

Horror Stories

Recently, there have been two incidents that should be of concern to anyone building or operating a gas booster - homemade or otherwise. Morton Frogner, whose booster is featured on a website listed in the back of the book, and pictures of which appear in the later editions, had an O₂ fire while boosting 50/50 that destroyed the boost cylinder of his rig. And a SCUBA shop in Hawaii had a Haskel explode, and the 14 cf aluminum tank that was being filled with 100% burst. No one was seriously hurt in either incident, but it was just dumb luck and where they happened to be standing at the moment that saved them.

In Morton's case, the O-rings clearly seem to have combusted, sending a jet of flame out the upper port of the boost cylinder, burning out a large hole in the cylinder where the port had been, and melting the piston. The port was the upper, unused port on his converted double-acting cylinder, which had been left open to vent the cylinder, though it had a fitting and a length of hose attached at the time. Both cylinder and piston were steel.

Morton was using standard (not internally lubricated or low friction) O-rings and lubricating them with O₂-safe lube. According to him, he'd boosted



Before. The hose in the middle going to the port is a vent hose, open on the end, to keep dirt and water out.

about 50 tanks of various mixes since last lubricating them, and they were due to for servicing. It appears the O-rings had been failing for some time, as the air in the last several tanks he had boosted before the incident was found to badly tainted.

In the Hawaii incident the booster



The cylinder showing the burnt-out port and melted piston.

IMPROVISED AND LOW COST HP GAS BOOSTERS

involved was a genuine Haskel, but a version originally manufactured for boosting nitrogen that had several aluminum parts, including the head, as well as lacking the intercooling and exhaust gas cooling the O₂ boosters have. Haskel says the unit is not suitable for boosting O₂, but a number of them appear to have been adapted over the years, how well and how thoroughly is not clear.

Interestingly enough, the booster was not actually in use at the time. The tank was being filled via the cascade, but with the Haskel in-line, so the gas was running through the Haskel from the cascade on its way to the fill tank. Speculation runs rampant on what actually happened. People on the scene report hearing two distinct bangs, a loud one followed by a much louder one. Current thinking is that the first one was a seal or check valve seat in the Haskel combusting and the second one the aluminum tank bursting as a surge of high pressure or combustible gases from the explosion in the Haskel struck, though this is only speculation. The aluminum head of the Haskel had a hole burned clear through it, and the tank was split open, "banana peeled" at the neck. The tank valve has not, as of this point, been found!

Anyone who wants the full details should check the "tank/Haskel ruptur" thread on the rebreather mailing list archives.

To fully appreciate the risks involved, one has to understand how combus-

tion occurs in these situations. We talk about materials as being O₂-safe or not O₂-safe, and flammable or non-flammable, but the truth is that just about nothing is either one or the other. The best we can hope for in selecting materials is "O₂ safe in most circumstances" or "non-flammable in most circumstances" Even steel will burn, as anyone who has used a cutting torch knows, and softer metals - aluminum and titanium especially - will burn enthusiastically.

The usual O₂ fire scenario involves the organic materials in the circuit overheating, such as lubricants or seals, either due to mechanical friction, compressive heating, or adiabatic surges, to the point where they ignite. The higher the fraction and pressure of O₂ are, the lower the ignition temperature and the more intense the ensuing fire.

As the seals or other components burn through the flow of O₂ increases, creating jets of intense combustion that can melt or burn harder to ignite materials such as hard plastics and metals, and a vicious cycle is created, that will continue until all the available oxygen or fuel is consumed. Hoses will often burst at this point, and the escaping gas cause them to flail about, spewing fire or oxygen. The combustion can also send high pressure surges of superheated gas in each direction, which can ignite additional fires down the the line, or over-pressure components to the failure point.

A fire extinguisher at this point is

unlikely to to have much effect because of the intensity of the fire and the continuing flow of O₂, so shutting of the O₂ (or getting the hell out) becomes the priority.

So what lessons can we learn from these incidents?

