1,2,3	Making a mistake

1,2,3	Making a fool of yourself
1,2,3	Being criticized--especially by superiors
2,3	Being too pushy--or crusading
1,2,3	Having your ideas stolen
2,3	Saying no to everyone who wants help
2	Being in the minority
2	Being different--not conforming
1, 6	Taking time to engage in fantasy
1, 3	Not knowing enough about the situation
1,2,6	Resistance to change
1,2	Desire for conformity
1,3	Competitive jealousy
1,3	Desire for security
1,2,3,6	Fear of ridicule
1,3,6	Cynicism
1,6	Concern for effect rather than cause
1,6	Distrust of wild ideas
1,3,6	Fear of failure
1,6	Desire for organized routine and order
1,6	No desire to experiment
1,3,6	You tend to narrow the problem too much--instead of thinking "big" or thinking "way out"
1,6	You cannot help wanting to be practical
1,6	You invariably will be drawn to dealing with the effect rather than the cause
1,6	You have difficulty focusing on what needs to be done -- you tend to want to look at what someone else (the boss) wants
1,3,6	Praise the idea for

1,3,6	An attitude for open-mindedness, for change, for improvement, for new ideas
1,6	Encourage free and informal communication
1,6	Discourage crash dead lines
1,3,6	Make allowances for failures
1,3	Listen without prejudice
1,6	Reward unusual thinking and ideas
1,6	Give recognition that ideas are being understood and used
6	Pair the creative man with sympathetic co-workers who can stimulate them, can interact with enthusiasm, can pick up the ideas and put them into use.
6	Blindness of rules
1,3,6	Complacency
1,2,3	Defensive rationalizations
6	Dogma
1,2,3	Inertia
1,3	Minimizers
1,3	Rationalizers
1,3,6	Apathy
1,2,3	Narrow minds
1,2,3	Negativism
1,6	Autocracy
6	Lack of Capital
1,2,3	Lack of knowledge
1,2,3	Prejudice
1,6	Legal difficulties
6	Marketing
1,3	Anticipation by others

1,6	Lack of time
1,6	Lack of facilities
1,6	Patent attorneys
1,6	Dishonest promoters
1,2,3	Disclosure to others
5	Financial gain
1,6	Part of work
1,3,6	Prestige

Form and Spirit of Questionnaire

Several references were studied to determine pitfalls to avoid and opportune directions in which to put forth effort. Good and Scates (15) place in simple language the reasons for a questionnaire. "The questionnaire is a major instrument for data-gathering in descriptive survey studies and is used to secure information from varied and widely scattered sources."

Taylor and Barron (54), pages 607 and 608 state, "The questionnaire is particularly useful when one cannot see all of the people from whom he desires responses or where there is no particular reason to see the respondent personally."

This is exactly the case with the inventors to be questioned. They are widely scattered and there is no practical way each could be interviewed personally for this study. Taylor and Barron (54) on pages 607 and 608 bring up another point which could easily be missed by the designer of a questionnaire.

> The practical implications are that a questionnaire study should not be undertaken unless the problem is of genuine importance, not only to the investigator, but to the

> particular field of knowledge; the questionnaire should be so devised that it will involve a minimum of the respondent's time.

Nine major recommendations for the criteria for questionnaires are given on pages 615-616. The substance of these are as follows:

1. It must be short enough so that the recipient will not reject it completely.
2. It must be of sufficient interest and have enough face appeal so that the recipient will be inclined to respond to it.
3. It must appear to have some depth to the respondent so that it does not produce superficial replies.
4. It must neither be too suggestive nor unstimulating.
5. It must elicit responses which are definite but not mechanically forced.
6. It must ask questions so not to embarrass the respondent.
7. It must not raise suspicions in the mind of the respondent that there may be a hidden purpose.
8. It must allow for responses other than the programmed selection.
9. It must be valid, the body of data taken as a whole must answer the question for which it was designed.

Some further problems of questionnaire design to be avoided were found as established by Patricia Kendall (33). She states on page 29, three of these problems:

1. Instability of response (turnover)
2. Equivalence of the alternatives
3. Difficulty of the required decision

The first is explained as the phenomenon that repetition of the question substance in various, similar ways to the same respondend produces more and more inconsistant responses. This appears to bring forth a doubt on some questionnaire techniques which employ requestioning to validate the previous answers.

Anonymity and some further questionnaire items to be considered are by A. N. Oppenheim (43). A fundamental must he places very clearly on pages 36-37, "Data obtained by means of interviews and questionnaires should always be regarded as confidential. . . In enlisting cooperation for the survey, respondents are usually given assurance to this effect and guarantee of anonymity."

Direct and extensive research on mail surveys was accomplished by Christopher Scott (49) and published which is unique as much of this research is considered proprietary information by the various commercial firms who contract mail surveys on a commercial basis. Scott shows that with no follow-ups, a response of over 50% is likely in ten days from the questionnaire mailing and that from day ten to day twenty the rise is nearly linear to over 60%. Little, if any, more response is seen after day thirty. With follow-ups at day eight and day sixteen over 90% is likely by day twenty.

A good study of these references allowed a questionnaire design to be attempted. The purpose of the questionnaire was to establish some research management policies and procedures which have allowed, encouraged, or at least not prevented the managed to produce inventions which are practical and economic.

An initial thought was to use the "open question," suggested by Oppenheim (43) on page 40, form of questionnaire. This allows the respondent to be free to place his best thought in answer and would be the ideal fulfillment of the above "Criteria for Questionnaires" numbers 3, 4, and 8. The respondents to this questionnaire are being asked for help on their own time. Ease and rapidity of completion are essential to the questionnaire. Open question formats prevent both ease and rapidity of response, says Oppenheim (43) on page 41. The open question has another disadvantage, it is difficult to analyze as the answers can be varied as the respondent views the question and has inspiration to answer in depth. These facts appear to overpower the advantages of ideal satisfaction of criteria 3, 4, and 8, thus, the open question format for the whole at least is contra indicated.

Oppenheim (43), page 40, further states, the "closed question" is the alternative. Here the respondent is given a choice of pre-selected answers to the question and unless care is taken these could quite easily and completely dissatisfy criteria 3, 4, and 5 and surely are the antithesis of the spirit of 8.

The obvious decision was then to include both closed and open questions. All of the authors studied indicated that the ideal questionnaire has a logical sequence of questions leading the respondent to more and more narrow choices of question scope to a valid statement of his beliefs on the matter of question. This procedure seems well adopted to the questionnaire for a situation where the questioner has some incentive to give the respondent to answer a lengthy series of questions. The present study makes no such incentive possible, nor many questions. The response variation with mail questionnaire length is presented by Scott (49) on pages 167-168, as being not significantly different for questionnaires of length from one side of a sheet to several sheets. The main difference is that the short ones produced a higher percentage of returns in the early days of the waiting period. On page 168, Scott notes very definitely an adverse effect on response rate from factor number 3 of Kendall (33) on page 29, quoted above "Difficulty of the required decision." The remarkable difference of almost twice the response to the question "Did you visit New Hampshire this summer?" or the response to the question "Where did you go for your vacation this summer?" provides a pointed indication of how questions should be structured.

A significant point difference to be noted in regard to the present and those of Scott was that his mailing was mainly to people at home where leisure time was used in filling out the questionnaire. The present study was to be sent to the inventors on their job where any but the most eagerly anticipated mail is looked on as an interruption in more interesting or at least more pressing work demands. This fact allowed excessive length to be well guarded against. Much personal experience on the job as a recipient of questionnaires re-enforced this position very strongly. It was observed that fellow engineers also tended to throw out questionnaires over one page long.

The communication from the questioner and intended respondent can suffer not only from an excessive number of questions but also from excessive directions or a repugnant covering letter. The authors touch upon this but Scott (49) on pages 174-175, who has deeply investigated the many aspects of mail surveys, has very useful information on the covering letter. A surprising finding was that a personal letter did not have a significant difference in response to the impersonal letter--89.6% return for the questionnaire with the personal letter and 91.4% for the impersonal letter accompanied questionnaire. The rather surprising slight bias, though termed not significant by Scott, is in what "common sense" would tell one is the "wrong direction." The personal version was to "Mr. John X. Gonsuilly;" the impersonal version was to "Dear Householder," etc.

The significant differences in response attributable to the accompaning letter involved content. Letters written in the tone of "Please help me out" and "Hoped for reply" cause in cases two to one better response than letters written in the tone "Answer questions 1 through 20" "reply in 5 days requested." Scott's conclusion was that letter content is much more important than the trappings. The format and layout of the questionnaire-letter combination shows definite (re Scott) favor for a letter on one side of a sheet and questionnaire on the reverse side, rather than a two sheet form: 95.8% for the former and 93.6% for the latter. A conflicting finding was that crowding all questions on one sheet was markedly poor to spreading out over two sheets. Scott concludes that the letter and questionnaire on opposite sides of the same sheet is best.

The form and spirit of the letter-questionnaire was decided to be:

1. Single 8 1/2" x 11" sheet letter one side, questionnaire otherside.
2. Statement of and evidence of guaranteed anonymity.
3. Pre-addressed, stamped, return envelope supplied.
4. Uncrowded appearance of questions.
5. Majority closed questions, minority open questions.
6. Questions attempting to generate (a) low turnover, (b) spread in alternatives (c) easy decision.
7. Interest stimulating in respondent.
8. Free of "hidden meaning" implications.
9. All possible depth of questions.

It was hoped that a questionnaire fulfilling the above form and spirit criteria and including the salient features of the following subject matter and question design discussion could be developed.

Subject Matter and Questions

The first consideration here is a general question and it proper answer as suggested by Good and Scates (15), on pages 606-607, criteria 9 above, "It (the whole questionnaire) must be valid, the body of data taken as a whole must answer the question for which it was designed." What then is the question for which this questionnaire is designed, and how shall an answer be attempted?

The effort of this investigation is to determine the management created environment which has allowed, encouraged or at least not prevented the invention of the useful and economic. This questionnaire is intended to obtain some indication of what the individual who has actually invented the useful and economic, considers as fundamental to the environment, created or allowed by management, in which he was able to invent.

A preliminary letter questionnaire combination was written up and submitted to the committee for suggestions and criticisms. (See Appendix C). The sources of the questions subject matter are in this appendix as is the reasonsing for its inclusion. Thus, it will not be repeated here but the main points of the committee's criticisms and suggestions are discussed below and the intended indication of each question in the final questionnaire is also discussed here.

Questions were raised as to the possible reticence of respondents to freely answer questions numbers 1, 5, 6 and 9, as being excessively in opposition to Good and Scates (15), on pages 607-608, criteria 6 above; specifically 1.c; 5.c; 6.a,b,c; 9.a,b,c; were pointed out as being, if not embarrassing, excessively blunt.

Question 2 also was seen as well aimed but missing the mark, not satisfying criteria number 3.

Open question number 12 was seen as needing prominance and direction so that the response might be better analyzed and also would be better aimed at "what existed that did help the inventor invent" rather than allow an interpretation of wanting his opinion of what might be better.

Some discussion was had on the other questions to create greater clarity and increase the "distance" between choices, in line with Kendall's (33), on page 29, items 2 and 3 above.

The letter, it was felt, should contain an indication of the definition of invention, more of the reason for the investigation and a statement of interest in <u>what was</u> when the inventor invented, to prevent data about a position in which the individual might be in now which could be non-invention inspiring.

The final letter-questionnaire form is as shown in Appendix D Exhibits 1 and 2.

The questionnaire is now ready to be discussed. Since it is not possible to subtly lead the respondent from the broad hint of the question to the narrow specific choice because of the required brevity, it was decided to include sufficient description in the question. The hoped for result was that an inventor reading it would understand the meaning more clearly than a non-inventor might as the inventor, it is reasonable to expect, has considered some aspect of each question. The criticisms and suggestions of the committee have been included.

Question by Question Discussion

1. When you are attempting to solve problems you get: (a) the best help possible; (b) adequate help; (c) what help is left, if any is left.

The object of this is to indicate whether management needs to give the inventor the secure feeling that help is being biased toward him, or whether invention apparently exists in spite of the lack of intended help. It is to directly assess the effect of facilities relation to invention.

2. Your boss is (a) as technically competent as you; (b) generally more inventive than you; (c) a manager, not technically qualified.

A fundamental question in management is always, "Does a manager need to be really a technical expert in the field?" or stated conversely, "A professional manager can manage anything." Heyel (21) page 295, indicates a definite need for the project manager to be technically competent in the field. Barnard (2) on page 288, states very clearly his belief that the leader must have high level technical knowledge.

> The strategic factor in cooperation generally is leadership which is the name for relatively high personal capacity for both <u>technological</u> attainments and moral complexity, combined with propensity for consistency in conformance to moral factors of the individual. [The underlining is the author's].

This question is intended to bring out statistics giving a manager the insight of what level of technical direction is most liable to allow the inventor to produce.

3. Your formal education (a) gave you a vital knowledge you needed to invent; (b) enabled you to get the job--the invention was based on other knowledge; (c) should be extended--you need more knowledge to invent more.

"Common sense" indicates that the more knowledge a man has, the more facts he can scan and assemble into the new and useful. "Common sense" thus enables a manager to reason that the most educated in his group should be given the problems most in need of invention for solution, as per Chapter IV.

4. Management (a) looks for new ideas only when in trouble; (b) energetically listens and looks into new ideas; (c) is interested only in cost reduction innovation or customer demand.

Concentrated (b) answers proves a challenge to a management to maintain suitable policy in effect. The maintenance of this effort on the part of management is an ideal lethargy and causes less than full approaches. High number of (a) answers indicates invention is spurred by a sense of urgency imparted to the inventor not by faith in "non-crisis" research. A great number of (b) answers indicates invention spurred on by a progressive research minded management; whereas (c) answers shows invention desired only as an improver of the status quo and/or to counter punch some other company's pioneering. Both (a) and (c) means possible "latent invention" present, unexposed because it only would be new and useful.

5. Your patents mostly are (a) to satisfy a need YOU SAW: (b) to satisfy a need POINTED OUT TO YOU: (c) to exploit an accidental discovery made while pursuing some other goal.

Answers here indicate a finite management policy, (a) indicates to a manager that he best see that his "to be inventors" obtain all sorts of experiences in the field, so they may see the vacancies which can and should be filled; (b) means he should set his men at recognized needs; (c) indicates management should try only not to prevent "fortunate accidents" resulting in invention. The implementation of this near humor might best be obtained by keeping everyone usefully busy.

6. Your boss (a) allows too much humor in meetings and too many witty statements in reports; (b) has a sense of humor equal to yours; (c) at times irritates the "big boss" by wise cracks or clowning.

The high incidence of the relation of a sense of humor to creativity causes this perhaps surprising "common sense" question to be included. Moore, (41) on page 24, "Sense of Humor." Two test groups of students, one high IQ-low creative, the other high creative-lower IQ were all asked to consider eight qualities, such as character, sense of humor, etc., and to rank themselves in the order in which they would like to be outstanding. Here comes a dramatic difference. The IQ group put sense of humor at the bottom. The creatives put it second from the top! The question is also aimed at indicating a level of "rapport with the boss." Moore (41), page 24, again with the same test group of students, shows that the high creative group was "at odds" with the teachers, being least desirable in the teachers' eyes. Answers to this question, it was hoped, would show management compatibility with humor.

7. You believe your less inventive associates (a) might not invent because of no incentive given by management; (b) might not invent because they see no requirement to be filled; (c) might not want to chance failure, rocking the boat, and being criticized.

This question was an attempt to determine an inventor's reason why others do not invent. It was inspired by the writing of most of the authors consulted and is very clearly stated by Harrisberger (19), on pages 44 through 49, in a chapter titled "Wanna Know Why You Aren't Creative?"

8. You believe (a) invention and product should be more personalized (like Browning Automatic Rifle named for inventor, John M. Browning); (b) management usually does all possible to publicly identify inventors with their inventions; (c) invention should be depersonalized.

This question was to determine, as well as a single question could, if satisfaction of the higher needs of Maslow's Hierarchy of Needs (14), on page 50, is a real incentive to invention. High response (a) indicates an additional incentive could be usefully supplied; (b) that invention is present when management is considered fair in its identifying of inventors; (c) indicates inventors consider this a detriment.

9. What incentives did you receive as a direct result of your inventions?

10. Were you aware of a specific incentive prior to your invention?

Please answer anywhere on this side, other side or separate sheet. Just a few words would be very generous.

11. Why did you do the "extra" that resulted in invention?

12. What incentives could or should management give that would cause more people to be usefully inventive like you?

Questions 9 through 12 are suggestions of Dr. E. J. Ferguson and are open questions to find in the inventors' own words the incentive which they believed were present which caused them to invent and what incentives management should offer to spur on creativity. The attempt was to determine if the respondents are spontaneously unknowing followers of Fein (10), whose main theme is "pay is what people work for." Since the questions are open, the response may be either interesting or hopelessly scattered. Optimism allows that the open questions will not make a severe reduction in the number or responses.

The Response

The response from the 1029 questionnaires mailed was interesting. At 53 days after the mail out, 234 came back because of bad addresses or marked "No longer at XXX Company." The mail out was not entirely to the company address of the patentee, where possible the home address was used, but 29 companies with returns marked "No longer at XXX Company" showed the following statistics.

The average percent "No longer at" answers of the original mailing was 34%. This means that 34% of the inventors who profitably contributed to the company's product were not able to be retained by that company. The company names are not to be divulged herein so these comments seem not unethical. Of the ten companies over the 34% average (one with a high of 72%), seven of them, including the highest, would be immediately recognized as ones which have been notable recently for involvement in mergers or financial reorganization and poor investor confidence. Of the five below 17%, all would be instantly recognized as either "old solid plodders" or exciting growth companies with products which dominate their field because of an obvious product superiority. The size of the questionnaire mailing to the 29 companies in this statistic ranged from three to thirty-four, the average to a company being twenty-three. The highest "No longer at" company had a mail out of eighteen, the lowest percent company, thirty-two.

The observation could be made that companies which are economically sound retain their contributing creative minds and those which are famous (in recent years) for not being economically sound lose their contributing creative minds.

