Part of Pan American Airways' Pacific fleet.

TURNING THEM AROUND

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THE AIR AGE

ACCORDING to current literature, we are now in the Air Age. Certainly there are few people today whose personal lives are not in some way affected, directly or indirectly, by air transportation. Furthermore, one need but read the newspaper headlines and thumb through the aviation magazines to become aware that our dependence on this form of travel is steadily increasing.

Significant, too, are manifold new developments and technical improvements. Thirty-five-hundred-horsepower engines, commercial airplanes that will weigh 300,000 pounds or more and fly in excess of 300 miles per hour at an elevation of 30,000 feet, luxury airliners capable of carrying 200 or more passengers in super-charged cabins wider than a Pullman (three seats on each side of the aisle instead of two), with berths and staterooms, as desired, at a cost of four cents or less per passenger mile—all of these the manufacturers are now not only designing but have started producing in some cases, and all are typical of the equipment U. S. airlines will utilize with the advent of peace. Every detail from now-secret radio-navigation aids to windows made of two thicknesses of polaroid glass that will never fog and can be adjusted to admit just the right amount of light will be provided. Plans for cargo carriers are just as elaborate.

Concurrently, to serve their own interests as well as to keep in step with the activities of manufacturers, operating organizations have been equally busy. Already the Civil Aeronautics Board has before it several hundred applications to increase the domestic route mileage of United States airlines from a present approximate total of 60,000 miles to more than 500,000 miles. The majority of these applications, intended to provide air transportation service to every city in the nation with a population of 25,000 or more, have been submitted by existing airlines and established surface carriers, such as the Greyhound Corporation, which applied to fly some 50,000 miles of helicopter feeder routes, supplementing its bus service and tying in with the major airlines. However, other interests, including the private citizen, also have made applications.

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THE COMMERCIAL AIRLINE

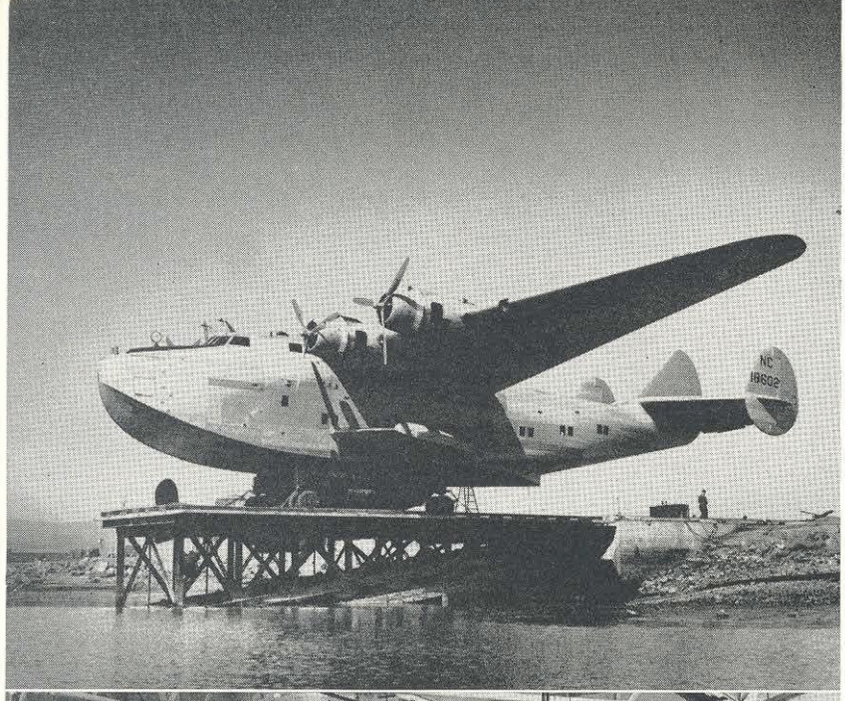
At the present time, successful commercial air carrier operation is a very complex activity. So that the reader may gain some idea of this complexity, let us consider a few of the problems facing an individual or group of individuals desiring to establish and operate an airline as a practical business venture. For the sake of brevity, we shall assume that our would-be airline operator already has obtained the necessary capital, qualified personnel, certificated air-borne equipment, and adequate ground equipment and facilities. Also that he has been granted a route certificate and, if his case is a good one, a mail contract by the Civil Aeronautics Board. Now the operator must make the airline, figuratively and realistically speaking, fly. To accomplish this, he must resolve such general problems as administration, accounting, purchasing, public and industrial relations, all more or less characteristic of any business, plus four special considerations:

