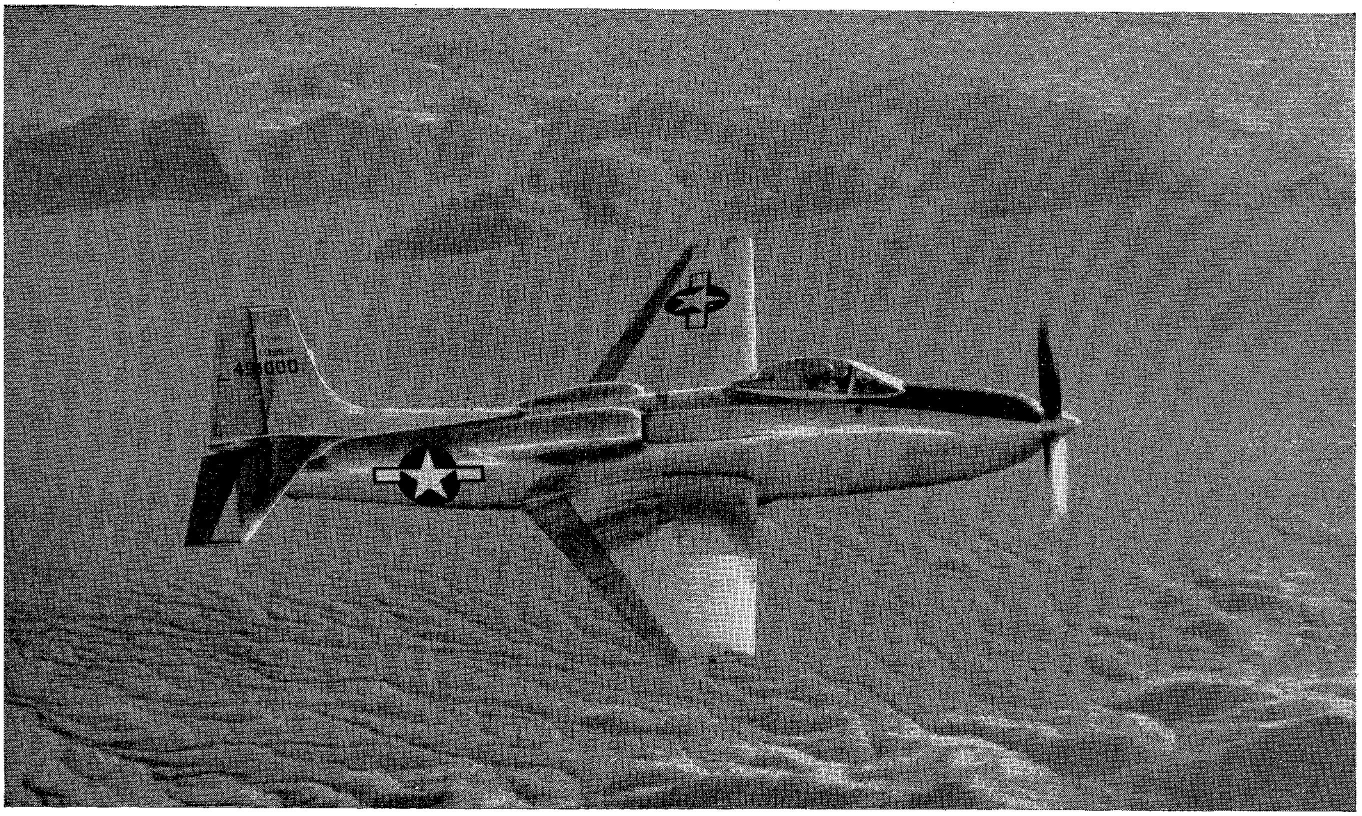


FIG. 1. The XP-81 shown above is the Army's latest fighter. Designed to escort B-29's on long range missions, it utilizes a gas turbine driving a propeller for cruising, plus a pure jet gas turbine for take-off and combat.

