The COLORADO Engineer

NOVEMBER, 1967

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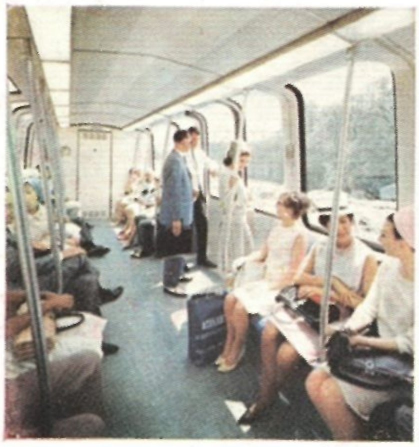

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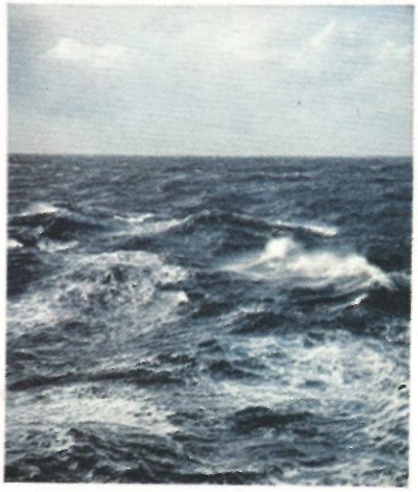

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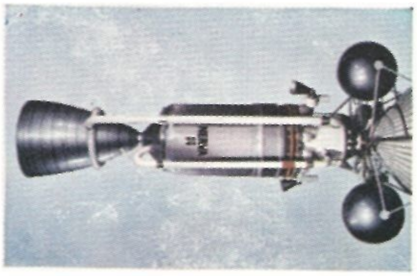

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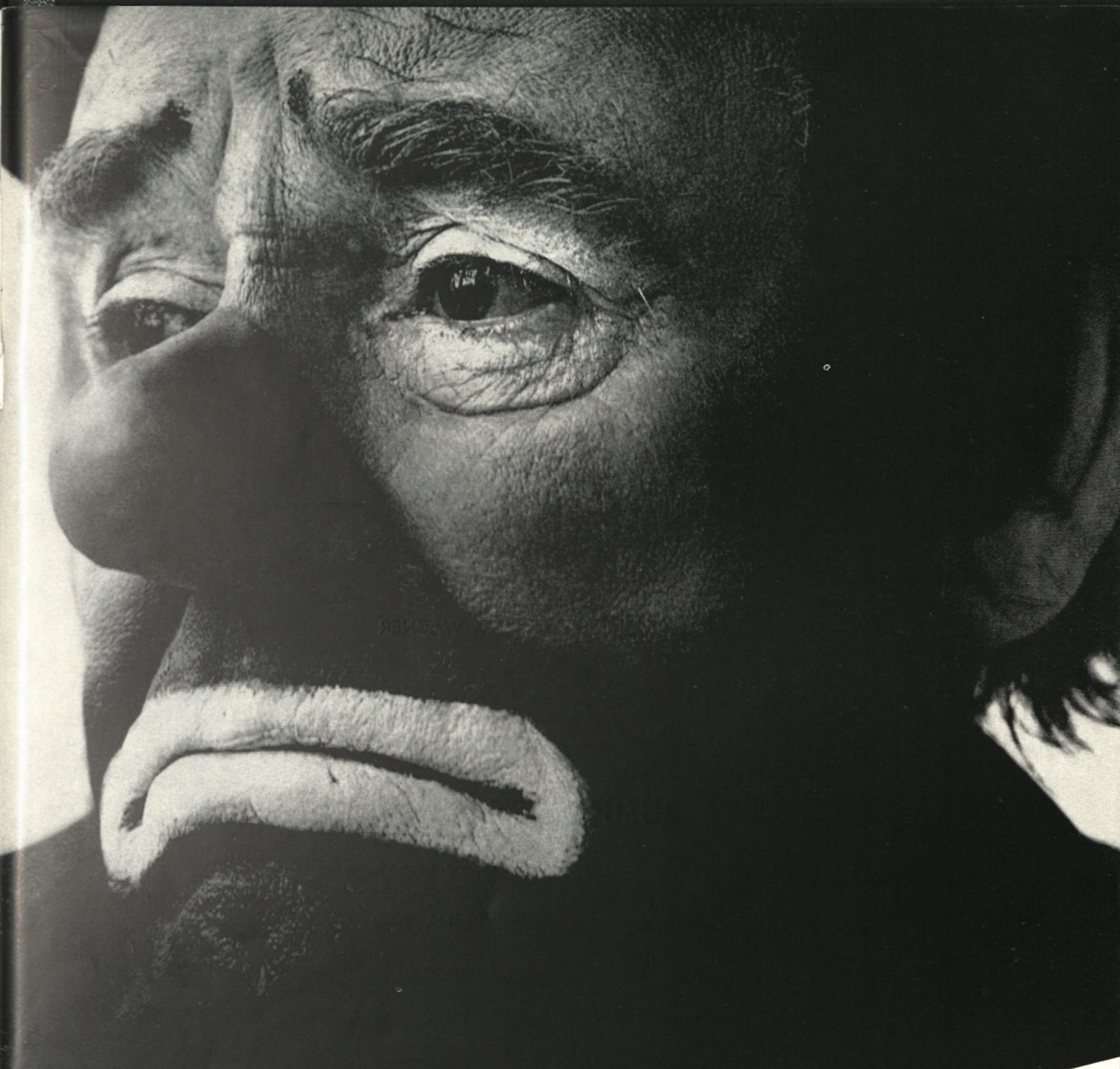

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The **COLORADO** *Engineer*

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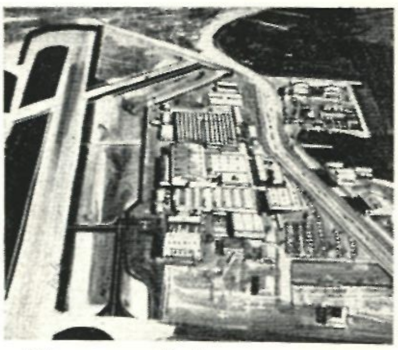
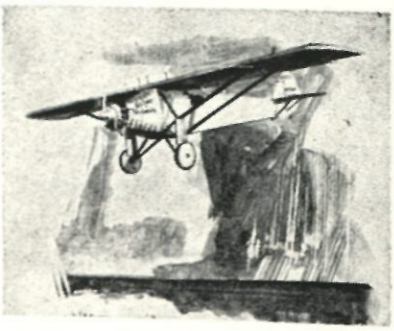
This Month's Cover: The laying of the Atlantic Cable permitted trans-oceanic communication between Britain and the United States. Our cover this month is a modern interpretation of the feat by Artist Donna Demong. In our feature article, Prof. Harold Sharlin discusses the Atlantic Cable in relationship to science and technology. See "Science, Technology and the Atlantic Cable" beginning on page 15.

Here's what we mean when we say, "Ryan is a better place to work."

We mean that a pioneer aerospace company still headed by the man who founded it 45 years ago has *got* to be a company that cares about its people. T. Claude Ryan, founder and chairman, is still at the office every day. To him, Ryan employees are friends. Old ones and new ones alike. Ryan headquarters, combining engineering and manufacturing facilities, are on the shores of San Diego bay, where it all started in 1922.



We mean that a company so rooted in aviation history is bound to be a leader in vitally important defense/space programs. The outgrowth of the original Ryan Airlines, Inc., that built the "Spirit of St. Louis" in 60 days from a standing start will always be ready to accept impossible challenges. And ready to listen to young men of vision who can dream up answers to those challenges. Ideas are given a chance at Ryan. So are the men who come up with them.



We mean that a company which led the world in the conception and development of jet-powered target drones is the kind of company where daring and untried ideas come to life. Over 3,000 Ryan Firebees, the most versatile aerial targets ever conceived, are in use with all three branches of our armed forces, helping to train our defenses against any airborne threat. A super-sophisticated, supersonic Firebee II will soon be flight tested and enter service.

We mean that a company whose heart has always been in the wild blue yonder would just naturally be there when man reached for the stars; that the products of its scientists, engineers and technicians would naturally play a key role in our race for space. Ryan landing radar systems made possible the first soft landing on the moon. And an advanced Ryan system will assure a soft landing for the first manned lunar visit. The men at Ryan already have their eyes on the space beyond the moon.

We mean that a company made up of men who taught themselves to fly straight up, while others said it couldn't be done, is the sort of place that puts no strings on a man's imagination. Or barriers in the way of way-out thinking. For over twenty years Ryan has been amassing an unmatched fund of technology in vertical and short take off and landing (V/STOL) aircraft. The list of accomplishments is long: Dragonfly, 1940. Vertijet, 1957. Vertiplane, 1959. The present day XC-142A tilt-wing and the XV-5A Vertifan. Ryan products can fly straight up. So can the men who work there.

We mean that a company with a strong and capable management—whose business success has led to majority ownership of large related companies — is the kind of concern that can match challenges with permanent opportunities. Ryan Aeronautical is majority owner of Continental Motors Corporation and its subsidiaries, suppliers of primary power for both piston and jet aircraft and agricultural, military, marine and industrial equipment. There is nothing provincial about Ryan. Including subsidiaries, it operates 16 manufacturing facilities in the USA and Canada.

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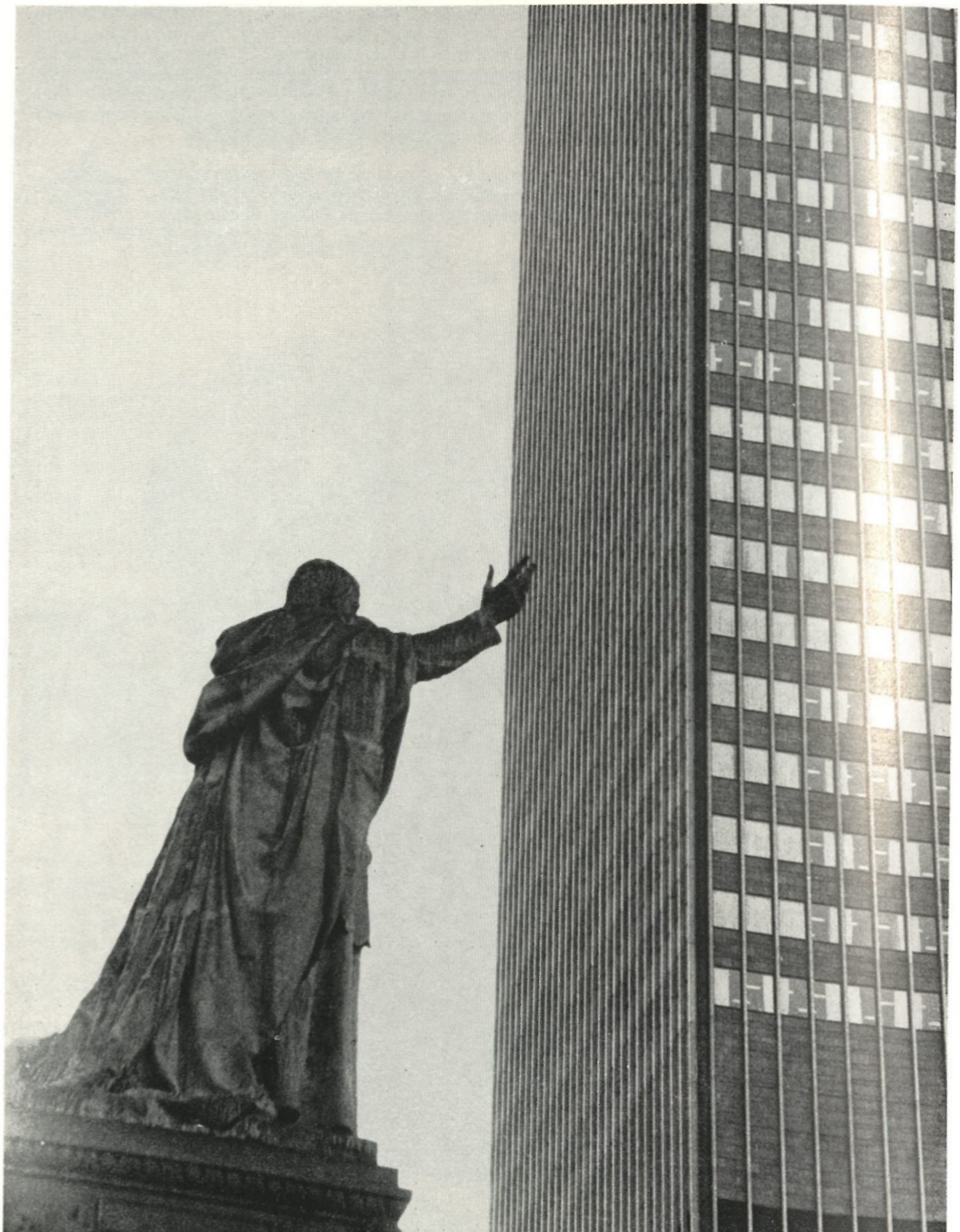


EDITORIAL:

CHANGE

The new must merge with the old. Somehow, everything must fit into the pattern — harmony must be achieved. Change is inevitable, sometimes hard to accept, but continuously occuring. It may be good — or it may not be — but it is always here, now.

Engineering is intensely involved in change. What is good today must be made better for tomorrow. What is bad must be at least modified. In the study of engineering, one learns that nothing is perfect — there is always a way to improve. And the job of the engineer is just that — to improve the old. There exists no ultimate, only an approximation. And tomorrow, someone will come closer to the ultimate. But it will never be achieved. If it were, engineering would become obsolete. Man would become obsolete.

As engineers, we must never be satisfied. We must continue to learn, and to improve upon what we have learned. Or we will be finished as engineers — and as men.

—Kathy O'Donoghue

Photograph at left by Mark Phillips.

DEAN'S COLUMN:

OUTLOOK FOR THE COMING YEAR

DEAN MAX S. PETERS

It is a pleasure to welcome all of our new freshmen and new transfer students, as well as our returning engineering students, to our campus for the 1967-68 school year. According to the official records released by the University, our undergraduate enrollment in Engineering is now 1,773 students, which is an increase of 11% over last year; the total number of entering freshmen increased by 24% over last year to 466 students.

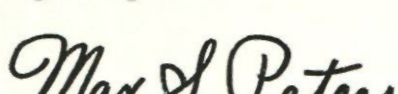
We have added a number of highly qualified new members to our engineering faculty. Featured elsewhere in this issue is a report on the new and visiting faculty in our College.

Mr. Richard Harpel has joined our staff as a full-time counselor, and we feel he will be a great help in improving our counseling arrangements with our students. The Dean's office will be open every Saturday morning and Mr. Harpel will be available to students who wish to receive counseling advice at that time. His office will also continue to be open regularly throughout the rest of the school week.

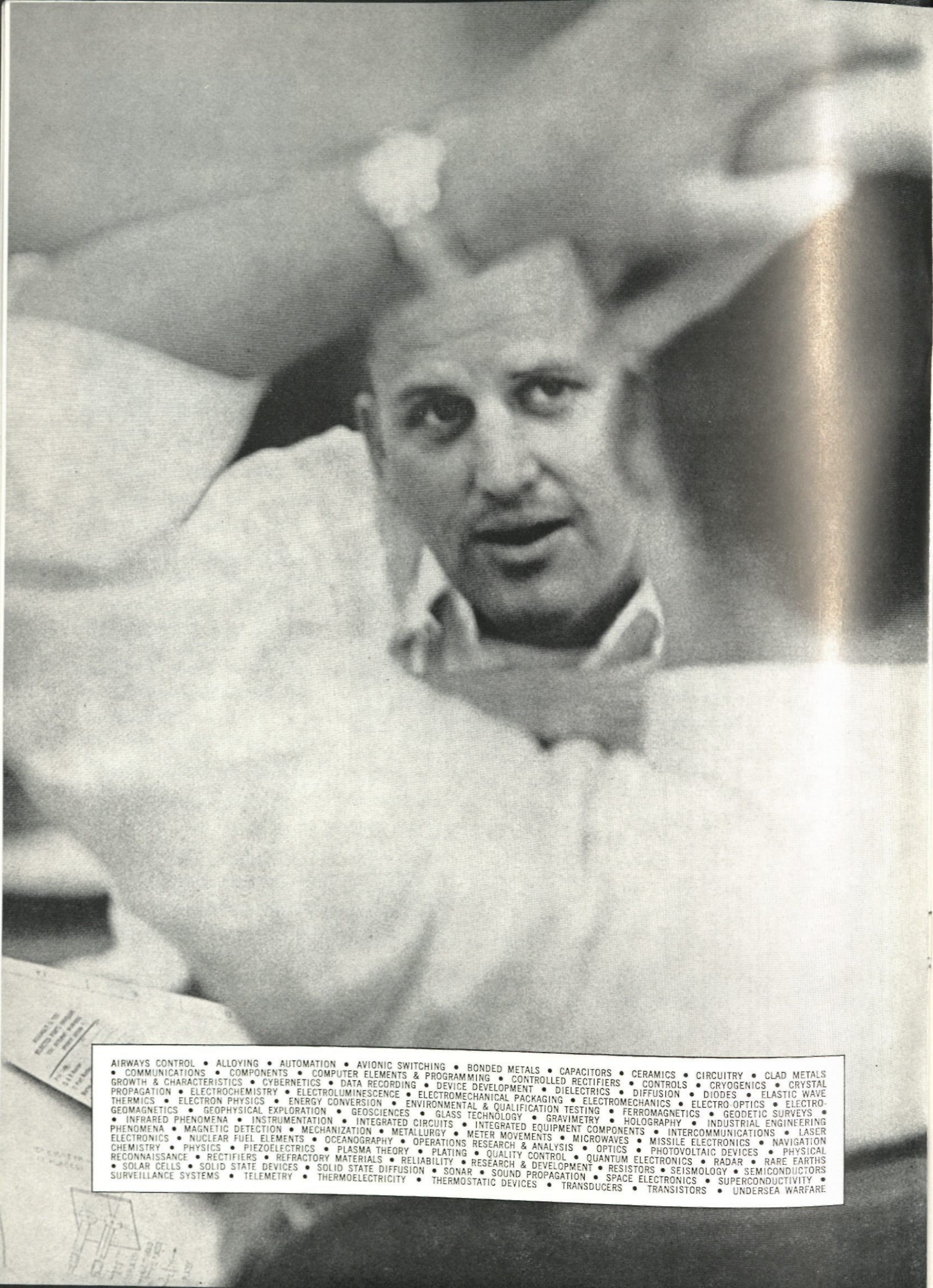
I am particularly pleased to see the increase in the number of women enrolled in Engineering this year, and I hope that this trend will continue. Our Associated Engineering Students group is continuing its important activities under the leadership of Don Caldwell. This is your organization, and I hope all of our undergraduates will take part in the AES activities throughout the coming year.

