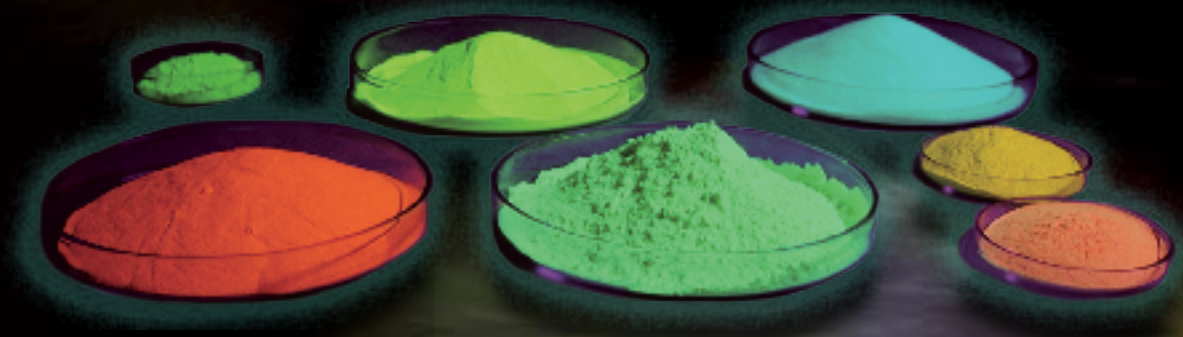
A Traser chronograph with bright tritium-gas-filled markers and hands

MB Mictrotec brand Traser offers this chronograph with bright tritium-gas-filled markers and hands.

Everything's illuminated

With lives lost, fortunes made and unraveled, and the U.S. Nuclear Regulatory Commission keeping tabs, there is much more to lighting up a watch dial than meets the eye



The many colors of SuperLuminova begin with these raw materials for RC Tritec's famous luminous compound.

With its surprising ferocity, the competition to make the best-lit dial leads one to think more is at stake than just telling time. In fact, it turns out even the most cursory look into the history of luminosity in watches reveals that, well, there actually is.

Reading the time when the lights are out, and the process of making that possible, is astonishingly, and without hyperbole, a matter of life and death. From the military battlefield, to the depths of the abyss, to the tragic lives cut short of the young women who painted their dials, watches that can be read in any light level are as integral to horology as movements

It is an exceedingly complex industry that blends science, art and engineering in both tedious and spectacular ways. Producing stable, safe and effective materials to illuminate watches in the dark has been a 300-plus year quest ever since, in 18th century Europe, the English physicist John Canton first prepared his luminous pigment from oyster shells that reacted with sulfur.

Today, watch companies, material manufactures and collectors everywhere tout the light emitting properties of their timekeeping devices with pride as new advances are regularly achieved.

This series of articles is the culmination of original research through interviews with industry leaders in the manufacture of watches and luminous materials. Additionally, traditional research methods of digging through already published works were employed. What you are reading wouldn't have been possible without the assistance of Ted Cossins and his website where he culled together a significant resource on the history and functionality of luminosity.

A retired British engineer and relative newcomer to horology, Cossins put his web-based article together because he was "dismayed by all the misinformation" he read on watch forums and other websites.

What follows is by no means intended to cover all aspects of luminosity, but to provide a broad, general overview that can be used to further your own exploration of the topic.

The earliest efforts

Like many of the world's great scientific achievements, the history of luminous pigments began in Asia millennia ago with the Chinese discovering they could grind photo-lu-

The Radium Girls were a group of female factory workers who contracted radiation poisoning from painting watch dials with glow-in-the-dark paint at the United States Radium factory in Orange, New Jersey, circa 1917. The women, who had been told the paint was harmless, ingested deadly amounts of radium by licking their paintbrushes to sharpen them; some also painted their fingernails with the glowing substance.

By the end of the 19th century, Swiss watchmakers were regularly treating the dials of watches with a natural luminescent paint created using the same techniques as the ancient Japanese artists

minescent jade and utilize it to craft glowing beads, wine cups and other ornamentations.

