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Bizarro Ignition: Cosmic-Ray and Atom-Decay Induced Fires in Oxygen?

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ABSTRACT: Desperate, even fantastic, theories are often used to explain intractable technical problems. Extreme notions as to potential causes of apparently random oxygen systems fires are suggested and analyzed.

KEY WORDS: cosmic ray, radioactive isotope, atomic decay, oxygen.

Oxidant Safety Practitioners (OSPs) have been long interested in the causes of ignition and fire in oxidant systems. Much progress has been made in identifying them. However, in some cases, there have been incidents that have not been adequately explained. In some cases even massive simulation programs have failed to reproduce some of the most nagging accidents. And in some cases, straws have been grasped to explain some of the most recalcitrant events.

Incident investigations always seek the cause, the operation, the upset, the pressure swing, that caused an ignition, but some events do not seem to be connected to specific "causes". This leads one to wonder if some ignitions are bizarre random events? If they are fickle?

The writer was an attendee of one the early offerings (about 1973, maybe even the first offering) of Chester Grelecki's now famous AIChE seminars on *Fundamentals of Fire and Explosion Hazards* (shamefully and regrettably no longer offered). In that session, Grelecki mused, and the writer does not know if he mused similarly in the hundreds of following classes, that static electricity is often cited as the cause of an accident *….until the real cause is found*. Static electricity is something that can be sold. People know what it is. They will believe you. But he added that static electricity is not nearly as dangerous as myth would have it[2].

Today in some accidents and even series of accidents, we might as well be blaming them all on static electricity as what we currently fault. This has led to further grasping at straws. For several years, "flow friction" has been cited to explain a number of events [*1*][3]

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[2] Hydrogen gas releases are similarly mythic, often thought of as igniting nearly every time they occur, although the writers experience is that they are not nearly so reliable.

[3] Italic numbers in brackets refer to the reference list at the end of the paper.

and is discussed in the ASTM Standard *G 88-03 Designing Systems for Oxygen Service*. Flow friction, like static electricity, is also plausible. Everyone knows what friction is. And “flow” friction [*1*] posits that under the exposure to moving oxidant that “surface waves” in polymers or shards or strings of fuzzies will shake rattle and rub, will pulsate and throb and wiggle, flexing internally and heating to a frenzied point of ignition. This mechanism would be a boon, because a plausible flow friction effect could well have been present in many incidents that can not be otherwise explained. It is the best we got just now.

Unfortunately, as of this writing, despite very creative efforts to make material ignite under flow friction in the laboratory [*1*], there has been significant progress made, but there has been as yet no final joy. So flow friction is presently a “tentative” explanation, credible in theory, and the first one to demonstrate its practical efficacy in vitro will be a hero. That day may come. Or not.

The fictitious detective Sherlock Holmes’s fame includes famously saying: “When you have eliminated the impossible, whatever remains, however improbable, must be the truth.” And Holmes was the best. And today, this thinking underpins many an incident investigation.

So maybe when old-fashioned science fails, one can turn to fiction-driven science and bizarro theories. This seems to be especially in vogue with those currently in government of both political parties. It is more important to them that science give them the desired results than that it conform to any set of constricting rules. In frustration, but also in keeping with this spirit, the writer once upon a time, long long ago (more than two decades ago), also attempted an exercise along these same lines with a bizarro draft unpublished but feel-good manuscript: “**Virus Induced Fires in Oxygen**” (not under his control and likely to remain unpublished).

But bizarro is a deep well one can return to often that can refresh the thirsty in so many ways. And so this effort will chase down some “remaining yet perhaps improbable explanations” and focus on the similar bizarro prospect of *Cosmic-Ray and Atom-Decay Induced Fires* in keeping with the subtitle to this paper.

Cosmic Rays

Cosmic rays (CRs) are not cutting-edge physics. They were well known of and were used to study and formulate atomic physics nearly a hundred years ago. A quick review of the cosmic-ray data in the Encyclopedia Britannica [*2*], Weidner and Sells [*3*], and Wikipedia.com[4] revealed the following background.

A CR is a particle moving at great speed with great kinetic energy (up to 10^{20} electron volts, eV, and most over 10^9 eV). Some come from the sun but most come from far beyond. Often it is an atomic nucleus or an electron. The majority (85%, it is said) are protons (hydrogen nuclei), but a bunch (12%) are helium nuclei.

Because they are electrically charged, cosmic magnetic fields make CRs fly along huge corkscrew paths and so their origins cannot be predicted and they may come from any direction regardless of their origin.