Our College is now well settled in the new Engineering Center. The pains of moving are essentially over, and we are able to concentrate on the appropriate development of our academic programs. It appears that the new arrangements with freshman mathematics and physics are working out satisfactorily, although we will be watching the developments in this program very carefully. As we strive to improve the over-all effectiveness of the engineering program, we are going to need input from our students as to what areas of the program might be improved. We hope, therefore, that all of our students will feel free to pass on any ideas they may have.

I am delighted with the attitude and spirit I find among our engineering students and faculty. Let's all continue to work together to make this another noteworthy year in the forward progress of our College of Engineering.



Dean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TEXAS INSTRUMENTS
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SCIENCE, TECHNOLOGY AND THE ATLANTIC CABLE

PROF. HAROLD SHARLIN

On April 13, 1967 Professor Harold Sharlin, professor of History at Iowa State University, spoke at the University of Colorado under the sponsorship of the Department of Engineering Design and Economic Evaluation. His speech, part of his forthcoming book, Dynamical Victorian: Sir William Thomson, F. R. S., is presented below.

The differences between a scientist, an engineer and an inventor, such as we know them now, are quite evident in a case study of the history of the laying of the Atlantic Cable. The differences between the men, their personalties, their responsibilities and their contributions will be evident in a discussion of the jobs involved.

I'd like to start with a description which appeared in the London *Times* of an event which took place in June, 1858. Her Majesty's ship, the *Agamemnon,* was supposed to rendezvous in the middle of the Atlantic with the *U.S.S. Niagara* for the beginning of the laying of the Atlantic Cable. And the *Times* correspondent reported the drama.

> At 10 o'clock the *Agamemnon* was rolling and labouring fearfully, with the sky getting darker and both wind and sea increasing every minute. At about half past ten o'clock three or four gigantic waves were seen approaching the ship, coming slowly on through the mist nearer and nearer, rolling on like hills of green water with a crown of foam that seemed to double their height. The *Agamemnon* rose heavily to the first, and then went down quickly into the deep trough of the sea, falling over as she did so, so as to almost capsize completely on the port side. There was a fearful crashing as she lay over this way, for everything broke adrift, whether secured or not, and the uproar and confusion were terrific for a minute; then back she came again on the starboard beam in the same manner, only quicker, and still deeper than before. Again there was the same noise and crashing, and the officers in the ward-room, who knew the danger of the ship, struggled to their feet and opened the door leading to the main deck. Here, for an instant, the scene almost defies description. Amid loud shouts and efforts to save themselves, a confused mass of sailors, boys, and marines, with deck buckets, ropes, ladders, and everything that could get loose, and which had fallen back again to the port side, were being hurled again in a mass across the ship to starboard.

Then the climax:

> Dimly, and only for an instant, could this be seen, with groups of men clinging to the beams with all of their might, with a mass of water, which had forced its way through ports and decks surging about; and then, with a tremendous crash, as the ship fell still deeper over, the coals stowed on the main deck broke loose, and smashing everything before them, went over among the rest, to leeward.

The only reason why I describe this, is I am trying to imagine what was going on in the mind of a young professor of Natural Philosophy at the University of Glasgow. He was aboard that ship on the cable laying

(Continued on page 18)

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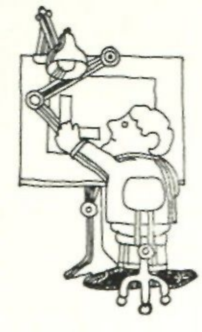

. . . how much technology depends upon science and how much science on technology . . .

(Continued from page 15)

expedition. And I imagine that he, on more than one occasion, as the ship pitched from side to side, when everyone thought that they were lost, wondered what he was doing there. Part of my question is just that. I am not so much worried about the storm, as I am interested in why one of the foremost scientists of the nineteenth century, William Thomson, who was later to become Lord Kelvin, was aboard this ship.

Turning Point in Thomson's Life

You might say that he was there by a chain of events which began in 1851 when he first became interested in electrical questions and electrical questions which dealt with submarine telegraph cables. I think though that it is significant that Thomson was, and believed himself always to be, a theoretician, a mathematical scientist, and yet should be aboard this ship involved in the very practical and dangerous business of the laying of the Atlantic Cable.

Now I am interested in the relationship between science and technology. I am interested in the inventor, the engineer, and the scientist. To many, this seems to be an obvious relation. We all know that this relationship exists between science and technology, but do we know what the relationship is? Do we know whether it is an interrelationship? Do we know how much technology depends upon science and how much science on technology? We are mistaken, I think, when we have a belief that this relationship is automatic. In the age of miracles, we think that once a scientific discovery has been made, this must and almost immediately will lead to some kind of technological improvement. Yet I think that the distinction is important. It is not important in order to separate men. I think it is important because it enhances our understanding of what these two types of enterprises are, science and technology.

For the time being, I would say and I am saying for the time being, this is my definition before we go into the more detailed discussion of the Atlantic Cable: the technologist or inventor is an imaginative modifer of a device or of devices. For the scientist, a device, a technological device, is a specific example, a creation of what he believes is a general scientific theory. Many scientists learn the hard way that you cannot convert easily; it is not a matter of going downhill.

Technology Involves Decisions

What is involved in technology is something which scientists are not trained for and are not accustomed to — decisions. A scientist will deal with theories; he will debate the validity of one theory verses another. The debate can be hot; it can be long. He can be very involved, but there is not a decision which must be made on this basis of the theory unless it becomes applied to technology. When it comes to something like the laying of the Atlantic Cable, you *must* decide the type of cable, the type of brake, the type of instruments which are going to be used. And it can't be possibilities, you *must* choose one device or the other.

And I think another thing which the scientist does not have to face, which is the technologist's must, is time. For a technologist and for an engineer, it is truly correct that time is money and if you can't finish the project within a reasonable time, the investment is lost, the whole reason for the project is lost. Whereas the scientist can wait a decade, a generation, for a theory to be demonstrated.

William Thomson's interest in electricity, and in particular in the Atlantic Cable, began with his interest in the study of heat. At the age of sixteen he was introduced to Fourier's analysis of the flow of heat. He became fascinated; he became enamored —it became for him a study that held interest for the rest of his life: Fourier's analysis in its mathematics and in its implications.

By 1850, Thomson was broadening his study, his interest in heat, and he was talking about a homogeneous infinite solid which has been suddenly heated. Now obviously, this is a theoretical question since there is no such thing as a homogeneous or an infinite solid that can be suddenly heated throughout. He then began to apply this to problems of electricity and you can see that what he was dealing with was the analogy of flow of electricity and flow of heat. In 1850, he wrote a paper which was not published then, but was in his notebooks and was published later. The title of the paper is forbidding, that is, it is forbiddingly long. I think it sounds like a Ph.D. thesis, but it is very descriptive. I think that after you have read the title you virtually don't have to read the paper. The title was: *"Compendium of the Fourier Mathematics for the Conduction of Heat in Solids and the Mathematically Allied Physical Subjects of the Diffusion of Fluids and Transmission of Electric Signals Through Submarine Cables."*

Beginning of Britain's Submarine Cable

The interest in submarine cables, I think, is normal because this is the beginning of Britain's attempts of laying submarine cables across the channel to France and across the other channel to Ireland. But now, he (Thomson) is beginning to broaden his question from a scientific point of view; he is not interested in the laying of the cables themselves, but he is associating Fourier with these electrical questions.

In 1855, he gave a paper to the Royal Society which was a lot more specific and brief. It was simply called: *"On the Theory of the Electric Telegraph."* He was by then interested in a more specific problem than Fourier's solids and electricity.

He became interested in this problem of telegraphy through his friend and correspondent, G. G. Stokes, at Cambridge, who had written him a letter in October 1854. Now I said at the beginning that Thomson had seemed to be on the *Agamemnon* by chance and I am trying to show you where there is chance involved, but at the same time there is every good reason for this development. One of the chances, you might say, is this letter from Stokes. Stokes said that he had been working on a problem of the delay time in telegraph lines. This was a current debate in Britain—Faraday was involved in it—because they had begun to talk about the possibility of an Atlantic telegraph. And Stokes asked Thomson if his (Stokes') explanation was correct, knowing that Thomson was familiar and interested in these types of questions. Thomson's answer was in the form of a sixteen-page letter which grew into another long letter and eventually, at Stokes' insistence, was published under the title, *"On The Theory of the Electric Telegraph."*

Adaption of Hypothetical Questions to Practical Considerations

He had arrived at an equation for the electrical excitation in a submarine telegraph wire, perfectly insulated by gutta percha (which is an insulation medium). Again, this is a hypothetical problem because he is talking about perfect insulation, and the equation which he arrived at was unsolved. But he noted, and this is not surprising, that this equation agreed with Fourier's equation of the linear motion of heat in a solid conductor. Thomson, as I said, was always going back to Fourier and he found this an extremely fruitful starting point. So the solution to this unsolvable equation was found in Fourier and, as Thomson noted, it was adaptable to practical questions regarding the use of telegraph wire because, as Thomson saw it, this question of the sudden application of heat to a solid, and the dispersion of this heat through the solid, was analogous to the spurt of electricity which goes into a wire when you close the contact by telegraph key.

The questions Thomson was talking about were the retardation of telegraph signals as they went through a long wire. And according to his solution, this retardation was equal to the distance squared. What that meant in practical terms was that the Atlantic Cable would have been four times as long as the longest submarine telegraph wire in operation at that time. Therefore, it would have taken sixteen times as long for signals to travel through the Atlantic Cable as through any other cable.

To Thomson, this presents a serious problem, because speed obviously is essential in telegraph transmission; it is money. The more messages transmitted in twenty-four hours, the more income for the telegraph. But Thomson said at the end of this article that he was sure that the Atlantic telegraph would succeed, as all one had to do was take into account the problem of retardation and do something about it.

Stokes Agreed with Thomson

Stokes agreed with Thomson's work and had, in fact, solved the problem from another approach, besides Fourier, and come to the same mathematical solution. Stokes congratulated Thomson for clarifying the mode of transfer by comparing light, heat, and electrical transmission.

We have then, the picture of the scientist, step by step, becoming involved in questions of submarine telegraphs. Because it is an interesting hypothetical question, it is associated with his own study and the question of submarine telegraph is very much in the public mind.

There is another man who was interested in the submarine telegraph, E. O. Wildman Whitehouse. Whitehouse was a physician who was self-taught in telegraphy. Wildman was a man who did not know about some of the more obtuse problems in electrical telegraphy. He had not read all of the papers but he did know about telegraphy.

The Advantages of Ignorance

You could compare him with a whole host of successful inventors who were self-taught. In this case, ignorance was an advantage. He didn't know it couldn't be done, and he was not bound by the old ways and by the old traditions—he did not follow the same ruts, the same paths. His enthusiasm was one of the reasons for the founding of the Atlantic Telegraph Company by Cyrus Field, who had consulted with Morse in the United States and Whitehouse in England. Both of them were enthusiastic. Whitehouse was certain, not only that the Atlantic Telegraph Cable could be laid, but also it could be laid then with the technology in its existing state slightly modified, and could be a success. Morse had said the same thing.

Field did not consult Thomson nor did he consult any of the scientific community. Why? Was this a short-sightedness or stubbornness on Field's part? Why didn't he get all of the information that was available? Why did he not consult with the scientists? Thomson was well-known and certainly must have been

(Continued on page 22)

. . . he was not bound

by the old ways and

by the old traditions . . .

(Continued from page 19)

known to Field. I think there are several reasons.

First of all, Field might have believed (and maybe he was right) that he would have been unable to understand anything that a scientist could have told him. It was practical men, self-taught men, like Morse and Whitehouse, who talked Field's language. Besides, these were practical men who had been successful, and why talk to a theoretician who had never really had any practical success? Field's decision not to consult with scientists was based on the idea that there are no new principles involved in the Atlantic Telegraph; it was nothing more than an extension of all other submarine telegraphs. One needed only to make slight adjustments in order to make the Atlantic Telegraph work. Thomson had insisted that it was a different case; that the distance-squared phenomena made it a different case. But Field, Whitehouse and Morse and many of the other practical men in the community, did not think there were new principles involved.

Field Wanted a Profitable Enterprise

Remember also that Field was interested in an enterprise which would be profitable; therefore, it needed to be successful, of course, but at the lowest possible cost. I would call this phenomena "the shaving of costs by blundering through." That is, do not worry about the ideal situation, but use what you know and go ahead on the assumption that you will make mistakes, but the mistakes will not be fatal, not stop you. You will have to make certain adjustments, but in the end, by blundering through, the end product will be cheaper than if you had taken the ideal, as Thomson wanted. And after all, the ideal is usually the most costly—not in the long run but in the short run. Since Field wanted to shave costs, it was probably wise of him not to consult with the theoreticians. I might add now that Thomson was consulted, but only after there had been several attempts to lay the Atlantic Cable which had failed.

Disagreement on Retardation Effect

Thomson and Whitehouse exchanged a series of letters in the *Athenaeum,* a British journal of opinion (these letters were published in 1856). The disagreement was over Thomson's theory that the retardation was equal to the square of the distance. Whitehouse insisted that he had conducted experiments and had found no such retardation. Thomson said that he did not disagree with the conduction of the experiment or the results, but he did disagree with the interpretation. He said that the problem was that retardation, due to distance, is not detectable or discernable until a very long distance, like 2,000 miles, is involved. Thomson said you may not be able to discover it in ten or one-hundred miles but he was certain of the theory and he said so unequivocally in the letter to the *Athenaeum.* But then he added that like every theory, this theory of retardation was merely a combination of established truths. Now I am not sure why he was so cautious or why he qualified his remark. One might say obviously every theory is a combination of established truths, but it seemed a qualification or a reservation which was unnecessary.

Thomson still felt and believed that he was practically concerned about the Atlantic Cable. He said at the end of this letter to the *Athenaeum:* "Capitalists ought to require a very matter-of-fact proof of the attainability of a sufficient rapidity on the communication of actual messages, by whatever cable may be proposed, before sinking so large an amount of property in the Atlantic." That always gave people something to think about because the Atlantic was not only 2,000 miles wide, it was two miles deep at some spots.

Cyrus Field, an American entrepreneur, a businessman, was so successful that he retired at the age of 30 and when the idea of cable was conceived in 1853, Field was 35. In 1856, Field came to Britain and formed a company, the Atlantic Telegraph Company, with three men: John Brett, Charles Bright and E. O. Wildman Whitehouse. Both Brett and Bright had experience in submarine cables—Brett, in a cable to France, and Bright, in a cable to Ireland. Whitehouse had the electrical knowledge that was necessary for the operation of this cable. Field obtained subsidies from both the American government and the British government which were dependant upon the successful laying of the Cable. Both countries also agreed to do surveys of the ocean bottom. A very careful survey of the Atlantic was done several times and the telegraph shelf was found which was ideal for the laying of the Cable. It was a sandy even bottom, not too deep.

The First Attempt to Lay the Cable

In 1857 the first ships went to sea to attempt to lay the Atlantic Cable. Field formed this company in the Fall of '56, the cable ships went to sea in June of '57, because as he saw it, this was an enterprise which required a quick return, and a good return. It was a very risky business. The people who put their money into it were doing it for a fast big return so Field rushed into the enterprise. He had chosen a small copper conductor because both Whitehouse and Morse had approved. Neither Bright, who was the engineer-in-charge of the ex-

. . . there were no new principles involved in the Atlantic Telegraph . . .

pedition, nor Thomson, who had written on the size of the cable, had been consulted. As a matter of fact, Bright wrote a letter to the executives of the Atlantic Telegraph Company urging a one-year delay because he said there were problems involved; nautical, mechanical, and electrical problems which were so unusual that it would require a year's experience before the expedition should be attempted. But he was overruled and the expedition sailed.

... the question of decisions on untried projects ...

This brings us to the question of decisions on untried projects. How do they come about? How are the decisions made? Of course, in any project the question is cost vs. revenue. The Atlantic Cable was a large investment; the revenue was also expected to be large. The question of failure has to come into this, but as far as the entrepreneurs were concerned, the idea of failure was ruled out. They were going to succeed. What they did consider was the idea of misstep, that is, not succeeding the first time. Of course, they all knew that eventually the Atlantic Cable would be successful. But the question of a misstep meant the increase in cost. If a telegraph fails on land, one can mend it if there is a flaw. If you loose a thousand miles of cable in 2,000 fathoms of water, you have to start over again.

The Engineering Question of Balance

So the issue, and this is an engineering decision, comes between balancing, for the Atlantic Cable, nautical considerations, mechanical considerations, and electrical considerations. And you *have* to balance them. The nautical considerations are concerned with the conditions of the sea; you can only go on these expeditions certain times of the year. (Incidentally, the *Agamemnon* was in one of the worst storms ever described in the Atlantic and it was at sea at the time when there was least probability of the storm.) And, in addition to the condition of the sea, as a nautical problem, there is maneuverability of the ship. This was a cable laying expedition and it was a floating one; the platform is the ship and the captain's cooperation with the engineer was essential.

Add to this the mechanical problems. The paying out of the cable from the ship had been the most difficult task in previous submarine cable projects. In the Atlantic Cable there was to be over two miles of cable hanging between the stern of the ship and the bottom. To manage this weight, the braking mechanism would have to be improved over anything used up until that time. The brakes would have to be rugged to withstand the tension and at the same time easily adjusted to compensate for the change in pull due to the pitching of the ship. If the brake payed out too fast, miles of the cable would be wasted in coils on the bottom. Should the brake be too tight, the cable would snap under the tension. The parting of the cable in 2,000 fathoms of water was to be the constant nightmare of those connected with the Atlantic Cable. There were also the electrical considerations of conduction in the cable and the speed of transmission of the signals.