FLIGHT TEST

By FRANK W. DAVIS

THE purpose of this article is to present a brief, comprehensive picture of flight test activity. Better reading might be provided by describing the true flight test history of some particular airplane, but not until military restrictions are lifted can this be done.

My reason for wishing first to present a picture of the job of flight testing is that I believe no such picture to be now available and, furthermore, I feel that most of the articles appearing in popular periodicals have tended to build up in the mind of the reader an altogether false picture of the aims and methods of the flight testing profession.

The subject of flight testing covers a broad field. There are almost as many different types of testing as there are testing agencies. Each has its own particular objectives and requirements. For example, the National Advisory Committee for Aeronautics (NACA) maintains flight test groups who conduct tests for the purpose of studying new aerodynamic developments, correlating wind tunnel and flight test data, and also to meet the special requests for information made by the Army and Navy. They also maintain flight test groups to determine compliance of new airplanes with contract specifications, to test new equipment and new tactics, and to carry out a host of other jobs. The Civil Aeronautics Authority maintains flight test facilities for licensing aircraft, studying safety measures, etc. Some manufacturers of aircraft engines and equipment maintain flight test staffs for studying their special problems.

In addition to these, each of the aircraft manufacturing companies maintains its own flight test groups. The manufacturers' testing includes two general types: production testing and experimental testing.

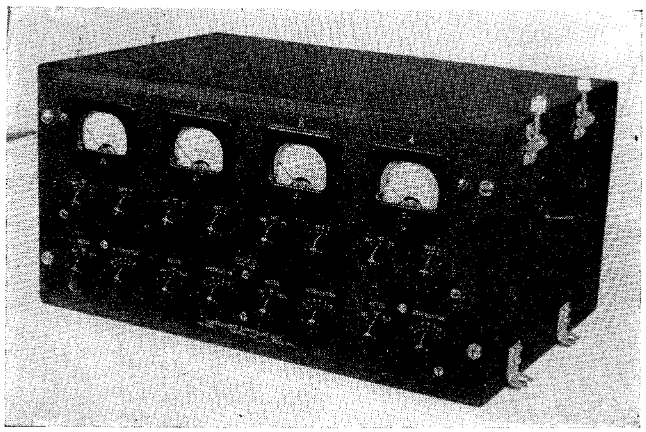


FIG. 2. Type I-106 amplifier.

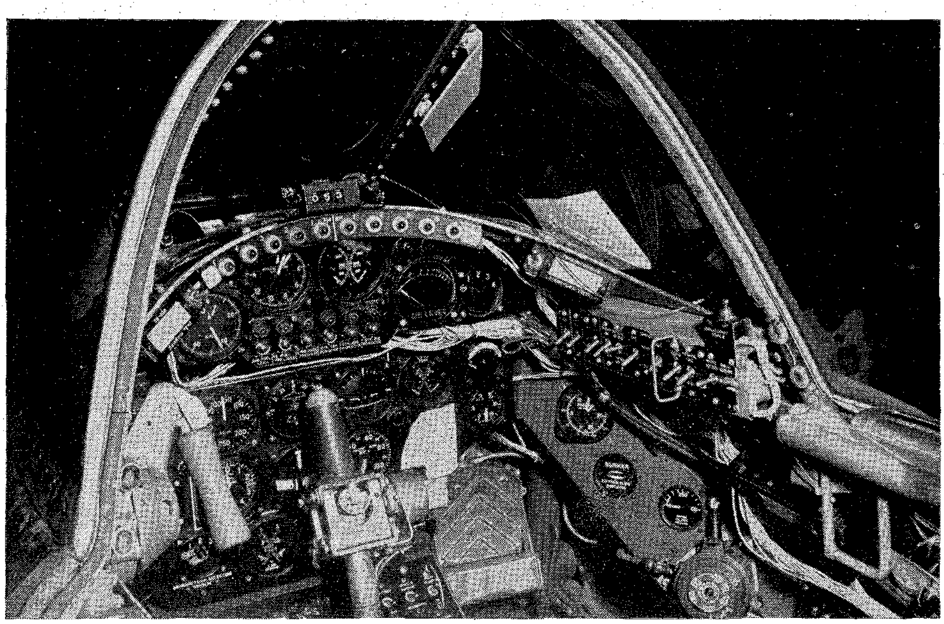


FIG. 3. Cockpit showing part of special instrumentation.

