Command Pilot
Systems Command

By Thomas P. Turner

Recently I saw this on the FAA's accident reporting website:

While enroute, an H35 Bonanza lost electrical power and on landing the gear collapsed….

It's something I see reported several times each year. It's tragic, because quite frequently a gear collapse causes enough damage that the airplane is totaled, and frankly they're not making many more. It's also avoidable, a symptom of a pilot who is not familiar with how the airplane's systems work. That may not be entirely the pilot's fault, as we shall see. But we're going to fix that right here.

Gear 101

Section VII, Systems Description, of the H35 Bonanza *Pilot's Operating Handbook* (POH) tells us this about the landing gear system:

> The landing gears are operated through adjustable linkage connected to an actuator assembly mounted beneath the front seats. The actuator assembly is driven by an electric motor. The landing gears may be electrically retracted and extended, and in an emergency may be extended manually.

Further in Section VII it also states:

> The landing gear can be manually extended by operating a handcrank at the rear of the front seats. This procedure is described in the EMERGENCY PROCEDURES section.

Section III, Emergency Procedures, provides a checklist for manually extending the landing gear, including advisories against manually retracting the landing gear, and a warning about operating the gear electrically with the manual hand crank engaged. It also warns about the hazard of gear collapse on the ground if the system is reconfigured (moving the gear switch, resetting the gear motor circuit breaker, etc.) after manually extending the landing gear. Section III also provides this advice:

> GENERATOR OUT PROCEDURE
> A failure of the generator will place the entire electrical operation of the aircraft on the battery. Generator failure may be indicated by the ammeter. When a generator failure occurs in flight, all non-essential electrical load should be discontinued to conserve the battery life.

The conscientious pilot who reads the POH, and the well-meaning flight instructor who does not know the airplane well but spends time reviewing the handbook thoroughly before conducting transition training to that pilot, would be left with this understanding of the operation of the Bonanza's landing gear:

1. The landing gear system operates electrically.
2. There is a manual backup system for extending, but not retracting, the landing gear in the event of electrical system failure.
3. If the generator (or alternator) fails, load-shedding will permit conservation of battery life, presumably for tasks including landing gear extension.
4. There are several cautions and warnings associated with the electrical and manual operation of the landing gear system.

Pretty thorough review, eh? Then why is alternator or generator failure often followed by gear collapse during landing?

Voltage

One possibility is that the pilot allowed the battery to become severely depleted before noticing the charging system failure, and battery conservation is not sufficient to preserve power for extension later. Another is that the pilot is not aware that it takes approximately nine volts of battery power in a 14-volt electrical system, and 17 volts of battery power in a 28-volt system, to energize and close the battery master relay. As the battery's reserve voltage declines following charging system failure, it will not work all the way until the battery voltage reaches zero. The master relay will open, and all electrical power will be lost, at approximately nine or 17 volts, respectively—long before the pilot might suspect, even if carefully conserving and monitoring electrical use.