Those who left, of course, are people who cannot be located through these contacts so no survey of reasons why they left can be attempted, but the fact remains an average of 34% of the inventors whose inventions are in use in the company's products left these companies after inventing something useful.

These known "bad addresses" reduce the "real mail out" to 795. Of these about 150 were to companies from which not a single "no longer at" or "cannot locate" response was received; thus, it might be conjectured that they lost none of their inventors! A response was received from one company where several of the questionnaires were opened and the rest were then stapled together and returned in a lump. Thus, it seems reasonable that some such censoring of the received mail, or of the response to it, is present.

It might be reasoned that the actual mail out which got to the addressee was approximately 645. At 53 days after the mail out 286 filled out questionnaires had been returned, nearly 45%.

A computer Fortran sort program was written and the answers to all questions of the questionnaire were put on data cards. The frequency count of the answers could thus be determined for any one or two combinations of questions and answers. As an example, a sort could be run on high school graduates (Question 13, Answer 1) with over twenty years experience (Question 17, Answer 6).

The questionnaire was interpreted into the data cards by question number and answer number defined in Table IX. Also included on the extreme right are the frequency of the answers computed in answers per theoretical 1000 inventors. It should be remembered that the sample was 286 total but it is believed that per 1000 is more meaningful.

TABLE IX

QUESTIONNAIRE QUESTIONS AND ANSWERS AND TOTAL GROUP RESPONSES

Questions = Q1, Q2, Q3, etc.
Answers = A1, A2, A3, etc.

	Response Computed Per 1000 Inventors
Q1. When you are attempting to solve problems you get: (A1) the best help possible; (A2) adequate help; (A3) what help is left; (A4) irrelevant; (A5) lone worker no help needed.	
A1 the best help possible	539
A2 adequate help	357
A3 what help is left	66
A4 irrelevant	0
A5 lone worker	21
A6 no answer given	21
Q2. Your boss is (A1) as technically competent as you; (A2) generally more inventive than you; (A3) a manager, not technically qualified; (A4) irrelevant.	
A1 as technically competent	622
A2 more inventive	91
A3 a manager	244
A4 irrelevant	7
A6 no answer given	34
Q3. Your formal education (A1) gave you a vital knowledge you needed to invent; (A2) enabled you to get the job--the invention was based on other knowledge; (A3) should be extended--you need more knowledge to invent more; (A4) irrelevant.	

TABLE IX "Continued"

		Response Computed Per 1000 Inventors
A1	vital knowledge to invent	336
A2	helped get the job	510
A3	should be extended	115
A4	irrelevant	10
A6	no answer given	28

Q4. Management (A1) looks for new ideas only when in trouble; (A2) energetically listens and looks into new ideas; (A3) is interested only in cost reduction innovation or customer demand; (A4) irrelevant.

A1	looks for new ideas	199
A2	energetically listens	538
A3	interested only in cost reduction	227
A4	irrelevant	0
A6	no answer given	35

Q5. Your patents mostly are, (A1) to satisfy a need YOU SAW; (A2) to satisfy a need POINTED OUT TO YOU; (A3) to exploit an accidental discovery made while pursuing some other goal; (A4) irrelevant.

A1	to satisfy a need you saw	647
A2	to satisfy a need pointed out	290
A3	to exploit an accidental discovery	56
A4	irrelevant	0
A6	no answer given	7

Q6. Your boss, (A1) allows too much humor in meetings and too many witty statements in reports; (A2) has a sense of humor equal to yours; (A3) at times irritates the "big boss" by wise cracks or clowning; (A4) irrelevant; (A5) is dull--none.

A1	allows too much humor	10
A2	sense of humor equal to yours	755
A3	at time irritates	14
A4	irrelevant	10
A5	dull	31
A6	no answer given	178

Q7. You believe your less inventive associates (A1) might not invent because of no incentive given by management; (A2) might not invent because they see no requirement to be filled; (A3) might

TABLE IX "Continued"

		Response Computed Per 1000 Inventors
	not want to chance failure, rocking the boat, and being criticized; (A4) irrelevant.	
	A1 no incentive to invent	157
	A2 no requirement to be filled	566
	A3 does not want to chance failure	91
	A4 irrelevant	24
	A6 no answer given	160
Q8.	You believe (A1) invention and product should be more personalized (like Browning Automatic Rifle named for inventor, John M. Browning); (A2) management usually does all possible to publicly identify inventors with their inventions; (A3) invention should be depersonalized; (A4) irrelevant; (A5) recognition by peers.	
	A1 invention and product should be personalized	301
	A2 management does all possible to identify	308
	A3 should be depersonalized	220
	A4 irrelevant	0
	A5 recognition by peers	21
	A6 no answer given	150
Q9.	What incentives did you receive as a dired result of your inventions?	
	A1 $1.00	108
	A2 money	350
	A3 none	318
	A4 self-satisfaction	126
	A5 promotion	73
	A6 no answer given	24
Q10.	Were you aware of a specific incentive prior to your invention?	
	A1 yes	42
	A2 no	50
	A6 no answer given	8
Q11.	Why did you do the "extra that resulted in invention?	

TABLE IX "Continued"

		Response Computed Per 1000 Inventors
	A1 necessity	73
	A2 money	35
	A3 part of job	230
	A4 pride	587
	A6 no answer given	73
Q12.	What incentives could or should management give that would cause more people to be usefully inventive like you?	
	A1 non-money encouragement	255
	A2 money	455
	A3 technical help	14
	A4 follow up	42
	A5 promotion	31
	A6 no incentive necessary or possible	203
Q13.	Please circle degree attained: (A1) high school; (A2) Bachelor; (A3) Master; (A4) Doctor.	
	A1 high school	171
	A2 Bachelor	158
	A3 Master	182
	A4 Doctor	171
	A6	17
Q14.	You are THE single inventor of how many patents?	
	A1 = 1 single inventor patent	136
	A2 = 2 single inventor patents	182
	A3 = 3 or 4 single inventor patents	213
	A4 = 5 through 9 single inventor patents	154
	A5 = 10 through 19 single inventor patents	98
	A6 = 20 or more single inventor patents	101
Q15.	You are the CO-inventor of how many patents?	
	A1 = 1 co-inventor patent	175
	A2 = 2 co-inventor patents	154
	A3 = 3 or 4 co-inventor patents	175
	A4 = 5 through 9 co-inventor patents	168
	A5 = 10 through 19 co-inventor patents	122
	A6 = 20 or more co-inventor patents	77

TABLE IX "Continued

	Response Computed Per 1000 Inventors
Q16. Your total patent number?	
A1 = 1 patent	70
A2 = 2 patents	87
A3 = 3 or 4 patents	210
A4 = 5 through 9 patents	247
A5 = 10 through 19 patents	175
A6 = 20 or more patents	213
Q17. How many years professional experience do you have?	
A1 = 1 year	0
A2 = 2 years	3
A3 = 3 or 4 years	3
A4 = 5 through 9 years	70
A5 = 10 through 19 years	241
A6 = 20 or more years	636

Open Question Response

Questions 9, 10, 11, and 12 are ones which could cause other than the programmed answers so the meaning for the numerical answers was the author's assessment of what were six or less definitions of the most common answers. Some respondents lumped answers to questions 9, 10, 11, and 12 in one or more comments or paragraphs, some of which were indicative of an amount of effort, others were "pent up" thoughts which were astray from the question. What were the more lucid comments in the judgment of the author are shown below. These are generally representative of what appeared to be the possible interpretations of answers.

"I saw a need and wanted to do something."

"Other than the monetary incentive, none!"

"Personal recognition."

"Give the inventor a percent of the profit from use of the invention."

"You do something for your company, they should do something for you."

"Creative people enjoy creating for the sense of achievement."

"To prove it could be done."

"Once the invention has been applied successfully for a period of at least one year, the inventor(s) should receive an occasional bonus based on the profits gained through the invention. However, it must be realized that the invention, its development and incorporation into manufacturing, cost the employer a lot of money which he extended (loaned in a way) to the inventor while the latter was being paid a salary to do this kind of work. Maybe its really a toss up whether or not the employer should hand out monetary rewards, no moral obligation there! But I like the idea, after all who hates money?"

"Definitely, more money would result in more people creating new things or ideas. Personally, creating or inventing is a natural thing with me."

"Publicize the issuance of the patent."

"Desire for recognition."

"I believe incentives per se are not the answer. Some people have the inborn ability to apply "free thinking" techniques resulting in a new idea or new way of doing a particular function. Others in the same general field can take the idea and make it work and work well but somehow can't seem to generate an original concept on their own."

"My job is design application or invention. I don't believe incentives by management will create inventors. A need, the opportunity and ingenuity will."

"Pay."

"Possibly more recognition, not necessarily financing, overdoing it can result in unhealthy competition among workers."

"Begin some freedom and encouragement to follow own ideas, of course, a financial reward always encourages!"

"A more liberal monetary incentive. Once every so often a list of things the company would like could be circulated. One thing is, in some departments the boss gets credit for the invention although they didn't originate the idea."

"I'll summarize these last four questions with one statement. I think personal satisfaction regardless of what inspiration you had to invent something is the most rewarding thing of all. Although money and promotions help.

It's my belief that man, ever since man began, has to prove that he is, in fact, a man. Many men do this in various ways, by building up their bodies, or by trying to impress and having many women, etc.

The fact that I'm an inventor might be my way to prove to myself and the world that I'm, in fact, a man. I don't really know, I'm sure all inventors have a reason for inventing things, but I think it's a personal thing with most.

Please excuse the pencil and paper.

(Signature of respondent)

P. S. If you really think you have a good idea, don't give it up without a fight. Good luck."

"Desire for recognition."

"Personal satisfaction."

"To get a better job, qualify yourself better."

"Promotion and or recognition."

"Be willing to maintain some level of exploratory research, even in times of rising costs and economic recession."

"$"

"I'm a professional, not money but recognition and opportunity."

"I invent things and sell them for a livelihood. My sole income. Adequate renumeration usually helps!"

"Poor questionnaire. I suggest you see a psychologist and learn how to do it right!"

"Make it clear that the inventor will be financially rewarded and publicize inventions."

"More flexible working hours, use more vacation time as a reward, such as a sabbatical."

"Encouragement from immediate supervisor is essential."

"Patents come more easily when you are near a problem of great company interest. Many good inventions are not patented since the company doesn't expect to make any money from them. Management must learn to culture the germ of an idea rather than to squelch it by doubts and indifference. Many people in our organization are so happy with the status quo that they don't like anything that might require extra work or which would rock the boat."

"Because I am me."

"Pay top practical creative people as much as they pay top management people both in salary as well as bonuses. Also, extend them the same privileges, company status, etc. I also think the company should see that a man who contributes substantially is entered in Who's Who at no expense to him. The commercial products made possible by my inventions have totalled well above a quarter of a billion, perhaps a billion dollars, but I am not in Who's Who. Not be so budget minded with successful individuals, and on the other hand litterally throw money away on non-creative paper publishing Ph.D's in research centers which seldom come up with a process, let alone a new product."

"Permit some boat rocking--not see a threat in a capable inventor--not steal his ideas and call them their own."

"Probably the greatest incentive to an inventor is a boss who is also an inventor, and has that "gut feeling" or intuition about a new design that tells you if it is good or not."

"The greatest of all would be follow through."

"Toughest job is not to invent but to sell management that it will sell in larger volume or bigger profit! Requires good psychology and knowledge of the market."

"I feel that management should reward through formal recognition for patents that are outstanding. I personally feel like a lot of unused talent is now hidden under the basket for lack of just rewards."

"I get paid to invent."

"Salary and recognition, your questions are not based on, or fit, the way research operates in industry." [No explanation on "how"]

"The management of my company, a $300K[2] business machine corporation, encourages invention by gifts of distinctive and expensive jewelry that identify the company's inventors, by cash awards in the 1 to 5 hundred dollar range, annual dinners and the like.

No program is in existence to foster invention, but everyone keeps logs, records and the like so that when invention occurs it can be properly assigned and defended for the individual and the company.

Management has men, like myself, who have ideas, some have managerial talent and no longer are in a position to invent. When I was in project work, I was inventive, now I encourage it, but seldom contribute. Several non-managerial contemporaries have gone on to invent steadily.

Out of thousands of company people the inventions are limited to the technical people, engineers, and sometimes technicians or servicemen. Of many hundreds of these only 120 odd have a patent, of this number only 10 or 12 have more than one. The number held by this dozen, of which I am a member, equals all the rest. Good luck, Conrad!"

"Answers to 11 and 12. Of my 30 patents, 12 are, or have been used commercially. Special incentives are good but I would have made the inventions if the incentive had not been present. I believe it is a matter of brains, familiarity with the field so that the idea is easily tested and temperment. A dissatisfied person may be as productive of inventions as a satisfied person--provided he is not too dissatisfied.

In a big company, the successful inventor makes much less money than the successful minor administrator. This I resent, but it does not affect my work."

"11. Why did you do the "extra" that resulted in invention?

An individual who is dedicated to designing the best equipment for a purpose is in a position to invent. Further, a sense of competitiveness is developed in a system in which one must compete to win a contract. A dedicated engineer should assume the responsibility of "winning" design competitions in order to support the production workers as part of the corporate team. An engineer must maintain the competitive technological position of the corporation or be replaced, jobs for "routine" responsibility are dull and not rewarding. Rewards in the form of incentives are welcomed as a corporative thank you for a job well done, but, serve little purpose in spurring the inventive mind into action.

12. What incentives could or should management give that would cause more people to be usefully inventive like you?

Incentive is an interesting word, but I question the "carrot on the stick" approach. Pay the inventor a sustaining salary, be sure to place him in a position where he can develop contributing design ideas to keep him abreast State of the Art technology. Make him aware of problems that could be solved with design improvements.

Incentives that are subject to tax deductions are worse than no incentive because it draws attention to the fact that it is a "payoff" subject to the inequalities of our tax system and serves to detract from the 'Corporation Thank You.' Would strongly advise a tax free 'thank you for a good job' as an incentive."

"Be careful to put genuinely competent people in charge at the various levels."

"To be usefully inventive requires close attention with the problem or need."

"Freedom to be."

"The biggest deterrant to inventors in industry is the doubt that management really wants something new rather than wishing it would go away."

"Do not box people in with staff "experts?", procedure, controls, engineers, industrial eng., etc."

"After money, then you can start with the self-fulfillment enrichment, etc., that the behavorial science classes tell you are so important."

"Managements willingness to take a chance on a new idea."

"Mr. Conrad R. Hilpert:

Much has been written on this subject. Your experiences as an inventor have occurred in an atmosphere that reflects in the choice of your questions. Due to the limited choices, I truly cannot answer some of them. I do see your point, however, and have much to say on the subject. My experiences are as follows:

1. Corporations tend to look outside for inventions as they relate to job title. Inventors do not necessarily have that title. In a research oriented company, the non-Ph.D. engineer, particularly the manufacturing or Mfg. Division Engrs. are hard put to be heard.

2. Patents cost money. Unless it is about to be marketed there is little interest. Patent departments are apt to not know business judgments as to the value of a disclosure. They seldom have a basis to do so.

3. To get a patent the inventor has to be a salesman, both to his "boss," to a marketing department and to the patent department.

4. To motivate invention:

   a. Commit motivation monies to patent any reasonably sound idea, regardless of its sales value.

b. Encourage the broadest possible exposure of personnel.

c. Some people are inventive and some are not. Try to identify inventors and cultivate their talent.

d. Allow inventors to share in the profit of their inventions.

e. Give inventors a degree of freedom to spend time and money to pursue sound ideas to a conclusion, even if they are not immediately applicable.

Generally speaking, inventors will invent regardless of their environment. If stifled at work, they invent at home.

In our corporation, the number of patents one has, has very little to do with their inventiveness. The least criteria is that the idea be patentable. The creative mind is at home in most any area. Give him time to drink in the existing information and he will synthesize a unique concept. From an economic point of view he should be pointed at a desirable area and one he has knowledge of. However, if he becomes over specialized he can lose the broad base which facilitates unique products ideas.

It must be said that corporation management does not like invention from within when a well thought out program is under way, unless it fits the program objective. Inventions happen both in and out of this main line of a program. The great invention outside the program means decisions and modifications of activity. To push such an idea through requires real champions, and a lot of boat rocking."

"Question 12. (1) publicize the patent program in the form of a departmental letter. The letter should briefly describe the idea, its objective and the author.

(2) Aggressively pursue the patenting process keeping in mind that patents for protection are as important as exploitable patents.

(3) Provide feed back to author of patent memo on status of idea.

Sorry I'm so late on this. I wrote a long letter while flying from San Francisco, but decided against enlarging on ideas about creative people.

(Signed)

P. S. Administrative type assignments are not conducive to creative thinking."

The interesting point that seems to come through clearly is that money is the top incentive but in some <u>individual cases</u> may not be <u>the</u> incentive to the particular inventor a director of research is bossing. While some said money was not a possible incentive to creativity, none said they would create for zero pay just to get other incentives. The only possible assumption is that these people had already had the need for money justly satisfied in their opinion.

The not infrequent mention of "idea stealing" is indeed a tragic relation of poor management, if idea stealers could be called management.

There was no real difference in the answers by the Ph.D.'s through high school graduates in apparent depth of thought on the subject but the inventors with the longer experience tended to write the longer answers. Many of these answers could be viewed as quite definite instructions to a director of research.

An imperative, almost earsplitting, shout comes through to the author that these commercially practical inventors need INDIVIDUAL ATTENTION by superiors. A person who invents, "Because I am me" seems bluntly asking to be treated as a person not as a hole in an IBM card. Obviously he believes he is "I am me" and quite unique, a manager will not "get to him" by the impersonal "from the desk of Joseph X. Blow, Director of Research." This "I am me" is not to be thrilled by communications from a desk!

The Average Answers

Table X of Questions and Answers and total group responses will be referred to and a reference "Q1A1" will mean the question and answer so indicated in Table X.