Debate Flourished on How to Do It

In 1857, there was a dispute between the mechanical and the electrical conditions. Bright wanted to begin the expedition in mid-ocean, the two ships splicing the cable and starting in opposite directions. This would take half the time and it would also assure rendezvous and avoid some of the nautical problems. Whitehouse wanted the cable begun in Ireland and laid out by one ship. After this ship had laid all of its cable, the splice would be made in mid-Atlantic, and the other ship would continue. This would not only take twice as long, but also the splice would have to be made after the cable had been laid. Bright was very much annoyed that the directors of the company accepted Whitehouse's decision and he wrote a rather bitter letter in which he complained about the electrical problems. Whitehouse wanted the cable begun in Ireland because he wanted the electrical communication with the base to be continuous. If they began in mid-ocean, nobody on shore would know anything about the electrical communication. Bright wrote to the directors that the electrical problem "must have existed from the first, and it is peculiarly embarrassing to me that the discussion of its importance—as compared with the other conditions necessary to success—should have been deferred until a fortnight previous to our departure, when we are under so great a pressure for time, if the undertaking is to be carried out this year."

The 1857 attempt was a failure: the brake was the problem. The ship lurched; the cable parted and disappeared into the Atlantic. The whole venture of '57 was a failure.

Immediately after the Cable laying, Whitehouse, Morse and William Thomson wrote a letter in which they endorsed the Cable as being feasible electrically. The problems seemed to be in the brake and a whole corps of engineers devoted the next six months to designing an improved brake. Thomson also said that the problem was in the telegraph receiver; because of retardation, a very sensitive receiver was necessary. He made an application to the Company to improve their receiver but he was overruled.

Thomson's Mirror Galvanometer

In 1858, Thomson patented a mirror galvanometer which was an un-

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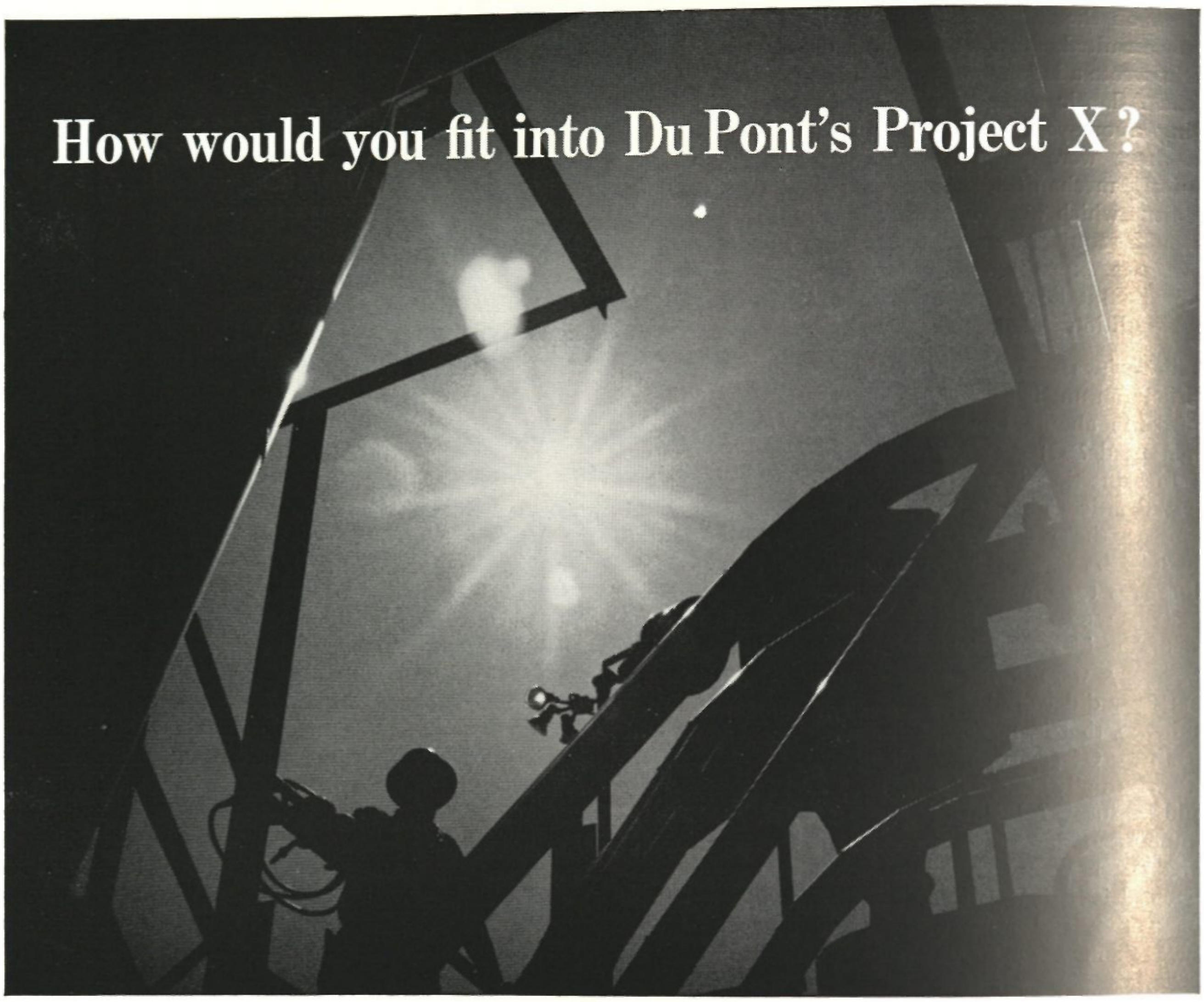

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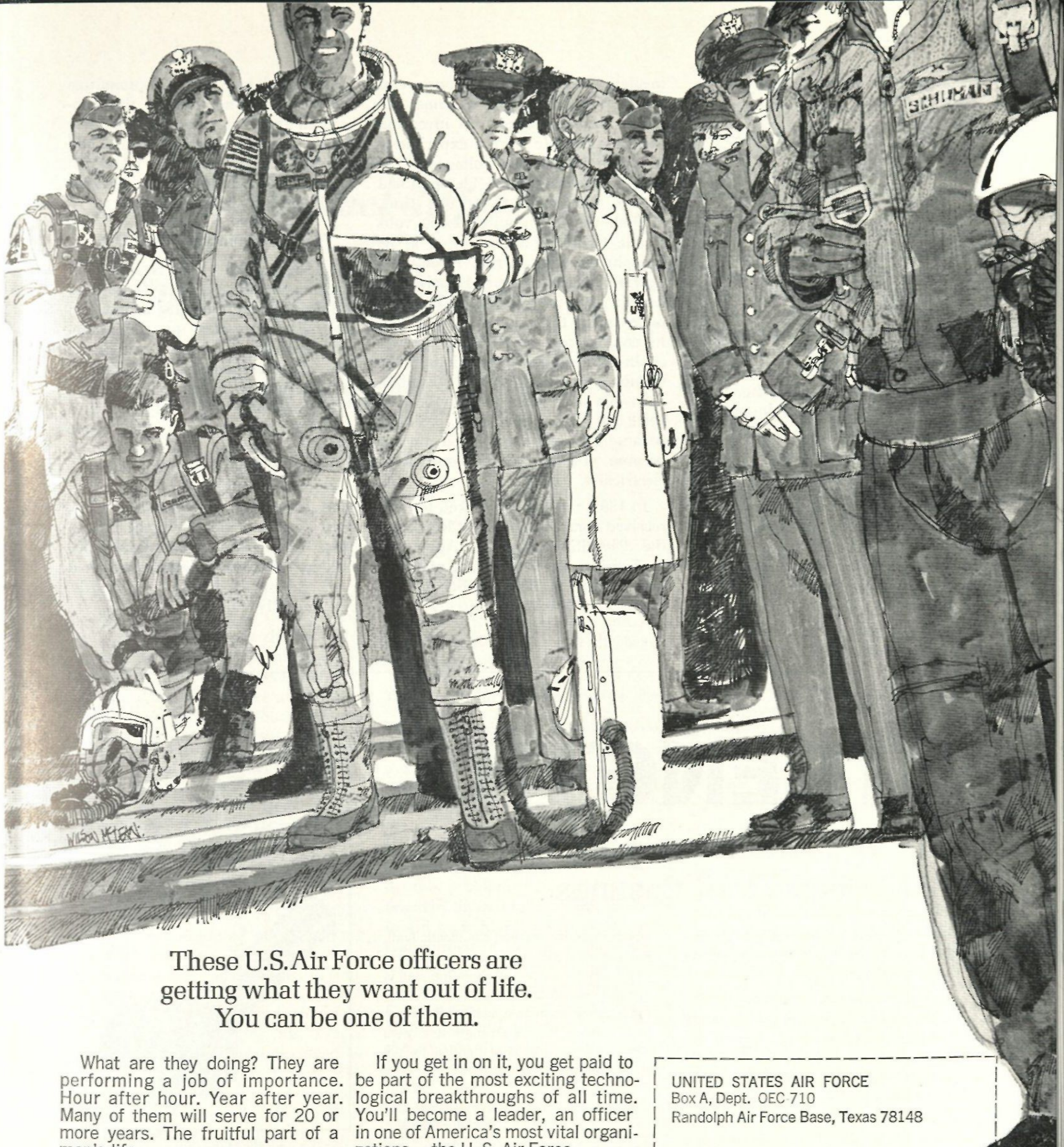

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usaully sensitive telegraph receiver. He wanted this to be used in the Atlantic Cable. He applied to the Company directors for 2,000 pounds sterling to underwrite the manufacture and the research on the galvanometer. He received a letter back saying: "The directors, having regard to the reports and observations of Mr. Whitehouse, and particularly to the financial state of the Co., are of the opinion that it would not be expedient to advance so large a sume under present circumstances." The Directors did promise Thomson 500 pounds later for the development of the device.

The Second Attempt Succeeds—of Sorts

In 1858, the second attempt to lay the Atlantic Cable was a mechanical success; that is, they succeeded in getting the wire from one end to the other. But they were beset at the beginning with electrical problems—the insulation seemed to be bad in several spots. Whitehouse now became desparate; his instrument, his invention was at stake. He started experimenting with raising the voltage in the Cable, something which Thomson had warned him against. At one time, Whitehouse had applied 2,000 volts to the Cable in order to get, as he thought, enough current through to operate his instrument. He also underran, that is, raised the Cable, in order to try to find the flaws so that he could repair it. This last act was against the explicit instructions of the Company and he was fired. That fall, the cable went dead, possibly because the 2,000 volts applied to it, probably because it would have failed anyway because it was poorly constructed electrically.

In 1863, the company asked for and received something called "Report of the Scientific Committee Appointed to Consider the Best Form of Cable for Submersion Between Europe and America." One of the group of scientific advisors on this committee was William Thomson. So the company in 1863, after first a mechanical failure, then an electrical failure, had decided that perhaps new principles were involved and perhaps scientists would have to be consulted.

Thomson Finally Wins Out

The rest of the story is almost an anticlimax. The Company agreed to the changes made by this committee; they agreed to every one of Thomson's suggestions as to the size of the wire, the conductivity of the copper, and the use of his mirror galvanometer. In 1865, the *Great Eastern*, a ship large enough to carry the whole Cable, set out and lost the Cable. It broke after 1200 miles. But now they were sure of success. In 1866, on another expedition, they laid one cable, went back and picked up the broken piece of the other cable in 2,000 fathoms of water, spliced it and had two cables operating, efficiently, economically, and profitably.

. . . a distinct difference between an engineer and a scientist . . .

Cable Succeeds With Trial and Error Approach

Everyone here was involved in the success of the Atlantic Cable. I am not suggesting that had the company listened to William Thomson at the beginning, they would have been successful. What I think we are talking about is a distinct difference between an engineer and a scientist (or whatever you want to call him) in an undertaking such as this. At the beginning, we see the company's attitude was to blunder through and save cost. (They consulted Morse and Whitehouse.) Thomson's attitude was cool towards being involved in the enterprise. He, like many other scientists, did not want to be involved in what he considered money-making practical schemes. There is a long tradition of this in the scientific community; Faraday was one who was very proud of not being involved in practical affairs. Besides this, Thomson found when he was involved in the testing of the cable that it was, as he described it, dull and heartless business. He was really interested in many different activities, and telegraphy was only one of them. He was interested in hydrodynamics and as a matter of fact, at the time of the laying of the Atlantic Cable, he and Stokes were exchanging letters. And as he said to Stokes, "I have changed my mind greatly since my freshman year [at Cambridge] when I thought it is much more satisfactory to have to do with electricity then with hydrodynamics, which only first seemed at all attractive when I learned how you had fulfilled such solutions as Fourier's by your boxes of water. Now I think hydrodynamics is to be the root of all physical science, and is at present second to none in the beauty of its mathematics."

Thomson's Broad Knowledge Base

He was also involved in electrodynamic qualities of metals. In fact, he was involved in many separate enterprises. His contribution to electrical technology had to do with his varied interests. The fact that he was interested in Fourier, in hydrodynamics and in solids means that he would see this problem in not only a much broader light, but also his solutions would be synthesis taken from a wide and unrelated, at the time, body of knowledge. For a technologist, the body of knowledge is past experience. For a scientist, it is a varied body of knowledge and there is no limit to the source of analogy. So the scientist, if you will, is a synthesizer; he brings bodies of knowledge together and dealing by analogy, he can say something about technology as an application or as a specific instance, but he is not concerned with decisions. He does not want to be involved in decisions of a financial nature, as to time and as to balancing of one against the other. Thomson was not interested in the Company's problems with cost; he knew his mirror galvanometer would succeed and, in spite of the Company' problems at the time, he advocated very strongly the mirror galvanometer. We must remember also that the scientist sees the technologist as a man best able to handle these practical problems.

Thomson was a friend of Whitehouse up until the end when Whitehouse was fired. He had proposed Whitehouse for the Royal Society; he thought that Whitehouse could succeed, he knew that his theory could succeed. He said when he was describing his interviews with Whitehouse at the very start that "I had assented too readily to his own over sanguine expectations of what his instruments could do. I put some fundamental questions to him which he answered so undoubtingly, that I thought he might possibly work with advantage by his instruments." And then Thomson said why he did not become involved: ". . . because I was much better pleased to let the practical telegraphic work be carried out by others." This then is what separates the scientist from the engineer. When the scientist wants to become involved in the practical questions he must give up this aloofness, this kind of isolation which, in many times, in many cases, is comfortable. You cannot become involved in mistakes when you are not involved in practical considerations.

The Differences in Approach Between Scientists and Engineers

So we contrast Thomson, the scientist-synthesizer, with Whitehouse, the inventor, the modifier who might have succeeded, and Bright, who was the engineer, the organizer of the whole expedition in trying to balance nautical, mechanical and electrical problems in order to make it all feasible.

I can only say now that my interest in Thomson extends beyond and prior to the Atlantic Cable. And I find that he became more interesting in engineering. He very wisely became associated with an engineer in an engineering consulting firm and this firm was the consultant on most of the submarine cables that were laid. So what I have tried to do by this case study is distinguish between what a scientist does, or what a man like William Thomson would do in an enterprise like this, to what a man like Whitehouse or a man like Bright would do.

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LASERS AND CHEMICAL LASERS

JOEL M. SNIDER

In 1960 a light-producing device called a laser was first demonstrated. There are four types of lasers (ruby and other solids, gaseous, injection,[1] and chemical[2]), each of which has wide potential application in science, medicine, industry, and national defense. The word laser is an acronym, which is a word made up of the first letters of other words. Laser was coined from another acronym: maser, which stands for Microwave Amplification by Stimulated Emmission of Radiation. Laser stands for Light Amplification by Stimulated Emission of Radiation.[3]

Lasers and masers are solid state devices which amplify light. The difference between the first ruby lasers and masers is that the early ruby lasers operated in the visible light part of the electromagnetic spectrum rather than the microwave region. Another difference between a maser and a laser is that the ruby of the maser must be supercooled to just a few degrees above absolute zero and a microwave oscillator must be used to supply the pumping signal needed for operation, whereas the first lasers were operated at room temperature with the pumping signal being supplied by a photoflash-like tube high-intensity light source.

Most light sources such as incandescent lights simultaneously generate energy over a large part of the electromagnetic spectrum. The laser generates single-frequency coherent light. A light source becomes more coherent as the portion of the electromagnetic spectrum over which it generates energy decreases. Since the light generated by the laser is very coherent, perfectly parallel, needle-sharp beams can be generated. The beams are less than one-hundredth of a degree wide and do not spread or scatter as does ordinary light.[4]

The Ruby Laser

The light which the laser beam generates is concentrated several million times more than a flash light.[5] This light is generated by the laser much like a radio frequently-carrier. The laser beam of a ruby laser is generated through a synthetic ruby contained in the laser apparatus which is smaller than a water tumbler.

The ruby, when the laser is in operation, has been irradiated by a powerful flash-tube lamp. This irradiation causes the ruby to absorb energy over a broad band of frequencies. This light energy excites the atoms of the ruby crystal to a higher energy state from which the energy is reradiated in a very narrow band of frequencies. To emit the desired radiation, the excited atoms are coupled to an optical sesonator. The sesonator stimulates the atoms simultaneously rather than individually and randomly, as in ordinary light sources. Other parts of the ruby laser are small mirrored surfaces located at the end of the ruby crystal to keep the energy bouncing back and forth long enough for the proper interaction to occur. The light flash which causes this interaction to begin is allowed to enter the ruby crystal through a small pin hole opening at one end of the mirrored surfaces.

