AIR FORCES MANUAL No. 10

ARCTIC and TROPIC MAINTENANCE OF AIRCRAFT

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ARCTIC and TROPIC
MAINTENANCE
OF AIRCRAFT

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CONTENTS

INTRODUCTION

The purposes of this handbook are to familiarize you with general conditions and problems of maintenance on the line in non-temperate areas (in arctic, desert and tropic theatres), and to tell you what to do about them.

In the kind of global warfare we are waging, in many different climates and lands, maintenance difficulties are created by the presence of excessive cold or heat, by the injurious action of dust and moisture and by other natural forces that can make the going rough. This handbook gives you a general picture of the special problems you may meet. It gives you information and knowledge that will make your job easier. For specific information covering the normal maintenance and operation of each particular aircraft, you will of course be guided by the individual Technical Orders and handbooks for each type of plane.

This handbook won't do your work for you. It tells you beforehand what to expect and what to do. The way you absorb and profit by this information, the way you use it, will make the difference between sweating out your job or taking it in stride.

ARCTIC MAINTENANCE

GENERAL

ARCTIC "PERILS." ***Some plain facts.*** No attempt is made to belittle the hardships and the problems of aircraft maintenance in cold weather. Yet much that is heard about arctic perils may be dismissed immediately as pure fiction, reflecting a natural tendency to exaggerate personal exploits and hardships. We are informed that equipment fails, allegedly because of the influence of sinister Gremlins or some mysterious alchemy caused by cold. Malfunction of equipment is immediately blamed on "Cold Weather," regardless of contributing causes.

The truth of the matter is that most arctic flying difficulties can be traced to a basic failure to follow maintenance and operation instructions. Most of the harrowing incidents experienced might have been avoided by a basic understanding of the problems that exist, a knowledge of the measures required to overcome them, and the taking of proper precautions.

MODIFICATION AND WINTERIZATION

Modifications. Modifications which will go a long way toward eliminating many past difficulties in the arctic, desert and tropic zones have been and are being developed and incorporated into production aircraft.

"Winterization." Winterization, the preparation of aircraft for cold weather operations (specifically, so that they will function satisfactorily down to a temperature of −65° F.), is best accomplished at factories, modification centers or air depots. Aircraft and items of ground equipment are usually winterized in production and necessary ground equipment is made available as required. Technical Orders should, of course, be complied with rigidly.

WINTERIZATION. ***What it may include.*** Winterization may include the following:

De-icing and anti-icing equipment. Pneumatic boots for wing, vertical fin and stabilizer, propeller anti-icing plumbing and slinger rings, and perhaps electrically-heated propellers, will be provided; pilot and bombardier compartments will be equipped with windshield wipers and heaters, and in some cases, with alcohol sprays; a heating system for the carburetor will be provided, together with some modification of the induction system which may include alcohol de-icing and the protection of scoop inlet air.

Heating. Some new aircraft will be "hot-wing" jobs, with wings, empennage and cabins incorporated into a heating system which adds greatly to comfort and safety. There will be cockpit, cabin and turret heating on all aircraft. (Double-panel heated windshields are recommended for all bombers and transports.) Carburetors will be equipped for heat application and provided with carburetor-air thermometers. Blast-tube or louver heat will be available for pilots, bombardiers and turret gunners. Special heating will be provided for certain engine accessories, for automatic pilots, bombsights, cameras, guns, instrument panels, batteries and pitot heads. Oil-tank immersion heaters may have been installed and socket provided for plugging in 110-volt external current source; hereafter, flexible electric oil-tank immersion heaters will be provided as ground equipment. Ground-heater accessory doors will be installed in each engine nacelle.

Mechanical. Provision will be made in the control system to permit adjustment required as a result of differential contraction and expansion; gear-type pumps will be installed with adequate clearance to compensate for case shrinkage. Surge valves or self-thawing oil coolers, condensation traps and drains in oil and gas tanks, stand-pipes in tanks, safety vents protected from outside temperatures and large oil drain plugs will also be installed. Fuel- and oil-tank drain cocks must be accessible and allow of a positive lock without safety wire; oil lines will be installed to enable complete drainage of the system. Hazardous screens must be removed from the carburetor ram. Some transport craft will have nose shutters, spoiler rings and oil shutters; most aircraft will be equipped with oil and coolant shutters with full-closing cowl shutters; turbo-supercharged aircraft will have full-closing intercooler shutters. Adequate clearance must be provided for retracting landing lights and for lowering and retracting the landing gear, flaps or air brakes.

Electrical. In accordance with applicable Technical Orders, there will be outlets for electrically-heated flying suits. Each rheostat will be individually protected by a 30-ampere circuit protector. A high-capacity ignition system and booster coil or induction vibrator will be provided. For battery-cart hookup, an external battery-connection plug must be available, equipped with a spring-loaded door so that the power line may be removed without subjecting the lineman to prop blast. In some cases, turret-motor output will be increased to carry heavier loads. Larger capacity batteries will be needed on some aircraft, as all electrical services will be increased. Carbon-pile regulators will be installed. Also, starters will be winterized to reduce failures caused by engine-oil leakage, and to eliminate excess oils and greases.

Hydraulics. All hydraulic fluid will be cold-weather specification grade. Hydraulic packing hose, rings, connections, diaphragms, cups and seals must be of approved materials which will not become brittle and show a high percentage of rupture, and which will remain pliant and exhibit an ability to return to their original shapes. All pneumatic-hydraulic shock absorber struts will have a combination of leather and synthetic rubber packing rings, installed with metal adapters. Wheel brakes will be equipped with low-temperature synthetic rubber seals or expander tubes.

Lubrication. Engine oil will be cold-weather specification grade. All lubricated surfaces will be cleaned and relubricated with approved oils and greases. Non-channeling grease will be used where prescribed for the elements of the control system. The propeller will be lubricated with special grease. Where direct-reading is employed, light oil will be worked into the oil-pressure gage line.

Miscellaneous. The aircraft will be equipped with form-fitting fabric covers or tarpaulins for engines, props, wings, tail, windshields, turrets and possibly carburetor air intakes. For operation on snow and ice surfaces, special tires will be installed to afford additional grip. The clearance of these tires in the stowage wells must be carefully checked. Circulation of warmer oil must be induced in the breaker boxes and in the hydromatic propeller dome by drilling oil passages where necessary. Control handles, including brake pedals, should be wrapped for insulation to add to the comfort and protection of personnel. Openings will be carefully sealed against draughts, and the sealing strips oiled with a non-freezing grease. The bombsight and AFCE (Automatic Flight Control—Electronic) will be maintained at not less than −25°F.; the A-3 type auto pilot at not less than +7°F.; air-driven gyro instruments and oxygen equipment at not less than −30°F. Electric-driven gyro instruments will operate satisfactorily at −65°F. Guncharger hose must be winterproof and gun breeches maintained at not less than +35°F. by means of hot air or electric heaters. Gun bays will be insulated in some cases and heated in others; barrels will be closed with Scotch masking tape which will be cleared when the guns are fired. A manual or automatic oil-dilution system will be provided. Each engine installation must scavenge satisfactorily, using 30 percent diluted 1100 A oil at take-off power for five minutes. Propane starting facilities may be installed. A clear vision window will be provided for the pilot.

Look for the yellow dot. All items of equipment or units that are modified for satisfactory operation of −65°F. to +160°F. (−54°C. to +71°C.) will be marked with a yellow dot, at least one-fourth inch in diameter and located in a conspicuous space. During the transition period, lack of the yellow dot is not an indication of lack of approval for the use of that equipment, but merely indicates that the equipment has not yet been thoroughly tested for operation in the temperature range mentioned. If tentative approval has been obtained, the item may carry a white dot. Marking will be done at the factory, modification center, or depot where the modifications are made.

These are the modifications and winterizing procedures required to fit aircraft for operations in cold weather. But they are only a part of the story. Proper maintenance and the intelligent conduct of the personnel performing it are the keys to continuous and successful operation.

INGENUITY AND COMMON SENSE. Follow rigidly the procedures laid down for cold-weather maintenance and operation. Learn the lessons of arctic maintenance early—learn them well. Get to understand the effects of cold. A certain fear of the unknown is inevitable, but don't get jittery about things that aren't there, or anticipate conditions which don't exist.

Aircraft can be and are successfully maintained under conditions of extreme cold. It takes longer, it's tough to do, and it's downright uncomfortable much of the time. It requires ingenuity to get the job done and to avoid the discomforts of cold and frostbite, but the most important thing is common sense. The discomforts and handicaps of cold-weather maintenance may tempt you to fix all blame for mechanical trouble and difficulty on sub-zero temperatures. Don't let yourself get into that frame of mind.

PERSONAL COMFORT

Sub-zero temperatures render maintenance difficult but not impossible. The troubles you experience will result primarily from the physical discomforts and inconveniences involved. All work takes longer to do in cold weather than in warm.

Simple operations, such as applying safety wire or checking valve clearances, may become heartbreaking experiences because you have to choose between two evils—either you risk metal-burned (frozen) fingers, or you wear a bulky glove and wrestle awkwardly with a pair of pliers. Yet, such work must be done, if aircraft are to fly or fight in arctic weather. You can do much to minimize the discomfort and inconveniences by the use of proper clothing and by the observance of certain simple common sense precautions.

CLOTHING FACTORS. The trick in cold weather maintenance is to keep warm and yet wear clothes in which you will be able to work efficiently. The idea is to get warmth without bulk. Heavy clothing for work on the line in bitter cold weather is a handicap. The importance of proper clothing can't be too strongly emphasized, and you should pay particular attention to footgear and gloves.

Footgear. It is pretty obvious that footgear cannot be both warm and waterproof at the same time. Yet in extremely cold weather it is most important to keep your feet both warm and dry. You will find that the "mukluk" boot issued to you is the most practical and serviceable footgear for extremely cold weather. Your arctic wardrobe should include at least three pairs of mukluks and all the inner soles and socks which go to make up this boot.

Body clothing. At present, two outfits are in the process of issue: one is a quilted down-filled suit which is wind-resistant and buoyant, for use in extreme cold; the other is a two-layer suit composed of an intermediate and an outer suit made of wind- and water-repellent cloth lined with alpaca, both layers of which should be worn in extreme cold. Wear your underclothing loose, with plenty of air space. Several layers of light underclothing are much warmer than a single, heavyweight layer.

Gloves. Gloves, of course, are the most difficult requirement to meet satisfactorily. Because cold metal sticks to flesh in sub-zero temperatures, some kind of protection for your hands is essential. But warmth ordinarily requires bulk, and bulk will impede the work you do, which demands the nimble use of your fingers. A satisfactory compromise is to use basic silk, rayon or light cotton gloves, plus the D-3 mechanic's gloves, which consist of knit-wool inner linings with outer horsehide covers, hung around the neck by a thong, and used for warming as required.

Headgear. As for headgear, any parka hood, correctly fitted and properly lined, will do the trick. It is important that the parka hood should project beyond the face and be trimmed with naturally oily fur, such as wolverine. This will prevent the wind from entering at the sides. The frost which accumulates on the fur can be brushed off with ease.

PERSONAL PRECAUTIONS. ***Avoid overexertion.*** If you unconsciously over-exert and start gasping large breaths of air, put your head down and breathe from inside your warm clothing until you begin to breathe normally again.

Avoid sweating. Sweating is dangerous in sub-zero temperatures. To avoid sweating, keep removing articles of clothing as neccessary. Ice will form in damp clothing, and damp portions of your body will freeze more readily. Don't let this happen. Take every opportunity to dry out your socks and underclothing. Always change when you get wet. If you perspire indoors, dry your body and change, or dry your clothes before you venture out in severe cold weather.

Don't spill gasoline. Gasoline spilled on the hands or clothing in sub-zero temperatures has an effect similar to liquid air. It will freeze flesh a few seconds after contact—watch out for this.

Don't touch cold metal without gloves. The moisture on your hands will freeze to the metal surface, or the cold metal may freeze the part of the hand in contact with it. Any attempt at forcible separation will rip off the skin. If you should get stuck, warm up the metal before attempting to release yourself; or else use water warmed to body temperature, or urinate on the point of contact. Insulate your tools with velour covers or wrap the handles with twine. Choose tools which lend themselves to cold weather use; that is, single-ended spanners and wrenches. Also cover all control handles in the aircraft itself.

Avoid prop wash. Avoid prop wash and assist each other if so exposed by checking for gray or white areas of frostbite on the face. Thaw by placing a warm hand or warm material over the frozen area until circulation is restored. DO NOT RUB.

Keep clean. Keep as clean as possible under the circumstances. Oil and grease on your clothing will reduce the insulating qualities of the fabric; so will perspiration. And remember that laundry facilities are not plentiful.

So much for the factors of clothing and personal precaution. Following are some of the preliminary aspects of actual maintenance.

GENERAL MAINTENANCE

PARKING AND MOORING. It is advisable that the parking area for wheel gear be sanded, or that grating, steel mat, fabric, grass, straw, green boughs or other insulating material be placed under the wheels to prevent the tires from freezing into the surface. Lack of such precautions frequently results in tearing off large chunks of rubber from the tires when the aircraft is moved.