PRODUCTION TESTING

Production testing normally consists of flying for a specified length of time, each airplane which comes off the assembly line in order to make necessary checks and adjustments in preparation for turning the airplane over to the customer. The airplanes are usually flown in a normal manner through a carefully planned routine which includes a complete functional test of the airplane and its equipment.

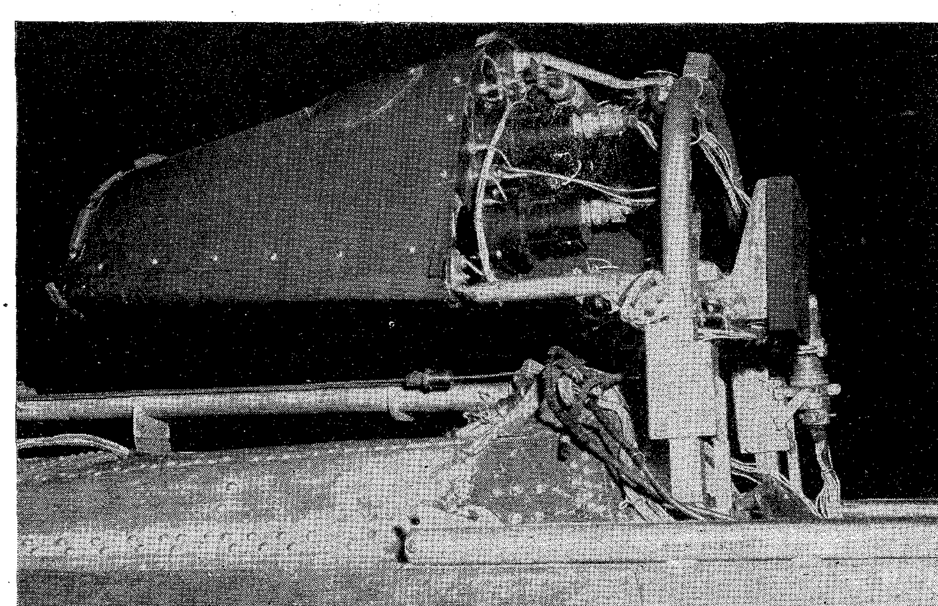
In spite of mass production methods, changes sometimes occur in design, materials, or workmanship, which may alter flight charcteristics. With the tremendous expansion of production facilities, the introduction of new methods, and the wide use of sub-contracting and inexperienced personnel, it was not uncommon during the war to discover that an apparently small change which had been made in some plant to facilitate production had markedly affected the aerodynamic characteristics of the airplane. In cases where these things eluded the persons who might have foreseen the trouble, their manifestations contributed to keeping the lives of the production test crews from becoming too dull.

While production testing constitutes the major portion of the manufacturers' flight test hours, it is in the category of experimental flight testing that the bulk of engineering work lies. It is with experimental testing that the remainder of this discussion will deal.

EXPERIMENTAL TESTING

Before going into any of the details of experimental flight testing, it may be well to lay down the primary objectives of such a testing program. Normally, the first objective is to bring a new airplane to a state of development where production can safely be started, and where the prototype can be turned over to the customer for his approval. This requires a careful exploration of the limits of safety of the airplane as well as a determination of its normal flight characteristics, its performance, and the satisfactory functioning of its power plant and equipment. After production has started, changes in design are often found to be necessary or desirable. These, likewise, must be thoroughly tested and developed before they can be applied. The second objective of experimental testing is to increase the background of engineer-

FIG. 4. Photo recorder for installation in canopy.



