The "E" powered Bonanzas use an oil cooler and reservoir that is completely different from H35 and later V-tails or any straight-tail models. Although the function of this innovative contraption has been explained numerous time in *ABS Magazine*, there still seem to be those – even long-time members and "E" owners – who do not understand the ins and outs of this system.

The first 150 airplanes used a very archaic layout, incorporating an oil cooler in the scavenge oil return line. The oil reservoir was only a reservoir and, except for the heat lost through the tank walls, served no part of the oil cooling. This first layout had hoses, radiators, baffling and other parts and pieces in great profusion.

Then came the firewall-mounted combination reservoir/cooler used on airplanes S/Ns D-151 through D-1116. Although slightly different in appearance from the later and final design that placed the tank on the upper left side of the engine, the internal goings-on of oil flow, cooling and quantity are identical.

The capacity of the tanks is 10 quarts. However, we hopefully will see, as this missive progresses, why we would never want to carry that amount of oil in the tank.

TANK/COOLER UNITS

The physical layout of the tank is shown in Fig. 1. As may be seen, the oil delivered by the scavenge pump is directed to and spills out onto the top of the cooler tube bundle assembly. This occurs on all tank/cooler units. Some of the very early tanks had the scavenge line penetrating the tank at the top, but on most of them the scavenge line entered on the tank bottom and continued to the tank top inside the tank.

There are 332 tubes in the cooler bundle. Each tube is separated from its neighbor by about 0.050 inch – quite a close spacing. On top of the tube bundle is a pan that is 7/8 inch deep with the bottom of the pan being the topmost row of tubes. When the oil is poured into the pan by the scavenge pump, it will cascade down through the spaces in between the tubes by the forces of gravity alone. In other words, the tank is normally unpressurized except for a very low pressure, which is only 6- to 8 inches water column or about 3/10ths of a pound.

The air pressure at the forward end of the tubes is higher than the rear due to ram air pressure within the upper portion of the cowl pressure vessel. So air flows through the tubes, removing heat from the oil which is hopefully cascading within the tank over the tubes.

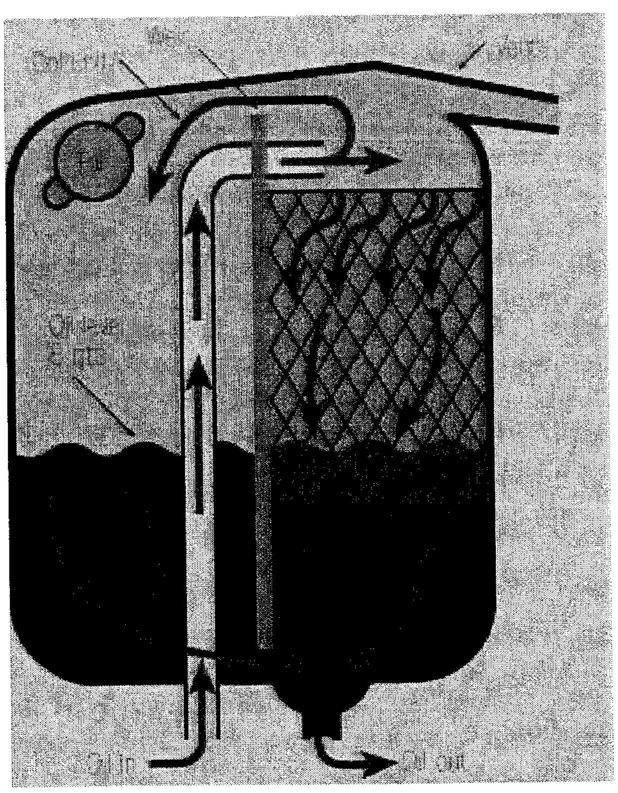

Figure 1

OPERATING THE SYSTEM

OK, that's the basics, but there gets to be a lot more to it all when operating the system. The pilot and mechanic not only need to know those few simple events described above, but also how mismanagement of the operation and/or maintenance of this system might defeat its intended function.

The scavenge pump has nearly twice the volume capability of the pressure pump. Although the scavenge pump gears are considerably smaller than the pressure pump, they turn over three times the rotational speed of the pressure pump, thereby moving more volume.

Since the excess pumping capability is there anytime the engine is turning, there will be about one-half oil and one-half air being returned to the tank. A relief vent is provided between the upper inboard corner of the tank and the upper left side of the accessory case. The early vents are 3/8 inch tube, while the later ones are 1/2 inch. If this vent or "equalizer" line were not in place, high tank pressure would result, rupturing the tank. Even with this vent line installed, the tank will or may bulge if the engine is over-serviced with oil.