When viewing the answers to the Questionnaire, it must be continually remembered that these are answers by inventors with a proven performance of practical, commercial economic creative ability. These are not the "average Americans" in performance. It cannot be absolutely said that the answers here show what would turn the "average American" into a similar productive person, but it can be said quite certainly that if conditions in a research department were such that the low responses fit, the department would suit only a summation as follows:

TABLE X

MIMIMUM INVENTION ENVIRONMENT

Question and Answers	Per/1000
Q1A3	67
Q2A2	91
Q3A3	115
Q4A1	199
Q5A3	56
Q6A1	10
Q7A3	91
Q8A5	21
TOTAL	650
AVERAGE	81 Per 1000

This is an indication that the department would fit perhaps only 81 of every 1000 practical contributing inventors.

Should the department be managed so that the maximums of each question was in effect, it would be shown as in Table XI. In this table the department would have conditions in which success is proven at about seven times the rate of the former.

TABLE XI

MAXIMUM INVENTION ENVIRONMENT

Questions and Answers	Per/1000
Q1A1	534
Q2A1	622
Q3A1	510
Q4A2	538
Q5A1	647
Q6A2	755
Q7A2	566
Q8A2	308
TOTAL	4480
AVERAGE	560 Per/1000

The answers producing the most successful conditions do not indicate any "impossible ideal" for the director of research to strive for, but in most cases are obtained by a change in policy he directly controls by simple decision.

It will also be noted that these inventors answered these questions from their beliefs which may have been the result of knowing the cold facts or from being led to believe them to be the facts. It may be observed, however, that since very few answered Q2 with A2, it is quite clear that few believed they had bosses smarter than themselves, thus, it is quite possible the inventors were not "being led to believe other than the facts." It would be fatal for the director of research to try to hoodwink the people he hopes are smart enough to invent what he has not.

The answers from Table IX will be discussed before presenting any of the computer sorts against the particular question-answer criteria.

Q1. The answers here are in direct contradiction to the existing practice in observed small company (and many larger company) research departments. The directive here is quite simple. "Convince the inventor he is getting the best help possible" (this, as noted, will probably be accomplished by actually giving him the best help possible).

Q2. The answers here are quite damaging to the accountant, lawyer, and MBA background for "managing research" as the best performance comes from bosses who are as technically brilliant as the people they manage. The "management only type," scoring much lower, is next most productive. The A2 response indicates that a boss who makes sure his subordinates are more ignorant than he and so far below him that the subordinates believe it themselves, supervises nearly no practical inventors.

Q3. Answers fit nicely in with the indications of Chapter IV--education really helps. The low A3 response indicates it is not generally productive to advance or transfer men to areas where their education is not compatible. This is surprisingly not in accord with some authoritative thoughts. Rossman (48) makes this point quite heavily in his chapter "Training Inventors." Rossman does, however, point out that the thought is mainly applicable to the great inventors he studied.

> An individual endowed with great inventive aptitude will probably invent, no matter how little or how much formal education he may obtain but this aptitude will be made more efficient and effective by teaching and training.

The inventors in the present study averaged 0.595 patents per year experience. The inventors in the present study in the low Q3A3 response indicate that the productive inventor is not, at least in his own mind, hampered by his lack of education. He has been guided or has guided himself into attacking problems "he thinks he knows enough about to lick." It is a very good direction to the director of research not to expect miracles by hoping for a "fresh approach" by putting the least educated at the most technically advanced task.

Q4. Answers contradict much management philosophy which believes a "ready made" inventor will spring forth in embryonic form by "listening to what the customer wants," or as many accountant type managers quite understandably see a sure success, "the same old product sold for the same old price but at half the cost."

Sales knows it can take orders for ("sell" is a misnomer) a product the customer asks for; the accountant knows reduced costs mean more profit. Neither really wants to make or sell a better one for the higher price it is worth. Electro Motive and its Diesel Electric Locomotive is interesting on this point, costing just four times as much as a steam locomotive. The diesel electric locomotive is, the steam locomotive is not. Neither could the three "greatest locomotive builders in the world" be deterred from following customer demand and cost reduction of a dead product. The diesel electric was not a new idea when the customer's demand unmistakenably was finally for it; it was "new" only to the steam locomotive builders who had policy not to answer Q4A2. The low Q4A1 response is quite typical of an easily observed fact, inventions are not usually "fixes." Edison's phonograph fixed no former malfunctioning "whachamacallit." (His invention predated its name!)

Q5. The large majority of A1 answers indicate "the invention," the point of crystallized creativity is not what is patented but the recognition of the need for the thing patented. This is very directly in support of the contentions in Chapters II and III. The almost total remaining response A2 answers is good support for the boss to be technically competent to enable him also to see needs he could assign inventors to attend. The accountant type boss could "see a need" for "cheaper bearings" as well as lower taxes, neither being a possible practical capability of the company facilities or personnel.

Q6. Nearly all answered A2 which indicates that the boss must be able to adjust to the personality differences that are present between himself and his subordinates. The gruff "all business" boss is not in charge of the largest group of inventors.

Q7. The high response A2 answers indicates two possible meanings to the author. (1) Inventors recognize the importance of "seeing the need" and thus consciously or unconsciously desire to be exposed as per Chapters II and III suggest. (2) Management is in error for allowing the non-inventive co-worker of the productive inventor to exist in a channel of effort that blinds him from "seeing the need." The low A3 response shows evidence that the productive inventor is not impressed with a need to avoid rocking the boat and, thus, sees it as no deterrent to others. Impress the need to avoid rocking the boat and he may not be in this study.

Q8. Answers were somewhat enigmatic to the author. A much higher amount of A1 answers was expected and in view of the high Q9A4 and Q11A4 answer rate, a high Q8A1 might be expected. Dr. Thomas B. Auer, however, had a pointed comment that there were many products on which the inventor might not want his name, a toilet for example. Of course, it is obvious many products must carry brand names to be competitive. A Ford automobile containing thousands of patented parts would hardly be namable for each inventor. Proof of this is seen in another field where businesses are named for the founders. Sears has practically dropped Roebuck and Ward's has practically dropped Montgomery. Long credit giving titles are not useful. Thus, perhaps, many inventors look for recognition in other ways. That management must fulfill this craving is shown by the written responses quoted earlier.

The open answers to questions 9 through 12 were reduced to the defined numbered classes by the author; thus, the definitions of the numbers contain an amount of his personal bias.

An interesting summation is possible that the total of the Q9A1 and A3 answers nearly equal the Q12A2 answers. The number of inventors who received $1.00 per invention or nothing, about equals the number who believe management should give money as an incentive to increase invention.

There is room for quandry as to the indications of what should be done AFTER available money incentive is applied. Q11 indicates a majority did not invent because of a money incentive; pride was the incentive, but in Q12 only about half as many thought non-money encouragement was what management should give. The greatest number wanted money.

There seems to be an instruction to the director of research to establish a finite money incentive related to invention and establish also a method of catering to the pride of the inventor. There is a very great pressure by the majority of employees and managers to suppress such "ego culturing" in the belief that it creates jealousy; however, if the action is always related to a concrete evidence of creativity such as a patent or useful product, jealousy may be beneficial in motivating others. The author's experience has been that all such moves to suppress the pride of the inventor are initiated by those who see the inventor and his inventions as a personal threat, invariably they are individuals who have never had an original thought. The copy of a completed questionnaire on page 119 is a most direct support for this.

Q13. is the number of inventors responding by educational level.

Q14. and Q15. indicate that there is not much difference in the number of single inventor, or co-inventor, patents among the practical inventions.

Q16. is simply the same but for all patents of the inventor.

Q17. is very interesting as it indicates a sort by years experience should be made. It shows that "to hire a bunch of young energetic 'hot shots'" could very well produce near zero invention as the great bulk of the practical inventors have over twenty years experience.

INVENTIVE ENVIRONMENT

You are THE single inventor of how many patents? 25 separate patents

You are CO-inventor of how many patents? 2

Please circle degree attained:

high school   Bachelor Journalism   Master   Doctor

How many years professional experience do you have? 40

1. When you are attempting to solve problems you get: (a) the best help possible; (b) adequate help; (c) what help is left, if any.

2. Your boss is (a) as technically competent as you; (b) generally more inventive than you; (c) a manager, not technically qualified. I am my own boss. My father, for whom I worked years ago, was not technically qualified at all.

3. Your formal education (a) gave you a vital knowledge you needed to invent; (b) enabled you to get the job--the invention was based on other knowledge; (c) should be extended--you need more knowledge to invent more.

4. Management (a) looks for new ideas only when in trouble; (b) energetically listens and looks into new ideas; (c) is interested only in cost reduction innovation or customer demand. All three are right, depending on who you are talking about. Unfortunately (c) is more often the correct answer.

5. Your patents mostly are (a) to satisfy a need YOU SAW; (b) to satisfy a need POINTED OUT TO YOU; (c) to exploit an accidental discovery made while pursuing some other goal.

6. Your boss (a) allows too much humor in meetings and too many witty statements in reports; (b) has a sense of humor equal to yours; (c) at times irritates the "big boss" by wise cracks or clowning. See question 2...am my own boss and I encourage a modest amount of humor to promote cooperation.

7. You believe your less inventive associates (a) might not invent because of no incentive given by management; (b) might not invent because they see no requirement to be filled; (c) might not want to chance failure, rocking the boat, and being criticized.

INVENTIVE ENVIRONMENT "Continued"

8. You believe (a) invention and product should be more personalized (like Browning Automatic Rifle named for inventor, John M. Browning) (b) management usually does all possible to publicly identify inventors with their inventions; (c) invention should be depersonalized.
(Incentive includes recognition as much or more than money)

9. What incentives did you receive as a direct result of your inventions? Money, national recognition in my field of interest (industrial photography) and the satisfaction of solving highly technical problems without an engineering background.

10. Were you aware of a specific incentive prior to your invention? Hell yes!

Please answer anywhere on this side, other side or separate sheet. Just a few words would be very generous.

11. Why did you do the "extra" that resulted in invention? I wanted to generate important industrial developments so badly I worked horrendous hours, through week ends and holidays, and still am doing so.

12. What incentives could or should management give that would cause more people to be usefully inventive like you?

Compliment others involved in development work and involve them in consultations with industry meetings, officials and supplier representatives so that each man thinks he is essential to making everything successful. In news releases we name names when we could easily skip doing so. I have surrounded myself with talented electronics men, optical engineers, draftsmen, and craftsmen of various kinds to make up for my own terrible deficiencies, and then give them credit to the Nth degree. They are all proud as can be of their individual contributions to the result . . . . the finest equipment of its kind in the entire world. We manufacture too.

Figure 1. Copy of a Completed Questionnaire

Production with less than five is negligible and not really sizeable until after ten years. This is very interesting as it indicates that the most productive period of years for the "non-great" inventor is possibly five to ten years later than Lehman (34) showed for the "great" inventor.

Sorts by Years Experience

A sort was made of Q17A4, Q17A5 and Q17A6 which computed the data on inventors with 5 through 9, 10 through 19, 20 through 29, and over 30 years experience. The results do not indicate "common ordinary" inventors' creativity lessens with age. Quite surprisingly, those with thirty years experience and over were the most productive. One might easily reason that they should have the most patents just because they have been at it longer. The seventy-four sorted were not significantly different from the average response except as shown in Table XII.

The Q5 answers indicate that these older more experienced inventors can "see needs" more readily than their younger counter parts. This can be construed as being another direct support of the suggestions of Chapters II and III.

The high A4 for Q11 and the zero for A2 presents an interesting set of facts. This most productive group is not money motivated and appear to accomplish their high production mainly because of pride. Since the questions were asked to be considered as referring to the inventors most productive period, not necessarily the present, could this mean that these men really never did care about money? Does it mean that their money needs were sufficiently satisfied and thus they viewed pride as the motivator? The latter appears to be the most reasonable as they have managed to live to advanced age, right through their "disinterest in money," instead of starving to death like a Mozart at an early age.

TABLE XII

AVERAGE COMPARED TO 30 YEARS EXPERIENCE AND OVER

Average Per/1000	Question and Answer		30 and Over Per/1000
647	Q5	A1	757
290		A2	208
56		A3	27
7		A6	14
73	Q11	A1	27
35		A2	0
230		A3	135
587		A4	757
73		A6	81
7.399	Patents per respondent for single inventor		12.944
7.201	Patents per respondent for multiple inventor		12.891
12.815	All inventors		23.568
.595	Patents per year per inventor		.683
21.531	Years experience per inventor		34.527

The number of patents per year is most surprising. These "old men" have not been idle in their latter years as the lower age sorts will emphasize. The evidence is very clear of the singular stupidity of retiring because of age, or not looking to the older more experienced minds for the practical inventions. It is an obvious indication that these people should be really stimulated rather than merely tolerated.

Looking at the low experience group with 5 through 9 years experience of significant production for contrast, it is seen that answers for the twenty inventors responding, are very near average except as shown in Table XIII.

The Q5 answer, contrasted to the 30 and over group, shows that the group with lesser experience requires the need to be cited for them in the plurality of cases. This is a clear indication that supervising all levels of college graduates, the non-technical manager will not be able to function at highest efficiency. The manager must be technical enough to spot the needs and point them out to the to-be-inventor. For instance, it is doubtful that a non-technical manager could have pointed out the need that resulted in the invention of the suppressor grid in a vacuum tube. The problems of secondary emission and space charge would not be foremost in an accountant's, or lawyer's mind, so that he could point out the need. That the result of experience would be so obvious is almost thrilling.

The Q2 answers re-enforce the recognition of the limits of the inexperience of the younger men. A greater portion of these inventors believe that their superior is more inventive than they are. This again negates the utility of non-technical management; in only 15% of the cases were these young inventors supervised by the non-technical.

TABLE XIII

AVERAGE COMPARED TO LOW EXPERIENCE
5 THROUGH 9 YEARS EXPERIENCE

Average Per/1000	Question and Answer		5 through 9 years
622	Q2	A1	600
91		A2	250
244		A3	150
7		A4	0
34		A6	0
647	Q5	A1	400
290		A2	450
56		A3	150
0		A4	0
7		A6	0
7.399	Patents per respondent single inventor		2.769
7.201	Patents per respondent multiple inventor		3.000
12.815	All inventors		4.350
.595	Patents per year experience per inventor		.617

These relatively young inventors, however, average about seven years experience. Many engineers find themselves in their second or third position by this time. It will also be noticed that these young men are more prone to be part of an inventing team than the thirty and over group. This is an indication that invention for them requires the combination of experience and views of several minds. These handicaps are no detriment, however, as this group was slightly better than average in inventions per year experience per inventor.

The sort of inventors with 10 through 19 years experience also showed most answers quite like the average except as shown in Table XIV.

TABLE XIV

AVERAGE COMPARED TO EXPERIENCE
10 THROUGH 19 YEARS

Average Per/1000	Question and Answer		10 through 19 years
539	Q1	A1	493
357		A2	406
66		A3	101
7.399	Patents per respondent for single inventor		4.750
7.201	Patents per respondent for multiple inventor		6.015
12.815	All Inventors		9.747
.595	Patents per year experience per inventor		.680
21.531	Years experience per inventor		14.406

The Q1 answers indicate that for some reason these inventors are less impressed that they get the best help possible and it appears that compared to the average, it is because more get only what help is left, if any. This appears to be a sad situation for management to allow. Inventors who should be at the peak of their production, are getting less help than they feel they need.

This is believable to the author, as many managements begin to "get used" to a person nearing the twenty year mark and also begin to see that he has family commitments and other responsibilities, which make him less likely to quit because of slight irritations. The engineer of this age bracket also is usually viewed and views himself as becoming specialized and less "saleable" to other companies. Management thus sees a cost advantage in trying to get a lot out of these men by putting the least in. That this seems to work is shown by the inventions per year experience which is again higher than average by a good amount.

Since all groups so far sorted have been above average, some group must be below average to have obtained the average. This sort is next and it is the 20 through 29 year experience group. This group seems entirely average except in production.

This group was intentionally chosen so that it would place its members as those who were beginning their careers during World War II. The low actual mean compared to the expected mean (22.796 vs. 24.500) indicates that the group lacks members who are inventors whose careers started from 1942 to 1946. That this could affect the production of the group is not surprising when viewed with the results of Chapter IV which gave evidence that the depression definitely held down the production of invention during those years by the class of 1925. It is possible that this group of inventors had an initiation to industrial experience where the great effort was to produce "what is" and the reward was for that rather than for innovating the new.

Of course this is a group which has even more of the possibility for the poor management practices previously mentioned to be existent.

These, added to the poor start during and just after the war, could explain this group's poor showing.

TABLE XV

AVERAGE COMPARED TO EXPERIENCE
20 THROUGH 29 YEARS

Average Per/1000		20 through 29 years
7.399	Patents per respondent single inventor	5.714
7.201	Patents per respondent multiple inventor	5.256
12.815	All inventors	9.565
0.595	Patents per year experience per inventor	0.420
21.531	Years experience per inventor	22.796

The fact is quite true that had the author not decided to divide the age groups in this manner, but used an increasing span of years for each grouping, this interesting evidence of the descriptive influence of the war would have been hidden by a slightly lower production by the groups on each side.

The most instructive deduction which appears to be reasonable here is that the encouragement to be creative early in a career is most essential to productivity. This is strongly indicated by the lower total number of patents per inventor of this group compared to the 10 through 19 year experience group. There is no way to "lose patents;" thus, this group must have just been lower in production than the other groupings for some reason.

Sorts by Degree

The relative productivity of high school graduates, B.S., M.S., and Ph.D.'s is of interest as differences might support or contradict Chapter IV which was very clearly indicative that a director of research should hire the men with the highest level of education possible.

In Table XVI the evidence is again clear: education does result in more invention sooner. The Ph.D. WHO INVENTS is capable of higher rates of invention than others, the recipients of other levels of education. This should tell the director of research something about what could be the economic reason to pay him more. There is today (1972) a wide spread feeling that Ph.D.'s are unwanted surplus, even useless human commodities. This appears far from the fact. The director of research should hire them in preference to others; they produce more quickly.

It is noteworthy that nearly no invention at all comes from any other level of education at less than five years experience, whereas the Ph.D. is already at significant production.

