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Project Summary

Chemical Reclamation of Scrap Rubber

G. C. Frazier, S. M. Chan, O. L. Culberson, J. J. Perona, and J. W. Larsen

A conceptual, commercial-scale plant design was formulated for processing 22,500 t/yr of scrap rubber tires to hydrocarbon fuel gases, oils, petrochemicals (principally ethylene and aromatic liquids), and carbon black. The process is based upon molten salt (zinc chloride) pyrolysis of the rubber, and pyrolysis data obtained in a bench-scale flow apparatus. An economic assessment of the plant was made in terms of late 1979 dollars, for ranges in scrap tire costs and prices for the principal products: carbon black and the fuel gases and oil. Profitability at these 1979 costs and prices is somewhat modest by chemical processing industry standards for new processes, but any increases in energy and carbon black prices would cause favorable changes in this assessment.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Interest in the utilization of scrap tires as a source of chemicals, fuel, and carbon black has been increasing in recent years. This rising interest results not only from environmental regulations but also from the increase in the cost of chemicals and fuels based on petroleum and natural gas which grew at rates much greater than the general inflationary trend during the late '70s. Numerous attempts are being made around the industrialized world to recover chemical and fuel values from tires. Most of the current processes being developed for this purpose rely on pyrolysis of the rubber, by one method or another, requiring the heating of the rubber to temperatures in the range of 500-600°C, or above.

Due to the chemical and physical nature of the tire itself, a number of problems are associated with the task of recovering chemicals from the tires. Tires may contain fiberglass and steel wire. The rubber is formulated to be abrasive resistant, so grinding is difficult and intensive energy is required. Because the quality of the main pyrolysis product, carbon black, seemed to deteriorate as the pyrolysis temperature is increased, this project sought to develop a process for recovering chemicals from tires which would have the potential to avoid some of these problems. That is, a process was sought which:

- does not require grinding of the rubber tires in order to avoid associated costs, and minimizes the task of separating wire and fiber particles from the carbon black,
- pyrolyzes the rubber at relatively low temperatures, and
- produces chemicals and carbon black of marketable quality.

A process route which seemed to satisfy these process objectives in bench-scale work was pyrolysis in molten halo salts. Such chemistry had earlier been used to produce hydrocarbons in the gasoline-boiling range from coal by Gorin's group at the Consolidation Coal Co. (now Conoco Coal Research). This work showed that the large coal molecules were rapidly broken into molecules in the gasoline-boiling range. Also, the Consolidation (Conoco) research dealt with one of the major disadvantages of processes of this type—the corrosiveness of the molten salts. Early work also indicated that halo salts would also break rubber into gases, a light oil, and carbon black at temperatures in the range 350-400°C. This project set out to develop the bench-scale data required for the formulation and economic assessment of a conceptual, commercial plant design. The results presented in this report are based exclusively on the use of zinc chloride as the heat transfer and catalytic agent.

Discussion

It is normal practice in the chemical process industries to develop a "conceptual process design" in the early stages of an actual project, in order to identify crucial areas requiring further development, to evaluate various process options which may be available, to assess the overall technical feasibility of the project, and lastly but most importantly, to establish at the outset whether or not the process has the potential for economic profit. The objective of the work reported here has been to obtain the bench-scale experimental data required for the formulation and evaluation of a conceptual process design for the conversion of scrap tires to chemical and fuel products by molten salt pyrolysis, and to use this design as a basis for estimating the potential profitability of the process. Experimental results and the associated economic analysis indicate that such a processing plant converting 22,500 t/yr of tires has the potential for profit at 1979 chemical prices and that energy prices of $3-$5/MM Btu, assuming that carbon black, the major product, is marketable at prices in the range of at least 15 ¢/lb. Although there are a number of process steps requiring demonstration at the pilot plant scale, the biggest unknown in our process is the marketability of the carbon black. A pilot plant is required to generate sufficient quantities of this material for testing its suitability in products such as rubber, ink, and plastics.

Although molten salt technology is not easy, advantages of this process lie in its relatively low operating temperature (in the range of 360-400°C), and in the fact that there is no need to pulverize the tires. However, in this process tires are chopped for compaction purposes, in order to increase the reactor throughput. Further, the relatively large pieces of fiberglass and wire, remaining after the chopping operation, appear to be readily separated from the carbon residue downstream of the reactor. A test of this separability at the pilot plant scale is desirable.