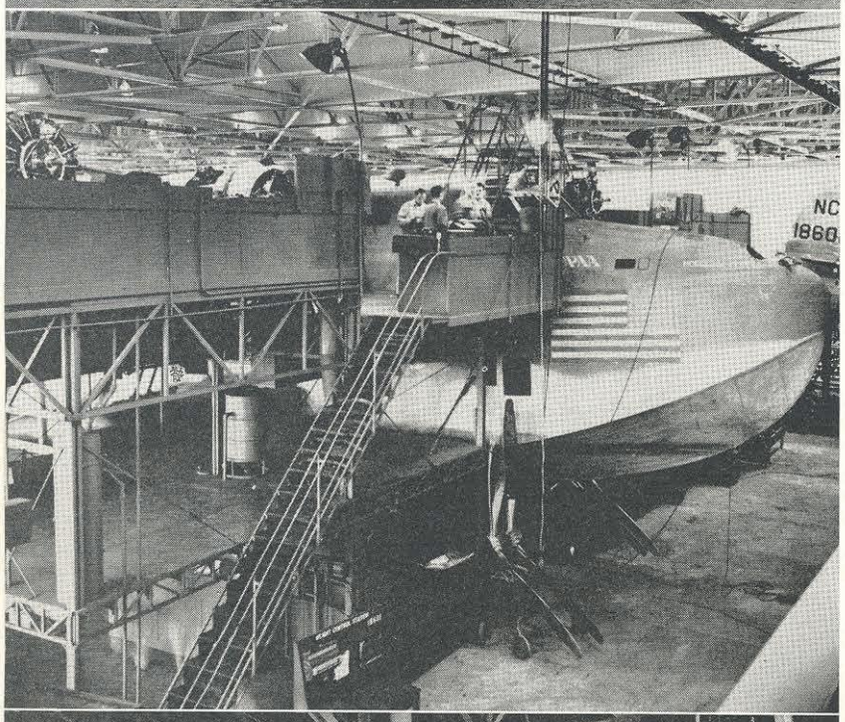
1. Operation of the aircraft.
2. Maintenance of the aircraft.
3. Communications and meteorology.
4. Traffic and passenger service.

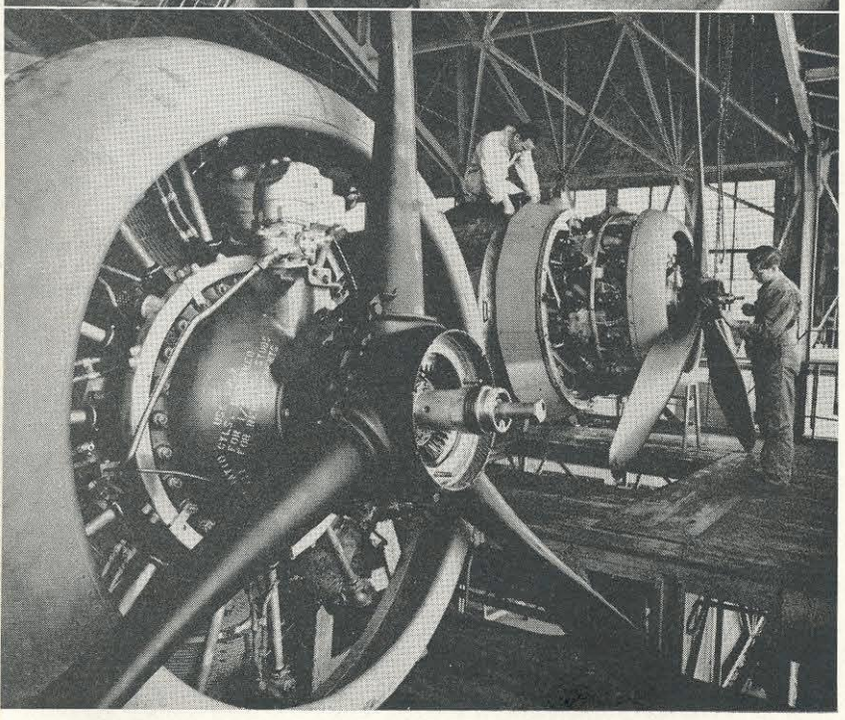
Since the authors are primarily concerned with aircraft maintenance, it is their intention, with no thought of detracting from the importance of other phases of airline operation, to confine this discussion to the subject of keeping large airplanes in first-rate flying condition. At this point, then, in order fully to appreciate the emphasis placed on thorough and efficient aircraft upkeep, or maintenance, the reader must realize that utilization, and that is average flying hours per airplane per day, determines available ton-miles and passenger-miles, which are the commodities an airline has to sell.

AIRCRAFT MAINTENANCE IN GENERAL

"Turning Them Around" refers specifically to major service and overhaul of airline aircraft at the main base.







Years ago most airline maintenance methods were far different from those of today and from those contemplated for postwar operation. Likewise, a utilization of six to eight hours per day was once considered normal and 10 hours per day exceptional; but now 10 hours per day is normal and we hear that 15 to 18 hours per day can be expected in the future. Obviously, then, maintenance and overhaul procedures have been and will continue to be revolutionized.