Economically Table XVII is approximately true. Stressed again, is the fact that this is NOT a comparison of the "average Ph.D." compared to "average high school graduates" etc., it is a comparison of those in each classification who are proven commercially practical inventors. Chapter IV compares the graduates with the "general average" of the

TABLE XVI

COMPARISON OF INVENTION BY DEGREE

	H.S.	B.S.	M.S.	Ph.D.
Patents per year experience per inventor	0.478	0.559	0.662	0.796
Years experience per inventor	23.490	22.305	19.077	20.000
Years experience	Distribution per 1000 inventors			
1	0	0	0	0
2	0	8	0	0
3 or 4	0	0	0	20
5 through 9	61	46	96	102
10 through 19	142	229	308	327
20 or over	735	687	519	530
NOTE: The above may not add to 1000 because some were blanks.				
Patents per inventor	11.224	12.473	12.635	15.918

TABLE XVII

RELATIVE VALUE OF DEGREED PEOPLE BASED ON PATENTS PER YEAR EXPERIENCE PER INVENTOR

	H.S.	B.S.	M.S.	Ph.D.
Relative value	1.00	1.17	1.39	1.67

population. This does NOT mean that Ph.D.'s who do not invent are more or less valuable than anyone else who does not invent. These latter, with any degree, should be ousted from the research department of the small company; however, not until after it has been proven it is not the organization's fault. The simple "hard bitten, axe swinging, no nonsense" manager type of dead wood clearing may only produce a department barren of even dead wood.

The indication on hiring, is to hire the more educated with a history of patenting and invention. Should it be necessary to hire right out of school, not even the Ph.D. will produce practical commercial inventions for several years, but he will be the quickest.

The author has often heard the expressed sentiment, "Because of his high level of education, the Ph.D. takes longer to train to usefulness." This never quite made sense and was suspected as a cover for not wanting to pay a Ph.D. more. Apparently it was just that, a real (if innocent) attempt to "knock down" the pay to the Ph.D. (or M.S.).

The variations from the average by degree classification is very minor. The high school graduate answered Q3A1 less frequently than the average, and A3 more frequently, showing as might be expected, that he could see he should extend his education. The high school graduate also answered Q9A3 about 30% more than the average, showing he "invented for nothing" more often. Surprisingly enough, the high school graduate did not have to have the need pointed out to him more often than average; this need was apparent. The Q8 results will be discussed later.

The B. S. inventor was near average and interestingly, but perhaps significantly, he could see needs by himself a little more often than the H. S. man.

The M. S. got less good help and was under a manager, not technically qualified more times than the B. S. or H. S. man. The M. S. was able to see needs by himself definitely more than the average and received money as a direct result of his invention more than average.

The Ph.D. understandably saw his education as giving him vital knowledge needed to invent nearly 50% more than average. This is a real blow to the detractor's cry heard continuously that the Ph.D. is too theoretical to do practical things like invent useful products. The Ph.D. answered Q10A1 more often showing he looked into, or was informed by management, of the incentive he was inventing for and he answered Q11 indicating he worked a little less for pride and more for money than did the average. He still looked at pride as what he invented for about four times as often as money.

The answers to Q8 are interesting, if not critically important. Both the high school graduate and the Ph.D. are 30% in favor of seeing their names associated with the product. The B. S. people are 30% in favor of not having their names associated with the product. The M. S. people are also not in favor of having their names associated with the product but not so much of that mind.

Sort by Performance

A sort was run in four criteria: Q16A6 plus Q17A5; Q16A5 plus Q17A5; Q16A4 plus Q17A6; and finally Q16A3 plus Q17A6. These sorted inventors into performance classes with patents per year experience per inventor as follows: 1.688 call them "HiA;" 0.890 call them "HiB;" 0.255 call them "LoB;" and 0.137 call them "LoA." The sort produced 12, HiA; 12 HiB; 43 LoB and 36 LoA inventors. As might be expected the

TABLE XVIII

PERFORMANCE SORT

Question and Answer		Responses Computed per 1000 Inventors HiA	HiB	LoB	LoA
Q1	A1	667	250	535	528
	A2	167	583	256	389
	A3	167	167	116	28
Q2	A1	500	583	651	639
	A2	0	167	140	83
	A3	417	250	163	250
Q3	A1	667	250	302	333
	A2	250	583	628	500
	A3	83	166	47	111
Q4	A1	250	250	209	139
	A2	333	333	581	500
	A3	250	416	186	278
Q5	A1	583	583	814	694
	A2	250	417	163	278
	A3	167	0	23	0
Q7	A1	250	0	209	111
	A2	333	667	512	639
	A3	83	167	70	111
Q8	A1	417	333	279	333
	A2	167	417	372	305
	A3	167	167	186	194
Q9	A1	167	83	140	305
	A2	417	417	442	139
	A3	0	83	279	278
	A4	333	0	93	139
	A5	0	0	46	55
Q10	A1	500	417	441	333
	A2	333	583	465	583
Q11	A1	83	0	70	55
	A2	0	167	23	0
	A3	167	167	186	222
	A4	583	667	698	583

TABLE XVIII "Continued"

		HiA	HiB	LoB	LoA
Q12	A1	250	167	279	333
	A2	583	667	418	333
	A3	0	0	23	28
	A4	0	83	70	55
	A5	0	0	47	0
	A6	167	83	163	250
Q13	A1	83	83	279	250
	A2	167	333	418	500
	A3	250	167	162	111
	A4	500	417	139	111
Q17	A5	1000	1000	0	0
	A6	0	0	1000	1000
Years Experience per Inventor		15.75	15.083	26.14	25.5
Single Inventor Patent per Inventor		12.167	5.273	3.674	2.194
Multiple Inventor Patents per Inventor		14.417	8.583	3.308	2.000
Patents per Year Experience per Inventor		1.688	0.890	0.255	0.137

comparison of the HiA with LoA is more striking. The easiest format is to tabulate the results question by question. (Table XVIII)

This sort gives even more support to certain of the previous findings, Q13 shows that Ph.D.'s dominate the high performance field and the mix of degrees follows the degradation of performance almost perfectly, only the high school graduates refuse to follow the performance exactly and their deviation apparently makes way for B. S. men to populate the poorest performance ranks.

Except for Q10, the answers to the other questions are not so obviously ordered with performance. The low performance people seem to do slightly greater single inventor patenting in proportion to their multiple inventor output than do the high performance but the difference in total output is so great that this is not clearly much else than data.

Q10 is indicative of the fact that performance seems to be coincidental with a lack of knowledge about "what is going on." The high performance people most frequently know that incentives or not are there before they invent; the low by about the same margin do not know.

The answers to the other questions are quite related to the mix of degreed people in the group and their experience. Some slight indications of use may be seen.

Q12 shows that high performance people believe money would be an incentive much more so than low performance people and the low performance people more often believe no incentive possible or necessary. This is coupled with the fact that most of the low performance people did not know if incentives were present or not. A clear case of management communication failure and result?

Q11 shows that no matter what they knew was coming to them, money or nothing, neither the highest or lowest performance people received money both did it for pride!

Q9 perhaps shows the real truth. The low performance people usually received $1.00, whereas the high performance people received "money," meaning a reasonable sum -- an incentive to the inventor. Far more often the low performance men got <u>no</u> incentive. The high performance people always got <u>some</u> incentive. The high performance people also got more self-satisfaction from their invention while not getting any promotions, a situation which did happen a little bit to the low performance people.

Q9 appears to be again a clear case of management failure in the case of the poor performers, were the performers INHERENTLY so, their answers to Q9 might have been exactly those of HiA. All facts of Q9 are management responsibilities, and completely at the mercy of simple decision.

Q8 indicates a definite majority against "depersonalizing invention." The highest performance inventors show great preference to more personal identification with their invention. It is interesting also that the low desire for depersonalization of invention increases slightly as performance decreases. All, again, is management's perogative to change to better or worse.

Q7 is a direction to management to continually point out needs to all as it is seemingly quite obvious to these inventors that the other people do not invent because they have been prevented from seeing needs to be filled. The next strongest reason is lack of incentive.

Q6 is not listed as the results were quite uniformly A2.

Q5 shows that all practical inventors most often see the need themselves but the highest performance invpntors have a significant number of "fortunate accidental discoveries." This question seems to be a directive to management to put people where they can see needs for themselves rather than pointing out needs to them, as per Chapters II and III.

Q4, again, reveals that the pressure of prevailing trouble is not productive of the bulk of invention; neither is customer demand nor cost reduction. Management which presses its subordinates for cures for trouble or customer demands probably is in trouble and not in sight of the customer's ideas because they are not really looking for new ideas.

Q3 is almost a mirror of the education level mix.

Q2 re-enforces the advantage of management being technically competent. The next most effective is a non-technical manager but he is at his most useful application supervising the highest performance people; this is perhaps because of the education mix again. In all cases, supervision which is more inventive than its subordinates is not effective in bringing out invention in these subordinates.

Q1 again tells management simply that it will get only "what invention is left" if it gives invention "what help is left." Compared to Ph.D. inventors the H. S. gets (or has to be satisfied with) much more self-satisfaction than the Ph.D. Q10, again, showed the H. S. less well informed as to the actual status of incentives to invent than Ph.D.'s. Q11 fits with Q9, none of the HiA H. S. inventors did it for money, while 10% of the Ph.D.'s did invent for money. The same amount of each thought invention was part of the job but 75% H. S. invented for pride whereas 50% of the Ph.D.'s invented for pride.

Q12 shows 50% of each believing money would be the greatest incentive management should give inventors. Thirty-five percent of the Ph.D.'s did not think incentives possible or necessary, whereas only 16% of the H. S. HiA inventors thought this.

Sort by Education and Performance

Dr. Clayton A. Morgan queried, "What might have been the reason some less educated excelled in invention?" A sort was run taking out the H. S., B. S., M. S., and Ph.D. who produced patents per year experience per inventor at 125% of average.

This sort showed great similarity between the high performance inventors of all levels of education except in Q3 education oriented and Q7, Q9, Q10, Q11, and Q12. Compared to Ph.D. high performance, the HiA H. S. inventors saw a significant number of their less inventive friends afraid to rock the boat and thus not inventive.

The open questions showed Q9 the HiA H. S. people getting little money reward. Discussion of these results with others causes the author to again point out that this chapter has not been concerned with the average employee of any level of education but only with inventors of proven ability to patent and invent the commercially practical. These are the approximately 10% of the college graduates scanned in Chapter IV who invent.

These inferences from the Questionnaire will be reduced to specific actions to be taken by a director of research in Chapter VI.

The overall conclusion possible from this questionnaire is, "Yes, management is directly able to influence the inventive output of its subordinates and it can be pointed out how."

CHAPTER VI

DISCUSSION, SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDY

Discussion

The four criteria for producing useful inventions were listed in Chapter I, page 11. Criteria one was dealt with in Chapter I. The admonitions dealing with it and criteria one are restated here.

1. A technical environment equal to the state of the art.

    a. Buy no hardware until after someone has gone through Rossman's (48) first six steps (see Chapter I, page 12) and obtained the invention.

    b. Buy only what the inventor needs for THAT invention to progress through step seven.

Two sentences from Chapter I, page 12, are repeated here as they focus on the finality of the above dealing with criteria one and point to the matter of criteria two, three and four.

> The fundamental truth is that people invent and create; test hardware only helps if it is completely subordinated to the will of the inventor to solve his singular immediate problem. General instrumentation so impressive to 'visiting firemen' only diverts the inventor from how to make his idea to have a problem an on-hand facility can solve.

The matter of criteria two, three and four is how to encourage, motivate, and direct PEOPLE to create. Chapters II, III, IV and V give some routes a director of research can follow which will accomplish these actions. Since this is not as simple as the technical environment was to solve, a discussion on these is required rather than a mere list.

2. True technical direction to the effort.

Providing true technical direction to the effort has been shown to be accomplished most productively by the inventor's supervisor being as technically competent as the inventor himself. Supervision by a non-technical manager allows some significant invention to take place but this criteria means "technical direction," thus, if the director of research wished to get the most (three times as much) invention from his department he should be as competent as the men he supervises.

What if he is in the position and is not a technical type? The situation is individual, but it could well be that when the department becomes large enough to require a "non-rowing coxwain" the non-technical manager should get someone under him who is technical to direct the efforts.

The director of research will definitely not run a high risk of having to decide what to do with a lot of useful invention by others if he obviously is the best inventor in the department. He must develop, obtain, and bring out the men under him so that they believe they are at least as smart as the director.

What if he just really is the best inventor in the company? To enable others to be something else than just efficient help to the "best inventor in the place" he must set off to the side, these others, who he thinks should invent by themselves. Thus, they can be their own bosses on "whole problem assignments" in which he takes only remote interest. Almost like an oracle, the highly inventive director of research must remain "on call" rather than "call on."

The director of research must utilize his inventiveness (if he is the greatest) to setting his subordinates at looking for solutions to either remote and obscure but inevitable needs he has foreseen and/or to distributing his subordinates abilities to present problems which are compatible.

So that this highly inventive director of research does not waste his talents, he should pick a very difficult problem to solve and stay at it, letting his subordinates do their "whole problem assignments" perhaps more slowly than he but as surely. As the subordinates invent, they will begin to see themselves "as smart as the boss" and may even prove they are.

It is in just this activity that the non-technical manager is at a loss. He cannot be a technical director but the technical inventor can be. The history of great and small research efforts is of the great inventor plus director; i.e., Kettering at General Motors or E. H. Land at Polaroid.

Invention is a "fresh approach" to a problem or a completely "fresh" first of a kind. It has been conclusively shown that invention comes most quickly and in greatest amount, not to the uneducated but to the most schooled minds. Only a technically competent manager can insure that the would be inventor has not retreated to a defensive position of exhibiting an obviously admirable quality of diligence and earnestness. The non-technical manager must wait to change work assignments until after inventions have not come. The technical director of research can change whole problem assignments when inventions are not going to come, long before they have not come.

The director of research should hire the best educated applicants. Should the new employees be "right from school" they should be assigned to help more experienced employees of MUCH LESS FORMAL EDUCATIONAL ATTAINMENT because no matter what degree the new man has, he will produce little invention before he has had five years experience. The Ph.D. right out of school is no more productive of practical, commercial, economic industrial invention than the high school graduate. The brand new Ph.D. obviously can provide great help to a more experienced researcher of any degree but will disappoint all if it is intended that the brand new Ph.D. invent. The brand new Ph.D. should be hired in preference to a brand new lesser degreed man as the Ph.D. will come into useful invention sooner but only after several years. Should the director of research see his problem as that of getting solutions quickly, the hiring should be of someone with more than five years experience and some patented inventions already a fact. Of course, the most rapid way of getting problems solved is by having the people invent who are already on-hand with in-line experience already accumulated. This is what the next two sections are aimed at helping get accomplished.

3. An effective motivation of creativity.

Money has been shown to be the incentive of primary importance. This is shown by Fein (10) and hammered home by him very convincingly for the case of the workers. It can however very truthfully be stated that Thomas Edison invented for money. His first patent showed him not to invent for any other reason! F. G. Crowther (5) states, "After this experience, Edison decided that he would never again invent anything for which the market was not evident." Why should it be expected that lesser inventors should find a different fundamental incentive? The study of Chapter IV brought out that only about 10% of the college graduates patent inventions duing what is expected to be their most productive period. It is unreasonable to believe that these 10% were independently wealthy and invented "because they had nothing better to do." The very basics of the patent system are to enable the inventor to realize a return on his invention, should an inventor just be inventing "for fun" he could do as much without the expense or trouble of taking out a patent. The least an individual probably would "sink" in costs for a patent of some merit is between \$1000.00 and \$2000.00. Few would find this kind of expense worth the possession of a patent which they were to give away with no thought of return. Many of the respondents to the questionnaire did not indicate that they invented directly for money but since they were gainfully employed, viewed it as part of the job or as an added pleasure, helping their pride.

People are consistently inconsistent, therefore the high percentage of inventors who received pride as the incentive for invention is a highly biased value. The respondents were of the small minority who did actually invent for some reason; thus, if any one truly did invent only to strengthen his pride, he is in the result. Those others who did invent for money or anything else are in the result. The vast majority of engineering college graduates do not invent and since the pride incentive is a thing of availability to all, it is quite reasonable to assume the majority do not view it as sufficient incentive to drive them to invent. This logic may be reasonably applied to most any other non-monetary incentive and it is seen as less than sufficient incentive.

The simplest explanation of the utility of money as an incentive, is that invention is work just as much as any other mental effort. The only really effective incentive that makes engineers show up at their desks at 08:00 A.M. and remain there until 05:00 P.M., five days a week is the pay they get. Few, if any, work for nothing. No rational sequence of thought could come up with the postulation that, "Since these men want time and one-half for overtime engineering, they will gladly do the overtime thought that results in invention for nothing."

There are some who are paid to invent and it may be reasonably assumed "they for sure better" earn their pay by inventing. It is not logical that the majority are such, and are continued on the payroll simply as disappointments to their employer. It is logical to believe that the majority do not get paid to invent and respond faithfully. They get paid for non-inventive engineering application of their knowledge.

The problem stated in Chapter I that the director of research has, is to cause a so-called research department of normally non-inventive types assembled by default to begin to invent. The questionnaire results showed that most, by far, proven inventors of industrially useful things think the incentive which would cause more people to be usefully inventive is money.

The first order of action the director of research must take is to cause everyone in the department to understand that he will get money in some appetizing form for inventing. If the director of research cannot do this he is going to find the effort to invent at the same level as if he told the men, "You can come in and work Saturday, Sunday and Christmas for no pay and it will be all right with management." Someone might show up once in a while on Saturday, and within recollection of older employees, may have done so on Sunday, but on

Christmas? Yet, for pay, industry runs all those days and for many those are the hardest days of work in the year.

The success of the nationwide contests in which people must do extensive research is evidence that the possibility of monetary gain will spur people to do things quite beyond their normal output.

The point has been belabored, but not beyond its importance. The inventor can choose to be an inventor or not. Management can choose to pay or not. The decision is all management's. It may be assumed that the director of research has decided to recognize the importance of the monetary incentive and now has the problem of what and how to pay.