OIL LEVEL

A common happening is an unknowledgeable pilot or mechanic will check the oil prior to engine start and see that the oil level in the tank is down around the seven-quart mark or lower on the dipstick or stick retaining chain. He/she adds oil to the 10-quart full mark. Since there will be approximately two to three quarts of residual oil in the engine accessory case sump waiting to be returned to the tank upon engine start, the tank will be over 100 percent full after starting the engine. This excess oil must, therefore, pass through the vent line into the engine.

The vent line will handle the volume of air (two +/- gallons at 800 rpm and seven +/- gallons at 2,650 rpm), which is normally all that passes through the vent line and does so at a pressure (3/10 +/- psi), which the tank will easily handle. However, if the engine has been over-serviced such as the example cited, this vent now needs to pass as much as seven gallons of oil per minute through it. The pressure required to push the same volume of oil through a line as air would be much higher – enough higher to bulge the tank walls and possibly rupture it.

TANK PARTITION

As seen in Fig. 1, the tank is divided down the middle with a partition. This partition does not go to the top or bottom of the tank, but ends about 1/2 inch short of both. Oil in the left side (reservoir-only side) can flow under this partition to the suction supply outlet of the pressure pump. The top end of this partition forms the left side of the cooler tube bundle pan and serves as a weir or dam 7/8 inch high. Upon start of a cold engine, the scavenge return oil is poured out into the pan, the bottom of which is the upper row of the cooler tube bundle.

Since the initial oil is cold and thick, it will not readily run or cascade down through the narrow spaces between the tubes. The pan immediately fills up and the oil runs over the weir into the reservoir-only side of the tank unit. As the oil warms and becomes thinner, it does cascade through the tube bundle and is therefore cooled.

HIGH OIL TEMPERATURES

By viewing Fig. 1, one may visualize that if the oil level in the tank were higher than depicted (about eight quarts), the high liquid level would impede the ability of the oil to do this cascading routine. One of the causes of high oil temperature is carrying oil above the eight-quart level. Oil levels between seven and eight quarts are ideal.

Of course, if an engine is burning a quart an hour and the airplane had tip tanks for a total of 100 gallons, and one were to plan a maximum range flight, then it would be necessary to start with the tank full at 10 quarts. That is, 10 quarts at the last engine shutdown, not overfilled to 10 quarts before a cold start.

In addition to the oil level being too high and causing high oil temperatures (215-225 F), accumulations in the tank that close the spaces between the tubes will produce high oil temps.

When the tank was new, it was bare, clean aluminum both inside and out. (A few tanks were treated inside with a zinc chromate sloshing compound.) Any accumulation of material inside or out will degrade the heat transfer capabilities of the heat exchanger, lessening the oil cooling capabilities. A heavy deposit between the tubes will restrict the flow of hot oil through the tube bundle and cause it to fill the pan and spill over into the reservoir-only compartment, bypassing the cooler altogether.

CLEANING DEPOSITS FROM THE TANK

To remove sludge-type deposits, remove the tank from the airplane and dissolve the deposits with methylene chloride, which is the main ingredient in most paint strippers and carburetor-type cleaners.

Using solvent or gasoline to remove these baked-on accumulations is a waste of time. Also, do not let a radiator shop do the cleaning unless they use a cleaner compatible with aluminum. Radiator shops use a caustic soda to clean copper radiators that will dissolve aluminum. Not good in this case!

Methylene chloride is potent stuff and must be handled as a hazardous material. Proper storage and disposal is necessary or you can expect a midnight visit by the EPA, FBI, CIA and Jane Fonda.

The last batch I bought was one-gallon cans at ACE Hardware and was ACE P/N 11190. This is the clear water-like version as opposed to the jelled paint-on type paint remover.

Plug the openings except the filler opening and pour two gallons of the stripper into the tank. Lay the tank on its right side so the tube bundle is submerged. Let it sit for about 30-45 minutes, sloshing around several times. Pour the stripper back into its containers through a piece of fine metal window screen. Fill the tank with water and rinse several times.

Look in the tank as best you can and, if you don't like what you see, do the procedure again. Do not expect bright shiny surfaces. One may somewhat judge how much was removed by what is in the screen.

After the last water rinse, place the tank in your kitchen oven at 200 degrees for several hours to dry out the last of the moisture.

COWL SEALS

The medium that removes heat from the engine and oil is air. It is useless to have large amounts of air entering the high-pressure plenum above the engine and exiting the low-pressure plenum through the cowl flaps if it does not pass over the engine cylinders or oil cooler. A tight seal between the cowl and the engine baffles must be maintained, as well as proper fit of the cylinder wraparound and splitter baffles, to achieve the desired routing of the cooling air.