The main one is that HP O₂ is largely unpredictable unless you have the resources to do some very heavy duty engineering and testing, which is why the book discourages using home-made or adapted gear for boosting high FO₂s. This isn't to say that it can't be done, but rather that doing so takes a high degree of planning and restraint. Anyone who chooses to do so, especially using homemade or improvised gear, must live with this reality and take every precaution - not just to avoid such catastrophes, but to also to deal with them should they happen anyway.

Some logical methods for this include keeping the mix setup in a garage or shed rather than a basement, so fire will not destroy your entire house, and maybe moving the cars and the Brough out of the garage while you mix, fire extinguishers, and locating the O₂ supply bank distance from the mixing/boosting setup, where you'll be able to get to the valve and shut it off in the event of trouble. A remotely operated valve or flow fuse (a valve which automatically closes if the flow rate gets too high) would be another alternative, but these are more com-

plicated. Avoiding using too much flexible line is a good idea too - the teflon inside them will burn at high temperatures, and and in the event they flail about, adding an unpredictable element and complicating efforts to deal with the fire.

While the O₂ is flowing it will be almost impossible to put any fire out, which is why being able to turn off the valve is so important.

Another key point is not to use aluminum anywhere in the system!

Ideally, the thing to do would be not to use soft seals on the piston of any booster being used for high FO₂s either since these are so often they initiator when combustion occurs. This is the main reason we say that using homemade boosters for high FO₂ mixes is a dubious proposition. It's difficult to do, though, since the most effective seals tend to be rubbers or teflon. Compounds are available that can stand considerably higher temperatures than normal nitrile O-rings, but that only offers a slightly thicker cushion before they combust - and some of these compounds, like viton, put out much more lethal fumes when they do! Compressors use metal or segmented carbon rings; these might worth looking into if one is determined to boost high FO₂s.

Note that none of the above will make the process safe! Only safer.

There are a couple of other points

IMPROVISED AND LOW COST HP GAS BOOSTERS

worth noting.

- Morton was only boosting 50/50. NASA research following the Apollo fire suggests that 50/50 and above act pretty much like pure O₂ in the event of a fire, but I think a lot of us have tended to dismiss this as being over-cautious.

- The output gas from Morton's booster was starting to smell bad for at least several tankfuls before the booster went bang. That suggests some possibilities for monitoring.

- The Hawaii incident is not really a boosting incident but rather a cascade/transfill incident as the Haskel was not functioning as a booster at the time, but lying passive in the system and creating an adiabatic mine-field for the incoming gas. This actually make it even scarier!

Both incidents, one suspects, ultimately boil down to speed. One of the cardinal rules of O₂ handling is that you can do almost anything safely if you do it slowly enough, but that almost anything you can do becomes dangerous if you do it too fast.

The biggest danger in O₂ handling is probably the almost inevitable tendency on the part of the mixer to keep incrementally edging up the fill rate, on the theory that if you got away with 70 psi/min last week, then you'll probably get away with 75 psi/min today. Just about all the PP mixing accidents

I've heard about have followed this scenario.

This isn't to blame the operators in either case, or suggest either incident was a simple case of them screwing up. Unfortunately, we don't have manuals, instructions, or built-in restrictors on for our homemade gear, like the commercial stuff has, to tell us where the line is, so it's very possible to operate in conservative mode, leaving large safety margins, and still blunder cross some invisible line. So each builder has to make his or her own determination of where that line is, and be prepared to cope with the consequences should the line inadvertently be crossed.

Hydraulically-driven boosters especially are capable of boosting massive volumes of gas, far more than a Haskel or other purpose-built booster, with correspondingly massive amounts of heat and friction. This leaves finding a safe rate entirely up to the restraint and judgment of the operator. Both these incidents underline the importance of calculating where the line is conservatively, and sticking to that limit. Heat, especially, is a good indicator. If the booster is too hot to touch, or if the output gas is smelling funny, back off!

The safest thing, of course, is to just keep elevated levels of O₂ out of your booster.