Bob Nuckolls
6936 Bainbridge Road
Wichita, Kansas 67226-1008
Voice/Fax: 316-685-8617
E-mail http://aeroelectric.com/bob.nuckolls

The Truth about Crowbar OV Protection

9 June 2007
Updated and Expanded 26 June 2007

I continue to receive requests for clarification on the simple-ideas and practice for the installation of OV protection systems for engine driven power sources on aircraft. Many of my readers cite the writings of individuals who have chosen to downplay the likelihood of an OV event in modern, internally regulated alternators. My critics further choose to brush aside well considered design goals for the creation of a low parts count, high reliability disconnection scheme for the malfunctioning alternator.

Finally, they place a lot of faith (firm belief in something for which there is no proof) in the pronouncements of folks who are practitioners of no art and have no demonstrable understanding of underlying simple ideas.

Most often cited recently is an item on the Vans Air Force Forum posted in March of this year. Ideas in this posting have been promulgated in many venues on the ‘net for years in spite of patient and laborious attempts to discover and explore the simple ideas behind the various OV protection methodologies and to identify and correct misconceptions and wholesale fabrications offered as fact.

I’ve added superscript (tags) to items within this posting to steer the reader’s attention to a discussion that follows a quotation of the Vans Air Force posting.

----
http://vansairforce.com/community/showthread.php?p=112471
At 03-18-2007, 07:34 PM, gmcjetpilot wrote:

I know Bob Nuckolls swears by his OV relay, but it has been the death of many ND alternators [A]*. The fact is ND alternators are very reliable and DON'T go super nova OV like Bob scares people into thinking*[B]*. The cure is worse than the ill. In fact an OV relay is heavy and adds more connections and chance for failure. Trust me or not, call Van. Bob N's answer is Van is ignorant and Bob. Of course Bob said that before he knew all the problems Van has seen with builders who follow his wiring, specifically the OV relay. Van also sells 10 alternators or more a month for a decade or more; do the math, they hear about all the problems and the common thread in many was Bobs OV relay and "crow bar"*[C]

My OV opinion is for most folks no additional OV protection is needed on the ND (NipponDenso) alternators with internal voltage regulation (I-VR). They are somewhat self protected or fail in a safe or benign way[D]*. There is the "Plane Power" brand of alternator, which is a modified ND with an extra OV module or protection device. It senses an OV and turns the alternator off automatically*[E]*. The few people that have experienced OV, with a I-VR ND alternator have found it to be mild. Mild means target voltage should be 14.3-14.6 volts, and the voltage wonders up to 15 or 16 volts. In general you can manually turn the alternator off your self in that unlikely event. 16 volts should not damage modern* *avionics which are designed to work from 10-30 volts, and tolerate a 60 volt Spike[(F)]. Of course you don't want to fly around for a long time with +15 volts as it will damage the battery. However as you know if you voltage is high you can usually get it down by lowering RPM and adding more load, like landing lights.[(G)]"*

Bob N's idea comes from main frame computer industry I think the 1970's. It is a Rube Goldberg device, one thing leads into another. The "crow bar" if anyone does not know what we are talking about is a small electronic device that senses voltage. When the device sees an overvoltage it "throws" an electronic switch (SCR) and grounds or SHORTS-OUT what ever it is attached to, in this case a CB. The TERM crow bar comes from when they actually threw a big metal CROW BAR into a device to stop it or short it out. Ouch! [(H)] His device is subject to nuisance trips because the voltage reference is not stabilized. It works but is subject to transient trips.[(I)] This method requires the "crow bar" and circuit breaker. When attached to an internally regulated alternator you must add a BIG master relay sized continuous duty relay in the B-lead circuit. WHEN the crow bar grounds (SHORTS OUT) the circuit breaker it POPS and removes power to the B-lead relay, which opens. Mr. Rube Goldberg would be proud.

