

Retiring



By Donald Jones and Helen Herlocker

You're walking through a city neighborhood and suddenly—what's this?—you're bouncing and springing along the sidewalk. You look down, and the pavement is some vibrant shade of brown or red—no graffiti, cracks, or chalked messages. Nice! Pedestrians with tired feet are giving it rave reviews. Tree roots can bend it but not crack it. What is it? It's one of the new rubberized surfacing materials generated from old tires. And the good news is that we're not going to run out of that source any time soon.



ld Tires



Presently, approximately 300 million used tires are generated annually in the United States alone. In the early 1990s the growing stockpiles of scrap tires reached as many as 3 billion, with at least another 240 million adding to the problem every year. Although limited uses were found for about one-quarter of them, the others remained, layer upon layer, in surface storage sites and landfills. There, they collected stagnant water and housed disease-spreading insects and rodents. Worst of all, they frequently caught on fire.

Burning ring of tire

Actually, why not burn them? Just ask anyone who has been anywhere near a burning heap of tires; they will tell you that you don't want to go there. Thick solid tires, unlike granular coal or liquid petroleum, burn slowly, releasing black clouds of noxious volatile organic compounds (VOCs). For every kilogram of tire, approximately 11 g of VOCs, 4 g of semi-volatiles, and 4 g of polycyclic aromatic hydrocarbons (PAHs)—especially dangerous carcinogens—are released into the atmosphere. Given the fact that the average tire weighs about 9 kg, you can appreciate the environmental impact of a burning heap of tires.

In February 1990, an arsonist ignited 14 million scrap tires piled outside the town of Hagersville, Ontario, Canada. The fire burned for an agonizing 17 days, caused the evacuation of over 4000 people, and cost over \$10 million in firefighting and clean-up costs. A similar fire plagued Wesley, CA, in September 1999, when firefighters from several states joined local firefighters to extinguish the blaze that started in a storage site containing 5 million tires.



CA INTEGRATED WASTE MANAGEMENT BOARD-TODD THALHAMER

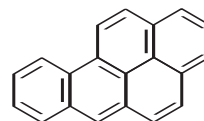
Some of the materials released when tires burn:



benzene
volatile organic compounds



1,3-butadiene



benzo[a]pyrene
a polycyclic aromatic compound

Zn Pb

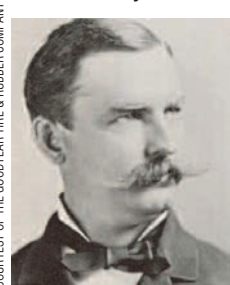
metals

Firefighters and environmental workers dread tire fires! They are especially difficult to extinguish when compared to other fires. Extreme heat liquefies the rubber, turning it into oil. With each tire generating about two gallons of oil as it burns and liquefies, a fire like the one in Ontario can release over 20 million gallons of toxic oil to either burn or leach into the soil of surrounding farmlands.

Rubber

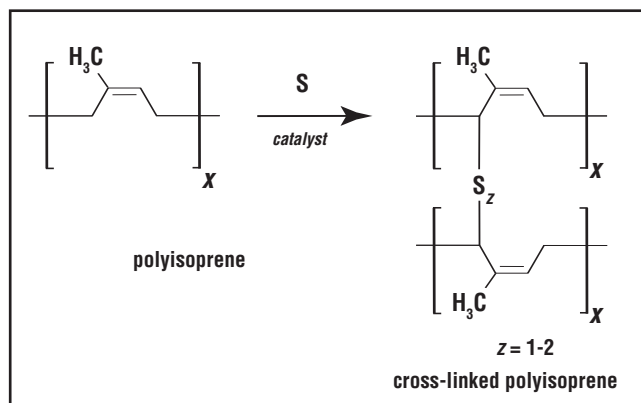
Natural rubber, a wet sticky plant product, is an example of a polymer, a molecule in which repeating molecular subunits form chains. These chains are generally linked to one another by atomic bridges called cross-links. It's the number of these cross-links that give rubber its characteristic properties.