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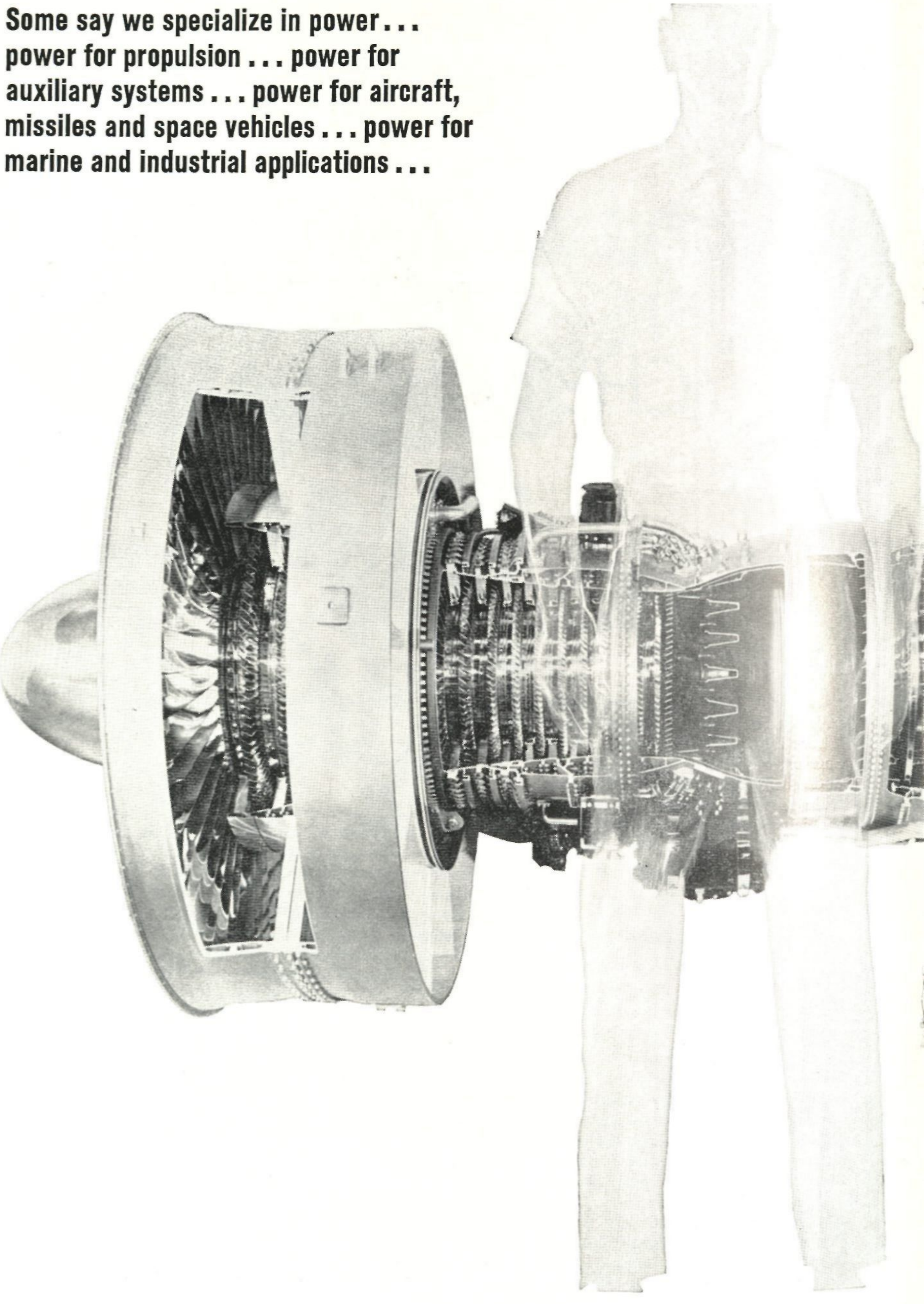

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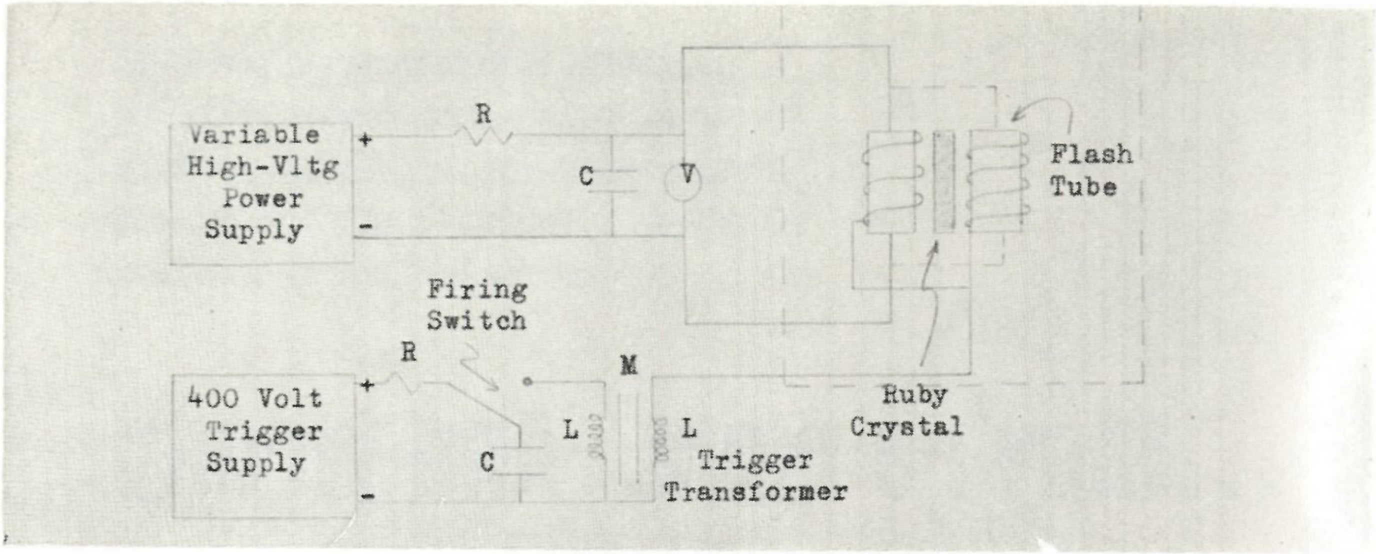


Fegure 1: A Typical Ruby Laser.

(*Continued from page 29*)

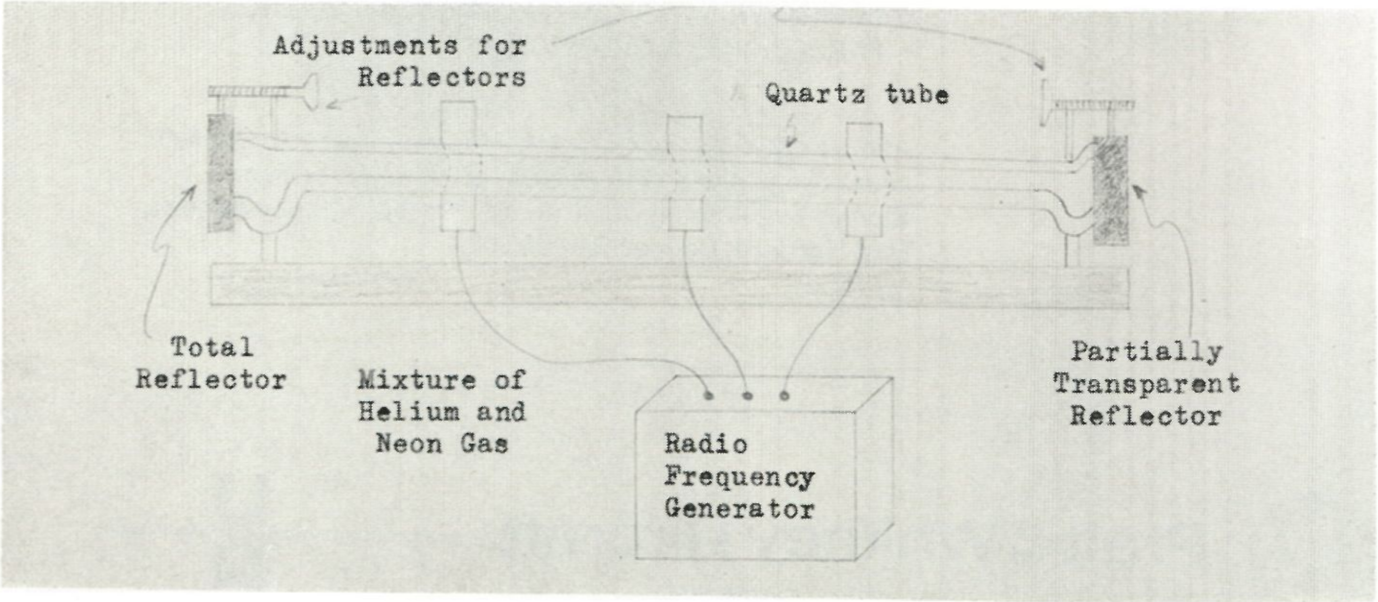
There is another pinhole opening in the other mirrored end which allows for the emission of the amplified light.[6] A diagram of a typical ruby laser is shown in Figure 1.[7]

The ruby laser was introduced to the American public by the American physicist, Theodore Harold Maiman,[8] and is in the class of optically pumped lasers. Since 1960 many other optically pumped lasers have been developed which use crystalline materials different from a synthetic ruby. Many of these lasers use doped crystals. Doped means that the crystal has been made impure by the infusion of small quantities of some other material. Examples of doping materials are some rare-earth elements (europium, neodymium, or an actinide element). Other optically pumped lasers have been made of doped glass, liquid or gas in a quartz cavity, and bundles of plastic fibers.

The Gas Laser

Another class of lasers is the gaseous laser. One type of gas laser has a working medium which is a mixture of helium and neon gas at very low pressure (one-tenth of a millimeter of mercury of neon and one millimeter of mercury of helium). The gas mixture is held in a cylindrical Pyrex tube about one meter long and seventeen millimeters in diameter. The gaseous laser has no mirrors at the ends of the Pyrex tube, but instead has at each end of the tube a quartz plate optical flat with a thirteen-layer dielectric (or electrically non-conductive material) on its inner-face. This apparatus emits a laser beam from both ends.[9] However, if one of the reflectors at the ends of the Pyrex tube is replaced by a total reflector, then the gas laser will emit only one beam from the other end of the tube.[10]

In 1962 several new gaseous lasers were demonstrated at the Bell Telephone Laboratories. Two of these new lasers contained mixtures of oxygen and argon and mixtures of oxygen and neon to generate an infrared beam. The scientists also demonstrated five other gaseous lasers which had as their active medium different pure noble gases. These noble gases were helium, neon, argon, krypton, and xenon. The gas lasers were able to send out continuous beams of coherent infrared radiation of fourteen different frequencies. Previously, this wide range of frequencies was thought



Fegure 2: A Typical Gas Laser.

available only from lasers using rubies or some other solid. The above noble gas lasers were developed by C. Kunar, N. Patel, William R. Bennet, Jr., Walter L. Faust, and Ross A. Mc Farlane who also was responsible for the oxygen-using lasers.[11]

The gas laser is not optically pumped and the emission of the laser beam is not pulsed every three or four seconds as is the beam of the ruby laser. Instead, the gas laser operates in a continuous-wave mode, its excitation being supplied by a radio frequency field (some gas lasers use direct current as a source of excitation). A typical gas laser uses a fifty watt transmitter operating on a carrier frequency of twenty-nine megacycles per second as an excition source.[12] A diagram of a typical gas laser is shown in Figure 2.[13]

The Injection Laser

A third type of laser is the injection laser. This laser consists of a semiconductor diode made of gallium arsenide or gallium arsenide-phosphide. The diode is an electronic part in which current flows easily in one direction, but almost not at all in the reverse direction. To make a diode out of a block of a semiconductor material, it is necessary to dope the block. This doping is done by allowing tellurium and zinc to diffuse into the block of semiconductor material at high temperature.

Tellurium atoms have one more valence electron than arsenic. Hence when tellurium atoms replace some of the arsenic atoms in a gallium-arsenic block, there are a few free electrons. Because of the negative charge on electrons, tellurium-doped gallium arsenide is called N-type (negative type) gallium arsenide. On the other hand, zinc has one less valence electron than gallium and when zinc atoms replace some of the gallium atoms there are several holes, or electron deficiencies. Because of the positive charge resulting from the holes, zinc-doped gallium arsenide is called P-type (positive type) gallium arsenide. The boundary layer between the two types of gallium arsenide is called the semiconductor junction. When the positive terminal of an electronic power supply is connected to the P-type region of a semiconductor diode and the negative terminal is connected to the N-type region, the diode will become biased in the forward direction, and current will easily flow across the semiconductor junction. If the power supply's negative terminal is connected to the P-type region, the diode will be biased in the opposite direction and very little, if any, current will flow across the semiconductor.

How injection lasers work is not exactly known. Most of the laser action seems to take place on the P-side of the junction. This indicates that the energy transitions occur when some energetic electrons making up the current flowing across the junction recombine with holes and give up the energy required to produce the laser beam.

The laser beam of the injection laser is emitted when extremely high current (twenty-five amperes or more) is passed between the terminals of the semiconductor diode; hence, light is emitted along the line that defines the semiconductor junction. Incoherent light is emitted at first, but as the intensity of the current increases, the emission becomes coherent. Because of the high current in the relatively small diode, the diode heats up rapidly. This extreme heat could destroy the semiconductor junction. To combat this heat, before the laser is operated, the diode is usually immersed in a cryostat, or double bottle, the inner bottle being filled with liquid nitrogen. The heat effect is also lessened by pulsing the current rather than passing it continuously through the diode.

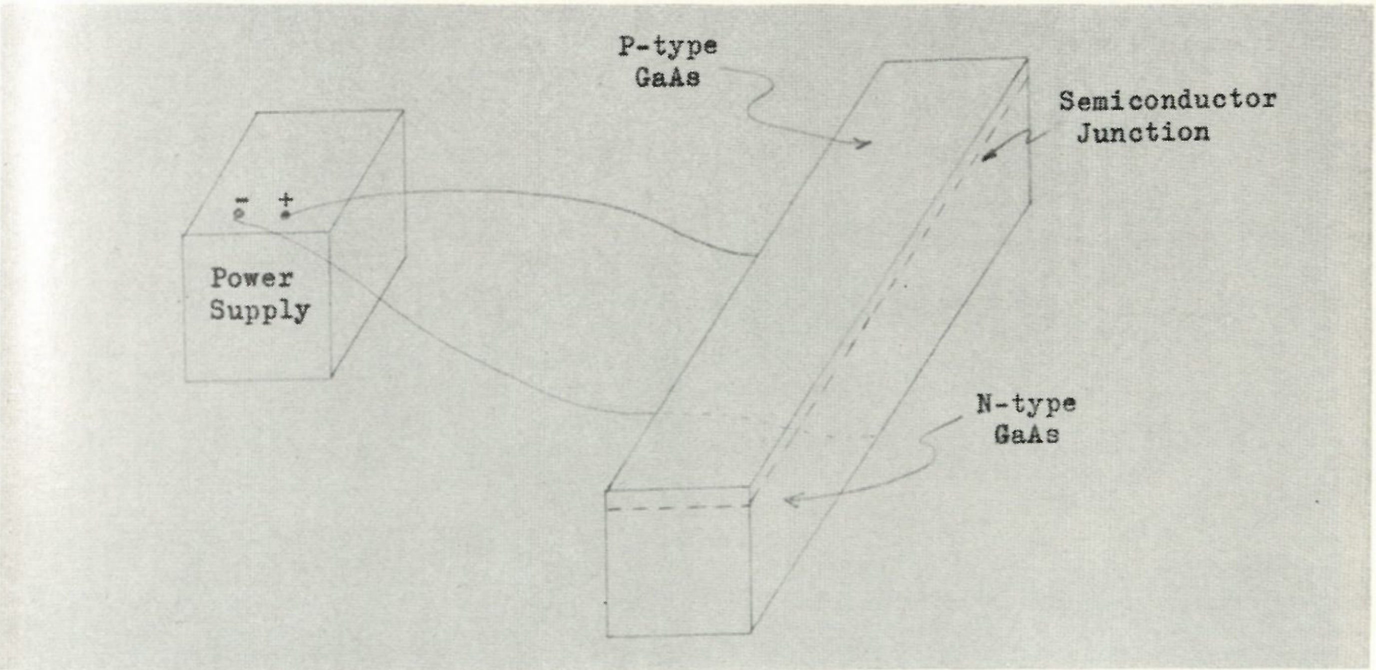


Figure 3: A Typical Injection Laser.