The Plane Power is 1000's of light years better. It just opens and its right on the alternator and there is not big heavy relays.[(J)]

I am not saying Bob's crow bar doesn't work, but it tends to be worse than the cure. Bob makes up stories about the wide spread OV problem?[(K)] Back in the days when they had mechanical voltage regulators OV was common. However how many cars made since the 80's have you had or seen get an overvoltage? NONE? It does happen but tends to be a minor 16 volt deal not a 100 volt nuke bomb Bob scares people with. He has stories but no facts to back it up. In a word it's a rare event and not very serious. Besides if you lower engine RPM and add load, it will alleviate the OV. My point is if you can't trust the crow bar and it may do more harm than good, leave it OFF. Now if you are IFR, electrically dependant engine, all glass, by all means by a Plane power unit with a secondary overvoltage device.[(L)]

When the crow bar trips with an internally regulated alternator the B-lead relay will try to open under load. It's like cutting or gnawing off your own leg to get out from a rock that rolled onto your foot. It works but its going to be a bloody mess. If you MUST have an add on secondary OV protection device to a I-VR alternator, please consider something else like this: http://www.perihelion design.com/lovm.htm You will still have to use a gosh awful BIG master relay type contactor on the b-lead. The way Plane power does it is elegant. You get what you pay for.[(M)]

For those with just a 60 amp alternator I suggest you do NOTHING but fly and have fun. Don't add the crow bar, it will add weight, cost, complexity and increase the chance of a failure. The chance of an OV with a stock alternator installed just like it would be in a car is small to none. The good nippondenso I-VR (not cheap aftermarket regulators) will control and protect you all day, every day with IC chip or microprocessor. Would you put a CROW BAR into you PC computer.[(O)] There are better ways (Sorry Bob Nuckolls and Rube Goldberg). Times have changed. It would take a very rare failure of the 60 amp alternator to ruin your day and where a crow bar would make any difference. Most of the time the alternator just dies, they don't OV. I would suggest a pull-able CB on the B-lead so if the alternator voltage starts to get wacky you have the option to manually pull the CB and isolate the alternator."

First, this posting uses some colorful metaphors, interesting similes and strained hyperbole which I will try to ignore except where his assertion mis-quotes me or attributes me with something I've never said.

(A) I don't I swear by anything. If I have to put my hand on a Bible to engender the trust of my readers, then I have failed as a teacher. Teachers offer understanding based on simple-ideas and logical assemblage of irrefutable facts. I've often stated my personal credo that strives for honorable behavior. This means that I don't lie to folks, I don't put my hands on their persons or property. Finally, I'll go out of my way to protect others against untruths (evil or ignorant) and attacks on their persons and property.

I have never spoken of the so-called "crowbar" OV protection philosophy in any terms other than to explain design goals and physics. In attempts to discount my efforts, several individuals have attempted to distort the physics, brush aside design goals, an minimize risks based on their faith in a particular product. Finally, they've resorted to demeaning my integrity and skills as a designer who has made a living in product design, system integration and customer service for over 45 years.

I find it particularly interesting that individuals with so little demonstrable experience and performance have been so effective in stirring up the muddy waters of misunderstanding, mistrust and bad information when they are obviously lacking in knowledge, understanding and skill to do anything better.

(B) I have never attempted to "scare" anyone into doing anything. Note that GMCJetpilot narrows the discussion to Nippon Denso alternators. Throughout my discussions on this topic, I've made it clear that my design goals are to accomplish a seamless integration of ***any modern, internally regulated alternator*** into aircraft while servicing these noteworthy design goals:

(1) Control - the pilot should be able to have the same control over the new engine driven power sources as he had for those of the past. Any time, any conditions, ON-OFF control without concern for damage to normally working components and

(2) OV protection for the admittedly rare but ***never zero*** probability that a regulation failure causes the alternator to run full-fielded with the risk of boosting bus voltage to level hazardous to the rest of the system's components.

These goals apply to any brand, any size internally regulated alternator. Even if ND alternators demonstrated GMCJetpilot's claims for reliability, the claims cannot be supported if the alternator has ever been overhauled or repaired by an after market activity. While I've always strived for a general case that doesn't care which alternator is used, GMCJetpilot has balanced his argument on the point of a pin by limiting his claims to one brand of alternator.

