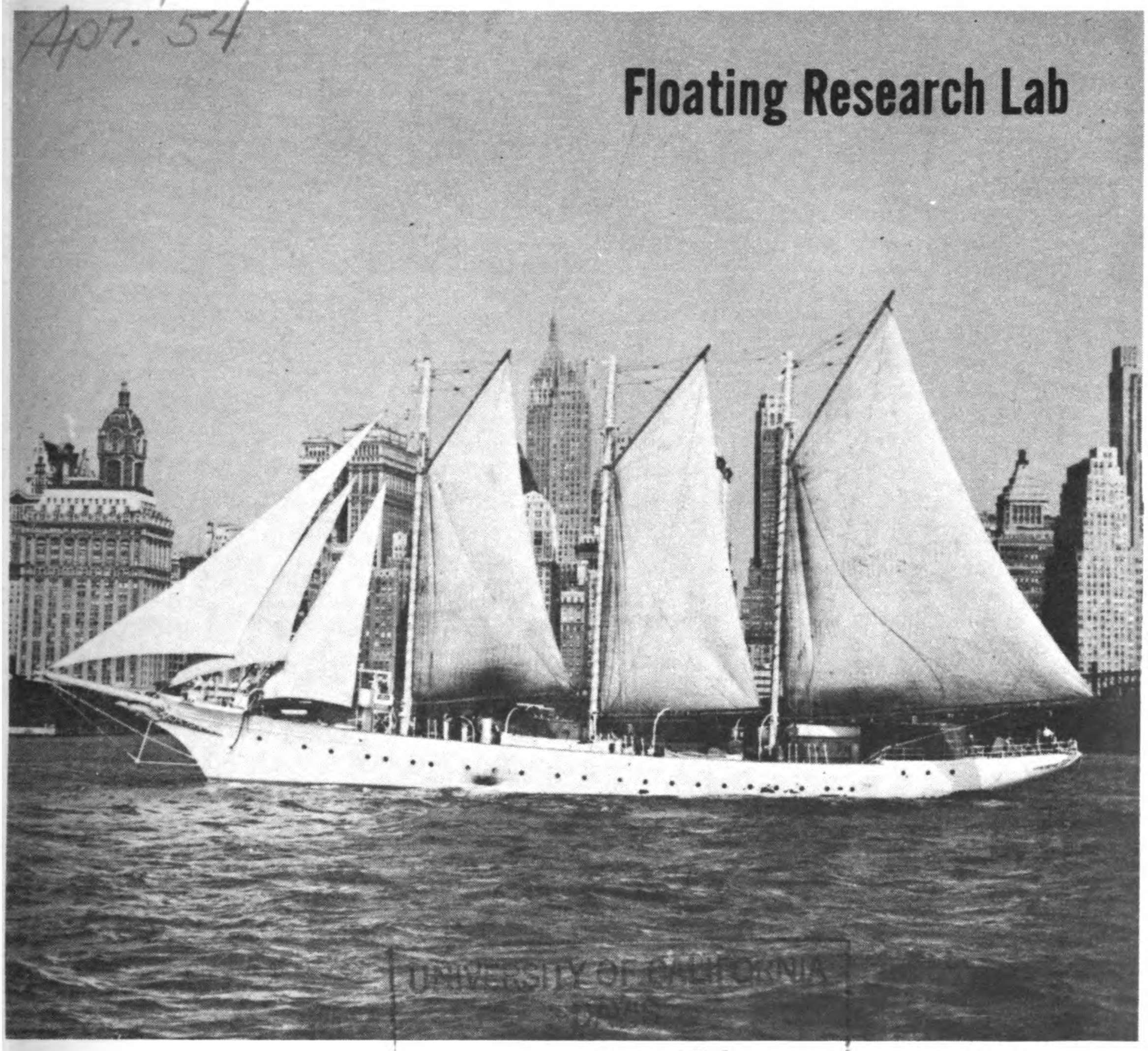
OFFICE OF NAVAL RESEARCH APRIL 1954

RESEARCH REVIEWS



NAVEXOS P-510

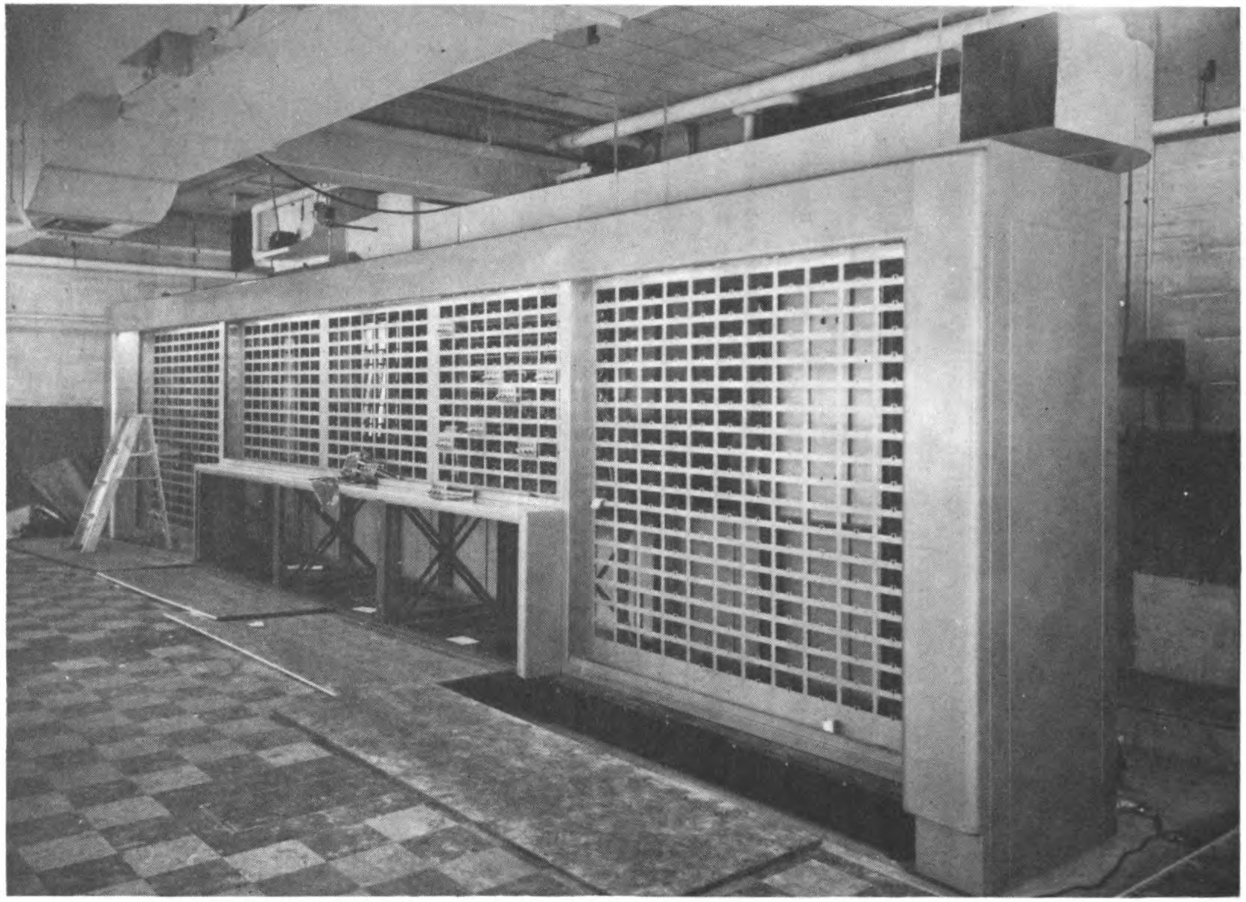
DEPARTMENT OF THE NAVY
WASHINGTON, D. C.

COVER PHOTO: The sleek three-masted schooner "Vema" appears against the lower Manhattan skyline as she returns from a recent voyage. This ship has served as a floating laboratory for many of the oceanographic investigations undertaken by scientists of Columbia University's Lamont Geological Observatory. These studies are designed to provide the data necessary for the preparation of more accurate maps and charts of the oceans. The Navy's interest in this field is described on page 23.

Research Reviews endeavors to report briefly highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 740, Office of Naval Research, Washington, D. C.

Approved by Bureau of the Budget, 14 February 1952

In This Issue



The electronic computer shown here can perform some million multiplications, ten million additions and twenty million other arithmetic and logical control orders in 48 minutes. The potentialities of this machine in making possible speedy and accurate weather forecasts are rapidly becoming realized.

Numerical Weather Prediction

Bruce Gilchrist

The Institute for Advanced Study, Princeton, New Jersey

In early days and indeed up until quite recently, attempts were made to forecast the weather by means of periodicities such as enable one to predict tides. Unfortunately the atmosphere exhibits no such periodicities and no simple set of causal relationships can be found which relate the state of the atmosphere at one instant of time to its state at another. It was the realization of this fact that led Jacob Bjerknes of the University of California's Dept. of Physics at the beginning of this century to postulate that the problem of weather forecasting was nothing less than the strict application of the principle of hydrodynamics and thermodynamics to the atmosphere. It was twenty years more, however, before Lewis F. Richardson, noted British physicist and author of "Weather Prediction by a Numerical Process," suggested a practical way of using the complicated mathematical equations in terms of which these principles can be stated. The method proposed was a numerical one and Richardson showed exactly how it could be used. The actual forecast used to test the method was, however, a failure, and, while at the time the work may have been regarded more as a curiosity than as of practical use, the spark had been lit.