For example, consider the case of a major transoceanic airline in the late 1930's when the public was not yet "sold" on flying and a 2,400-mile overnight trip to Honolulu was regarded as a pioneering venture. With but a few airplanes (all flying boats) in scheduled operation, it was not practical to establish mass production-line types of shop layout, work scheduling, and production control. In addition, the airplanes, engines, and propellers, as well as numerous instruments, accessories, and "gadgets," were the first of their type ever used in commercial airline operation. Therefore, until the new equipment had been proved in service and all the "bugs" eliminated, practically full time was devoted to detailed inspection and service of almost every part of the airplane—the system used being analogous to that of a professional auto-racing driver who is mechanic for his own racing machine.

Today both inspection and service of the aircraft are no less thorough; they are, in fact, more comprehensive. However, methods and procedures have been streamlined. Specialized testing machines have been developed, portable hoists have been obtained, so that now when a propeller, engine, or other heavy part must be removed, the hoist is brought to the airplane instead of the airplane to the hoist—the industrial analogue of pushing the piano stool to the piano instead of vice versa. Many parts that once were returned to the manufacturers for servicing, repair, and overhaul now receive complete overhauls at the base.

Besides, there are three other important developments: The first springs from the fact that nowadays when an airplane becomes useless, the reason is just as frequently depreciation as obsolescence. Perhaps the outstanding illustration of this point is the Douglas DC-3. For over 10 years the DC-3 has been the outstanding commercial air transport in all parts of the world. Indeed, it was

AT LEFT:

UPPER: Coming ashore or being launched, Boeing 314 on marine railway in the up position. At this point, the airplane may be towed onto the apron and thence into the hangar or may be lowered into the water via inclined tracks (upper portion of which are visible) and cast afloat. Note wheeled cradle supporting the plane as described in the text.

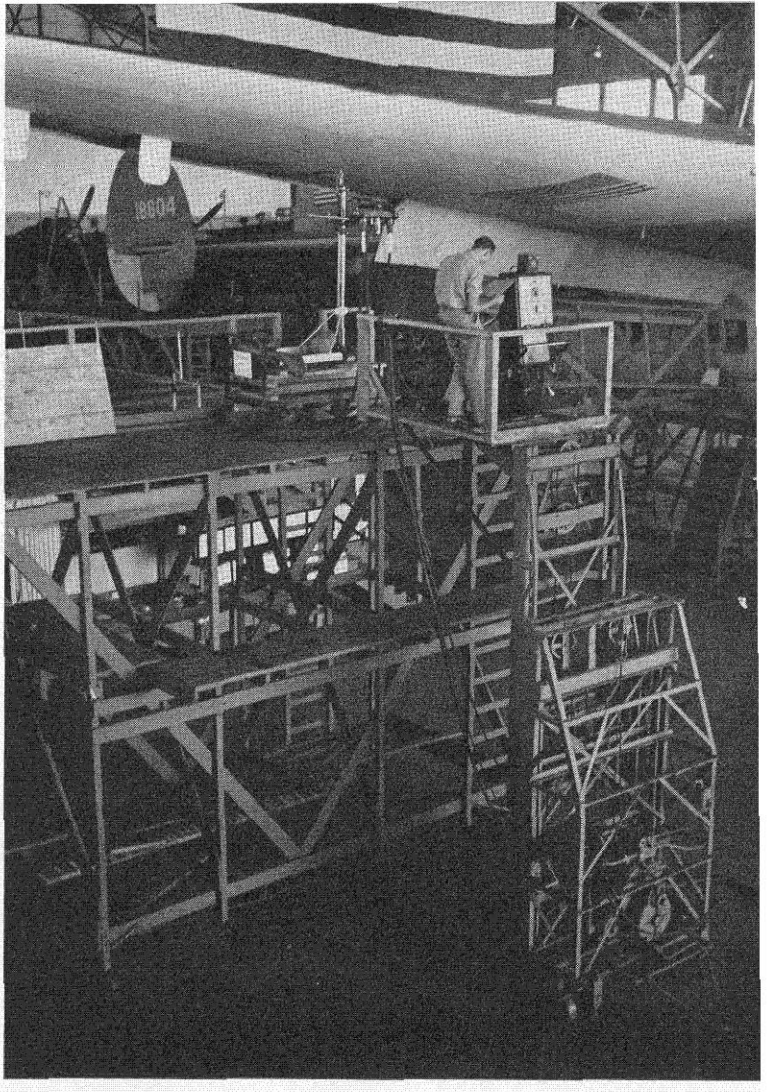
CENTER: Honolulu Clipper gets the works. With workstands in place, the service proceeds. Propellers have been removed for checking and await reinstallation. Note stile-like arrangement for access to either workstand over top of plane, tracks for overhead hoist, and weight control station in lower foreground. Also, portion of a second airplane's tail assembly visible in right background.

LOWER: Engines and propellers rate meticulous attention. View from top workstand platform shows mechanics at work on No. 1 engine and propeller. In the foreground a portion of the hydraulically operated propeller blade pitch-changing mechanism may be seen.

not until September, 1944, that the last commercial airplane of this general model was built; and now plans seem to indicate that production will be resumed. Hence, the DC-3 is not yet out of date, although any given one may wear out—a process that takes a lot of time if good maintenance practices are observed.