(C) **"Trust me or not" he says, "Call Van."** Van's demonstrated and extraordinary ability as a designer of airplanes and businessman as a supplier of kits does not make him an authority on the simple-ideas that support the functionality of the alternators he sells.

I have never argued with the fact that when attempting to exercise ***control***, the well known load-dump phenomenon exhibited by all alternators killed the alternator's own internal regulator. The underlying assumption by GMCJetpilot is that this was a factory stock ND alternator that was abused beyond it's design limits.

I humbly suggest that the pedigree of these alternators is not all that clear. It may well be that the failed alternators were fitted with regulators that were not designed to withstand the inevitable load-dump event that is a function of the regulator's own dynamic limits. A loose b-lead nut would have produced the same failure as those experienced by folks who had the AEC OV Protection and Control system installed. See this supplementary document on my website:

Adapting_IR_Alternators_to_Aircraft.pdf

This is not an issue I would expect anyone at Van's to understand . . . and they've demonstrated a lack of understanding in the matter. Further, GMCJetpilot's citation of demonstrably ignorant pronouncements by others in support of his own argument illustrates his own inability to teach based on understanding of the simple-ideas.

(D) "No OV Protection is needed on ND alternators" For this to be a true statement, GMCJetpilot needs to have knowledge of the design goals for the alternator and the manner in which the designer accomplished those goals. I've conducted Failure Mode Effects Analysis (FEMA) and reliability studies (MTBF) studies on dozens of products. These activities require an intimate knowledge of parts list, manufacturing processes and schematics.

Lacking such data, one is ill advised to offer personal pronouncements on the reliability of any particular product. This is especially foolish when folks have experienced OV conditions in a variety of internally regulated alternators, some of which had ND logos on them and none of which had traceable pedigrees. But here again, GMCJetpilot's advice balances on the point of that pin suggesting that one restrict choices of useful alternators to factory stock ND alternators of unspecified year or model. ND has been building alternators for a very long time.

(E) **Plane Power's protection device senses an OV condition and shuts the alternator off automatically.** Yes, that's what OV protection systems do. But wait, he says Plane Power's alternator is a modified NipponDenso device. Why should it need OV protection? What does Plane Power know that GMCJetpilot doesn't know?

I spoke with the folks at Plane Power and they told me that they go into the stock regulator's wiring and break the internal connection between the regulator's field power input and the alternator's B-terminal.

The lead is then brought out through a switch and breaker to the bus so the switch breaks power to the field thus offering the pilot ***control***. Further, their ***OV protection*** device is a curiously simple circuit that puts a dead short on the field supply breaker thus causing it to open, which "shuts the alternator off automatically".

Correct me if I'm wrong, but except for the fact that they choose to retain and use the internally regulated alternator, the system architecture and operation is no different than that propose in a number of my published Z-figures that use a combination of crowbar module and external regulator (or one of B&C's regulators with the crowbar system is built in). The only difference is that Plane Power doesn't use the word "crowbar". This is probably good marketing strategy. It seems that a few vocal but un-informed individuals have painted the term "crowbar" in a bad light.

(F) These words describe notions of "few events" (not zero) which were "mild" and easily controlled manually. I can't speak to "few" . . . it's non-quantified. From my perspective as a designer of systems for certified aircraft, "few" is greater than the industry definition of "insignificant" of 10^{-6} failures per flight hour. Further, GMCJetpilot is still hanging his hat on the factory-stock ND product while I am obliged to address the wider constellation of choices open to my customers.

GMCJetpilot suggest that you can shut the alternator down yourself. How? These alternators are not designed to be turned off externally. The signal input lead to the back of the alternator is intended only to turn the alternator ON after a car's electronic controlled fuel injection had determined that the engine is ready to accept more loads after starting. In other writings he's suggested that you pull the b-lead breaker. I can accurately assert that pulling a breaker in series with the b-lead of a runaway alternator is likely to start an electrical fire between the parting contacts within the breaker. This is NOT a reliable means for disconnecting a runaway alternator from the rest of the system.

