Are You Ready for Pressurization?

Some tips — and cautions — on operating the new breed of high-flying general aviation aircraft

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There are probably more absurd misconceptions about aircraft pressurization than about any other aspect of flight.

Consider, for example, the popular belief that a bullet shot through a pressurized fuselage will cause explosive decompression and an uncertain fate for those inside.

And how about the myth perpetuated by the motion picture *Airport* '77? After the Boeing 747 came to rest at the bottom of the Caribbean, the intrepid captain (Jack Lemmon) allayed his passengers' fear of drowning by proclaiming authoritatively, "Don't worry, folks; this airplane is pressurized!" Apparently pacified, the naive passengers headed for the piano bar to sip martinis until rescued.

Someone should have nominated this movie for the "Best Comedy of the Year" award.

Unfortunately, many general aviation pilots also are unrealistic about pressurization. Modern technology enables them to cruise nonchalantly at 25,000 feet (or higher) in living-room comfort without fully appreciating that only inches away is an alien, hostile environment that can challenge their very survival. Man cannot tolerate such extremely frigid temperatures and oxygen deprivation for very long without suffering partial or total incapacitation.

Pressurization failure is unusual, but considering the proliferation of these systems in the general aviation fleet, it is appropriate to consider the potential hazards. But first, let's review some basic principles.

Pressurizing an aircraft cabin (the pressure vessel) is similar to pumping air into a tire that has a controllable leak. In the case of piston-powered aircraft, pressurizing air is provided by the engine turbochargers (illustration). The "leak" consists of one or more outflow valves at the rear of the cabin. These valves allow air to escape continuously. This prevents excessive pressure from causing structural damage and provides an exit for venting stale air overboard. Pressurization is maintained by pumping in more air than is allowed to escape.

Many believe that cabin pressure is determined by varying the amount of air pumped into the aircraft. Not so. The flow of incoming air is approximately constant. Cabin pressure is determined by the outflow valves, which modulate automatically to vary the amount of air flowing overboard and maintain the selected degree of pressurization.

In effect, the cabin is always "open." The addition of a bullet hole, therefore, would have no effect on cabin pressure. The outflow valve would compensate by closing slightly and automatically to maintain a constant flow of air through the cabin. Larger holes in the structure, however, may result in decompression.

In the case of jetliners, the outflow valves are so large that the loss of an entire cabin window may not affect cabin pressure significantly. (It would be unfortunate, however, to be seated near such a window.)

Should an outflow valve stick closed, an emergency relief valve opens automatically to prevent excessive cabin pressure and possible structural damage.

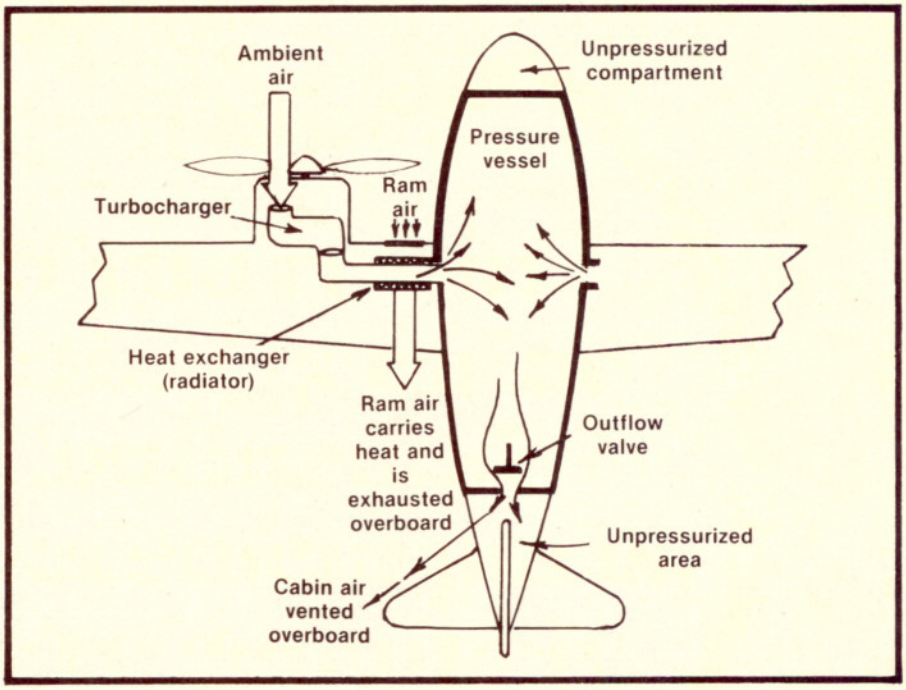
Maintaining cabin pressure obviously relies on a continuous source of air from the turbochargers. At least one engine, therefore, must always be developing a moderate amount of power. Retard the throttle(s) excessively and cabin pressure will be lost. (One can only wonder how the Boeing 747 in *Airport* '77 was able to provide sufficient engine power while underwater to maintain cabin pressure and prevent sea water from flooding the aircraft.) Engine power, therefore, should always be maintained until the cabin has been depressurized conventionally.

