Conserving the Future Through the Recycling of Materials Using the Cryogenic Technique

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ABSTRACT

More than 2.5 billion used tires are scattered throughout the United States. More than 234 million tires are added to the scrap pile each year. Since only a small percentage of these tires are recycled and inherent properties prevent conventional disposal means to be used, many tires are often dumped wherever it's most convenient for the owner.

Only in the last few years have people really noticed the growing piles of tires blotting the landscape. Car shredders have managed to control and reduce auto scrap heaps, but not tire heaps. It becomes almost frightening to think that a product manufactured continuously since 1895, in very large quantities, cannot be completely disposed of.

Before paranoia sets in, it should be stated that recent developments offer some hope. As industry awakens to the fact that recycled rubber is a useful material and means are developed to efficiently obtain it, those mounds of tires should begin shrinking.

This paper is intended to define the problems surrounding the disposal of rubber tires, and suggests a solution to not only the recycling of tires but also other materials, such as certain nonferrous metals, by using cryogenic techniques.

THE TIRE DISPOSAL/RECYCLING PROBLEM

Certain inherent properties of rubber tires make it virtually impossible to use conventional disposal methods (i.e., landfill, composting) with them. Tires are not biologically degradable in the general sense of the word. They may become encrusted with barnacles or coral when dumped in the oceans, yet scrape the coating off and the same tire (in its original shape and condition) remains. The same holds true when tires are buried at landfill sites. They will not decompose or even lose their resiliency.

Rubber has a very high energy absorbing capacity. This affects the tire disposal/recycling problem in two ways. First, it is extremely difficult to break a tire into smaller, easier to handle pieces. Until recently, this could only be done with a great amount of horsepower, such as in a cracker mill. At landfill sites, if tires are permitted to be buried, they compress under the weight of other refuse. As the other refuse decomposes voids appear and stresses within the tire are allowed to release, causing the tire to assume its original shape and fill the voids.

Another phenomenon closely related to the resilient effect, is the tire's capacity to "float" up through the ground. Not much has been reported on this aspect, other than that it has been observed at a number of landfill sites. One theory that tries to explain this is that a buried tire will have material from on top of it trickle down around its sides, until there is more pressure forcing the tire up than is keeping it down (analogous to the "life" of airplane wing). Although the result does not occur immediately, in the space of a few years tires could work their way up to the surface. Multiplied by thousands of tires, arranged in a

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random array, all working their way upward, it soon becomes apparent why many landfill sites do not accept discarded tires.

Another problem is with the size and geometry of the tire. If a buyer could be found for the discarded product, shipping it to him would be very expensive. Its doughnut shape is not conducive to efficient transporting. Too much wasted space exists to make delivering them to a central point feasible. This holds true for a whole tire configuration.

Tied in to this is the fact that there is no real market for discarded tires. Figures released by the U.S. Environmental Protection Agency showed that in 1968, only 9.1% of the discarded tires were reclaimed. Another 20.8% were retreaded, which merely delays their being discarded by a couple of years; so actually 90.9% of the discarded passenger car tires went to waste.

The final aspect of this problem is that there is no end in sight. In the United States, over 215 million tires were produced in 1968. This rate is increasing 7% each year. Assuming each tire will eventually be scrapped, it will mean an additional 4.3 billion pounds of solid waste (average weight of a used tire is 20 pounds).

The tire disposal/recycling problem has reached enormous proportions. It would be fallacious thinking to assume an "ignore it and it'll go away" attitude, with the problem as immense and complex as it is. The following section will delve into current practices and methods of tire disposal.

PRESENT DISPOSAL METHODS

Open pit burning for many years was a cheap and easy way to get rid of tires. However, the large amounts of particle pollutants (mostly hydrocarbons and various sulfur and nitrogen oxides) have made this type of disposal illegal. It's mentioned primarily as an example of a pattern that people will usually follow; namely, taking the path of least resistance and greatest ease. Even when shown the shortcomings of open pit burning, many people still try to do it, but in an unobtrusive fashion. Fires that mysteriously start in junkyards and selectively burn refuse such as tires, seat cushions, etc., are still occurring.

Some discarded tires are being burned in landfills, although a great many of these sites refuse to accept them. Goodyear tire dealers in Madison, Wisconsin send their discarded tires to a central gathering point in Joliet, Illinois. Here the tires are graded, with the good ones being sent to retread plants and the remainder dumped into a nearby quarry. The question now raised is what will happen to the quarry once it's filled with tires. Can enough abandoned pits or quarries continue to be found to handle all these discards?