The first recorded use of luminous paint occurred roughly 1,000 years ago in Japan. Documents housed at the Palace Museum in Taipei, Taiwan, tell of the emperor Zhao Tai Zhong's fascination with the cave painting of a cow that appeared only at night. The story goes that the cow couldn't be seen in the daylight as it "went to the meadow for eating" and then "returned to the cave in the evening."

According to research by Nemoto & Co., which currently produces luminous material in Japan under the trade name LumiNova, the emperor ordered his scientists to investigate. Their inquiries revealed that the cow "was painted with special paints made from shells of the sea" which led to its appearance only at night. Other similar stories chronicling the early proliferation of luminous paints, some combined with volcanic materials, are known from this time, with China and Japan developing the first known trade in illuminating substances.

About 700 years later, the Italians invented the first synthetic luminescent material from a compound of barium sulfide, christened the "Stone of Bologna" or "Sponge of Light." Englishman John Canton then followed this with his production of sulfur-reacting, light-emitting materials. By the end of the 19th century, Swiss watchmakers were regularly treating the dials of watches with a natural luminescent paint created using the same techniques as the ancient Japanese artists.

The "Radium Girls"

Then along came radium.

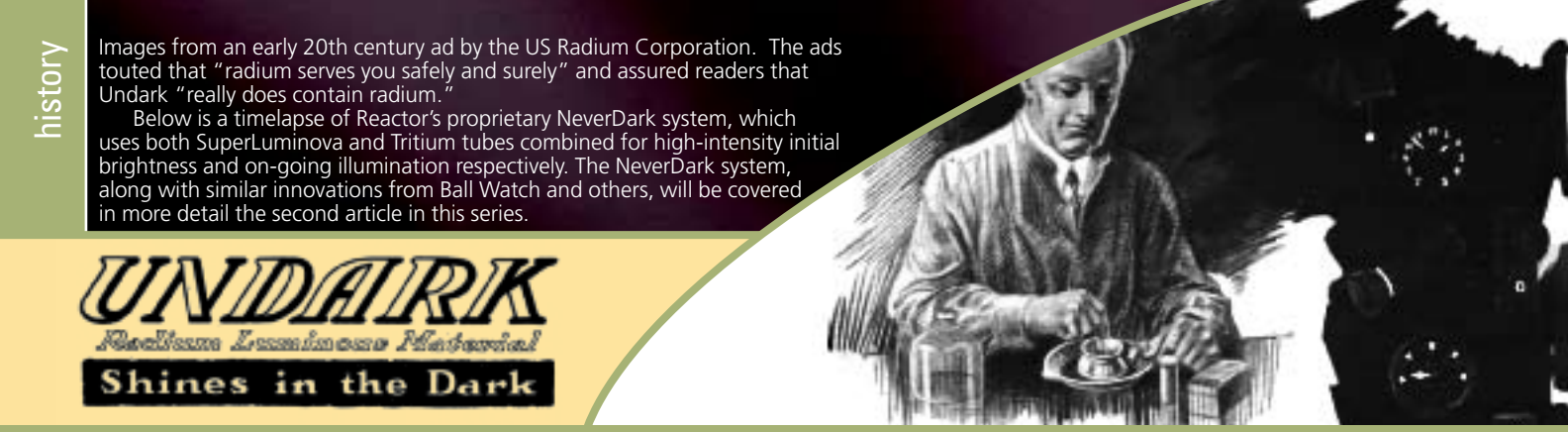
"We were not aware of the risks of radium," sounds more like words that would be uttered by the surgeon general from a podium in Washington, and not those of Albert Zeller, the third-generation CEO of RC Tritec, Swiss makers of the trademarked Super-LumiNova materials. "It was actually used for health reasons at the time, and most thought it even had positive influence," Zeller told *iW*.