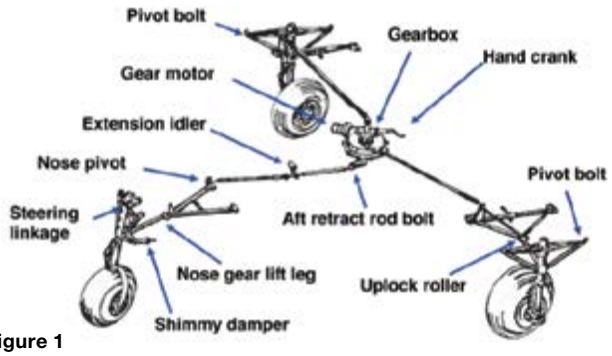

Figure 1

Figure 2: The sector gear contained within the gear actuator

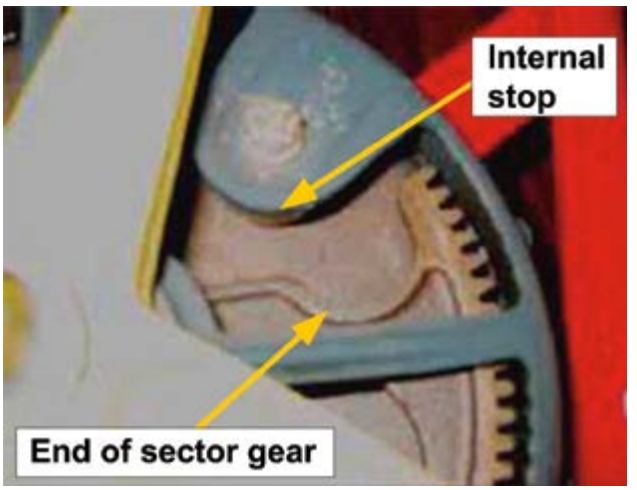

Figure 3: Sector gear and internal stop

Even if the battery is fully charged, however, it may not (and historically sometimes does not) fully extend the landing gear. This is where it takes system knowledge beyond that contained in the POH to successfully respond to the situation.

Limit Switches and Downlocks

The Beech landing gear extends and retracts by the rotation of a gear actuator ("gearbox") mounted beneath the pilots' seats. Rotation of the gearbox moves pushrods that in turn push or pull the landing gear to extend or retract. Additional pushrods mounted to the gearbox open and close the inner main gear doors (**figure 1**).

Inside the gearbox is a half-circle, or *sector* gear (**figure 2**). The gear motor, or the pilot turning the manual handcrank, drives a worm gear that engages the teeth on the outside perimeter of the sector gear, causing it to rotate and spin the gearbox's central shaft. This shaft is connected to the four-point "star" on the top of the gearbox, which in turn is connected to pushrods for the main gear and inner gear doors. A single arm on the bottom of the shaft is connected to the nose gear pushrod. As the gearbox turns, the landing gear cycles up or down.

Figure 4: A sector gear that shattered as a result of mis-rigged limit switches and repeated powered contact with the internal stop

The "flat side" of the sector gear has two semicircular cutouts. When the landing gear is fully up one of these cutouts is near an internal stop in the gearbox; when the gear is fully down the gear has rotated so the other cutout is near this same stop on its other side (**figure 3**). In normal operation the sector gear should not come into contact with this stop, but only come close. If the sector gear hits the stop under full electrical power it can strip gear teeth or even shatter the sector gear (**figure 4**). These pictures appear in the *ABS Air Safety Foundation Landing Gear Inspection Checklist and Repair Guide,* available free to members under MAINTENANCE and then INSPECTION GUIDES at *www.bonanza.org* (**figure 5**).

Limit switches on the gearbox, when contacted by the gear very near the end of the cycle, shut off power to the landing gear motor or, in 28-volt electrical system Beechcraft, convert the motor to a dynamic brake. This halts the gear travel shortly before the sector gear hits the stop. The ABS Technical Advisors have created a quick test you can do in the air or when the airplane is on jacks to ensure the limit switches stop the gear motor at the correct time (**figure 6**). ABS/ASF's landing gear guide amplifies this procedure, noting minor changes in the design that determine precisely where the limit switches are set. All Bonanzas, Barons, Travel Airs, and Debonairs should have about 1/8 to 1/4 of a handcrank turn remaining prior to coming up against the stop *except* these airplanes, in which there should be 5/8 to 3/4 turn remaining:

- V35B serial number D-10375 and after
- F33A serial number CE-968 and after
- A36 and G36 serial number E-1876 and after
- B36TC serial number EA-239 and after
- B55 serial number TC-2414 and after
- E55 serial number TE-1195 and after
- 58 and G58 serial number TH-1269 and after
- 58TC serial number TK-147 only
- 58P serial number TJ-384 and after

This list is also in the landing gear guide, where it notes that if more than the expected number of crank turns exists the gear may not be fully extending or retracting, and if you can't crank the handle as far as expected the gear is being powered too far into the cycle. In either case the limit switches should be adjusted. If the gear handle cannot be turned at all toward either up or down, as appropriate, the motor is powering the sector gear into the stop and the gear motor and transmission should be rebuilt.