Brakes. After allowing approximately half an hour for the brakes to cool, expander-type brake should then be placed in the "On" position. All other type brakes should be left in the "Off" position.

Don't use flat-based wooden chocks. They won't hold on snow or ice surfaces. Use metal-tube chocks, preferably with spurs, and block the wheels fore and aft.

Mooring lines. Because of the freakish winds which develop suddenly in the arctic, it is essential that planes be tied down at all times. Mooring bits should be installed during summer at permanent stations. If bits are not available, the mooring arrows provided in the aircraft mooring kit should be used. If no fixed anchorage is available and the ground is frozen too solidly to use the mooring arrows, improvised methods may be employed, such as freezing coils of rope, logs or other available materials in holes in the frozen ground or snow. Similarly, various methods may be improvised for parking on ice. Mooring lines should be tight to prevent the aircraft from rocking in the wind; a slack line is of little value. Controls should be locked with surface control locks in preference to those locks incorporated in the control-cable system.

Solidly frozen ground. When the ground is frozen so solidly that it is impossible to drive the mooring arrows, or to dig holes, first prepare the ground by building fires over the desired mooring points, or else use a hand-operated portable heater to thaw the ground sufficiently to permit placement of mooring devices.

NOSE HANGARS. The maintenance of tactical aircraft in cold weather is greatly facilitated by the use of portable nose hangars. These may range from small, improvised structures to large and elaborate installations, built on skids or permanently located. The latter are floored, solid-framed, insulated and heated, fitted up with tool benches and storage room, with one side composed of canvas openings equipped with draw-strings, through which intrude the aircraft nose and engine nacelles. This latter arrangement makes a very acceptable hangar for all normal maintenance and represents the ideal. Types are available to accommodate one-, two-, and/or four-engined aircraft.

It is good practice to provide a rink of glare ice in front of a permanent nose hangar, to facilitate moving the aircraft in and out; if tractors are not available, anchorages for block and tackle should be laid in the ice to allow for movement by a small crew.

At most fields, portable nose hangars (field maintenance shelters) are available. When used in conjunction with ground heaters, these are a good substitute for a hangar. In case there are no nose hangars available, makeshift shelters of tarpaulins can be erected. Lighting equipment requiring an electric generating source must be secured and set up; otherwise it is usually too dark to work in the shelter (although plastic windows are provided).

Sweating. For tactical aircraft operating in cold weather it has been found desirable to park outside even though hangar space is available. The necessity for dispersion in some areas makes this practice compulsory. However, aside from dispersal considerations, cold aircraft wheeled into a warm hangar, will sweat. If not thoroughly dried—and this will require the better part of an hour, with all areas vented—the aircraft will fog up upon being returned into the outside temperature, and considerable takeoff delay will be experienced.

Frosting. When aircraft is parked for the night, either the emergency escape hatch or some other opening should be left partly opened. This will permit the circulation of air inside the cabin or cockpit, and so prevent the frosting up of the windows, which is certain to occur in cold weather if no circulation of air is provided. Precautions should be taken to prevent blowing snow from entering the opening..

COVERS. Cover the engines, wings, tail surfaces, windshields, propellers, turrets and carburetor air scoops with the covers provided for that pupose.

Form-fitting wing and tail covers will be of two types: a preshrunk airplane cloth for regions of extreme cold, and a waterproof material for warmer climates subject to rains followed by freezing temperatures. All covers will be of the quickly detachable type and of such design that they may safely be left on the airplane while the engines are running. These covers will prevent the formation of frost on the horizontal surfaces when the airplane is on the ground, as well as when taxying. To accomplish their purpose, covers must be "skin-tight" to prevent frost formation under them and to resist tearing action of the wind and the slipstream.

Installation. If the wing covers were folded properly when removed, replacing them is a fairly easy task. On fighter-type aircraft, covers can be installed by one man. However, difficulty is encountered in the large bomber class. Here it becomes necessary for three or four men to install covers. The folded wing covers are first placed on top of the wing preferably near the tip. One man remains on the wing and the other two or three on the ground. The wing-tip pocket is first installed and adjusted by the man on top of the wing. Next the cover is unrolled back to the fuselage and spread evenly over the wings. As all wing covers are tailored for each aircraft, it is readily apparent whether or not the wing covers are properly installed. Most of the installation of wing covers must be performed on the hands and knees or damage will result to the wing surface. Mechanics must be particularly careful when working near the wing tips as the wing structure was not designed to withstand much weight or pressure. One good rule to remember is to be astride the main spar as much as possible. De-icer boots are often damaged when inexperienced personnel attempt to cover a wing—use caution on the leading edge. Wing cover tie-down ropes should be drawn tight to prevent the wing covers from whipping in the wind, which in a short time can tear the covers to pieces. On the older type of wing covers, it is advisable to tie slip knots so that the covers can be removed easily without removing your gloves. The newer wing covers have a pulley and block arrangement which makes it very easy to install and remove them.

Removal. In removing wing covers, the first step is to untie all the ropes. One man should mount a maintenance stand at the wing tip of the airplane, and one man should be at the trailing edge of the wing where it meets the fuselage. The man on the wing tip pulls the covers toward him until he is able to reach the cover from the ground. During this entire operation, the other man is busy watching the cover to see that it does not foul or tear on any projection. The wing cover is removed with a steady pull directly in line with the wing. Caution must be exercised in the removal of those covers having tie-down hooks or blocks which may damage the de-icer boots and control surfaces.

Care of covers. Covers are essential to arctic operation and care should be exercised in their handling. Before you fold the covers, all the snow (if present) should be shaken free and the ropes untangled. Remember that if wing covers are carried in the plane, and cabin heaters cause the temperature to rise above freezing, the snow will melt and then freeze upon landing, causing the covers to be stiff and unmanageable. The only cure for this is to take the covers into a hangar (if available) and allow them to dry thoroughly. If inspection of the wing covers reveals tears, they should be repaired immediately.

SNOW, ICE, AND FROST REMOVAL. ***Frost.*** Aircraft will frequently be covered with a layer of frost. No matter how thin it may appear, always remove it, particularly near the wing tips. The simplest method is to sweep the surface with a stiff broom, preferably one with a long handle.

When aircraft are dispersed in the open overnight, hoar-frost will usually form just as the sun is rising, and its presence should always be suspected and investigated before take-off. Aircraft wheeled from a warm hangar usually will accumulate frost as soon as it gets outside.

Remember that a very small amount of hoar-frost will so seriously disturb the air-flow over a wing on take-off that a loss of lift and very treacherous stalling characteristics will be caused. Remove hoar-frost.

Under some conditions, notably with ground haze, frost will form so rapidly that it will be necessary to taxi out to take-off position before removing covers. (Mopping the wings with alcohol and glycerine before covering will delay frost long enough for take-off.)

Snow must be removed. Snow will not blow off during the take-off and once it has become frozen to a wing surface, it may be very difficult to remove. It can be brushed off by sweeping with a stiff broom, or by the use of ropes thrown over the wings, snapped and sawed back and forth. This is best done by two men, but it can be accomplished by one man holding both ends of the rope behind the trailing edge of the wing. Usually it is necessary to sweep the surface afterwards, as the rope method will not give a smooth finish.

Lightly blown snow may accumulate in the wings and fuselage wherever openings remain uncovered. Inspect for and remove such accumulations to prevent take-off with an overload of drifted snow.

Ice removal. Ice can be removed by applying heat sufficient to loosen the ice particles which can then be easily removed with a hard brush. When removing ice with heat, care should be taken not to allow the heat to melt the ice completely, as the water may get into control-surface bearings and freeze. As a last resort, remove obstinate ice from localized areas with an alcohol spray. Remember that the thinnest film of ice provides a base upon which more ice can and will rapidly form.

Frost removal. Frost will usually form on the windows either during engine heating or when the crew enters the aircraft, and this should be removed with heat, alcohol, gasoline, or copper or steel wool. CAUTION—don't use copper or steel wool on plastics. Light mist forming on the windows usually will disappear when circulation is established. Ice on prop devices and blades can best be removed by direct application of heat. The same applies for shock struts.

Controls and mechanisms. When there are sharp changes from moderate to extreme cold, condensation will cause ice to form inside the wings and fuselage as well as outside. Careful inspection must be made to insure the freedom of all controls and mechanisms from such icing. Removal of this ice is difficult and generally can be accomplished only by the application of heat, since chipping may result in damage to the aircraft.

Exterior surfaces and mechanisms. Remove ice and snow from the under-carriage to prevent jamming or hindering the retraction of wheels and to permit the proper operation of locking devices. Loose snow also tends to blow into the engine nacelles on the take-off and then freeze on retraction so that it may be difficult or impossible to lower the under-carriage. A liberal application of anti-freezing oil will permit the ice to break off when power is applied to the hydraulic jacks.

Bomb-bay doors and flap-operating gear may also lock through accumulation of ice or frozen snow, and should be treated in the same manner as the undercarriage components. Those parts of pneumatic firing gear which are adjacent to the point at which the compressed air is discharged should be similarly treated.

Remove snow packed in the carburetor intake. Carburetor screens should be removed for snow operation.

Clean antenna of snow and ice before take-off.

Inspect for ice all exposed hinges on flaps, elevators, ailerons, rudders, trim tabs and bomb-bay doors. Remove such ice. Heating of the engines or cabins will often melt snow on top of the wings which runs into the control-hinge crevices and solidifies.

Operate all ailerons, elevators, rudders and trim tabs through several complete cycles, noting the resistance. If resistance is excessive, investigate. Controls should be checked pre-flight for operation and also to loosen the grease in the bearings. Trim tabs are just as important for safe operation of the plane as the primary controls. As some of the trim-tab mechanisms incorporate a gear box in their systems and as these gear boxes are filled with grease, it is readily apparent that these tabs also may be rendered useless by the freezing of the grease.

Turrets. Turrets should be checked before take-off and operated through the full range of traverse, elevation and depression, in order to remove congealing fluid from remote parts of the mechanism and to maintain the temperature of the working parts. This will prevent sluggish operation and, in extreme instances, the sticking of the turret. Always use external power supply for ground checks.

ROUTINE CHECKS

The routine of cold weather maintenance should become habit and second-nature to line personnel. Certain essential checks must be made routine and observed vigilantly.

Sumps and filters. Drain all fuel and oil-tank sumps, Y-drains and filters prior to each flight. Check the Y-drain and oil-tank sumps for fluid oil. If no oil comes out, indications are that the drains are clogged with ice or congealed oil. Apply heat to thaw. Be sure to lock drain immediately after water is drained or as soon as oil flow occurs. If drains are not of self-locking type, safetying is necessary. Hydraulic filters should be drained at fairly frequent intervals.

Fuel and oil tanks. Service fuel tanks to full capacity immediately after flight. Oil tanks should be checked after oil dilution is accomplished. If it is then found that tanks require replenishment, add additional oil and dilute.

Vents. Check to see that fuel, oil-tank, and engine-crankcase vents are free of ice. Condensation may permit droplets of water to form in the vent line, where they may freeze and cause a stoppage; the result—a burst tank.

Struts. Keep struts clean. This cannot be over-emphasized. The shock-strut piston tubes must be wiped clean of all snow, ice or dirt, with a rag soaked in the hydraulic fluid used in the strut. If hard dirt or grit is encountered and difficulty is experienced in cleaning, kerosene should be used as a solvent to remove the grit and the piston again lubricated with hydraulic fluid. This procedure should be repeated before take-off. Shock-absorber packings are quickly cut and spoiled by ice and grit, especially at extremely low temperatures when they have lost much of their resilience.

After cleaning, wrap the struts with a clean dry rag which should be removed prior to take-off. Boots have been developed which may eliminate the procedure described. However, these boots add to maintenance time involved, as it is necessary to remove them for checking the strut height. They have been deleted from current requirements.

In spite of precautions, leakage will occur and struts will deflate. Leakage is evidenced by fluid in the snow. Correct inflation is measured according to the instructions contained on the plate which is fastened to the strut itself. Continual malfunctioning of these struts necessitates constant inspection and reinflation.

Hydraulic units. Check for leaks in such places as hydraulic system, shock-strut seals, brake cups, fuel pump and accumulator diaphragms and pressure lines to brakes. If there is continual leakage, check the type of strut packing employed. Winterized hydraulic units are identified by special markings, indicating the type of packing employed. Check the strut air valves; these frequently give trouble. If there is leakage, replace with high-pressure cores and seats designed to function under cold weather conditions. Increased leakage of all hydraulic units and connections makes it necessary to inspect frequently the fluid level in the reservoir. Breakage of bases and lines also adds to the maintenance of the hydraulic system. If continued refilling of the reservoir is necessary, checks should be made to determine where the leak is located in the system. All hydraulic units should be checked through their entire range of operation to be sure they are operating correctly. Probable causes for most trouble are broken lines, ice in the lines, sheared hydraulic pumps, ruptured diaphragms, low air pressure in the accumulator, and sticking of selector and relief valves. These conditions should show up during engine run-up; they must be corrected before flight.