The author looks at invention as an "expense" to the inventor of three types. All three must be paid. To the about-to-be inventor, who has not yet convinced himself that by some means he will eventually get what he deserves, each of these expenses must be paid as they occur. These three "expenses" are:

A. The accountable time. This is the time the inventor (not his boss necessarily) feels is the voluntary overtime. Even should it be during working hours the inventor knows he is doing a little more than his fellow workers who "are not thinking." The prospect of no return for this is enough to eventually dissuade the neophyte inventor from this vital (to invention) slight extra. The boss who "administers" this according to policy insuring all are treated equally will get just that kind of invention, equality at zero. To inspire each to try to invent, there must be some way of allowing this embryonic inventor to be paid for this "expense." There are, no doubt, "high pressure management" types who might say, "I am not interested in inspiring anyone with that little a will." This is exactly right, if this manager can accurately predict the worth of the invention he has prevented. It could be observed that a manager with this ability to predict the unknown is certainly headed for a brilliant career. The ability to truly predict the future ever so slightly is a highly saleable ability, (if only to the weather bureau). The director of research must pay for this "accountable time."

B. The unaccountable time. This is the time spent inventing that the inventor finds breaking up family discussions, the time that will cause his wife to complain, "Can't you leave your work at the office, even on Christmas?" The should be inventor, seeing no pay for this, will train himself to leave his work at the office even on Christmas. If there is some pay possible for this that both he and his wife can see, the good woman will be prone to ask, "How's the new idea coming?" and may even ask this on Christmas.

This is of greatest importance to the "has not yet invented," the proven inventor who has come to see the advantage in inventing or has come to see the no advantage in inventing will not need this. He will be going after the rewards his boss gives him or he will be in the 34% of the proven inventors whose questionnaires came back, "No longer at XYZ Corporation," "resigned 1967," "Left no forwarding address." Without this incentive pay for this unaccountable time, the "has not yet invented" will remain on the payroll doing from satisfactory to excellent work, but not inventing. At this point some manager type will put forth a truism that such is entirely satisfactory and people like that are needed too. The object of this study was not on how to be satisfied with no invention. The director of research described in Chapter I was given the mission to produce invention from "our research laboratory" which was already doing satisfactory to excellent non-creative work. The director of research must pay for this "unaccountable time."

C. The loss of profit. Assume the inventor is one of the approximately 11% who got all of $1.00 for his invention and the invention is in daily use. He finds that the company is saving $38.73 on each unit as a result of his invention and production is 100 per month. Since he was smart enough to invent it he is "smart" enough to calculate that he has "lost" $3873.00 per month which he could have gotten at no expense to the company, in seventeen years he has "lost" $790,092.00. Management will quickly rise to the task and show, perhaps entirely validly and accurately, that such a "loss" to the inventor is entirely fantasy and the inventor would instantly agree had he gotten something more commensurate with even the realistic than his whole $1.00.

Should this inventor be paid something reasonable relative to the inventions worth he would never have seen this $790,092.00 loss but would only have seen his real profit as reason to invent again.

It is management's decision whether this man (and worse his fellow workers) is shown to be a $790,092.00 chump or a winning inventor by $100.00 per month (amounts are for example only, not relative). The director of research must allow the inventor to recover this loss of profit.

The foregoing has described certain of the possible money incentives which must be provided for, especially for the beginning inventor. The question is now "how to pay" "how to calculate the amount?"

The above three expenses exist for all inventors in any line of product or process. The basis for pay must vary extremely.

An accountant's ideal would be to "give" the inventor a portion of what is left after all costs have been subtracted from the gross profit or savings the invention produced. This may be the "good" or even "righteous" way but it places the return so remote that the beginning inventor will just not be interested at all. Management does not do the same for its customers; that is, give them free use of the product until the customer clears a profit. It is as absurd to believe inventors are going to be inspired to enthusiastically jump at a management offer to let management have free use of their invention product, hoping on hope that management will be able to show a profit (or admit it) and give them some of it.

This "pay after profit" pay for invention will work absolutely, at about the same effectiveness that automobiles and homes are sold on a cash and carry basis. Management has found how to overcome this stumbling block for sales.

Many respondents asked for just plain money which is non-informative but others gave informative answers, a share of the profit or savings, bonuses, stock options, or stock rewards. Some thought a fixed sum per patent, some type of royalties, and additional vacation. The latter is actually a form of money. Each of these could be an answer satisfactory to an after the fact inventor which each respondent was. These suggested incentives might not appear so strong to the has-not-yet-invented since his interest in inventing is essentially zero. It is at this stage management's interest 100% in the has-not-yet-invented to get him to attempt an invention.

It is a firm conviction of the author, from his experience, that the "accountable time" must be the starting place; if the individual never puts in this time he will not go on. This time has two characteristics. First, it must be initiated and terminated by the inventor; second, it must be scheduled by the inventor.

Previously great inventors have been quoted and have indicated that they did not know quite when they were going to "see the light." If Edison could not have inventions on schedule, it is far out, indeed, to believe someone who has yet to invent item one will do it when some boss schedules him to do so; nor, will he do it in the "six hours 'the boss' gives" him.

A system which appears to be a possible solution to this pay for accountable time is as follows. Employees are allowed to put in paid voluntary overtime (reimbursed at least at straight time rate) as they desire for working on ideas of their own. Several of the questionnaire respondents suggested such and it has been a strengthening concept of the author's as experience is accumulated. Since they are being paid, monitoring by supervision can be accepted by them, if done by a sympathetic, knowledgeable, and strict supervisor. This will require very hard work for the supervisor and faith on the part of higher management. It is an immediate fear that everyone will put himself on voluntary overtime, however, this will not be the case if the boss is intelligently involved in the project. It has been seen that pride is a large part of the non-monetary incentive that an inventor gets and thus to be working on something which turns into a complete bust, will be a threat to an individual's pride and by being so, will cause the inventor to self-monitor any milking of the company. The sincere concern on the part of the individual about the waste of company resources that occurs when he makes a mistake of any kind has been usually so very strong that the mistake maker usually needs encouragement by management that "all is not lost" so he may quit worrying and get back to work.

Inventors on voluntary overtime can be kept out of blind alleys by a director or research who himself is on some "voluntary overtime" and appears at the office or lab frequently to try to understand what the inventor is doing.

Such leadership is exactly the same as that used by an infantry platoon commander in combat. The platoon commander's actual personal belligerent efforts against the enemy are certainly never more than one man's worth, but what he does is insure that the "voluntary" belligerent efforts of each platoon member is maintained. The platoon commander does this by being in the critical areas when needed. This he DOES NOT DO by being more knowledgeable about each man's combat problem than the man himself. This he DOES DO by simply being in the area as great an amount of time as possible and he will find he is seemingly there at the CRITICAL TIME simply because he was observant while fleetingly on location during the much longer duration of a decision wanting to be made.

Thus, it will be with the director of research who is head of a department whose members can go on voluntary overtime to work on ideas. He will have some decisions wanting to be made and a duration of time for him to be intelligently decisive in. Without this incentive to try, there would be nothing.

The thrift with which employees will use this voluntary overtime will be quite amazing, if not thrilling. This can be evidenced by a change in attitude and action which takes place when engineers and technicians "are taken off the clock" or "put on the clock." The author has been in both situations both as the worker and supervisor. It is immediately seen that "when the clock is ticking" the job stops with the clock, and restarts only when authorized overtime is present. When the man is not harrassed by the ticking clock he will finish the job, he will, himself, remember ten minutes he really did not give the company in the last eight hours. The voluntary overtime will never be turned in at the actual true value, always much less.

Supervision must, however, be prepared to lead the effort and avoid the psychology of looting by total absence. Normally, honest men often take part in looting simply because "everybody is doing it so I might as well get mine." Should such occur, the director of research is simply in need of replacement, not the plan.

Variations may be necessary. Some inventive efforts will require teams, some individuals may need technical help. In such cases, the team and/or help should be allowed to be inspired by the inventor himself to put in voluntary overtime, reimbursed exactly as for the inventor. It should not be expected that the inventor should get straight time while the mechanic gets time and a half.

The "accountable time" expense to the inventor is actually man hours. Thus, it seems reasonable that the above system, reimbursing for man hours, is a solution.

Monetary compensation for the "unaccountable time" is a real problem and one which at least to the author has no direct solution as neither to the employee or employer does it have any chronological quantitative measure.

Unaccountable time may tell management how compensation should be made if it is seen why the inventor accrues this expense. The inventor puts in unaccountable time on his idea because of the "push" from having put in accountable time, and because of the "pull" from the anticipation of eventual reward. Thus, it might be possible to include this reimbursement for the expense of unaccountable time by proper reimbursement of the other two expenses.

If the inventor is not reimbursed for his accountable time, it will not be put in and he will have no "lurking thoughts" on which to put in unaccountable time. If the inventor has no prospect of eventual reward, he will not see reason to move beyond his accountable time and management has by this simply turned a motivated inventor into a worker on aimless overtime. THIS IS EXACTLY the result of the bitter humorless "$1.00 per invention" policy many companies have. The impact of this "reward" is seen in the response from the questionnaire. The average inventor had about thirteen patents which would today almost buy Christmas dinner for the inventor and his wife, less his children. This average inventor did this with nearly twenty-two years experience, his reward 60¢ per year; not much unaccountable time can be paid for with money like that.

Several respondents indicated that high rewards for invention could cause on the job jealousy and uncooperative attitudes. The above voluntary overtime for inventions would help solve this trouble as it would remove the observation of the inventor from the jealous, and would enable him to be a full time member of the department on assigned work during regular hours. Other respondents, as mentioned above, have proposed a fixed price per patent, others royalties and profit saving related payment.

The fixed price per patent is, in the author's view, a very reasonable part of a plan. Since a patent attorney gets a fee based on the work he did getting the patent, it appears to the inventor that his contribution to the patent is at least no less important than the attorney's. Some fee of similar magnitude might be in order. Some management will question "Even if the patent is no good or is never used?" The inventor looks at it exactly as the patent attorney. The attorney does get his money if the patent is no good and/or never used so why not the inventor? Both could be equally responsible for it being no good and/or never used and it is probably management's fault it is either.

Perhaps a reasonable fixed price per patent would be to pay the inventor an amount equal to the average patent attorney's fee for patents the company has obtained. This is easily obtained and is an explainable amount which has a record of being an incentive for competent professional work. It made the patent attorney apply himself diligently.

Since the value of a few inventions far eclipses the cost of the patent, the inventor will see great saving or profit to the company as a loss to himself if no explainable part of this is reimbursed to him. There can be no simple suggested way to do this as the patent may be a part of something, a process of manufacturing, or some other not easily calculable contributing value to the company. The value of many patents lies in the fact that mere existence of such allows negotiation for license to another patent of even more value. All such are real return to the company. For management to avoid reimbursing the inventor for this is not only impeding further invention, it is immoral if not dishonest. This does not mean that the inventor "deserves it all" any more than management deserves to keep the whole selling price. The inventor does not believe he deserves even a major portion of the gross saving or profit his invention produces but he can easily reason that he should get more from the good inventions than the useless ones. Management also expects more return from its products.

Non-Monetary Incentives

Some form of publicity is an outstanding suggestion by the respondents. The answers to Q8 have been previously discussed and the tenor of the open question response allows that inventors would like to see their names in print and would be happy to be publicly pointed out. Some believe invention should be depersonalized. No real reasons could be found for this feeling but it occurred less than one-fourth of the time. A few thought publicity caused jealousy and thus, it was bad. The author's view is that very definitely inventors are much like the soloists of a band or orchestra. Undoubtedly, the attention they get causes jealousy, but that very jealousy is often an incentive for an otherwise mundane talent to be driven to superiority. It is absolutely a travisty of justice to remove the incentive for the excellent to become better and remove the chance that the company beat its competition because some small minds are envious of their superiors. It must be remembered by the director of research that the most jealous of his department's output of commercially useful invention will be the competitor's whole company. If his group is good their competition will be jealous; if one of his men is good it is reasonable to believe his competition may be jealous. The jealous must be shown that the easiest way to become quite unjealous of a superior is to outdistance him; if that is not possible the problem is definitely not the superior's nor the judge's of the contest.

The methods of publicity are well known and in use daily for every "star" from the high school quarterback to president of the Kiwanis. A very lucid practical description of how this can be done in the case of inventors is contained in the complete questionnaire answer on page 119, Chapter V.

A fine method of inventor recognition is by naming the device after the inventor. Some examples are the "Eccles-Jordan Flip Flop," "Schmidt Trigger," "Lamb Noise Silencer." These are common electronic circuits and are parts of many pieces of equipment but long since their invention the circuits are still referred to by their inventors' names. The experience of the author has been that public recognition of the inventor has beneficial effects out of proportion to the effort on management's part securing the recognition. Even those who do not appear in the publicity will take boastful pride in telling, "I work with those fellows!" or "He's my boss."

The amount of non-monetary incentive which can be of use is nebulous. Once the non-monetary incentive is obviously "cheaper than money" to management, it will be as obviously cheaper to the inventor and in truth he will see that he is getting gyped. Fein (10) puts this very bluntly. "Is job enrichment morally justified?" he asks, and then proceeds to put forth a very good case for the contention that it is not. It can, therefore, be reasoned that if it is not morally right for management to accept more profit from a blue collar worker's brain work and return only a true feeling of wormth, it is bad for management to accept profit from a white collar worker's brain work without a reimbursement in kind. The only way this non-monetary incentive will be effective is when the inventor is as hungry for a pat on the back as management is for a dollar. This can occur, but only after the inventor has lost his primary interest in money. The director of research should, upon giving an inventor a clipping about himself and his invention, watch for the sentiment, "Fine, this and a dime will allow me to call home from anywhere in town." The publicity is no longer an incentive; it has become an irritant. It is emphasizing the inventor's belief that he has not been properly reimbursed for his three invention expenses previously listed. Non-monetary incentives must be viewed as seasoning is by a chef: it will only improve a good meal if used correctly; by itself, it is not edible in useful quantities and in excess it will spoil even the best food, but when used with skill it makes a merely nourishing meal an experience to remember and enjoy for a long time.

Incentives mentioned by some were follow up, promotion, and technical help. The low frequency of these responses indicate that they are unique conditions but each is of course a management perogative.

4. <u>An administrative environment in which creativity is encouraged</u>. The administrative environment in which creativity is encouraged is not really different from the administrative environment which encourages any other profitable product. Each such successful case is the result of leadership which is fitting. The term leadership is quite nonspecific and is a quality like creativity which is very like the wind, its results may be seen more easily than the cause.

One of the most often neglected administrative leadership duties is the facilitation of the organization's tolerance of the inventor's necessary oddities. Many a man would like to stay on "after five" and ponder about some problem but cannot because the janitors always start with his office first and, thus, he is stopped from being creative by a motivated mop bucket. Perhaps it is "not possible" to give the inventor office keys; the reason is "we can't give everybody and his dog a key." This is really a policy supported by the lazy boss so he will not have to drop in once in a while to see if "everybody and his dog" are really abusing the keys he authorized for some sincere engineer or technician. The author was a first hand observer of a company which encouraged all to "promptly leave the parking lot at quitting time." The reason was so that the guards could lock the gate to prevent a neighboring company's employees from short cutting to the highway. When the absurdity of the situation was pointed out, the management excuse was, "well, it only affects a few!" The few it affected were the three engineers in the research department who never seemed able to drop their work at 5:00 P.M. and promptly convenience the guards who were on duty all the time anyhow. This let these should be inventors know that their efforts were, in management's view, more worthless than a guard's inconvenience and just above inconvenience to someone else's employees.

The usual department mess causes the director of research to be the iron willed buffer between the top management and the research effort and sales led "visiting firemen." The director of research must be immersed in the department so that he can insure that the mess never impedes the research and that research effort is never diverted to "painting white rocks." The author was involved with a research effort which was carried on at an outdoor proving ground under the worst possible handicaps of adverse climatic, instrumentation and technical help, because the test was "too messy" for the lab, which top management likes to be neat. The effort consumed about ten weeks instead of two and resulted in questionably accurate results whereas, in the lab the instruments were on hand for this exact situation.

CPM and PERT are two examples of paperwork which is especially trying to the inventor, NOT BECAUSE HE CONSIDERS HIMSELF ABOVE IT. The inventor's problem with filling out in any detail just what he did is that until after he has invented he usually really does not think he has done anything worth recording and the "invention" really occurred while shaving yesterday morning. The previously noted words of Kettering as quoted in Von Fange (63) Chapter IV, page 3, are to the point here, "But an inventor is almost always failing." By asking an inventor continuously, "What did you do today?" "What did you do today?" "What did you do today?" etc., management is forcing him to say, "Nothing" over and over or fill in eight hours of fiction. The author has been active on both sides of CPM/PERT efforts, progress charts, etc., and the truth about research progress is never acceptable. It is not compatible with the more "reasonable" data from production, maintenance, sales, etc., (if indeed they are not also reporting fiction).

The author is not against CPM/PERT, etc., but is against having research personnel fill out any such report entry. The director of research will be greatly aided by these types of management systems but the data must be gathered by observing what is going on, not by asking the participants. Research is a contest every bit as intense and competitive as any sporting event or mortal combat. It is a contest where the inventor has two adversaries, the problem and the competition's researcher, who is trying also to solve it. More like mortal combat than sports, research cannot be replayed next season, the inventor either wins or loses the chance in this problem forever. Interrupt the activity for some non-contest pertinent diversion and research changes from an all out effort to win to a scheduled performance like T. V. wrestling, synchronized exactly with the commercials.

The small organization called "our research department" in Chapter I should allow the director of research to completely keep the CPM/PERT, etc., charts all by himself for the entire department's activity and not have anybody else write a bit of data. As the research department gets bigger sub-supervisors should do it and perhaps a "PERT CLERK" could be of good use to keep it going. The inventor himself should not consciously be asked, if this appears necessary, it is an indication that the superior's technical direction is lacking and no administrative management system will fill in for this.

The simplest fundamentals of leadership practiced by a military squad leader may be doing nothing but at least he is with his men. This is a function that, as one rises in industrial management, is completely suppressed to being with the boss; or, better yet, the boss's boss. The usual director of research has almost spotlighted pride in how he no longer knows how to "read the dials and twist the knobs," since "the boys in the lab are way beyond me." He wears the same immaculate clothes as the vice president, engineering or sales do. When he does come into the lab, he obviously does not know what many tests of importance look like and certainly does not get near things throwing oil or mud. He comes to the proving grounds only when it is neither muddy or dusty, nor hot or cold, and may even call up to see if it is "nice out there."

