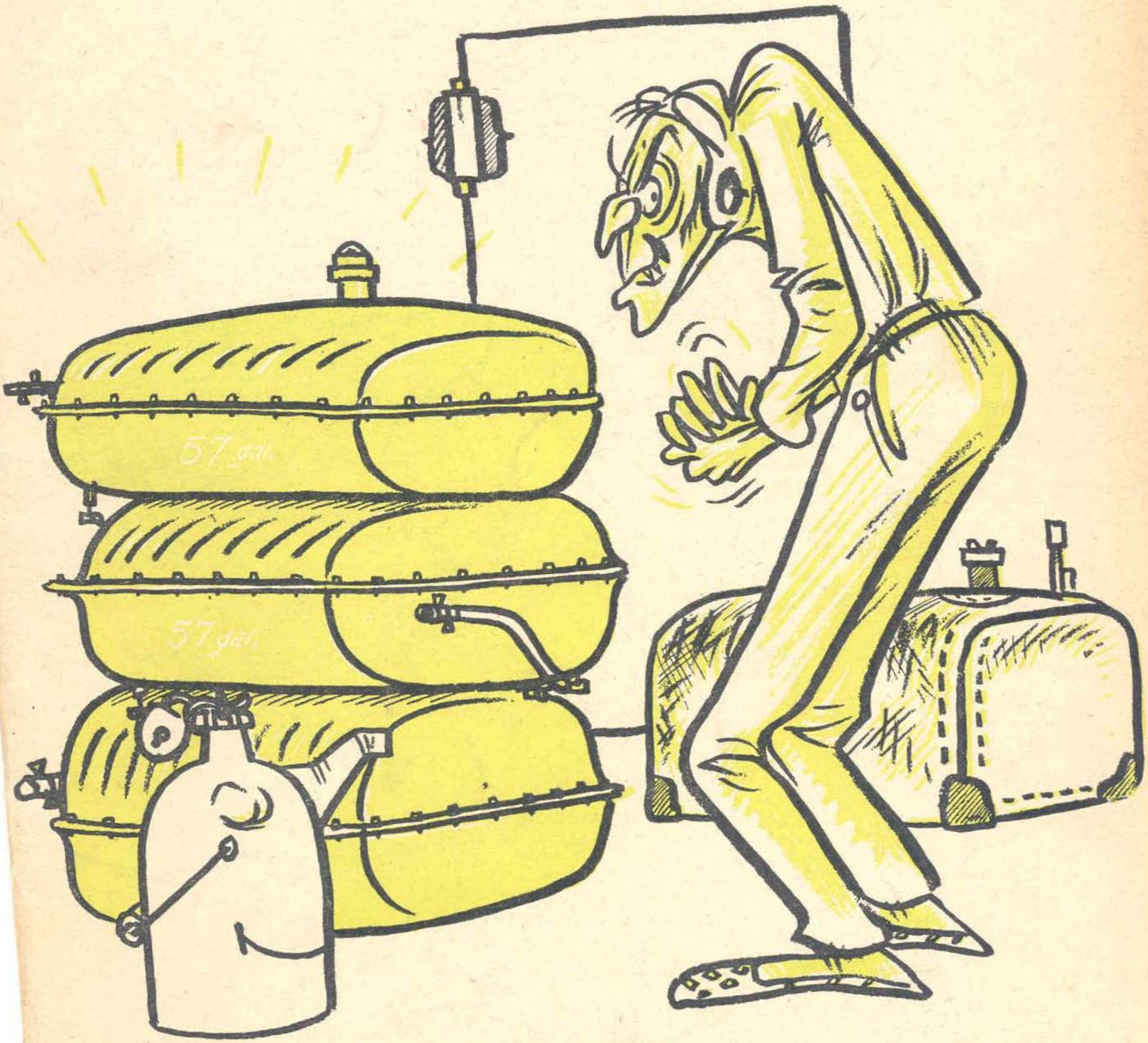
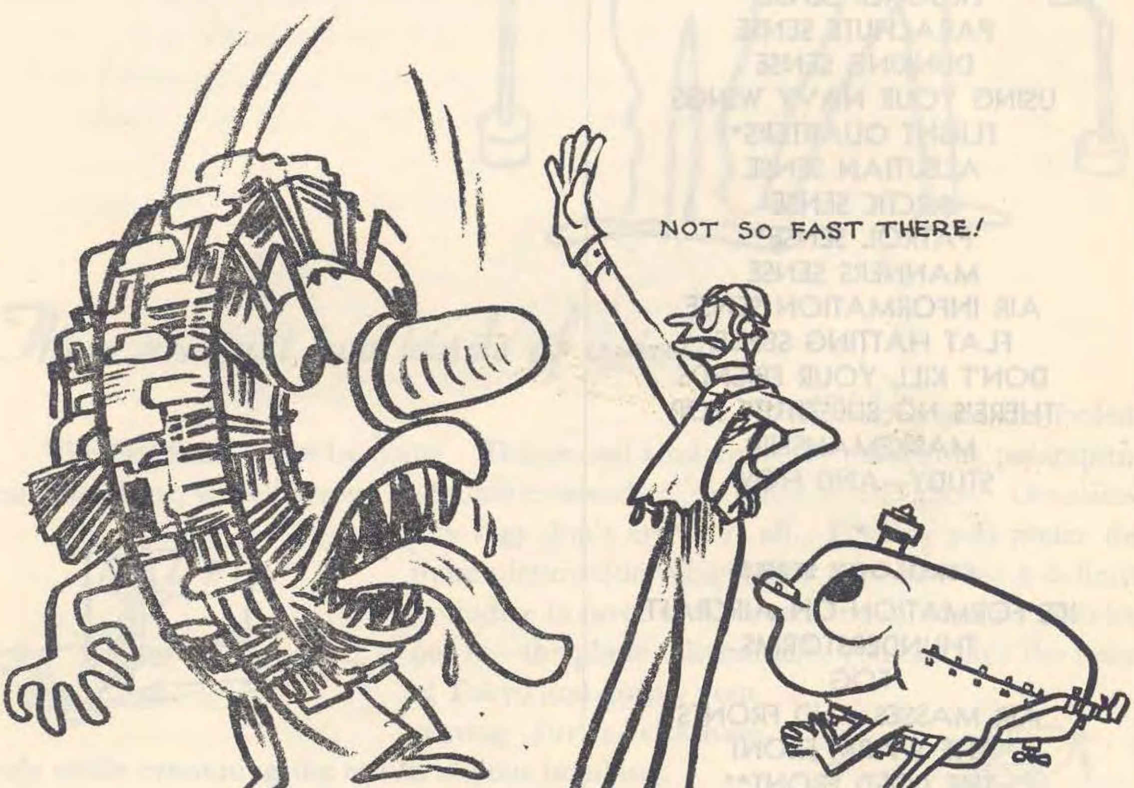
FUEL SAVING SENSE