As the hydraulic Cuno collects most of the moisture in the hydraulic system, it is necessary to check this unit frequently for the presence of ice. It must be remembered also that ice can collect in other parts of the hydraulic system just as well as in the Cuno.

Control surfaces. Control surfaces are more often damaged in arctic operations than under normal operating conditions. Running up the engines in deep snow, as well as taxying through it, causes pieces of ice to be blown through the elevators. As aircraft operate in snow most of the winter, it is obvious that fabric-covered control surfaces will be damaged quite frequently. The removal and installation of wing covers often injures the control surfaces. Tears in the control surfaces should be repaired under shelter because heat is necessary to prevent the dope from blushing, which would prevent the patch from adhering; but don't direct a blast of hot air at the patched surface in order to dry the dope.

Never apply force to any fabric-covered control surface by leaning on it or by gripping it in intense cold. Because of the hardened condition of the doped fabric, cracks or "ring worms" may result which will weaken the control surfaces.

Propellers. Propellers become nicked frequently and therefore require considerable maintenance. Aeroprops, particularly, are subject to "wrinkling" after taxying through deep snow. With the Hamilton Standard constant-speed governor the pilot valve may stick; the exterior of the electric head should be coated with airplane dope to prevent moisture from entering. In the Curtiss electric governor, rusting of the rack and pinion gear may occur. Sticking and rusting are indicated by fluctuating r.p.m. in flight. One remedy is to drill a hole in the head of the governor and install a vent at right angles to the direction of flight, creating a constant vacuum inside the governor head. Propeller governors are a problem. Any congealed oil or condensation will cause unsatisfactory operation. Governors require constant inspection

Cleaning. Cleaning aircraft at 40°F. is a problem. Experience has shown that the best method is to wipe it with gasoline, and then with a dry cloth. Care should be taken to prevent freezing of the hands when applying gasoline. Windows and windshields can best be cleaned with alcohol.

Anti-icing and de-icing equipment. Operate the prop anti-icing system. Check de-icing equipment during engine run-up. All tanks for anti-icer fluid should be checked for proper level. De-icer boots should be visually checked for tears and abrasions caused by wing covers, ladders or wear; don't treat them with de-icing oil.

Windshield wipers should be checked with a wet windshield.

Two types are in use at present: electric and hydraulic. Each has its own maintenance problems. The electric wiper must be checked for a sheared flexible drive shaft. Hydraulic wipers must be checked to see that sufficient fluid at the proper pressure is being delivered to operate the unit satisfactorily. Sticking of the de-icer distributor valve may occur, making the de-icer boots inoperative.

Electrical equipment. Watch for corrosion of electrical equipment caused by condensation. Spark plugs, magnetos, harnesses and leads are all susceptible to the effects of condensation.

At or below 20°F. (–5°C.), the aircraft battery should always be removed when practicable, stowed under cover, and charged in room temperatures above freezing. However, if you lack facilities, there is little object in removing the battery. Quick battery disconnects and accessible locations are currently being provided for this purpose. Portable generators, when available, should be used at every opportunity to build up the battery. Whenever possible, use a battery cart to start an engine or to run electrical equipment. Do not operate electrically-heated flying suits, turrets or other electrical devices unless a suitable generator is kept in operation.

Replace battery, if the specific gravity of the electrolyte falls below 1.240. The battery charge decreases proportionately with the temperature because the electrolyte becomes less active on the chemicals of the plates as the temperature decreases. The freezing point of the electrolyte depends upon its specific gravity. For example, electrolyte with a specific gravity of 1.250 will freeze at –62 °F.; with a specific gravity of 1,200 at –16°F.; and with a specific gravity of 1.10 at +19°F. A frozen battery may burst.

Instruments. Below –31°F. (–35°C.), air-driven flight and turn indicators are subject to malfunction and sluggishness. Prior to take-off, ground heaters should be used, to bring the temperature of instruments to at least –31°F. (–35°C.) and to maintain it above that temperature in flight with cabin heat.

Condensate or moisture may collect in the manifold pressure gage line, causing stoppage. To clear the line, disconnect the gage and force hot alcohol through.

Electric tachometer indicators may occasionally fail to operate immediately when you start the engine. However, these instruments become self-heating when the generator cuts in. Allow a 5 to 15 minute warm-up period before condemning the instruments.

Directly connected oil-pressure gages should have diaphragms mounted in front of the firewall. The oil line from diaphragm to instrument should be filled with compass fluid. Autosyn transmitters should likewise be mounted forward of the firewall.

The plug valves in the instrument vacuum systems often become sticky at low temperatures. To ensure satisfactory operation, disassemble the valve without disconnecting the lines; clean the plug and the inside of the valve thoroughly, and apply a light film of low-temperature grease.

Instrument field test sets contain dry cells which have a very limited life (2-3 hours) especially if subjected to extreme cold when in an inoperative condition. Keep the instruments in a warm place and expose them to low temperatures for only short periods, or keep them well-wrapped in insulating material when exposed for long periods at a time without being used.

Tires. All aircraft operated in the arctic should be equipped with approved snow and ice tires. At present there are two makes of tires suitable for this purpose. One type has metal inserts, called "bottle caps," moulded into the tread; the other has lengths of coil springs moulded into the tread. Tires and tubes must be mounted in a relatively warm place. Do not use cactus-proof tubes in the arctic. Tires must be properly inflated at the lowest operating temperatures encountered and with the full weight resting on the tire. Low temperatures harden rubber and low pressure will cause the walls to crack and pinch.

If tires are first inflated in a warm hangar, they will lose pressure after standing in the cold. Tires lose about 15 per cent of their pressure for every 60°F. temperaure drop.

Keep tires free of engine oil and hydraulic fluid as these oils cause rapid deterioration of rubber.

Tires should be inspected for cuts or cracks caused by contraction from the cold. Bear in mind also that ice has a tendency to tear the inserts from the tires during landing; if enough of these inserts are torn out it makes a tire unsafe for use and it will have to be replaced.

MISCELLANEOUS. ***Mechanisms and parts.*** Check solenoids; they may stick in cold weather as a result of condensation and freezing. Apply heat and tap lightly with a mallet.

Check boosters and fuel transfer motor operation.

Check fuel shut-off valve operation.

If the engine throws oil out of the breathers, or if there is a loss of oil pressure, check seating of dilution valve.

Exhaust collector rings and exhaust stacks often crack as a result of rapid cooling immediately after engine shut-down. Rings and stacks should be inspected frequently.

Check engine oil outlet connections for tightness.

Check shimmy damper operation and antenna shock mount for deterioration.

Lagging. Improved oil circulation has made lagging unnecessary.

Tools. Watch tools and small parts when you're working in snow. If you lay them down they'll sink out of sight. Carry them in a belt kit, keep your box with you, or lay some canvas or cowling on the ground on which you can place tools and parts.

Exercise care when making emergency repairs or replacing cold equipment. Don't use too much tension when tightening nuts, bolts and cables. They will expand upon warming and may freeze or snap. Hose and electrical wiring are stiff and brittle in sub-zero temperatures and are easily cracked or broken if handled roughly.

PRE-FLIGHT AND DAILY MAINTENANCE

In most temperate climates, preflight and daily maintenance resolves itself into a fairly simple routine, easily performed by minimum crew in a short time. However, the intense cold, snow and long hours of darkness of the arctic winter magnify this simple daily routine into a sizeable chore. The number of man-hours required under arctic conditions is doubled for first and second echelon maintenance and is even greater for major maintenance involving such operations as engine change. Normal maintenance required is at least three times as great. Therefore it can readily be seen that about six times as many mechanic-hours will be required for arctic operations. This demand is usually solved by striking a compromise between larger crews and longer hours.

Shutdown. In the arctic it is customary for the crew chief to shut down the engine, or to supervise the shutdown, and thus insure that oil-dilution is properly performed. See discussion of oil-dilution, pages 25-29.

Servicing. The aircraft must be serviced immediately after flight, as rapid cooling after shutdown causes condensation in fuel and oil systems with consequent danger from ice in tanks and lines as the moisture freezes. With full tanks, the danger from condensation is lessened, hence the necessity for immediate servicing. Normal methods prevail in the servicing of fuel. If the oil system requires service it must be done between dilution periods; that is, divide the dilution period, dilute for a short time, then stop the engine, service oil, restart engine and complete dilution. This is necessary to assure dilution of the service oil.

Do not service oil tanks to maximum in cold weather, as the addition of fuel to the oil in the dilution process requires additional expansion space in the oil system. If filled to maximum the system will overflow, particularly in the P-40, in which any overflow that occurs runs into the cockpit.

Preparation for night. After shutdown and servicing are completed, engine covers must be put on. If power source and heaters are available, immersion heaters must be installed (see page 29.) Batteries must be checked for specific-gravity reading. If reading is below 1.250 during extreme cold, batteries must be removed and stored in a warm shelter. Check oil tank sump drain cock to remove water condensing in the tank as the oil cools. This must be done after the oil cools, but before it has a chance to freeze. Also check Y-drain valves to remove possible moisture. Wipe down struts.

Pre-flight inspection and preparation for flight. Apply heat to the engines from ground heating equipment, such as Stewart-Warner, Herman Nelson, or similar type. Most available heaters have three heat ducts. One should be placed on the nose section, one on the accessory section and one on the oil cooler. The starter in particular should be heated to free it from the load of congealed oil and contracted metals. If immersion heaters have been used, leave them connected until ready to start the engines. Install batteries, or if they have not been removed, apply heat from ground heaters through available access door. Check the oil-tank sump drain cock and the Y-drain cock to assure free flow of oil to the engine. If no flow can be obtained from either of these drains, it will be necessary to apply heat until a free flow is obtained. A few minutes labor here will save an engine from serious damage. Wipe the struts down.

The usual pre-flight checking of fuel-tank sump drains will be found impossible in sub-zero weather. Any moisture appearing in the fuel tanks will freeze rapidly in the drains, sealing them so that they can't be opened.

All the foregoing checks and inspections can be made while heat is being applied to the engines. The length of time for application of heat will depend on outside temperatures, varying normally from 20 minutes to 3 hours. The best check on air-cooled engines is the cylinder-head temperature gage. When the heat temperature shows $+10°C$. the engine is warm enough to start.

STARTING THE ENGINE. Use a battery cart or auxiliary power source. The chances of starting without an external power source are slight; damage to the battery is more than probable. Have a fire extinguisher handy, as the heavy priming often necessary greatly increases the fire hazard. After heating, it is good policy to turn starters by hand and thus make sure they are free before attempting a start. Pull the prop through several times to make sure the engine is free. Start the engines in the usual manner, being careful to have carburetor heat off while starting, to prevent damage to the carburetor heat control caused by backfiring usually encountered in cold-weather starting. Proceed with the engine run-up in a standard manner.

Watch the oil pressure very closely when starting. On ships equipped with oil-pressure transmitters, stop the engine if you get no indication in 10 seconds. This is extremely important, as during cold weather you will frequently encounter conditions where congealed oil or ice formation will block the oil line to the engine. If you are not on the alert, you can very easily burn up an engine. Do not close cowl flaps or radial engines to hasten warm-up, as this causes heat pockets in certain parts of the engine and can cause overheating and permanent damage to those parts, particularly to spark-plug lead elbows. On ships so equipped, the nose shutters may be closed part-way to hasten warm-up; never close them completely. On liquid-cooled engines proceeed normally using cowl flaps and radiator shutters judiciously to bring oil and coolant temperatures up together. Keep engine-idling speeds around 1,200 to 1,400 r.p.m. as spark plugs foul easily in cold-weather operations. Frequently you may find that the engine will continue to run rough for a few minutes after starting. This can often be remedied by application of carburetor heat.

Adequate spark. To ensure that an adequate spark is produced at the plug points, make certain they are clean and dry. Proper use of the idle cut-off at shutdown will materially reduce accumulation of condensed moisture and possible formation of ice on the points. The object is to avoid leaving any products of combustion in the cylinders.

Spark plug fouling from condensation is to be expected if a cold engine fails to start readily. After three or four unsuccessful tries it is useless to continue the starting attempt. Partial firing rapidly expands moisture-laden air, and before another start can be attempted an equally rapid condensation leaves the spark plugs with small beads of ice on the electrodes. Each additional attempt to start, once an unsuccessful try has been made, lessens the chances because more and more plugs become iced. There is also the danger of washing the cylinder walls of the oil film from repeated priming. Proceed by removing at least one plug from each cylinder and heat to 65°C. or 75°C. (150°F. or 165°F.—comfortably warm in the hand) to dry the points. Replace and attempt to start immediately. It will seldom be necessary to remove more than one plug from each cylinder, since if the engine can be made to fire on these dry plugs, the others will usually dry sufficiently for proper operation.

