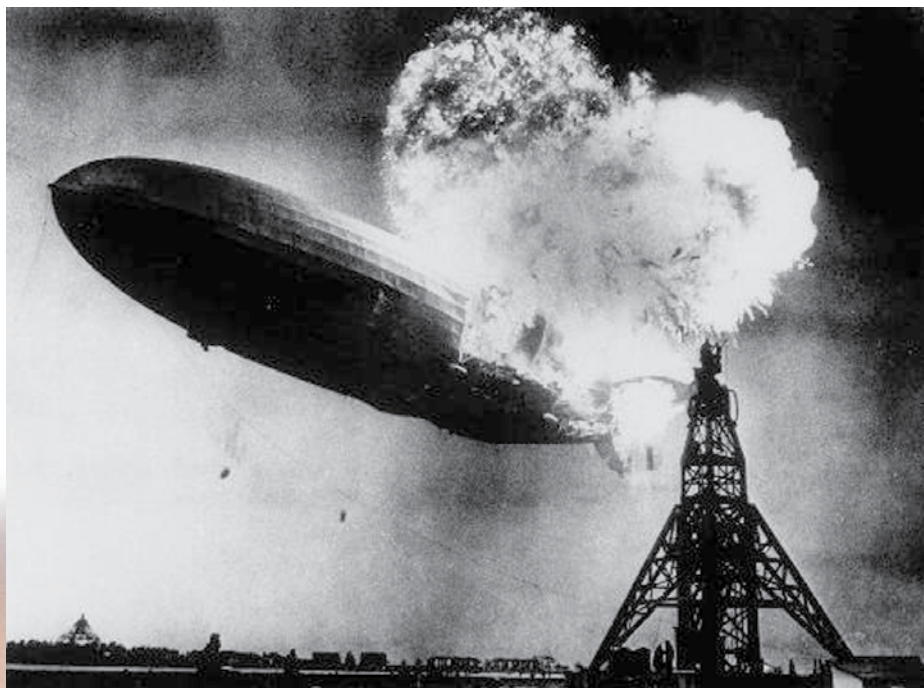


HINDENBURG: Formula for Disaster



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The Hindenburg Story

Let's start by setting the record straight. The Hindenburg did not explode. It burned rapidly. There's a difference. The 804-foot-long Hindenburg burned from back to front in less than 35 seconds, but even that rapid burn doesn't qualify as an explosion.

The Hindenburg was a huge ship—larger than four Goodyear blimps combined, longer than three Boeing 747s! Its steel frame was covered by a canvas-like material. Within the frame were 16 large bladders that contained the “lighter-than-air” gas called hydrogen. With a density of 0.08988 g/l, about 1/14th that of air, hydrogen-filled objects are very buoyant in the atmosphere. But the use of hydrogen gas in an airship carries one important risk—it is extremely flammable. Once ignited, it burns rapidly in air. In fact, the Hindenburg had been designed to use the inert gas helium, but Germany was unable to acquire the quantities needed to operate a fleet of airships. The United States held most of the world's supply of helium at that time. Suspicious of the political unrest growing in Germany with Hitler's rise to power, the United States was not willing to sell its helium.

As the Hindenburg approached the Lakehurst airfield, it passed through a thunderstorm. The storm had just subsided when the Hindenburg burst into bright yellow flames that shot into the air starting at the rear of the airship. The airship was consumed within 35 seconds! The mystery remains: What ignited the hydrogen? Was it a case of sabotage? Was it ignited by lightning? Could an electrical problem have started the fire? Investigations carried out by the governments of the United States and Germany were inconclusive. The cause of the disaster remained a mystery.

By Tim Graham

“Oh, it's crashing ... oh, four- or five-hundred feet into the sky, and it's a terrific crash, ladies and gentlemen. There's smoke, and there's flames, now, and the frame is crashing to the ground, not quite to the mooring mast ... Oh, the humanity, and all the passengers screaming around here! ... This is the worst thing I've ever witnessed!”