AVIATION TRAINING DIVISION ★ OFFICE OF THE CHIEF OF NAVAL OPERATIONS
★ UNITED STATES NAVY ★

FUEL SAVING SENSE



AVIATION TRAINING DIVISION ★ OFFICE OF THE CHIEF OF NAVAL OPERATIONS ★ U. S. NAVY ★ ISSUED NOVEMBER 1943

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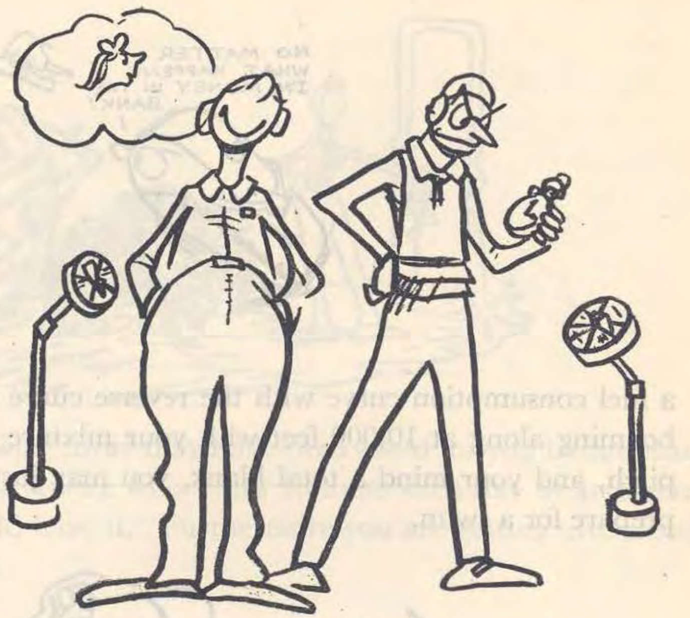
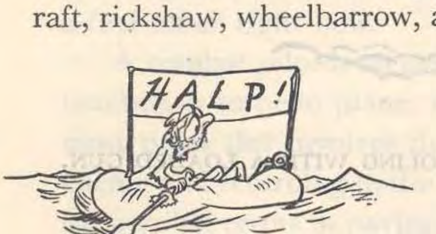
*Restricted **Forthcoming



There are just two kinds of aviators

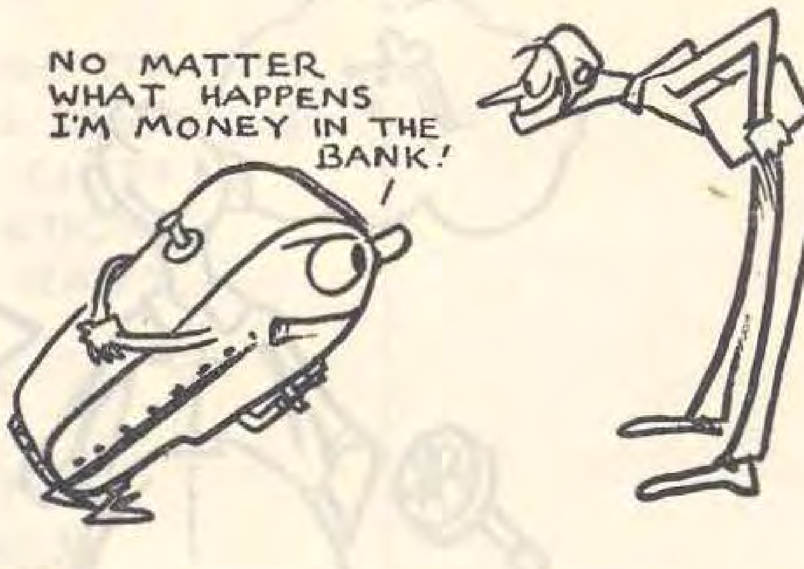
the fueled and the fooled.

The first kind arrive by plane. The second kind arrive by parachute, palanquin-raft, rickshaw, wheelbarrow, ambulance, stretcher, or other conveyance. Occasionally they don't arrive at all. Possibly you prefer the more picturesque vehicle, but the Navy has a definite prejudice in favor of your arriving in what you started out in—the plane. Eventually you can visit the ruins of Tokyo and gratify your craving for a rickshaw ride while examining the results of your bombing.