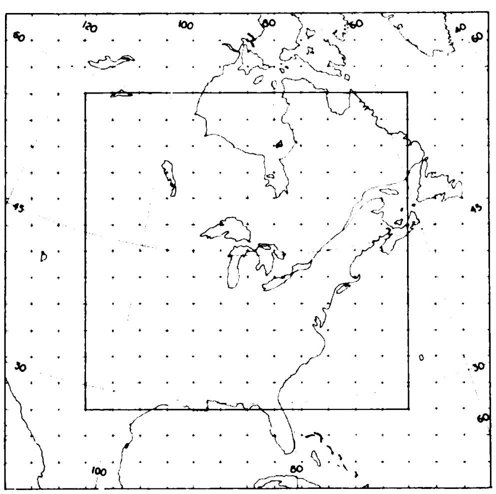
For a long time, no one ventured to follow in Richardson's footsteps. The lack of observational data over many areas and the magnitude of the computing task stood as apparently unsurmountable barriers to the dream that one day it might be possible to advance the computations faster than the weather. The Second World War, however, brought two important developments, namely the increase in the use of the radiosonde which made possible a great increase in the number of upper air observations, and the electronic computing machine, which enabled computations to be performed at very high speed. Thus, with the end of the war, interest revived in Richardson's problem and, with numerical weather prediction as its major objective, the Meteorology Group at the Institute for Advanced Study at Princeton, New Jersey, was set up under the sponsorship of the Office of Naval Research.

Richardson tried to include all available knowledge regarding the atmosphere in one ambitious forecasting scheme. In contrast to this the Princeton Group has confined itself, at least in its initial stages, to more limited objectives. Instead of attempting to deal with the atmosphere in all its complexity, we have considered simplified mathematical models approximating the actual motions to a greater or lesser degree. By starting with models incorporating only what are thought to be the most important of the atmospheric influences, and by gradually bringing in others, one is able to proceed inductively and thereby to avoid the pitfalls inevitably encountered when a great many poorly understood factors are introduced all at once.

A necessary condition for the success of this step-wise method is, of course, that the first approximation bear a recognizable resemblance to the actual motion. Fortunately we know some of the main factors governing the large-scale atmospheric motions and the use of the simplest model, the so-called barotropic one, resulted in a recognizable forecast. At any rate it would seem clear that a model embodying in mathematical form existing forecasting methods could not fail completely. This conviction has served as the guiding principle of the Princeton Group.

Up to the present time, three models of increasing complexity have been developed and tested. These may be regarded as being characterized by the fact that they respectively take into account observations of pressure at one, two and three different heights in the atmosphere and are usually referred to as one-level, or barotropic, two-level and three-level models, respectively. It is clear that in the barotropic model we consider the atmosphere as being uniform in the vertical whereas in the two- and three-level models we allow successively more variation in this direction. It is still not clear how much definition is required in the vertical in order to obtain a reasonably accurate forecast. Theoretically, for a perfect forecast we require continuous definition in the vertical. This is clearly impossible in practice as indeed is the giving of data at closely spaced intervals owing to the enormous time required to obtain consistent analyses of the weather maps at all the required levels. We, therefore, have to find a balance between theoretical requirement and practical possibility. The answer to this will probably only be found by a series of trials with various models.

Since the earth is a spheroid we would, if we forecast for the whole atmosphere, have no horizontal boundaries. However, to define only the reasonably large-scale atmospheric motions for such an area would require so much data, that even ignoring the meteorological difficulties of such a problem, the memory requirements could not be met by existing electronic computing machines. The present models have therefore only used data from a grid of 361 points each 300 km apart, an area sufficient to cover the major part of the United States and Canada as shown here. The effect of introducing these artificial boundaries is easily seen if we consider a part of the boundary at which air is entering the forecast region. This air enters the region with unknown properties and thus some assumptions as to these properties have to be made. This of necessity introduces errors along the boundaries. It can be shown that these errors propagate inwards at about the mean wind speed and thus for very short range forecasts they will not be too serious. These boundary effects do,



Location of finite-difference grid used in the forecasting models. Large square outlines 19 x 19 grid used for computations; smaller square outlines region over which verification was made.

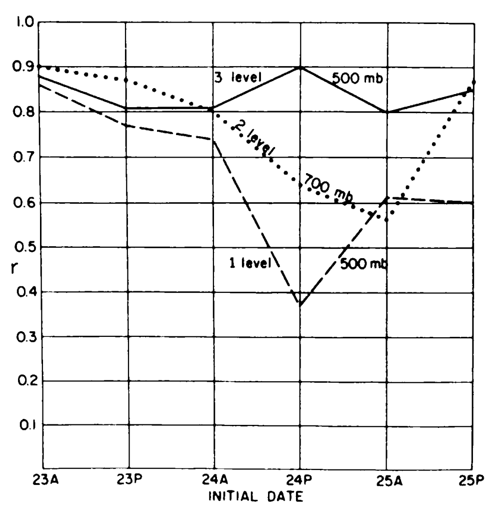
however, limit the forecast period for the area used with the present models to about 36 hours.

Similar boundary errors are introduced at the top and bottom of the atmosphere since, for instance, we at present for simplicity assume the surface of America to be flat. The mean vertical velocities in the atmosphere are, however, very small compared with the horizontal ones and thus the influence of these errors is no more serious than those introduced at the lateral boundaries.

The principal meteorological assumptions made in the derivation of the multi-layer models are that all the motions are quasi-geostrophic; that is, the horizontal wind field can be derived sufficiently accurately from the horizontal pressure field. Secondly, it is assumed that the motion is quasi-hydrostatic; in other words, the pressure at any level is due to the weight of the air above and the forces produced by the vertical motions can be neglected. Thirdly, there is no supply of heat to the air from external sources such as heated land masses. These assumptions are justifiable provided the forecast period is limited to about thirty-six hours—a condition also necessitated by the present area and boundary conditions.

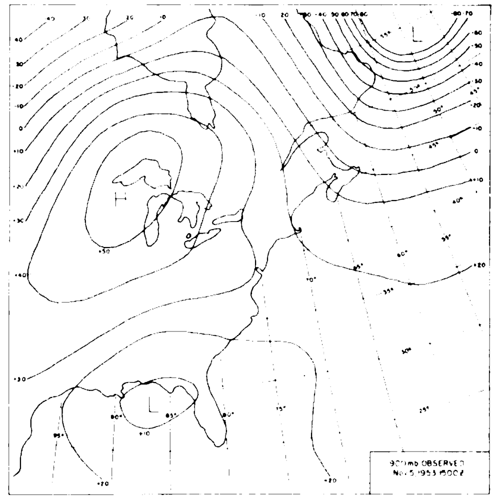
The observations used in the forecasts as stated previously are the pressures at various heights or what may be regarded as equivalent, namely the heights of given pressure surfaces. It follows from the quasi-geostrophic assumption that these give the three-dimensional wind field. The initial data thus defines the "motion" of the atmosphere and the forecast is for the corresponding motion at a later time. As yet no attempt has been made to forecast directly the more humanly relevant weather elements such as rainfall and sunshine amounts. A human forecaster given the "motion" field accurately could, however, forecast these weather elements much more accurately than at present when he has to first make a "motion" forecast. This "motion" forecast is the part of his work which is most subject to errors and which probably accounts for some 70% of bad forecasts. We have thus regarded the first phase of our work to be the production of good forecast of the motion as defined by the pressure distribution in the horizontal and vertical.

A typical three-level forecast is made at Princeton in the following way: First, observations from the various stations and weather ships are plotted on maps and analyzed. The height values are then read off at the 361 grid points at each of the three pressure levels to be used. (The best so far have been the



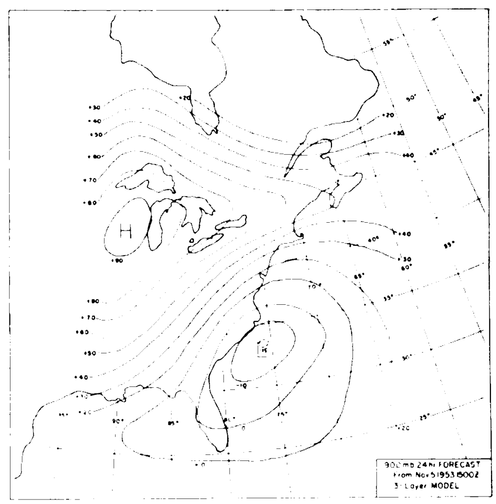
Correlation coefficients between forecast and observed twenty-four hour changes of the height of the pressure surface indicated for each of the three forecasting models.

900, 700, and 400 mb levels; these are at approximately 24,000, 10,000 and 3,000 ft., respectively.) These values are then punched on IBM punch cards which together with a number of instruction cards are fed into the Institute's electronic computing machine. At the end of approximately 48 minutes of computation, during which time the machine performs some million multiplications, ten million additions and twenty million other arithmetic and logical control orders, the machine punches out the 24-hour forecast of the pressure at each of the 1083 grid points. These cards are then fed into a tabulator which prints the pressures on maps which can then be analyzed. If required, a forecast of the associated phenomena such as precipitation can then be made.

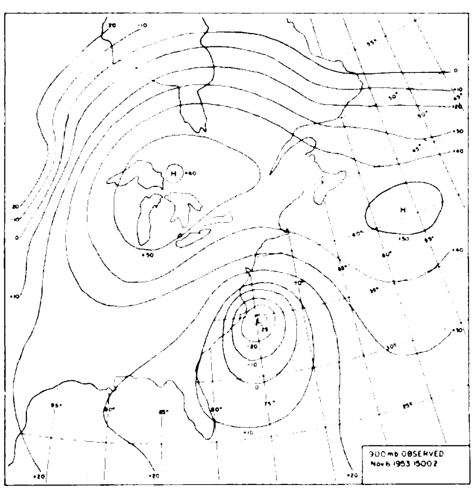


Initial 900 mb map (units are deviations from the standard height of the 900 mb surface in tens of feet).

In order to test the various models, the weather for the period November 23 to November 26, 1950 was chosen and careful analyses of the observed data were made at numerous levels. The observations were for every 12 hours; thus when 12 and 24-hour forecasts were made from a given set of observations we were able to verify the forecast changes against the observed changes. The particular situation chosen has some personal interest to the residents of Princeton as the period covered that of an unexpected but very intense storm which did considerable damage locally. Meteorologically the situation is interesting in that it is an example of rapid cyclogenesis the onset of which was not forecast by conventional methods.