Primer technique. To assure successful engine starts in extremely cold weather, considerable priming is required. A light priming should be given before the starter is engaged and then, while the engine is being turned over, the primer should be operated until regularity of firing results. Don't prime an engine until you are actually ready to engage the starter.

The handling of the primer pump often leaves much to be desired, and in many cases the method of priming has been a direct cause of the engine's failure to start. It has frequently been noticed that when a start is to be made, the pilot or crew chief will prime his engine, then proceed to carry out a cockpit check, all the while discussing affairs in general with the other occupants of the aircraft. This is bad practice since the delay permits the fuel to condense, flow down into the lower cylinder and fill up the combustion space, resulting in bent rods or broken pistons when the engine is turned over. Therefore, operate the primer when you engage the starter and operate it forcibly to ensure that the fuel is at least partially atomized and sufficiently finely divided to burn satisfactorily.

When starting from cold, it will frequently be found necessary to keep the engine running with the primer before it will pick up on the jets. Anticipate this. Keep your primer operating until the engine is firing regularly. Remember, your first attempt at starting is your best.

Ordinarily, for example, you will turn on the fuel booster pump and, with the mixture control in idle cut-off and the throttle just cracked, an initial fire can usually be obtained on the prime alone. The trick is to prime properly (5 to 10 seconds with the electric primer or from 10 to 20 shots with the hand primer). There are slight differences from engine to engine and installation to installation which may affect the priming period; practice and experience with the individual aircraft will determine the surest method of making a start. Once the engine fires, continue to prime, and at the same time move the mixture control to auto-rich. Continue to prime for several seconds after moving mixture control to auto-rich, or until the engine is firing evenly; then cease priming and steady r.p.m. at approximately 1,000.

Carburetor air. An easier start may often be obtained, if a hot air blast is directed into the carburetor air intake while the starter is engaged.

Warm-up is facilitated, if carburetor air is put on hot as soon as the engine is firing regularly. Apply heat slowly and only in the amount the engine will take without back-firing.

Oil-dilution factors. A normal start should be made without regard to the oil-dilution system. After starting the engine, if a heavy viscous oil is indicated by high oil pressure or by oil pressure that fluctuates or falls back when the engine r.p.m. is increased, the dilution control may be pushed momentarily several times to decrease the viscosity of the oil as a means of correcting this condition. Under no circumstances dilute to exceed the percentage specified for one normal dilution period. This procedure must be used with caution as it is possible to cause an engine failure by supplying the engine pump with pure gasoline in case the oil is sufficiently viscous or stopped by ice which prevents flow; the oil pressure gage may indicate sufficient pressure due to the gasoline to lead operating personnel to believe oil is flowing, which may not be the case. This method is suggested only if time and extreme temperature conditions do not permit engine warm-up in the normal manner.

MISCELLANEOUS. If there is no oil pressure after 30 seconds, or oil pressure drops after a few minutes of ground operation, check:

1. For blown lines or oil coolers.
2. Y-drain for congealed oil or ice.
3. Oil-tank sump drain for water; if no oil flows, heat must be applied and water drained when heat has thawed the ice.
4. Oil strainer for foreign material which might indicate that engine failure is the cause of low pressure.

If the oil-tank sump or Y-drain is frozen, or oil lines or coolers are blown, indications are the pilot did not properly follow shutdown instructions. NOTE: Remember that cowl flaps must be kept open for all ground operation, and keep non-essential electrical units off until generator cuts in.

OIL-DILUTION SYSTEM

PURPOSE. To overcome the difficulties experienced in starting aircraft engines in cold weather, an oil-dilution system has been developed to dilute the oil immediately before the engine is stopped and when a cold start is anticipated. Inasmuch as the high cranking torque of a cold engine is due to the high viscous drag of the cold sluggish oil, particularly between the pistons and cylinder walls, it is evident that a decided thinning of this oil immediately before the engine is stopped will greatly reduce the cranking torque and make for an easy start.

With the exception of the installation of the hopper tank, this oil-dilution system requires little change in any aircraft oiling system. A line is connected from the fuel pressure line to a special "Y" drain cock in which a spring-loaded poppet valve is installed. The valve is operated manually from the cockpit, and before the engine is stopped in cold weather, a small amount of fuel is allowed to enter the oil "in"-line at this point by holding the dilution control open for a short time with the engine operating. This operation permits the diluted oil to replace the heavy oil throughout the entire engine, thereby facilitating starting in cold weather. Inasmuch as some of the diluted oil is returned to the hopper in the supply tank during the last minutes of operation, this diluted oil will be the first used at the next start, thereby insuring a more positive flow to the engine pump.

OPERATION. Before stopping the engine, when a cold-weather start is anticipated, hold the oil dilution control in the "On" position for a period of time as indicated in the table which follows. The dilution of the engine while the oil temperatures are above 50°C. (122°F.) is not particularly effective. Fuel vaporizes at temperatures of 70°C. (158°F.) and above. Furthermore, gas fumes from engine breathers are a serious fire hazard. If oil dilution is to be accomplished and engine oil temperatures are too high, stop the engine and, after the oil has cooled to below 40°C. (104°F.), restart the engine and proceed with oil-dilution. In some instances, particularly during sub-zero temperature, when a long dilution period is required, the engine oil temperature may rise above the maximum desired values for oil-dilution, 50°C. (122°F.). If this occurs, it may be necessary to dilute the oil in two or more short periods. Breaking up the oil dilution period into several short periods is neither detrimental nor beneficial to the general dilution procedure. If it is necessary to service the oil tank, the oil-dilution procedure must be divided so that some of the dilution is accomplished before servicing the oil tank, and the remainder is accomplished after the oil tank is serviced. After dilution has been accomplished, shut off the engine in the normal manner (with the exception of an engine which must be stopped by shutting off the fuel to prevent after-firing), continuing to hold dilution valve "On" until the engine stops. Where an engine must be stopped by shutting off the fuel, the engine will first be stopped in this manner and allowed to cool, then restarted and the oil diluted as previously prescribed. After the oil has been diluted, the engine will be stopped, by shutting off the switch, the dilution valve being held "On" until the engine stops.

Effects of insufficient dilution. Insufficient oil dilution will result in broken oil lines and blown-out cooler cores, as well as difficult starts and possible engine failures caused by poor lubrication.

DILUTION PROCEDURE. The following table indicates the percent of dilution time required (for grade 1100 oil) to provide the same oil viscosity at each of the temperatures given:

Air Temperature	4°C. (40°F.)	−12°C. (10°F.)	−29°C. (−20°F.)	−46°C. (−50°F.)	−54°C. (−65°F.)
Percent Dilution	0	10	20	30	35

Dilution Time	4°C. to 12°C. 3 minutes	−12°C. to −29°C. 6 minutes	−29°C. to −46°C. 9 minutes	*

*Below −46°C. (51°F.) add 1 minute to indicated time for each 5°C. (9°F.) interval. Any deviation from these dilution periods (up to 100 percent), which is considered desirable and gives satisfactory results, is authorized.

Maintain oil temperatures below 50°C. (122°F.) while diluting. If oil temperatures continue to rise with the oil-cooler shutters open, close shutters, as the oil in the cooler may have congealed.

Dilute at idling speed (1,000-1,200 rpm). Avoid spark plug fouling. A short acceleration period of 10 seconds at the end of a dilution run is usually satisfactory to clear spark plugs.

Under all conditions release dilution switch only after engine stops. Do not permit engine oil pressure to fall below 15 pounds per square inch, or oil temperature to go above 50°C. (122°F.). If necessary stop the engine, wait 15 minutes, and continue dilution

If oil tank servicing is required, split the dilution period in half and service the oil tank at the end of the first period.

Operation of the dilution system is indicated by a substantial fuel pressure drop. If this fuel pressure drop is not obtained, investigate; the dilution solenoid may be stuck or the line plugged.

On all aircraft equipped with Hamilton Standard hydromatic propellers, depress the propeller feathering button for a 2- to 4-second interval, or a maximum change of 400 r.p.m., and pull out. Do this near the end of a complete dilution minute. Repeat three times. This will displace the undiluted oil from the feathering lines, which otherwise would congeal and prevent feathering, and provide diluted oil from the hopper so that emergency feathering can be accomplished under extremely cold conditions.

Oil leakage. A slight amount of oil leakage through blade packings is to be expected.

Exception—V-1650 engine. Oil dilution as described is not applicable to the V-1650 engine. This engine will not scavenge satisfactorily with diluted oil. If oil dilution is used, the engine will be warmed up normally and tested at high r.p.m. for 90 seconds to determine that loss of oil through the breathers will not occur. If oil discharge is noted, continue the warm-up to evaporate the fuel in the oil system. If oil is expelled from the engine breathers during ground run-ups, check oil level in tank prior to release for take-off. These precautions must be taken to avoid loss of oil in flight.

Turbo-supercharger regulators. During dilution, turbo-supercharger regulators operating on engine oil should be operated in order to expel all undiluted oil from the piston chambers. During the last 2 minutes of the last dilution period the regulator control should be repeatedly operated from low to high boost position, this to be accomplished in a minimum period of 8 seconds.

Automatic oil-dilution. Some airplanes will be equipped with an automatic oil-dilution controller switch in the cockpit. This device is designed to close the dilution valve when the dilution in the oil system has reached a preset percentage. Procedure consists of setting the desired dilution percentage on control unit, operating engine at 1,000 to 1,400 r.p.m. using lowest r.p.m. which will maintain 25 pounds per square inch or more oil pressure. The dilution switch is then turned on "Automatic." Fuel pressure will naturally drop or a lamp will light to indicate dilution is taking place. When the desired dilution is reached the control will automatically shut off. If the controller does not function for any reason, dilute manually as previously described.

Oil scavenging system. Where an engine-oil scavenging arrangment is inadequate or critical, oil dilution may have an adverse effect. The term "overdilution" has been used to indicate any amount of dilution which causes the engine scavenging system to break down and discharge oil through the engine breathers. This condition is serious, as it may result in the complete loss of all engine oil in a short period of time. These difficulties will not normally occur if the outlined procedure is followed, and if care and judgment are exercised by the operating personnel. High percentages of dilution have no serious effect on engine bearings if the oil temperatures remain normal. If oil discharge occurs under cold conditions, it may best be stopped by reducing power and r.p.m. immediately. Satisfactory dilution should be arrived at by the operating personnel, based upon experience with similar conditions of engines and anticipated weather temperatures. Whenever engines have been previously diluted and have not been flown, the engines should not be given a full dilution until 30 minutes operating time and oil temperatures above 50°C. (122°F.) have been obtained. If a short ground run-up is made, the engines should be rediluted in accordance with the procedure outlined by reducing the time period to equal the ratio of operating time to the one-half hour period mentioned. Under these circumstances the dilution period at shutdown should never be less than 30 seconds.

Unsatisfactory scavenging systems. On planes which have unsatisfactory scavenging systems, to avoid loss of engine oil in flight, it may be necessary to ground run the engines to boil the gasoline out of the diluted engine oil before take-off. Ordinarily, the procedure is to operate an aircraft engine at normal operating temperatures for approximately one-half hour to permit the fuel in the oil supply to evaporate and cause the oil to resume its normal viscosity. Higher temperatures will shorten this time period slightly. If necessary, immediate take-off may be made after oil dilution without the normal warm-up, provided there has been a rise in oil temperature and the oil pressure is steady.

Oil pressure. Engines equipped with oil dilution, which suddenly show a loss in oil pressure or throw oil out of the breather during flight, should be checked upon landing to insure that the oil dilution valve is in the "Closed" position and fully seated. If equipped with an electrically operated valve, it may be momentarily turned "On" and "Off" in an attempt to complete the seating of the valve. The fuel pressure should drop when the switch is on. If dilution causes the loss of oil pressure, satisfactory operation will be resumed when the viscosity of the oil is restored by running the engine and evaporating the gasoline in the oil.

IMMERSION HEATERS

Normally, immersion heaters are unnecessary for starting and should not be used unless difficulty is encountered with oil dilution. Oil tanks are provided with receptacles to permit the use of 110-volt immersion heaters, if required. The heaters are electrical resistance elements encased in a tube supplied with energy from an outside power source. Under no circumstance should the immersion heaters be connected to the airplane battery. If used, the heater should be connected to a C-10 battery cart or generator.

The oil level in the tank should be checked to insure that the heaters are entirely submerged. Immersion heaters should always be installed before the oil has cooled and should not be relied upon to thaw congealed oil, as the oil has no chance to circulate and will carbonize about the heater and burn.

All oil immersion heaters require a 110-volt power source. Two sizes have been standardized, 250-watt and 750-watt. Use the 250-watt size in self-sealing tanks. Oil immersion heaters are being made ground equipment as rapidly as possible. (Certain types of planes will retain the heater permanently installed until oil tanks are altered to accommodate the filler neck type.) Immersion heaters are inserted through the oil filler cap and plugged into the power source. They must be removed just prior to starting and must be thoroughly cleaned to prevent adhesion of particles, which will contaminate the oil when the heater is next used.