May 6, 1937, from the live radio broadcast of Chicago WLS reporter Herbert Morrison with sound engineer, Charlie Nehlson

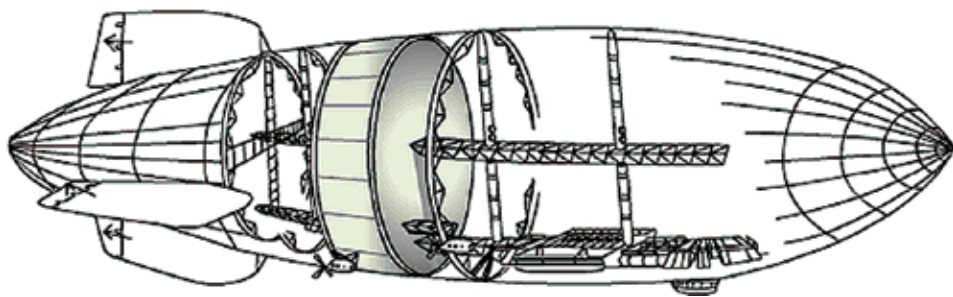
Morrison's dramatic eye-witness account of the crash of the German airship Hindenburg, one of the most famous disasters of aviation, still resonates in radio broadcast history. As the Hindenburg prepared to land at an airfield in Lakehurst, NJ, the passengers were treated to views of the Statue of Liberty while enjoying the luxuries of the Hindenburg's spacious cabin—fine food, piano music. Then, without warning there was chaos as the ship burst into flames killing 36 aboard.

Since then, speculation as to the cause of the crash continues. A new theory has only recently rekindled debate over one of the past century's great disasters, and chemistry is at the heart of the discussion.

The Incendiary Paint Theory

In 1997, former NASA scientist, Addison Bain, suggested that the cause of the disaster involved a flammable material used to seal and insulate the airship's fabric covering. It is Bain's Incendiary Paint Theory (IPT) that has stirred up the recent debate. Bain points out that the Hindenburg was coated with a mixture of components commonly found in incendiary bombs! It is his theory that these chemicals ignited to cause the Hindenburg disaster. He argues that flammable hydrogen gas was not the central culprit after all! While his theory has some support, many in the scientific community are unconvinced.

Bain's IPT theory is based on two major points: Hydrogen burns with an almost invisible flame, not like the yellow fireball that was witnessed, and the painted covering of the Hindenburg was responsible for both starting and propagating the fire. Analysis of film from the event supports Bain's first point. The flame that rises for hundreds of feet above the tail section is yellow, suggesting that something other than hydrogen is burning. Also one can



The Hindenburg, classified as a rigid airship had a steel frame with 16 large bladders filled with hydrogen gas.

see that the tail section remains level and buoyant for quite some time, suggesting that the hydrogen bladders are still intact.

Bain's second point is even more compelling. The mixture used to paint the fabric contained iron II oxide (Fe_2O_3), aluminum (Al), and cellulose acetate. Bain points out that aluminum + iron oxide is exactly the mixture used in the thermite reaction (See **ChemMatters February 2002**), the basis for some incendiary bombs. The mixture is extremely difficult to ignite, but once ignited, the reaction is terrifically exothermic.

To support his first point, Bain obtained

remnants of fabric recovered from 1937 and subjected them to burn tests. The results confirmed what he suspected: The fabric burned with a yellow flame similar to the one seen in film footage of the Hindenburg disaster. Bain believes that the storm caused a buildup of electrical charge on the surface of the Hindenburg, generating a spark with sufficient energy to ignite the surface compound on the tail of the ship. Flames moved rapidly across the surface, consuming the Hindenburg in 34 seconds. He argues that hydrogen gas was *not* responsible for initiating or propagating the flame that consumed the Hindenburg.

Ignition!



NASA's Space Shuttles are launched into orbit with lift generated by two solid rocket boosters and one external tank.