Retreading of tires is but a temporary solution, since retreads will eventually be discarded and added to the pile. At present, about 20% of discarded tires are being retreaded, but the process itself requires the tire to have its original tread buffed off. In 1968 this accounted for 6% by weight of the discarded tires. So even the retreading industry directly generates solid rubber waste.

Rubber reclaiming is the only tire disposal/recycling process of any size. As pointed out earlier, it accounted for 9.1% of the discarded tires used in 1968, and projected figures show a decrease. Basically there are three rubber reclaiming processes. In order of importance, there is first the Digester or wet process, in which chopped tires are heated to 482°F by steam under pressure. The fabric is charred and washed away from the rubber by the action of the steam and heat; the process accounts for 58% of the reclaimed rubber. Second in importance is the Devulcanizer or dry process, where finely ground rubber and reclaiming oils are mixed and put in autoclaves. Only 34% of the reclaimed rubber is obtained this way. Finally, there is the Mechanical process, which utilizes the shearing heat generated by the rubber being torn apart in a cracker mill. Just 8% of the reclaim was acquired by this method.

In the United States there were only 20 reclaim plants in 1968. Over half the reclaimed rubber goes into the making of tire sidewalls and inner tubes. The other half is used for such things as car floor mats, hard rubber battery cases, solvent cements, shoe heels, vibration pads, etc. The demand for rubber in these aforementioned areas, is not anywhere near the supply available for use. It was W. E. Stafford of the Rubber Regenerating Co., Ltd., Manchester, England who wrote in 1972,

> Contrary to common assumption, as far as can be ascertained, reclaiming will only provide a minor contribution to the economic disposal of waste rubber .... excluding the Eastern block, upwards of 190,000,000 tires are discarded annually, and this figure is increasing rapidly. In 1954, the U.S.A. had a yearly scrap figure equivalent to 3,000,000 lbs. of rubber compound of which only 560,000 lbs. were reclaimed.

This statement accurately describes the role reclaimed rubber has today.

A few miscellaneous disposal/recycling methods are all that remain to be covered. One is the Wave-Maze, Floating Breakwater in which floating tires were used to attenuate waves. This was accomplished by forming a triangular shaped array of tires, filling them with a floating material (such as polystyrene or polyurethane), and fastening them together. The patented idea was tested by the U.S. Army Corps of Engineers and found to be quite effective. A negligible number of tires were used though, not even enough to dent the vast amount available.

FUTURE DISPOSAL/RECYCLING METHODS

Until now, this paper has had an apocalyptic view towards discarded tire disposal and recycling. However, recent developments and results of studies makes one feel rather optimistic in this area.

Work done by the Firestone Tire and Rubber Company of Akron, Ohio in conjunction with the U.S. Bureau of Mines, determined that the destructive distillation of scrap tires is technically feasible. The economic feasibility has yet to be determined; cost of shipping the tires to distillation plants is a key critical point. In this study, over 150 gallons of oil per ton of tires, 1500 cubic feet of gas per ton of tires (comparable in heating value to natural gas), and 850 pounds of residue per ton of tires were obtained via destructive distillation. With present day energy sources rapidly being exhausted, old tires may provide a new source. Extensive research still needs to be completed.

In Jackson, Michigan, the Goodyear Tire Company has installed a heating plant that uses old tires as its fuel, exclusively. The pollution-free operation completely burns the tire, with only the tire bead and ash remaining. Since the plant was first to start in late Summer 1972, it is too early to measure its effectiveness.

Rubber has been mixed with asphalt binders for road surfaces and found to have certain favorable characteristics. A 5% mixture of rubber in asphalt has resulted in raising the softening point of asphalt, hence, less flow at high temperature. It has lowered the brittle point so less cracking has occurred at cold temperatures; plus it imparts elastic properties to the asphalt. Further, a rubberized asphalt binder has also been found to hold the stones better.

Although adding rubber to asphalt was first tried and patented over 130 years ago, accurate records since then have not really been kept. In the 1920's and 1930's some roads of this material were laid in Europe, with one particular stretch in New Cross, England, lasting until the 1960's. It has been only recently that interest has been rekindled.