If the director of research wants his researchers to go to the base of the problem and stick there until it is solved, he must be there also. If a research engineer is expected to stay down in the bilge of a shrimp boat trying to analyze a marine gear problem, the director of research should "spell him off" and make sure he does this when it is hottest, noisiest, and dirtiest. Should some phase of a project require risk of damage to equipment or personal safety to an extent which could cause a question in the minds of the research personnel, the director of research should either run it himself "to show how it is done" or at least be there in the middle of it at its worst.

Very often the director of research feels that his attainment of the impressive title signifies his "graduation" from such mundane things and his "commencement" of the opportunity to act like the suave executive seen on T. V. Nothing could be farther from the truth. When he was a research engineer, he needed only to be at the worst of his projects, as director of research he needs to be at the worst of all projects.

If Edison, Steinmetz, Armstrong and Collins, could be this type of leader in their monumental efforts and accomplishments, the director of "our research laboratory" cannot be less and expect any production of invention at all.

James Swanson (53), in Chapter III brought out a point of research management which must take place and is the domain of the director of research. That is, Jim says, "acting as 'judge and jury.'" A good part of this, of course, is the previously discussed technical direction, but inventors need the inspiration of a superior to "go try it." The director of research is the one individual who must decide when to press management for a chance to show off. It is exactly the analogy of the orchestra director who decides when to let the soloist play to which audience. The common director of research will step aside and let the inventor approach management usually to fail to sell the idea. This appears to the novice inventor as "his real chance to shine in front of the big shots." Nothing could be farther from the truth. The "freedom" given the inventor by the "magnanimosity" of the director of research is simply a decision avoiding action on the part of the director of research. The director of research has simply protected himself from a chance to fail. The common director of research believes that success is obtained by avoiding failure. True one never loses a fight never entered, but this does not produce any wins either.

The director of research must be willing to put his job on the line behind any product of his department he has let come to a state of development such that he could think of anyone carrying it to management.

The above administrative action suggestions are certainly not unique to what a director of research should be. Any department head should do the same. These are courses of action which may be less habitual to the average director of research than to the average much less educated infantry squad leader. These are the only things the squad leader gets sustained training in and are the only things a technically educated person could have completely avoided any training whatsoever in. It is in these areas of leadership, that in the opinion of the author, the non-technical-management-only type is able to excel and in many cases completely overcome his lack in the technical field. An outstanding example is suspected when reading the completed questionnaire in Chapter V, from the "journalist" inventor of optical instruments.

Studies of creative environments have been made and the bibliography contains such. Several are, perhaps, of interest as modern augments to the above. A new technique called "Synectics," has been suggested by Dr. Clayton A. Morgan as a possible augment to, or substitute for, the proposals of Chapter II and Chapter III, to give a single person the wide knowledge needed to see all the facts to assemble into an invention. [A complete description of it by its designer is found in Synectics by William J. J. Gordon (16) and more recently by a co-worker of Gordon, in The Practice of Creativity by George M. Prince (46).] The technique appears to the author to have great merit, expecially, for "our research department" when it is first changed "overnight" by edict from the described antithesis of research to a research department. It also, of course, is a proven tool to use when all seem stumped and progress has stopped. Synectics extends the pioneering work of Sidney Parnes (45) in presenting "brainstorming" as a technique to cause group creativity where individual creativity was not sufficient. The author's experience with these group techniques is almost none since having been a part of the "buzz" in the so-called "buzz sessions" of years ago. These were as disappointing as they were (in the author's case) disorganized. Synectics appears to have incorporated an organization and direction in a system which has some proof and is founded on a thorough study and development. Taylor and Barron (54) in their Chapter XVI present some interesting criteria for the administrative environment for a research department.

One is that it should have an academic atmosphere similar to the universities who turned out the Ph. D.'s, M. S., etc. This is possible for Bell Telephone or any slightly smaller organization but just is not suited to attempt in "our research laboratory" from Chapter I. It would be much wiser to allow the members of this organization some time periodically to return to school to get "recharged" with the academic environment.

Several of the respondents suggested management should allow sabbatical leaves for their inventors. It is the opinion of the author, that nearly nothing could be finer in this avenue. Here at Oklahoma State University it is tragic that only government agencies seem to be giving scholarships or sabbatical leaves, or sponsored education to their employees in any great number. Not only will this draw the keenest minds from industry but it will hone them to their sharpest condition. The attempt by the small company to create a university like atmosphere in its lab is bound to be farcical, but returning engineers to the university for more education is bound to be beneficial. Both Chapters IV and V show that education does actually help invention.

An adverse administrative environment is usually set up by the patent contract. Nearly all technical people sign these as soon as going with a company. These "protect the company from invention." The idea behind the contract is that the employee must be prevented from utilizing company research facilities to invent the "great thing" and then quitting and patenting it himself or getting a patent on it and forcing the company to use it at exorbitant royalties.

This all seems entirely fair and necessary for the company to do. After all, the company has provided the very tools the inventor used, the company provided the chance for the inventor to be in the situation to see the need, the company paid him while he was working on developing it, and the company provided the technical help to perfect it and the lawyers to get the patent through the U. S. Patent Office. For all this, it is natural that the company should be protected against the brilliant, dishonest employee who would cheat them so easily.

To someone who has never struggled through the inventing process in industry and has only seen the movie and T. V. versions of invention the above may seem real. To the real industrial inventor it is positively funny, as from experience he knows that even should he invent the cataclysmic answer to the most pressing problem in the company's files, and have it be perfectly functional, there is no danger whatsoever that it will be snapped up by anyone. The seventeen years a patent is in force is barely long enough for a company to understand what has been given them and to use it.

Usually, this is put down as "production change-over time working out the bugs," perfecting the idea, etc. The actual time to accomplish this is nearly zero. The big lag is the mental absorbtion time of management, even the management to whom the brilliant, dishonest inventor would sneak his invention off to. There is nearly no chance that an inventor could put the squeeze on management by not having signed the contract and inventing and patenting something great.

Inventions are just not looked for by much of management with an intense decisive, intelligent, aggressive attitude that would allow an inventor the ability to sell his patent to eager competing companies. Even the great independent inventors were nearly frustrated to death by the rejection their inventions received by organizations which later were almost willing to murder to monopolize the market, not via the patent but by financial, political and coercive measures.

The policy making management who never had an original thought hires lawyers to write an air-tight contract so that if a latter day Thomas A. Edison was hired and he invented a myriad of fantastic, useful items, management could give him $1.00 each and reap millions in profit. The fact is that the same timidity which spurs on the desire to be "air-tight" against their own local genius is the timidity which will prevent them from decisively utilizing and exploiting the inventions of this contained, restrained and harnessed local genius.

The only thing the patent contract protects anyone from is the necessity for management to make a decision to move NOW on an employee's invention or forever hold their peace. The patent contract enables management to vacillate for up to seventeen years waiting for a competitor to move on the same problem with a different solution at which time the old patent is dusted off and change to it is forced. Had no contract been signed, management would have had to decide "It's good, let's go" or "No, let the competition be afflicted with it," and in either case have the chance of being wrong.

The reference to a patent contract was purposely left off the questionnaire because the responding companies were nice enough to help the author in this study, so this inciting subject was avoided. This patent contract is an infringement which everyone is "resigned to" and any statistical survey will show most engineers do not mind at all, but most engineers do not invent at all nor in their situations are inspired to try. Thus, the patent contract is no more restraint than are the laws restricting murder. Most do not intend to invent or murder. Another overlooked point is that the engineer who is not inventing the useful is not inventing the useful because of EFFECTIVE negative forces and the absence of positive forces. The fact that the patent contract did not prevent Joe from inventing is no proof that it is not the restraining element in keeping Bill from inventing what is obvious, useful and profitable.

The possibility that he just might invent something great that he could make millions on is the almost gambler like long chance many individuals need to invent what is actually a mundane improvement, which after much procedure is profitable in a small way to the employer. Remove this outside chance by a contract and the inventor is turned off. The company has completely protected itself, as Sir Walter Raleigh said of the headsman's axe, ". . . a sure cure for all diseases."

With no contract how could the company protect itself? The simple truth is that if the employees are left so out of touch by management that they could secretly come up with something worth stealing, management needs replacement, anyhow. This simple solution of eliminating both the patent contract and the type of management that feels protected by it is probably quite unsaleable since "everybody is doing it."

A practical modification suggested by some of the respondents might be to allow the company exclusive right to the patent for three years at which time it reverts to the inventor, or the patent could be renegotiated for another three years.

The previously mentioned monetary incentives reapplied in some modified form could cause management to keep on its toes as to which patents were worthwhile and which were not. The inventor would have three years to reasonably assess his patent and to also see it more realistically. The result would not be a loss to management but a complete sweeping out of "trash patents" every three years and a spot-lighting of the useful ones, both of which management needs to have happen in all companies. The effect would be much like buying an option on a piece of property. Nobody continues options on worthless property or lives in fear that a competitor will pick up the option on worthless property.

The only disadvantage to the system, that is apparent to the author, is that it would cause management to make a decision where the contract allows avoidance of decision by management.

The more general administrative environmental conditions which could affect invention can be visualized if the characteristics of the creative are studied. The lists of characteristics of the creative contained in Appendix A, have been sorted into two lists, one List A and one List B. List A is of characteristics which the administrative environment really does not have to "content with." The director of research will observe these more or less intensely concentrated in his subordinates as their inventive capacity varies. These characteristics he can feed and exploit. These characteristics include those which seem obvious as necessary to creativity.

LIST A

Characteristics of the Creative (Selected from the references)

1. Dedicated to problem solving.
2. Aggressive in goals sought.
3. Relentless worker -- great zeal.
4. Rejects theological arguments.
5. Intelligent (I. Q. 100-140).
6. Likes to explore ideas.
7. Can easily accept failure.
8. Strong motivation.
9. High degree of initiative.
10. High self-sufficiency and independence.
11. High introspectiveness.

The above, and most of those listed in Crosby (4), would cause a "yes" answer to the question, "Do you think the creative person should be intelligent?" (as an example). Yes answers would nearly assuredly be coming forth if the question were asked about nearly any technical worker. A family doctor should certainly have all these characteristics. Remove one or some from an automobile mechanic and he is a poor mechanic (unfortunately likely). The encouraging thing here is that the list includes no extreme characteristic such as I. Q. over 160, the ability to visually focus on subjects three inches from the eye, smell like a bloodhound, or mentally manipulate ten digit numbers. It appears that "any good man" could be creative.

The other characteristics of the highly creative which are listed appear as possibly real challenges to management to create an administrative environment which can happily endure or allow to thrive.

LIST B

Characteristics of the Creative
(Selected from the references)

1. Does not value job security.
2. Likes to clown around -- childish play.
3. Unimpressed by status symbols.
4. Good sense of humor.
5. Accepts chaos and change anti-symmetry.
6. Non-conformist -- enjoys non-conformity.
7. Independent -- observant -- says what he thinks.
8. Gullible -- open to experience.
9. Needs continual reinforcement -- an understanding listener.
10. Preference for complexity in phenomena.
11. Preference for imbalance in phenomena.
12. Openness to variety in phenomena.
13. Breadth of interests.

These characteristics are unfortunately most irritating to the usual manager or boss. Having a high degree of any of these is a sure fire way to be continually on the nerves of the Director of Engineering or the Vice President of Engineering or his subordinates who emulate him.

An engineer possessing a generous dose of each of the characteristics of List A would invariably spoil it all by exhibiting a visible amount of number 2, in List B.

The man picked for promotion, all else equal, would be the man rating high on the A list and near zero on the B list. The man to whom the challenging problems would be given is also certainly the high on list A and low on list B man. Most bosses would rather have a pleasant wrong answer than a right answer and a wise crack.

The unfortunate (?) truth is that nearly all the creative people the author has seen appear to be higher on the B list than on list A and almost never seen is a top company executive who could stand B list characteristics. The result usually is that the creative person is eliminated or reduced to an apparent low B list type.

To have a creative person in a job, his characteristics on both lists must be exploited or at least enjoyably endured. A man with a high A and B list rating penalized for high B list characteristics will cause his creativity to be transferred out of his work. This man, (if he stays with you), will just be another worker and will cause the remark "Joe does a fantastic amount of real ingenius work at the model railroad club, but is just so, so, at his job."

A paradox exists in research departments. The ideal research department is one where lay-offs from the normal ups and downs of the economy are not prevelant. Jobs in research are usually some of the most secure. The ideal research man is one who does not value this security. The research department thus attracts most non-creative types! The ones who most likely stick the longest and try hardest to stay are those who highly value security. The research department thus concentrates on the non-creative and distills out the creative.

A good part of management knows research is just "waste." There is nothing so irritating to this type of manager than to see people "wasting" his money with smiles on their faces. When the vice president of engineering flies out to the proving ground, he does not want to see a test engineer laying out a nude woman half a mile long while testing a bull dozer.

Gradually, or rapidly, the research department collects a concentration of low B list types. These might be called, meticulous meter readers. They are dedicated to the production of endless data exactly as per the last request.

It might be suspected that were management to encourage B list characteristics they might find increased creativity coming forth. Peter Drucker (7) in Chapter 4, page 71, states, "The effective executive fills positions and promotes on the basis of what a man can do. He does not make staffing decisions to minimize weaknesses but to maximize strength." Drucker points out the fault seen in research departments full of meticulous meter readers. They have been kept because they had B list characteristics. The B list characteristics, of course, were viewed as a weakness by the boss.

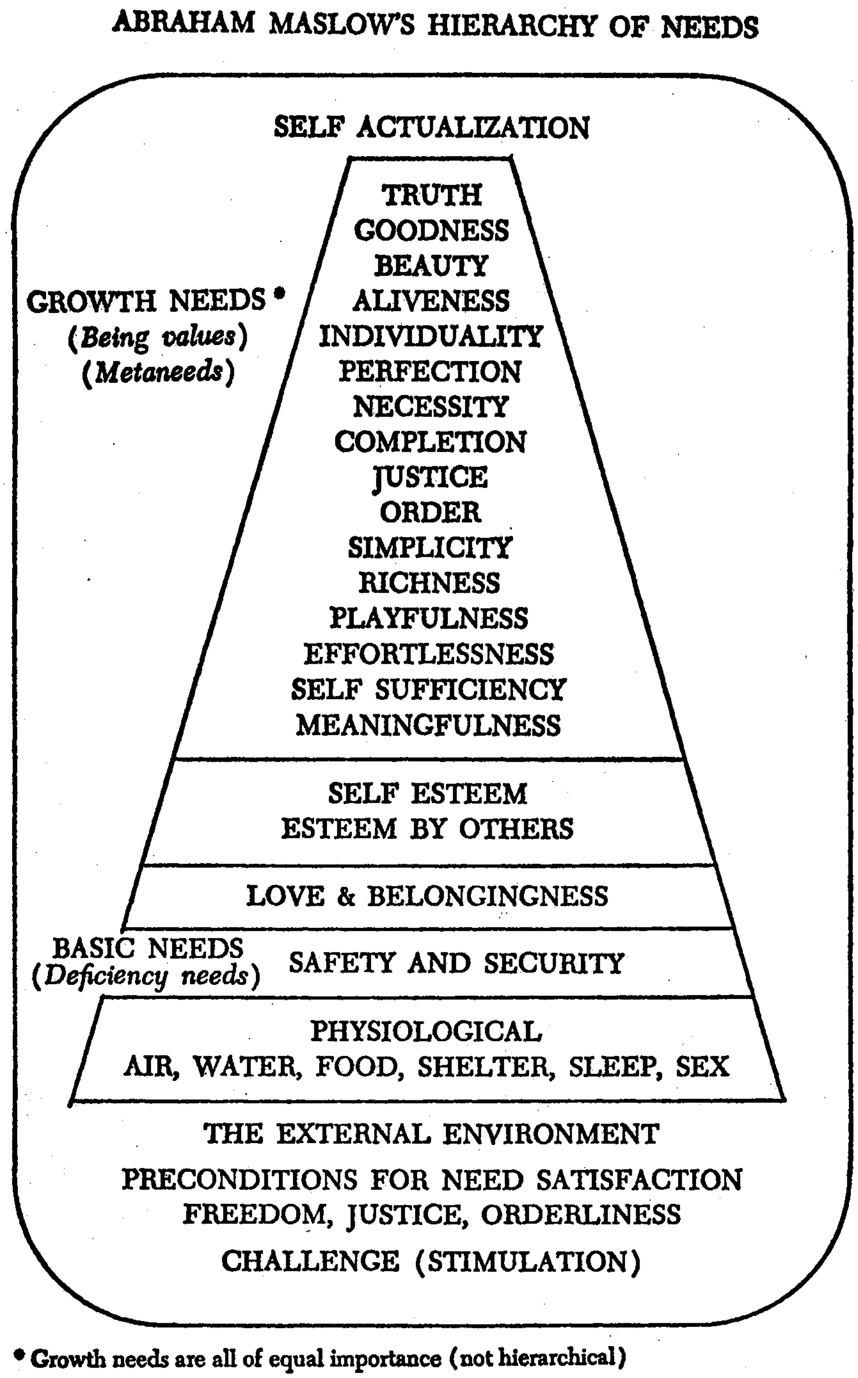
An example of such administrative environmental intolerance of B list was seen by the author. A very creative mathematician was rarely creative at his job because he was "beat down" repeatedly for such things as this. Joe thought he could develop an easy way to allow draftsman types to calculate the polar moment of inertia of complicated shapes of revolution. This he did in a very ingenious manner; simply by counting the usually complicated calculation is easily accomplished. To aid this, Joe included the densities of the shop's commonly used engineering materials, cast iron, steel, aluminum, brass, bronze, etc., but at the end of the list he added feldspar, mutton tallow, indian ivory, and brimstone. This caused a vice president to jump up and down and recall the whole report. The V. P. told Joe's superior to scold Joe but the superior said he could not do so with a straight face so the V. P. did the scolding himself!

Discussions of the matter take two channels, the usual manager type contends that Joe was wrong for being unserious; the working engineers think the list very funny but are disgusted that nobody told the V. P. off.