This raises an interesting point regarding pressurized singles such as the Cessna P210N. An engine failure at altitude would result in rapid decompression. Although the outflow valve would close automatically in a vain attempt to preserve cabin pressure, other leaks in the aircraft would allow cabin pressure to escape. There is no such animal as a completely airtight cabin. Allowing one fuel tank to run dry before switching to another, therefore, is not recommended when operating a pressurized single.

Since air used for pressurization is compressed by the turbochargers before being pumped into the cabin, it is much warmer than ambient air outside the aircraft. As a result, pressurized air often must be cooled before entering the cabin, especially when flying at the lower altitudes on a warm day. This is done by ducting the high-pressure air through a heat exchanger (or radiator) where it is cooled by ram air (see illustration).

When ambient temperatures are well below freezing, the pressurized air may not be warm enough to maintain a cozy cabin. At such times, a conventional cabin heater is used.

Although a turbocharged, pressurized airplane allows flight above *much* of the weather, it certainly can't get above *all* of it. Anything that flies can expect to encounter some form of weather, no matter how high the altitude. In his book, *Operation Overflight*, Francis Gary Powers related how he gazed upward at the nearly 100,000-foot top of a Middle-Eastern thunderstorm while cruising near the operational ceiling of his Lockheed U-2. And what pilot can ever forget the quip transmitted by one of America's pioneer astronauts after being established in earth orbit: "Another thousand feet and we'll be on top."



It can be said, however, that as one flies higher, he will experience increasingly less weather, but he must be careful not to become complacent. Weather at the middle altitudes can be damnably inhospitable.

This past winter, for example, a 160-knot jet stream was found as low as 18,000 feet msl over the United States and the associated clear air turbulence (CAT) varied from light to severe.

Although similar turbulence can be found in the lower layers, it can be more hazardous at altitude. Consider, for example, the 145-knot maneuvering speed of a Cessna 414A Chancellor. When cruising at 25,000 feet (FL250) on a standard day, true airspeed is 200 knots. But at this altitude, indicated airspeed is only 134 knots, 9 knots below the maneuvering speed. During a turbulence encounter, the aircraft would not have the stall protection it has at the lower altitudes. Above 25,000 feet, indicated airspeed and the available stall margin become significantly less. The obvious solution to such a problem is to descend.

One advantage of flying in the frigid climate of the middle altitudes is that structural icing is rarely encountered because the indicated outside air temperature usually is less than –15°C. Such air is simply too cold for water to exist in the liquid state. Most clouds consist only of harmless ice crystals, which do not cling to an airplane. (Exceptions to this rule can be found within the chimney of a thunderstorm.)

Although the lack of moisture eliminates icing worries, the arid air can be physiologically concerning. This is because long flights at altitude result in some dehydration. The pressurized air in the cabin may have the density normally found at lower altitudes, but it is woefully dry nevertheless. The adverse effects of dehydration can be avoided by drinking water (not coffee!) during lengthy, high-altitude flights. (You can flip a coin to see who gets to empty the potty.)

