SCRAP-TIRE PYROLYSIS— THE IMPOSSIBLE DREAM?

MANY HAVE TRIED TO MAKE SCRAP-TIRE PYROLYSIS A COMMERCIALLY VIABLE BUSINESS, BUT NONE HAS SUCCEEDED. A NEW PROCESS HOPES TO CHANGE ALL THAT.

BY JONATHAN V.L. KISER

Despite more than 30 years of research and development, the use of pyrolysis to process scrap tires and related materials has yet to achieve commercial success in the United States, with economic viability and product quality being the primary stumbling blocks. Yet even with this questionable track record, pyrolysis continues to be proposed as a means by which scrap tires can be converted into usable products.

According to the U.S. Department of Energy, pyrolysis is "the thermal distillation or decomposition of organic materials into oils, gases, and char." Traditionally, products resulting from tire pyrolysis have been of a comparatively low quality and have thus had limited marketability. Refining these products to meet market specifications requires capital investment and operating expenses that have made them cost-prohibitive from a competitive standpoint.

These challenges, however, haven't dissuaded Metso Minerals Industries Inc. (York, Pa.) from advancing its own patented tire-pyrolysis system. Will this new process be the one that finally makes pyrolysis commercially viable? Here, we examine what appears to make Metso's approach different as well as the formidable hurdles it must overcome to turn the pyrolysis dream into reality.

ENTERING THE PYROLYSIS FRAY

In 1997, Svedala Industri AB (which was merged in 2001 with Nordberg to form Metso Minerals) began developing a process to convert scrap tires into valuable commodities. After conducting a market study, the firm concluded that a tire-pyrolysis process could be economically feasible if it could produce a good grade of carbon black.

Svedala also reviewed other pyrolysis approaches to determine why those efforts had failed. This review pointed to several weaknesses in previous systems, including process-control flaws, mechanical problems, material-feeding and -discharging difficulties, and the production of low-value products.

Armed with this knowledge, Svedala next conducted laboratory bench tests to evaluate process conditions and assess the quality of carbon char. The company found that by pyrolyzing material in an indirect-fired batch kiln it should be possible to generate a product comparable in properties to a medium-grade carbon black. The next step was to prove this could be done on a continuous-operating basis in a pilot plant, using an indirect kiln capable of processing up to 200 pounds an hour of scrap tires.

The first task at the pilot plant was to resolve the previous feeding problems with tire shreds by using a positive-feed mechanism that would force material into the kiln with minimal air leakage. In the end, Metso adopted an infeed system featuring an air-lock chamber with a modified Archimedes screw configuration.

The next task was to evaluate process conditions in the kiln and the resulting products—namely carbon, oil, and gas. To achieve maximum separation of the carbon from the tire wire and to alleviate any discharging problems, Svedala settled on a tire-shred size of 2 inches. In addition, the discharge end of the kiln was modified with a trommel to achieve the desired separation.

Svedala also had to address the significant costs associated with the air pollution control system typically required to clean the off-gas that contained oil mist. The company ended up developing a unique oil-condensing system that addressed both the condensing of the oil mist and

the handling of gas-stream particulates.

The firm then analyzed the products that the pilot plant generated during more than 400 hours of testing. It found that the carbon material falls into the middle range of carbon-black quality, says Bobby Faulkner, manager of Metso Minerals' research and test center in Danville, Pa. The oil generated by the pilot plant is similar to a No. 2 oil, but with fewer Btus per pound and a higher sulfur content (see Table 1 on page 36). An analysis of the noncondensable gases, which reportedly have a heating value comparable to propane, is provided in Table 2 on page 36.

GOING 'COMMERCIAL'