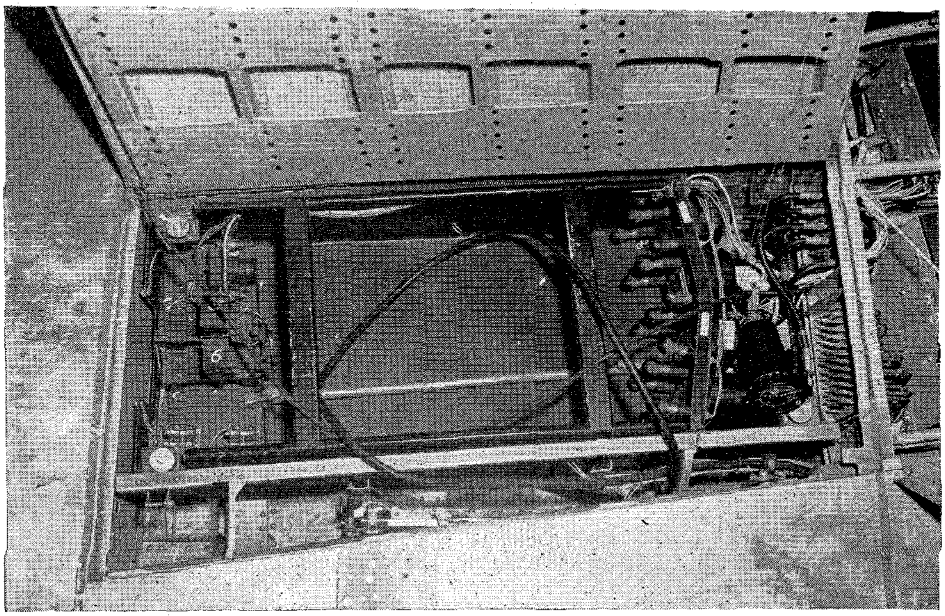


FIG. 5. Wing installation photo recorder.

ing knowledge by correlation of flight test results with calculations and the results of simulated tests, such as wind tunnel tests, static load tests, equipment tests, etc., in order to make future airplanes better.

The work of the flight test group begins long before an airplane is ready to fly. Even during the preliminary design stages, information concerning previous airplanes will be selected from the flight test files in order to help solve the design problems arising on a new airplane. What was particularly good about a former airplane? Why was it good? How can that feature be incorporated in the new one? What things have given trouble? How can similar trouble be avoided? These are questions which the flight test group should be able to answer.

Several months prior to the initial flight the work immediately connected with flight testing begins. By this time the airplane has begun to take shape. If it is a pursuit, for example, people are probably calling it the *XP* and are getting a little impatient to see it fly. Nevertheless, several months of hard work remain before there will be much daylight between the runway and the wheels. At this time it is necessary for the flight test group to crystallize its ideas and to outline a tentative test program which will tell what is to be tested, what things must be measured, and how they can be measured.

MEASUREMENTS

With any scientific test the problem of measurement is of high importance, as is also the problem of recording measurements. In the *XP* the problem is doubly complicated for several reasons. The airplane is almost completely filled with engine, guns, fuel, radio, and other equipment, and the few small spaces left are not necessarily accessible. The instruments used may be subject to changes in atmospheric temperature from 120 degrees F. to —60 degrees F. and to changes in atmospheric pressure from around 15 pounds per square inch to 3 pounds per square inch. They will be subjected to the vibration which is bound to result from hanging several thousand horsepower on a structure which is light enough to fly, and to an acceleration which may vary from —130 feet per second per second to 250 feet per second per second.

The problem of recording has the added complication that the only fellow available to operate and observe all