A typical injection laser is a rectangular parallelepiped with dimensions one-tenth by one-tenth by one and one-fourth millimeters. The sides are finely polished and reflect light back into the laser. This causes the emission of the coherent light to be in parallel rays coming from the square sides of the block. The current is applied to the retangular sides of the block; thus, the current flow is perpendicular to the semiconductor

(Continued on page 36)

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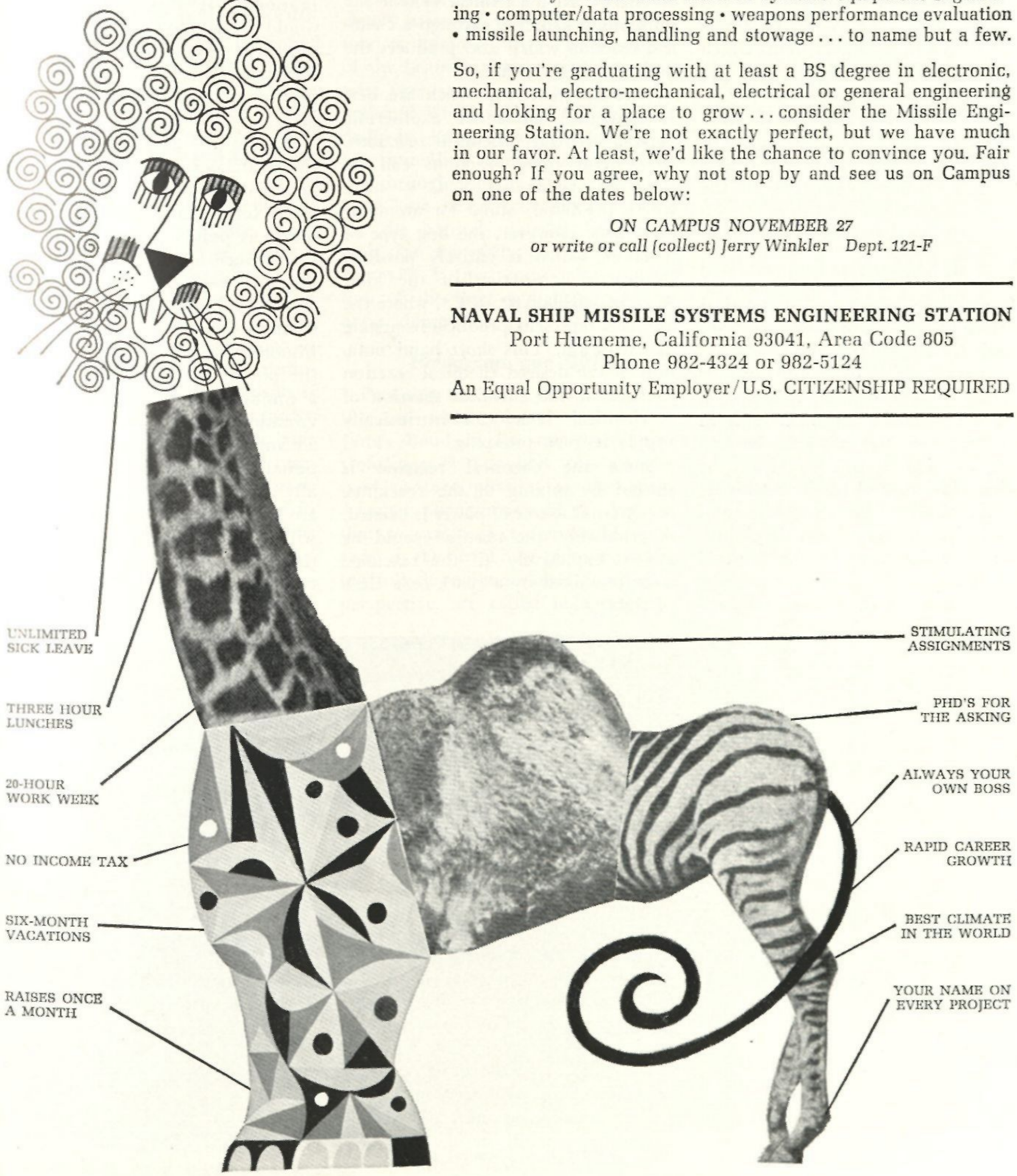

(Continued from page 33)

junction which is a narrow plane cutting the block along its axis.

When the block is gallium-arsenide, an injection laser emits coherent light at 8,400 angstroms. This light is in the near infrared region of the electromagnetic spectrum and is invisible to the human eye. Gallium arsenide-phosphide lasers have emitted coherent light of wave length 7,000 angstroms which is in the deep red region of the electromagnetic spectrum. A diagram of a typical injection laser is shown in Figure 3.[14]

Lasers have produced some three-hundred and thirty wavelengths which span the light spectrum from the near-ultraviolet region to the far infrared. All the lasers discussed above use electricity as a pumping source of outside power. The efficiency of these systems is rather poor—that is, the laser effect is much less than the input energy required for operation of the laser.

The Chemical Laser

A new laser which uses a chemical reaction as a source of power has been found. A chemical reaction which has begun tends to go to completion (or at least to equilibrium). Hence, a laser which uses a chemical reaction as a source of power would be self-pumping. This system would also be highly efficient and produce a highly intense laser. Two experimental chemical lasers have been developed, both of which emit in the infrared part of the electromagnetic spectrum.

Any laser has three essential components: a suitable set of energy levels, a pumping system, and an optical cavity.[15] For example, the energy levels of a ruby laser are the energy levels of the ruby, the pumping system is an electrical circuit, and the optical cavity is also the ruby crystal.[16] The search for new pumping methods led to the chemical laser. Chemical lasers are unique in that they are the only type of laser which has an internal pumping system. Other systems pump to the desired energy level through an outside source of energy. In a chemical system the pumping is achieved through a chemical reaction which also produces the desired energy level.

Chemical reactions which are best for chemical lasers are exothermic (giving off heat) chemical reactions. In general these reactions can be A + BC yields AB + C + heat, where the letters stand for atoms or molecules. However, the best type of reaction, which is entirely possible, would be a reaction of the kind A + BC yields AB* + C*, where the asterisks represent products in a state of excitation. This short hand notation of the desired chemical reaction shows how the chemical reaction of a chemical laser can intrinsically supply its own pumping.

Since the chemical reaction is started by mixing of the reactants, no external source of power is needed. Alternatively, the reaction could be started explosively (if the reactants were premixed by a spark or a flash of light.

Possibilities of the Chemical Laser

The chemical laser offers yet a third advantage over conventional lasers. This advantage might be more important than either the self-pumping or intrinsic pumping aspect of the chemical laser. This advantage is the potential population inversion in an energy level system that chemical pumping can achieve. It is possible that the distribution of energy in an energy level system following a chemical reaction might exclusively exist in excited states, either electronic or vibrational. If this happened, there would be no lower-state population until the slow de-excitation process occurred. This implies that the efficiency of chemical lasers would be great.

Despite the great efficiency of a chemical laser, it does have some inherent disadvantages. If the reaction is set off in an explosion the light source is pulsed. A second pulse can be obtained only after the remains of the first explosion are cleaned out and new ingredients placed in the reaction vessel. If reactants are continuously mixed in order to supply the power, reaction rates might pose a limitation factor. Lasers based on vibrational excitation have the disadvantage that each excited vibrational state has a variety of rotationally excited sublevels. The sublevels are generally occupied in accordance with the existing temperature, and they tend to dilute the possible occupancy of any particular level in which laser action is sought. This

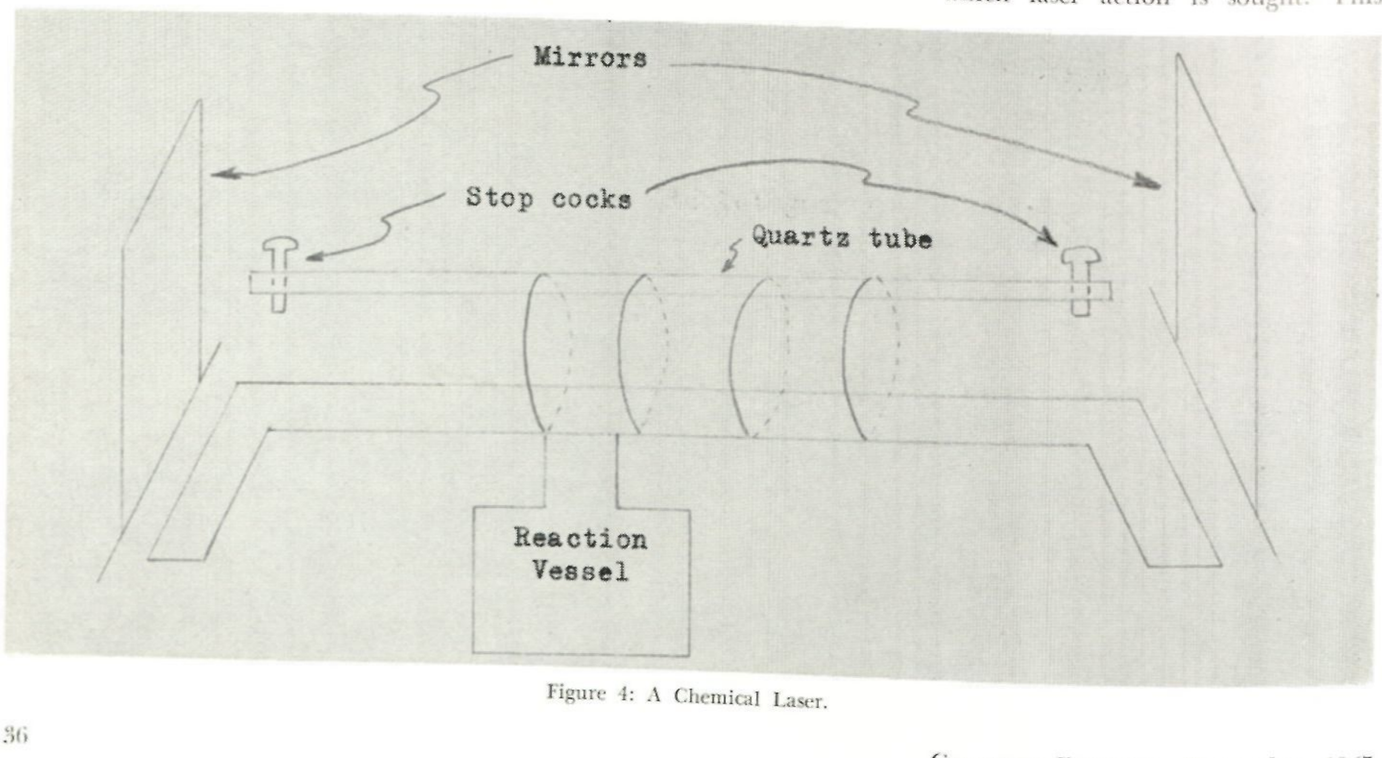

Figure 4: A Chemical Laser.

dilution reduces the potential gain of the laser action. A final limitation is that there are very few chemical reactions for which the reaction can be predicted to cause laser action.

Because of these problems, the development of the chemical laser was paralleled to the four minute mile—it was thought to be next to impossible. The first chemical laser was discovered by Jerome V. V. Kasper in 1964. This laser was called a "photodisassociation laser"; it is based on the breakdown of organic compounds containing iodine. Soon after this discovery, a second chemical laser was discovered. This laser might be called an "explosion laser," as it involves the violent reaction between hydrogen and chlorine. A diagram of a typical chemical laser is shown in Figure 4.

Even though the chemical laser is mostly an experimental device, it has had some applications. The chemical laser yields data about the microscopic distribution of energy in chemical reactions. Another result the chemical laser has yielded is information on why laser emission of iodine terminates so suddenly. The termination is so sudden because the temperature rises so quickly in the process of laser transmission that new chemical reactions become important. One future use of the chemical laser might be to furnish a tool, equivalent to a new chemical microscope, that will focus on the distribution of energy in reactions revealing the exact energetic state of the product species as they are formed during a chemical reaction.[17]

Many uses for conventional lasers have been found, from an easer to a death ray.[18] For example, lasers may be used, and in some instances, have been used in experiments on matter and basic experiments on physics, space communications, industrial purposes, chemical purposes, and medical purposes.[19]

Medicine and Lasers

In medicine lasers have been used to kill malignant tissue, burn away warts or tattoos, and remove birthmarks with little pain and a minimum of scarring. The laser used as a "light knife" makes possible bloodless surgery. For medical use the laser is usually of low intensity. Patients have stated the laser feels like having hot candle wax fall on your skin.[20] Lasers can and have been used in connection with the retinal detachment; an exposure of the eye to the laser beam of only 1/1000 of a second is needed. The laser beams can be used to destroy certain blood-vessel tumors in the eye. A laser can even create a new pupil in the iris which has been pushed out of position as the result of partial unsuccessful eye surgery to remove a cataract. A final use of the laser in eye surgery is the destruction of certain tumors on the surface of the eye.

Lasers have been put to use in industry in several ways. Lasers can be used in microwelding. The smallness of the beam enables it to be used to join very small electronic parts together.[21] The laser may be used as a drill. In Aztec, New Mexico, a 280-ton tunnelling machine is kept boaring through solid rock by a helium-neon laser beam.[22] Diamonds, which are the hardest material known to man, can be easily pierced by laser beams.[23] A final industrial application of the laser is lighting up the ocean depths.[24]

Holograms and 007

Probably the most famous laser is the one which almost disposed of James Bond in the motion picture *Goldfinger*.[25] The laser can also be used to take pictures in the dark. Another phenomenon of the laser is that it can project remarkable pictures in the air. These pictures, showing full three-dimensional depth and perspective, are called holograms.[26]

Lasers Today and Tomorrow

The present use of lasers has increased greatly since they were first discovered, but their future uses are almost unlimited. All kinds of communication systems may be developed from lasers. A regular television signal was produced by a gaseous laser of helium and neon gas operating at 6.328 angstroms in the deep red region of the electromagnetic spectrum. Lasers may also be used to produce a radio signal. In the future lasers may be used in telephone communication. Lasers may also be used in digital computers in place of wires and pulsing electrons. This would increase the speed of the digital computer considerably. Since the laser beam travels at the speed of light (186,000 miles per second) and since the laser can produce such an intense brightness and an intense heat, lasers definitely can be developed as weapons.[27] Several specific potential uses of laser beams are the following: (1) Finding the range for precision bombing and—in portable form—battle field pinpointing of such targets as tanks. (2) Illuminating targets for reconnaissance and for artillery fire. (3) Guiding the blind with laser-flash lights whose distance-echoes are translated into audible signals of varying pitch. (4) Probing the atmosphere to determine its composition. (5) Warning pilots of obstacles ahead by picturing them on cockpit television screens. And (6) determining why jet planes in rare instances have crashed in perfect weather.[28]

Lasers have had far-reaching effects on many phases of scientific work. The laser can and has to some extent reshaped the field of electronics.[29] The chemical laser as it is continued to be developed, may bring about drastic changes in lasers; however, first a continuous chemical laser must be developed.[30]

FOOTNOTES

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25. Issacs, Robert P., *op. cit.*, p 12.
26. Meloy, Thomas, *op. cit.*, pp 875 and 878.
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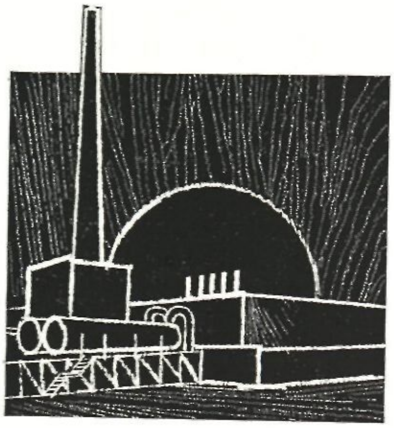
29. Carrol, John M., *op. cit.*, p 169.
30. Pimentel, George C., *op. cit.*, p 39.



NEW AND VISITING FACULTY

ADMINISTRATION:

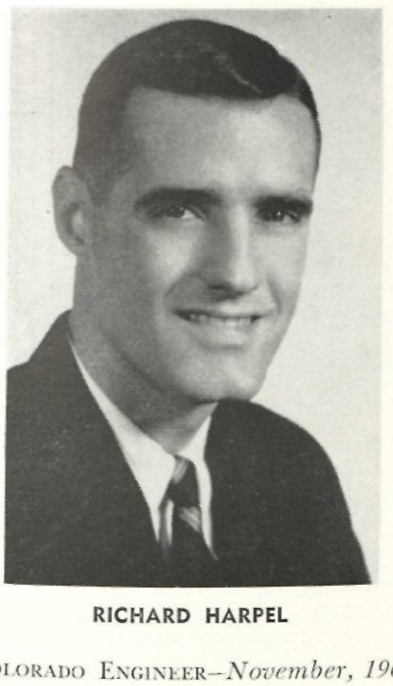
RICHARD HARPEL, director of engineering counseling and advising, comes to the staff from a position as assistant dean of student affairs at the Denver Center. A graduate of Wheaton College, Illinois, Harpel obtained his master's degree in personnel service at the University of Colorado and is now working toward his doctorate in guidance and counseling.

AEROSPACE ENGINEERING:

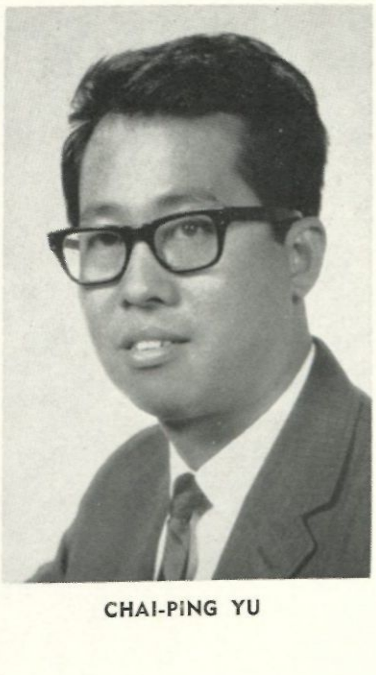
LUDWIG OSTER, associate professor of astronomy at Yale University, will teach in the department during the current year as visiting associate professor. He is a Fellow of the Joint Institute for Laboratory Astrophysics with a special interest in the applications of plasma physics to astrophysical problems. He has made fundamental contributions to the understanding of the structure of the solar atmosphere and mechanisms of energy transfer, with recent studies centering on a theory of the radio emissions accompanying solar activity phenomena. Dr. Oster was a postdoctoral research fellow of the German Science Council of the University of Kiel before joining the Yale faculty in 1958. He has worked recently under grants from the U.S. Air Force, NASA, and the National Science Foundation, and is the author of over thirty publications in technical media.

Also teaching in the department this year as visiting associate professor is CHAI-PING YU, of the faculty of the State University of New York at Buffalo, N.Y. Dr. Yu, a graduate of National Taiwan University, received his Ph.D. from Purdue and is a specialist in physics of fluids with astrophysical applications. He has been principal investigator for two National Science Foundation grants: for studies of convective stability of stellar atmospheres in a magnetic field, and hydromagnetic pipe flow and stability of conducting fluids of variable density. He is the author of more than a dozen technical articles; his doctoral research was a study of magnetoatmospheric waves in a horizontally stratified conducting medium.

PETER FREYMUTH, assistant professor, has been for the past year a research associate in the department. He is a graduate in physics from the Technical University of Berlin, where he earned his doctorate in the field of turbulent flow phenomena. His other research interests are fatigue effects in quartz crystals, hot-wire



RICHARD HARPEL



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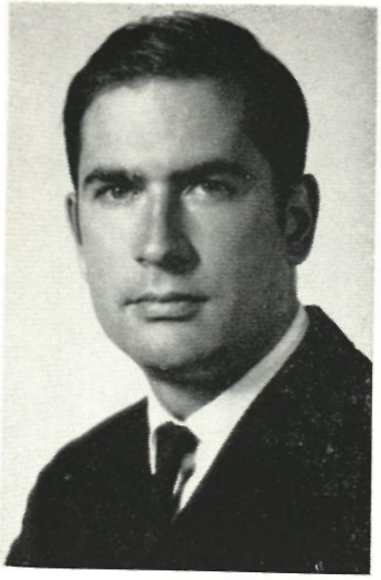
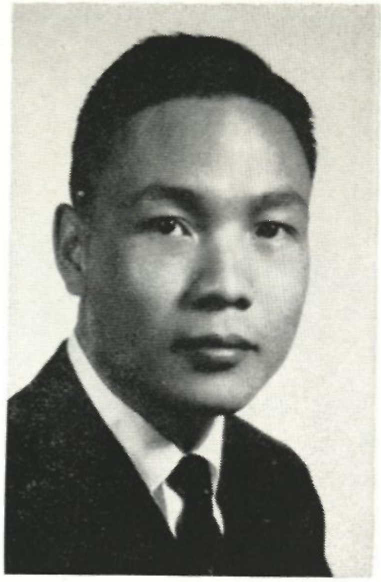


PETER FREYMUTH

techniques and hydrodynamic stability. Dr. Freymuth received the 1966 award of the German Society for Flight Sciences for research in turbulence.