Second, the service life of various aircraft components has been greatly extended. Some certificated airplane engines are now overhauled after as much as 800 hours of flying time, and many parts no longer show any appreciable wear. Airplane propellers no longer have specified retirement time limits, but may be operated indefinitely by replacement of worn parts.

Third, airframe and engine manufacturers have come to realize that building an airplane is not merely a matter of putting together a structure which, once assembled, requires a welding torch to pull apart. Engines, accessories, controls, functioning systems, etc., should all be readily accessible. If something goes wrong with a magneto, for example, the mechanic should not have to spend hours in a superhuman struggle, cutting safety wire, loosening sequestered bolts, unsoldering connections, and doing acrobatics to reach the failing unit. Hence, we now sometimes find these vital accessories mounted on the nose section of the engine, where not only better cooling is obtained but immediate repairs can be effected. Electrical connections are made by quick disconnects, separable in seconds. Fuel, oil, prestone, and other fluid lines are "broken" with a half turn of a nut, and on being broken are automatically sealed. One reads of "packages" of one sort or another, particularly "power packages." The modern trend is to develop the various functioning devices as complete units. Suppose an airplane comes in with a defective engine cylinder. Mechanics, instead of sweating over the removal and replacement of the faulty part, could remove a few supporting bolts and detach the entire engine assembly. A new unit, already run up on the test stand, could be quickly installed and the airplane dispatched on schedule. Later, on a convenient workstand at floor level, the mechanics, with leisure, safety, and a vastly improved disposition, would make whatever changes are necessary to recondition the original engine.



A special inspection of internal wing structure is made. The illustration shows a typical setup of X-ray equipment used to inspect parts of the main wing spars. The particular aluminum alloy tubes used to fabricate these spars are subject to stress-corrosion cracking under certain conditions; and the illustrated X-ray inspection procedure is used to examine critical areas in search of possible hidden defects.

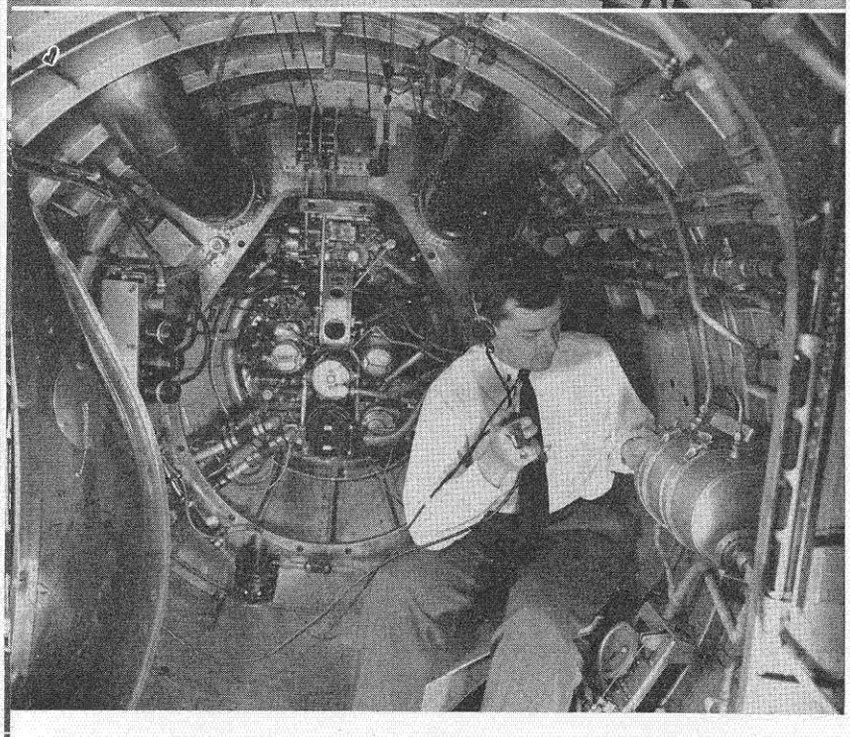
A FUNCTIONING MAINTENANCE ORGANIZATION

So that the reader may obtain a truly vivid picture of a modern airline's maintenance procedures, we shall suppose that a Pan American Airways Boeing Clipper, due for a periodic hangar service, is just coming in from across the Pacific, and we shall follow it from its landing, through the shops, up until the time it is released for its next scheduled flight.

As the airplane lands in San Francisco Bay, 16 hours out of Honolulu, various members of the 10-man crew not actually engaged in operation of the 42-ton flying boat are making final entries in their logs, noting any irregularities, indicating what repairs and corrections must be made before the next flight. Serious troubles, if any, already have been radioed in to the base, thus enabling the Maintenance Planning Group to set up schedules for their handling.