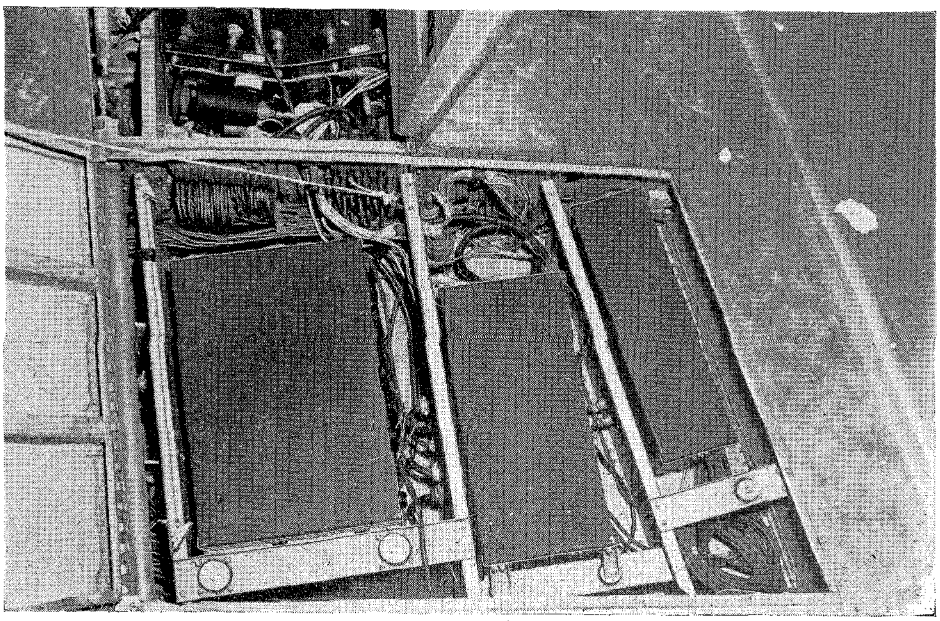


FIG. 6. Wing installation of oscillograph amplifiers.

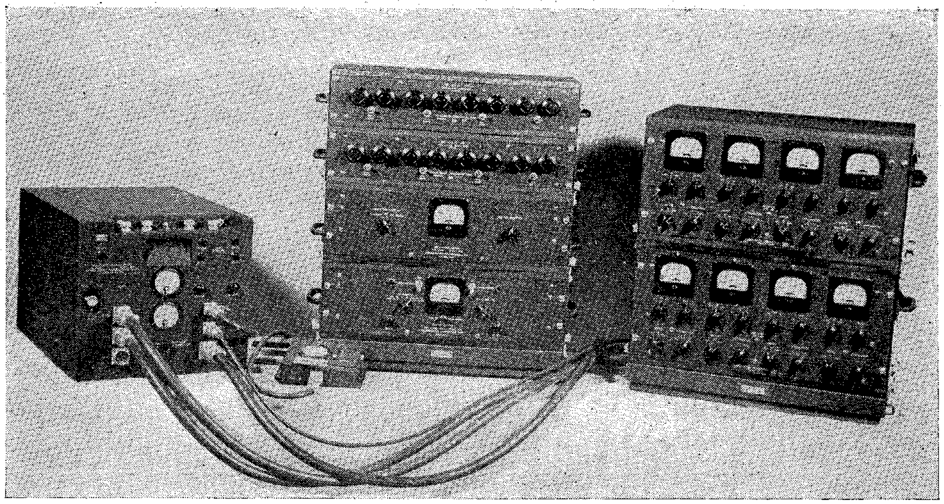


FIG. 7. Vibration and strain measuring equipments.