Manual Extension

If you manually extend the landing gear, you do not know when the sector gear is rotated far enough that the landing gear is fully locked down. The only reliable indication is that the sector gear reaches the internal stop—it's a little farther than necessary, but at least you know it's far enough. Since you crank the gear a lot more slowly than the electrical motor runs, you won't damage the sector gear by coming into contact with the stop. The emergency extension checklist tells you to crank not a precise number of turns, but until you cannot turn the handle any more at all. The LANDING GEAR MANUAL EXTENSION checklist says:

> Handcrank – ENGAGE and TURN COUNTERCLOCKWISE AS FAR AS POSSIBLE (approximately 50 turns)

Note the word *approximately*—it may take more than 50 turns. Knowing how the system works, this makes sense.

Back to the Electrical System

When extending the landing gear using full system voltage (14 or 28 volts as applicable), when the gear motor stops there is enough inertia for the landing gear to travel a little further to go over center and lock down. If extending with anything less than full system voltage, on battery power alone even with a fully charged battery (12 or 24 volts, respectively), the motor spins less rapidly and the gear extends more slowly. The limit switch stops the motor in the same physical point in the extension cycle, but the landing gear has less inertia

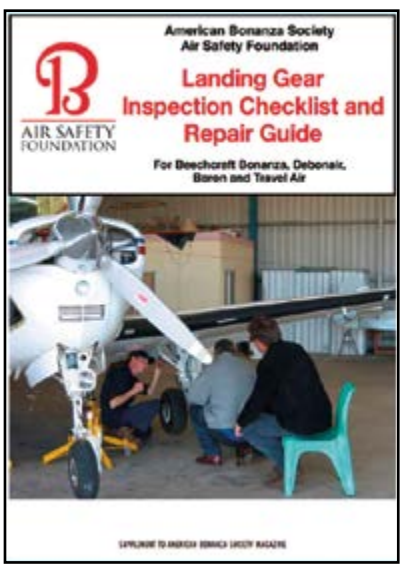

Figure 5: The ABS landing gear guide

and may not continue quite far enough to lock firmly down. If the battery is depleted even a little the situation is worse. Enough voltage may be drained by the gear motor that the master relay opens while the gear is in transit, stopping extension with the gear partway down.

Because of when in the extension cycle the landing gear light switch(es) engage, it's even possible the gear can go down far enough for the green light(s) to be on and the gear still not be fully locked down. The airplanes with a single down light and a mechanical pointer may have it a little better, but not by much; the pointer connects to the nose gear idler and moves to the down position at the point the pushrod has extended the nosewheel. But I've seen enough of these pointers to be slightly out of adjustment to say unless I'd had its own rigging checked lately, I would not trust it alone when extending the gear with less than full system voltage.

The fix? *Any* time you extend the landing gear with *anything* less than *full* system voltage, do so at altitude and away from the airport. After extending the gear on battery, pull out the LANDING GEAR MANUAL EXTENSION checklist and do the procedure, including pulling the gear motor circuit breaker, extending the handcrank, and turning the crank counterclockwise, as the checklist says, *as far as possible*. That way, if it's not locked down using battery power, you'll do the rest manually before you land. We make this recommendation in the Beechcraft Systems, Procedures, and Techniques course ("BPPP Initial"), free to members in the ABS Online Learning Center.

INFLIGHT LANDING GEAR DYNAMIC BRAKE TEST PROCEDURE

LANDING GEAR IN DOWN POSITION
Gear switch in DOWN position
Pull LANDING GEAR MOTOR breaker
Unstow emergency handcrank
Turn counterclockwise until crank stops
Handle should turn 1/8 to 1/4 turn
Stow handle and reset breaker
Retract gear

LANDING GEAR IN UP POSITION
Gear switch in UP position
Pull LANDING GEAR MOTOR breaker
Unstow emergency handcrank
Turn clockwise until crank stops
Handle should turn 1/8 to 1/4 turn
Stow handle and reset breaker

ABS Air Safety Foundation
Beechcraft Pilot Proficiency Program
www.bonanza.org

Figure 6: Dynamic brake test

Systems Command

It's important to be very familiar with what's in the *Pilot's Operating Handbook* for each airplane you fly. Even then you may not have all the information you need under all circumstances. Commanding the airplane includes mastering the airplane's systems. This isn't difficult, but sometimes you have to go beyond what's in the *POH*.