No sooner is the airplane secured at a dock than mechanics swarm through it, crawling through the leading edge of the wing into the nacelles and out through doors just back of the engines, from which access to still-warm cylinders and spark plugs is gained. The latter are immediately removed, taking advantage of their relative looseness while hot. Meanwhile, after the passengers have disembarked and the cargo and mail have been carried off by the loading crew, the airplane is towed to the marine railway, on which it is lifted from the water to the apron on shore. This is made possible by sliding a wheeled cradle underneath the hull while still in the water, to support and permit easy handling of the great weight on dry land. Here the salt water, whose effects on the aluminum skin are devastating over a long period of time, is washed off with fresh water. Then the airplane goes into the hangar. Continuing their work on the hull, cleaners scrape off any scum that may have accumulated. In this connection, it may be of interest to note that but a few days after December 7, 1941, an eastbound Clipper arrived, showing not only its battle scars—shrapnel gashes and bullet holes sustained as it escaped from Wake Island—but also carrying the first direct proof of what had happened at Pearl Harbor. Its bottom was stained with oil, a condition which prevailed for months on other airplanes as well until the harbor was at last cleaned up.

To facilitate work on the airplane, three-story work stands are utilized. These are simply de luxe portable scaffoldings of dimensions suitable for working on an airplane whose wing span is some 150 feet. The lowest workstand platforms are slightly above floor level and are equipped with cleaning fluid tanks and outlets, junction boxes for connection to hangar electrical and compressed air outlets, and desks for the filling out of work



UPPER: The empennage gets its share of attention. Control surfaces and mechanisms are extremely important parts of an airplane and must be checked and serviced as carefully as the engines or propellers. To facilitate such work, stands of convenient height are utilized as shown. Note openings to permit inspection of and access to control cables, pulleys, etc., inside the tail assembly structure.

LOWER: Nacelle and engine are checked in flight. A flight engineer works inside No. 3 nacelle during flight operation. Illustration shows engineer officer checking the prestone tank before reporting to the control deck via the interphone system.

sheets and inspection write-ups. The middle platforms are at the passenger deck entrance level of the airplane, and the highest ones are just below the level of the engines. These last are furnished with work benches, engine and propeller wells, safety wire, mineral spirits hoses, and everything else needed to service the engines.

A tractor is used to position these work stands, locating them deftly within an inch of each side of the plane. While this is being done, mechanics are converging upon the aircraft; ship's equipment men and women, instrument technicians, engine experts and their helpers, sheet metal crews, and others skilled in the maintenance and repair of particular parts of the airplane. The engine cowling is removed by giving a half turn to Dzus fasteners, a clip with a flush screw head that secures the cowling to the engine frame. Parts-control "runners" take the individual sections to the proper benches for cleaning, sheet metal repair, painting, and storage until such time as the engine is ready to be "buttoned up." The propellers are removed and checked, or, if their time is up, sent into their proper shop for complete disassembly, thorough cleaning and inspection, etching, buffing down, balancing, and refinishing.

Should any portion of the metal structure be found defective for any reason (usually corrosion or accidental physical damage), sheet metal mechanics either repair the damage in such a manner as to restore the original strength or simply replace the weakened member with heavier new material. Plane-service men crawl into the bilges, ventilated by a powerful blower, to check for leaks and to make sure that the main fuel pumps and plumbing system are in good condition. Plane-service mechanics also open inspection doors and remove cover plates throughout the plane, thus enabling experienced inspectors to make certain that every part of the aircraft is in an airworthy condition.

THE AIRLINE ENGINEER

Engineers also are mixed up in what to an outsider may appear to be a general melee. The flight engineer's logs may show that an engine has been running rough, overheating, using excess oil, or otherwise performing in a not altogether accountable manner. Now, a power plant engineer is making an investigation to discover definitely what is wrong and will continue his study to its logical conclusion—determination of what can be done to prevent recurrence of the trouble.

Suppose a report has come in that a thermostat in the hot water system is out of order and, rather than repair of the present one, a job that the mechanic and the inspector could adequately handle, some modification is desired. In this case the instrument engineer would be on the airplane, working out the details of such modification. And while there, he might pause to note the progress on a new installation, such as a fire detection system for the engines. Some weeks ago he planned how this installation was to be made, arranged for preparation of a drawing, complete with exploded and pictorial views, and drew up a set of written instructions. This material then filtered down to the shop, and now the installation is in process.

The aircraft engineer is primarily a structural man. It may be that the flight stewards have requested some change in the galley. Incidentally, before the Boeing Clippers went into service few people would have dreamed that a four-course meal with filet mignon as the entree could be served to more than 50 people from a galley five feet long, four feet wide, and slightly over six feet high. Nevertheless, the Boeing Clipper galley can produce just such a meal; but here have had to be all sorts of additions and improvements, for no original designer could anticipate all the problems in so new a development. The engineering for these changes is handled by the aircraft engineer. Likewise, that connected with structural mounts for new radio equipment, design of a compartment for fragile express, modification of the water tank support to strengthen it against high landing loads, rework of the flap operating mecha-

nism, and so on. The water tank problem, by the way, is one that soon may exist no longer; for in tomorrow's planes it is highly probable that the drinking water supply will be obtained by condensation and purification of the exhaust products of the engine fuel, the device for accomplishing this feat weighing considerably less than the present tank with its load of tap water.