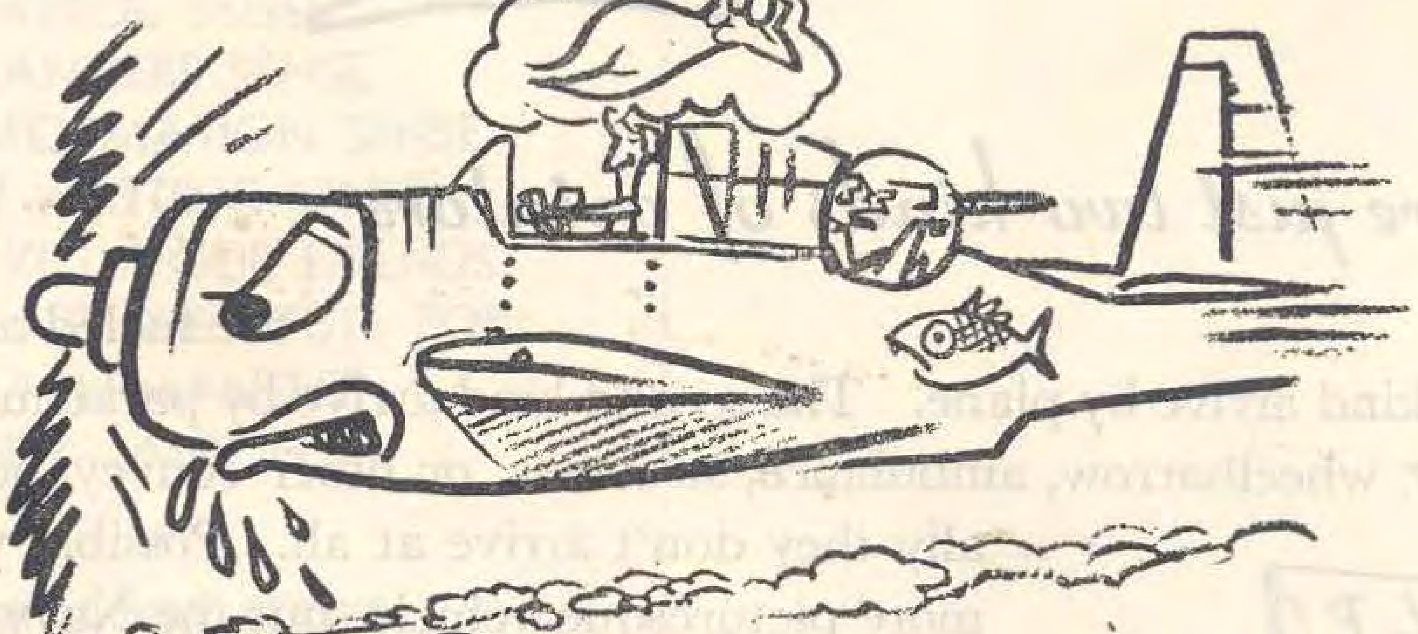


Of course you can be fooled legitimately. The carrier may change course and the tactical situation be such that you cannot be notified or you may have to drop a fuel tank. But if you've been saving gas, and watching your fuel consumption you may have a good chance to set down on an island or on an emergency field. At the

worst, you will have enough to make your dunking a lot easier, because a forced landing at sea is greatly helped if you can use your engine.



However, if you confuse a fuel consumption curve with the reverse curve on Milly the Model and persist in booming along at 10,000 feet with your mixture on full rich, your propeller in low pitch, and your mind a total blank, you may just as well call Dilbert "cousin" and prepare for a swim.



WASTING FUEL FALLS INTO THE SAME CATEGORY AS FOOLING WITH A LOADED GUN.

You, too, can be an Axis ace

by crashing American planes, ruining engines, and uselessly burning up fuel. You can be a pretty solid liability to the war effort before you ever see a Zero or a Messerschmitt simply by flying too high with too rich a mixture thereby causing carbon deposits on cylinder heads, pistons and spark plugs as well as on the souls of the mechs who have to clean up the

mess. That gasoline you're throwing away may have been saved for you by the man in Kentucky with four sons in the service who walks 10 miles each day to and from his job in a war plant so you could have it. Furthermore you are getting into a bad habit that may cost you your life.

Well, it's your life

and you can do with it what you want, but you probably like the idea of keeping it around as long as possible. If you do, start being a fuel miser right now.

A combat pilot is an aviator who flies out to meet the enemy in a fighter, a dive-bomber, a torpedo plane, or a patrol bomber and knocks the hell out of him. In most types this involves flying at high altitudes over long distances, engaging the enemy and returning to the carrier or base with a margin of endurance to compensate for possible errors in navigation or other contingencies. Owing to tactical necessities many operational flights are made at almost maximum range. Right there is one good reason to start hoarding gas from the beginning. But in wartime flying in a combat zone, you never can tell when even the most routine flight may turn into the aerial equivalent of a 5-year whaling voyage, enlivened by a few coveys of Zeros and a flock of perambulating AA shells. Therefore guard against contingencies and handle your fuel supply at all times in a manner calculated to get the maximum out of it. A DROP OF GAS SAVED NOW MAY SAVE YOU A BUCKET OF BLOOD LATER.

Can you stop this?

Contingencies have a way of arising. Here's an actual example:

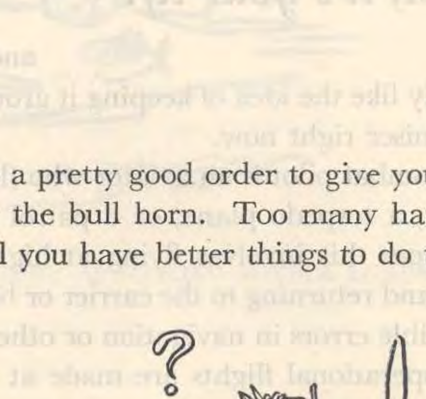
A scout-bomber took off with a 500-pound bomb and 264 gallons of fuel. The pilot took the plane out 300 miles, across 60 miles and back 200 miles, during the course of which he was attacked by Jap planes. He dumped his bomb and engaged

them for 20 minutes at full power. On his return to his rendezvous he found the carrier gone. He located her 75 miles away unable to take her aircraft aboard. He spent 30 minutes spotting survivors for a destroyer, then flew 60 miles to a second carrier. A note was dropped on that ship, reporting that only 30 minutes fuel remained and requesting permission to land. It was not, however, until 28 minutes later that the scout-bomber landed safely with only 2 gallon of gas left in the tanks.

Just how far would Dilbert have got with that set-up?

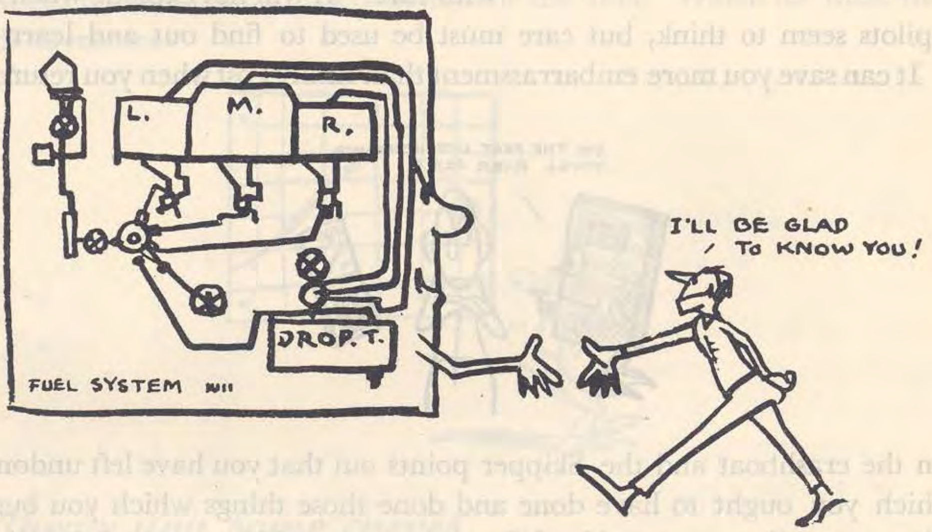
"Pilots meet your planes"

is a pretty good order to give yourselves before "Pilots man your planes" comes over the bull horn. Too many have only a nodding acquaintance. Sometimes you feel you have better things to do than sit in the cockpit of a grounded plane and learn the exact location of every switch, knob or gimmick that you may have to pull, press, turn, or wrestle with in the dark or in the excitement of action, or of an emergency. However, combat pilots and life insurance companies regard it as time well spent. It may save you a very red face, for example,