It is not necessary to run immersion heaters continuously. 2- to 4-hour periods of operation with similar "off" periods will be sufficient to maintain fluid oil in the tank. The use of immersion heaters in no way eliminates the necessity for diluting the oil as previously indicated.

EXTERNAL HEAT

While oil dilution and immersion heaters play an important part in cold weather starting, they have their limitations, and must be supplemented with external heat when outside temperatures are below −20°F. To facilitate easy starting at all times, it is desirable that such external heat should be applied at 0°C. (32°F.) or below. When used in combination with either oil dilution or immersion heaters, successful starts have been made in −65°F. temperature.

TYPES OF HEATERS. A number of standard heaters are available. All of these burn a fuel-air mixture in a hermetically sealed chamber. The resulting hot gases are directed to an oven surrounded by copper fins which radiate heat. Air is then passed across these hot fins, becomes heated, and may be directed as desired. Heaters may be classified as spot heaters, space heaters, and preheaters.

Spot heaters are small compact units, chiefly used for localized heating of armament, instruments, windshields or personnel.

Space heaters are larger and produce a great deal more heat. They are provided with a flexible-hose duct system which carries the heat to several different outlets.

Preheaters are independent units having their own engine, blower, fan, heat exchanger, duct system and fuel tank. Preheaters may be moved about to any place where heat is desired. Their uses are innumerable, since this type of unit is designed to do any kind of heating job. Its chief use is to preheat aircraft engines and accessories. (There is also another type of preheater called the "Hand Crank." This small, hand-operated unit is used to preheat the engine of the large preheater and to heat batteries, wheels, or parts and locations where a quick application of heat is needed.)

Oil-truck heater. Type L-2 oil trucks will have a gasoline-burning oil heater installed for servicing hot oil to aircraft.

Commonly used types. At the present time, there are two types of ground preheaters commonly used by the AAF. These are the Type D-1 and the Type F-1.

Type D-1 heater.—The D-1 heater weighs 183 pounds; it has a capacity of 80,000 B.t.u. per hour, and an 8-hour gasoline supply tank. It is mounted on retractable wheels and has auxiliary sledge runners. At temperatures down to –29°C. (–20°F.) one type D-1 heater will serve to keep two engines warm. When the temperature is down to –40°C. (–40°F.) or lower; one D-1 heater is required for each engine.

Type F-1 heater.—The F-1 heater is a large portable ground type with a capacity of 250,000 B.t.u. per hour.

Comparison—D-1 and F-1 heaters.—Either of the two heaters may be used for the same purposes. Because of its higher heat rise at the duct outlet, its lighter weight and its portability, the Type D-1 is usually preferred as an aircraft engine heater. On the other hand, the Type F-1 with its greater volume of air handled, is more desirable for the heating of portable maintenance shelters, temporary buildings or the interiors of aircraft. If a condition exists where only one of the two types of heaters is available, either may be used for all of the purposes mentioned.

Hand-crank heater.—The hand-operated heater has a 2-hour gasoline supply tank, weighs 10 pounds, is ignited manually and has an output of 25,000 B.t.u. per hour. It is particularly valuable for the quick warming of small mechanisms. At $-29°$C. ($-20°$F.) or below, this heater will burn only 100 octane gas. CAUTION: Don't use this hand-operated heater to heat shelters or occupied enclosures as the air delivered carries carbon monoxide.

Conditions for use. Heaters must be kept sheltered and warm, if easy starting is to be expected. If, however, it is impossible to keep heaters warm, the hand-crank may be used to preheat the engines of both D-1 and F-1 heaters for starting. In order to keep heaters warm, two methods are now in process of development. One involves the use of a small shelter in which the heating units and ground power plants are kept, the heat for the shelter being provided by an Evans stand-by heater. The other method involves the use of a sledge on skis having an insulated cover and warmed by a stand-by heater; this sled will contain a Type D-1 engine preheater and a Type C-13 auxiliary power plant.

Under conditions where either of these two methods is not available, the heaters may be kept warm enough for easy starting by covering 10 to 20 units with a large tarpaulin fastened down to the ground around the units and then inserting the ducts of a stand-by heater under the edges of the tarpaulin. This procedure will require the use of from one to four heaters, depending upon the severity of the temperature. It will also require the presence of a man to operate and service. In an emergency, when no heaters are available, open-flame fire pots, if used with care and ingenuity, may supply necessary heat.

Use of heaters. Heat should be applied to engines, accessories, cabin and turrets. Each large preheater has three canvas ducts which permit heating all the points mentioned simultaneously by leading the ducts into the various locations. For example, to heat a twin-engine aircraft, lead one duct to each engine through a special cowl door situated so that sufficient heat will be distributed to the accessories section; the third duct is led to the cockpit and directed so that the instrument panel will receive heat. On four-engine aircraft, at least two heaters will be required.

In extremely low temperatures, it may become necessary to install all three ducts in one engine cover at the following locations: the forward lower section of the cowling, the oil cooler, and the accessory section.

Heat should be applied to both the front end of the engine and the accessory section until cylinder-head temperatures reach 20°C. (70°F.) (Standard engine covers of 7.9-ounce duck are provided with sleeves for attachment of heater hoses at the strategic points—suitable canvas covers or snug-fitting, reasonably airtight tarpaulin makeshifts, are essential to secure satisfactory engine heating.) If sufficient heat is not available for effectively heating the entire engine, concentrate on the rear accessory section with second priority going to the nose gearing and propeller hub. CAUTION. Do not permit hot air from heaters to blast against ignition harness, flexible hose, self-sealing tanks, or other rubberized or fabric materials unless the hand can be held comfortably for at least 1 minute in the same position as the part in question. Do not apply heat directly to oil tanks having self-sealing liners, as inner liners will melt and cause the failure of the oil system. Because of the insulating qualities of such tanks, several days of above-freezing temperature will be required to loosen congealed oil in the system.

When temperatures fall below –21°C. (–5°F.), heat, when available, should be applied to that portion of the grounded airplane where instruments are located. If the airplane is to remain on "alert," heat must also be applied to bomb sights and AFCE batteries. To assure immediate operation, it is necessary to maintain a temperature of 2°C. (+35°F.).

EMERGENCY PROCEDURES

CONTINUOUS OPERATION. When extreme cold is encountered and adequate heating facilities are not on hand to assure engine starting, it may be necessary to keep engines running throughout the lay-over period. This is only practicable when sufficient fuel is available for the necessary time of ground running at about 1,000 r.p.m., and for flight to the next suitable source for renewing the fuel supply. When necessary to resort to continuous operation of engines while the airplane is grounded, a crew member must be constantly on watch for any troubles which may develop. The engine should be run up to 1,500 r.p.m. occasionally to clear it, and oil pressure should be maintained at normal, even though it is necessary to operate the oil dilution periodically to reduce the oil pressure.

DRAINING OIL. It should never be necessary to drain oil when the proper dilution procedure has been accomplished, except when it is expected that ground heating facilities will not be available at starting and that temperatures will be below −20°C. (−4°F.). All AAF airfields in areas requiring them, will be equipped with ground heating equipment and auxiliary power supply. With these two facilities and proper dilution, starts have been made in outside temperatures as low as −65°F. When it is expected that external heat will not be available for starting, or when dilution cannot be accomplished, drain all oil into clean containers and store the oil in a sheltered location where the temperatures will not be lower than freezing. Where warm storage space is not available, the oil must be heated on a stove or other heat source until free-flowing and then poured back into the oil tank immediately before starting the engine. Oil should be heated to 70° or 80°C. (158° or 176°F.) if possible.

IN EXTREME EMERGENCIES. When containers and heating facilities are not available for draining and warming oil, the following procedure may sometimes be successfully used if the minimum temperature does not fall below −30°C. (−22°F.):

1. Use normal oil-dilution procedure before shutting down engine.

2. After shutdown, drain sufficient oil from the system to bring the oil level to two-thirds of its total capacity.
3. Restart engine and run with covers over cooler if necessary, until oil temperature shows 50°C. to 60°C. (122°F. to 141°F.).
4. With engine still running at 800-1,000 r.p.m., slowly add enough gasoline at the oil filler neck to fill the system. This gives a 2:1 ratio of oil to fuel and will produce some dilution of the oil adjacent to the tank hopper.
5. Restart after 20 to 30 minutes and give a second dilution, using only the normal dilution procedure, followed by final shutdown.

CAUTION. This is strictly an emergency procedure, to be used only when immersion heaters are not available and when equipment is lacking for draining and warming oil. It should also be remembered that when the fuel evaporates, only two-thirds of the total oil capacity remains in the system and that this capacity must be sufficient for the flying that will be necessary to reach a new oil supply.

COOLANT

If proper glycol mixture is maintained, and particularly if ground heaters are utilized for starting, draining should never be necessary. If it becomes necessary, however, and if clean containers and heating facilities are available, the coolant fluid may be drained, warmed and replaced in the system just prior to starting the engine. Warm coolant materially assists in starting. In order to avoid sudden chilling of the engine parts, do not drain until coolant temperature falls to 5°C. to 10°C. (40°F. to 50°F.). Always leave drain cocks open until just before the heated coolant is returned to the system.

LAY-OVER INSTRUCTIONS

When extreme cold is encountered and an aircraft lay-over is necessary, the dilution procedure outlined may be increased to provide additional fluidity and safety in accordance with the experience of operating personnel. After several days' lay-over, during which time the engine has been started and diluted several times, it is advisable to ground-run the engine for at least one-half hour at normal temperatures, prior to take-off. It is also desirable to check the oil level which may have fallen considerably as a result of evaporation of gasoline. This will tend to eliminate any excess dilution which might otherwise cause oil discharge through the breathers or loss in oil pressure during high-power take-off or operation.

When extreme cold is encountered, if adequate heating facilities are not on hand to assure engine starting, and if the airplane must be kept on the alert, it may be necessary to run the engines periodically throughout the lay-over period. The cylinder head temperature should be kept above 0°C. (32°F.).

For long lay-overs the battery should be removed and stored in a warm place, and the oil and coolant systems may be drained. If, during the lay-over, the temperature rises above 0°C. (32°F.), drain all fuel-system and oil-tank drains immediately of condensate, before the temperature drops and the water freezes.

TROPIC MAINTENANCE

GENERAL

WHAT IS MEANT BY "TROPICAL." To obtain a picture of the conditions and maintenance problems you will encounter on the line in the tropics, it is necessary to understand what is generally meant by "the tropics." There are plenty of local differences between tropical areas, but ordinarily two types are recognized: (1) the wet tropic areas, and (2) the desert regions.

The "Wet Tropics." This belt is characterized by heavy rainfall and thick vegetation. While temperature is seldom higher here than in Washington, D. C., in summer, it is relatively high, and it stays high throughout the year, with only small variations between day and night temperatures. The year-around average is about 80°F., but what makes the wet tropics a difficult place in which to live and work is humidity that averages 85 to 90 percent. This makes the climate hot, damp, oppressive and enervating. The humidity is responsible for the chief maintenance problems in the wet tropics: the corrosion of metal surfaces, the malfunction of electric equipment and deterioration of fabric control surfaces. Heat, mud, dust and fungus growth create secondary problems. The oppressive heat causes personal discomfort. Mud affects operations and necessitates constant cleaning. Dust is often encountered in local areas (between rains); it has a powerful abrasive action on engines and close-fitting parts. Fungus growth attacks delicate instruments and accessories.

Desert Areas. These regions are distinguished by their striking lack of water and vegetation, low humidity, very high daytime temperatures, extreme daily temperature ranges (hot days and cool to cold nights), and sudden violent winds. The number one maintenance problem is caused by dust which is always present. It gets into everything, grinding the life out of engines, injuring instruments, armament and accessories. Heat is another important factor, particularly in its effect on personnel—physical discomfort at times makes maintenance work downright rough.

Certain tropical areas share the characteristics of both the wet tropics and the desert.

The following pages give you information and knowledge about the special problems of tropical maintenance which will help you do your job with maximum assurance of success.

TROPICALIZATION

"TROPICALIZATION." To make your work easier, much has been and is being accomplished with respect to the modification of aircraft and equipment for tropical operation. Tropicalization is the word that describes the preparation of aircraft for operation in these areas (specifically, so that they will function satisfactorily in temperatures up to 160°F. and withstand the effects of humidity and dust). Tropicalization is best accomplished at factories, modification centers or air depots. In overseas theaters, tropicaliaztion kits must be requisitioned and Technical Order instruction complied with rigidly.

TROPICALIZATION MEASURES. De-icing and anti-icing equipment, including pneumatic boots, are removed. Properly fitted covers (for protection against dust and moisture) are provided. Filters and cleaners are supplied. Provision is made in control systems to permit adjustments required as a result of extreme differential contraction and expansion. Anti-corrosion measures will be taken, especially with reference to the proper finishing of surfaces susceptible to corrosion. Operating controls will be wrapped or otherwise insulated to protect personnel against surface heat. Electronic equipment is processed to enable it to withstand the effects of moisture and heat.