Anyone who has ever flown commercially is aware of how flight attendants brief passengers on the use of emergency oxygen. This is because pressurization systems can fail. And if supplemental oxygen isn't *immediately available*—especially to the pilot—the airplane and everyone on board may be in jeopardy.

Unfortunately, many general aviation pilots apparently consider oxygen to be immediately available as long as the tank is full and the masks are *somewhere* on board. But if rapid decompression occurs, sufficient time may not be available to find the masks, connect the hoses and turn on the system. Cockpit masks should be connected and *tested* before climbing to altitude.

At 25,000 feet, a man deprived of an oxygen mask has only three to five minutes of useful consciousness; if oxygen deprivation is caused by rapid decompression, the time available is reduced by 50%; if the pilot is a smoker, he may have less than a minute of useful consciousness. At 30,000 feet, these times are cut in half.

With an oxygen mask at hand, decompression usually is not a serious problem (unless caused by airframe failure); without a *handy* supply of oxygen, it can be disastrous.

Rapid decompression—inaccurately called explosive decompression—is not as dangerous physiologically as it sounds unless the victim is suffering from blocked ears or sinuses. The feeling is that of a sudden expansion of air in your lungs followed by an outrush through your nose and mouth. It's sort of like having the wind knocked out of you without being hit. Your cheeks and lips may flap somewhat as the wind goes out, but that's about it. No one is incapacitated or knocked out. (And you get to find out if anyone on board is wearing an inflatable brassiere.)

Decompression can cause a few anxious moments. For example, the cabin may temporarily become IFR as moisture in the aircraft condenses into a cloud and uninformed passengers begin to panic. But first, to your own self be true. Calm down and don't allow hyperventilation to worsen the problem. Rapid breathing not only can cause dizziness and spots to appear in front of your eyes, it also can result in numb fingers and toes and expedite unconsciousness. Control breathing before and after donning the immediately available oxygen mask.

One of a pilot's first considerations is to determine whether an emergency descent to a lower altitude would be appropriate. Moderate or heavy icing reported in the clouds below, for example, might make it more prudent to remain aloft and suffer the indignities of an oxygen mask until conditions below improve. In such a case, be certain to determine that all passengers are properly masked.

An untimely descent also could affect range adversely because of increased fuel consumption and loss of a tailwind, an unfortunate set of circumstances when over large bodies of water.

If decompression is caused catastrophically by a blown-out window or other structural failure, it's possible for someone on board to have been injured from flying debris; an emergency descent could be dictated by medical reasons.

Also, be aware that a large hole in the fuselage can decrease cabin pressure to *less* than that outside the aircraft because of Venturi effect.

If the decision is to remain aloft for awhile, be extremely careful about opening a thermos of hot coffee. When at altitude, the boiling point of water can be so low that opening the thermos could result in an explosion of steam that can have serious consequences to those nearby.

Decompression isn't always involuntary. There may be times when it's desirable. One way to fight a cockpit or cabin fire, for example, is to starve the fire of oxygen. A controlled decompression does this nicely. It's also a handy way to remove smoke caused by an electrical or air conditioning malfunction. With the outflow valves open, the cabin can be cleared almost immediately.

Depressurizing the airplane also is advisable if an impending window failure is noticed or if the turbochargers are pumping contaminated air into the cabin.

If a rapid decompression dictates an emergency descent, be careful about simply lowering the nose and accelerating to redline airspeed (V_{NE}) as is usually recommended. Consider the possibility (and sometimes the probability) that turbulence may be encountered when penetrating the lower altitudes. Such an encounter while diving at V_{NE} may be difficult for the airframe to sustain.

Also, if structural failure was responsible for the decompression, such a high-speed descent could further damage the airplane—even in smooth air.

When at high altitude (20,000 feet or above), indicated airspeed is so much below the redline that a large, negative body angle may be required for timely acceleration. But don't be in too much of a hurry to dump the nose lest the negative G-load toss objects (and unbuckled passengers?) against the ceiling. One technique to help avoid this is to roll into a moderately steep bank during the pitch-down. In this way, the positive G's of the turn help to offset the negative G's created when pushing forward on the yoke. When the desired pitch attitude has been established, the turn can be stopped.