Why do such scoldings keep Joe from creating on the job? Well, in Joe's eyes it was all part of the creation of a useful tool. He really cannot tell where to draw the line. One might say the characteristics on the A list are necessary--those on the B list essential? The administrative environment must not reject the B list or it has rejected creativity.

Interesting support for this is given by Abraham Maslow's Hierarchy of Needs, which is presented by Goble (14) on page 50, and is reproduced on page 172 of this study. Maslow shows that these needs must be satisfied in the ascending order to maintain motivation of employees. It appears that without much stretching of meanings, the B list characteristics extend from "love and belongingness" upward. Love and belongingness might be number nine on the B list and Maslow's need "playfulness" is number two on the B list. The other B list characteristics would not seem foreign objects if placed on the Hierarchy of Needs.

The inventor is a McGregor (39), pages 33-48, theory Y person with an essential theory X component. He needs to see a "loss in a chance for gain" if he does not invent.



Source: Frank G. Goble, The Third Force, The Psychology of Abraham Maslow. New York: Goble, Grossman Publishers, 1970.

Figure 2.

Summary

As with any summary to technical reports, if read and acted on without comprehending the entire report, the result is nearly sure to mislead. So the following truncated phrases should not be followed within their limits but should mainly be reminders of the whole previously presented.

<u>Instructions for the Director of Research</u>

1. Organize and finance the people, not hardware.
2. Only order hardware after the specific need has been established for it.
3. Study up to a respected level of competence in your department's field and MAINTAIN it.
4. If you are a non-technical type be "in on things" as an observer continuously and decide on the apparent merit of the propositions -- but decide.
5. If you are the best inventor present get out of everything and into some one tough thing; let your men solve some things with you only being on call.
6. Assign whole problems to your men and insist and show them how to "go to the bottom and look up." Allow no "human computers" who specialize in solving problems with ordered, cleaned up and reduced data from "lesser minds."
7. Hire the best educated people possible, load them up and have faith. Let the brand new Ph.D. help the long experienced high school grad solve problems neither could working alone.

8. Look for a history of patented invention in hiring experienced men.

9. Pay for creative results and transfer out the meticulous meter reader; other departments need them you need inventors. (If everyone is uncreative it is not all their fault.)

10. Set up an incentive of meaningful amounts of money for invention and inform and reinform how it can be obtained.

11. Pay for the inventor's "unaccountable time," "accountable time" and "loss of profit."

12. Pay for patents.

13. Be a squad leader. Do not expect your men to do anything you do not do. If you show you can, they will race to show they can too, and better.

14. Beyond blunt money incentive increasingly determine non-money incentives by the individual you are trying to motivate. Some men have no possible use for membership in a country club, but may really want their name on a flour sack bottom.

15. Shield your creatives from irrelevant and harassing duties. A mad man can drive nails and be using his imagination seeing each with the head of his boss. This concentrated intense stimulation of the imagination is not liable to result in constructive invention.

16. CPM/PERT can help expedite invention only if the inventor does not have to solve those problems too.

17. If you must spend more time with your boss and boss's boss than with the department you must stop this foolishness and return to the department.

18. Do not let imperfection impede trials -- failures are inevitable.

19. Put your job on the line with every presentation to management. If you will not risk it why should they?

20. Give credit to the people who did the work over and over again, louder and louder, (even if you did some of it yourself, your men will not let you hide).

21. Get a realistic patent contract, one which will give the company absolutely no "protection against invention."

22. Get some sort of company sponsored education in a challenging form into actual functional existence.

23. Allow B list characteristics freedom to exist. (See page 168)

24. Utilize the latest techniques in releasing creativity (synectics?) wherever at all plausible.

25. Maintain the principle that research is very like war, the only battle worth winning is the last.

Conclusions

It may be concluded that:

1. Management controlled causative factors can be defined that will allow the establishment of the four criteria for the occurrence of useful and commercially economic inventions.

2. Courses of action can be defined which a director of research should follow so that his company may benefit from latent inventive genius inherent in its research employees.

3. A functional number of the factors of conclusion one and the courses of action of conclusion two have been presented.

4. Three sub-conclusions are:

   a. The prospect of a high monetary reward is the greatest incentive for the inventor.

   b. Management can increase the rate of invention by developing experience in employees who have attained the higher academic degrees of Master of Science and Doctor of Philosophy rather than the high school graduate or the Bachelor of Science.

   c. Management cannot immediately increase the rate of invention by hiring inexperienced technically educated minds of any level of scholastic attainment but the higher degreed minds will produce in the shortest time.

5. Management of most companies is seriously at fault in failing to establish an inventive environment.

Recommendations for Future Study

It is recommended that:

1. A study be made as to why the universities seem to be doing no better at producing inventors than they did a half century ago and what can be done to increase the inventiveness of college graduates.

2. A study be made of the reasons why inventors leave the companies they have benefitted. This study would be made from: (a) the inventor's view, and (b) the employer's view. These two opposite views should be informative of a divergence which needs convergence.

SELECTED BIBLIOGRAPHY

(1) Baker, Samm S. Your Key to Creative Thinking. New York: Harper and Row, 1962.

(2) Barnard, Chester I. The Functions of the Executive. Cambridge, Mass.: Harvard University Press, 1968.

(3) Chambers, J. A. "Relating Personality and Biographical Factors to Scientific Creativity," Psychological Monographs General and Applied, Vol. 78, No. 7, whole No. 584. The American Psychological Association, Inc., 1964, pp. 16-18.

(4) Crosby, Andrew. Creativity and Performance in Industrial Organization. New York: Tavistock Publications, 1968.

(5) Crowther, F. G. Six Great Inventors. London: Hamish Hamilton, 1954.

(6) DeSimone, Daniel V. Education for Innovation. New York: Pergaman Press, 1968.

(7) Drucker, Peter F. The Effective Executive. New York; Harper and Row, 1967.

(8) Drucker, Peter F. The Practice of Management. New York: Harper and Row, 1954.

(9) Dun and Bradstreet. Million Dollar Directory. New York: Dun and Bradstreet, Inc., 1972.

(10) Fein, Mitchell. "Motivation for Work," American Institute of Industrial Engineers, Monograph No. 4, New York.

(11) Foster, Emery M. "Biennial Survey of Education in the United States," Statistical Summary of Education 1925-1926. Washington, D. C.: U. S. Government Printing Office.

(12) Garrett, Alfred B. The Flash of Genius. New York: D. Van Nostrand Co., Inc., 1936.

(13) Gilfillan, S. C. The Sociology of Invention. Chicago: Follet Publishing Co., 1935.

(14) Goble, Frank G. The Third Force, The Psychology of Abraham Maslow. New York: Goble, Grossman Publishers, 1970

(15) Good, Carter V., and Douglas E. Scates. Methods of Research: Educational, Psychological, Sociological. New York: Appleton-Century-Crofts, Inc., 1954.

(16) Gordon, William J. J. Synectics. New York: Harper and Brothers, 1961.

(17) Haefele, John W. Creativity and Innovation. London: Reinhold Publishing Corp., Chapman Hall, Ltd., 1962.

(18) Harmon, Lindsey R., and Herbert Soldz. Doctorate Production in the United States Universities 1920-1962. Washington, D. C.: National Academy of Sciences--National Research Council Publication No. 1142, 1963.

(19) Harrisberger, Lee. Engineersmanship: A Philosophy of Design. Belmont, California: Brooks/Cole Publishing Co., 1966.

(20) Herbert, Wally. A World of Men. New York: G. P. Putnam's Sons, 1969.

(21) Heyel, Carl. Handbook of Industrial Research Management. New York: Reinhold Book Corp., 1968.

(22) Hilpert, Conrad R. "Gyroscopically Induced Failure in Multiple Disc Clutches, Its Causes, Its Characteristics, and Its Cures." Society of Automotive Engineers No. 6990066.

(23) Hilpert, Conrad R. U. S. Patent No. 3,202,018, August 24, 1965.

(24) Hilpert, Conrad R. U. S. Patent No. 3,352,395, Nov. 14, 1967.

(25) Hilpert, Conrad R. U. S. Patent No. 3,358,796, Dec. 19, 1967.

(26) Hilpert, Conrad R. U. S. Patent No. 3,446,323, May 27, 1969.

(27) Hilpert, Conrad R. U. S. Patent No. 3,472,348, October 14, 1969.

(28) Hilpert, Conrad R. U. S. Patent No. 3,482,668, December 9, 1969.

(29) Hooper, Mary Evans. Earned Degrees Conferred: 1969-1970, Institutional Data. Washington, D. C.: U. S. Government Printing Office, National Center for Statistics Office of Education Catalogue No. HE 5.254: 54013-70-B.

(30) Hylander, C. J. American Inventors. New York: MacMillan Co., 1945.

(31) Iles, George. Leading American Inventors. New York: Henry Holt and Co., 1912.

(32) Jewkes, John; David Sawers, and Richard Stillerman. The Sources of Invention. London: MacMillan Co., 1969.

(33) Kendall, Patricia. Conflict and Mood Factors Affecting Stability of Response. Glencoe, Ill: The Free Press, 1954

(34) Lehman, Harvey C. Age and Achievement. Princeton, N. J.: Princeton University Press, 1953.

(35) Lindgren, B. W., and G. W. McElrath. Introduction to Probability and Statistics. New York: MacMillan Co., 1969.

(36) Lipschutz, Seymour. "Theory and Problems of Probability," Schaum's Outline Series. New York: McGraw-Hill Book Co., 1966.

(37) Loughead, Flora Haines. Dictionary of Given Names with Origins and Meanings. Glendale, California: The Arthur H. Clark Company, 1958.

(38) Mackinnon, Donald W. "What Makes a Person Creative?", Saturday Review, Feb. 10, 1962, pp. 15-17 and 69.

(39) McGregor, Douglas. The Human Side of Enterprise. New York: McGraw-Hill, 1967.

(40) McRoberts, Richard C., and Bruce C. Arnold. U. S. Patent No. 3,613,469, October 19, 1971.

(41) Moore, A. D. Invention-Discovery and Creativity. New York: Doubleday and Company, Inc., 1969.

(42) Olson, Gordon C. U. S. Patent No. 3,537,557, November 3, 1970.

(43) Oppenheim, A. N. Questionnaire Design and Attitude Measurement. New York: Basic Books, Inc., 1966.

(44) Osborn, Alex. Your Creative Power. New York: Charles Scribner's Sons, 1949.

(45) Parnes, Sidney J., and Harold F. Harding. A Source Book for Creative Thinking. New York: Charles Scribner's Sons, 1962.

(46) Prince, George M. The Practice of Creativity. New York: Harper and Row Publishers, 1970.

(47) Quartermain, L. B. South to the Pole. Wellington, Melbourne: London Oxford University Press, 1967.

(48) Rossman, Joseph. Industrial Creativity. New Hyde Park, N.Y.: University Books, 1964.

(49) Scott, Christopher. "Research on Mail Surveys," Journal of the Royal Statistical Society, XXIV, Vol. 124, Series A. London: 1961, pp. 143-195.

(50) Seidel, George J. The Crisis of Creativity. Notre Dame, Ind.: University of Notre Dame Press, 1966.

(51) Smith, Elsdon C. American Surnames. Philadelphia: Chilton Book Company, 1969.

(52) Smith, Elsdon C. The Story of Our Names. New York: Harper Brothers, 1950, pp. 23-26.

(53) Swanson, James P. U. S. Patent No. 3,417,845, December 24, 1968.

(54) Taylor, Calvin W., and Frank Barron. Scientific Creativity: Its Recognition and Development. New York: John Wiley and Sons, 1963.

(55) Taylor, Jack W. How To Create New Ideas. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1961.

(56) U. S. Department of Commerce, General Information Concerning Patents, Washington, D. C.: U. S. Government Printing Office, Reprinted, February, 1970.

(57) U. S. Department of Commerce, Official Gazette of the United States Patent Office, Washington, D. C.: Government Printing Office.

(58) U. S. Department of Commerce, Social and Economic Statistics Administration, Washington, D. C.: Bureau of the Census.

(59) U. S. Department of Commerce, Statistical Abstract of the United States, Washington, D. C.: Bureau of the Census.

(60) U. S. Department of Health, Education and Welfare, Report of Distribution of Surnames in the Social Security Account Number File, Baltimore, Md.: Social Security Administration, June 1, 1964.

(61) U. S. Department of Interior, Annual Report of the Commissioner of Patents for the Year 1911, Government Printing Office, 1912.

(62) U. S. Patent Office, Index of Patents, Part I, List of Patentees, Washington, D. C.: U. S. Government Printing Office.

(63) Von Fange, Eugene K. Professional Creativity. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1959

(64) Whaley, Donald L., and Richard W. Malott. Elementary Principles of Behavior. New York: Appleton-Century-Crofts, 1971.

(65) World Almanac and Book of Facts. New York: Doubleday and Co., Inc., 1970.

APPENDIXES

APPENDIX A

FIVE LISTS OF THE CHARACTERISTICS OF CREATIVE PEOPLE

APPENDIX A

FIVE LISTS OF THE CHARACTERISTICS OF CREATIVE PEOPLE

General Discussion

The characteristics of creative people some authorities give are as follows:

Excerpt from Crosby (4).

In order to summarize the ideas which have been stated or implied in this section, and to relate earlier pertinent material, it will be useful to construct a profile of the creative personality. It is emphasized that the features listed are based on a wide body of research, but cannot be regarded as absolute criteria. Highly creative individuals may reflect only some of the features along with others not listed. A convenient presentation can be obtained by grouping the characteristics in relation to four aspects of behavior: perception, self-awareness, communication and motivation.

Traits of the creative person seen in his perceptual behavior:

- (a) tolerance of ambiguity
  - (i) preference for complexity in phenomena
  - (ii) preference for imbalance in phenomena
  - (iii) openness to variety in phenomena
- (b) breadth of interest
- (c) perceptual control
  - (i) flexibility
  - (ii) deferment of judgment.

Traits of the creative person seen in his awareness of himself:

- (a) personal complexity
- (b) rejection of suppression as a means of controlling impulse

(c) accommodation of some feminine interests and impulses
(d) exploitation of hedonic response.

The importance of self-awareness has been stressed by several investigators. Abercrombie [1960] found that students were disturbed on realizing that their judgment in scientific matters was influenced by habits of thought which seemed to belong to another field of behavior. Taylor and Holland [1964] mention in their summary of traits that creative people are more open to the irrational in themselves, and that they have more fantasies. Barron [1957] believes that one of the strongest characteristics of the creative person is his ability to regress, at will, to naive, primitive fantasy, then to return to a high degree of rationality and rigorous logic. This uncompromising use of the imagination is possible because his intellectual efficiency gives him confidence in his ability to return readily to reality after having allowed regression.

Traits of the creative person seen in his interaction with others:

(a) self-assertion; tendency to dominate through drive
(b) verbal fluency
(c) expansiveness
(d) impulsiveness
(e) non-conformity
(f) tendency to release tension readily through motor activity
(g) femininity in some interests and reactions
(h) independence of judgement.

Traits of the creative person seen in his motivation:

(a) rapid personal tempo
(b) high level of drive.

Mace [1962] states that motivation is based in a sense of difficulty or a consciousness of the existence of a problem, which, for a creative person, sustains the essential curiosity. Taylor [1964] also lists awareness of problems among other factors of motivation, such as striving for general principles, desire to bring order out of disorder, and desire for discovery. These aspects of motivation, observable in the creative person, may reflect the specific 'creativity motive'.

Extensive work has been done by Barron on the relationships between personality and originality. In one study, a battery of diverse tests of originality was given to a group of subjects who were also observed in various situations and rated on aspects of personality [Barron, 1957]. Comparisons of ratings and test scores allowed some conclusions to be drawn confidently, and indicated some interesting approaches to further work. The study also provided further insight into the relationship between intelligence and creativity. Other studies have shown the relevance of independence of judgment to the creative personality [Barron, 1958].

Excerpt from Haefele (17).

In describing the personality of the creative individual, many of the authors already referred to--and others whose work will be mentioned later--have ascribed to the creative individual traits presented under the following headings: (1) In relation to others, (2) In job attitudes, (3) Attitudes toward self, and, (4) Other characteristics. The listing which follows is not intended to be all-inclusive. It does, however, cover those traits which, in the opinion of the present author, appear to be most significant.

(1) *In relation to others:*
- (a) Not a joiner.
- (b) Few close friends.
- (c) Independent.
- (d) Dominant.
- (e) Assertive, bold, courageous.
- (f) Little interest in interpersonal relations.
- (g) Independence from parents.
- (h) Independence of judgement, especially under pressure.
- (i) Conventional morality.

(2) *In job attitudes:*
- (a) Preference for things and ideas to people.
- (b) High regard for intellectual interests.
- (c) Less emphasis on and value in job security.
- (d) Less enjoyment in and satisfaction from detail work and routine.
- (e) High level of resourcefulness and adaptability.
- (f) Sceptical.
- (g) Honesty, integrity.
- (h) Precise, critical.
- (i) Ability to toy with elements--capacity to be puzzles.
- (j) High tolerance for ambiguity.
- (k) Persistence.
- (l) Emphasis on theoretical values.

(3) *Attitudes toward self:*
- (a) Introspective, egocentric, internally preoccupied.
- (b) Openness to new experiences.
- (c) Less in need to protect self.
- (d) Great awareness of self.
- (e) Inner maturity.
- (f) Great ego strength, strength of character.

(g) Highly responsive emotionally.
(h) Less emotionally stable.
(i) Less self-acceptance.

(4) *Other characteristics:*
(a) Spontaneity, enthusiasm.
(b) Stubbornness.
(c) Originality.
(d) Adventurousness.
(e) High excitability and irritability.
(f) Compulsivity.
(g) Impulsivity.
(h) Complexity as a person.
(i) Anxiety.

Excerpt from Harrisberger (19).