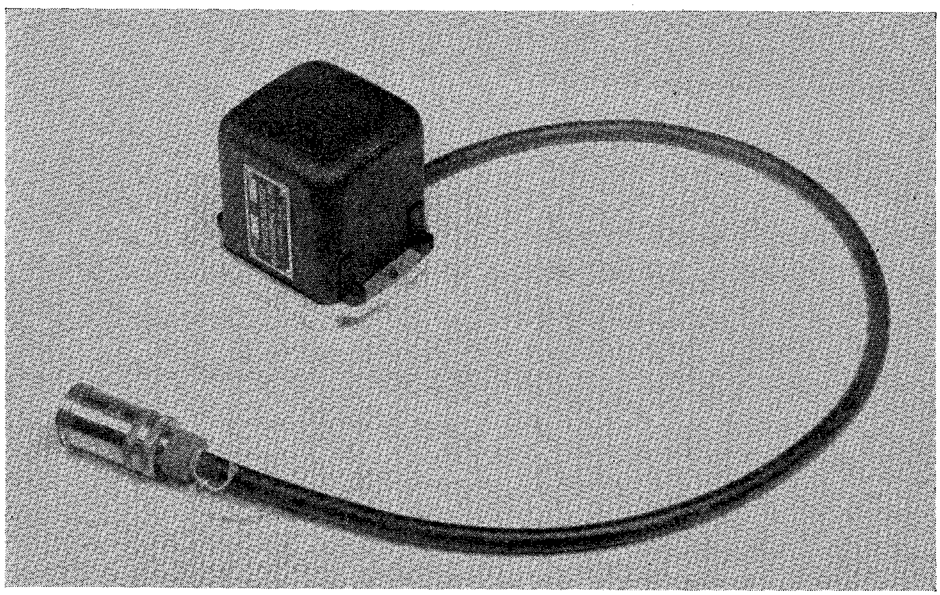


Fig. 8. Type 4-101 accelerometer.

of these instruments is the pilot who, even in the normal course of flying a modern pursuit, is not particularly famous for having nothing to do.

A glance at the items to be measured shows that the instruments can be grouped into relatively few types. Temperatures, pressures, angles, forces, time, and acceleration, constitute the bulk of instrumentation, plus some other special items, such as rate of fuel flow, stresses, and frequency and amplitude of vibration.

The temperature measurements serve partially to define the atmosphere in which the airplane is operating and to tell whether the engine is receiving the correct cooling, the cockpit the correct heating, etc. The greater part of temperature measurement in aircraft is done by thermocouples, and some very clever equipment has been developed for automatically recording the output of a large number of thermocouples.

The measurement of pressures serves further to define the atmosphere, and in addition is used to measure airplane speed, air flow through ducts and around the engine, and to deal with numerous other items such as oil and fuel pressure, engine power, etc. Pressure gages, either recording or direct reading, are preferred for aircraft work, but under carefully controlled circumstances manometers can be used to good advantage. Photographic methods of recording are usually employed.

The measurement of forces and angles is of itself not a difficult procedure, but the transfer of the measurement from, say, a wing tip to the cockpit or a recording instrument in an airplane is more difficult. The fact that the wing may deflect several inches, or even several feet, under load, rules out any transfer of measurement mechanically or by light beams. The method in most common use now for transferring angular measurements from the source to the place of reading or recording is that of the Selson or Autosyn transmitter. Forces are generally measured as spring deflections, which may be transmitted in the same manner as angles. Considerable work is being done with strain gages for force measurement, and the method holds much promise.

Acceleration is generally measured by its effect on a mass suspended by a spring.

Photographic recording is probably the most widely used method at the present time, but much work is being done along other lines, such as the recording on the ground of signals sent out by radio from the airplane's measuring instruments (telemetering). This process is probably the most promising development in the whole field. By its use it has been possible to record actual data occurring under the most violent flight conditions in airplanes, and even in rockets and projectiles. One of the main drawbacks to this equipment is the limited number of channels which can be broadcast simultaneously.

After the decisions have been reached as to what things are to be measured, and how, the construction and installation of the instrumentation are begun. Most of the work should be finished by the time the airplane is ready to fly. In the meantime considerable work will have been done in gathering information about the airplane, its power plant and equipment, and in formulating a complete program for the testing.

THE PROGRAM

The program will probably be laid out with the following objectives, in order of priority:

1. To correct any flight or power plant characteristics which would be dangerous to further flying.
2. To obtain a power plant installation which is safe to operate at maximum power.
3. To obtain sufficient performance information to evaluate the airplane's worth.

4. To determine accurately the flight characteristics and correct as many unsatisfactory items as practicable.
5. To make final power plant installation and performance checks after all changes have been completed.
6. To explore the absolute limits of safety in so far as diving speed and pullout severity are concerned.

Work toward the completion of this program starts with the initial flight and normally continues through several score flights.