Forecast 900 mb map twenty-four hours after initial date.



Observed 900 mb map twenty-four hours after initial date.

In order to compare the three sets of results, correlation coefficients between the forecast and observed pressure changes were computed. These are shown on the bottom of page 3 from which it will be seen that for the forecast period beginning on November 24 at 1500 GMT, the time of the intense storm, the accuracy increased with the number of levels considered. The maps opposite show a particular forecast for the 900 mb or 3,000 ft. level for a more recent occasion obtained with the three-level model. This is a very good example of the accurate numerical prediction of the motion of a depression along the East Coast which resulted in considerable snow fall along the eastern seaboard and which the human forecaster had said would move out to sea. The forecast is by no means perfect but gives ample hope of increased success with more physically realistic models.

It is intended to try the various models on more situations in order to test their general applicability. Three cases of cyclogenesis have so far been considered with the three-layer model with definite success in each case. A much longer series will be necessary before any definite conclusions can be drawn but it seems that the three-level model can in difficult situations predict cyclogenesis as well, if not considerably better, than the regular forecaster can using conventional methods.

Research is very actively proceeding on two variations of a five-layer model as well as on the incorporation of such features as a variable land height and heat sources such as are produced by latent heat when there is precipitation. Preliminary results of this research indicate that considerable improvements in numerical forecasting can be expected in the near future. The whole subject is, however, a very new one and a very great deal of work will have to be done on it before a foolproof numerical forecasting system is put into general use.

Symposium on Origins of Drug Resistance

A symposium on "Origins of Drug Resistance" was held at the Hotel Statler, Washington, D. C., March 25-27. Joint sponsors were the Office of Naval Research and the University of Pennsylvania.

Dr. Manasseh G. Sevag, Associate Professor of Bacteriology, School of Medicine, University of Pennsylvania, was chairman of the committee arranging for the conference. ONR representatives were Dr. Roger D. Reid and Dr. Orr E. Reynolds.

Participating in the program were outstanding medical scientists from England, France, Germany, Canada and the United States. The sessions were devoted to the following topics: the origins of microbial drug resistance, tolerance and addiction to drugs and alcoholism, resistance to insecticides and herbicides, factors in resistance to infectious agents and biochemical mechanism of carcinogenesis and the nature of tumor immunity.

CORRECTION

The article on "Synthetic Mica for Vacuum Tube Use," which appeared on pages 7 to 10 of the February 1954 issue, should have credited the Brush Beryllium Company with current study and development of synthetic mica under ONR contract.

ONR Research Policy

Emanuel R. Piore

Deputy and Chief Scientist, ONR

Almost eight years have passed since the Public Law creating the Office of Naval Research was approved by the President, in August 1946. If an additional year is added for the life of the Office of Research and Inventions, ONR has been operating essentially for about nine years. It thus seems appropriate at this time, when everyone in the Department of Defense is concerned with the "new look," to make some observations in regard to the Office of Naval Research and the new look.

In its nine years ONR has become an important member of the scientific and engineering community, concerned with the prosecution of research and development programs to increase the effectiveness of the forces afloat. During these years, the youngest organization in the Department of the Navy saw the scientific community convert from war to peace, and participated actively in this dramatic event which saw American science assume leadership in, and almost domination of world science. It watched the growth of naval laboratories and the continuation of certain OSRD/NDRC activities with changes of management and sources of funds, and modification of programs and tempo. It participated, essentially as an observer, in the creation of the Department of Defense. The ability to react to Korean hostilities, in making available to the Navy the best in science and technology, demonstrated the wisdom of those who were responsible for the initial planning and programming. During this period new laboratories, such as Lincoln, were created. Although the Navy's interests were not dominant in these particular laboratories, the Navy participated through ONR.

There were also organizational changes in the Department of Defense and in the Government in Washington. The Office of Scientific Research in the Air Force and the Office of Ordnance Research in the Army were created. Congress established the National Science Foundation. There was the Berkner Report which resulted in the formation of the Office of Science Adviser in the State Department. Actions such as the modifications of the program and the scope of the National Bureau of Standards should be noted.

Being a dynamic, creative, and imaginative organization, ONR modified its program and activities with changing conditions to ensure that the best in science, engineering, and technology are available to the Navy—more specifically to the fleet, the Chief of Naval Operations, and the Bureaus. These modifications are necessary. The actions taken are determined by the changing needs of the Navy and the changing conditions in the community in which ONR lives half of its life—the scientific and engineering community. Thus one always looks forward, and the new look has been part of ONR's operational concept for nine years.

In considering the current basic operational concept that formulated the program and activities that ONR prosecutes, it is well to reiterate and reproduce in part from the basic documents that created ONR, that gave it authority and an appropriation so that it could contribute to the effectiveness of the fleet, to the common defense and the general welfare of our country. The preamble to Public Law 588, 79th Congress, is the best summary written to date:

To establish an Office of Naval Research in the Department of the Navy; to plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power; and the preservation of national security; to provide within the Department of the Navy a single office, which, by contract and otherwise, shall be able to obtain, coordinate, and make available to all bureaus and activities of the Department of the Navy, world-wide scientific information and the necessary services for conducting specialized and imaginative research; to establish a Naval Research Advisory Committee consisting of persons preeminent in the fields of science and research, to consult with and advise the Chief of such Office in matters pertaining to research.

A more explicit statement of the heavy burden placed on the Chief of Naval Research can be found in the directive issued by the Secretary of the Navy to implement Public Law 588. It is reproduced here in part:

(a) The Chief of Naval Research shall be the principal adviser to the Secretary of the Navy on all research matters and such developments as may be expected from research.

(b) The Chief of Naval Research shall keep the Chief of Naval Operations advised of findings, trends, and potentialities in research and shall disseminate information to interested Bureaus and offices within the Navy Department, and to other Governmental or private agencies as may be appropriate, on naval and other research.

(c) The Chief of Naval Research shall be the principal representative of the Navy Department in dealings of Navy-wide interest on research matters with other Government agencies, corporations, educational and scientific institutions, and other organizations and individuals concerned with scientific research.

(d) The Chief of Naval Research shall survey the trends, potentialities, and achievements of scientific research and development and shall plan and coordinate research programs throughout the Naval Establishment.

(e) The Chief of Naval Research shall study and collaborate with the Chief of Naval Operations and the Bureaus in the formulation of the principal development programs of the Navy.

(f) All plans within the Navy Department for establishment of, abolishment of, or significant changes in, all laboratories concerned with research or development shall be referred to the Chief of Naval Research for comment and recommendation prior to final action.

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(g) The Chief of Naval Research shall supervise, administer, and control all activities within or on behalf of the Navy Department relating to patents, inventions, trademarks, copyrights, royalty payments, and similar matters, and correlate such activities with the research and development activities of the Navy.

(h) The Chief of Naval Research shall undertake, (i) upon his own initiative, or at the direction of the Chief of Naval Operations, or at the request of any Bureau or office of the Navy Department, the development, design, maintenance, modification, and improvement of training devices and aids, and components thereof, and, (ii) at the request of the Chief of Naval Operations or any Bureau or office of the Navy Department, the production of training devices and aids, and components thereof, to the extent that appropriations are made available therefor.

The Chief of Naval Research has available to discharge these heavy responsibilities:

(a) The Naval Research Laboratory, for the conduct of basic research, applied research, and development.

(b) The Special Devices Center, for the development of training devices and aids, and related matters.

(c) The Patents Division, for the patent and royalties administration for the Department of the Navy.

(d) The Research Group, for the conduct of research by contract at universities, non-profit and commercial institutions, and other government laboratories. This Group also performs the staff functions of coordination, dissemination, planning, and evaluation of research, and related developments as assigned.

(e) The Branch Offices and Resident Representatives in the United States, to aid in administration of contracts at universities.

(f) The London Branch Office, to discharge the foreign responsibilities referred to in the Preamble to Public Law 588.

(g) The Underwater Sound Reference Laboratory, to act as a source of standards for underwater sound equipment and perform research in standards.

ONR's operation is based on the premise that it must continually be a "new look" in the research and development area, and introduce or sell this new look to the Secretary of the Navy, the Chief of Naval Operations, and the Bureaus. ONR's reputation in the outside world is based on the record that has been established in the conduct of research by contract, and in its own laboratories—the largest one with the broadest scientific coverage being the Naval Research Laboratory. The reputation of ONR within the Navy is based on the utilization of these research programs in coordination, planning, and advising the Secretary of the Navy and the Chief of Naval Operations on the impact of science and technology on the Navy's requirements. These latter responsibilities are the most difficult to discharge. Many organizations have met disaster in planning and coordinating research and development programs. Thus it is well to review how ONR has been operating in this area and how it will continue to operate in the immediate future.

The philosophy of planning and coordinating research programs is based on the concept that formalities be kept to a minimum and that people at the bench be brought together as often as possible. Coordination is finally achieved only if groups working on similar problems have sufficient respect for each other that they do not question each other's results or procedures; there is no need to have the work re-done to ensure from everyone's point of view that it is correct. To obtain this mutual trust and respect requires that a forum be provided in which people with common interests, working on related problems, can meet and pick each other's brains. Thus symposia are held; committees on specialized fields, such as underwater sonar propagation and human engineering, are formed. Inter-laboratory committees are encouraged. Sponsorship of meetings, such as the meetings of the senior scientists of Navy laboratories, is being continued. Coordination is being accomplished by persuasion rather than by fiat.