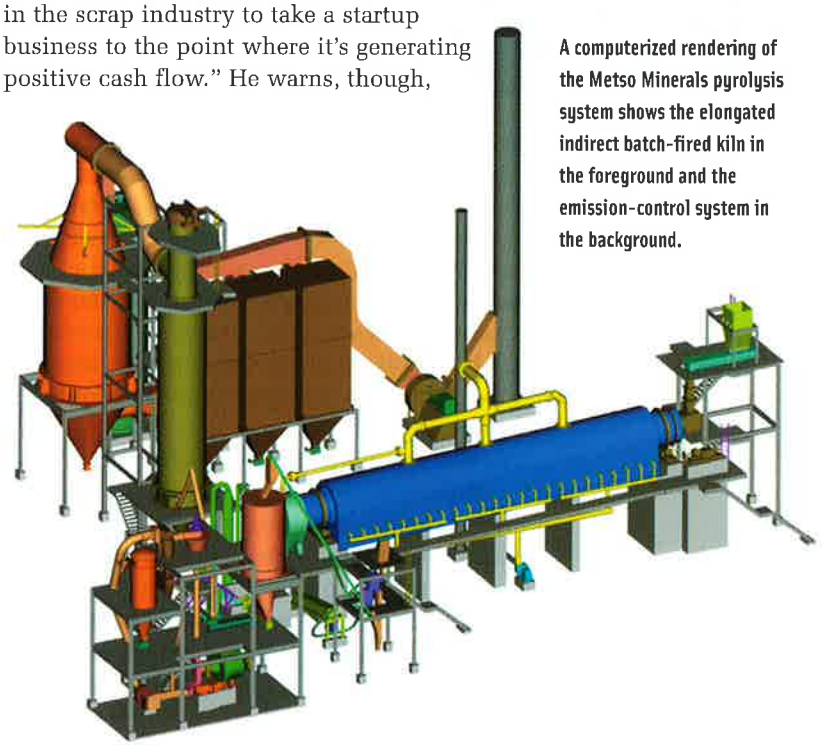
Based on the pilot-plant results, Metso Minerals developed a commercial plant design with the capacity to process up to 100 tons per day and secured a patent recognizing 24 claims of process and equipment design.

The features of Metso's proposed commercial plant include:

- a tire-feed system capable of conveying passenger and/or off-the-road tires processed to 2-inch shreds;
- an indirect rotary kiln measuring 8 feet in diameter and 96 feet long. This kiln achieves oxygen-starved, internal temperatures of 850 degrees F through the heating of its outside shell by 24 natural-gas burners in three zones;
- a kiln-discharge system;
- an oil-condensing system;
- a char-cooling (chiller) system;
- a magnetic-separation system to recover tire wire;
- a char-grinding system to achieve a uniform fineness and a carbon product size distribution specification; and
- an air pollution control system (which may or may not be installed in a specific plant depending on the usage of its noncondensable off-gases).

According to Metso Minerals, its 100-ton-per-day commercial pyrolysis plant should generate 28 tons of carbon, 12 tons of steel/tire wire, 5,500 gallons (20,800 liters) of oil, and 690,000 standard cubic feet dry (19,600 cubic meters) of noncondensable gases. This basic plant would likely cost $12 million to $15 million, not including the emission-control system, says John Trescot, Metso Minerals' vice president of mineral processing systems sales, who notes that Metso "prefers to locate its process adjacent to an operating gas user, waste-to-energy plant, or oil refinery to take advantage of their existing emission-control system."

As for a projected return-on-investment, Metso officials say that operators could realize a 20-percent return—or more—after two years. That's a normal timetable for scrap-tire ventures, says Michael Blumenthal, senior technical director for the Rubber Manufacturers Association (Washington, D.C.)—"a two-to-three-year period is typical in the scrap industry to take a startup business to the point where it's generating positive cash flow." He warns, though,



A computerized rendering of the Metso Minerals pyrolysis system shows the elongated indirect batch-fired kiln in the foreground and the emission-control system in the background.

that "any investor should carefully consider the cost to buy and install the equipment, site and permit the operation, test the facility for regulatory compliance, and operate and maintain the plant. A clear understanding of the product markets and the tip fee one can charge to secure a steady stream of scrap tires is also essential."

Metso's target clients for its pyrolysis system are "companies that shred and handle tires, and small companies in the environmental cleanup business," notes Bobby Faulkner. The hope, of course, is that such clients will be able to operate the system commercially, making money from the sale of the system's products.

TABLE 1–COMPARISON OF METSO MINERALS PILOT-PLANT OIL PRODUCT AND COMMERCIAL NO. 2 OIL

Characteristic	Metso Oil	No. 2 Oil
Heating Value (Btus/lb.)	17,500	19,000
Pour Point	< - 27F	- 7F
Viscosity @ 100F (cst)	6.3	2.7
Carbon/Hydrogen Ratio	10.10	6.98
Sulfur	1.2%	0.2%

Source: Metso Minerals Industries Inc.

TABLE 2–METSO MINERALS PILOT-PLANT GAS PRODUCT PROFILE

Component	Weight Percentage
H2 (hydrogen)	0.7
CH4 (methane)	13.2
C2-C5 (organic compounds)	67.8
C6+ (organic compounds)	14.1
Sulfur	1.2
Others	3.0

Source: Metso Minerals Industries Inc.

That hope could become a reality thanks to two proposed commercial-scale plants—one in Richmond, Va., and one in New Brunswick, Canada—that would feature Metso's pyrolysis process. "Preliminary engineering drawings have been ordered for both projects," notes Trescot.