One of the big problems of any scientific investigation is the elimination of uncontrollable variables from the experiments. The number of variables possible in an airplane is almost unlimited, and continuous and close cooperation is necessary between the pilot and the flight test engineers in order to reduce them to a minimum. At best, considerable detective work is necessary in order to track down the problems which arise. A fairly straightforward example of this type of sleuthing occurred a few years ago in connection with a serious vibration problem. The pilot was able to determine that there were two types of vibration superimposed on one another: first, a pitched vibration of high frequency which was a function of engine RPM, and, second, an unpitched vibration which was apparently a function of power. It was determined that the pitched vibration was caused by resonance of the propeller blades and engine. This was corrected by cutting a few inches off the end of the propeller, thereby changing its vibrational frequency. By use of a recording oscillograph and vibration pickups at several points on the plane it was found that the unpitched vibration was caused by the effect of the engine exhaust on the tail of the airplane. This was then eliminated by changing the shape of the exhaust outlet.

By far the greatest part of experimental flight testing is concerned with the solution of problems such as this, plus the determination of performance and the refinement of flight characteristics.

BETTER PLANES VERSUS HEADLINES

The so-called "heavy performance" has received much attention, because it lends itself to sensational presentation. The general public has been led to believe that the intrepid test pilot climbs into the prototype airplane, "gives it the gun", climbs immediately to the airplane's ceiling, comes screaming back down in a vertical dive, tries valiantly to pull the wings off, lands, lights a Camel, and turns the plane over to the Army.

Actually, nothing could be farther from the fact. Most of the pilots involved in experimental testing are relatively old-timers, who didn't get that way by the above procedure. Many of them are first-class engineers whose interest in flying is in making better airplanes and not headlines. Many have families and have no intention of collecting their insurance at an early age. And finally, most of them are acutely aware of the irreplaceable work and time which go into a prototype airplane.

Actually, the "heavy performance", such as the initial flight of a new prototype, the dives, pullouts, and spins, is approached with a tremendous amount of caution and patience. In every case the limits of safety are explored by progressing toward them in small steps, meanwhile keeping accurate records of all critical items possible, and using them, by extrapolation, to predict the results of each succeeding step before it is taken.

In the case of the initial flight, runs along the ground are made at successively increasing speeds up to take-off speed. During each of these runs the pilot "feels out" the various control characteristics of the airplane and endeavors to predict whether or not the airplane can be handled at a higher speed. This process may take several days or even several weeks, if airplane changes are necessary, before it is finally decided that full flight can be safely accomplished. Incidentally, this process is a telling test of a pilot's patience. Normally there is considerable pressure to fly the airplane as soon as possible. This comes from everyone interested, including the pilot, and the temptation is very great to say, "To hell with this fiddling, let's get the thing over with." However, in cases such as this, remembering the old adage helps a great deal: "There are Old Pilots, and there are Bold Pilots, but there are no Old Bold Pilots."

In the case of dives and pullouts where the airplane is being tested to the calculated limits of its strength, it is felt that radio recording and radio control will eventually replace the pilot. This would certainly be the economical way to do the job. It is sometimes hard for the civil or mechanical engineers to become reconciled to the fact that the airplane is stressed to yield at just above its maximum flight load, with no safety or ignorance factor. Such practice is absolutely necessary in the interest of lightness, but it means that failures sometimes occur which may very well produce disastrous results. Since a good engineering pilot represents a rather expensive and scarce piece of test equipment, it is felt that considerable saving can and will be accomplished by carrying out these tests initially in radio-controlled airplanes.

DEVELOPMENT AND APPROVAL

In this discussion, full justice has hardly been done the job of flight testing. It is actually the most interesting job in aviation. It is truly a rare privilege to be "the first by which the new is tried" when "the new" is a piece of equipment which represents the combined efforts of several hundred of the best engineers and artisans in the world.

Undoubtedly the perfect airplane will never be built, and as long as this is true the flight test crew should continue to have the first word in pointing the way for improvement and the last word in accepting each improvement.

FIG. 9. Type 4-106 linear pickup.