Then, in addition to those mentioned above, there are other engineers who are specialists with regard to some aspect of the aircraft or its operating characteristics, among them the weight-control and equipment engineer, an authority on aircraft interiors and on emergency equipment, such as oxygen masks, life rafts, special rations, signaling devices, etc. He also guards the weight of the airplane with as much care as a fond mother watches over the weight of her child. All these men can be classed as aircraft maintenance engineers and certainly there is great variety in their duties. Primarily, though, they are concerned with changes in the aircraft and/or changes which must be standardized on every plane, which require C.A.A. approval, call for calculations relative to stress limits, and are connected with airplane engine operating characteristics or other technical matters with which the mechanic would not be expected to be familiar. The successful aircraft maintenance engineer understands every detail of his particular section or function of the airplane, has the know-how when it comes to designing all manner of gadgets within his bailiwick, and is able to prepare clear, written instructions for the mechanics and equally clear reports for management and various governmental agencies. He should keep up with current aircraft literature and must be agreeable to working at all times of the day or night—such is the nature of the transportation business. Finally, he possesses the ability to get on with others, the all-essential attribute without which he could not hope to accomplish his manifold duties.

The close interweaving of effort which initially may have caused the airplane to look like something of a shambles—certain services require that even sections of the wings and tail be taken off, although doing this is not so difficult as it may sound—now begins to put it back in shape. The mechanics have signed off most of the items on their work sheets. These are subsequently initialed by the foreman and lastly must be accepted by the inspectors. Engineers have moved on to other newer projects—all but two of them, the weight-control engineer and the performance engineer. Now, as completion of the service draws near, it is the responsibility of the former to list all changes made to the aircraft involving an alteration in weight and a possible shift in the center of gravity. Every pound of weight added to the aircraft weight empty means one pound less of payload carried, for the allowable gross weight cannot be exceeded. And even though for the Boeing Clipper this gross weight is in the neighborhood of 42 tons, compared to which a pound of payload more or less seems insignificant, each decrease of one pound in the weight-empty figure means an increased revenue amounting to more than one hundred dollars per airplane per year. Hence, it becomes vitally important for the weight control engineer to keep a careful record of weight changes, so that the airplane will always depart at full gross weight and no more or less. It also behooves him, both by personal contact and through more formal channels, to impress upon every employee the importance of keeping the weight of the airplane as low as possible. Toward this end, substantial awards are made by the "suggestion committee" to those employees who submit practical ideas for weight reduction.

With respect to the center of gravity, anyone who has piloted a plane or anyone, for that matter, who can project himself from a childhood seesaw to an imaginary pilot's seat, knows that the location of the center of gravity has a very great effect on the performance of the airplane, especially upon its take-off and landing characteristics. The weight engineer calculates the center of gravity, using a specially constructed slide rule; then, working with Operations, he determines how the passengers shall be seated and the cargo loaded so that its final position will be the optimum one.

AIRLINE PRODUCTION ENGINEERING

Naturally, this last arrangement is made after the airplane has been released from the hangar and announced ready for flight—and here we may consider who does the releasing. This is done by the "maintenance planning group," which is the king pin in the entire maintenance routine. Back in the days when both airplanes and personnel were few, the division engineer and the shop superintendent personally watched over the servicing and release of the aircraft. Today, a division engineer, responsible for all maintenance work performed by the vastly expanded group of personnel under his direction, not only at the home base but also at distant island and foreign stations, has such a multitude of