The Richmond facility would be operated by Tire Recyclers Inc., a scrap-tire processor and producer of tire-derived fuel. This marks the firm's second attempt to operate a successful pyrolysis system at its Richmond location. Its first system, which consumed whole tires, operated from 1994 to 1996 but was ultimately closed because it couldn't generate a carbon product of sufficient quality or quantity. Not to be deterred, the firm has "since worked closely with Metso Minerals, supplying the shredded tire feedstock for pilot testing," says Charlie White, executive vice president.

The Richmond pyrolysis operation will cost $10 million, including the installation of a $2.5-million air pollution control system, according to Tire Recyclers. In this system, the noncondensable gases will first pass through a secondary combustion chamber capable of reaching temperatures of 2,000 degrees F, then a lime-bathed scrubber and fabric-filter system before being released to the atmosphere.

The New Brunswick facility, meanwhile, is the brainchild of Unisphere Waste Conversion Ltd., a Toronto-based scrap-tire recycling company. The 100-ton-per-day plant is expected to be sited on a 20-acre parcel in Belledune, with operations to be conducted in a 50,000-square-foot building. Though the plant isn't slated to come online until November 2003, Unisphere says it has already secured markets for the plant's carbon char, oil, steel, and noncondensable gases.

WILL IT WORK THIS TIME?

While the news of the Richmond and New Brunswick plants is encouraging, it also begs a critical question: Why will Metso's pyrolysis process succeed where others have failed?

According to Bobby Faulkner, the company's system is "an entirely different process from both an operational and product-output standpoint. While it follows the basic concept of pyrolysis, we do it better based on our understanding of process control and how to break the tires down chemically in the kiln." This enables the Metso pyrolysis process to generate products that "are better and more marketable," Faulkner states, adding that "Metso is a big company that will stand behind its product. We will warranty the continuous operating efficiency of this process and the quality of the product output."

In addition, "the economics associated with Metso's process are way different than previous attempts by others," maintains John Trescot. "This is because of Metso's experience building commercial thermal processing plants and grinding systems, coupled with the end objective of making a commercial product from carbon black."

Charlie White of Tire Recyclers is at least one tire processor who concurs. "Being so close to Metso," he says, "we've seen the consistency of the carbon product and believe this is different from what anyone else has ever done."

Other veteran tire processors have their doubts, however. As Bill Vincent, CEO of Colt Scrap Tire Centers Inc. (Scott, La.) and chair of ISRI's tire and rubber division, asserts, "I've been in the scrap tire processing industry for 20 years and have visited every pyrolysis test plant possible. Nothing has ever come from any of them."

Then there's Mark Rannie, vice president of Emanuel Tire Co. (Baltimore) and president of ISRI's Scrap Tire Processors Chapter, who visited Metso's test facility in Danville in 2001. "The carbon I observed wasn't of a high quality, and the process wasn't clean," he states. "It gets on you and won't come off. It's a mess. I didn't see the practicality of the process in a real-world situation."

GETTING DOWN TO ECONOMICS

Given such strong views among scrap-tire processors as well as the dubious commercial track record of pyrolysis thus far, Metso Minerals' process clearly faces an uphill battle.

For any pyrolysis process to be more than a technological dream, it has to make economic sense—that is, it must be able to turn a profit. And according to Frank Bernheisel, vice president of waste management consultants Gershman, Brickner & Bratton Inc. (Fairfax, Va.), "the profitability of pyrolysis systems hinges on their ability to make a high-enough-quality carbon product. If Metso Minerals is able to solve the challenge of profitably selling its carbon product, that would be unique from a tire-pyrolysis standpoint."

The Carbon Question. Carbon black is used in numerous products, including tires, industrial rubber products, and as a pigment in printing inks, paints, and plastics. "Tire manufacturers use carbon black as a reinforcement agent to improve the physical properties of the tire," says Alan Gottesman, senior project chemist with tire maker Continental Tire North America Inc. (Charlotte, N.C.), noting that "about 25 to 30 percent of the rubber in a tire is composed of carbon black."

While pyrolysis companies often say that their systems produce carbon black, that isn't technically correct. In reality, the pyrolysis product is a carbon char of lesser quality than virgin carbon black. As Michael Blumenthal explains, "Pyrolysis works from the standpoint that you can physically melt a tire in the absence of oxygen to create a carbon char material. But carbon material from a pyrolysis process has a size and structure that falls short of the carbon black properties required by tire manufacturers."