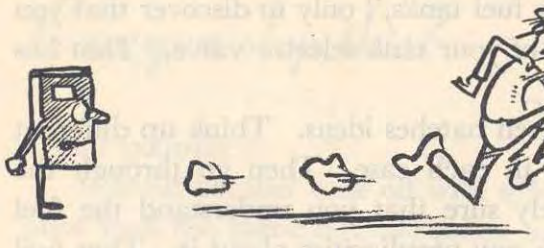
when you make a forced landing with "empty fuel tanks," only to discover that you have shifted the fuel indicator switch instead of your tank selector valve. That has happened.

Cockpit sitting, then, lays few eggs and even hatches ideas. Think up different emergencies and figure out what you'd do in each case. Then go through the motions. While you're there make absolutely sure that you understand the fuel system of your type of airplane, together with any peculiarities about it. That fuel



indicator switch isn't the only trap for the unwary. Take one type of patrol plane as another example. In it the hull tanks normally feed to the engines through the wing tanks, with an emergency feed direct from the hull tanks to the engines. Each wing tank will feed only to the engine on its own side. Now, if you exhaust your hull tanks, each engine will have to depend on the fuel remaining in its own wing tank. As a precaution, it's good practice to keep about 100 gallons in the hull tanks and feed as required to the engines when the wing tanks run dry. Otherwise one engine may run out of fuel some time before the other.

Were you the guy who was laughing a minute ago about those other pilots who doped off?

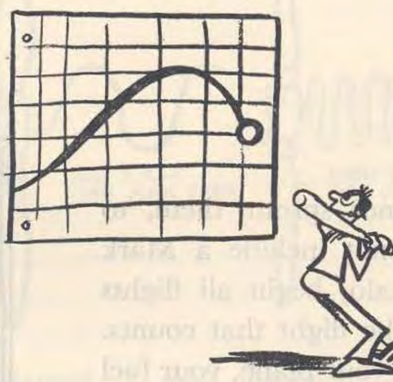


Handle the handbook

with care. It will not explode when opened as some pilots seem to think, but care must be used to find out and learn what's inside it. It can save you more embarrassment than Emily Post when you return home,

all wet, in the crashboat and the Skipper points out that you have left undone those things which you ought to have done and done those things which you ought not to have done according to page 13. When you were a kid you read the directions on the mechanical mouse before you turned it loose in the ladies room. How about reading the directions on your mechanical Jap-Buster before you turn it loose in the middle of Hon. Tojo's picnic and outing for the Nippon Poetry, Uplift and Prisoner-Shooting Society? The dope is right there.

Pilots fly, good pilots learn about their plane's endurance while flying, and the best pilots pass on what they've learned for your benefit. This knowledge you'll find in Technical Orders and Technical Notes, so don't neglect them while you're in the ready room with your mind idling at a thousand revs. The Bureau of Aeronautics is putting out a new series of publications to supplement the Pilots' Handbook. They are called either "Preliminary Operating Instructions" or "Supplementary Operating Instructions," depending on whether they are published before or after the handbooks. They will be issued for each type of combat airplane as fast as exhaustive tests can be completed. Torque meters, fuel flow meters, and other special instruments are fitted to these planes to help determine the data. Watch for these thrilling tales of high adventure!



They throw you some curves

in these publications which you had better be able to handle. On the first look you're all for the glider as the plane of the future, but if you keep on looking and study them a bit you'll have some idea of a flight plan which will bring you shoutin' down the sawdust trail to the carrier or base. It's all hot dope and really duck soup when you dig into it.

Carburetors throw monkey wrenches

at slide rules and give flight test activities the urge to end it all, so don't put utter trust in any fuel consumption data that comes to you all printed up and ready for instant application (or that comes to you on the ferry pilot's cuff for that matter). Check it out in your own airplane. Remember, too, that you must know your take-off weight and balance and how to figure the density altitude. And, as a reminder, a clock or watch frequently is more accurate as a fuel indicator than a fuel gauge.

One ten-thousandth of an inch tolerance in a carburetor times a long flight may equal an aviator minus a plane. When flying compare your actual fuel consumption with your prognostications and, by keeping a record, have a pretty good average of what you can accomplish. It's accomplishment that counts among aviators, not just the ability to fly a plane.

To pin on wings

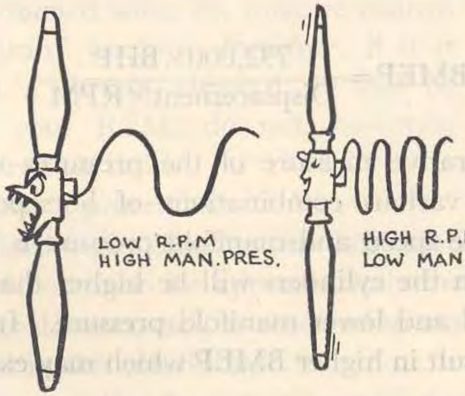
not sprout them, to draw flying gear that does not include a Mark Six harp and a regulation halo, begin all flights long before you take off on the flight that counts. Practice cockpit sitting, study your plane, your fuel system, and your engine. Check to see that your fuel tanks are full; don't take somebody's word for it. Then make your flight plan after having verified performance by actual experience in the air. By doing this you will learn to save your life. If you spend your flight time in training booming around the empyrean like a bumblebee with a hot-foot and learning nothing, you won't suddenly change to a wary and knowledgeful flyer when you go out on operations. You've got to maintain at least as good an average on fuel economy as anybody else in your squadron, otherwise you may be the weak link which spoils the entire operation.

Interlock your ground work and your air work until your air crew, the hardest judges of your airmanship, can stop taking the water temperature before you (and they) take off.

Oil up your slide rule,

roll up your sleeves, for here we go on a conducted tour of RPM-Manifold pressure relationships.