Radium-226 is an alpha emitter with a 1,600-year half-life. In layman's terms, that means it is radioactive—not at all good for you—and won't decay for thousands of years.

Unfortunately, when mixed with zinc sulfide, linseed oil and glue, it also makes an excellent luminous material for watches. The radioactive emissions of the radium

Images from an early 20th century ad by the US Radium Corporation. The ads touted that "radium serves you safely and surely" and assured readers that Undark "really does contain radium."

Below is a timelapse of Reactor's proprietary NeverDark system, which uses both SuperLuminova and Tritium tubes combined for high-intensity initial brightness and on-going illumination respectively. The NeverDark system, along with similar innovations from Ball Watch and others, will be covered in more detail the second article in this series.



NeverDark after 1 minute

NeverDark after 25 minutes

NeverDark after 120 minutes

excite the zinc sulfide to produce the glow.

In the early 1900s, a Tiffany & Company gemologist named George Kunz and a chemist named Charles Baskerville patented this mixture, after inventor William J. Hammer failed to grasp the importance of protecting his original 1902 concoction, which used Damar varnish rather than the linseed oil. Hammer's fascination with radium began that year when he visited Marie Curie herself in Paris and she gave him nine vials of the substance she had discovered four years earlier.

A protégé of Thomas Edison, Hammer eschewed the patent due to the scarcity and high cost of radium. An important civil suit later vindicated him, citing that no subsequent radium-based luminous paint could have emerged absent his original work. Hammer also has the distinction of creating the first colored and white luminous materials.

For the decade to follow, radio-luminescent paints saw little practical application in all but, not surprisingly, Switzerland. Ross Mullner, author of *Deadly Glow: The Radium Dial Worker Tragedy*, notes that "there were so many radium dial workers in that country that it was common to recognize them on the streets even on the darkest nights, because of the glow around them; their hair sparkled almost like a halo."

By 1914 the first U.S.-based company had launched in Orange, New Jersey, which by 1922 evolved into the U.S. Radium Corporation. Carrying the brand name Undark, the company applied the radium-based paints to watches, clocks, pens and house numbers among other items. The government issued watches to infantrymen during the First World War, utilizing Undark to make them readable at night.

To achieve this, U.S. Radium recruited an army of young women, mostly in their teens and early 20s, to hand-paint dials, attracting them with an above-average wage for comparatively easy work versus their other options of the day. The going rate for painting 250 dials a day was about a penny and a half per dial, which at that time was good money.

Deadly tips

To keep the camel-hair brushes with which they applied the glowing paint stiff, management encouraged them to wet the tips with their lips between applications—a process known as "tipping." The dial painters became so comfortable with the cocktail they were known to use it as lipstick and coated their teeth to shock their boy-

Manufacturers put naturally phosphorescent materials on steroids with a high-temperature process that results in a nontoxic light storage material

Sports brands are particulalry avid users of SuperLuminova.

friends or husbands when the lights went out.

Dubbed the "Radium Girls" due the eventual radiation poisoning and highly-publicized deaths of many of their number, the subsequent lawsuits created the foundation of legal precedent for the rights of workers to sue their employers for occupational diseases. It was the first successful litigation of its kind.

Sources differ as to the extent U.S. Radium company officials knew of the real dangers of the material and when they knew it, but all mention management's use of protective lead screens, masks and tongs–but these were not offered to their line workers.

Zeller of RC Tritec points out as well that, unlike in the US, precautions were steadily implemented in Europe to help mitigate risks, both known and unknown, that reduced the impact to the workers.

Radium continued to be used to produce luminescent materials until 1968, though with much tighter controls and safer methods.

What is used today and how it works

For watch manufacturers today, there are two basic methods of illuminating timepieces, setting aside the use of actual electronics. These options last longer and glow 100 times brighter than the natural compounds of the past, and don't have the deleterious effects of radium.

The most prevalent material is made of ceramic aluminate type crystals, collectively and more commonly referred to as "lume." It's also applied as a paint, which consists of ceramic crystals and utilizes harmless, non-radioactive rare Earth metals to produce its glow. The phosphorescent crystals collect and store UV or artificial light and then release it in the darkness.