GMCJetpilot speaks to observed OV events as mild and relatively non-threatening elevation of the bus to about 15 volts. I have worked with these systems in all manner of vehicle and in the lab for decades. I assert (and can demonstrate) that the runaway alternator goes into an unrestrained output with respect to voltage but current limited. The rise in bus voltage is restrained by a combination of two things: (1) current draw by system accessories and (2) the battery's willingness to absorb the elevated output as best it can.

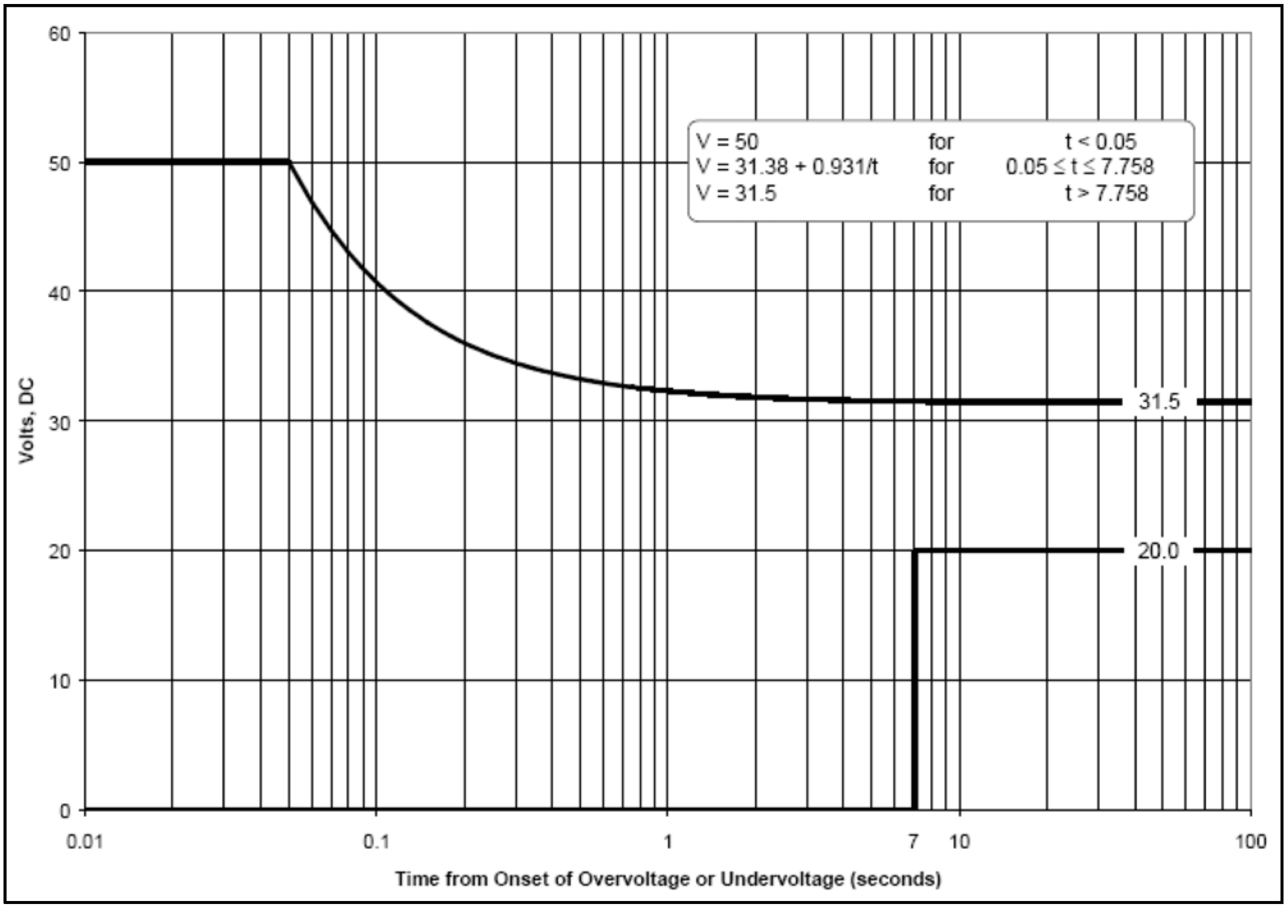
Assuming system loads of 20A and a 60A runaway alternator, we can guess that alternator output will go to something on the order of 70A. This leaves 50A of overproduction to be absorbed by the battery and it WILL do its best!. The first thing that happens is a fairly fast (100 mS or so) rise in bus voltage where the battery starts getting a grip on things. This will be on the order of 16-17 volts depending on the size of the battery. This is followed by a more sedate rise (.05 to .5 volt per second) as the battery's grip on things begins to unravel. This assumes a good battery. A worn battery will not fare so well in this tug-of-volts competition.