It is possible, in planes equipped with constant-speed propellers, to get the same indicated airspeed when using a considerable number of combinations of RPM and manifold pressure. You can do this because you can either adjust the propeller to take big bites in the air (low RPM, high manifold pressure) or smaller bites (high RPM, low manifold pressure). So far, so good. Now remember when you



hand-cranked the inertia starter? It took more grunts and more energy to turn the crank at high speed than it did at low speed. Well, the engine works the same way; more power is lost *in the engine* (engineers call this friction horsepower) at high RPM than at low RPM. Consequently, when operating at low engine speeds a greater percentage of the power produced in the engine actually gets to the propeller. Sometimes, of course, at these low propeller RPM's, the propeller's pull on the airplane deteriorates (reduced efficiency) and results in lower airspeed. From a practical point of view, however, in cruising condition at a given brake horsepower less fuel *generally* will be consumed at a low RPM than at a high RPM. (Prick up those ears, fuel misers!) The lowest RPM which may be used with a particular engine installation may depend upon propeller efficiency, propeller governor limits, carburetor idle enrichment setting, or generator cut-out speed. The lowest RPM at which a given power can be safely attained is limited by the setting of the high propeller stop or by maximum permissible BMEP (what's that?). To find the operating limits—you're right, Willie, look in the pilot's handbook.

Come again

with that BMEP.

BMEP (brake mean effective pressure) is the hypothetical average pressure obtained from the formula:

$$\text{BMEP} = \frac{792{,}000 \times \text{BHP}}{\text{Displacement} \times \text{RPM}}$$

It is a convenient comparative measure of the pressures which occur in engine combustion chambers at various combinations of horsepower and RPM. For instance, if a certain engine speed and manifold pressure is used to obtain a given power, the pressures within the cylinders will be higher than if the same power is obtained at a higher RPM and lower manifold pressure. In other words, the first condition described will result in higher BMEP which may exceed permissible limits.

"Lean, hot and detonating"

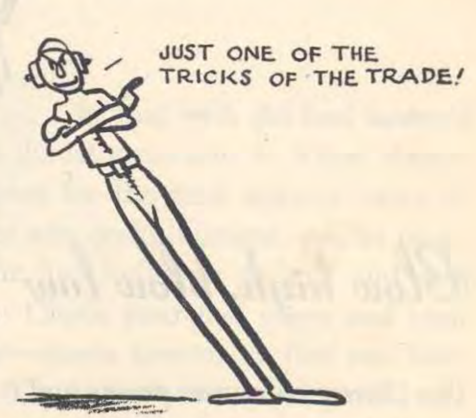
is another way of saying "fat, dumb, and happy." This interesting, though rather repulsive, condition can be attained by not reading the engine operating instructions and then manually leaning indiscriminately without regard either to proper procedure or limiting power. However, fuel misers know that if the proper procedure is used, no damage will result and the cylinder head temperature will be at least as low as when the mixture control is in the "automatic lean" position. The RPM-manifold pressure relationships which the handbook gives you for "automatic lean" are suitable for manual leaning at 50 percent power and below unless the handbook for your type of airplane specifically warns you not to use manual lean. Remember that the power obtained for the same RPM and manifold pressure when fully leaned will be less than that obtained when the mixture control is in the "automatic lean" position; therefore, if it is necessary to maintain a certain airspeed, it will be necessary to increase your RPM; do not, however, exceed the maximum cruising limit.

Use this manual leaning procedure:

(a) Set up a stabilized flight condition in "automatic lean" using the optimum RPM-manifold pressure condition for approximately the desired airspeed, adjusting the cowl flaps, oil cooler shutters, etc., as required to maintain proper temperatures, fly for about 15 minutes in this condition.

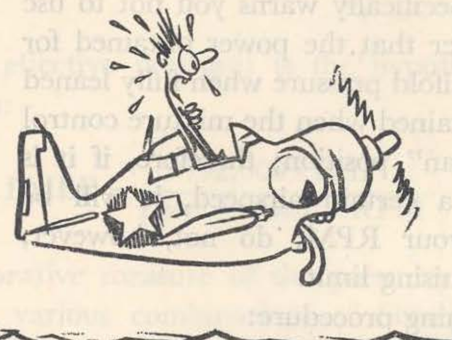
(b) Lean manually past the "automatic lean" position, moving the mixture control toward "idle cut-off" until the tachometer hand starts to swing, then allow the engine to stabilize, enriching just enough to steady the tachometer hand. The cylinder head temperature should not be above the limit for "automatic lean" operation. (In several types of airplanes the head temperatures will be lower than when in the "automatic lean" position; if such is the case for your airplane, don't lean more than is required to reduce the head temperature about 10° C.; in general no improvements in economy will result from further leaning.)

Remember, know how to lean manually in the proper way, but in the interests of long engine life and a minimum of maintenance, don't use it habitually. Use it only if your mission requires nearly maximum endurance or save it for that last extra mile when you've chased Zeros too far and aren't too good at rowing a boat.



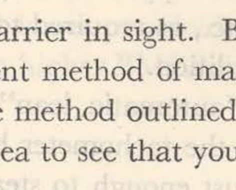
"That ain't the way I heared it"

may be perfectly true, but the procedure just given you will result in safe operation and better fuel economy when you're in a tight spot in combat aircraft. If you don't use it you may have to conduct some interesting experiments of your own, probably with your last five



gallons of gas and no land or carrier in sight. Bear in mind, though, that if your handbook recommends a different method of manual leaning for a particular type of airplane, use that one, not the method outlined above.

By the way, it's not a bad idea to see that you're using both mags.



Blow high, blow low

but usually blow low with your supercharger. The blower consumes power and it takes more power in high gear than it does in low. Avoid frequent changes because most instructions require that you use "automatic rich" mixture to make the shift properly and this to you, by now a confirmed fuel miser, is equivalent to a deep incised wound or stab. Service experience has proved

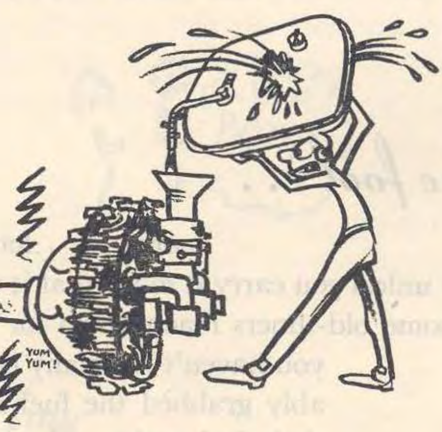
that if at the end of each 5-hour period of continuous operation in one ration, you will operate in each of the other supercharger control positions for 5 minutes, no accumulation of sludge will result in "no blow" at the crucial moment. Keep an eye on your fuel supply, however, and don't do it if you're running low. The best precaution is to shift the clutches prior to each flight as part of the engine's daily check. Some experienced carrier pilots also advocate shifting clutches and de-sludging after a hop as additional insurance. This MUST be done in the case of Wright engines.