The surveying of trends and potentialities of science, and collaboration with the Chief of Naval Operations and the Bureaus in the formulation of important development programs in the Navy, are approached, again, as cooperative ventures. At times, external groups are used and studies are initiated, such as HARTWELL that dealt with undersea warfare; and studies in specific technical fields, such as METCALF that dealt with infrared. Then internally, principally within the Research Group with the cooperation of other components of ONR, such as NRL and the Branch Offices, warfare fields are studied in great detail to form the basis for the Navy's research and development planning. Guided missiles have been looked at, as well as the whole problem of CIC, and air defense. In addition to the internal studies, there is the contract mechanism of using commercial contractors and universities, such as the Operations Evaluation Group. The Chief of Naval Research is a member of the Navy Research and Development Review Board, which pulls together the entire research and development program for the Navy.

In summary, the philosophy has been to resist any establishment of formal machinery in order to coordinate, plan, etc. We act as an umbrella for inter-Bureau and inter-laboratory groups to meet. We move into technical areas that appear critical or warfare areas that require pulling together. It is the general feeling that this is the most effective way to operate, for no one acquires a vested interest or a career in coordination, and one always looks at the content of programs, rather than the mechanics of getting data on beautifully designed charts so that to the untutored eye it may appear that everything is rosy. The coordination, the pulling together, of the research and development program in this seemingly informal way, rather than by complex mechanics in administrative procedure, imposes a thorough look into the content, which, in turn, requires a high degree of competence on the part of those carrying the burden. The ability of the Navy, through the Office of Naval Research, to operate in this fashion stems in a large measure from the scientific programs that are supported in laboratories and through contract, by providing information on what is best in science and technology, and providing contact with the best minds in these areas. There are also other compelling reasons for the Navy to engage in and support scientific research.

The Navy in carrying out its mission to support national policy has always relied on technology. In the early days of our Republic, the sailing ships used very crude instruments, principally for navigation. Skipping over a period of a hundred years or more, let us examine very briefly the operation of the fleet during the Spanish-American War, for example—Dewey at Manila. The navigation instruments were a bit more refined; the communication between ships, essentially by candlelight and semaphore, was the same. The detection of the enemy was by the seaman's eye.

Contrast this with the changes in naval technology during the last 25 years. Not only has the time span been shortened in introducing more complex technical equipments into the fleet, but the rate at which they have been introduced has been accelerated. Similar observations can be made in regard to equipments below deck, such as power plants. A hundred years ago science was a very leisurely occupation, an avocation of brilliant minds. Today it has become big industry. In physics, it took more than a hundred years of experimentation to provide information that could test the validity of Newton's concept of light in terms of corpuscles. At present, the time between a theory and the critical experiment may be as short as a week. Science is now a professional occupation. Thus the impact of science on technology is much more immediate, and the impact of technology on science is also very immediate. This acceleration of time between the birth of a scientific concept and its application forces the Navy to be deeply involved in science. These realities are recognized by maintaining scientific programs within the Naval Research Laboratory and by contract with the external scientific and technological community. The reasons for this twofold approach are very similar.

Scientific ideas are generated by the curiosity of the human mind regarding the external world—the theory of relativity is an example—and by the interplay of technology on science, the desire to make this world a better place to live in. In order to participate fully in this interplay of technology on science and science on technology, the Navy must be in science. In the market place of ideas, where science gets some of its inspiration, the Navy's needs, its problems, and its technical frustrations, get a fair hearing. This is the reason that one finds a program in scientific research in some naval laboratories. This also is the reason why ONR balances the large Bureau effort in development with a scientific and applied research program through contract. The entire technical effort has an organic Navy unity through the coordination that ONR performs.

The guide lines for the new look for scientific research are:

The scientific research of the Department of the Navy should provide a flow of fundamental knowledge of the sort the Navy needs in connection with present and future weapon developments; maintain contact with the scientists in the country in order to encourage their interests in fields of potential importance to defense; make the military services aware of new scientific findings; and provide a base for prompt mobilization of the scientific effort in case of severe emergency.

In order to ascertain those areas of potential contact that are vital to the Navy, the programs can be classified into three general areas:

(a) Scientific areas that are of vital importance to the Navy with regard to exploitation for future readiness of our naval forces and which have at this time limited interest for exploitation to other components of the nation's community. Some examples are oceanography, Arctic research, upper atmosphere research, numerical analysis, applied mathematics, high energy (explosive) chemistry, and fluid mechanics. In these areas it is necessary at times to stimulate interest among the scientific and technical community. The military departments in these cases are usually the only source of such stimulation.

(b) Scientific areas that are of vital importance to the progress of naval technology and operations, and at the same time of great significance to industry and other components of society. Examples of such fields are solid-state physics, statistics, microbiology, physiological psychology, electrochemistry, meteorology, and personnel training and selection.

(c) The last scientific area deals with those fields that at present appear to have comparatively remote possibilities as a source for naval exploitation, but yet there is sufficient potential to warrant modest support in order to ensure awareness of these areas and rapid exploitation when the occasion arises. This listening-post activity must be of the highest quality and in balance with the rest of the effort.

These are our current ground rules in the program in scientific research performed by contract and in naval establishments.

When ONR started nine years ago, the needs of the Navy in these three areas of research were much broader. ONR was then the only organization in the Federal Government equipped to deal with science, and it assumed that responsibility. As the National Science Foundation came into being, the needs of the Navy gradually changed. The needs were modified again as the Army assumed certain responsibilities by creating the Office of Ordnance Research, and the Air Force by creating the Office of Scientific Research. This was according to plan.

Our funds throughout the years, as even now, are limited. Once guide lines are set, the expenditure of funds is planned to maximize the benefits to the Navy. The programs of other Government agencies, of industry, and even the programs abroad, play a vital role in maximizing our effort. The content is bound to change with time and changing conditions. The scientific program will be continued with the same vigor, enthusiasm, and imagination that has characterized it in the past.

Flight Research on a Personal Type of Airplane

August Raspet and George Lambros

Aerophysics Department, Mississippi State College

Designers of small planes have faced a serious handicap in that they have either not had windtunnel measurements on their projected designs or that such windtunnel measurements as were made were done in a high turbulence tunnel. In rare cases, tests were made with power on and power off. There is still another factor which militates against tunnel testing, and that is the large scale corrections which must be made from the small models usually used to the full size airplane.

When an airplane is brought to the prototype state, it is already too late to make any major modifications for production tooling is already well advanced. If manufacturers would treat the prototype as a flight research article for the next model of their series, then modifications and improvements on the prototype would see application and would therefore appear worthwhile.

The philosophy of treating a flying airplane as a research bed for collecting fundamental information, which will guide the designer in projecting the next generation of airplanes, is not new. Such a technique has resulted in the development of the world's highest performance aircraft, the sailplane RJ-5, which as laid out had a glide ratio of 29 but after six systematic modifications reached a glide ratio of 40 to 1.

What the newer flight research techniques offer is the possibility of separating the various contributions to performance. On an airplane in addition to parasite drag, profile drag, and induced drag, there are the effects due to propulsion. It is most necessary to know what the propulsive efficiency of the airplane is, the cost in power of cooling the engine, and the effects of slipstream on the aerodynamics of the airplane.

By utilizing the available and well-developed techniques for sailplane performance measurement, it is possible to delineate many of the aerodynamic performance parameters of an airplane. In particular, by making glide tests with the propeller removed and the cowl sealed, one gains a true measure of the aerodynamic losses of the airplane in its clean condition. By comparing the power required in level flight with power on with that required over the same speed range in gliding flight, the aerodynamicist is able to duplicate in full-scale flight the power-on and power-off tests he so fervently desires in the windtunnel.

The beauty of the full-scale flight research technique is its extremely low cost when compared to full-scale tunnel tests. There is hardly a manufacturer in the U.S.A. who could afford full-scale tunnel tests, but there are many who could afford full-scale flight tests yielding just as good if not better data obtained in the turbulence-free atmosphere under actual conditions of airplane utilization.

As an example of full-scale flight research technique, the authors offer the results of a series of measurements made on an airplane no longer being produced but whose external form, low wing, tractor with retractable landing gear still finds favor among the designers. The aircraft used for these flight tests was the 1947 Bellanca Cruisair Senior Model 14-13-2, a four-place low wing monoplane with retracting landing gear, with the Franklin 150 horsepower six-cylinder opposed engine. The aircraft is equipped with an Aeromatic propeller. Wing span is 34 feet; wing area 161 square feet; yielding an aspect ratio of 7.12. The gross weight of the Bellanca as glide tested was 1735 pounds.

For the glide tests, the propeller was removed and a standard glider tow release installed on the propeller shaft flange. A 450 horsepower Stearman served very well as a tow plane. A nylon rope of 3/8 inch diameter provided the connection between tow plane and test airplane.

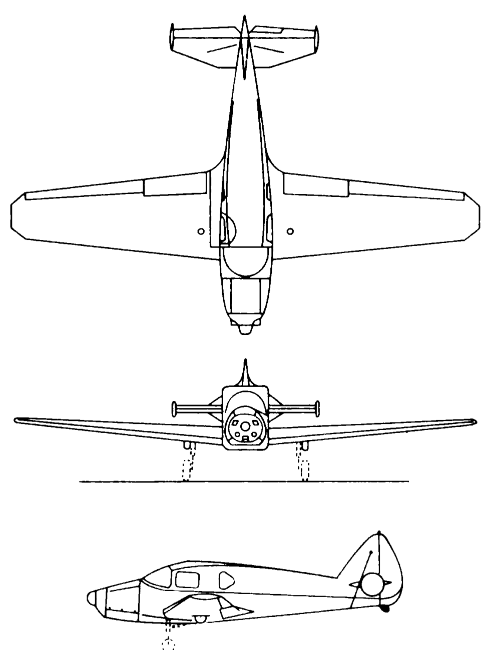
1. The airspeed system was calibrated by means of timing upwind and downwind passes over known distances on the ground. Indicated airspeed is plotted versus true airspeed giving the Position Error Curve shown on the top of page 14.

2. Power required for level flight was found for three conditions. In normal level powered flight, measurements were made of manifold pressure and rpm; horsepower was then computed from the engine manufacturer's performance curves at the ambient air temperature. The value of horsepower thus found was plotted against airspeed.