F. YATES SORRELL, JR., assistant professor, has for the past year been a research associate with JILA, coming here from the California Institute of Technology, where he obtained his graduate degrees. At Cal. Tech. he carried on the work of Dr. Vlases in shock wave propagation in the inverse pinch geometry, and brings to the department considerable experience in laboratory gas dynamics. Dr. Sorrell has held Convair and NASA fellowship graduate awards, and has had industrial experience with aircraft companies as an engineer and draftsman. He is a member of the American Physical Society and the AIAA.

XUAN XINH NGUYEN, assistant professor, is a solid state physicist who has been associated for the past six years with the French National Scientific Research Center. As a research scientist for the Center he recently was visiting scientist to the Westinghouse Research and Development Center in Pittsburgh, Pa. Dr. Nguyen received his training at the University of Paris, where his graduate work was in advanced astronomy, advanced theoretical physics and solid state physics. His studies have included non-linear electromagnetic theories and general relativity; thermal properties of semiconductors and impurity induced phonon-photon interactions in solids.



XUAN XINH NGUYEN

JOHN ZINN, visiting assistant professor this year from the Los Alamos Scientific Laboratory, is a research physicist currently working under the sponsorship of the Atomic Energy Commission. His studies are concerned with magnetohydrodynamic behavior of nuclear explosions at very high altitudes. He has investigated in particular the question of appropriate numerical techniques in the radiative transfer problems during the radiative regime, and the treatment of radiative-coupled flow during the mixed radiative-hydrodynamic regime. He received his doctorate from the University of California at Berkeley.

ARCHITECTURAL ENGINEERING:

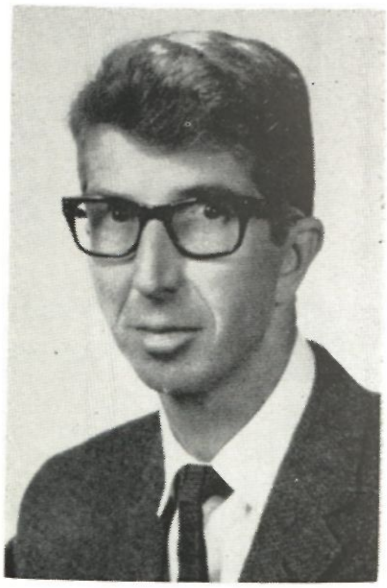
WALTER MEYER, associate professor, joins the department after a year of teaching here as a visiting lecturer. Owner and president of the Meyer Construction Company in Littleton, Colorado, Meyer has had twenty-five years of experience in the construction business. He is a colonel in the Corps of Engineers, U.S. Army Reserves, and has been an advanced instructor in the Engineering School, Fort Belvoir, Va. Meyer received his master's degree in architectural engineering and business from CU this summer. Recently he was awarded the Bate-Petry Memorial Award for outstanding service to the construction industry of Colorado.

F. YATES SORRELL

JAMES KONKEL, visiting lecturer, is a graduate of the University of Colorado (Ch.E., 1949) and is a Denver consulting mechanical engineer specializing in commercial and industrial buildings.

CHEMICAL ENGINEERING:

WILLIAM MANOGUE, visiting lecturer, comes this year from the E. I. duPont de Nemours Company, where he is a senior research chemical engineer with special interests in kinetics, catalysis, and thermodynamics. His doctoral research, conducted at the University of Delware, dealt with the kinetics of absorption of phosgene into water and aqueous solutions, and was published in the AIChE Journal in 1960. He is also the author of "Effective Diffusivities from Carbon Burning Rates," published in Chemical Engineering Progress, Vol. 58, Number 12. Dr. Manogue comes to the department to fill



JOHN ZINN

WALTER MEYER

WILLIAM MANOGE

the place of Lee Brown, who is on leave for the academic year in the Netherlands. He will further the investigation of the application of adsorption isotherms to catalytic reaction kinetics, which Brown is conducting with National Science Foundation support. This arrangement with duPont is in line with the department's desire for closer industry relationships.

WILLIAM KRANTZ, assistant professor, comes to the department from the University of California at Berkeley, where he has been a teaching assistant while working toward his graduate degrees. He has taught undergraduate courses in unit operations and mass transfer and graduate courses in ion exchange, mathematical methods in chemical engineering and chemical kinetics. His doctoral research is an experimental study of the stability of a thin film of liquid flowing down a plane, and is in progress. Krantz has held a National Science Foundation undergraduate research fellowship, and received the Merck Award as the outstanding chemical engineering graduate at the University of Illinois in 1962. His special interests are fluid dynamics, non-Newtonian flow, surface phenomena, particulate systems, thermodynamics and phase transition studies. He is a member of AIChE and AAAS.

THOMAS FLYNN, of the National Bureau of Standards, returns to the department this year as lecturer. Dr. Flynn is a recognized authority in the field of cryogenic engineering and has contributed to the development and improvement of cryogenic engineering courses in the department in the past. He has assisted in the direction of cryogenic research in the graduate school, especially those students in the NBS laboratory. He is the author of more than a dozen publications in technical media. His graduate degrees were received from the University of Colorado.

CIVIL ENGINEERING:

RICHARD BAUMAN, assistant professor, brings to the department specialized knowledge in transportation and in soils. He comes from Arizona State University, where he has been an instructor. A graduate of Iowa State University, Bauman received graduate training at the University of Utah and his doctorate at Arizona State. He has been a technical report writer for the Utah Geologic Survey and a materials engineer for the Utah Highway Department. His principle publications have been on the subjects of vehicle performance at street intersections due to changes in driver population (an Arizona State Report), foundation characteristics of sediments in the Salt Lake Metropolitan area (a Utah geological and mineralogical survey study), and heave stabilization of Mancos shale, (a paper presented to the Highway Research Board, Washington, D.C.) His doctoral studies were concerned with urban transportation systems, statistics, and operations research.

MICHAEL P. COLLINS, assistant professor, is a specialist in structures who has been a research fellow and lecturer at the University of New South Wales, New Zealand. A graduate of the University of Canterbury, New Zealand, he received his doctorate from the University of New Wales. His research has been in the field of the behavior of reinforced concrete beams loaded in combined bending, and in torsion and shear. A graduate member of the Institution of Engineers, Australia, Dr. Collins has had industrial experience in design and in concrete structures.

HON-YIM KO, assistant professor, has been associated for the past four

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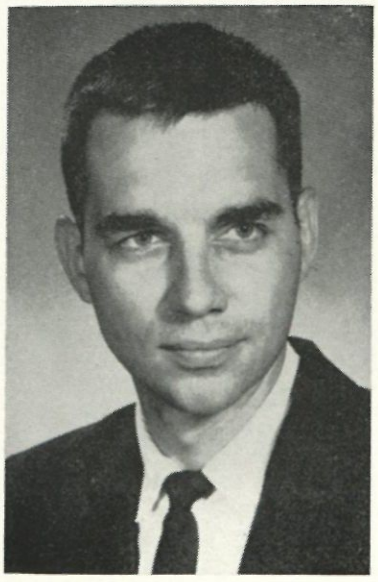
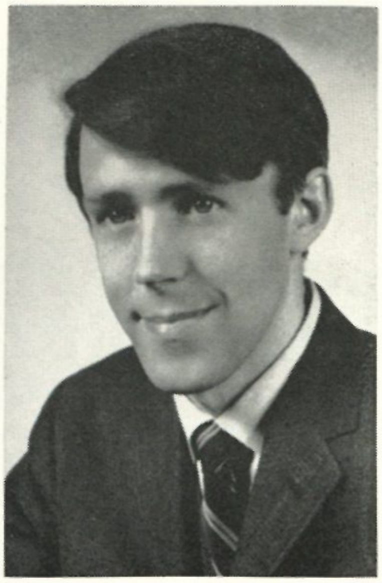


RICHARD BAUMAN



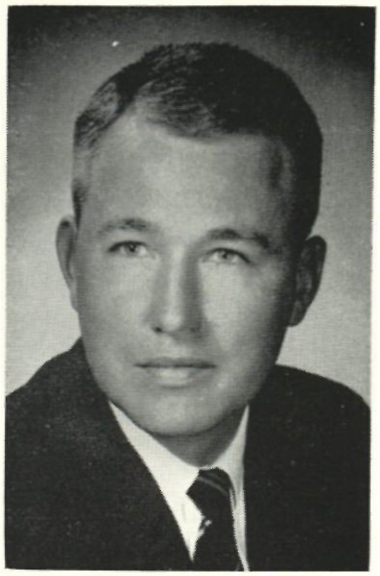
MICHAEL P. COLLINS

HON-YIM KO

(Continued from page 41)

years with the California Institute of Technology, most recently as a research fellow. He is a specialist in soil mechanics; his doctoral thesis was a study of static stress-deformation characteristics of sand. Dr. Ko has been an industrial engineer in Los Angeles and Hong-Kong, and has conducted research in structural mechanics at the University of Hong-Kong, where he obtained his bachelor's degree. He was awarded a Woodrow Wilson Summer Fellowship in 1965.

K. DANIEL LINSTEDT, assistant professor, represents a new breed of nuclear civil engineer who could play an important role in Colorado development. His specific education has been in nuclear techniques and radioactivity use, including an acquaintance with use of nuclear explosives for underground effects such as mining and water resources development. His graduate work at Stanford University was concerned with water resources, with special interest in sanitary engineering. Dr. Linstedt recently published a paper on electron activation analysis for determination of carbon in submicrogram quantities of virus, in the proceedings of the International Conference on Modern Trends in Activation Analysis, and is the author of a paper on determination of vanadium in Colorado River waters, presented to the American Nuclear Society last June.



K. DANIEL LINSTEDT

DAVIS C. HOLDER, a research associate for the U.S. Department of Defense, will teach in the department this year as a visiting lecturer. He has been instructor of mechanics, strength of materials, and hydraulics at the University of Wyoming, where he obtained his master's degree, and until recently was instructor and head of

DAVIS C. HOLDER

MARK TSU-HAN MA

department of surveying and graphics at Mesa County Junior College in Grand Junction, Colorado. His special interests are water supply and structures.

ELECTRICAL ENGINEERING:

ISAAC M. HOROWITZ, professor, has been conducting research for the past six years in feedback theory and active networks. He has been a senior scientist for Hughes Aircraft Company and a professor of electrical engineering at City College of New York. He has received a patent as a result of his work on magnetic amplifiers, and has made contributions to feedback (adaptive) theory and optimization theory. His experience includes meteorological instrumentation, ballistic and chemical instrumentation, audio and magnetic amplifiers. Dr. Horowitz earned his graduate degrees at Brooklyn Polytechnical Institute and is a senior member of the IEEE. He is the author of the widely used text, *Synthesis of Feedback Systems*.

MARK TSU-HAN MA, who has been a visiting lecturer in the department since 1964, has been appointed professor-adjoint with ESSA. He is an electronics engineer doing research and consultative work in the antenna research section of ESSA, and was previously associated with the General Electric electronic laboratories in Syracuse and New York. Dr. Ma's paper, "A New Mathematical Approach for Linear Antenna Array Analysis," co-authored with D. K. Cheng, was awarded the National Electronics Conference Annual Best Paper Award.

EDMUND ALLEN QUINCY, a senior research engineer with ESSA/ITSA who lectured in the department last spring, will teach as a visiting lecturer this year. At present he is engaged in theoretical studies in information transmission, particularly the optimization of transmitter and receiver design for improved high-speed communications. His work is also concerned with various modulation detection schemes for digital communication. He is contributing toward design and evaluation of an ionospheric simulator which will be used ultimately to help in the laboratory evaluation of new concepts in modern design. Dr. Quincy received his graduate degree at Purdue.

BEDRICH HELLER, visiting professor, will teach in the department during the current year in place of Edward Erdelyi, who is on leave of absence in London. Dr. Heller, a graduate of the German Technical University in Prague, is a recognized authority on transient phenomena, electrical mechanics, and dielectric phenomena, with some thirty years of experience in the field of rotating electrical machines. For the last twelve years he has been working on surge phenomena in transformers and rotating machines, and on discharge phenomena in dielectrics. He became director of the Electro-Technical Institute of the Czechoslovak Academy of Sciences following the war and was elected a member of the Academy in 1960. He holds an honorary doctorate from the Polytechnic Institute in Lodz, Poland, and is the author of three books and over a hundred technical papers.

EDWARD ERNST, visiting associate professor from the University of Illinois, will work on a laboratory development program under the auspices of the BUILD program. He has done research on the undergraduate laboratory in engineering education, and is a member of the laboratory development committee of the Commission on Engineering Education. A graduate of Illinois, where he obtained his doctorate, he has special-

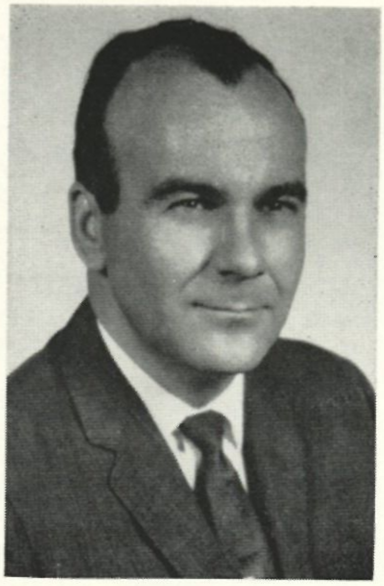
ISAAC M. HOROWITZ

EDMUND ALLEN QUINCY

ized in radiolocation systems and digital processes as well as electronics and experimentation. At one time he was manager of the advanced engineering department at Stewart-Warner Electronics Company in Chicago, in charge of new product development and planning. Dr. Ernst has been president of the National Electronics Conference and is a senior member of IEEE.

JACK R. BAIRD, assistant professor, comes from the University of Illinois, where he has been assistant professor for the past three years, and where he received his undergraduate and graduate degrees. His teaching has been in the areas of radio frequency transmission lines, vacuum tube and transistor electronics; for four years he was an Air Force instructor of radar. A specialist in physical electronics, his doctoral dissertation was a study of deflection modulation and millimeter waves.

DAVID C. CHANG, assistant professor, is a specialist in cylindrical antenna theory who has been a teaching fellow and research assistant at Harvard, where he obtained his Ph.D. degree last June. He has taught courses in passive microwave circuit and electromagnetic theory (radiation), and has conducted research under a Gordon McKay Fellowship at Harvard. His study topics have been traveling-v-antennas, large element circular arrays, and electrically thick, tubular dipole antennas. Articles on his research have been published in technical reports of Harvard's Crufts Laboratory.

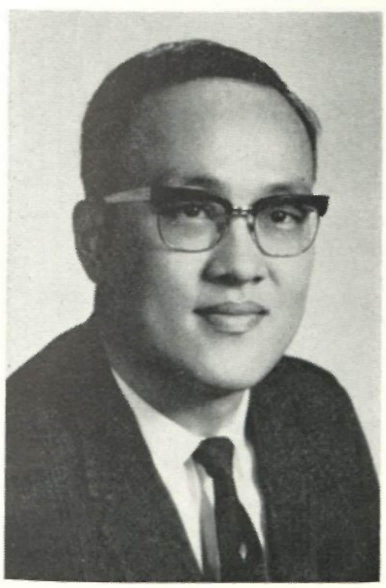


JACK R. BAIRD

LYMAN B. ELWELL

MARVIN JENKINS BARTH, visiting lecturer (honorarium). is an instructor in the electrical engineering department of the U.S. Air Force Academy. A major in the Air Force with continuous military service since 1950, he is a graduate of the U.S. Naval Academy, received his M.S. at the Air Force Institute of Technology, and his Ph.D. at Syracuse University. He has lectured at Northeastern University, Boston, in probability and statistics, and network synthesis. He has had research experience at U.S.A.F. Rome Air Development Center, in LF and VLF antenna design and evaluation, and VLF propagation measurements and has done propagation studies at Cambridge Research Laboratories (USAF) recently.

LYMAN B. ELWELL, visiting lecturer from the National Bureau of Standards, is well known to the department, having lectured in previous years. His activities at the Bureau have been in research and development in the field of microwave measurement standards; more recently he has been project leader of the microwave high power project. His teaching is in the field of microwave measurement. Elwell is a member of IEEE special groups on microwave theory and techniques and electron devices. He is a graduate of the University of Colorado, where he received his master's degree.

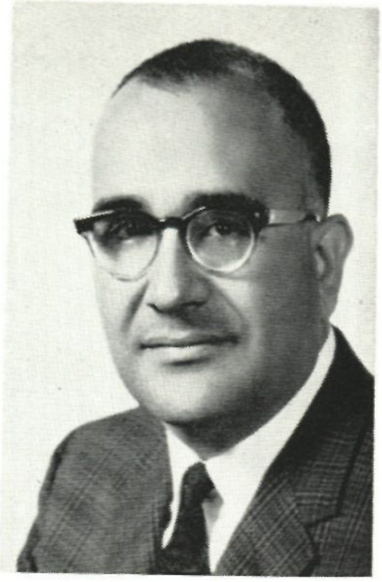


DAVID C. CHANG

WILFRED K. KLEMPERER

Radio wave propagation specialist WILFRED K. KLEMPERER, chief of the solar radio astronomy division of ESSA/ITSA, will teach in the department this year as a visiting lecturer. Dr. Klemperer has been senior scientific staff member of the NBS-Jicamarca Radar at Lima, Peru. His doctoral research, at Cornell, was a study of spread F echoes from the ionosphere. He is a Fellow of the Royal Astronomical Society of London.