Be aware that as altitude loss progresses during an emergency, high-speed descent, air density increases. For a given body angle, therefore, indicated airspeed will increase steadily. This requires gradually reducing the nose-down attitude to prevent airspeed from creeping beyond the redline.

If the descent is made in turbulence, maintain at or near the maneuvering speed (V_A) and extend flaps or landing gear, if airspeed permits, to obtain a respectable rate of descent. A clean descent (gear and flaps up) at V_A is also a glide and hardly qualifies as an emergency descent necessitated by rapid decompression.

Time permitting, notify ATC about your predicament and squawk code 7700 on the transponder. A midair collision with IFR traffic would be even more disturbing than a sudden loss of cabin pressure.

Fortunately, pressurization malfunctions are rare. But a professional attitude toward flying demands system familiarization and emergency preparedness. ☐

Standard Atmosphere

Altitude (feet)	Pressure (pounds/ square inch)	Temperature (degrees Fahrenheit)
Sea Level	14.7	59
1,000	14.2	55
2,000	13.7	52
3,000	13.2	48
4,000	12.7	45
5,000	12.2	41
6,000	11.8	38
7,000	11.3	34
8,000	10.9	31
9,000	10.5	27
10,000	10.1	23
11,000	9.7	20
12,000	9.3	16
13,000	9.0	13
14,000	8.6	9
15,000	8.3	6
16,000	8.0	2
17,000	7.6	– 2
18,000	7.3	– 5
19,000	7.0	– 9
20,000	6.8	–12
21,000	6.5	–16
22,000	6.2	–20
23,000	5.9	–23
24,000	5.7	–27
25,000	5.5	–30
26,000	5.2	–34
27,000	5.0	–37
28,000	4.8	–41
29,000	4.6	–44
30,000	4.4	–48
35,000	3.6	–66
40,000	2.7	–70
50,000	1.7	–70

Dealing With Differentials

Pilots are accustomed to dealing with atmospheric pressure in terms of mercury. Standard pressure at sea level, for example, is 29.92 inches Hg and decreases with altitude.

Pressure also is measured in pounds per square inch (psi). At sea level on a standard day, atmospheric pressure is 14.7 psi. The accompanying table provides the standard pressure (and temperature) for various altitudes.

The degree to which an airplane can be pressurized safely is expressed in terms of a "differential." For example, the Cessna 414 has a maximum allowable pressurization differential of 5.0 psi. This means that the airplane can be pressurized to a point where pressure inside the cabin is 5.0 psi greater than atmospheric pressure outside the aircraft. Additional pressurization is not permitted because of system or structural limitations.

The maximum allowable differential of an airplane becomes considerably more meaningful when used in conjunction with the accompanying table.

Assume that a pilot wants to fly his Cessna 414 at 25,000 feet. According to the table, atmospheric pressure at that altitude is 5.5 psi. But when the aircraft is pressurized, pressure within the cabin is 5.5 psi (outside pressure) plus 5.0 psi (the pressure differential) which equals 10.5 psi.

According to the table, 10.5 psi equates to an altitude in the free atmosphere of 9,000 feet. In other words, when a Cessna 414 is at 25,000 feet, the "cabin altitude" is only 9,000 feet.

Now assume that a 414 pilot wants to fly as high as possible, but doesn't want the cabin altitude to exceed 5,000 feet where standard atmospheric pressure is 12.2 psi. Subtracting the pressure differential of 5.0 psi from 12.2 psi equals 7.2 psi. Referring again to the table, it is found that 7.2 psi is normally found at about 18,000 feet. In other words, by flying no higher than 18,000 feet, the pilot can maintain a cabin altitude of 5,000 feet.

The table can be used similarly with the pressure differential of any airplane. A Boeing 707, for example, has a maximum allowable pressure differential of 8.6 psi. At 29,000 feet, the ambient pressure is 4.6 psi. Adding the pressure differential to the outside pressure results in a cabin pressure of 13.2 psi, which equates to a cabin altitude of 3,000 feet. ☐