These and other tropicalization measures help fit aircraft for operation in hot climates. But they are only a part of the story. Proper maintenance and the intelligent conduct of the personnel performing it are the keys to continuous and successful operation.

WHAT IT TAKES. It takes guts, intelligence and ingenuity to keep aircraft flying and fighting in the tropics. At forward bases you may have to work around the clock with inadequate equipment and tools. Often you may have a touch of malaria or dysentery. Mosquitoes, flies and other insects may plague you, to say nothing of mud or dust. You may be all-in with the heat and humidity at times. But maintenance work goes on. Aircraft fly and fight because the men who maintain them have mastered the problems of living and working in the tropics.

PERSONAL COMFORT

The climate and environment of the wet tropics and the desert make maintenance difficult. Most of the difficulties arise primarily from physical discomforts and inconveniences. Therefore, it is important to know how to take care of yourself, to know what clothing is best to wear, and what simple, common sense precautions you must take to minimize discomfort.

CLOTHING FACTORS. The trick in tropical maintenance is to keep cool and yet to wear clothes which will protect you from the sun and from disease-carrying insects. Because excess clothing on the line in hot weather is a handicap, certain simple rules with regard to clothing should be observed.

You are expected to wear the clothing issued, although you probably will feel more comfortable half-naked. However, a certain amount of clothing (hat, shirt, pants and shoes) is necessary for protection against absorption of heat from the sun and against insects which may be deadly threats to health in certain areas.

Your body is cooled by the evaporation of the sweat it puts out, but sweat that just rolls off your bare skin does not evaporate or cool. The idea is to trap sweat, and the best way is to wear clothing that will absorb the sweat so that it will evaporate and cool you.

In many areas, insects—especially mosquitoes—carry the germs of diseases such as malaria, dengue and filariasis. If the choice is between staying cool by wearing a minimum of clothes (say shorts and shoes alone) or risking disease through insect bites, the sensible decision is to wear adequate clothing that will protect the surface of your body.

Wear your clothes loosely, so that you get circulation of air close to the skin where it will have the greatest cooling effect, so that wet clothes will not bind you, and so that mosquitoes cannot bite through.

Body clothing. Generally speaking, long-sleeved shirts and long pants are the best clothing for both the wet tropics and the desert, particularly in areas where disease-carrying mosquitoes are found. (Shorts may be worn in the daytime unless otherwise ordered.) "Long" clothing has further advantages in affording protection against skin cuts and wounds, and against burns caused by contact with hot metal surfaces. It is desirable to wear underclothing which helps trap the sweat long enough to allow evaporation to produce a cooling effect. In certain desert areas, the nights may be bitterly cold and winter days can be raw; suitable clothing will be issued for these areas.

Headgear. Wear something on your head during the day and especially when working in the open sunlight. The cap issued you is suitable, although it does not provide protection for the back of the neck. A handkerchief covering may be improvised.

PERSONAL PRECAUTIONS. Keep in the shade and out of the sun as much as possible. Improvise shelter and shade, such as umbrellas, awnings and thatch shelters. If you feel you must have a "sun tan," get it slowly.

Avoid overexertion. Work as smoothly as you can, and organize your work so that you do not waste energy. Deliberate movements produce less body heat than jerky, strenuous or tense actions. If possible, heavy work should be scheduled for the early morning or late afternoon, when heat is less intense.

Protect your eyes. Wear dark glasses when working around polished metal surfaces or in sunlight, or wherever there is reflected glare from the sun.

Don't touch hot metal. Wear gloves or mitts to grasp metal tools or surfaces exposed to the sun. Insulate tools with velour grips or wrap the handles with heavy tape or cord. Choose tools which lend themselves to hot weather use; that is, single-ended spanners and wrenches. Use mats and pads to protect your knees from hot surfaces on which you may have to work.

Drink plenty of water. Be sure to drink plenty of water but drink it slowly. Take extra salt to prevent exhaustion—one to two tablets dissolved in every quart of water you drink.

Observe malaria discipline strictly. Take atabrine as ordered; you will experience no ill-effects. Use mosquito repellent on exposed skin surfaces—especially in the late afternoon and at night. At night, wear full clothing and wear a mosquito headnet if so ordered; the net may be inconvenient but it's preferable to a bout with fever. Before working inside the cockpit or fuselage of a plane, spray the interior thoroughly to eliminate any mosquitoes that may be hiding there.

Take care of cuts and abrasions. Minor cuts and wounds get more easily and seriously infected in the tropics than at home. Take care of them immediately by applying iodine and dressing. Don't neglect even the most superficial scratch or abrasion—it may lead to serious trouble. Care in time will spare you days or weeks of serious infection and disability.

Stay clean. Keep your person and your clothing clean. Bathe as often as you can—not only to stay clean but to keep cool as well (body heat is removed by water twenty times as rapidly as by still air). Take special care of your feet and folds in the skin, such as in the armpits and crotch. Dry carefully after bathing and dust skin folds often with G. I. powder. Keep your socks and shoes clean and dry. Greasy or dirty clothes lose their absorbent quality, so keep them as clean as you can. In the wet tropics, put on dry clothing before getting into bed.

These are the important points to remember regarding personal care. Common sense observance of these rules will result in maximum working comfort.

GENERAL MAINTENANCE

There are certain general problems of maintenance which are common to both the wet tropics and the desert.

EFFECTS OF HEAT. Heat is a factor of great importance in the tropics, particularly as it affects working conditions. In both the wet tropics and desert, keep the sun out of cockpits, turrets and nose sections by throwing canvas or native matting over them. With windows, canopies and hatches open, interior temperatures may be 10 degrees to 20 degrees cooler, but there is the risk of permitting the entry of moisture and possibly dust in the wet tropics, and of dust in the desert. If the weather is clear (no rainfall in the wet tropics, no wind and dust in the desert) and the aircraft is attended by maintenance personnel, ventilation of pilot, bombardier and navigator compartments is desirable as a means of guarding against heat warping of delicate instruments. Under other conditions, keep all openings closed.

When you work inside a ship, the motor generator may be used to rig up a fan or blower system. This will create circulation, and will help to equalize inside and outside temperatures, as well as increase evaporation.

Structural surface temperatures are dependent upon the heating effect of the sun and whatever cooling effect wind and humidity may create. Skin temperatures will be 1.4 to 1.5 times the free-air temperatures. Interior temperatures generally will remain between free-air and skin readings. However, wing, empennage and fuselage interiors may rise to 1.4 times the free-air temperatures. Intense heat of the dry type encountered in desert areas as well as the humid type in the wet tropics, is destructive to certain aircraft materials. It is important to check carefully and frequently lubrication, hydraulic systems, cable tension and the life of materials such as rubber and hydraulic packing equipment. Watch bungee cords, de-icer boots (which should be removed for tropical operations), and hatch seals. Watch tires for blisters, and check their inflation for variation of air pressure with temperatures. Check cable-control tensions frequently. Tension will increase during the day and decrease at night. If adjustments are made without regard to probable contraction or expansion caused by temperature changes, either slack cables, frozen controls or broken pulleys will result. Allow for anticipated temperature changes when making adjustments, and perform the proper adjustments for the temperatures at which the plane will be flown.

COMBAT CONDITIONS in most tropical theaters, and especially in the wet tropics, impose certain difficulties on maintenance operations. Equipment, tools, repair and maintenance parts will often be difficult or impossible to obtain. This is especially true as the front progresses and as squadrons push up. Technical supply, of course, has the job of furnishing equipment, tools and parts; but supply may fail, and it is up to you to provide solutions, using all your common sense and ingenuity. There are four ways of solving shortages in equipment: (1) by "cannibalism," (2) by salvage, (3) by anticipating needs, and (4) by saving parts.

"Cannibalism". The practice of making one flyable plane out of two or three grounded planes—called "Cannibalism"—has been developed to a fine art in the tropical theaters. You can't afford to wait until you get the parts you need to put all three planes in the air, so you strip a wing from one plane, an instrument from another and so on, and pretty soon you put a plane in the air, instead of having a couple of dead ducks sitting on the ground. American standardization and interchangeability of parts make this possible.

Salvage. Because there is always a desperate need for parts, salvage is extensively practiced. In the wet tropics, long treks have been made into the jungle on foot, light planes have been landed, and boats have been utilized for a water approach to cracked-up planes in what would otherwise be considered inaccessible jungle. In the desert, salvage trailers have been dispatched over great distances to retrieve wrecked aircraft. In the tropical theaters, the tactical and supply situation may be such that you will often have to go to great lengths to reach cracked-up planes and strip them of desperately needed parts.

Anticipating needs. The particular conditions under which your planes are flying and fighting will determine the amount and types of "spares" you will need. Needs under combat conditions, adverse tropical climate and rough landing strips will be far different from those back home. Through experience, you must develop the ability to estimate and anticipate what you can expect in the way of spares from cannibalism and salvage, and then attempt to get the balance through supply, in advance.

Saving parts. Don't throw anything away. Bolts and screws, distributor points, insulator tips, some tubing you've salvaged, may mean the difference between a grounded or a fighting plane. Save everything—some day a seemingly insignificant part saved may pull your outfit out of a jam. Metal parts that are salvaged or removed from service should be carefully cleaned, covered with cosmolene or similar grease, wrapped in burlap and stored in dry lockers or bins.

Have a parts system. In tropical theaters, dispersal creates a difficult problem from the maintenance standpoint. You will not have the elaborate inventory system you were accustomed to back home. It is absolutely necessary to work out some sort of inventory or record system so that you know where you can lay your hands on certain materials when they are needed. A good example of the trouble you can experience without an inventory system is illustrated by dispersal in China which was often carried to such an extreme and with such secrecy that parts and supplies were at times actually dispersed out of existence. Remember always that dispersal is intended to deceive and confuse the enemy—and not your fellow crewmen.

TOOLS. Tools as well as spares are priceless possessions in the tropics. Give them your best care. In the wet tropics, protect them against corrosion by cleaning and oiling them often. Infrequently used tools should be covered with grease, wrapped in burlap, and stored in lockers in a dry place. In desert areas, clean tools often; when not used, wrap in burlap and keep in a sand-free place; never use sand-incrusted tools on aircraft. Don't lay tools or parts on the ground. In the wet tropics they will get lost in mud, dust or vegetation, and it is quite a trick to find them under a steel mat. In the desert, every article, large or small, is either lost (as its weight burrows down and loose sand and gravel drift over it) or damaged. If you must place tools or parts on the ground, place them in a clean receptacle.

DISPERSAL. Dispersal practiced in tropical areas obviously requires mobile service and maintenance. Get all the transportation facilities you can lay hands on. Maintenance in isolated jungle revetments or widely dispersed desert stations is difficult enough without transportation facilities, no matter how crude they may be.

These are the general maintenance considerations common to both the wet tropics and the desert. A discussion of the specific problems encountered in these areas follows. The wet tropics are hot and wet and have their own special problems. The desert areas are hot and dry and present quite a different situation. For these reasons, special maintenance problems in the wet tropics and in the desert are treated separately.

WET TROPICS MAINTENANCE

WORKING CONDITIONS. Airfields generally consist of single strips cut out of the jungle and paved with any one of several types of perforated steel mats, crushed coral or native soils. Working conditions are generally hot and damp. In revetments in the open, with the sun shining directly on a hot fuselage, with the heat reflected from steel matting, with the humidity consistently high, the inside and the immediate vicinity of the ship resemble a Turkish bath. At other times, you will work in tropical rain. In jungle bays, humidity will keep you bathed in sweat.

Equipment. Hangars or permanent structures of any sort will be rare. In most areas improvised thatched sheds and mat awnings will provide what little shelter you have. You probably will have to do without hoists, jacks and many of the special tools and gadgets to which you have been accustomed. You will have to face it like the men who went before you into the South Pacific—they made hoists from lumber salvaged out of the "Bay of Wrecks," a small inlet in the Solomons where the tide had deposited scores of wrecked ships. They improvised tools and parts on the spot; they licked seemingly insurmountable problems by sheer Yankee ingenuity.

Maintenance shelter. Improvise some sort of shelter which will be consistent with camouflage considerations, but which at the same time will enable you to carry on your maintenance work with a minimum of discomfort. A canvas, thatch, or matting lean-to, or half-tent, an improvised nose hangar—all these will repay the effort it takes to construct them.

CORROSION—NO. 1 PROBLEM. Corrosion, particularly salt-water corrosion, is the chief problem in the wet tropics. Corrosion is essentially a chemical process of oxidation undergone by metals when exposed to the action of air and water or to salt solutions. Metals are usually found in nature in an oxidized state as ore, and in order to make them suitable for industrial use, they must be reduced from the ore; that is, the oxygen, water and other substances are removed. But when the metal has been so processed, it tends to reassociate with oxygen and water, whenever it comes into contact with these under suitable conditions.