Fueling with the fool . . .

sorry . . . fooling with the fuel tanks in flight is an excellent habit unless you carry it so far that it turns into St. Vitus' dance. Every 15 minutes or so some old-timers reach down for the tank selector valve (if you haven't done any cockpit sitting, you've probably grabbed the fuel indicator switch) and shift their fuel tanks. Check your fuel gages and your fuel consumption—know how much fuel you have in your tanks. Your watch is a good guide, too. Time will tell!

The order in which you use your tanks may well be of importance. In one type of scout-bomber, for example, only Dilbert uses the wing tanks in a dive. If you're in a plane of that type and have carefully saved only the wing tanks and have to dive, comment seems superfluous. Your own aircraft may have its peculiarities. If you have a belly tank which you can drop, always give it priority in use so as to

eliminate the fire hazard and relieve the plane of its weight. The same applies, especially if you are on an offensive mission, to purge tanks. Of course you can't drop them but you can get rid of the danger of fire by flushing them with CO_2. Logically if you have a shot-up or leaking tank, shift to it right away and salvage all the fuel you can.



Some pilots advocate, in view of carburetor variations, emptying one of the less important tanks completely and then using the Mark Eight computer to give a nearly exact figure on fuel consumption under given conditions.

You got an up-check somewhere

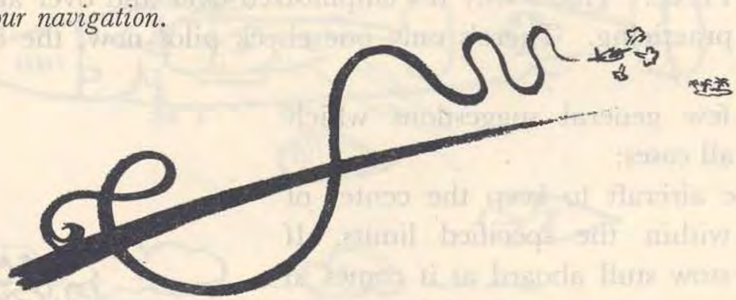
or you wouldn't be in a cockpit. Maybe the Flight Board was at peace with the world the day your case came up, but you're a pilot. There is nothing in the following advice for fuel saving while flying that will present such mechanical difficulty. The catch comes in following the procedure all the time until it becomes second nature. Fuel saving, habitual fuel saving, is VITAL. That's why it's emphasized over and over again. Practice it and keep on practicing. There's only one check pilot now, the bony one with the cold breath . . .

Here are a few general suggestions which apply in almost all cases:

1. Load the aircraft to keep the center of gravity within the specified limits. If you just stow stuff aboard as it comes to hand, you may do a careless job that will make you nose heavy or give you a high tail-load and increased drag. Don't load just to take off. Load to arrive where you're bound.

2. Make as few power adjustments as you can. Such adjustments usually involve richening the mixture temporarily and that sort of thing mounts up in fuel expenditure.
3. Fly straight and level unless you are ordered to do otherwise to baffle Joe Banzai or Herman Dumkopf.

4. Do not vary operating altitude any more than is necessary. The energy expended in a climb is never fully regained in a glide.
5. Avoid rough air if possible. Rough air makes a plane climb and descend and affects efficiencies.
6. Average your airspeed indicator readings over several minutes. Gusty air affects airspeed readings and a single glance might give you a very erroneous result.
7. *Watch your navigation.*



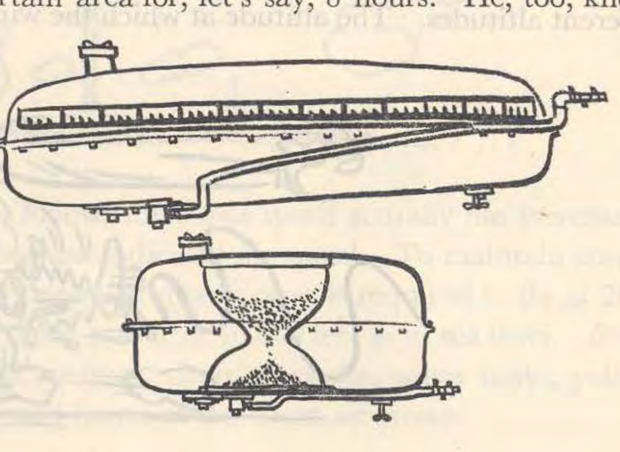
Are you soiled?

Or just plane dirty? Keep it clean, aerodynamically at least. A clean plane gives the greatest economy. Be sure the wing flaps and landing gear are fully retracted. (On some patrol types the wing flaps may droop. Watch for it.) Use every possible means to maintain proper operating temperature with the cowl flaps opened as little as necessary. They are an important requisite to proper engine cooling but they can also defeat their own purpose. Opening the flaps so the engine will cool means that more power is required to maintain flying speed. This increased power in turn may mean more cowl flap opening and in some installations a vicious circle exists which may become critical at patrol speeds.

When her old man aims his shotgun

Wolves have two choices; either to flee for the tall timber so as to put the longest possible distance between them and Dan'l Boone or to soar into the air and hover there as long as possible so that the charge will go by underneath. In the first case, the wolf is trying for maximum *range*, in the second for maximum *endurance*. For range, then, we are trying for the greatest possible distance (without regard to time) while for endurance we are trying to get the greatest possible time in the air.

Let's take an example for each. A pilot is ordered to fly from San Diego to Honolulu direct. He knows that this will require most of his fuel, but he also knows that he won't have to hang around and can land immediately. He therefore tries to get every mile he can out of every gallon of gas and flies for maximum range. Another pilot is ordered to patrol over a certain area for, let's say, 8 hours. He, too, knows that this will require most of his fuel, but here his chief worry is not about distance, but about the time he must spend over the area. Obviously he's trying to get every minute of flight time he can out of every gallon. He's flying for maximum endurance.