An OV protection system can be expected to sense and catch the OV condition in the first few tens of milliseconds. But the thing that keeps the voltage rise relatively benign during the shutdown sequence ***has nothing to do*** with his supposed "mild" failure within the regulator. The hero in this unfolding story is described by a battery's ability and willingness to sacrifice its all until the OV protection system can react and bring the system back to order.

(G) Lowering RPM and adding load is recommended by GMCJetpilot as a Plan-B for mitigating a failed alternator event. This presumes that the airplane has more loads to add. It also presumes that engine RPMs are available to toss off and it further presumes that the prior supposition about a 15-volt end point to rise in bus voltage is correct. From the systems integrator perspective, these ideas are not something I would insult a customer with by suggesting that they be a part of the pilot's operating handbook for his project.

(H) Mr. Goldberg was famous for his exceedingly complex, always whimsical but nonetheless ***effective way of getting some cause to have a predictable effect***. On the other hand, a design goal of the crowbar OV protection system was to craft the ***absolute minimal parts count*** to achieve the desired effect while asking no part of the system to do any task for which it was not designed.

The crowbar OV module as supplied by AeroElectric Connection combined with the crowbar protection system offered in thousands of B&C alternator controllers for both OBAM and TC aircraft have achieved these design goals. The fact that the philosophy has been adopted by other suppliers to the industry is a validation of the idea.



Abnormal System Voltage Dynamics per Mil-STD-704

GMCJetpilot infers that the crowbar OV protection system is flawed with respect to meeting its design goals and then suggests it's something Rube Goldberg would be proud of. I'd like to believe the talented Mr. Goldberg would not allow such childish prattle to be worthy of his attention.

(I) **Nuisance tripping due to an un-stabilize voltage reference** is the next claim to be considered. I have published the schematic and parts list for several versions of the crowbar OV protection system. Nonetheless, no suggestions from this learned gentleman have been offered as to how one might improve upon the design. This "un-stabilized voltage" statement underscores the GMCJetpilot's lack of understanding about the design, manufacture, and integration of OV protection systems, particularly the one he's so intent upon covering with mud!

For decades, the dynamics of OV protection systems for aircraft have been tailored to exploit the recommendations of Mil-STD-704 that speaks to the quality of DC power systems aboard aircraft. Referring to a figure from that document cited above, we see that the static strip point for an OV protection device in a 28v aircraft should be set at or just above 31.5 volts. Most of my designs have used 32-33 volts. For 14 volt aircraft I use 16-16.5 volts. We see further that response to a step change from nominal to 50 (25) volts should be no faster than 40 mS. We usually shoot for 50 mS.

Once those dynamics have been selected and achieved in the product. We must now accept the fact that the data shown above describes the nominal system performance based on industry practice of the time. In the OBAM aircraft, there is precious little cognizance of industry practice and even less practical efforts to see if any particular project meets those goals.

Hence, there is always risk that the occasional system will exhibit noise and overshoot events that are antagonistic to ***every*** over voltage protection scheme. When a nuisance trip occurs, it behooves the troubleshooter to deduce whether selection of the OV protection system dynamics is inadequate or the system has transient features that fall outside industry practice for crafting OV protection systems.