When they get to us, many smack into the atmosphere, and “smack” is a euphemism as used here. The impact produces some number of secondary particles which may all be

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[4] Wikipedia entries change so often that a regular reference is not attempted.

moving fast enough to still qualify as cosmic rays. These particles themselves soon collide and produce tertiary particles, all potentially still cosmic ray in intensity. Next come quaternary impacts and on and on in what the atomic physics types call a cascade. Wikipedia suggests that lightning is caused by these cascades, an interesting and reasonable prospect. Indeed, early identification of CRs involved the way in which charged electroscopes discharge over time under their influence [*3*].

"Flow friction" in the presence of particles (dust or ice crystals or the like) rubs electrons off some portions of the atmosphere setting up an intense electrical field just waiting until its field-strength exceeds the insulating capacity of the atmosphere, or until some trigger (some ignition) event starts a current and an avalanche of electrons. Indeed, the Geiger Counter is a tool that charges a chamber and waits for ionizing radiation to impinge into the chamber to set off similar cascades that manifest themselves with a "click" of sound.

The writer once flew west over the great planes states over what seemed like a thousand-mile-long thunderstorm (thousand-mile-long Geiger Counter?) and could look down to see the random flashes of lightning far below. Random in frequency and random in location. Were these all ignited by cosmic rays that had flown past the plane? If so, the rate was great enough to give pause. These strikes may have occurred only when there was *both* a cosmic ray passing and a simultaneous charge separation. The actual population of cosmic rays must be greater than the observed rate of lightning. Some of those rays must have been hitting people and oxygen systems on that airplane and on the ground.

And indeed, there have been speculations that in the course of one's life, perhaps more so in the latter years of greater vulnerability, a cosmic ray might strike for the umpteenth time and smack one's DNA setting off an evolutionary process, possibly including a cancer (whether that process is a draw of the evolutionary cards or whether the cosmic ray was aimed at one specifically with perfection by a cruel Intelligent-Creator/God).

Potential Ignition Scale

Among the necessary criteria that must be exceeded before an ignition can occur are the minimum ignition temperature and minimum ignition energy. What are these numbers for a single cosmic particle in the range of 10^9 eV to 10^{20} eV?

Temperature relates to velocity. Statistical thermodynamics teaches the temperature of a gas is related to its average velocity/kinetic-energy (Boltzman's Law: $E=3KT/2$). On this basis, the average kinetic-energy of a single particle is its actual kinetic energy. For a 10^9 eV to 10^{20} eV particle, the temperature would be about 10^{13} to 10^{24} K, fairly high enough to meet any common minimum ignition-temperature requirements. Minimum ignition energy requirements data are less well obvious and more likely to be the limiting threshold.

Physicists express such energies in the electron-volt units. Electron volts are energy units uncommon to Oxygen Safety Practitioners. One eV is the energy that would be achieved by a particle with a one electron charge passing through a one volt differential potential. This is $1.6x10^{-19}$ Joules. Therefore a 10^9 eV to 10^{20} eV cosmic particle would provide from $1.6 \text{ x } 10^{-10}$ to 16 Joules of energy. Keep in mind that gaseous fuel/oxidant mixtures typically have minimum ignition energies ranging from fractions of a milliJoule to several tens of milliJoules. Automobile spark ignition systems, which ignite gasoline/air mixtures with high reliability, provide sparks up to several hundred milliJoules. The upper end of this

(1.6×10^{-10} to 16 Joules) range is equivalent to a 4 gram-calorie energy.

This suggests that cosmic rays have energies over a range that should easily ignite gases and perhaps precarious liquids like dry-boiled hydrocarbons in LOX sumps and fuel/GOX mixtures (which using Holmes's approach in the past have often been attributed to fickle [unstable] acetylides of copper). They might be in the lower end of the range necessary to ignite perhaps some fines and polymers. But they should be marginal or unlikely for direct ignition of metals, if current igniters are any reflection of the minimum energy parameter for metals (ASTM G 124 employs about 1400 calories of combusting aluminum as "strong" ignition).

The writer is unaware of any work done by high energy physicists to explore the ignition potential of high-energy particles. The Encyclopedia Britannica [*2*] indicates that the following extreme particle generators are in service:

Stanford Linear Accelerator: electrons of 50 billon eV
Los Alamos labs: protons of 800 MeV.
Protons in classical cyclotrons: <25 MeV
Synchrocyclotron particles: ~1 GeV

And the Large Hadron collider (proton collisions at up to 7 teraelectron volts, 10^{12} eV) is still bigger and is expected to shed "temporary" black holes.

These energies might allow for meaningful experiments to be accomplished—but perhaps not cheaply. Still within the writer's knowledge no one has ever set a Geiger counter or other ionization detector into an oxygen system to crudely estimate the frequency of potential events over time.

Related Events: Atomic Decay

Besides cosmic rays, other phenomena that may operate similarly include electromagnetic radiation (X-rays and gamma rays) from ionizing radiation sources and induced fission or natural decay (the latter of which does not require stimulation).