History credits New Jersey chemist Charles Goodyear for inventing a process in



Charles Goodyear

the mid-19th century for controlling the number of cross-links in uncured rubber. The initial result was a product much more durable and chemically resistant than the original, but would begin to deteriorate within a few days, gradually breaking down into a wet crumbly mess. Vulcanization, a chemical process named after Vulcan, the Roman god of fire, adds more cross-links by introducing sulfur at high temperatures. Along the rubber molecule, there are several sites called *cure sites*, which are particularly attractive to sulfur atoms. During vulcanization, highly reactive sulfur atoms form chain-like bridges that span from a cure site on one rubber molecule to one on a neighboring molecule.



Vulcanization of natural rubber

Chemists have developed ways to control the vulcanization process to favor either short or long sulfur cross-links between rubber molecules. Short cross-links (1 or 2 sulfur atoms) result in a product with good heat resistance, while longer cross-links (3–8 sulfur atoms) give the rubber more elasticity and flexibility. Blends of natural and synthetic rubber (along with many other materials) can be used to make a very sturdy automobile tire that can last around 40,000 miles.

Then what?

Given the danger, public safety issues, and the negative environmental impact of costly tire fires, all but eight states have laws severely restricting the disposal of scrap tires in landfills. In some rural areas, regulations like these have led to unfortunate measures of local convenience. Streams, rivers, and hillsides are often found littered with old tires with no uses and no immediate means of disposal.

So, what do you do with hundreds of millions of old tires? Just as the problem seemed hopeless and the stockpiles were reaching a critical mass, economic reality entered the picture. The cost of virgin rubber on the world market started to rise as dramatically as the price of crude oil rose. Manufacturers began eyeing the vast and growing stockpiles of rubber tires with new interest. Today, new and creative uses for recycled tires, like the sidewalk mentioned earlier, are springing to the forefront.

Three uses for an old tire

Light my tire

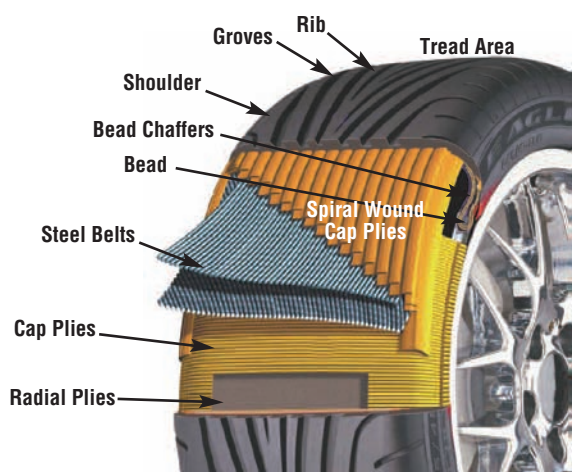
The first use—as fuel—may be particularly hard to believe, given all we've said about burning tires! But nearly half of the used tires generated in the United States over the past few years have become tire-derived fuel (TDF), providing energy for a variety of industrial and public utility applications. Major users include cement kilns, pulp and paper mills, electric utilities, and various industrial boilers. In all three uses the steel "bead" used to attach the tire to the rim

of the wheel is removed before shredding. For some applications, whole tires, including their fabric and steel components, are used. In others, whole tires are preshredded to expose more surface area for combustion. Burned under carefully controlled conditions, the energy recovered per ton of tires is somewhat larger than that for coal and about the same as for oil—not so surprising given the largely hydrocarbon composition of vulcanized rubber.

TDF has another advantage: Under the right conditions, it is a cleaner fuel than either coal or oil. With no nitrogen content, TDF combustion results in less nitrogen oxide (NO_x) emissions into the atmosphere. Although any burning in the presence of air will result in a reaction between atmospheric nitrogen and oxygen to form NO_x , fuels like certain coals and oils bring enough of their own nitrogen to the mix to increase NO_x emissions dramatically. Oil can contribute as much as 50% of the total, and coal, as much as 80%. As for TDF, make that a zero. Burning TDF will result, however, in some SO_2 emissions, because of the sulfur introduced in the vulcanization process.