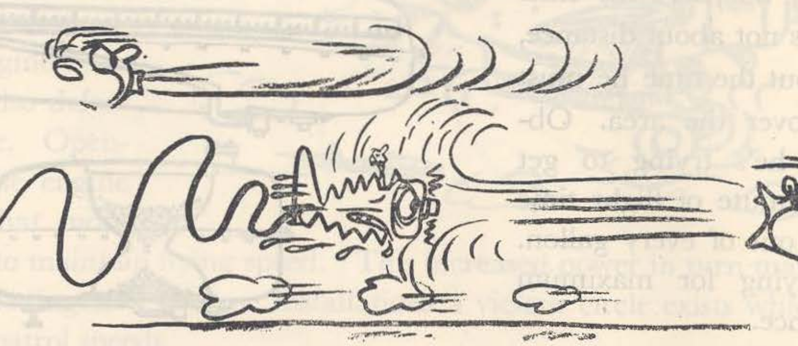


The good old handbook backed by the "Operating Instructions," rushes into the breach with most of the dope on airspeeds and power settings, but there are some general considerations you might like to know. Let's take range first.

You can call a bullfrog "pal"

because pilots and bullfrogs have a lot in common. Both of you are proud of a good long hop. Both of you use it to save your lives. Both of you holler "Jug-o-rum" when you hit the water, but he's doing it for fun and you're doing it only in hopes. Well, here's a shot in the leg:

For maximum range, the best use must be made of wind force and direction at different altitudes. The altitude at which the wind is most favorable is the governing



factor. Consult the aerologist before taking off and make your choice carefully. Don't waste fuel by wandering all over the blue looking for a good altitude.

Maximum range airspeeds for various gross weights are tabulated in the "Operating Instructions." These also contain recommendations for changing these speeds should one be flying in a headwind or tailwind.

When you're "endurin' the war"

and trying for maximum endurance, sometimes you get a break. The books say: "Flying for maximum time in the air means flying at the speed which requires the least expenditure of energy per hour." Pilots restfully making up flight time need no such reminder but, as a matter of fact, it also applies to the plane. To get maximum endurance, the engines should be run at the lowest horsepower that gives the speed at which drag-power requirement is least.

At a given weight, drag is the same at all altitudes for any given indicated airspeed. The power required at each speed is the product of the drag times true airspeed. As altitude is gained, power must be increased, if it is desired to maintain a

constant indicated air speed. This follows since true speed actually has increased, as altitude is gained in spite of the constant indicated air speed. To maintain constant indicated air speed, approximately one-third more power is required to fly at 20,000 feet than at sea level, and twice as much power at 40,000 feet as at sea level. *For long endurance fly low* with due regard for rooftops, church steeples, water tanks, pelicans, Yellow Perils and other such flora and fauna of the lower air strata.

But here, George, the Handbook, bloody but unbowed, raises his head again and gives a number of limitations and recommendations based upon certain special factors which may have to be considered with different engines.

The best endurance speed in smooth air is theoretically just above the "mushing" point, but this is impractical for level flight under average conditions. The "Operating Instructions" therefore usually give you a somewhat higher figure. This speed varies with the weight of the plane, and, as you consume coffee, sandwiches, gasoline, and other expendibles, you should make a periodic reduction in air speed for the corresponding reduction to weight (every hour while the plane is heavy, but with greater time intervals as the weight decreases). *Attempt to maintain a constant indicated air speed between these periodic adjustments.*

The best general conclusion for endurance is this:

The power to fly at endurance airspeed may be attained with various combinations of manifold pressure and RPM, but to save the most fuel, use the minimum RPM permitted by the handbook.

If you're afflicted with engines

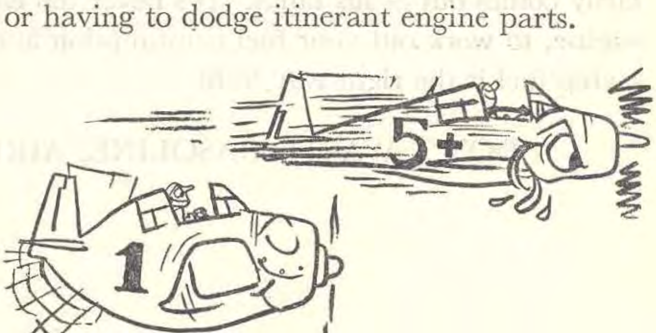
in twin or multi-engined planes and either you or they decide you can get along with a few less, obviously you will have a different maximum range and endurance IAS than you will when all are present and accounted for. In twin-engined aircraft that can just maintain altitude on one engine, these two figures will coincide. Check with George the handbook or with his pal the "Operating Instructions" to find out what your performance will be with various engine combinations and gross weight, and be ready to meet each circumstance if it happens. Last-minute experiments usually fall flat . . . and so do you.

When teasing the monkey-men

by heaving lead at their planes or bombs at their ships, you are going to need full power to catch up with them. The handbook tells you the maximum permissible RPM and manifold pressure, and the length of time for which you can safely use this condition. Maximum permissible manifold pressure usually varies with altitude and blower ratio. Know how much power you can use and how long you can use it without sending your temperature-gauge needles around the high stops or having to dodge itinerant engine parts.

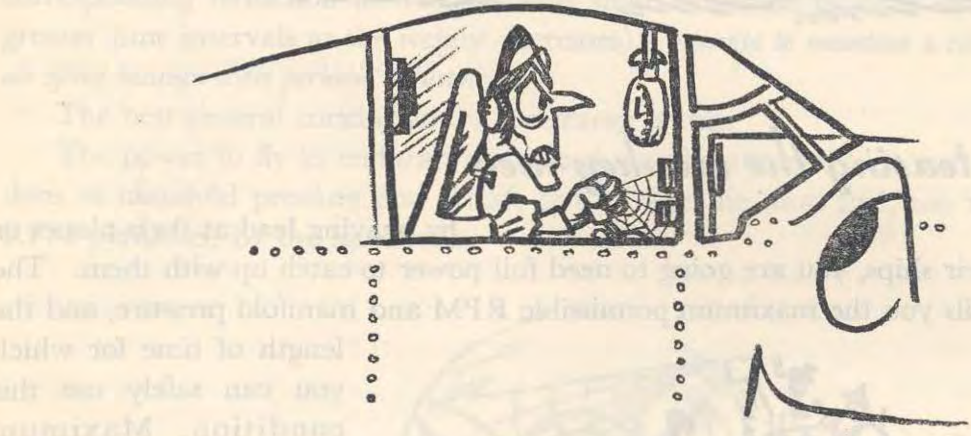
When you're shooting the works, your's and their's. keep a careful watch on your engine temperatures and remember that your fuel consumption may be more than five times what it is at maximum range conditions.