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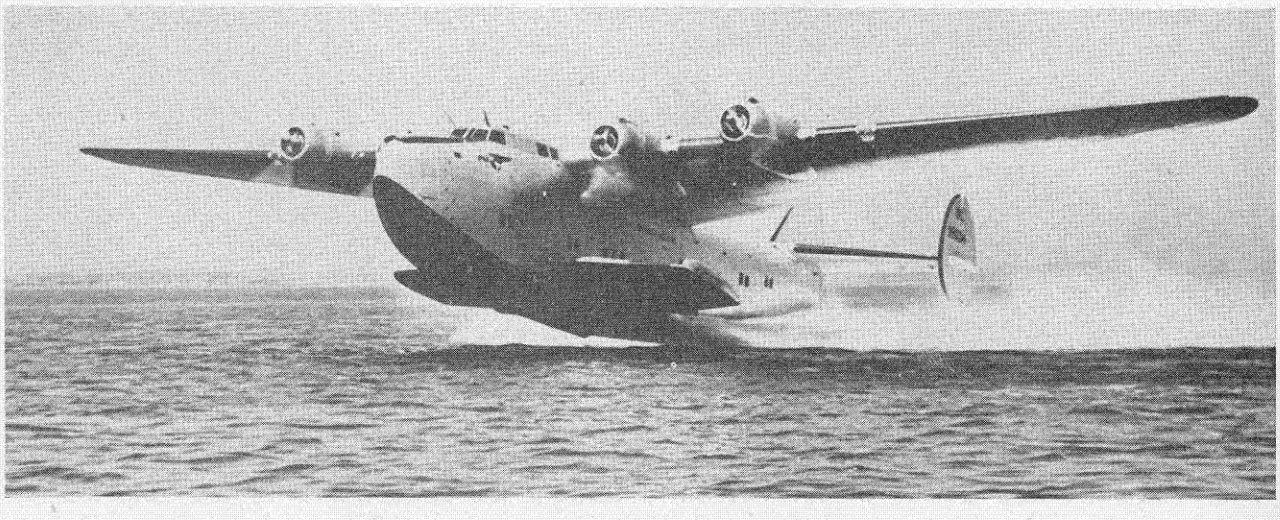

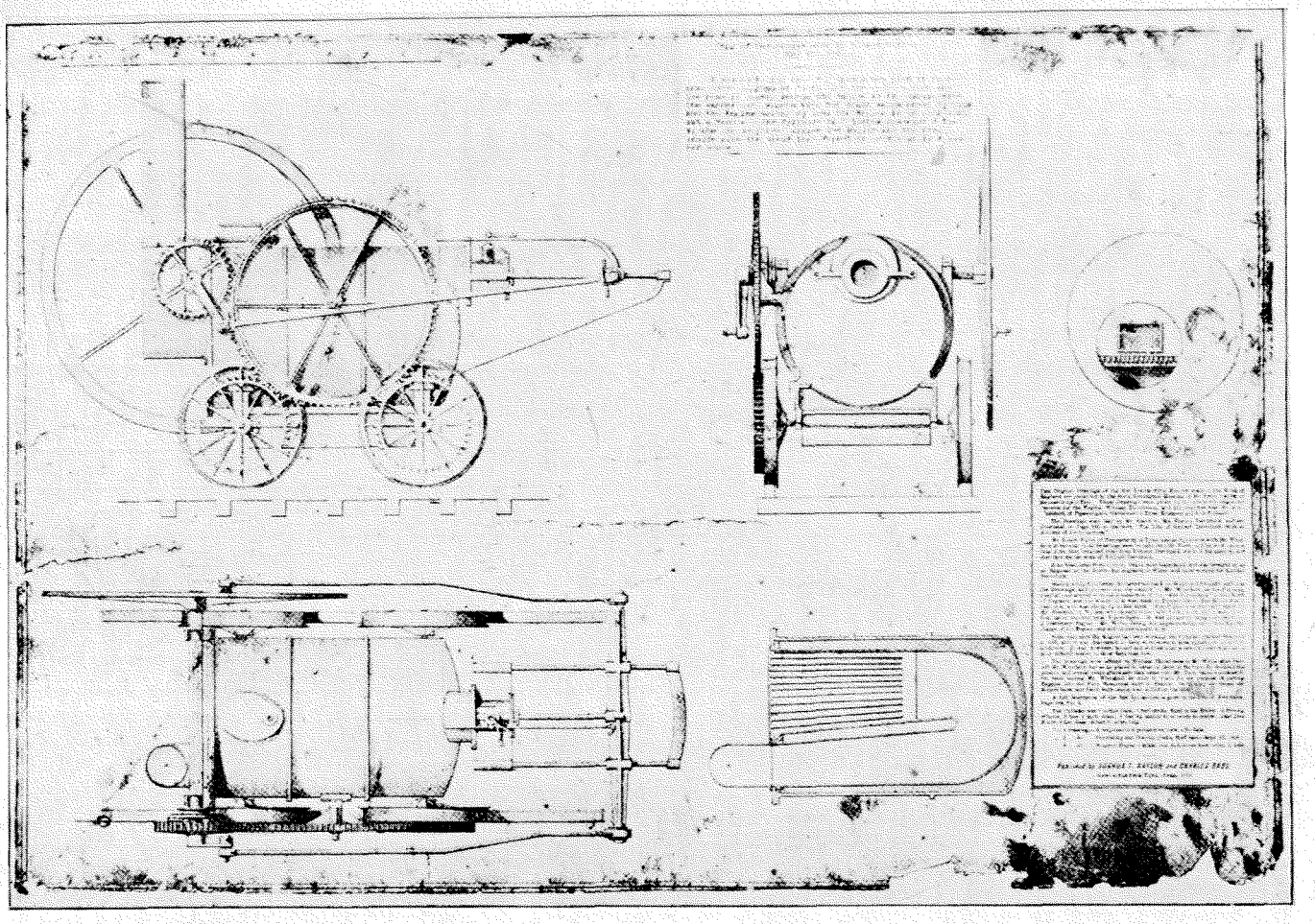

FIG. 2. Trevithick's Newcastle locomotive, 1805. (From the original drawing in the Science Museum, London).