The hot humid climate of the wet tropics, particularly in those areas where air is salt-saturated, makes an ideal combination of corrosive influences. In addition to all this, the rate of corrosion varies directly with the mechanical stress to which the metal is subjected. Metal parts which take the most punishment are the parts that corrode most rapidly. For example, the metal components of landing gear that takes a beating on jungle landing strips will corrode a great deal more rapidly than other metal parts not subject to such punishment. Wherever violent tropical weather and rough landing strips produce abnormal stress and strain, you will find corrosion at its worst.

Pitting. This is a particularly nasty form of corrosion. It is usually started by foreign metal particles, imbedded dirt or excessive strains that damage protective surfaces and allow corrosion to set in. The formation of just a few deep pits will weaken metal much more than a larger area of metal removed uniformly but at a shallower depth.

Effect of dissimilar metals. Different metals show different rates of corrosion. However, if two or more dissimilar metals are exposed together, corrosion by electrolytic process may proceed faster than the rate at which the more active metal would corrode when exposed by itself. Whenever possible, in making repairs, use the same metal that was originally used; if you can't, provide insulation between the two metals.

How to tell corrosion. It is easy to recognize corrosion. It shows up in spots on the surface of the metal. For example, it appears as brown rust on iron or steel, as white specks on aluminum, whitish powder on magnesium, blue or green on copper, black tarnish on silver; it may penetrate so deeply that such mechanical properties as tensile and fatigue strength are seriously impaired.

What to do about corrosion. There is only one thing to do—protect your finishes, such as plating, enamels, dopes, varnishes, lacquers and paints. These finishes are shields against corrosion; they resist the injurious influences of climate which are death on base metal. Remember that if any erosive influence, such as sand abrasion, removes a protective coating, you're in for corrosion. Keep surfaces clean—wipe off foreign particles and imbedded dirt. Avoid scratches, gouges, dents, and chipping; touch up all damaged spots and weak places in the finish so that corrosion cannot attack the base metal. Remember always that the service life of much of your equipment in the tropics depends on how you care for the protective coating.

DUST—NO. 2 PROBLEM. While humidity and mud constitute the main problem you will encounter in the wet tropics, dust is often an equally bad problem. In wet areas you may come up against dust which may be mud one day and dust again the next. Learn how to fight dust.

It is absolutely necessary to protect induction-, fuel-, and oil-systems from dust. An engine breathes dusty air part of the time in some parts of the tropics and all of the time in others. Such dust, when mixed with oil has terrific abrasive action, especially if it happens to be volcanic ash or coral dust, which will often be the case. The result is serious and rapid wear of pistons, rings, cylinder walls, and valve mechanisms. That means excessive oil and gas consumption, loss of compression and plenty of trouble for some pilot who needs all the power he can get. Engines will last only a fraction of their rated life when ground to death by dust. (See page 53 for detailed discussion of effects of dust on aircraft and equipment.)

What to do about dust. Use filters, particularly for ground operations. Remember that air cleaners, oil and gas filters are only as effective as the amount of care you give them. They should be cleaned and inspected on a rigid schedule. Replace worn-out filters and cleaners immediately. Keep an ample reserve stock on hand—don't get caught short. (See pages 55-56 for detailed discussion of filters, their use and maintenance.)

USE OF COVERS. Covers serve a double purpose in tropical maintenance. They minimize trouble resulting from tropical rains and from dust. Install engine and cockpit covers immediately when you park aircraft. Covers should be tight-fitting and tailored to the job; otherwise, they will be of little use in the tropics, where it really rains. A tropical downpour can drown out and shorten the life of all unprotected electrical equipment and help promote corrosion elsewhere. Dust can start trouble in engines and will multiply your problems. So keep engine covers on the plane at all times when not being serviced or prepared for flight. After servicing, replace them. This should become an automatic habit. (See page 55 for discussion of covers.)

THE PROBLEM OF LUBRICATION. It is difficult to make any flat statement about lubrication in the wet tropics. Ordinarily, when humidity is high and corrosion is a threat, it is well to lubricate liberally and frequently. But here is the difficulty: working in dust, you invite trouble when you mix lubricant with dust, because the combination makes a grinding abrasive which is deadly on engines or parts working closely against friction. This factor makes it difficult to offer any hard and fast advice on lubrication. You will have to decide on the basis of experience in the particular area in which you find yourself. You will have to anticipate conditions of wet and dry. Generally speaking, wet conditions call for plenty of lubrication. Dusty, dry conditions call for a minimum of lubrication. In lubricating practices use common sense and experience.

CLEANING. In most wet tropic areas, mud gets all over an aircraft. After every landing wash off the ship. You will be accomplishing two things: you will get an appreciable increase in speed with a clean plane—speed the pilot needs; and you will be making sure that gear will retract, extend, lock and unlock properly. It is important to keep the plane clean inside as well as outside; otherwise some pilot may get an eyeful of dirt that won't do him any good in combat.

Concentrate especially on cleaning landing-gear assemblies. It helps prevent corrosive action. Check control cables, particularly where they pass through fairings and pulleys.

It is important to remember that water will condense in all dead-air spaces in the wings, fuselage and tail group. It has been known to gather in such quantities that it may seriously change the weight distribution and actually affect the balance and maneuverability of the plane. This water condensation is also a serious corrosion hazard. You can best solve the problem by providing drain holes where they will do the most good, but make certain you do not weaken the structure or alter flight characteristics. Scotch tape can be used to seal miscellaneous small openings through which moisture may condense.

CARE OF AIRFRAME, CONTROLS, LANDING AND AUXILIARY GEAR. The following points cannot be emphasized or repeated too often: Clean and inspect for corrosion, and relubricate frequently such moving parts as landing gear, bomb door, tail wheel and flap screws and worm gears, anti-friction bearings, plain bushings, gear boxes, control bearings and cowl slides.

Remember that the violence of tropical storms may result in leaking tanks and loose rivets. Check them often.

Cloth, fiber, rubber and leather disintegrate rapidly in the tropics. In addition, they are attacked and damaged by fungus and various insect pests. Check fabric surfaces often by tapping lightly with your knuckles. If the dope shows signs of cracking, sand the entire surface lightly with fine sandpaper and apply new dope. If the fabric is too worn to repair, replace it.

Remember that tires, hatch seals, self-sealing fuel tanks, plexiglas, bungee cords, boots, safety belts, chutes, life rafts, vests, covers, upholstery, navigation and medical kits all require constant inspection. At the first signs of disintegration, either repair or replace. De-icing equipment should be removed for tropic operations. Watch fuel and oil lines carefully; they deteriorate rapidly, blowing out especially around the fittings. Lubrication and hydraulic-system packing must receive special care.

Flaps may require reinforcement to prevent their being damaged or broken by flying mud or coral.

A slippery steel mat causes excessive wear and strain on main strut links and bolts. Check them often. Abnormal side loadings are imposed on bracing by the slippage from side to side. Watch for structural weaknesses. Where conditions permit, grow grass as a cushion, or cover mats with dirt and coral. A gravel base, of course, will improve drainage.

CARE OF TIRES. Tires wear rapidly in the wet tropics. Steel mat or crushed coral, when dry, can cut tires to pieces in short order. Water and mud will cover the strips much of the time. These conditions also are hard on tires, because some sliding on take-off and landing is unavoidable. Sliding wipes the steel dry and, before take-off is completed, tire temperatures will rise and rubber will burn, leaving a flat spot on the tire. At Milne Bay, the average life of front tires was five landings. While this was an extreme case, it does indicate the kind of conditions you may meet. You will find that a diamond tread tire is best for steel runways. On a coral runway, smooth tires throw up fewer pebbles against elevators and props.

CARE OF ARMAMENT. Corrosion attacks armament rapidly in the wet tropics. When the aircraft lands, cover or seal all guns and seal the chutes immediately. Make sure you remove seals from chutes and covers from guns before take-off. Guns may be left sealed for a maximum air speed; the first shot will clear the muzzle.

Armament must be stripped, cleaned, and oiled much more frequently than in temperate climates. Clean daily or oftener all guns, bomb racks and shackles.

Store ammunition in a dry place. Don't keep it in the plane over long periods of time. Corrosion may cause disastrous jams. Moisture may affect electric-turret operation—watch for its effects. Bomb sights and reflector sights are particularly susceptible to fungus growths which will cloud and etch the lenses.

CARE OF INSTRUMENTS. Instrument maintenance will be a continuous job. Instruments are not only affected by condensation, but the damp and humid climate also will encourage mildew, mold and other fungus growths. You will have to clean, dry, air and oil continually to guard against this fungus which attacks metal, glass, and plastics, and, especially lenses, etching the reticule.

CARE OF ELECTRICAL EQUIPMENT. You must fight the effect of moisture on electrical equipment. Wires and cables will tend to corrode and short circuit. Check wire sheathing for deterioration; keep plugs and jacks dry or else you will have leakage. Remember that the ignition harness and leads are especially susceptible to the effects of moisture.

Electrical props are affected by condensation and moisture. Pitch-changing mechanisms require constant inspection; this applies especially to governors, relays and solenoids.

Generator brushes and distributor fingers must be kept dry. Magnetos should be sealed against moisture. Starters are liable to short out.

Condensation in conduit boxes and elsewhere may be corrected by drilling drain holes, but make sure you do not weaken the structure or alter characteristics.

Battery terminals and cable connections must be cleaned frequently. Vaseline applied to the terminals will minimize corrosion. Check the specific gravity of battery electrolyte frequently and do not allow the battery to get overcharged. While there will be little evaporation, you will experience active chemical reactions in the battery.

Electronic equipment. This equipment is particularly susceptible to the excess humidity of the wet tropics. It is also subject to fungus growths in critical circuits, and to the attacks of bacteria and insects.

Various steps have been taken to thwart the effects of humidity. While it is true that the operation of a piece of electronic equipment generates heat which helps to keep it dry, continuous operation of such equipment is not feasible. It becomes necessary to apply some form of external heat. This is usually accomplished by placing a lighted ordinary electric bulb near the equipment which provides a sufficiently high temperature to prevent moisture from condensing.

Another method of keeping critical electronic parts dry, whether in operation or not, is by the application of water-proof or water-repellent coatings. Wax or pitch are commonly used: they are applied in liquid form at fairly high temperatures and then permitted to cool and solidify. Other compounds, less widely used until recently, are special chemical preparations such as Dogardite, varnishes such as Glyptol, and vapors of methyl chlorsilane substances. An auxiliary external-drying method employs packets of a dehydrating agent, such as calcium chloride or silica gels, placed close to the apparatus. These absorb water, but must be replaced and renewed.

Wires and cables are also affected by humidity. Some types of insulation, such as certain compounds of rubber, or cellulose products, are likely to deteriorate with excessive humidity, allowing the penetration of moisture, finally resulting in short-circuiting. The solution is to use specially treated material for the insulation or to protect standard wiring against condensation of moisture.

Fungus growths. Fungus growths will attack glass and plastic surfaces; bacteria, which will grow anywhere, cause molding; insects, dead or alive, can cause disintegration of electrical material, short-circuiting and leakage. Special preparations, such as camphor gum, will prevent the growth of fungus and mold, and careful inspection and cleaning will prevent the accumulation of injurious molds. Simple shields can be improvised to prevent the entrance of insects.

MISCELLANEOUS. Carburetors are especially susceptible to internal corrosion. They should be removed, disassembled into major parts without disturbing critical adjustments, inspected and cleaned.

High humidity causes excessive condensation in fuel tanks. Potassium dichromate has proved to be effective in holding back corrosion in fuel tanks. Tanks and fuel strainers must be drained immediately prior to flight and maintained full.

DESERT MAINTENANCE

THE PROBLEMS. "The desert may be a tactician's paradise, but it's a maintenance man's hell." These words effectively sum up the picture of desert maintenance. Heat and sand are the two oustanding problems. The problems of heat primarily affect personnel; the general measures for overcoming the handicaps it imposes on maintenance work have already been covered (see pages 39 to 41). Sand and dust are the chief foes of aircraft and associated equipment in the desert, and it is important to understand their effects and the techniques required to overcome the maintenance problems they create.

SAND AND DUST. Aircraft maintenance in the desert involves an endless fight against sand—not only the sand on the terrain, but the dust suspended in the air. Wherever the hard crust of the desert floor has been broken, you will be faced with the deadly scratching gouging action of quartz-hard grains and pebbles, and the terrific abrasive qualities of dust with the fine consistency of talcum powder.

You can't avoid the sand and dust. It gets into everything—into engines, instruments, armament. "Every time an airplane takes off it creates its own sandstorm. Every minute an airplane is in the air it is reaming out its own cylinder walls, ruining valves and, in fact, tearing down every moving part just as surely as if a saboteur had sprinkled emery dust throughout the engine." Once sand and dust gain the upper hand, the life of an airplane and its parts is unbelievably short.

The abrasive power of sand depends on the size, shape and hardness of the particles. The smaller the grains, the more angular and sharp-edged they are, the more damage they do. Grains between 0.2 and 0.02 mm are sub-angular, having both round and sharp edges. Deadliest of all are the grains smaller than 0.02 mm, which are entirely angular and sharp-edged.