Don't use full power more than is necessary.



A fuel miser flies her

even when his flight plan has been knocked galley west by something unexpected like a shot-up tank. Depending on the circumstances, he shifts to procedure for maximum range or maximum endurance. He lightens his load, flies a straight-line course, switches to the leaking tank to use what he can of the fuel and either starts to use, or keeps on using, the manual control.

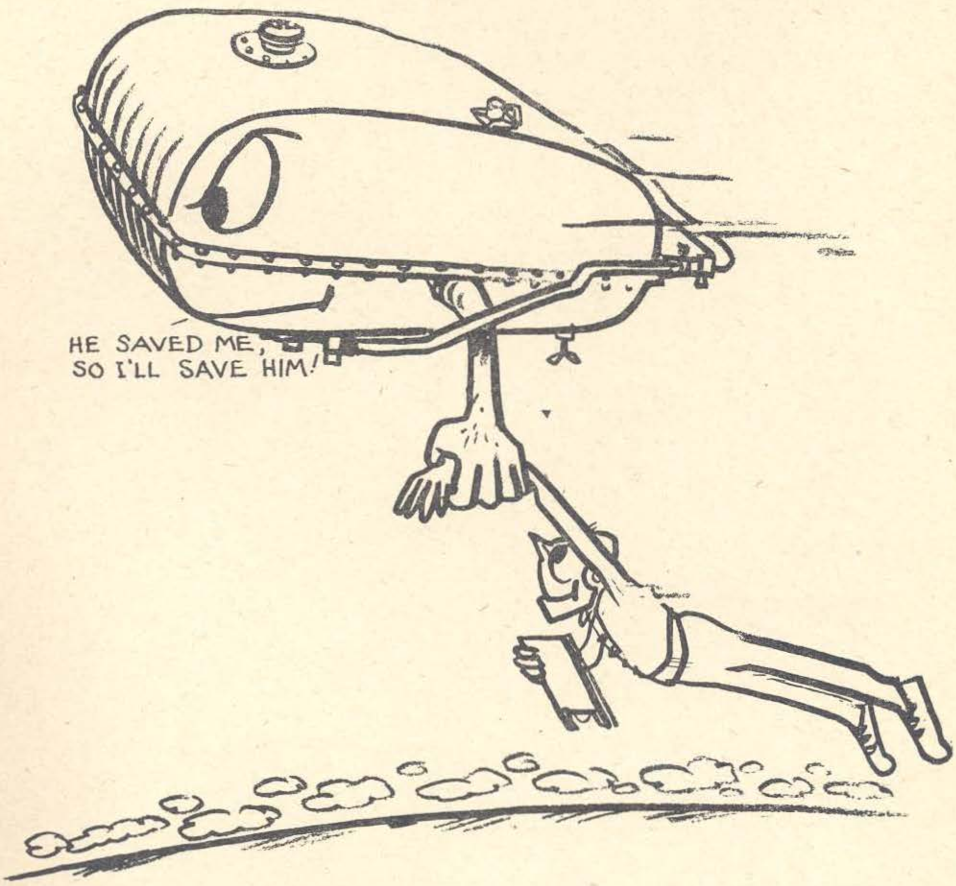


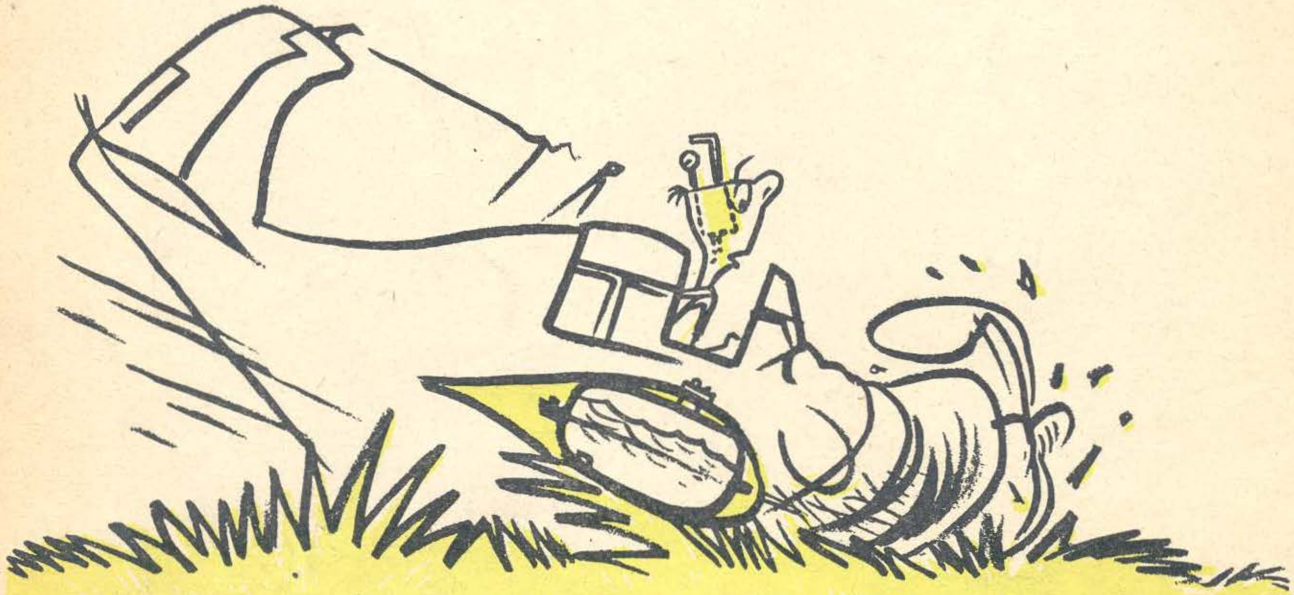
You're in a combat area

no matter where you are when it comes to saving fuel. Even if you're on a ferry trip, or on a training flight or just making up flight time, you're flying wingman with a combat pilot. The gas you burn unnecessarily comes out of his tanks. It's never too early to begin to study your plane and engine, to work out your fuel consumption and to know the right way to fly. And saving fuel is the right way to fly.

DON'T WASTE GASOLINE, AIRPLANES, OR VICTORY!

U. S. GOVERNMENT PRINTING OFFICE: 1943


HE SAVED ME, SO I'LL SAVE HIM!



TWO FULL TANKS AND
ONE EMPTY ONE!