THE HIGHLY CREATIVE PERSON

Childhood Characteristics (4):

- Persistent--purposeful
- Quickly thinks of alternatives
- Sees gaps--finds hidden meanings
- Self-winding--Self-feeling
- Toys with ideas
- Accepts disorder
- Tremendous energy
- Lags in verbal ability
- Attracted to the mysterious
- Playful--spirited in disagreement
- Emotionally sensitive
- Finds fault
- Courageous--adventurous
- Takes risks

Adult Characteristics (7):

- Seeks autonomy and privacy
- Dedicated to problem-solving tasks
- Aggressive in goals sought
- Relentless worker--great zeal
- Does not value job security
- Likes to clown around--childish play
- Unimpressed by status symbols
- Rejects theological arguments
- Good sense of humor
- Intelligent (IQ: 100--140)
- Likes supervision--regimentation.
- Accepts chaos and change, anti-symmetry
- Insensitive to others' feelings
- Likes to explore ideas
- Nonconformist--enjoys nonconformity
- Independent--observant--says what he thinks
- Gullible--open to experience
- Can easily accept failure
- Needs continual reinforcement--an understanding listener

Excerpt from Rossman (48).

The replies of 176 patent attorneys to the question "What are the mental characteristics of inventors?" are given in Table 1 which gives the frequencies of the characteristics mentioned.

TABLE 1

FREQUENCY OF CHARACTERISTICS MENTIONED BY 176 PATENT ATTORNEYS

Originality	64
Analytic ability	44
Imagination	34
Lack of business ability	26
Perserverance	20
Observation	18
Suspicion	12
Optimism	12
Mechanical ability	6

There were, of course, many other characteristics mentioned but the table gives those which were most frequently given. It will be seen that the first five characteristics emphasized are originality, analysis, imagination, lack of business ability and perserverance. Next in order came observation, suspicion, optimism, and mechanical ability.

A questionnaire was also sent to the directors of the research and development departments of some of the largest corporations in this country such as DuPont, General Motors, Radio Corporation, Bell Telephone, General Electric, Goodyear Tire and Rubber Co., etc. They were asked "What are the mental characteristics of research workers and inventors?" The frequencies of the characteristics mentioned are given in the following table.

TABLE 2

FREQUENCY OF CHARACTERISTICS MENTIONED BY 78 DIRECTORS OF RESEARCH

Analysis	48
Perseverance	41
Originality	37
Imagination	35
Training and education	20
Reasoning and intelligence	20
Competence	16
Observation	12

It will be observed that analysis, perseverance, originality, and imagination head the list corresponding closely with the order of frequency given by patent attorneys. Training, education, reasoning, confidence, and observation appear next in this table.

An insight into the characteristics of the inventor was obtained from inventors themselves who were asked in a questionnaire "What are the characteristics of a successful inventor?" Table 3 gives the frequency of the characteristics mentioned by 710 inventors.

TABLE 3

FREQUENCY OF CHARACTERISTICS OF A SUCCESSFUL INVENTOR GIVEN BY 710 INVENTORS

Perseverance	503
Imagination	207
Knowledge and memory	183
Business ability	162
Originality	151
Common Sense	134
Analytic ability	113
Self-confidence	96
Keen observation	61
Mechanical ability	41

Excerpt from Chambers (3).

PERSONALITY CHARACTERISTICS OF CREATIVE SCIENTISTS

Characteristic	Investigator(s) and measuring instruments	Present study and measuring instruments
Strong Motivation	Roe (1953a)--over-all assessment Barron (1959)--over-all assessment	Supported--biographical factors
High degree of initiative	Roe (1953a)--over-all assessment Barron (1959)--over-all assessment	Supported--Ghiselli Initiative Scale
High self-sufficiency and independence	Roe (1953a)--over-all assessment Barron (1959)--over-all assessment	Supported[a]--Factor Q_2, 16PF Questionnaire

PERSONALITY CHARACTERISTICS "Continued"

Characteristic	Investigator(s) and measuring instruments	Present study and measuring instruments
	Cattell & Drevdahl (1955) Factor Q_2, 16 PF Questionnaire	
High degree of dominance	Cattell (1959)--biographical data Cattell & Drevdahl (1955) Factor E, 16 PF Questionnaire	Supported--Factor E, 16 PF Questionnaire
Many basic insecurities	Roe (1953a)--over-all assessment	Not supported--items from Maslow's Security-Insecurity Inventory
High on adventurousness	Cattell (1959)--biographical data Cattell & Drevdahl (1955) Factor H, 16 PF Questionnaire	Not supported--Factor H, 16PF Questionnaire
High introspectiveness	Cattell (1959)--biographical data Cattell & Drevdahl (1955) Factor F, 16 PF Questionnaire	

[a]Psychologists only.

COMPARISON OF PSYCHOLOGISTS AND CHEMISTS: FINDINGS ON PERSONALITY AND BIOGRAPHICAL CHARACTERISTICS

Characteristic	Investigator(s) and measuring instruments	Present study and measuring instruments
Personality		
Psychologists more dominant	Cattell and Drevdahl (1955)--Factor E, 16 PF Questinnaire	Not Supported--Factor E, 16PF Questionnaire
Psychologists more enthusiastic and cheerful	Cattell and Drevdahl (1955)--Factor F, 16 PF Questionnaire	Not Supported--Factor F, 16PF Questionnaire
Psychologists more adventurous	Cattell and Drevdahl (1955)--Factor H, 16 PF Questionnaire	Not supported--Factor H, 16PF Questionnaire
Psychologists more Bohemian, introverted, unconventional, imaginative and creative in thinking and behavior	Cattell and Drevdahl (1955)--Factor M, 16 PF Questionnaire	Supported--Factor M, 16PF Questionnaire
Biographical		
Psychologists more rebellious against parents	Roe (1953a)--biographical data	Supported --biographical data
Psychologists more often have feeling of family superiority	Roe (1953a)--biographical data	Not supported--biographical data
Psychologists more socially oriented	Roe (1953a)--biographical data	Supported--biographical data

COMPARISON OF SCIENTISTS AND (MALE) POPULATION NORMS: FINDINGS ON PERSONALITY CHARACTERISTICS

Characteristic	Investigator(s) and measuring instruments	Present study and measuring instruments
Scientists more dominant	Cattell and Drevdahl (1955)--Factor E, 16 PF Questionnaire	Not supported--Factor E, 16PF Questionnaire
Scientists more introspective	Cattell and Drevdahl (1955)--Factor F, 16 PF Questionnaire	Supported--Factor F, 16PF Questionnaire
Scientists more adventurous	Cattell and Drevdahl (1955)--Factor H, 16 PF Questionnaire	Not supported--Factor H, 16PF Questionnaire
Scientists more self-sufficient	Cattell and Drevdahl (1955)--Factor Q , 16 PF Questionnaire	Supported--Factor Q_2, 16PF Questionnaire

[a]Cattell and Stice (1957)

APPENDIX B

EXHIBIT I

LETTER TO UNIVERSITIES

EXHIBIT II

REPLY REJECTING REQUEST

EXHIBIT III

REPLY FROM UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

EXHIBIT IV

REPLY FROM OHIO STATE UNIVERSITY

APPENDIX B

EXHIBIT I

I am doing research on inventions, and inventors, as related to advanced education and progress in education. The aim is to determine some ways to increase the invention of the useful.

My research is entirely "on my own" subjectively, objectively and financially, and is to be my Doctoral Research. I hope to inject an amount of the unique in the study as my background (see resume enclosed) is somewhat different from most investigators of creativity.

An essential of this research is a list of the Engineering (all branches) B. S., M. S., and Ph.D. degree recipients from your university for the three years:

1900 only
1925 only
1950 only

The need for this is so that I may determine the patented inventions of these men and women by checking the Patent Office files.

Thank you very much for your time and I look forward greatfully for any help you might give.

Thank you again.

Yours very truly,

Conrad R. Hilpert
Graduate Student
School of Industrial
Engineering and Management
Oklahoma State University

APPENDIX B

EXHIBIT II

COLLEGE OF ENGINEERING

October 20, 1971
1058-71

Mr. Conrad R. Hilpert
Graduate Student
Industrial Engineering and Management
Oklahoma State University
Stillwater, Oklahoma 74074

Dear Mr. Hilpert:

I must reject your request for the listings which you need for your doctoral research. I am sure you realize that records dating back to 1900 and 1925 are now in "dead storage." What you may not realize is that for years such as 1950 we graduated approximately 1,000 students and the clerical work necessary to fulfill your request is simply beyond our means.

Yours very truly,

Dean

APPENDIX B

EXHIBIT III

COLLEGE OF ENGINEERING
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
URBANA, ILLINOIS 61801

OFFICE OF THE ASSOCIATE DEAN
101 ENGINEERING HALL

TELEPHONE: AREA CODE 217
333-2281

November 8, 1971

Mr. Conrad R. Hilpert, Graduate Student
Industrial Engineering and Management
Engineering North, Room 322
Oklahoma State University
Stillwater, OK 74074

Dear Mr. Hilpert:

Earlier this year you asked for a listing of graduates from this institution for the years 1900, 1925 and 1950. Enclosed are the listings of those students receiving degree for each of those years.

In the 1900 listing we have written to the left of the names receiving a bachelor of science degree in engineering the field in which they received the degree. In a few instances this information has been placed to the right hand side if space did not permit otherwise. You will also note that there is a masters in architecture and degrees granted in civil engineering, electrical engineering and mechanical engineering.

The degrees granted in 1925 are self-explanatory although you will have to separate the names of those students receiving engineering degrees from others receiving bachelors degrees in that same year. You will also note that those receiving masters degrees and professional degrees in engineering are also provided.

The degrees granted in 1950 were granted at three different times--in February, June and August of that year. Thus, you are provided with three listings. You will note that the degrees granted in each area are listed separately in this later listing.

I am hopeful that this will provide you with the information that you desired; but, if you should have any question regarding the lists or the interpretation thereof, please do not hesitate to contact this office.

Cordially,

H. L. Wakeland
Associate Dean

eb
encls.

APPENDIX B

EXHIBIT IV

THE OHIO STATE UNIVERSITY
COLLEGE OF ENGINEERING
2070 NEIL AVENUE
COLUMBUS, OHIO 43210

Office of the Dean

November 12, 1971

Mr. Conrad R. Hilpert
Industrial Engineering and Management
Engineering North, Room 322
Oklahoma State University
Stillwater, Oklahoma 74074

Dear Mr. Hilpert:

In reply to your recent letter to Dean Bolz, my secretary compiled the attached list of graduates from the years 1900, 1925 and 1950. Starting in 1925, graduation programs were conducted four times a year and lists of graduates from each of the graduation classes are included.

In 1900 only an advanced degree was given, but this degree was probably nearly comparable to the present day Bachelor of Science in Engineering. To our knowledge, no Master's or Ph.D. degrees were given in engineering that year.

This is a rather formidable task you are undertaking and we wish you success in the venture.

Very truly yours,

Marion L. Smith

Marion L. Smith
Associate Dean

MLS/ls
Enclosure
cc: Dean Harold A. Bolz

APPENDIX C

PRELIMINARY QUESTIONNAIRE

APPENDIX C

PRELIMINARY QUESTIONNAIRE

INVENTIVE ENVIRONMENT

You are THE single inventor of how many patents?____________
CO-inventor of how many patents?_______________

Circle the most correct phrase:

1. Your boss could do your job: (a) better than you, (b) as well as you, (c) is not qualified for it.

2. Your boss: (a) jokes and kids a lot, (b) forces laughs, Ha Ha, (c) is all business, (d) is sure damper for smiles.

3. (a) You would like more identification with your inventions (like the Browning Automatic Rifle named for inventor John M. Browning).
   (b) The company over does trying to make its patentees well known and you feel self-conscious.
   (c) Invention is depersonalized intentionally.

4. (a) It is very easy to put forth a new idea, people listen and act.
   (b) New ideas are fine if they do not change or cost anything.
   (c) Many times you hesitate to put forth a new idea.

5. (a) You definitely get reasonable monetary reward for invention.
   (b) Your invention has helped your job security
   (c) You are not sure anyone knows.

6. (a) Your boss is proud to have an inventor under him.
   (b) The boss might feel you "showed him up".
   (c) If somebody mentions your invention the boss might volunteer that others are as smart

7. (a) New ideas get the best help possible.
   (b) New ideas get the help available.
   (c) New ideas get what help is left.

8. Your formal education: (a) gave you the vital knowledge you needed to invent, (b) enabled you to get the job--the invention was common sense, (c) did not really help your invention.

9. The patent assignment contract: (a) irks you when you think of it, (b) could be improved, (c) does not effect your attitude at all.

10. The fellows you know are about: (a) about as inventive as they could be, (b) not inspired, (c) definitely discouraged about invention.

11. Your patents mostly are: (a) new things to fill a need you saw, (b) to secure routine protection on a routine design, (c) cover an accidental discovery made while doing something else.

12. What <u>one</u> thing would help most to raise the invention level in your company? (Please answer anywhere on this sheet.)

13. You feel you are (a) very inventive (b) about average, (c) not really inventive.

APPENDIX D

EXHIBIT I

FINAL LETTER

EXHIBIT II

FINAL QUESTIONNAIRE

APPENDIX D

EXHIBIT I

Oklahoma State University

INDUSTRIAL ENGINEERING AND MANAGEMENT

STILLWATER, OKLAHOMA 74074
ENGINEERING NORTH, ROOM 322
(405) 372-6211, EXT. 7561

Dear Sir:

Please excuse me for not addressing you personally, but I really have a reason! Should you be so kind as to give me a little assistance, I would like your help to be anonymous. Therefore, your name does not appear anywhere in this communication.

Your name has come to me because you are the inventor of a useful and economic patent under which products are made. This, I call real invention.

I am an inventor also and have taken some time off so that I could study and do research on how to better manage research so I might better inspire others to invent the useful and economic.

It would be most generous and kind of you if you would fill out the questionnaire on the reverse side and drop it in the mail in the stamped and addressed envelope enclosed.

Please view these questions as referring to the period of employment you consider your most inventive.

I really appreciate your help as this entire project is mine including the financing, which I pay myself.

Thank you very much, again.

Yours very truly,

Conrad R. Hilpert
Graduate Student

CRH:jl

Enclosure

P.S. My signature is printed to help assure anonymity.

APPENDIX D

EXHIBIT II

INVENTIVE ENVIRONMENT

You are THE single inventor of how many patents? ____________________
CO-inventor of how many patents?______________________________

Please circle degree attained: High School Bachelor Master Doctor

How many years professional experience do you have?

Please circle the most correct phrase:

1. When you are attempting to solve problems you get: (a) the best help possible; (b) adequate help; (c) what help is left, if any is left.

2. Your boss is (a) as technically competent as you; (b) generally more inventive than you; (c) a manager, not technically qualified.

3. Your formal education (a) gave you a vital knowledge you needed to invent; (b) enabled you to get the job--the invention was based on other knowledge; (c) should be extended--you need more knowledge to invent more.

4. Management (a) looks for new ideas only when in trouble; (b) energetically listens and looks into new ideas; (c) is interested only in cost reduction innovation or customer demand.

5. Your patents mostly are (a) to satisfy a need YOU SAW; (b) to satisfy a need POINTED OUT TO YOU; (c) to exploit an accidental discovery made while pursuing some other goal.

6. Your boss (a) allows too much humor in meetings and too many witty statements in reports; (b) has a sense of humor equal to yours; (c) at times irritates the "big boss" by wise cracks or clowning.

7. You believe your less inventive associates (a) might not invent because of no incentive given by management; (b) might not invent because they see no requirement to be filled; (c) might not want to chance failure, rocking the boat, and being criticized.

8. You believe (a) invention and product should be more personalized (like Browning Automatic Rifle named for inventor, John M. Browning); (b) management usually does all possible to publicly identify inventors with their inventions; (c) invention should be depersonalized.

9. What incentives did you receive as a direct result of your inventions?

10. Were you aware of a specific incentive prior to your invention?

Please answer anywhere on this side, other side or separate sheet. Just a few words would be very generous.

11. Why did you do the "extra" that resulted in invention?

12. What incentives could or should management give that would cause more people to be usefully inventive like you?

2

VITA

Conrad Roth Hilpert

Candidate for the Degree of

Doctor of Philosophy

Thesis: CAUSATIVE MANAGEMENT FACTORS RELATING TO INVENTIVENESS

Major Field: Industrial Engineering and Management

Biographical:

Personal Data: Born in Allentown, Pennsylvania, September 19, 1921, the son of Mr. and Mrs. Meier George Hilpert.

Education: Graduated from Liberty High School, Bethlehem, Pennsylvania, in June, 1939; received Bachelor of Science degree in Mechanical Engineering from Pennsylvania State University in 1942; received Master of Science degree in Mechanical Engineering from Pennsylvania State University in 1948; received the degree of Mechanical Engineer from Pennsylvania State University in 1953; enrolled in doctoral program at Oklahoma State University in August, 1970; completed requirements for the degree of Doctor of Philosophy at Oklahoma State University in July, 1972.

Professional Experience: Entered the United States Army Corps of Engineers as a Second Lieutenant in 1942 and served as an Engineer Assault Reconnaissance Officer from Omaha Beach to the Elbe River in Germany and as Machine Gun Officer and Combat Reconnaissance Officer when employed as infantry. Released from active duty in 1946 with rank of First Lieutenant Corps of Engineers; employed as a Project Engineer, The Engineer Research and Development Laboratories, Fort Belvoir, Virginia from 1948 to 1950; employed as a Project Engineer, The Industrial Power Division, International Harvester Company, Melrose Park, Illinois from 1950 to 1952; joined Twin Disc, Incorporated, Rockford, Illinois in 1952 as Research Engineer and promoted to Chief Engineer Research, which is position at present; granted a two year sabbatical leave from Twin Disc in 1970 to work towards degree of Doctor of Philosophy at Oklahoma State University; registered Professional Engineer Illinois #18072 since 1954 and Oklahoma

#8714 since 1971; granted thirty patents by United States Patent Office.

Professional Activities: Member Society of Automotive Engineers; American Society of Mechanical Engineers; The Society for Experiemental Stress Analysis; American Institute of Industrial Engineers; National Society of Professional Engineers; Illinois Society of Professional Engineers; Alpha Pi Mu; Phi Mu Alpha; Recipient of the Arch T. Colwell Merit Award given by the Society of Automotive Engineers, 1970.