Turning Them Around

(Continued from Page 11)

problems to cope with that he can no longer concern himself with the details of servicing individual airplanes. Similarly, the shop superintendent, charged with the responsibility of supervising more than 20 different shops and crews which may number as much as 1,000 men, finds his time occupied to a large degree by personnel matters whose ramifications can be and sometimes are quite complex. He, too, therefore, must restrict his activities to those dealing with the over-all picture.

Hence, the creation of a work-scheduling and planning organization. It is the planning supervisor, assisted by his staff, who schedules the many aircraft maintenance projects requested by various individuals or groups within the airline organization, plans all jobs within the shops, coordinates with the purchasing department in the procurement of supplies, keeps detailed records on engine, instrument, and accessory times, sees that job orders are issued when cost accumulation on a particular undertaking is desired, and develops work analyses leading to job simplification and standardization. Finally, it is the planning group that releases the aircraft to the operations department for scheduled operation.

THE END IN SIGHT

This release is accomplished in two steps. There is first the test flight. Although new installations on the aircraft may have a previous shop test—propellers and engines on a run-up stand, instruments inside pressure chambers and on wobbling mounts that simulate all types of flight conditions—there is always a test flight to make certain that items which functioned separately satisfactorily will perform just as correctly on the airplane. The plane goes into the water; its engines are run up and thoroughly checked by qualified mechanics; and inspectors commence a survey of the ship which lasts for the duration of the flight. Next the flight crew comes aboard and makes a second check of the entire airplane before the actual flight test begins. When all is in readiness, engines are started, the ship is taxied to the take-off area, and a carefully controlled and observed take-off is made. The flight test is under way.

During the test flight, each functioning system of the aircraft is carefully checked for proper operation. If any irregularities are noted, they are recorded and must be corrected before scheduled flight operation is resumed. In addition to routine checks, there may also be special engineering tests or investigations to he made. For example, engine tests may be run, not only for the purpose of testing the particular airplane involved, but to obtain data that may be useful to the entire aircraft industry, or an instrument calibration of some nature may be required. Normally, it is here that the performance engineer steps into the limelight, gathering his data for subsequent reduction and application toward more efficient or safer flight operation of the aircraft. On some occasions, where a number of diverse tests and checks are being made simultaneously, the inside of the plane resembles the main intersection of a metropolitan community, such is the bustle of engineers, flight per-

sonnel, mechanics, and inspectors, each independently carrying out his individual assignment. There is even activity in the wings, their unusual thickness permitting access to the engine nacelles in flight. As the airplane makes its circuit about San Francisco Bay, men crawl into the nacelles five feet in back of the propeller to make sure that everything there is in tip-top running shape. Should it be necessary to communicate with the pilot, the radio operator, or the flight engineer, push of a button will connect them via the interphone system with any of these men.

The test flight ends—it may be the middle of the night. Back on the ground, Inspection tells Planning what loose ends must be tied together and this information is passed on to those who will accomplish the necessary work involved with maximum speed. If calibration tests have been required, the performance engineer finishes the reduction and plotting of data obtained during the test flight and his conclusions are posted within the airplane for the use of the departing flight crew. Planning, estimating accurately how much time will be required to accomplish these finishing touches, has already called Operations, announcing just when the plane will be ready. The traffic department has notified the passengers and the loading crew is standing by.

BACK ON SCHEDULE AGAIN

At the time agreed upon, the airplane is released to Operations; and except for the beaching crew that does the casting off and the line crew mechanics and inspector who again warm up the engines, the maintenance department has already turned its attention to another airplane. The passengers' going aboard, the thundering taxi run, the ultimate take-off—features which still thrill the bystander—are now accepted as routine. That is the difference which numerous departures a day have made. If one were to desire additional evidence, he should note the passengers going aboard. Before the war began, it was orchids, dress clothes, cameras, flashlight bulbs, plus innumerable friends and relations. Now it is a group of military personnel, commissioned and enlisted, some of them in shirtsleeves, their luggage merely a khaki bag under their arm, their departure unheralded and unattended.

To summarize, it may be stated that for Pan American Airways' Pacific-Alaska Division, the net results and benefits derived from improved products and streamlined maintenance methods over a 10-year period have included a 250 per cent increase in utilization and a 30 per cent decrease in elapsed service times required. Such an increase in utilization is tantamount to almost tripling the size of the fleet on the basis of seat-miles and ton-miles made available. Finally, since the actual number of units operated has increased even more than this, it is evident that operations have been stepped up tremendously.

In this light, then, "Turning Them Around," while still retaining its adventurous side, is today a mature business.

Month in Focus

(Continued from Page 3)

Recently, and probably in the past as well—at least more obviously now—several cases have been observed in which the membership of a union organization have