Neither GMCJetpilot, nor Van's, nor any of the customers for our OV protection products have taken it upon themselves to deduce the simple-ideas behind any of the nuisance trips they experienced, observed, or heard about on the grape vine. Nor have any aforementioned critics contacted us for design criteria and test data which would validate their investigative deductions. Therefore, it follows that any pronouncements they might make concerning the validity of the design (or the skill of the designer) comes from where the sun don't shine demonstrates their ignorance on the matter.

(J) "The Plane Power is 1000's of light years better." I have shown the EQUIVALENCY of Plane Power's design for OV protection of their products with that of my own design. Therefore, I can suggest that GMCJetpilot's superlatives attributed to Plane Power's design are equally applicable to the AEC/B&C line of products . . . he just hasn't figured it out yet.

(K) "Bob makes up stories." I've demonstrated that GMCJetpilot makes up stories about Bob making up stories. I'll suggest that if any of his arguments is supported by a lie, then all of his arguments are suspect and need confirmation by honorable sources. Every regulator failure (internal or external) cited in my writings has come from first hand narratives of individuals who experienced, diagnosed, and repaired the problem. I have fabricated nothing.

(L) "If you can't trust (Bob's) crowbar . . . then leave it off. But if you really, Really REALLY depend on an ND alternator (which never fails) not ruining your day, by all means install Plane Power's version of the crowbar on their ND alternator/regulator." This seems to support the notion that only glass cockpit or electrically dependent airplanes are intolerant of the "mild" elevation of bus voltages. Other folks don't need to worry about it because "modern avionics will run on 10-32 volts". This logic is so convoluted that I won't attempt an analysis of simple ideas. There aren't any.

(M) If you must have an secondary OV protection device, consider this product . . . Here GMCJetpilot offers up a design that is exactly like the architecture that exposed Van's alternator vulnerability to self-destruction-by-load-dump. However, this architecture leaves out the switch that I included with the notion of offering the pilot CONTROL over the alternator.

I know nothing about the design goals or philosophy behind the recommended product . . . but it too is subject to the same nuisance trips as any other design. Now, given that the CONTROL switch is left out, there is no risk that the designer of this product will be pasted with the broad brush of "incompetent design." Without the switch, his customers are incapable of accidently or deliberately causing the load-dump event.

However, if the SYSTEM produces a nuisance trip of the OV protection system while the alternator is under load, guess what? The load-dump is just as likely to kill the regulator as surely as if the pilot had manually disconnected the alternator in an attempt to turn it OFF.

Should such an event occur, the owner will perceive an OV trip. The killed regulator will now produce OV conditions during future attempts to bring the system back on line and the OV system will trip again. Except this time it trips for good reasons. The owner will assume that the regulator failed first causing the OV protection system to do its job. Yea! Let's hear it for OV protection systems. There's no way the owner will know if the first trip was a nuisance event that killed his inadequately designed regulator in the first place.

Again, GMCJetpilot claims that Plane Power's approach is elegant. Yes, they've done their homework. They take an alternator off line by killing the source of power to the field . . . just like AEC and B&C have done for over 20 years. They did not attempt to integrate the un-modified, un-pedigreed alternator into Nuckolls' design goals. That task is yet to be accomplished . . . but it will happen.

I started to parse the last paragraph into about three sections for discussion but I think I've run out of steam. I believe I've adequately demonstrated this individual's dearth of understanding and willingness to engage in dishonorable behavior to support his ignorant opinion.

I'm also tired of fielding questions from individuals who upon reading the words of GMCJetpilot (and a few others) find them sufficiently convincing to cause concern. GMCJetpilot and crew have proven themselves to be simple propagandists against my person. They have never demonstrated an understanding of the simple ideas by being teachers. They've never offered a sifting of the simple-ideas to refine a product to meet design goals.