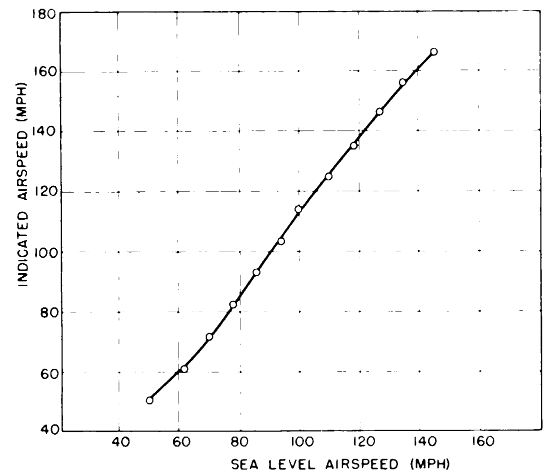
In gliding flight, both with cowl opened and with cowl intake and exit sealed, horsepower required was calculated from the rate of sink and the aircraft weight. These two curves are also plotted against airspeed.

3. The flight polars for the aircraft in gliding flight are shown on the top of page 15. The Bellanca was towed to 12,000 feet altitude and measurements of sinking speed made at various airspeeds. Data were taken for both configurations, opened cowl and sealed cowl, and then corrected to standard sea level conditions.

The installation of the pitot-static head 20% of the chord below and 20% of the chord ahead of the leading edge of the wing leads to



Bellanca Crusair Senior

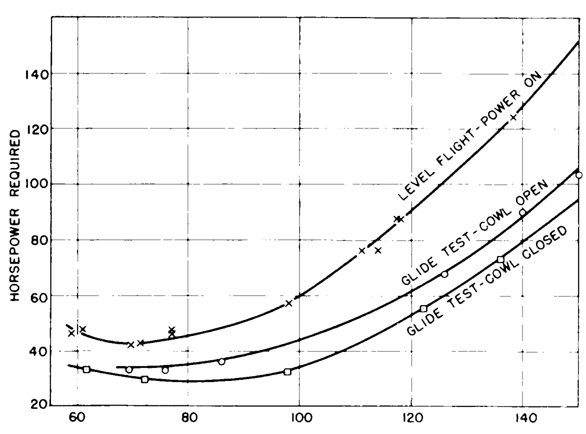


Position Error Curve for Bellanca Crusair

a negative error going from 4% at 60 mph to 7% at 110 mph according to Thompson. Perhaps in an effort to reduce this negative error, a ring of wire was soldered to the pitot-static tube of the subject airplane just ahead of the static holes. This ring effectively decreases the static pressure, thereby yielding a larger pressure differential on the airspeed indicator. For the airplane examined in this work, the correction applied with the ring was too large, resulting in indications of cruising speeds much too high. At 120 mph actual sea level speed the indicated airspeed was 150 mph.

A better way to solve the problem of reducing position error for airspeed systems than by using a ring around the pitot-static tube is to select a position on the airplane where this error is very small. The highest point on the vertical tail is one such point. The removal of the pitot-static head from the high velocity region on the leading edge would also result in a drag reduction because the laminar boundary layer on the lower surface of the wing would be retained farther back on the wing, and the form drag of the tube would be less since pitot base is not longer in an accelerated flow region.

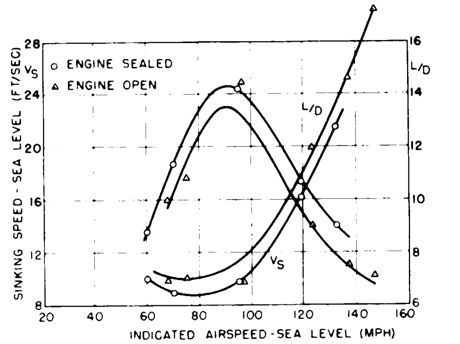
The span efficiency factor of a complete airplane is defined as the ratio of effective aspect ratio to geometric aspect ratio. What this factor means in performance is that the induced drag of an airplane of low span efficiency factor is correspondingly high. At cruising or top speed, the span efficiency has little influence on performance since the lift coefficient and consequently the induced drag is usually quite low at speeds, but in the climb, a low span efficiency factor means a lower climb out of a small field.



Horsepower Required for Bellanca Crusair

The graph on the bottom of page 15 shows the linearized drag polars for the airplane tested for three conditions, glide with cowl opened and cowl sealed and under power in level flight. The adverse effect of the propeller slipstream on the span efficiency factor is seen directly to involve a reduction from 55% to 46%. However, the low factor of 55%, even under ideal conditions of gliding, is a serious deficiency in the design of the wing root intersection. This low value of span efficiency factor is typical of most low wing single engine airplanes.

A careful treatment of the wing root should bring the span efficiency to at least 85%. Several mid-wing sailplanes have been modified in the wing root with resultant span efficiency improvements.



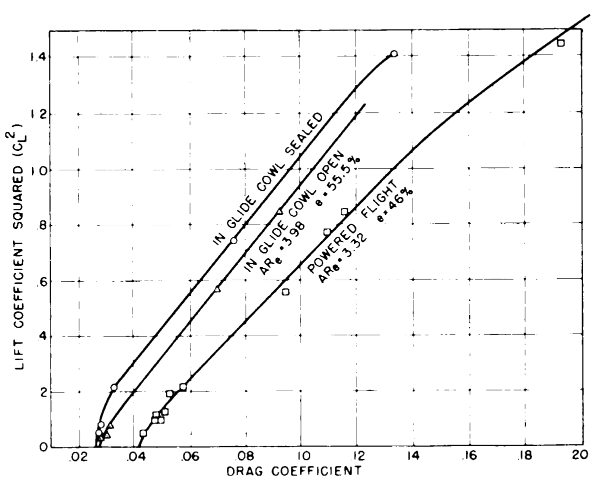
Flight Polars Obtained in Glide (Gross Wt 1735 Lbs)

During a series of tuft tests on this airplane, it was evident that the flow on the upper surface of the flap and aileron was separated even at the low lift coefficients of cruising flight. This separated flow no doubt causes the rapid increase of drag with lift coefficient squared on this airplane. This high drag rise appears as an induced drag since it is a function of lift coefficient. Were this flow improved, the efficiency would appear larger. Also the gaps in the wing root between wing and flap showed the adverse influence of the jet of air escaping from the bottom to the top of the wing. On the test airplane the door fitted poorly, allowing an air leak onto the upper surface of the left wing.

The minimum drag coefficient of the Bellanca Cruisair is 0.0265. This is a comparatively low value for small personal airplanes. For example the Cessna 120, measured in a glide test in a similar manner but with cowling opened and fixed landing gear, was 0.034. However, a clean sailplane of exceptional performance yielded a minimum drag coefficient of 0.0106, less than half of that of the Bellanca.

On examining the drag polar obtained in powered flight, the minimum drag coefficient is found to be 0.043, considerably higher than that obtained from the drag polar in gliding flight. Even after considering the propeller efficiency, the value of the minimum drag coefficient is still higher than measured in gliding flight. The effect of propeller slipstream on the drag is perhaps the largest single element in explaining the drag increment between that measured in powered flight and that in gliding flight without a propeller.

Another interesting feature between the drag polar with cowl opened and with cowl closed is the early break occurring in the drag polar with cowl sealed. With no flow through the engine, the cowl flap acts as a spoiler. A sizeable reduction in drag resulting from this

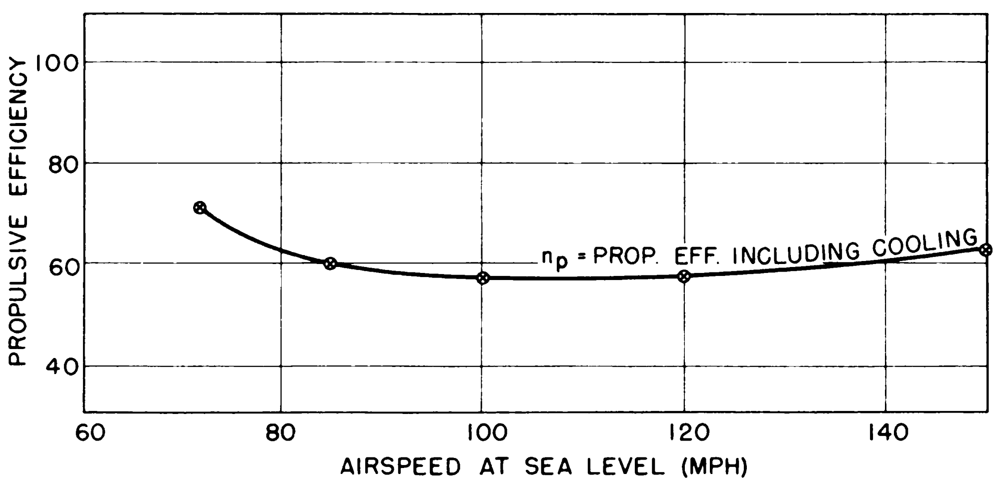


Drag Polar for Bellanca Crusair

separation could be achieved if the separation could be delayed to a lower lift coefficient, postponing it to a lift coefficient near that corresponding to top speed. Tuft tests made in powered flight showed this region of separated flow behind the cooling air outlet.