Induced fission and natural decay are interesting prospects. Tramp neutrons with appreciable velocity have great penetration ability. However slow neutrons are inevitably captured. When captured, something that is greatly increased in probability when neutrons are moderated (slowed down in certain media), neutrons create isotopes, many of which are stable but some of these isotopes of which are unstable and decay (some quickly in cases like the atom bomb). The mechanics of decay are a favorite study of high-energy physicists. A decaying isotope may spew numerous secondary sources of energy (for example, beta-ray or alpha particles or electromagnetic radiation in the form of X– or Gamma-rays) and many can trigger avalanches in Geiger Counters. A few prospects of interest to designers of materials for oxygen systems are shown in Table 1 [*4*], since these atoms are often found in polymers or alloys of common metals that are used in oxygen.

The scale of this energy for a single atomic decay is up to a few MeV. Table 1 lists them but does not split them into specific radiation types. These particles, even for the decays that yield the atom bomb, are of much smaller energies than those of cosmic rays, but then these particles may be generated within an oxygen system and do not have to slam through an atmosphere or system to impinge upon the vulnerable targets.

In other words, if a rare neutron, bumps around sufficiently in passing through the

TABLE 1—*Radioactive Isotopes of selected common oxygen system materials* [*4*].

When an isotope, such as ${}_{8}O^{18}$ (which is stable and represents 0.204% of natural oxygen abundance, captures a neutron, its atomic number increases by one, in this case to ${}_{8}O^{19}$ which has a 29.4 second half-life and yields a 4.8 MeV decay energy in the form of Beta ray and Gamma ray radiation.

Target	**Abundance**	**Product**	**Half Life**	**Decay Energy**
${}_{8}O_{18}$	0.204%	${}_{8}O^{19}$	29.4 Seconds	4.8 MeV
${}_{1}H^{2}$	0.015%	${}_{1}H^{3}$	12.26 Years	0.0181 MeV
${}_{2}He^{4}$	99.99987%	${}_{2}He^{5}$	$2x10^{-21}$ Seconds	Not specified
${}_{6}C^{13}$	1.11%	${}_{6}C^{14}$	5750 Years	0.156 MeV
${}_{7}N^{15}$	0.37%	${}_{7}N^{16}$	7.35 Seconds	8.7 MeV
${}_{9}F^{19}$	100%	${}_{9}F^{20}$	11 Seconds	7.03 MeV
${}_{12}Mg^{26}$	11.17%	${}_{12}Mg^{27}$	9.5 Minutes	2.62 MeV
${}_{13}Al^{27}$	100%	${}_{13}Al^{28}$	2.3 Hours	4.65 MeV
${}_{14}Si^{30}$	3.09%	${}_{14}Si^{31}$	2.62 Hours	1.48 MeV
${}_{18}Ar^{36}$	0.337%	${}_{18}Ar^{37}$	34.3 Days	0.82 MeV
${}_{18}Ar^{38}$	0.063%	${}_{18}Ar^{39}$	260 Days	0.57 MeV
${}_{18}Ar^{40}$	99.60%	${}_{18}Ar^{41}$	1.83 Hours	2.49 MeV
${}_{22}Ti^{50}$	5.34%	${}_{22}Ti^{51}$	5.80 Minutes	2.46 MeV
${}_{24}Cr^{50}$	4.31%	${}_{24}Cr^{51}$	27.8 Days	0.75 MeV
${}_{24}Cr^{54}$	2.38%	${}_{24}Cr^{55}$	3.5 Minutes	2.8 MeV
${}_{25}Mn^{55}$	100%	${}_{26}Mn^{56}$	2.58 Hours	3.71 MeV
${}_{26}Fe^{54}$	5.82%	${}_{26}Fe^{55}$	2.7 Years	0.231 MeV
${}_{26}Fe^{58}$	0.33%	${}_{26}Fe^{59}$	45 Days	1.56 MeV
${}_{27}Co^{59}$	100%	${}_{27}Co^{60}$	5.27 Years	2.82 MeV
${}_{28}Ni^{58}$	67.88%	${}_{28}Ni^{59}$	$8x10^{4}$ Years	1.07 MeV
${}_{28}Ni^{64}$	1.08%	${}_{28}Ni^{65}$	2.56 Hours	2.10 MeV
${}_{29}Cu^{63}$	69.09%	${}_{29}Cu^{64}$	12,8 Hours	1.68 MeV
${}_{29}Cu^{65}$	30.91	${}_{29}Cu^{66}$	5.1 Minutes	2.63 MeV
${}_{30}Zn^{64}$	48.89%	${}_{30}Zn^{64}$	245 Days	1.35 MeV
${}_{30}Zn^{68}$	18.57%	${}_{30}Zn^{69}$	14 Hours	0.44 MeV
${}_{30}Zn^{70}$	0.62%	${}_{30}Zn^{71}$	3.9 Hours	3.9 MeV
${}_{42}Mo^{92}$	15.84%	${}_{42}Mo^{93}$	6.9 Hours	2.43 MeV
${}_{42}Mo^{98}$	23.78%	${}_{42}Mo^{99}$	66 Hours	1.38 MeV
${}_{42}Mo^{100}$	9.13%	${}_{42}Mo^{101}$	14.6 Minutes	2.82 MeV