Oblivious of the fact that his favored supplier of the moment does it the same way Bob does, GMCJetpilot says "there are better ways" and apologizes to Bob and

Rube Goldberg. If an apology is called for, it's to the OBAM aircraft community for being an uninformed, no-value-added troublemaker. This article will be permanently posted on aeroelectric.com so that future inquiries on the matter may be directed to it.

On June 22, 2007, the following narrative was posted to the AeroElectric List:

At 09:23 PM 6/22/2007 +1000, you wrote:
--> AeroElectric-List message posted by: "Bob Barrow" <bobbarrow10@hotmail.com>

The following copy of a post on the Yahoo GRT_EFIS group site is most interesting. It seems the internal regulator on a Vans supplied alternator failed on an RV and the resultant overvoltage fried all of the avionics.

FOR THE WHAT ITS WORTH COLUMN. WE HAVE HAD THE GRT EFIS AND EIS INSTALLED IN AN RV9A AND HAVE NOTHING BUT GOOD THINGS TO SAY ABOUT THE COMPANY, THE PEOPLE AND THE EQUIPMENT.

WE HAD OVER 300 HRS ON THE GRT EQUIP AND WE WERE FLYING FROM TYLER TEXAS TO VICKSBURG MISSISSIPPI WHEN OUR ALT (FROM VANS FIREWALL FORWARD PACKAGE) TOSSED ITS INTERNAL VOLTAGE REGULATOR INTO THE ARMATURE. THE RESULT WAS THAT EVERYTHING FRIED.

AS YOU ALL PROBABLY KNOW , AN OVERVOLTAGE IS NOT PROTECTED BY BREAKERS. OUR SL30, 327 AUTO PILOTS AND .....EVERYTHING FRIED.

WE SENT OUR COOKED EFIS, AND EIS TO GRT AND TOLD THEM THAT IT WAS NOT THEIR EQUIPMENT THAT FAILED BUT RATHER THE ABOVE,,,, THEIR RESPONSE.... THEY SENT US NEW ONES ? IT IS RARE TO FIND A COMPANY WITH THAT MUCH EXPERTISE AND ... HOW DO YOU DESCRIBE THAT KIND OF SERVICE? GOOD WILL?

FRED HOLLOWAY

I responded to this sad post with:

Any student of the assemblage of simple-ideas that form a useful invention ultimately comes to understand that the risk for such events is never zero . . . and the $time$ to achieve 1x10^-6 reliability is great.

The cost effective approach hangs a hat on a parallel concept . . . failure tolerance.

Assuming we know nothing about the pedigree of the simple-ideas and cooks that crafted any particular alternator, the prudent system designer simply assumes that the alternator can and will fail in ugly ways at some point in time.

The traditional approach to making that failure tolerable is to (1) fit the system with a means by which the pilot exercises absolute control, (2) fit the system with active notification of malfunction and (3) install an automatic, milliseconds fast responder to the OV event that exercises feature (1) which causes feature (2) to announce that the alternator is off line . . . for whatever reason.

In terms of SYSTEM reliability, one can easily deduce that the likelihood of a failure in the alternator and in either (1), (2) or (3) happening together on the same tank full of fuel is exceedingly small. Now if one has a well considered plan-b for the unexpected alternator shut-down event, then the builder has crafted great SYSTEM reliability from a collection of components for which there is little or no data as to the reliability of any one component.

The anecdote cited has no "hard evidence" by virtue of an autopsy of the alleged failure but the byproducts of that failure are inarguable and the source of the energy that caused the damage is not debatable. This is an expensive lesson that has taxed the $time$ of someone else . . . who has seen fit to make us beneficiaries of his/her experience and observations.

It would be foolish of us not to exploit that information and apply the best-we-know-how-to-do as a prophylactic against sharing Mr. Holloway's unpleasant and expensive experience. This ladies and gentlemen is not a dark-n-stormy-night story that yields little data for refining a recipe for success. It's a bright-light-of-day-illumination of how a recipe failed in expensive ways but fortunately without injury to the "cooks".

Thank you Mr. Barrow and Mr. Holloway for sharing this with us.

Bob . . .