To check for proper fit of cowl sealing gaskets, hang a 100-watt light bulb behind the engine near the generator. Use a blanket over the front of the cowl and, like an old-time photographer, look into the air inlets adjacent to the spinner for light leaks (which are air leaks in flight) around the rear baffle seal. Place the light under the engine and, with one cowl half open, look for leaks along the opposite rocker box strips. Fix the discovered leaks with adjustments of existing cowl seals or install new ones.

A good fix for poor-fitting cowl seals along the rocker box covers is detailed in the October 1996 *ABS Magazine*, page 2563. Usually, to make the seal strips fit, an attempt is made by cutting the rubber seal strips at the rocker box "ears." The result is less than acceptable. With the addition of the modification described in the October 1996 article, a good continuous fit with no gaps will result.

Only a few places along the cowl seals which permit the valuable cooling air to flow over an area that does not need cooling air flow will degrade the effectiveness of both cylinder and oil cooling. Each pound of air flow through the cowl is capable of carrying away a certain amount of heat. But it must flow over a spot or area needing cooling, not some "gap-osis" in the cowl seal.

If the oil tank mounting strap rubber covers are in poor condition, a very durable and attractive fix is the application of two layers of heat-shrink tube directly over the rubber strap covers. This heat-shrink tube is available at any good electronics supply house (not Radio Shack) in a multitude of sizes and colors in 48 inch lengths.

The pieces required are four 33 inch lengths of 3/4 inch diameter tubing (two per strap cover). Use a heat gun to do the shrinking or very carefully use a small propane torch. The heat gun is by far the best. I've repaired several of these straps which looked very bad before and like a new factory one after.

Although I've only used black heat shrink for this repair, one may get this material in white, orange, yellow, red, purple, green and even some striped colors. So much for interior decorating.

One operational item that will assist in cooling both engine and oil is detailed in the January 1998 *ABS Magazine*, page 5082. This relates to speeds used during a climb-to-cruise altitude. Using the climb schedule discussed in this article may alleviate or eliminate a cooling problem. Most airplanes have such limited engine instrumentation that a reliable set of readings from all desired engine areas is impossible to obtain. Give this climb schedule a try. You may like it.

HOW MUCH IS ENOUGH

There are two great scientific mysteries yet to be explained. One of them deals with the question of whether the "Big Bang" theory is a valid concept.

The second question being, "How much oil should there be in a dry sump 'E' series engine?" Let's discuss question two first and save question one for a later time.

At least once a month I talk with someone who tells me it's impossible to check the oil level in his/her "E" engine because by the time they hop out of the airplane, run around and pull the dipstick, the oil level is "already drained down so it's off the stick or chain."

Although nothing is impossible, I cannot picture anything which would cause that condition to exist, provided the engine has enough oil in it to start with.

Start with no oil

Let's start with an engine which has no oil in it. Both the oil tank and the accessory case sump have been drained, the oil filter or oil screen has been removed, and the engine has drained for at least 30 minutes. All drains are then plugged, the filter or screen reinstalled and the engine washed down or by other means cleaned up for service.

Filling the tank

How much oil should be put back into the engine? The oil tank holds 10 quarts when filled full. If 10 quarts are put into the tank, will 10 quarts show on the dipstick? Yes, it will until the engine is started and then never again will 10 quarts show unless additional oil is added.

Do we want 10 quarts of oil in the tank for normal operation? No! The ideal oil tank level during engine operation is eight quarts. Carrying a higher level than eight quarts may cause high oil temperature.

Since the oil cooler depends on gravity to run the hot return oil down through the cooler tube bundle, if the oil tank is too full of oil, the distance from the top of the tube bundle to the top of the oil is not great enough to provide the necessary "head" to run all of the oil through the cooler. Some or all of it would spill over the dam into the reservoir side, with the result being higher than desired oil temperature (see *ABS Magazine*, April, 1986).

Where the oil goes

Within a few seconds of engine start after draining and refilling per above, there will be a loss of two to three quarts of oil from the tank. This oil is still in the engine, but will never show as oil quantity on the dipstick.

One quart in the filter and two additional quarts will be pumped out of the tank and hung up throughout the engine. The scavenge pump is unable to extract all of the oil in the engine crankcase and accessory case and return it to the tank.

The layout of the scavenge pump inlet, oil in the process of draining back, oil caught up in the "windage" of the rotating crankshaft and aircraft pitch attitude all affect the "hung up" oil quantity in the engine.

An idling engine (1000 rpm or less) will usually hide about two quarts while one in-flight will hide three quarts due to the greater effect of crankcase windage at higher rpm.

So when we start our newly oil changed engine, we should expect to show between two and three quarts less on the dipstick after shutdown than we put in the tank .