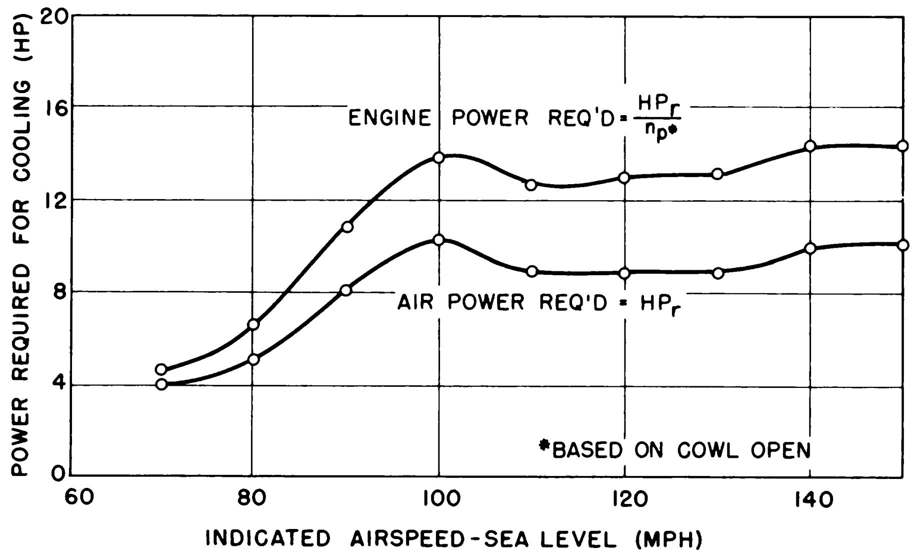
There is also a region of separated flow behind the wheels when retracted. The extent of this region could be reduced by having a well-sealed clam shell enclosure for the wheels in their retracted position in the wing or by sealing the wheel into the well with a strip brush seal.

The real contribution which is made by combining glide measurements with powered flight measurements lies in the direct evaluation of the overall propulsive efficiency defined by $\eta_P = THP_\rho / BHP_\rho$. THP_ρ is the thrust horsepower required and BHP_ρ is the horsepower required of the engine. It is obvious that the thrust horsepower is measured by the power required in glide with the cowl sealed. When this ratio is computed over the complete speed range of the airplane, the curve of propulsive efficiency versus airspeed is obtained. It is quite revealing to see that only 58% of the power delivered by the engine is effective in propelling this airplane through the air at cruising speed. If one assumes the propeller efficiency to be 80%, the losses due to cooling and to slipstream effects amount to 22%. By taking the propulsive efficiency for the cowl opened versus powered flight, one obtains a propulsive efficiency of 68%. The slipstream losses then are seen to amount to 12%. This computation neglects the thermoaerodynamic effects in the engine cooling process.



Propulsive Efficiency (Gross Wt 1829 Lbs)

The power required for cooling, not including any aerodynamic effects due to heat transfer is seen from the two glide power required curves to amount to about 10 horsepower over the cruising to high speed range of the airplane. However, since this power is obtained through the propulsive efficiency of the airplane, the power which must be supplied by the engine to provide the cooling is $10/\eta_p$ where η_p is the propulsive efficiency for the airplane with cowl open. The power required for cooling at cruising speed amounts to 13.1 H.P. Looking at



Power Required for Cooling

this cooling power as a drag increment, one sees from the graph shown above that the drag coefficient increment in the unseparated region is 0.008, a value amounting to 31 percent of the minimum drag of the airplane.

Examination of the chart on the bottom of page 14 shows that the level flight top speed with 150 H.P. delivered by the engine would be 149 mph. Cruising at 75% power would result in a sea level cruising speed of 131 mph. Advertised values for these speeds are considerably higher than measured in this work. This is no doubt due to the reliance on the pitot-static tube location as being without essential error.

ONR Represented at Aviation Medicine Conferences

On 9 March, Capt. C. P. Phoebus, MC, USN, Head of the Biophysics Branch, Biological Sciences Division, ONR, addressed Research Reserve Company W-5 at the Naval Medical Research Institute, Bethesda, Md. His topic was "Research in Aviation Medicine."

LCDR G. Hoover, Air Branch, ONR will speak before the Fifth Meeting of AGARD at the Hague on 3 May. His talk will be entitled "A Methodology for Aircraft Instrument Display Design." His paper will appear in a future issue of Research Reviews.

Precise Wavelength Measurement in the Near Infrared

D. H. Rank

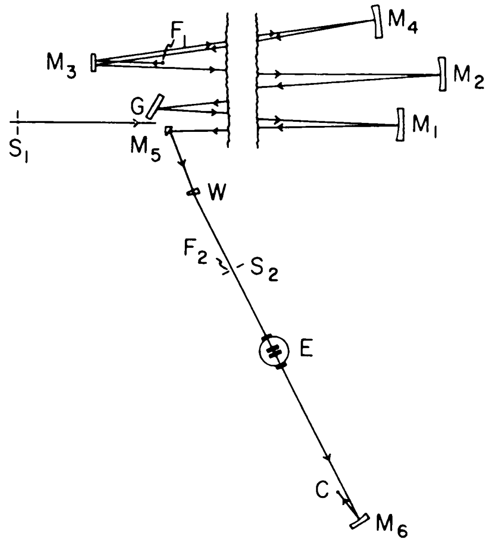
Professor of Physics, Pennsylvania State University

Development of lead sulfide photoconducting cells and suitable amplifiers has greatly stimulated work in the 1 to 3μ region of the near infrared spectrum. During the past few years several laboratories in this country and abroad have been able to obtain spectra only slightly inferior in frequency resolution to the spectra obtainable in the photographic infrared. However, very accurate measurement of the frequencies of absorption lines in the 1 to 3μ region has been severely limited by lack of suitable standard wavelengths sufficiently closely spaced in the spectrum.

The development of the double-pass long focus spectrograph, along with the use of the new Bausch and Lomb "transfer" grating has increased the resolution obtainable in this region of the spectrum by almost an order of magnitude. A diagram of the optical layout of the spectrograph and auxiliary interferometric equipment is shown on the next page. The problem of paucity of standard wavelengths has been solved by the use of interferometric methods which are essentially grating methods. The use of "channeled" spectra in juxtaposition to the infrared spectrum furnishes a multiplicity of standard wavelengths which are closely spaced and accurately known. However, these grating methods are only capable of producing a wavelength precision of the order of one part in 10^6 both absolutely and relatively.

It is well known that measurements of wavelength made with the best diffraction gratings are very much inferior in precision to measurements made with the Fabry Perot etalon. However, the method of exact fractions which is in common use for wavelength measurement in the photographic regions of the spectrum is only applicable to emission lines or absorption lines superimposed on narrow emission lines. In addition, it is not feasible to use the method of exact fractions in the infrared, even for emission lines, because of flux limitations necessitated by the scanning geometry. Therefore, a new procedure was developed for determining the velocity of light. The value obtained is in excellent agreement with all modern determinations of velocity of light and in addition, has a probability of error of the same magnitude as has been obtained by other methods. This is an independent method for measuring this important physical constant which appears in so many formulas in different physical equations and on which so many other physical constants are based.

Development of the new procedure was facilitated by the fact that the infrared spectrum consists mainly of absorption lines. The highly precise measurement of wavelength of these lines can be accomplished



Schematic diagram of double-pass plane grating spectrograph with interferometer. S_1 entrance slit, M_1 and M_2 collimating and objective mirrors of 10-meter focal length, F_1 primary focus, M_4 return concave mirror of 10 meter radius of curvature, G plane grating, M_3 plane folding mirror, M_5 plane mirror, W sliding wedge prism, S_2 exit slit, F_2 double-pass focus, E Fabry Perot etalon, M_6 concave condensing mirror, and C is the PbS cell.

by the use of a newly developed technique which we have called "The Method of Exact Orders." The opposite chart shows the Fabry Perot etalon enclosed in a container in which the air pressure can be varied. This interferometer can be fed with a very narrow band of wavelengths, varied continuously by causing the spectrum to scan the exit slit of the spectrograph. Scanning can be accomplished rapidly by rotating the grating G. Much slower and smoother scanning can be accomplished for a narrow region of the spectrum by translating the wedge prism W with the grating in a fixed position.

It is well known that if parallel light falls upon a Fabry Perot etalon, the maxima of transmission are given by $n\lambda = 2\mu t$, where n is the order of interference, λ the wavelength of the light in vacuo, μ the refractive index of the air enclosed by the plates, and t the separation of the partially reflecting plates. With regard to a continuous spectrum the etalon will behave like an interference filter of very high order. As one scans the continuous spectrum with the high resolution apparatus shown here, the maxima and minima appear, the maxima being given by the above equation. A reproduction of a record showing such a so-called "channel" spectrum is shown at the top of the next page. If an absorption line were superimposed on such an interference maximum, the appearance would be that shown in the A portion.

In general, absorption lines will appear at random in the spectrum and can be located with reference to the maxima of the "channel" spectrum which maxima can be accurately measured by the application of well-known procedures. However, this interpolation is not nearly so precise as one's ability to locate an absorption line at the peak of the interference fringe. Experience has shown that an absorption line can be located with reference to the peak of an interference fringe with a precision equivalent to a change in wavelength as small as one part in 20 million.