Quartz comprises about 85 percent of the average desert sand, the bulk of which will pass through a 200-mesh screen. Quartz cannot be scratched with a penknife and is an extremely effective abrasive. A wind of 20 m.p.h. (higher velocities are common in the desert) is capable of moving grains up to 0.2 mm.

Desert dust becomes air-borne with very slight agitation and remains suspended for hours. Dust clouds in the African theater, for example, normally reach an altitude of 8,000 feet and have been reported as high as 17,000 feet.

Every cubic yard of air drawn in through the air intake includes microscopically fine, abrasive sand. You can't avoid the sand and dust, but its effect can be minimized by the application of common sense measures, constant vigilance and continuous inspection.

SELECTING MAINTENANCE SITES. Locate maintenance sites on hard standings whenever possible or on terrain where fine sand grains of high quartz content are at a minimum. The dispersed character of desert operations offers plenty of location choice. Take advantage of all shielding topographical features. Attempt to locate your maintenance sites to the windward of loose sand areas. Consider carefully the direction of prevailing winds and avoid location in the path of blown sand resulting from the breaking of the desert crust or its disturbance by other installations on the field. Avoid areas which have been chewed up by vehicle tracks.

If possible, improvise some sort of shelter which will keep sand out sufficiently to permit servicing, or at least minimize sand blast. A canvas lean-to, a half-tent, a properly improvised nose hangar, or a sand-break around the aircraft, placed to windward, will help. Small tents, erected on hard clean ground, should be provided for the purpose of cleaning parts under relatively sand-free conditions.

Wherever and whenever possible, test engines on a suitable platform. Revving up on open desert ground results in dust intake and sand-blasting which pits the prop, fuselage, and tail surfaces. Improvise a platform: (1) any hard natural surface, swept free of sand and dust, may be used; (2) landing mats, if available, and of two or three thicknesses, are ideal; (3) an improvised mat may be constructed by digging a large pit about 7 to 8 inches deep; fill the pit with cobble-sized (over 4 inches in diameter) or larger stones and rocks, and bring the top of the rock mat about 3 inches above the ground level. The space between the rocks provides a trap for wind-blown sand and the prop will not suck it up into the blades. After several weeks of use, remove the rocks, clean out the pit, replace the rocks, and then the mat will be serviceable again. Never run up engines on the ground any longer than absolutely necessary. Never run up engines to windward of other planes, personnel or ground installations. Never taxi planes under their own power when it is possible to tow them. During violent sand and dust storms, delay repairs and service (if there is no combat emergency) until the storm lets up. Do only such work as cannot be affected by dust or sand.

LUBRICATION. The most injurious action of sand and dust results from its adherence to oil-bearing surfaces. When mixed with oil, desert dust becomes an efficient grinding agent. Guard against it constantly—especially where it attacks close-fitting parts or parts that work against friction. Clean and inspect regularly, frequently, continuously. Lubricate sparingly and only where absolutely necessary. Sacrifice lubrication rather than risk the grinding, abrasive action of dust and sand.

Some surfaces must be lubricated, and these should be cleaned, inspected, relubricated (lightly) and wiped much more frequently than in non-desert areas. Many surfaces (lubricated under normal conditions) can best be operated dry in the desert, but they should be inspected and cleaned as frequently as possible.

COVERS. As soon as the engine ceases to fire, and regardless of the position of the plane, seal all engine openings with dust-proof covers and plugs provided for the purpose. This includes the plugging of all openings such as air intakes, exhaust stacks (wait until cooled; otherwise cover cloth will burn), breathers and vents. Make sure that plugs and covers are clean and free from sand before each installation. Install engine covers over the propeller hub, spinner, and feathering dome, extending the covers back over the cowls and exhaust outlets, and point the aircraft into the wind. Covers should be tight-fitting and tailored to the job. (There should always be two sets of covers: one stored in the aircraft; the other available for immediate application on the ground.) Keep engine covers and all plugs on the aircraft when not being serviced or prepared for operational flights. After servicing, replace covers and seals immediately. This should become an automatic habit with all maintenance personnel.

FILTERS. Air Cleaners, oil and gas filters are only as effective as the amount of care you give them. Because desert dust and sand quickly choke cleaners and filters, they should be cleaned and inspected on a rigid schedule. Clogged air-cleaner elements obstruct air passage to the conductor and thereby greatly reduce the operating efficiency and power output. Replace worn-out filters and cleaners immediately; keep an ample reserve stock on hand at all times.

Wet and dry types. There are two types of dust filters used in induction systems at present: the wet type and the dry type. The wet filter usually consists of wire mesh, heavier where the air enters the filter, finer and closely woven where the air leaves the filter. This type usually requires periodic cleaning in solvents and dipping in oil. (Thoroughly dry the element after washing and prior to immersing in oil; otherwise the filter will not be properly coated.) In many instances, it is well to include this operation in the daily inspection. The dust-laden air is forced through the wire mesh and sticks to the oil film. The dry filter consists of felt framed on both sides by wire screen (usually about 1/32 inch thick) that is bent in accordion shape so that a great area of filter is confined in a small space. This type of filter is mounted obliquely, presenting enough surface area so that air goes through the filter at a much slower rate. Because the air is slowed down, the air-borne dust particles are not driven through the filter, but instead they lightly strike the filter surface. Since the filter is mounted obliquely, dust falls away. Thus, less service is required of the dry filter than of the wet type, but the dry type is not as effective.

INDUCTION, FUEL AND OIL SYSTEMS. An engine breathes dusty air in the desert, and as already indicated, dust mixed with oil has terrific abrasive qualities. The result is serious and rapid wear of pistons, rings, cylinder walls and valve mechanisms, and subsequent excessive oil and gas consumption and loss of compression. Check oil consumption carefully—keep a chart. Watch for a sharp rise; it's the first reliable indication of trouble. While the engine can still be operated at decreased efficiency, never push it. Change the engine in time—so that it can fight again another day.

GENERAL CHECKS. In spite of all precautions, the prop blades will become pitted during takeoff and taxying. The pits in the blades should be very carefully smoothed with a fine file and emery cloth at frequent intervals. Be sure to remove all the rough burrs and ragged edges around the pits. Keep the prop blades clean and wipe them daily with the recommended oil; otherwise sand will wear the plating off the blades, and they will rust.

Very little trouble has been experienced with turbos. If necessary, plugs may be inserted in turbo inlets, intercoolers and vents. If this is done, remove the inlet plug before starting, or it will be sucked down into the impeller.

Remember that Prestone expands under conditions of extreme heat; check coolant-tank level frequently. Drain and flush coolant system at least every 50 hours.

Use a high-pressure spray gun filled with liquid fluid to clean engines. It does the work quicker and more effectively.

CARE OF AIR FRAME, CONTROLS, LANDING AND AUXILIARY GEAR. Clean, inspect and relubricate regularly such moving parts as landing gear, bomb door, tail wheel and flap screws and worm gears, anti-friction bearings, plain bushings, gear boxes, control bearings and cowl slides. Keep lubrication at an absolute minimum.

Bolts tightened during the heat of the day have been known to snap at night when the cooler air causes them to contract. Determine by experience either the time of day when temperature is most suitable for tightening operations, or make the proper compensations for temperature changes.

Keep sand out of brake shoes. While the plane is on the ground cover the wheels, pistons, struts and retracting screws. You'll also be protecting tires from the action of hot sun and sand. Brake disks should be blown out with compressed air frequently. Brakes should not be left "On" when the airplane is parked; they may stick or "seal" because of the heat.

Protect nose sections, cockpits, turrets and other enclosures by fitting them with tight canvas covers. Wind velocity is frequently strong enough to hurl sand and gravel against glass and plastic surfaces with such force as to frost and pit them, and the sun's rays have been known to distort such surfaces. Check fabric-covered surfaces for deterioration. Test by tapping them lightly with knuckles; if fabric dope cracks, sand the entire surface lightly with fine sandpaper and apply new dope. If the fabric is too worn to repair, replace it.

Tires wear rapidly in the desert. Check their air pressure at night and in the morning. It is well to remember that tire pressure varies 15 percent for each 60°F. variation in temperature. Keep brake clearance adjusted, otherwise differential expansion will occur, rims and wheels will heat up and tires will blow. Check tires for cuts.

Clean tail-wheel assemblies and landing gear frequently to prevent corrosive action of salts collected on desert terrain. Keep landing gear shock struts clean.

Don't lubricate control cables or coat them with rust-preventive compounds; wipe them clean where they pass through fairings and pulleys.

Sand will collect in all dead-air spaces in the wings, fuselage, and tail group. It may gather in such quantities as seriously to change weight distribution and affect the balance and maneuverability of the plane. Salt incrustation also is a serious corrosion hazard. Clean the sand out of all dead spaces. Sand in the cockpit is a menace, as it will fly about on takeoff. Clean out the sand. A vacuum cleaner with flexible hose attachment will do the job well. Scotch tape may be used to seal miscellaneous small openings through which dust and sand may enter. It is desirable to use a light portable blower to clean sand out of controls which become stiff and hard to move as a result of sand accumulation in crevices. In spite of all protective measures, after each sand "blow" your ship will require a thorough cleaning. Desert sandstorms penetrate.

ELECTRICAL EQUIPMENT. Instruments will cause little trouble provided they are properly filtered. Instrument filters should be cleaned throughly on a rigid schedule and worn-out filters replaced promptly. Install new filter elements when the vacuum drop becomes excessive. Sand may creep in outside the edge of the filter and just inside the adapter. It then will be necessary to use a supplementary flannelette filter, cut oversize to ensure a good seal. This should be replaced every 10 hours.

It may become necessary to filter the generator blast tubes. Dust can foul up the armature, since there is a slight amount of lubricating oil in the brushes which will mix to form an abrasive. Generators, voltage regulators, and ignition harness should be blown free of dust frequently.

Keep pitot heads covered on the ground to exclude sand and dust. Gyro instruments venturis likewise should be kept covered.

Water level in the battery should be checked and water replaced frequently, since evaporation may be rapid. Check battery overflow jar; inspect battery vents for clogging. Battery water may be difficult to secure in the desert; water with salt content is unfit for the purpose. If there is any doubt about the purity of the water, distill it before it is used in the battery. Batteries will require removal and recharging if left in an unused airplane for a week or more.

ARMAMENT. As soon as the engine ceases to fire, cover or seal all guns and seal the chutes. Make sure guns are clean before covering. Be certain to remove seals from chutes and covers from guns before take-off. Guns may be left sealed for maximum air speed; the first shot will clear the muzzle.

Clean daily all guns, bomb racks and shackles. The sand and dust which gather on their lubricated surfaces may result in disastrous jams.

Store all ammunition where dust and sand are at a minimum. When rearming, be especially careful to avoid contact with sand. Don't keep ammunition in the cartridge bins in wings over long periods of time. Dust and sand will collect on the cartridge cases, causing jams in the chamber after firing. Bombs should be loaded into bomb bays as quickly as possible, to avoid entrance of sand. To insure electrical contact make sure the release catches are free from sand.

Hydraulic turret systems may or may not require filters. With electric turrets, dust will work into control boxes. Sliding contacts on coils must be cleaned frequently; otherwise motors burn out and you'll get poor operation at low speeds.

REFUELING. Gasoline delivery from cans should be made through a filter funnel that fits snugly into the tank opening. For gasoline delivery from drums, efficiently muffle with a chamois leather cloth at the point where the hose connection enters the fuel tanks. Also use a strainer fitted with a chamois cloth. If gasoline or oil must be poured into the tanks during a sandstorm, take every precaution to exclude sand from the liquids.

Extreme care should be taken with high octane fuel at desert temperatures. Watch out for sparks. Open gas drums with bronze or other non-sparking tools. Make sure the plane is grounded, as well as the funnel and nozzle. Make sure that there is a conductive connection between the chamois hoop and the funnel, and that the funnel is in constant contact with some metal part of the ship. The tank rim will do. If possible, keep gasoline drums covered and below 102° F. If you can, do your refueling at night. The temperature 30 inches below the desert surface is approximately 60° F. Bury gasoline drums if practicable.

Never handle or transfer gas unnecessarily, as exposure to air dissipates the lighter fractions and reduces the octane rating. Some pilot may need that extra power.

Oil delivery should be directly from the can to the oil-tank opening without using an intermediate measuring can or open container. Clean oil and gas tanks periodically, as sand accumulates in the corners, seams and bottoms of the tanks.

MOORING. Sudden violent wind and sandstorms are common in the desert. When aircraft is on the ground, lock controls and moor all planes with equipment provided for the purpose. In tornadic winds, employ 2 x 4 inch "spoilers" lashed to the topside of the aircraft wings, immediately behind and parallel to the leading edges. This will break the airflow and nullify the normal lifting characteristic of the wing.

Requests for additional copies of this publication should be addressed to Commanding General, Army Air Forces, Assistant Chief of Air Staff, Intelligence, Office Services, Washington, D. C.

Capt. W. D. Peedie

Lt. W. H. Kitt.

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