Battelle Institute recently published a report on work they had done with rubberized asphalt. Since the experimental strips were only laid in May, 1972, no major trends can be concluded at this time. However, a freeze ground sample of rubber, with 90% of the fiber removed, has so far shown excellent stability and very good appearance in either a 5% or 25% concentration in asphalt.

The City of Phoenix, Arizona laid 208,000 square yards of rubberized asphalt on its major streets and airport aprons. It was laid in the Summer of 1971, with far less disruption of traffic and far less cost than with conventional materials. The city expects 10 years of maintenance-free service, all at a substantial savings to the taxpayer.

Recycled rubber particles are utilized by Minnesota Mining in making a base for athletic fields, tennis courts, race tracks and track fields. The Savannah River Ecology Laboratory at Aiken, South Carolina is researching the feasibility of using rubber particles to filter mercury from contaminated streams. General Motors Research Center has found that by mixing 10 to 30 percent rubber with proportionate amounts of coal, a desirable fuel is developed with a Btu of 13,500 per pound of mixture. The undesirable hydrocarbons usually associated with the burning of tires reportedly disappear.

A new development that the University of Wisconsin has been involved with may have far reaching effects on the tire disposal problem. A remark in the EPA report aptly points to the direction this development took,

> 'If automotive tires are considered indicative of rubber waste, considerable economics could result if they are crushed or chopped as locally as possible prior to shipment to use points. The average tire occupies 1.3 cubic feet of space but when chopped, only occupies 0.5 cubic feet. More weight may be shipped per vehicle load or stored in any storage area by a factor of approximately 2½ in. to 1 in.'

At the University of Wisconsin, faculty and students are studying various techniques for shattering tires after selecting them to cryogenic temperatures. After this treatment, the hammermill can reduce the original volume of the rubber by 82 percent. Such volume reduction makes transportation of the reclaimed rubber both practical and more economical and stimulates further development of the recycling processes.

Experiments using liquid nitrogen (-319 degrees F) and mechanical refrigeration (-83 degrees F) to lower tire temperatures to -80 degrees F before subjecting them to impacts have resulted in both instantaneous fragmentation of rubber materials and almost complete and automatic separation of wire and cords from rubber materials.

The goal of the University of Wisconsin research team is to develop a portable mill which can be moved from city to city to fragment and separate 30 tires per minute. At this rate each mill could handle 43,000 tires in a 24 hour day. In a 5 day week a single mill could prepare 215,000 tires for recycling. In a year one mill's total would be 10,750,000 tires. At this rate, it would take 20 mills just to keep abreast of the current tire problem allowing no opportunity to begin work on the billions of backlogged tires.

The greatest obstacle to this operation is the need for a ready market for the end products. This would require making use of a half million pounds of rubber, 43,000 pounds of wire and 215,000 pounds of fabric produced every 24 hours be each mill.

The process is effective and efficient; the proper market for the separated materials can make it economical. With the priorities of our country put into proper prospective, wide use of the process can become a reality.

Freezing does not stop with the recycling of the tire. It appears that this is just the beginning. Mr. George, of Liege, Belgium, freezes the entire automobile for recycling. The freezing makes it possible to use less horsepower for the fragmentation and, even more important, aids in separating the nonferrous from the ferrous metals. The freezing technique for the separation of metals in small units such as generators and starters also looks promising as well as profitable. Freezing does not affect the metals such as burning does, therefore, this process produces a high grade of nonferrous metal.

A more recent study at the University of Wisconsin is the removing of insulation from large cables of small diameter wires with cryogenics. In brief, it works beautifully. The insulation was 100% removed leaving only compacted balls of shiny red metal.

Another interesting area in which freezing appears applicable for recycling is that of animals. The University of Wisconsin has done some work in the fragmentation of rats for pet food using the cryogenic technique. It is conceivable that large animals could likewise be processed in a similar manner for possible mink food.

The financial help of a Wisconsin based industry is making it possible for the first portable cryogenic recycler to be built. This unit is being researched, designed and constructed with the help of the University of Wisconsin Physical Science Laboratory, the University Industry Research Group and the College of Engineering. The first unit is expected to be in the field sometime during the last half of 1973. A smaller semi-automatic research unit is available for demonstrations to the public and is located in the Mechanical Engineering Department on the Madison Campus.

It would appear that the cryogenic age is upon us. The surface of its future has only been scratched. It will be interesting to watch the development of many different applications with cryogenics for *Conserving the Future*.