It is possible, within certain limits, to always place an absorption line at the peak of an interference fringe. By changing the air pressure between the etalon plates, the refractive index μ is changed. In this way, it is possible to "tune" the interference filter so as to give the absorption

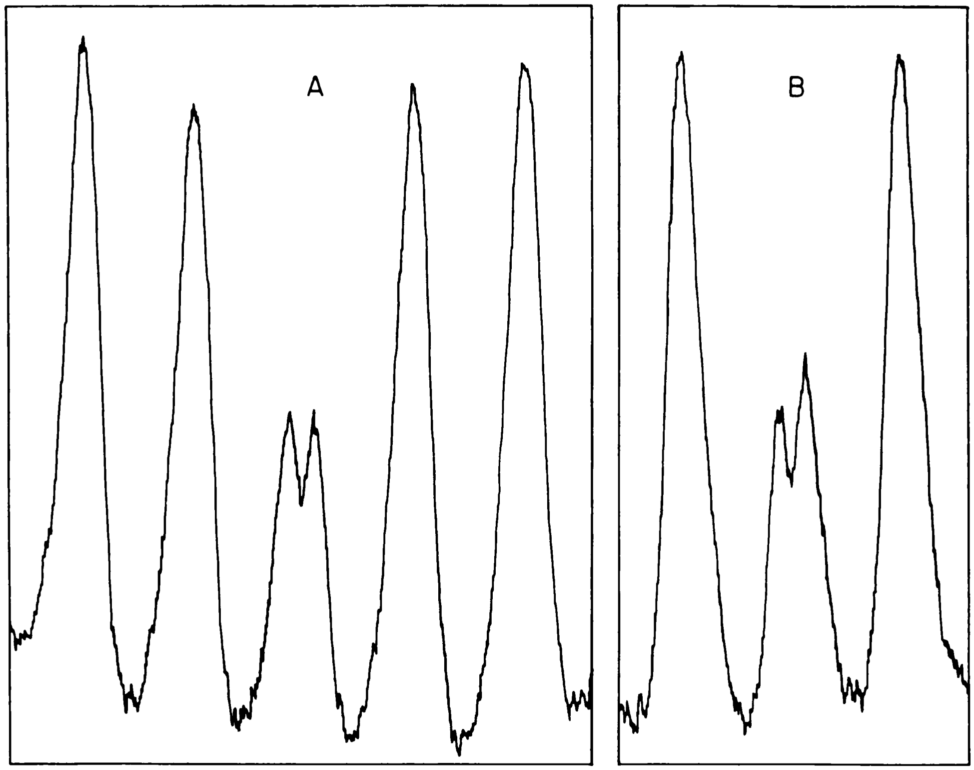


Illustration of the "Method of Exact Orders." A shows the "channeled" spectrum with an absorption line "tuned" to the peak of an interference fringe. B shows an absorption line "detuned" by .007 order of interference corresponding to a change of wavelength of .007 A approximately.

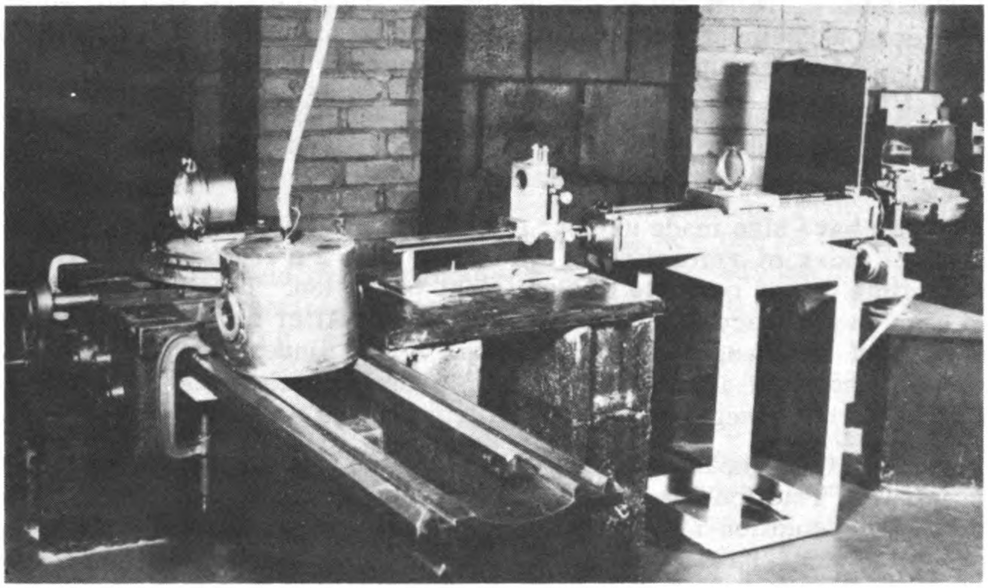
line—which has a constant frequency—the proper wavelength to make the order of interference exact. In the B portion, we have shown the "channel" spectrum with an absorption line superimposed. The air pressure is such that the line is "detuned" by .007 order of interference. With the spacer used this amount of detuning corresponds to a change in wavelength of .007A compared to that illustrated on the top of this page. For the above-mentioned reasons we have called the method described for measuring absorption lines "The Method of Exact Orders." The apparatus employed is illustrated in the photograph, at the top of the next page which shows the grating, Fabry Perot etalon, and scanning device.

The theory of the Fabry Perot etalon shows that the contract K of the fringes is related to the reflectivity R by the relationship:

$$K = [(1 + R)/(1 - R)]^2 = I\ max/I\ min$$

It has been found that very good wavelength sensitivity can be obtained with "The Method of Exact Orders" if R is .60 or somewhat greater.

Coating the interferometer plates with partially reflecting aluminum films of the requisite reflectivity has not proved to be satisfactory since the amount of light transmitted by the interferometer is too small for



Photograph of grating, Fabry Perot etalon and scanning mechanism schematically shown on the top of page 19

proper use in the infrared. The use of multiple-layer dielectric films, however, has proved to be quite satisfactory. If $\lambda/4$ layers of ZnS - MgF_2 - ZnS are evaporated upon the plates, a reflectivity of .66 is obtained at the wavelength where the optical thickness of the film is $\lambda/4$ and the absorption is negligible.

The use of dielectric films for interferometer plate coating is not, however, an unmixed blessing. Multiple-layer dielectric films exhibit a phase change on reflection which varies with wavelength and is relatively large. The existence of this large phase change and its variation with wavelength is one of the chief barriers to obtaining precise absolute wavelengths in the infrared. Correction for phase change vs wavelength must be made, even to obtain precise relative wavelengths. These corrections can be obtained by making measurements of the same wavelengths using two different interferometer spacers. Fortunately, it is also possible to calculate the relative phase shift from electromagnetic theory with an error of probably less than ten percent.

There is hope that it will shortly be possible to circumvent the phase change vs wavelength of the interferometer films in a differential manner. It is hoped that absolute wavelength can be measured interferometrically in the 1 to 2μ region with a precision of one part in 5,000,000 or even somewhat more precisely. There is also considerable promise that relative wavelength measurements can be made with $\lambda/4$ germanium films for interferometer plate coatings. These germanium films would have very considerable advantages once two precise absolute wavelengths—well separated—had been measured.

The first work which has been completed making use of the Method of Exact Orders has been the determination of the velocity of light by means of the band spectrum method. Our first trial making use of the

.002 band of HCN has given a value for c of 299789.8 ±3.0 km/sec which is in good agreement with all the modern determinations of c and has a probable error comparable with that of other methods.

After further obvious slight improvements in our methods it should be possible to reduce the probable error of the c determination to a fraction of the error we now have.

We have also made use of "The Method of Exact Orders" to measure the index of refraction of air in the 1 to 2 μ region which is the first time this is possible to significant precision. The results appear to have an accuracy of at least 1 part in 5000. After a sufficiently large number of wavelengths have been used for the index determination, it will be possible to derive a dispersion formula which should fit throughout the entire spectrum from the ultraviolet to the microwave region.

Finally, it should be stated that many features predicted by theory in infrared rotation vibration bands can now be observed by means of the high resolution attainable. It will also be possible to investigate so-called "hot" bands with great ease once these techniques have been extended to the "fundamental" 3 to 4 μ region of the spectrum.

Jet Propulsion Experts Meet at Princeton

"Science of today is Technology of tomorrow." This might be called the theme of a cooperative venture in science which has been proceeding quietly for eight years. Project SQUID is a joint effort on the part of the Army, the Navy and the Air Force to foster basic research in those fields of science which relate to jet propulsion of aircraft. With funds provided by the Office of Naval Research, the Office of Scientific Research of the Air Force, and the Office of Ordnance Research of the Army, SQUID has been harvesting new knowledge in heat transfer, fluid mechanics, and combustion.

Universities having subcontracts on Project SQUID have encouraged graduate students to participate in the program. As a result, approximately 350 student years of graduate employment training have been provided.

The administrative structure of Project SQUID is somewhat unique. It comprises a prime contract between the Office of Naval Research and Princeton University. Princeton, in turn, lets subcontracts with other university and corporate laboratories. Altogether there are three companies, eleven universities, and one government laboratory in the program.

In terms of high government finance, SQUID operates with a minuscule budget. Moreover, it imposes no hardware commitments upon its participants. Its efforts are directed largely at the pursuit of basic information. Nevertheless, in addition to over 200 technical reports and publications, it has given birth to important practical developments which are now contemplated for operational use.

In accordance with what is becoming a custom, a gathering of the SQUID clan took place on March 17-19 in Princeton. Literally from all over the country investigators met to report their progress for the preceding year. In return they received new ideas and inspiration in their quest for the knowledge which will make tomorrow's planes and missiles outperform today's models.

Oceanographic Studies Aboard the Vema

Battered by winds and whipped by one of the worst storms encountered in her history, the Vema sailed into a Bermuda port after a recent trip from New York. This vessel is being used to conduct oceanographic studies and was carrying aboard a distinguished group of scientists from Columbia University's Lamont Observatory headed by Prof. Maurice Ewing, when the storm struck. Prof. Ewing was one of the four men swept overboard and one crewman was lost. This was but one more of the harrowing adventures the Lamont team has run into in the course of its explorations of ocean areas.

The Vema was built in Copenhagen thirty years ago and used by the Navy during World War II. It was then purchased by Columbia University to conduct its oceanographic researches. Many of these studies are being carried out under Navy sponsorship. Under contract to ONR, Prof. Ewing's group is undertaking seismic surveys at sea to obtain much-needed geophysical information in oceanic areas. They are also trying to develop better equipment for obtaining the gravity data so urgently needed for geodetic purposes (78% of the earth's surface is oceanic). Present equipment is so bulky and difficult to operate that many years would be required to obtain this data under presently available means.

Another task of this group is to obtain information on 1) the geologic structure and acoustic properties of the ocean floor from underwater explosions using seismic refraction methods and 2) the sound velocities in the layers composing the ocean floor and the thickness of the layers. Specifically, this task aims to determine the geologic structure of the continental shelves, the transition to the ocean basins, and the structure of the ocean basins themselves.