GEORGE R. SUGAR, visiting lecturer, is well known to the department, and to the Department of Chemical Engineering, having taught courses in the College of Engineering in the past. He is leader of the instru-



GEORGE R. SUGAR

ment group of the Upper Atmosphere and Space Physics Division of the National Buraeu of Standards, and is a specialist in digital instrumentation. Sugar is the author of numerous technical papers in the areas of ionospheric propagation and meteor scatter, and is a member of IEEE, AAAS, RESA, and Commission III of URSI.

RICHARD C. WEBB, visiting lecturer, has taught courses in the department from time to time over the past six years, notably in pulse and digital circuitry, his professional field. He founded Colorado Instruments, Inc., a research firm engaged in development and manufacture of digital electronic instruments, controls, and image transmission systems. He has been a research engineer for RCA laboratories, a professor of electrical engineering at the University of Denver, and has instructed at Purdue University, where he obtained his graduate degrees. Dr. Webb holds an impressive list of patents for inventions and designs ranging from electrical circuits to encoding apparatus. He is a Fellow and former chairman of the Denver Section of the Institute of Radio Engineers.

ENGINEERING DESIGN AND ECONOMIC EVALUATION:

CHUNG H. SUH, assistant professor, has taught machine design and allied subjects at Seoul National University and at the University of California. His research interests have been gear analysis, non-standard gear design and gear production systems, plane and spherical linkage synthesis and analysis, space mechanism synthesis and analysis. He has also studied the biomechanics of prosthetic devices. Dr. Suh began his teaching in the department last spring.

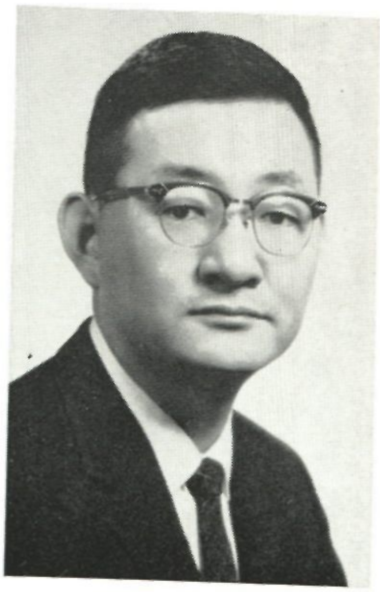
WILLIAM B. JAHSMAN

JAMES D. CUNNINGHAM, part-time lecturer, EDEE, has been instructor in the department. He will be associated with senior projects group. He is chief engineer for LASP.

MECHANICAL ENGINEERING:

WILLIAM E. JAHSMAN, professor, is an international authority on shell structures. He has been a research and consulting scientist with Lockheed Missiles and Space Company, Palo Alto, for ten years, and has lectured in the Stanford University aeronautics and astronautics department since 1959. A graduate of Cornell University holding masters and doctorate degrees from Stanford, Dr. Jahsman's research has included elastic and inelastic wave propagation, crack propagation, plastic instability, plastic limit analysis and creep buckling, as well as shell theory. His publications reflect the wide range of his investigations. He comes to the department widely recognized in the field of solid mechanics.

VELJKO MILENKOVIC, associate professor, comes to the department from the General American Transportation Corporation, Illinois, where he has been for some years senior technical advisor in the division of general research. His research activities at GATC have resulted in numerous patents for inventions and designs in the areas of artillery ammunition, dynamic modes of transportation, stability and dispersion of projectiles, a boosted rocket artillery system and three-dimensional fabric structures. Recently he has conducted analysis of towline dynamics related to Navy sonar systems, and has invented the basic control logic for an industrial tape-controlled machine. Dr. Milenkovic studied for his graduate degrees at the Illinois Institute of Technology.



CHUNG H. SUH

VELIKO MILENKOVIC

FACULTY FEATURE:

Reading for Writing

PROF. SIEGFRIED MANDEL
Dept. of English in Engineering

The topic for this paper was suggested by a colleague's remark to the effect that if an engineer cannot write, he is no engineer. Any statement that has a dogmatic ring makes me bristle, but on thinking it over I am inclined to agree with the somewhat harsh verdict—or at least to modify it by saying that the engineer-scientist who does not know how to write does himself and his profession an injury. So bewildered, for instance, is the Provost of Columbia University, Jacques Barzun, by the unexplained scientific "intent on a speck of matter," that in a recent book called *Science: The Glorious Entertainment* his intellectual rage is vented in chilling prose:

> Life turns to comedy, suddenly, when one takes a second glance at those creatures at work behind a grillwork of tubes and rubber hose, gravely intent upon a speck of matter or a flicker of motion, wearing the expression of gifted squirrels watching for a nut. They are the eager beavers of common speech and their manhood (womanhood too) is not enhanced but made comic when we know that the object of their passion is the quarter-million-dollar mouse, that the day and night anxiety of their lives is whether the subject's thumb will jerk or not.

Trying to mediate between the writing-reluctant scientist and the intelligent layman who wishes to understand what goes on behind the engineer-scientists grillwork, John O. Osmundsen, a New York *Times* science reporter, writes:

> Science is fundamentally no different in practice today from the way it was 100 years and more ago. Nor is there any basic difference between scientific thought and any other kind. Scientific thinking is simply damned good thinking and nothing more. This means that science need not be beyond the ken of the non-scientist, and the sooner this is made clear to everyone, the sooner we shall be able to get on with the solutions of the annoying little problems Mr. Barzun discusses in his book. . . . Scientists have not accepted their responsibility sufficiently to communicate the quality of their experience to the world and . . . persons who misunderstand these matters such as Mr. Barzun, have added to the confusion.

At the latest meeting of the American Association for the Advancement of Science, one conclusion reached was that science in America is in trouble with the Federal Government, with a sizeable segment of the general public, and, to a large extent, with itself. Dr. Alvin Weinberg, director of the Oak Ridge National Laboratory in Tennessee, noted that scientists are failing to transmit effectively their findings to others and often to each other. Proper control and command of language and its forms of expression are the chief troublemakers. Why should this be so? Two explanations may suffice before we turn to some suggestions for the engineer-scientist.

First, in most professions, specialization has become inevitable with the leapfrog growth in knowledge. The term *specialist* has awe-inspiring implications; whereas, in the medical profession, specialization holds enormous advantages for the practitioner, it more often is a blight rather than a blessing for the engineer-scientist. I am reminded of a ironic anecdote told by the novelist William March. He entitled his anecdote, *The Doctor and the Hippopotamus,* but he might just as easily called it *The Engineer and His Speciality:*

> A young orangutan was ambitious to cure the ills of others, and when he saw how often his friends died because a bone or some other object was lodged in their throats, he decided to specialize in that branch of healing. Gradually stories of his skill were told all over the jungle, and when the hippopotamus yawned one morning

and got a log crosswise in his gullet, he sent for the orangutan as a matter of course.

The doctor came promptly, but although he tried with all his instruments, and even stretched his arm forward as far as it would reach, he couldn't touch the log, much less remove it. As a last resort, he asked the hippopotamus to raise his neck and stretch his jaws even wider, and when he did so, the doctor walked into his mouth, braced himself, and tugged with all his might at the obstruction. The log came loose unexpectedly, and at the same instant the hippopotamus flinched and swallowed. Then, when he had got his breath again, he began smelling about for his benefactor, not realizing he had swallowed his doctor when he swallowed the log, nor knowing, at the time, that it is the fate of specialists to perish of their own specialties.

The necessity for specialization should not result in communication withdrawals; on the contrary, the more intense the specialization, the more vital it becomes for the engineer to explain and relate his experiences—in writing.

The second explanation for poor communication practices fits the theme of the conferences on continuating education. Whatever has been learned in the classroom may not have been pressed into service outside of it. Except for several companies that recognize the value of in-service writing courses or seminars, the self-advancing responsibility to improve one's writing rests with the individual.

Perfection of a writing style that says precisely what one means—or on some occasions deliberately avoids it—is a game of word and syntax strategy that has a fascination to those that are willing to master it. Thought and writing are inseparable from each other; matter and expression are parts of one; and style is a thinking out into language. Constant awareness of how writing—good, bad, or indifferent—is written should lead to a more discriminating manipulation of language. The more accurately words are used, the clearer definition do we give our thoughts. Writing with awareness then, trains our minds to filter and clarify our thoughts. To go full cycle with the idea, it is not psychologically unsound to say that what an engineer cannot state he does not perfectly know and that inability to put thoughts into words sets definite and debilitating boundaries to one's thoughts.

The point is that whatever one reads—technical or semi-technical, prose, fiction or exposition, article or essay, one should read with the idea of immediately spotting the strengths and weaknesses of a man's style and instantly benefiting by this awareness. We might call such an approach *reading for writing.* Even the engineer who has a respectable command of language will soon find that this approach will charge his own writing with new force. Those who are less adept with language may discover that with this approach, their reading is slowed down but that their writing will eventually speed up and become firmer.

To sharpen one's awareness of the possibilities of writing, I would like to suggest reading sessions with a group of authors who not only know a great deal about the craft of writing but who demonstrate it as well. High on my list are Sir Ernest Gowers' *Plain Words: Their ABC's,* Sir Arthur Quiller-Couch's *On the Art of Writing,* S. I. Hayakawa's collection on *Language, Meaning, and Maturity,* Stuart Chase's *The Tyranny of Words,* Theodore M. Bernstein's *Watch Your Language,* and Reginald O. Kapp's *The Presentation of Technical Information.* These writers represent such varied professions as architecture, Shakespearian scholarship, semanticism, journalism, and electrical engineering.

Many persons in an attempt to crash through the barriers between themselves and good writing have fallen into the attractive traps of the one-day circuses that come to town under the respectable label of "Institute" or they have pounced on the books that promise clear writing in several easy lessons. Little except delusion can be gained by gunning one's intellectual apparatus and hoping to reach the top in one spurt; the flesh may be willing but the means are inadequate.

Reading for writing and reading about writing should teach you more than a string of misleading precepts that promise to open the secrets of writing without effort. The first popular bit of pap is "keep sentences short," maximum 20 words: Let us demolish that one with two sentences.

Sentence #1: In the spring of 1918 the commission undertook an extensive study of the power situation of the upper St. Lawrence, involving accurate contour surveys on both shores of the St. Lawrence River between Prescott and Cornwall, foundation explorations in in the vicinity of possible sites for dams, extensive sounding operations in the river itself, and a comprehensive and continuous study of the variations in water level.

This sentence is 70 words short.

Sentence #2: The lobby door opened and a young woman carrying a baby and her husband entered.

This sentence is 15 words long. Aside from that, it embodies the neatest trick of the week. By judicious handling of subordination, parallelism, and series elements, our 70-word sentence is clearer than the 15-word sentence. The precept on sentence length is as blind as those who follow it. Length or brevity are never substitutes for clarity or ease of comprehension.

Another precept of the professional simplifiers is "write as you talk." This can be disastrous for most people. At a certain conference last year one of the simplifiers underlined this point with a solid bit of profanity. When I asked if this is the way he writes, he saw my point and admitted that in writing he edited his talking style. There is no disagreement, however, with anyone who says that writing should not be stilted, pompous or excessively colloquial or, on the positive side, that writing should have vigor, grace, and fluency.

The simplifiers have a categorical imperative that says, "write to express, not to impress." This is as falsely glittering as Polonius' advice to his son. Instead, we might turn to the source of the idea which the simplifiers have distorted. Sir Arthur Quiller-Couch says:

> But let us philosophize a little. You have been told, I daresay, often enough, that the business of writing demands two—the author and the reader. Add to this what is equally obvious, that the obligation of courtesy rests first with the author, who invites the seance, and commonly charges for it. What follows, but in speaking or writing we have an obligation to put ourselves into the hearer's or reader's place. It is his comfort, his convenience, we have to consult. To express ourselves is a very small part of the business, very small and almost unimportant as compared with impressing ourselves; the aim of the whole process being to persuade.

These are two entirely different views. Couch sees *expressing* and *impressing* as two relative aspects of persuasive writing.

Among the dialogue of injunctions by the simplifiers is "use simple words, not big words." For example, use *begin* for *initiate, tell* for *acquaint* and so on. If the reduction of one's vocabulary to that of a fourth grade child is desirable, the advice is correct. But there is a world of difference between the synonyms in tone and intent of the words used. It is illusory to think that the road to good writing is paved with simple words. The spontaneously right word in the right place and the preservation and intelligent drawing upon the richness of our large vocabulary—these are aims worth the writer's pursuit.

Perspicacious reading for writing should not only develop one's sense of logic but it should also help one to spot illogic in others. Try to analyze these simple sentences: "The cow has a fine sense of smell; one can smell it far away. This is the reason for the fresh air in the country." If, in a flash, one cannot spot the illogic, it may be time to turn to Reginald Knapp's *The Presentation of Technical Information* and his discussion of logic.

Under the bulletin heading of "Winners & Sinners" Theodore M. Bernstein, as assistant managing editor of the *New York Times,* has been cajoling the staff of one of the great newspapers to improve writing through critical reading. Typical of his no-quarter given to poor writing are his definitions of perpetrators of crimes against language:

A monologophobe (don't try to look it up) is a guy who would rather walk naked in front of Saks Fifth Avenue than be caught using the same word more than once in three lines of type. Wht he suffers from is synonymmomania (don't look that one up either), which is a compulsion to distract and, if possible, puzzle the reader by calling a spade successively a garden implement and an earth-turning tool.

Short comments by Bernstein are usually sufficient to put offenders to shame:

Sheriff Tidwell said a leopard had been spotted . . .

Naturally Gobbledygook:

Improved financial support and less onerous work load . . .

Translation: Higher pay and less work.

And/or: "The law allows up to $25 fine and/or thirty days in jail."

Leave that monstrosity to the lawyers. Say simply, "$25 fine or thirty days in jail or both."

Several sessions with editor Bernstein will help one's sense of propriety and perspective in handling language.

To inlulge in the pleasure of quoting—just once more, let me put on record a quote by Ivor Brown that heads one of Gowers' chapters on *Plain Words:*

> The craftsman is proud and careful of his tools: the surgeon does not operate with an old razor blade: the sportsman fusses happily and long over the choice of rod, gun, club or racquet. But the man who is working in words, unless he is a professional writer (and not always then), is singularly neglectful of his instruments.

Rather than be neglectful of these instruments, one must give them professional attention. One way to do this is to pursue "reading for writing." Let me say finally that writing awareness is an essential part of continuous and continual self-education—strenuous at times but rewarding always.

LASER COMMUNICATION

DENNIS NEWMAN

One of our country's most pressing problems is the conservation of its natural resources. One resource that is often overlooked is our electromagnetic spectrum. Even though this resource is never consumed, its value can still be reduced by overuse or misuse. The FCC has kept misuse to a minimum, but because there are more than five and one-half million licensed transmitters in the United States, overuse is a problem. Since the development of the laser, scientists have become interested in using it to transmit information at frequencies in the optical and infrared portions of the spectrum, 10^{13} to 10^{15} Hertz (cycles per second).

To study a complete communications system, we must consider at least three distinct parts: transmitters, the transmission media, and recievers.

Transmitters

Transmitters, in turn, are usually broken down into three parts, the oscillator, amplifier, and modulator. The laser is the oscillator and the key to our system. Before its invention, there was no source of high power radiation which had the property of being coherent. This coherent property is necessary for any meaningful communications work, and it simply means that the small particles of light, called photons, coming from the laser are moving in the same direction at the same time, i.e., they are in phase. Most sources, such as flames or heated wires, send out their photons randomly.

Though the first laser was not made until 1960, much progress has been made. The first lasers put out less than a milliwatt of power but modern ones have powers of more than 1,000 watts, though most are still less than one watt.

Like so many other electronic components, lasers have gone to solid state. Small solid state lasers are commercially available but so far have low output powers and usually require temperatures of $-176°F$ to operate continuously. They show no signs of replacing other types.

Lasers can be used as amplifiers, too, but it is generally easier to strive for more power from the oscillator than to use a second laser to amplify the beam.

Modulation is one of the biggest problems remaining in laser communications. Modulation is usually accomplished outside the laser. Many optical modulators use an electro-optic effect in which certain materials

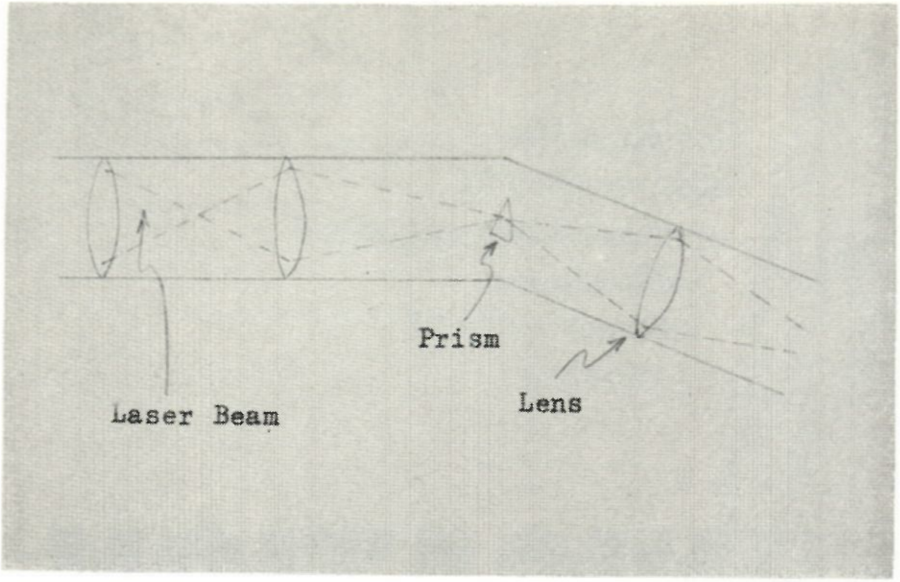


Figure 1: Laser Beam Travel through a Pipe.

will change the phase of the laser beam if an electric field is applied to the material. This scheme works to modulate up to about 10^{10}Hz. Solid state lasers can be internally modulated by varying the voltage applied to them up to 1.2 x 10^{10}Hz. These rates, though very fast, are far from using the laser to its full potential, but basic difficulties remain to be overcome.