Therefore, if 10 quarts were installed, there would be seven quarts showing after initial engine run if a CH48109 filter is installed, and eight quarts if the original antiquated, inefficient, ineffective, beat-up, lack of engine-protection oil screen is installed.

After a short run of two or three minutes, we would check the oil level and add any necessary to bring the dipstick reading to eight quarts. This would amount to between none and two quarts, depending on that particular engine.

NORMAL REQUIREMENTS

How much oil do we need to maintain in the tank for normal flying? That depends on the engine. In most three-ring piston engines which are doing three hours or better per quart of oil, the eight quart beginning level will be adequate for airplanes which even have 20 gallon tip tanks, and are flown for maximum endurance flights.

Engines which are only doing an hour per quart could run out of oil unless the oil tank were topped off before flight.

When I say "topped off" before flight I do not mean arriving at the airplane, pulling the dipstick and adding oil up to the 10 quart level.

Never add oil to a cold "E" engine! There may be a one-to-three quart increase in oil tank oil quantity when the engine is started (see *ABS Magazine*, March 1986). Dry sump "E" engines, as opposed to the wet sump ones used in Navion airplanes, will drain down between one and three quarts of oil after sitting overnight or longer. Therefore, oil should be checked and added to after shutdown. Expect the oil in the tank to look quite aerated after shutdown.

Once the scavenge pump has returned to the tank the excess oil due to draindown (30 seconds +/-), it will be pumping about half air and half oil into the tank. This excess volume of air is relieved through a one-half diameter tube/hose connection between the upper right corner of the oil tank and the upper left corner of the accessory case.

This equalizer vent line will handle the air flowing through it just fine; however, if one were to add enough oil to the tank of a cold engine to fill it to 10 quarts and the engine scavenge pump then returned the extra draindown oil to the tank, this line would then be handling about seven gallons of oil per minute at takeoff rpm and about five gallons at cruise.

The oil level in the accessory case would also be deep enough that the scavenge pump would not pump air out of the crankcase but only oil. The result is excess pressure in the tank and excess oil being flung around inside the engine causing everything to leak.

OTHER METHODS OF CHECKING

If you still have doubts about how much oil is in the oil tank when the engine is running, take a look. I do not, nor does the ABS, recommend this procedure because of the obvious hazards involved while being in close proximity to an operating propeller.

An experienced mechanic, however, could remove the oil tank cap with the engine idling and, using a strong light source, observe the tank oil level. Expect some amount of oil spattering out of the tank filler neck and possible oil smoke in the tank.

USING THE "SKINNY DIPPER"

Another neat gadget to use in the learning process of the system is the "Skinny Dipper" tank quantity and temperature system manufactured by Airborne Electronics, 707-542-6053. The changing oil tank quantity caused by rpm, pitch attitude, oil burn, g forces, etc., can be observed, or at least observed within the limits of the multiple LED presentation used on the unit.

One LED equals approximately one quart or 10 degrees F which is not exactly the decimal place digital-type readout that everyone thinks is necessary these days. Of course, the same guy who needs his EGT to within one degree and his rpm readout to one rpm can't control the airspeed, heading or altitude even within reasonable analog values.

OIL TANK DRAINDOWN

Anyone who has attended more than one of the seminars I give on the "E" engine, props, accessories and engine operation knows that they are more or less (mostly more) a repeat of the last time. Review of an airplane's systems – even though they are relatively simple ones – on a regular repeating schedule is a productive exercise.

The airlines do a repeat of subjects on a yearly schedule and the "students" are people who think about or use the covered subjects on a daily basis. Maybe 90 percent of the recurrent training material is already known, but there is always that 10 percent left over that brings out an "Oh, yeah, so that's the way it works."

There seems to be enough new owner/members or old members who purchased one of the first 5,000 V-Tail airplanes, or those who never knew or just forgot how it works, to revisit the oil tank draindown quirk of the "E" dry sump engine. I make this judgment about the need for a refresher on this subject based on the number of telephone calls I receive asking about the reason for this phenomenon and the requests for information received at ABS Headquarters.

In my flying career, I've been lucky enough to have flown a wide variety of light planes, ranging from very basic tube and fabric, tail draggers to top-of-the-line models by Beech, Cessna, etc. Every time I put my own G35 away, I cannot help saying, either silently (if an audience is around) or aloud (if alone), "That is one hell-of-a-good airplane," and I think it pays to know more about it than just casual stuff.

A much misunderstood system of the "E" series powered Bonanzas is the engine lubrication system in general and the condition known as "oil tank draindown" in particular.

Due to the height of the oil reservoir, a means to prevent the oil in the reservoir from draining into the engine is provided while the engine is not running, at least, from draining through the bearing system.