Until recently, only scant gravity data were available for oceanic areas. These data are necessary to determine the shape of the earth and the deflection from the vertical as well as for the preparation of accurate charts and maps. Therefore, the Lamont group was also assigned the task of making gravity surveys from submarines since this vessel is the only one from which such studies can be properly conducted. No one has yet devised an apparatus to make these measurements from a surface ship.

The Vema is equipped with some $300,000 worth of sounding equipment for its undersea studies, from which have emerged some interesting facts. For example, we now know that the Gulf of Mexico has always been a part of the Atlantic Ocean and not the result of a collapse of a portion of the North American mainland. We also know the location of new sea mounts and the structure of a part of the earth lying underneath the Atlantic Ocean. Sofar is one of the better-known developments resulting from principles coming out of Lamont research. Developed by Prof. Ewing during World War II, this technique makes possible the location of seamen and pilots lost at sea by means of signals transmitted from small explosive charges for several thousands of miles through the ocean body.

On the Naval Research Reserve

PRNC Reservists Attend Key West Exercises

From 4-6 March 1954, a group of 45 Naval Reservists from Research Reserve Companies of the Potomac River Naval Command participated in a three-day training and operational exercise afloat at Key West, Fla. The group was transported from Washington, D. C. in two R4D aircraft.

On Friday morning the officers divided into six different parties at which time they boarded operational development vessels for anti-submarine training and evaluation exercises. They were assigned duty aboard lighter-than-air aircraft, patrol bombers, destroyers and submarines to familiarize themselves with the latest methods of conducting submarine and anti-submarine warfare. Vessels participating in these exercises were the U. S. S. SARSFIELD (EDD-837), U. S. S. SAUFLEY (EDDE-465), U. S. S. HUSE (EDE-145), U. S. S. BATFISH (SS-310), U. S. S. PICUDA (SS-382) and the Airship ZX-11.

On Saturday morning, 6 March, the group attended a lecture on new developments in the field of Naval ordnance at the Naval Underwater Ordnance Station.

This training program afforded Naval Research Reservists the opportunity of observing firsthand many of the experimental devices presently being developed and evaluated for use by units of the fleet. Captain F. C. Wiesner, USNR, Commander, Research Reserve Companies, PRNC, was in charge of the training operation.

Naval Research Reserve Company 6-10

Front Row, left to right: LT Everett E. Cushman, CAPT H. R. Wright, CAPT Clifton G. Grimes, CDR Norman R. Buchan, CAPT J. M. Boyd, LT Frank Thompson, LT R. T. Anthony, Jr., CDR Paul Brake, ENS R. H. Richard, LT Gerald Franklin, LT Alexander A. Salchnoosky, LCDR Edwin H. Lombard, and LTJG Robert Erwin

Pictured above are members of the University of Miami Research Reserve Company. Capt. Clifton G. Grimes, USN, Deputy and Assistant Chief, ONR, addressed this group at a meeting on Thursday evening, 18 February, at the Coral Gables Country Club. His topic was the role of research in the cold war, as it relates to the mission of the Office of Naval Research; he emphasized the importance of the Research Reservists to the science effort of the Navy in providing a readily available source of competently trained scientists in the event of a national emergency.

Captain Grimes and Commander Buchan

Capt. Grimes was the developer of ship fire-control and other control communications systems and oversaw their installation on naval vessels during World War II.

CDR Norman R. Buchan, USNR, Head of the Dept. of Journalism, Univ. of Miami, Commanding Officer of Naval Research Company 6-10, Miami, served as Chairman. The West Palm Beach panel of Company 6-10 also attended this meeting. This unit is headed by LT John Coleman, Director of Radiation Research Corp; Miami, Fla.

New Program Officer Reports To ONR Chicago

LCDR Herbert T. Wordell, USNR, has reported for duty as Program Officer, Naval Research Reserve, in Chicago. He was Commanding Officer, USS KYNE (DE-744), operating under the Commandant, Third Naval District as a Naval Reserve training vessel, for the past twenty-seven months. Prior to his recall to active naval service in October 1950, Commander Wordell was Director of the Department of Physical Education in the New Bedford Public Schools, and also Commanding Officer of New Bedford Organized Naval Reserve Division 1-22.

A native of Dartmouth, Massachusetts, and a graduate of New Bedford High School and DePaul University, Commander Wordell also did graduate work at Northwestern University and Boston University. Prior to appointment in the New Bedford School Department he served as Assistant Supervisor of Physical Education in the Chicago Park District, Chicago.

Before assuming command of the USS KYNE (DE-744) in December 1951, Commander Wordell served for 14 months as Inspector-Instructor for Naval Reserve in Rochester, New York. During World War II he served in the Armed Guard, Local Defense Force, Boston, and as Range Officer at the 7th Naval District pistol range, and saw service in destroyers as torpedo officer, gunnery officer, and executive officer.

Appointed to command of the USS BRISTER (DE-327) in 1945 in the Pacific Area, he participated in action in Saipan and Okinawa, and was commended by the Commander of the Seventh Fleet for participation in the liberation and evacuation of allied prisoners from Japanese forces in Formosa. In 1946 he returned to Formosa in command of a mine patrol force with headquarters in Kiirun. While commanding the USS BRISTER he participated in the U. S. Navy's first post-war good-will world cruise in 1946, visiting Shanghai, Hong-Kong, Singapore, Colombo, Ceylon, Aden Arabia, Suez, Port Said, Alexandria, Naples, Marseilles, and Funchal, Madeira Islands. He was released from active naval service in January 1947.

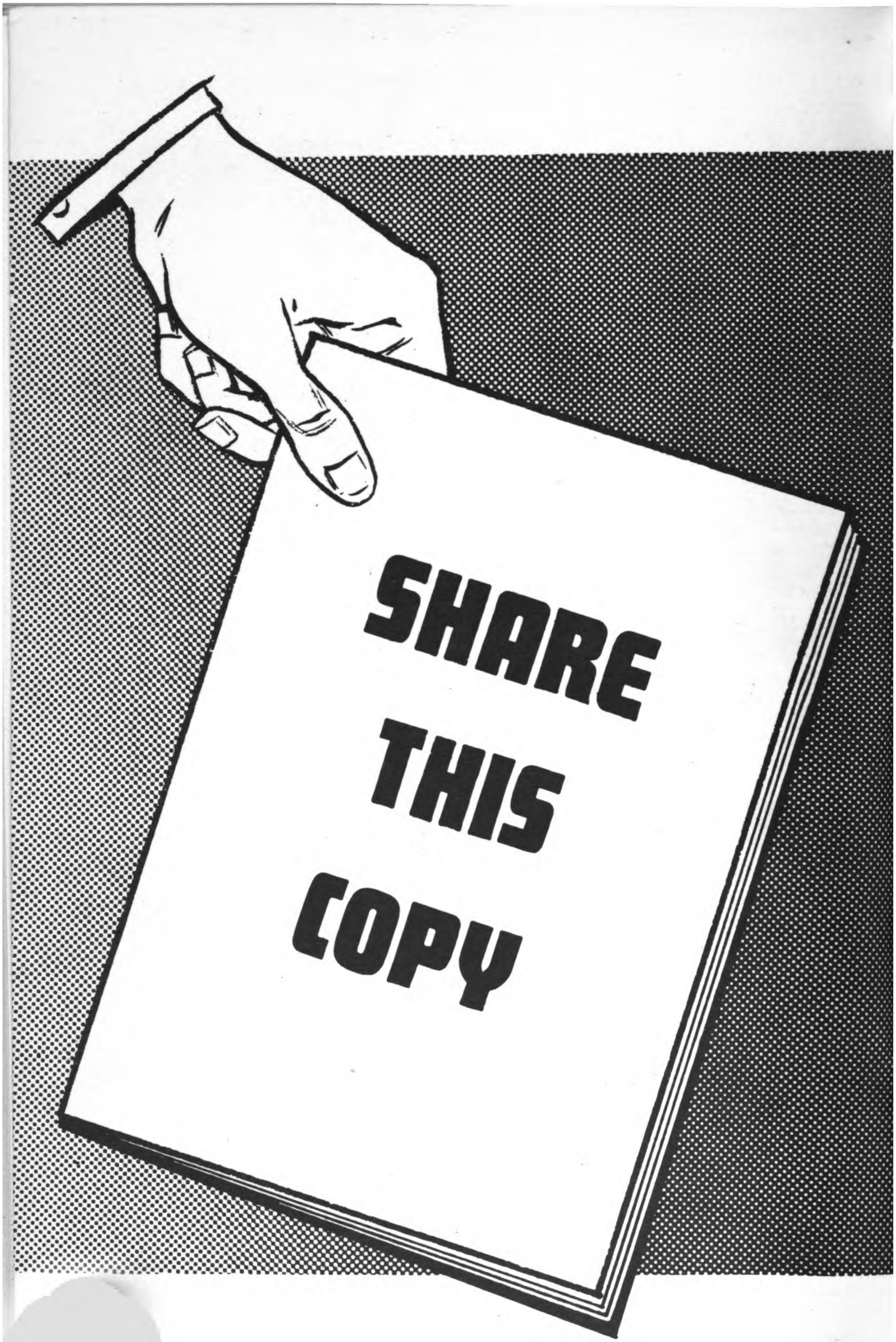
Awards and decorations: Naval Reserve Medal, Atlantic, European and Pacific area ribbons, World War II Victory Medal, Navy Occupation ribbon, China Service Ribbon and Expert Pistol ribbon.

Mrs. Wordell, the former Lillian Stromwall of Chicago, and their three children, Janet, Martin and Fred are residing in Baldwin, New York.

LCDR Wordell is one of three brothers in the naval service; Captain Malcolm T. Wordell, USN (ret), was a Naval fighter pilot ace in World War II, and LCDR Milton P. Wordell, USN, is Assistant Inspector of Naval Material and Type Repair Officer, Treasure Island.

U. S. GOVERNMENT PRINTING OFFICE : O—1954

(Designing the Small Plane See pp. 12-18)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