Atmospheric Interference

How to get the laser beam from our transmitter to our receiver is another major problem. Except for very short distances, the atmosphere may degrade the beam until no information is transmitted. Fog, rain and snow are the obvious offenders; they will scatter and absorb the beam. Many infrared laser frequencies are absorbed in a short distance by just the humidity normally present in the air. Scintillation, the effect that makes the stars twinkle even on a clear night, also can make a laser beam wander off the receiver. Heat waves and other turbulence in the air also makes the beam wander and destroy the coherence of the beam.

Because of these factors, many schemes have been proposed to send the beam down evacuated pipes, using lenses and prisms to keep the beam in the pipe and enable it to turn corners. (See Figure 1.) Other ideas include pipes which are polished on the inside and thin threads of plastic or glass (fiber optics).

All of these systems will work but so far none are economically feasible. The lens pipe is too difficult to keep aligned, and the others absorb lots of the beam and are hard to manufacture.

Interplanetary space does not present these problems, and it is here that laser communications may have their first major usage. Several studies show that laser systems can have an advantage over others in, for instance, rocket to satellite communication.

Receivers

Receivers are the least of the system's problem. Photodiode and photomultiplier detectors are capable of responding as fast as the beam can be modulated. Past the detector, receiver techniques are generally similiar to those used in the radio and microwave portions of the spectrum.

Comparison With Other Systems

If we compare our laser system with a system using microwave frequencies ($\sim 10^8 - 10^{11}$Hz) we shall see that is has several advantages, but also many disadvantages. Lower frequencies are so crowded and have such narrow bandwidths available that the laser system won't compete with them in its intended uses.

Advantages

The laser system's main advantages are:

1. The small angular dispersion (spreading) of the beam.

2. The vast amount of spectrum available and consequent large bandwidths attainable.

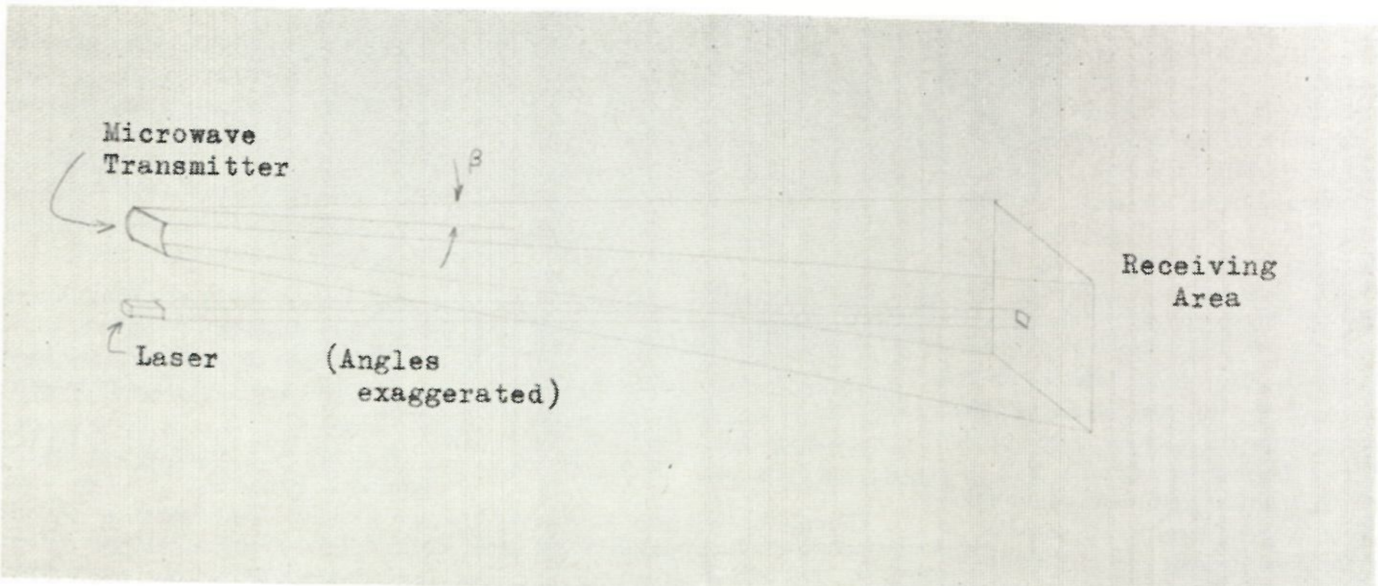


Figure 2: Comparison of Laser and Microwave Beams.

The major disadvantages include:

1. The state of the technology.

2. The narrowness of the beam. (True, this is one of the advantages but finding and keeping such a small beam can be major problem.)

3. The effects of the atmosphere on the beam.

4. The increased noise in the signal at higher frequencies.

Laser and Microwave Beams

Both of the advantages of the laser are a result of its high frequency operation. Theoretically, all of the information being broadcast in the world could be sent over a single beam if it could only be modulated fast enough. As was pointed out in the section on modulators, they are fairly slow at the moment. These high frequencies imply short wavelengths, and theory shows that the width of the narrowest possible beam is directly related to the wavelength. The angle is a thousand times narrower for the laser. If we look at Figure 2, we see that the area covered by these beams is related to the square of the angles. Thus the area for the laser is a million times smaller. If the laser and the microwave transmitter transmit the same power, since that power spreads out over the whole area in the beam, the power per square unit at the receiver is a million times greater for the laser than the microwave. In other words, the microwave transmitter needs to put out a million times as much power to get the same signal on the receiving antenna as the laser.

Disadvantages

As for the disadvantages, those of newness and atmospheric problems have already been discussed. Finding the narrow beam can be a problem, especially in the infrared, when you can't see the beam with your eye.

The last disadvantage, increased noise, is more fundamental; it cannot be overcome by advancing technology or complicated systems. This noise is a result of quantum mechanical considerations. It is sufficient for our purposes just to note that noise at laser frequencies is about 100 times as great as at lower frequencies. Also, in the same category, is the fact that detectors in the infrared and optical regions have had quantum efficiencies of only one to ten percent compared to almost one hundred percent at microwave frequencies. (That is, an average of only one to ten electrons will be emmitted from the detector material for each one hundred photons received). The lower efficiency and higher noise mean that we lose a thousand or ten thousand of the million times extra power required, so the microwave transmitter has to be only a thousand or ten thousand times as powerful.

Thus it is possible for the laser to have advantages, but present technology and economics are keeping it from being used to any great extent. It may well be a good system in the future.

INDEX TO ADVERTISERS

PUZZLES:

THE ROLE OF APPLIED MATHEMATICS IN EARLY AMERICA

OR

PACK MY SLIDERULE WITH MY BEAR-TRAPS BETSY!

MIKE COLGATE

Phineus Fitzgerald, applied mathematician, mountain man, trapper and part-time Notary Public was a walker. He could run, when forced, but he could walk five miles per hour day and night without stop, slowed down by nothing on the North American Continent (except, perhaps, buffalo grass, as you'll see below). Being a walker, Phineus decided to walk, from his home in Tonganoxie, Missouri, across the Great Plains, over the Rocky Mountains and across the Great American Desert to the Sierra Nevada Mountains. The following is the here-to-fore untold story of his trek.

* * *

Phineus crossed the main part of the plains without incident and had just reached Marker Rock, 1,000 yards due east of an important river crossing, when he noticed a curious thing. Due north from the rock there was a perfectly circular area of tall, lush buffalo grass, 200 yards in diameter, when the rest of the country for miles around was bare earth or short, tough wire grass. The center of this circle was exactly 1,000 yards from Marker Rock.

Being an amateur ecologist, and naturally curious, Phineus started toward the phenomenon to investigate. He had walked just twenty yards from the rock, however, when an armed Indian sprang from behind the rock and ran toward him, yelling most savagely. Phineus ran immediately but was only ten yards ahead of the Indian when he reached the buffalo grass. The grass slowed him down considerably, but when he reached the exact center of the circle, he turned and saw that the Indian hadn't entered the grass, but was waiting, watchfully, on the perimeter.

It didn't take Phineus long to realize what the Indian had known all along: on the bare ground outside the circle, the Indian could run exactly four times as fast, unhampered by the buffalo grass, as poor Phineus could in the grass. Phineus escaped, of course, but assuming the chase from Marker Rock to the buffalo grass was a good indication of their relative open ground running abilities, by how much did Phineus beat the Indian to the river crossing and safety?

After crossing the river and living through several hair-raising adventures which won't be related here, Phineus reached a village of Parahoochie Indians, on the edge of the desert, at exactly 12:00 noon on a Monday. It took him precisely one hour to learn the following things:

1. It was exactly 120 miles to the next water, at a Hapaheechie village on the other side of the desert. Anyone crossing the desert needed one pint of water for each five miles he walked, but the wild tribesmen of the desert would attack and kill anyone carrying more than two gallons of water. It was safe, however, to leave a closed flask of water in the desert without fear of theft or evaporation.

2. Phineus would be furnished with drinking water during his stay at the village, but he would have to earn the water for the desert crossing at the rate of one pint for each hour of work.

3. Anyone entering the Hapaheechie village from the desert must present to the Head Chief, Head Medicine Man, Assistant Chief and Assistant Medicine Man, in that order, a gift of an intricately carved buffalo bone. Moreover, the bones must be carved in advance at the Parahoochie village and must contain the exact time and day of their arrival at the Hapaheechie village. Failure to do any of these things, or doing them in the wrong order, would result in being burned at the stake at the hands of the Hapaheechies.

4. Only the above mentioned Hapaheechie officials were allowed to wear feathers and each wore a different color. The Parahoochie villagers would not reveal the correspondance between color and office, but they did mention that the one wearing blue feathers was on bad terms with both the Head Medicine Man and the one who wore red feathers. They further revealed that the Head Chief was a good friend of both the Assistant Medicine Man and the one who wore yellow feathers.

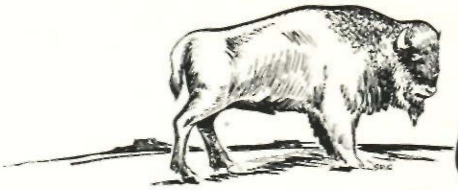
Phineus immediately informed the village buffalo bone carver the day and time to carve onto the four bones and set to work earning the water necessary to allow him to arrive at the Hapacheechie village at the earliest possible time. He rested neither day nor night in his work. When he finished he began his trek and arrived at the Hapaheechie village at precisely the hour indicated on the four bones he was carrying in one of his two empty one-gallon water flasks. What day and what time of day was it?

A man with blue feathers met Phineus at the village gate and introduced himself as the Assistant Chief's son. The only other information he would volunteer was that the villager with green feathers was a good friend of the Assistant Medicine Man. Phineus spotted the other three feathered individuals and immediately presented each a buffalo bone. Phineus wasn't burned at the stake, so in what order, in terms of feather color, did he present the bones?

This, of course, completed Phineus Fitzgerald's trek, since the Hapaheechie village was at the foot of the Sierra Nevada Mountains. We may see more of him, however, in future issues.

* * *

The answers to the questions posed in the above story will appear in the next issue.



Chips

Teacher: "Spell straight."
Second-grader: "S-t-r-a-i-g-h-t."
Teacher: "What does it mean?"
Second-grader: "Without Coke."

A minister was making a call on one of his parishioners when his hostess' small son came running in, carring a dead rat.

"Don't worry, Mom. It's dead. We bashed his head in and beat him until . . ." (at which point he noticed the minster) ". . . until God called him to heaven."

The frowning woman walked up to a little boy on the street corner who was smoking.

"Does your mother know that you smoke?" she admonished.

"Lady, does your husband know you stop and talk to strange men on the street?"

Did you know that in certain parts of Boulder, you can still buy a drink for a dime—or so a recent autopsy discloses.

Sunday School Teacher: "Lucy, why did Noah take two of each kind of animal onto the arc?"

Lucy: "Because he didn't believe in the stork."

Love makes the world go round—but then, so does a swallow of tobacco juice.

An engineer at a large company was examining drawings and specifications for a new instrument which had been ordered by one of the firm's largest clients. Attached to the plans were the coded instructions, "MIL-TDD-41." Not being familiar with these instructions, the engineer called the customer.

"Would you please tell me what MILTDD-41 means?" he asked.

"Sure," replied the customer. "It means 'Make it like the damned drawing for once.' "

We knew he'd never make it in engineering. He thought a slide rule was a baseball regulation.

This is my slide rule. There are many like it but this one is mine. My slide rule is my friend, and I shall learn to love it as a friend. I will obey my slide rule. When my stick tells me that 5x5 is 24.8, then, by god, five times five is twenty-four point eight. I will learn the anatomy of my slide rule, though I die in the struggle. I will use faithfully every scale, the black scale and the red, the inverted C and the inside-out log, the reversed A and the mutilated D. I will master them all, and they will serve me well, they will! I will cherish my slipstick and never shall profanity sear its long, graceful magnesium limbs. My slide rule shall be my brother in suffering. Through long hours of midnight toil we will work together, my slide rule and I. And on the great day when my slide rule and I have finished our appointed task and the problem is done and the answers are right, I will take that damn stick and have one hell of a fire, I will!

They finally put a clock on the Leaning Tower of Pisa . . . no sense saving the inclination if you don't have the time.

The draftee was awakened roughly by his platoon sergeant after the rookie's first night in the Army barracks.

"It's four-thirty," roared the sergeant.

"Four-thirty!" gasped the recruit. "Man, you'd better get to bed. We've got a big day tomorrow."

Then there was the Pollock who tried to beat the train to the crossing. He hit the seventy-sixth car.

"I have a splinter in my finger."
"Been scratching your head?"

Four Marines were playing bridge in a hut in Viet Nam when a sailor burst in.

"The enemy is landing a force of about four hundred men on the beach."

The Marines looked up wearily. Finally one said: "I'll go. I'm dummy this hand."

The closest our civilization has gotten to perpetual motion so far is street repairing.

When a GI saw LBJ at the airport in Viet Nam, he ran over and asked: "Aren't you President Johnson?"

"Yes."

"Man," replied the soldier. "That's what I call a draft board!"

Rumor has it that the prerequisite for Engr. 301 is a pervious course in Engr. 301.

Then there is the hippie couple who had their baby christened in Greenwich Village so he could have a fairy godfather.

Walter was explaining what a dull town the small burg was.

"No night life?" Jim inquired.

"Nope. She left last week."

What is white on the outside, green on the inside, and hops?

A frog sandwich.

Which reminds us of the IBM salesman who dropped LSD. He went on a business trip.

In Hungary, a commissar asked a peasant how the potato production was going.

"Oh, fine," replied the peasant. "We have so many potatoes that if we put them in a pile, they would reach clear up to God."

"But you know there isn't any God," replied the commissar.

"Well, there aren't any potatoes either."

—Randy Lorance

Here in the hills of East Tennessee we are known as Eastman and the atmosphere is sort of different

Ladies' picnic on a Thursday afternoon in Warrior's Path State Park near Kingsport, Tenn. Down in the valley the chemical engineering is as up to date as any on earth, but the tensions of the big cities seem slow to penetrate the hills of East Tennessee. Some call this isolation and like it. Some wouldn't. We offer choice.

You may have first heard of Kodak when you were eight years old and grandpa pointed a camera at you. In Kingsport, Tenn., Longview, Tex., and Columbia, S.C., there are 15,000 of us who make no cameras and no photographic film but turn out fibers, plastics, and chemical ingredients for a hundred other industries. In fact, we can offer no less a variety of chemical engineering opportunities in those communities than in Rochester, N.Y., where we produce our renowned photographic goods for enjoyment, for business, for education, and for the professions.

Although many Kodak chemical engineers eventually move into production or management functions, none start there. First assignments are in development and process improvement, or systems and research. A chemical engineer might also make full use of his professional competence in liaison with our customer companies, in which case he is in marketing and had better count on moving around quite a bit. Otherwise we are so set up that we can give an engineer all the opportunity for advancement he wants without ever asking him to change communities.

We make the same promise to mechanical, electrical, and industrial engineers, by the way.

Drop a note about yourself to Business and Technical Personnel Department, Eastman Kodak Company, Rochester, N.Y. 14650. If you have any geographical preferences or any other category of preferences in work, mention them. We are an equal-opportunity employer.

And here, just to be specific, are what occupy the chemical engineers down in the valley:

RATHER SPECIAL

- Solid-phase polymerization
- High-temperature vapor-phase pyrolysis
- Liquid-phase air oxidations
- Non-Newtonian flow
- Drying of tacky pastes
- Extrusion of hot, viscous, temperature-sensitive materials
- Design of systems for melt- and solvent-spinning
- Oxidation of ethylene to acetaldehyde and ethylene oxide
- Oxo process
- Olefin polymerization
- Vapor-phase dehydrogenation

MORE GENERAL

- Design of pilot plant and plant equipment from laboratory data and basic chemical engineering unit operations
- Drying operations for fibers, plastics, and chemicals
- Viscous flow and heat transfer
- Chemical kinetics rate models
- Dispersion systems
- Mixing studies
- Use of computer hardware and software in plate-to-plate distillation program, hydraulic design, heat-exchanger design, mass transfer equipment design, reaction simulation

Kodak

"Traffic is terrible today!"

". . . Accident in the left hand lane of the Queens-Midtown access ramp. Right lanes moving slowly. Fifteen minute delay at the Brooklyn Battery Tunnel. Lincoln Tunnel backed up to the Jersey Turnpike. Extensive delays on Route 46 in the Ft. Lee area. That's the traffic picture for now, Bob."

However, technical people at GE are doing something about it. Development and design engineers are creating and improving electronic controls and propulsion systems to guide and power transit trains at 160 mph. Application engineers are developing computerized traffic control systems. Manufacturing engineers are developing production equipment and new methods to build better transportation products. And technical marketing specialists are bringing these products and systems to the marketplace by working with municipal and government agencies.

Young engineers at GE are also working on the solutions to thousands of other challenging problems—products for the home; for industry; systems for space exploration and defense. When you begin considering a career starting point, think about General Electric. For more information write for brochure ENS-P-65H, Technical Career Opportunities at General Electric. Our address is General Electric Co., Section 699-22, Schenectady, New York 12305.

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