The Solid Rocket Booster contains:

- 69.6%** ammonium perchlorate (NH_4ClO_4) which serves as the oxidizer;
- 16%** aluminum metal (Al), a fuel component;
- 12%** rubber binder, for holding the solid components together;
- 2%** curing agent, used to assure a homogenous mixture for proper burn rate
- 0.4%** iron oxide (Fe_2O_3), the catalyst for the reaction between aluminum and the perchlorate salt.

A typical fireworks "sparkler" recipe might contain:

- 70%** potassium chlorate (KClO_3), the oxidizer;
- 15%** aluminum metal (Al), a fuel component (reducing agent); and
- 15%** dextrin (carbohydrate derived from corn starch) acts as a binder and contributes to the fuel.

Clearly, the components of Solid Rocket Boosters and sparklers are similar to those found in the mixture used to coat the fabric covering of the Hindenburg. Mystery solved? Maybe.

IPT: Fatally Flawed

A. J. Dessler, a scientist at the University of Arizona and former director of the Space Science Laboratory at NASA's Marshall Space Flight Center, suggests that Bain's theory is "fatally flawed." Dessler's arguments are based on chemistry concepts of stoichiometry and reaction rate. Could the Hindenburg fabric burn as quickly as it did without hydrogen being involved? Were the chemical components in the right ratios to support the reaction? Dessler emphatically says, "No." to both questions. Dessler's experimental data suggest that the coating compound should not be compared to "rocket propellant." Although some of the components are the same, the proportions or *stoichiometry* are very dissimilar. In fact, historical records show that the Hindenburg had been struck several times in previous flights by lightning. The outer covering even had burn holes from such strikes, yet, Dessler points out that it had never reacted as it did that day in May of 1937.

Next, Dessler points out that a spark of sufficient energy could not have been produced to ignite the coating mixture. Instead, he argues, an electrical discharge, possibly from a buildup of static electricity from a storm, would have sufficient energy to ignite the hydrogen gas. Most who have viewed the Hindenburg film believe it looks as though the Hindenburg is burning from the inside-out. This strongly suggests that the hydrogen was the source of the fire. As hydrogen rushed out of the bladders, oxygen from the air would be pulled in to sustain the fire. This scenario would also explain why the Hindenburg appeared to remain level in the film footage. The forward momentum of the Hindenburg along with updrafts produced by the burning hydrogen kept the airship buoyant. Finally, the invisible burning hydrogen would continue until the outer fabric caught on fire. Only then would the flame take on the observed yellow color.

Dessler's most convincing argument against Bain's IPT theory is that of reaction rate. Even if the Hindenburg were coated with the exact composition as the propellant



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used in a Shuttle solid rocket booster, the fabric would need approximately 12 hours to burn from tail to nose. Solid rocket fuel is not designed to burn quickly. Even a sparkler takes about 1 minute to burn completely. If a

sparkler burned at the rate of the Hindenburg, it would be consumed in 0.04 seconds! Hardly enough time to enjoy the show!

Thus, Dessler concludes that the fabric coating alone could not be responsible for the Hindenburg's rapid burn rate and that Bain's theory simply lacks experimental support.

That's also the conclusion of the Discovery Channel's popular "Myth Busters." In a program airing in January 2007, the intrepid science team explored the incendiary paint theory and the hydrogen theory. Using two 1:50 scale models, they demonstrated that while a thermite reaction was possible with the Hindenburg's skin and would make the fire accelerate considerably faster, hydrogen was the main fuel. The model burned twice as quickly when it was filled with hydrogen instead of inert gases and produced a fire that matched the newsreel footage quite well. It was only with hydrogen that the fire actually



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came out of the nose in the same way as the Hindenburg. The program concluded that the IPT myth was "Busted."

Is that the final word? Even the Myth Busters would agree that in science there is never a *final* word. New information, new discoveries, and new lines of thought are always on the horizon. We may agree on a most probable explanation for the Hindenburg disaster. But we need to be prepared for it to be "busted" like countless others. That's what makes science interesting! ▲

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