earth and slows down to where it might be easily captured as it passes into the sump of an air separation plant and happens to be captured by an atom there (or by a tramp uranium or a copper acetylide particle, or a hydrocarbon in a dry boiled slurry or even the oxygen itself) it conceivably might release only up to 10^{-10} mJ of energy, not nearly enough to provide the minimum ignition energy for what might appear to be a random direct-ignition event of even combustible gas mixtures, but nonetheless, enough to trigger a cascade current if there is a charge separation (“static electricity”) present.

Might this (like the cosmic ray prospect) provide the random or otherwise fickle igniter that produces seemingly un-triggered events in oxygen systems? For example, the unexpected past LOX-sump explosions occurring when acetylene levels rose to provide a required concurrent condition.

Carbon Effect

There are a few scant data that might support the thesis of this manuscript, one involves the behavior of carbon. Carbon is a very interesting material that the writer has speculated may be important in several ways in controlling or enabling oxygen fires [*5*-*7*].

In the past, carbon was considered for possible use as a “safe” explosive. The writer is aware of only one or two papers that relate this experience and does not have access to any at present, but one may be reference [*8*]. The idea was to place containers of safe fine-carbon particles in mines and the like with blasting-cap detonators or even just simple igniters. Then when the explosion is required, to fill the containers with LOX as one evacuates the mine, rendering the carbon fines into a potent high explosive. If anything were to go awry, then the LOX could be allowed to evaporate and the mine could be re-entered safely.

However, in laboratory tests of the explosive carbon/LOX mixtures, it exhibited a tendency to ignite early at inopportune times. It was fickle and apparently was therefore never commercialized.

Perhaps the carbon mixtures were being ignited by cosmic rays or atom decays. Carbon is a well known moderator for neutrons. It is one of the more effective materials used to slow neutrons down to facilitate fission in atomic reactors. Perhaps cosmic rays were impinging. Perhaps carbon/LOX mixtures were slowing passing neutrons capturing them or allowing them to be captured by other materials leading to atomic decay and ignition. In a LOX/carbon slurry, charge separation might also be a quite plausible concurrent condition.

Potential Work

Literature searching for instances in which flammable gas mixtures may have been exposed to naturally radioactive isotopes might lend credence to this notion. If none are found, then at significant but not inordinate expense radio-isotopes might be placed in standard gas phase flammability test apparatuses, possibly as one plate that is charged like a Geiger counter cell. Any positive results would be a red flag for the need for additional work. Detectors for ionizing radiation could also be placed in oxygen systems for long-term measurement of whether there is any measurable rate of cosmic-ray or atom-decay events.

Conclusions

- Cosmic rays and atomic decays are ubiquitous. They occur at universal rates that are beyond our powers to count. And if ignition obeys a normal statistical distribution then infrequent incidents that have no obvious cause may just result from a statistical event, even if one far out on the tails of one of these processes’ distributions.
- Although efforts to simulate a cosmic-ray- or atom-decay-induced ignition

in oxygen hardware would be very costly (possibly prohibitively expensive), it would be quite practical to put Geiger or other radiation detectors into oxygen hardware to identify if non-ignition events are occurring and at what frequency. And it might be possible to study fickle carbon/LOX ignition relative to CR, neutron capture or natural decay probabilities.

- If rays and decays are present in oxidant equipment, then the industry should seek to identify patterns that may be important. Are there "seasons" of CRs (like during sun-spot activity or when the earth passes through certain regions of space in which random events are more likely. If there are patterns, they may be relatable to past random incident timings. And plants could someday be equipped with monitors to alarm if any high-rate events are possible.
- Similarly, if atom decay is observed during a survey, it may be possible to identify what the decadent material is and factor such information into future designs. For example materials likely to contain radioactive isotopes or to produce them upon neutron capture, or to have more significant decay products can be avoided.

Summary

There are random "bullets" in the form of high-energy atomic particles and ionizing radiation that permeate us and our equipment or are spontaneous events therein. On occasion they apparently starts fires, big ones, with a mammoth kindling chain when they trigger lightning that ignites forests. The prospects for the same thing to happen in much smaller scale in oxygen equipment has been considered. While this theory is grasping at straws in some ways, to explain apparently random oxygen system fires, and while it contains only a very improbable germ of possibility "however implausible" for some kinds of apparently random incidents in oxidants, like flow friction, they may be the best explanation we got.

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