Continental Tire tested Metso's carbon material and found that it "was not a true carbon black," says Gottesman. "Most of these types of materials that I've seen compare in properties to an ASTM classification of N770 or higher. Continental uses carbon black meeting a superior N660 classification or below."

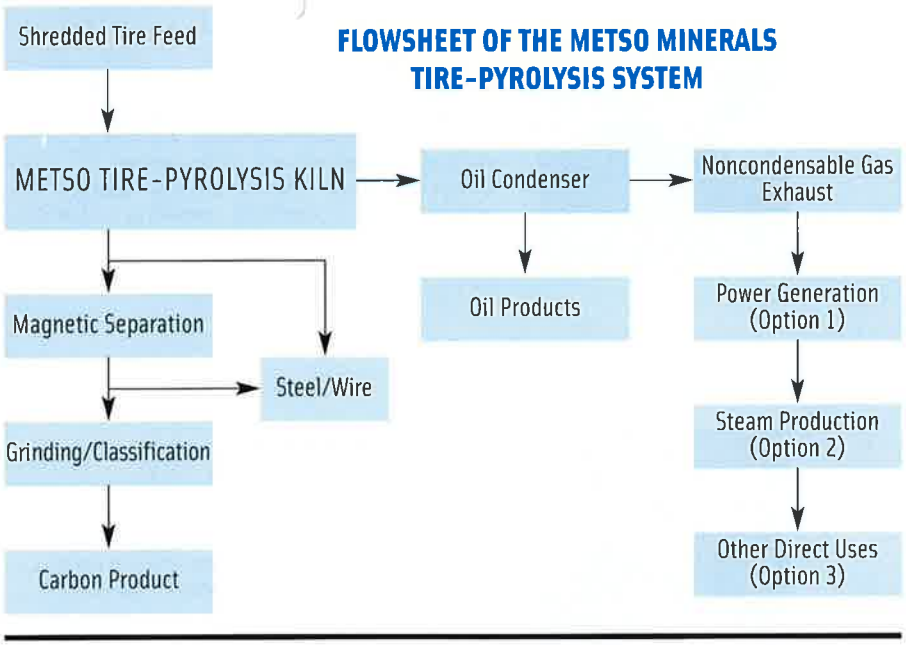
In Gottesman's view, Metso's carbon material would be best used as a filler in tire production, not as a replacement for carbon black. "This pyro black was a relatively good product that would have to be pelletized before Continental would be able to use it as a filler on any type of ongoing commercial basis," he notes. "We'd also need further proof that this material is economical and of a consistent quality. Quality was hard to gauge during our investigation since our laboratories wouldn't test for carbon-black structure for fear that any contaminants might damage our testing equipment."

Aside from quality considerations, carbon char from pyrolysis plants has to compete with carbon black on price as well. While on-spec carbon black can reportedly command 25 to 40 cents a pound, off-spec carbon material generally fetches less than 20 cents a pound, says Blumenthal. In comparison, Metso's Trescot says, "We'd expect our product to sell at some discounted rate compared with virgin carbon black—in the 18-to-30-cents-per-pound range. The price will depend on factors like the size of the user and where they're located."

Charlie White of Tire Recyclers agrees that selling the carbon product made by his proposed Richmond plant will be the key to its success. "We'll have to establish new markets for our carbon product since no one has done it before," he says, conceding that "it'll take time."

The Oil Factor. The pyrolysis process produces an oil product that compares favorably with No. 2-grade oil on several criteria. Metso says that the oil "can be upgraded to remove the sulfur, used directly in some applications, as a blend with other heavy oils, or can be used to generate carbon black." Such oil could be used, for instance, in the production of new tires, with Gottesman noting that Continental Tire would have a poten-

FLOWSHEET OF THE METSO MINERALS TIRE-PYROLYSIS SYSTEM



tial interest in using the oil from Metso's process.

Still, as George Dalton, president of scrap-tire processor Tire Disposal & Recycling Service (Waxhaw, N.C.), notes, "The availability of markets for pyrolysis oil will vary, depending on what part of the country you are located." Also, he notes, "this pyrolysis oil could have to be further refined at extra expense, sold cheap, or be disposed of as a waste material" Charlie White, however, says that his company won't have to refine the oil product from his Richmond plant "since a heavy-oil distributor in the Richmond area has indicated they will take whatever we supply."

A pyrolysis plant with the capacity to process 100 tons per day would require about 3.5 million passenger tires a year (assuming 100 tires per ton).

Metal Matters. An average passenger tire contains about 2½ pounds of steel in the form of bead and tread wire. This metal is recovered through the pyrolysis process and can be sold under certain conditions. As Mark Rannie of Emanuel Tire explains, "So long as the steel has less than 10 percent rubber content by weight, the market will buy this material. It can be baled or made into briquettes for handling purposes." The recovered steel from the Tire Recyclers plant, for example, is expected to be consumed by a South Carolina steel mill that makes wire for automobile tires.