The manufacturers basically put known phosphorescent materials on steroids by mixing inorganic compounds in a super-high-temperature rendering process. This results in nontoxic, yet highly effective, sintered crystals that act as a light-storage, or photo-luminescent, material, much like a battery without the acid.

"Simply put," says Zeller, "the more crystals packed together over more surface area, the higher the light capacity." In other words, the more lume applied and the more concentrated the more resulting illumination. But there is a point of diminishing returns. Anything more than 400 microns thick and the curve flattens out to saturation, according to Zeller.

Formed in 1962, Zeller's compa-

MB Microtec's tritium tube technology is expanding into new markets all the time. Above, the Vostok-Europe Caspian Sea Monster is the first Russian timepiece to incorporate the trigalight tubes. Developed in 1969, GTLS (Gaseous Tritium Light Source) technology is like putting a tiny, conventional television tube on the chapter ring of a watch.

ny bought the rights to SuperLight from the elder Nemoto Company of Japan, which today makes the LumiNova material used in most Japanese watches. This is distinguished from Super-LumiNova made by Zeller's group in Switzerland. The two companies ultimately formed the joint-venture LumiNova AG Switzerland, which is the licensed manufacturer and exclusive distributors and service center for Europe and selected overseas customers for the Swiss pigments. The exact mixture of activating ingredients is, of course, a trade secret. Seiko's in-house version for its watches is called LumiBrite.

Zeller's company doesn't actually apply the substances, it only produces them. Watch and dial manufacturers then license the use of the pigments under strict quality guidelines and can produce 200-1,000 dials with each gram of lume they purchase. Depending on the grade—there are quality grades of SuperLuminova—and how aggressively the paint is applied, this adds one to ten cents to the final price of a watch.

While RC Tritec doesn't actively police the quality of end products, if alerted to a problem it will investigate. The firm has stripped companies of their rights to use the Super-Luminova name.

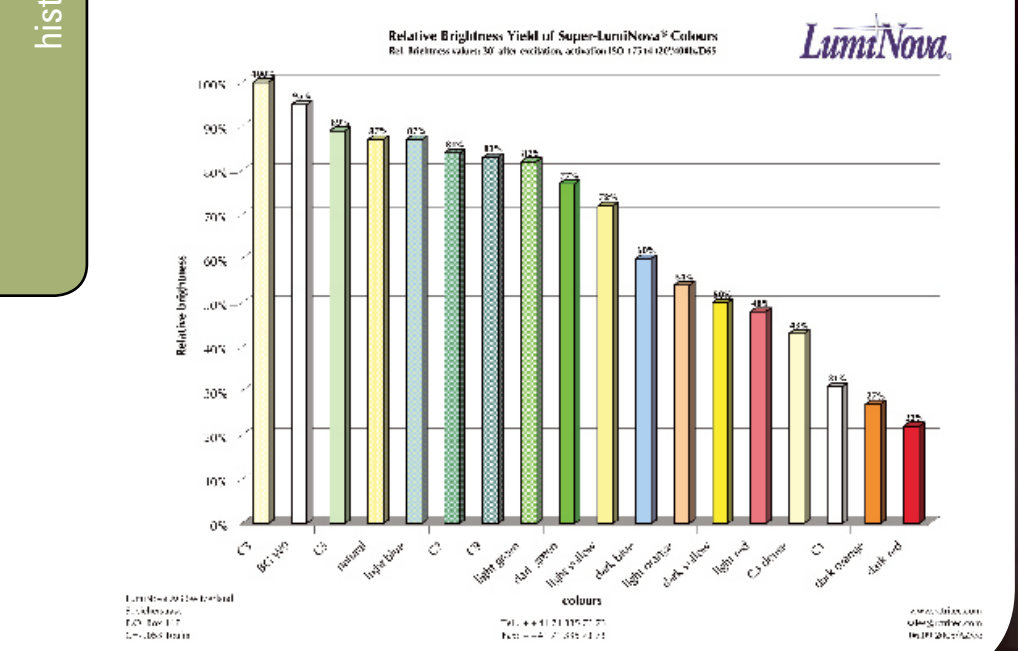
"We cannot allow the use of our materials in an improper way," Zeller says. "It's our brand that gets injured when a watch advertised with Super-Luminova doesn't glow properly."