A conceptual, commercial-scale plant for converting scrap rubber tires into hydrocarbon gases, oil and carbon black was formulated and evaluated for its economic potential in terms of late 1979 dollars. The conceptual plant processes 2,500 t/yr of scrap tires (68.5 t/d) to 115 MMSCF/yr of gas, 1.91 MM gal/yr of oil, and 19.9 MM lb/yr of carbon black. The process is of the semi-batch type, with the tires chopped prior to their conversion in the reactor by molten zinc chloride pyrolysis. The economic analysis was based upon "over the fence" sale of oil and gas for recovery of chemical values (both olefin gases, principally ethylene, and aromatic liquids). The remaining gas and oil was assigned fuel values. Carbon black is the principal product in terms of both quantity and economic value at current prices.

The conceptual commercial-scale plant design was developed primarily on a data base generated from a bench-scale experimental setup of the flow type, in a system constructed of 316 stainless steel. Among the data provided by these experiments were the product yields, reactor operating conditions (temperature and molten salt-rubber contact times), salt makeup requirements, and salt reuse data. Suitable reaction temperatures are in the range of 680-752°F (360-400°C).

The primary advantages of this process include:

(a) pyrolysis at moderately low temperatures, due to the catalytic heat transfer action of the molten zinc chloride salt. The carbon black produced in this relatively low temperature range may have special properties, and

(b) the ability to convert the scrap rubber to products of commercial value, without grinding the rubber. This fact not only saves in terms of grinding costs, but also reduces the problem of separating the fiberglass tire cord and steel wire from the carbon black.

A principal disadvantage of this type of process is the corrosiveness of the molten salt, but experience on this project at the bench scale indicates this problem can be overcome.

The economic analysis was based on a total investment of $6.93 MM (including 20 percent working capital), straightline depreciation over an 8-year period, 10 percent interest on total investment, construction over a one-year period, and marketability of all products at late 1979 prices (except for the steel wire and fiberglass, both of which were assigned no value). The profitability of the process depends strongly on the values of the carbon black and of the fuel gases and oil, as well as upon the cost of the scrap, feed tires, and less strongly on the cost of separating (purification) the chemicals from the gas and oil products. The most uncertain parameters in the cost study are the value of the carbon black, the cost of the scrap tires, and the cost of chemical purification. The percent return on investment (ROI) is shown in Table 1 for a selected range in each of these parameters. A plant of this size (22,500 t/yr of tires) is profitable for scrap tire costs in the range of 20 $/t or less and with fuel and carbon black values in the range of 3-5 $/MM Btu and 15-21 ¢/lb, respectively. This margin of profit is probably insufficient to attract venture capital. Fuel and carbon black prices will need to rise considerably for a plant of this size to be profitable, especially if the cost of purchasing and collecting scrap tires should be as high as 40 $/t.

If prices increase in petrochemicals and energy above 1979 levels, improvements can be expected in the profitability numbers given in Table 1 for this process. There may then be sufficient incentive to demonstrate this process at larger scale of operations. It is recommended that provisions for the following tests be included in such a demonstration program:

- Generate sufficient quantity of carbon black for test marketing in products such as rubber, plastics, ink, and activated carbon. The marketability of the carbon black is the greatest uncertainty in this process, and profitability of the plant is strongly tied to the carbon black product and its price.
- Establish the fraction of the carbon black which can be recovered in relatively pure form.
- Establish the effectiveness of the molten salt in the long term, confirm the salt make-up requirements, and establish the fraction of the salt which must be recovered from the reaction residue for recycle to the reactor.
- Establish the efficacy of existing screening technology for separating and dealing with the fiberglass fluff.
- Conduct long-term corrosion testing and generate system maintenance data.

Despite the somewhat marginal profitability picture for this process at this time,

Table 1. *Return on Investment (ROI) for Selected Ranges in the Cost and Product Value Parameters. Plant Capacity = 22,500 t/yr of Tires*

Case	Tire Cost $/t	Purification Cost* %	Fuel/Value $/MM Btu	Carbon Black Value, /lb	ROI, %
A	0	30.	5.0	21.	15.2
B	0	90.	5.0	21.	9.9
C	0	30.	5.0	15.	6.9
D	0	30.	3.0	21.	10.7
E	20.	30.	5.0	21.	11.7
F	20.	90.	5.0	21.	6.4
G	20.	30.	5.0	15.	3.4
H	20.	30.	3.0	21.	7.2

**As a percent of the Chemicals Value.*

favorable trends in the prices of its major products might dictate that the economic potential of this process be reassessed in the future.

George C. Frazier, S. M. Chan, O. L. Culberson, J. J. Perona, and J. W. Larsen are with the University of Tennessee, Knoxville, TN 37916.

***W. W. Liberick** is the EPA Project Officer (see below).*

The complete report, entitled "Chemical Reclamation of Scrap Rubber," (Order No. PB 84-162 718; Cost: $11.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

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