The Gas Issue. All pyrolysis systems generate gases as they break down materials, and most systems propose using these gases to help power the operation itself, says Blumenthal. This is not the case with Metso's process. Gases generated by its process first pass through the gas-condensing system that removes residual oil in the gases. The noncondensable gases can then be used in several potential applications, including "generating electricity, waste heat boiler uses, process gas for other operations, or a combination of uses," says Trescot. Or the gases can be run through an air pollution control system prior to release, as Tire Recyclers plans to do at its Richmond facility.

Financing Concerns. Thus far, pyrolysis projects have had a difficult time securing financing and, even when built, have invariably run aground, usually due to the inability to produce a marketable carbon product. "Generating a product that meets target specifications at the stated price, plus securing solid contracts, will underpin project financing," states Frank Bernheisel. The proposed Tire Recyclers pyrolysis plant in Richmond, for instance, has already experienced financing problems. Its initial financing plan fell through because the bank reportedly had concerns about the commercial viability of the operation. As a result, says Charlie White, "the project financing is being restructured."

THE SUPPLY SITUATION

In addition to the above product and financing issues, successful operation of a tire-pyrolysis plant would depend on access to an adequate supply of scrap tires to feed the operation.

A pyrolysis plant with the capacity to process 100 tons per day, for instance, would require about 3.5 million passenger tires a year (assuming 100 tires per ton), notes Michael Blumenthal. "Securing this many tires will not be easy and will depend on where the facility is located and the tip fee it can charge," he says.

Tire processor George Dalton points to other considerations, noting that "to secure tires in any market, one must have their collection system in place and realize that markets don't typically extend beyond a 200-mile radius. Also, most tire companies will only offer processors a one-year contract, subject to ongoing renewal."

Mark Rannie concurs, stating, "Securing more than 3 million tires from markets that aren't already under contract will not happen. This is because established markets for crumb rubber and civil-engineering applications are growing and tire-derived fuel markets are stable."

Such supply limitations would prevent a pyrolysis plant from locating—or succeeding—in certain areas. "It would be almost impossible for a 100-ton-per-day tire-processing facility to locate in North Carolina since all of the counties are already under contract for disposal," says Steve Peters of crumb-rubber producer Tires Inc. (Winston-Salem, N.C.). "It's hard for a new facility to break through unless the tipping fee is low enough. The current tip-fee range for tires in North Carolina is $57 to $90 per ton."

Charlie White says that Tire Recyclers has the supply issue covered for its Richmond pyrolysis plant. Last year, the firm processed 3.5 million tires, and this year it says it will collect 5 million, thanks in part to its tipping fee of $45 per ton.

REGULATORY REQUIREMENTS

Then there are all of the potential air quality and waste management regulations a pyrolysis plant could face.

In Virginia, for example, a 100-ton-per-day pyrolysis plant would likely require a major air permit, with each facility needing to be assessed on a case-by-case basis, says Frank Burbank, who

works in the air permit division of Virginia's Department of Environmental Quality. Also, notes the department's Tamera Thompson, "If emissions from the pyrolysis process exceed the state's significant ambient air concentration thresholds [SAAC], then air modeling and additional controls would be required. If sulfur dioxide levels exceed the SAAC threshold, the process would be subject to the new source review permitting requirements."

Randy Johnson of Tennessee's Department of Environment and Conservation (DEC), says that such an operation in Tennessee would likely have to "go through the standard air-permitting procedures. This would include emissions stack testing following plant startup and possible facility adjustments if emissions exceed regulatory requirements."

With regard to solid waste management requirements, Ron Wilhoit, also in Tennessee's DEC, says that the solid waste rules for tire storage would apply to a tire-pyrolysis plant. Typical requirements would specify the quantity of tires allowed on the premises and outline a fire-prevention plan, including fire lanes, among other points.

Given all of the above factors, Metso Minerals faces numerous obstacles in its quest to realize the first commercially successful tire-pyrolysis system. Many have tried before and failed, stymied by two ongoing hurdles—the ability to generate salable, quality products and operate the process in an efficient, profitable manner.

Despite the hurdles, the pyrolysis dream lives on in companies like Metso Minerals and people like Charlie White of Tire Recyclers, who remains optimistic about the prospects for his proposed plant in Richmond. "We hope to break ground before the end of the year and be commercially operating by next summer," he says, concluding, "We have a lot invested here."

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