Engineering projects

A second broad area of use for about 20% of used tires is in civil engineering projects—projects taking advantage of the chemical stability and resilience of vulcanized rubber. For these projects, tires are shredded into tire-derived aggregates (TDA)—pieces and particles ranging in size from 2 to 12 inches depending on the intended use. The *U.S. Scrap Tire Markets 2003 Edition*, published by the Rubber Manufacturers Association, describes several applications for TDAs.



Parts of a tire.

Most of them are used as filler in landfills, where their superior properties make them useful for enhancing drainage, venting gases, closing caps, lining collection vessels, and providing additional surface cover. In addition, less costly than stone, TDAs work well in septic drain fields, where they enhance the drainage spaces for wastes. For large-scale, civil engineering projects, TDAs are valued as subgrade fill for embankments, where the existing soils are too weak for the task. You might see TDAs at work in highway construction projects as fill material behind walls and bridge abutments—projects in which the light weight, superior drainage properties, and low-cost make TDAs the best choice for the job.

Crumb rubber products

The third application for scrap tires, about 11% of them, includes a growing array of products requiring an initial and somewhat costly pretreatment to yield crumb rubber. For these applications, the steel and fabric components of the tire must be separated away, leaving the vulcanized rubber to be ground or cut to the required crumb size.



Crumb rubber may be used for shock absorbing playground floors.

Imagine the logistics. It would be difficult enough to rip away the fabric and steel from one tire. But for hundreds of millions of them? The task on that scale requires knowledge of the physical and chemical properties of all of the tire components. One separation strategy begins by physically grinding whole tires into pieces of about 2 inches in diameter. These pieces are fed into a granulator where their size is reduced even further. At this stage, the remaining steel is removed by magnets, and the fibers are sifted out on shaking screens. Finally, the separated rubber is refined to the

particle size required by the manufacturer.

A second method, called the cryogenic method, uses liquid nitrogen or super-cooled air to freeze the ground tire stock into solid chips. A hammer mill pounds and shatters the chips, liberating the steel and fabric in the

process. Then, as in the previous method, magnets and sifters remove the extraneous material, leaving exceptionally clean vulcanized rubber. By either method, clean crumb rubber is generated for any use to which

costly virgin rubber is suited.

The applications and demands for crumb rubber increase every year. About one-third of it is used in the manufacture of rubber-modified asphalt (RMA), for a wide variety of surfaces. Arizona and California use most of the available RMA with growing demands in Florida, Texas, and other states. While initial production costs are high, RMA produces long-lasting road surfaces with low maintenance requirements, thereby making it cost effective in the long run. Used on highways, RMA surfaces reduce noise and shorten braking distances—features appreciated by consumers. Resilient and stable crumb rubber is attrac-



What's in your tires?

The Goodyear P195/75R14, a popular sized tire, weighs about 21 pounds and contains:

Approximate Composition

Carbon	85%
Ferric material	10–15%
Sulfur	0.9 to 1.25%

tive for surfaces under playground equipment, as a soil additive under athletic fields, and as surface material for tracks—applications with obvious human safety advantages.

Clean crumb rubber has one more obvious use, one that may eventually overtake all of the others—tire manufacturing! Presently, it constitutes a portion—about 10% in the United States—of the mix used to manufacture new tires.

Looking to the future

How far have we come toward solving the environmental problem of scrap tires? Recall that in the early 1990s there was a growing mountain of them, as many as 3 billion crowding landfills and other collection sites. Then, only about 25% of scrap tires were being reused and repurposed. Today, the news is getting better—a lot better thanks to economic realities and new industrial techniques. Today, about 80% of our annual crop of 300 million used tires will find new uses. And as for that stockpile? There are about a quarter of a billion left. Got any ideas? ▲

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Making sandals from old tires!



How about getting 40,000 miles out of a pair of sandals? For information on how you can make your own pair of tire sandals, go to <http://www.hollowtop.com/sandals.htm>.