More often, watch companies will ask Zeller's team to test their own watches so as to ensure they are meeting the approved standards, particularly since dial painting is often an outsourced process.

Gas methods

The other prevalent illuminating material on the market today overcomes the major weakness of painted lume, which is that it only lasts a few hours per charge at most. In contrast, tiny glass vials filled with tritium, a low-energy beta-emitting gas, have a half-life of 12.5 years. They can't glow as bright as lume does when it is first activated, but they maintain a consistent light level all the time.

Like lume, no one company has the monopoly on Tritium (H3) technology, but the best-known name in North America is certainly MB Microtec of Switzerland. MBM's



Not all colors of lume are created equal. This chart from RC Tritec shows available colors and their relative "yield," which translates into brightness and longevity.

trademarked process is known as trigalight illumination technology, which the firm guarantees to light up for ten years.

The tritium-filled gas tubes, which are coated with fluorescent material on the inside, are then sealed gas tight with a laser. The electrons emitted by the gas activate the fluorescent material permanently. The decay rate of tritium is so mild it cannot even penetrate human skin. The capillary glass tubes that encapsulate the gas are small enough to fix to the indicators and dials of watches.

MBM will tell you anecdotally that if forty watches filled with trigalight tubes were smashed with a hammer, they would emit the radioactive equivalent of a decaying banana. Nevertheless, tritium is a substance regulated by US Nuclear Regulatory Commission and the watches that make it to this side of the Atlantic arrive via a fairly circuitous route. Also, they must be licensed to do so.

Prior to coming to the US, a watch equipped with tritium tubes must have a sample lot of thirteen or fifty watches to be tested at the MBM facility in Switzerland. The watches undergo a leakage submergence test to ensure no active material is released. Once passed, a lot of thirteen allows for 1,200 units to be imported into the United States; a lot of fifty allows for 34,000. Once that number is exceeded, the process starts over.

The license to import tritium legally in the United States is cost-prohibitive for most individual watch companies, so the MBM license is generally used as an umbrella. This requires first shipping the watches to a control facility in Buffalo, New York, where the firm then ships them to distributors or watch companies domestically. Various guidelines and restrictions of this ilk exist around the world, with some countries banning the import of tritium altogether.

Craig Hester is the founder and CEO of Russia2All, which distributes Russian-build wristwatches, including Aviator, Vostok, Volmax, Sturmanskie and Poljot.

In part II of his series, Hester will look at the various watch manufacturers that use luminous substances.

THE SPECS

Technically speaking, the unit used to express luminous intensity is Candela/m2—a bit large for a watch dial. In watches it makes more sense to refer to nCd/mm2, which means nano candelas per square millimeter. For those who don't have an engineering degree, this just means that the output of measurable lume is base on the performance and quality of the phosphorescent pigment. Zinc sulfide is the weakest, aluminate is ten to twenty times better and the patented material compounds are 100 times better

- Quantity or mass of applied pigment on dials and hands per millimeter squared
- The color of the pigment used. (See chart).
- The luminous pigments are mixed with RC Tritec's binders to form a "liquid to viscous luminous paste," which is applied to dials, hands and engravings by a Stylograph pen.
- The Stylograph pen enables a faster and more precise application of luminous paint than is possible with older paintbrush methods. The device creates a continuous feed of the luminous compound so that dots, signs or numbers can be covered more evenly. A highly adjustable nozzle allows for the feeding pressure, flow-rate or dot-diameter to be attuned minutely.