Confirmation of American Combustion Technologies, Inc. Pyrolytic System for Pyrolysis Oil from Tire Feedstock

Doug Smith
April 22, 2010

Abstract The use of pyrolytic combustion to convert feedstocks of used, unwanted, and waste materials to a usable fuel product is a growing industry that derives products with a low to neutral carbon footprint. Operation of a pyrolytic unit designed by American Combustion Technologies, Inc. (ACTI) was viewed at their facility in Paramount, California in operation utilizing ground tire feedstock to make pyrolysis oil, syngas fuels, and carbon material with some metals. Confirmation of the processing and products were reviewed.

Introduction The use of pyrolysis to convert tires to a fuel has been around for quite some time, with economics of low cost fuel being a factor in the growth or lack of growth shall we say. The rubber tire is heated in a reaction chamber in the absence of air, so there is no oxidation of the tire components as they break down. The longer rubber molecules are broken down into shorter hydrocarbon molecules, and other small gaseous molecules.

The products that are given off of the tires are usually within a range of a few +/- percentage points when compared to other similar pyrolysis processes, but the products and quality of the products can vary with the quality of the feedstock used, the temperatures used in the reaction chamber, and the pressures that the process is run at to name the most direct influencing variables.

Many of the pyrolysis systems seen are set up to run at atmospheric conditions, which yields the most common products and percentages. There are some systems that run with a vacuum or negative pressure in the reaction system which can yield a distinct product profile and can have the advantage of preventing a secondary decomposition of the gas product hydrocarbons.

Temperature of the reaction chamber has an influence on the products yielded. The temperature for producing syngas is at a higher temperature around 1250ºF for the gasification of the feedstock. At lower temperatures around 850ºF materials such as the tire feedstocks will begin a self sustaining exothermic reaction producing gaseous material that is carried over and condensed to a liquid fuel.

The products that are produced at the lower temperatures to produce a pyrolysis oil will tend to be in the ranges seen in table 1.

45-50%	Pyro Oils
8-10%	Syngas
30-40%	Carbon Black
9-15%	Steel, Fiber, other metals

Table 1.

The pyro oils produced can then be sent through fractional distillation to separate the various liquid products to enhance their value, or sold as is to refiners for similar or additional processing such as hydro treating. Fractional cuts can be made as simple light, middle, and heavy cuts and directed to the appropriate market. Some selective fractional distillation can separate more high value products out, such a dl-limonene for use as a fuel additive.

The gases produced can be utilized on site for the starting of the reactor portion of the pyrolysis unit, and heating when required to maintain the retort. The gas can be cleaned up for sales to the gas line for a combustion fuel, or if cleaned up to the specifications needed it may be used to power fuel cells for the production of electricity. This electricity can be utilized in house to keep the electrical consumption from the grid very low. If the local electrical grid allows, then the surplus electricity can be sold.

The carbon black produced under the tire pyrolysis oil conditions is of a marketable grade. The carbon black material will have metals and fibers that need to be removed. Processes using hydrochloric acid to wash the carbon black will remove the metals improving the grade of carbon black. Excess heat from the unit or heat from the combustion of the syngas can be used to dry the carbon black.

The hydrochloric acid wash from the carbon black washing will produce a ferrous chloride solution from the steel that is dissolved. This solution has some market value and can add to the profitability of the system.

Process Method The pyrolysis unit and processes used were developed by ACTI, and is designed to convert tire rubber to a liquid fuel, syngas, and carbon black. The system used has five main units, a pyrolytic gasification unit, a wash system for the gases produced, a separation unit to separate the gas and liquid, a gas drying unit, and gas storage unit.

The tires were pretreated by grinding to a size of 20 to 30mm (0.75 to 1.25 inches) and then placed in a receiving hopper above custom designed dual airlocks to prevent the introduction of oxygen into the system. The run being observed started with 38.8 pounds of ground tire. As the ground tires exited the second airlock they enter into feed screw made of 310 stainless steel. The feed screw moves the tire material into the pyrolytic converter at a very low speed. The unit observed operated at a speed of about 1rpm, which gives the tire material a residence time in the retort around 60+ minutes. The ACTI system is designed to give a residence time of 65 minutes to establish a complete conversion of all gasification matter. However the system design by ACTI is made to have a variable speed control, so depending on feedstock and the quality of the feedstock the screw conveyor speed can be adjusted. This adds to the flexibility of the unit by design.

The temperature of the reaction area was set at 850ºF and stayed at that temperature with only an occasional firing from the burners to help maintain an even heat. The burners were set at a high and low temperature acceptance and the electronic controls did maintain that preset temperature as designed. In general the reaction ran 95+ percent of the time on its on generated heat. This supports the claim that the heating system becomes self sustaining due to the heats of formation.

The system is operated at a slight negative pressure of about -0.50 inches during the entire process. The pressure is regulated by a transducer that monitors the pressure and either speeds up or slows down the blower motor to maintain the pressure. It also acts to give a margin of safety in the event that oxygen was to enter the retort and cause any over pressure conditions. As a side effect the carbon black has some activation due to this setting.

The gases exiting were measured at around 650ºF as they were sent through a venturi separator wash phase. This venturi facilitates the removal of any carbon particulates from the gas that may have been carried over. Secondly it helps to condense the heavy portion of the products coming over as a gas to a liquid product.

It should be noted that the wash liquid used in the spray system should be clean to prevent nozzle clogging and therefore should be filtered to prevent clogging and then cooled below 170ºF, via a heat exchanger, before utilizing for the washing process.

These heavy condensed liquids are moved to a holding tank by a level controlled valve opening at a preset level. The heavy liquids that are condensed in the venturi account for about 25% of the condensable liquids that are coming over from the reaction chamber. The lighter condensable products were carried by the gas through a large condenser to condense the remaining condensable products to the liquid phase. The lighter condensed products were then pumped to a holding tank. These lighter condensable products accounted for about 75% of the condensable gaseous matter that comes from the retort.

The remaining gases without any condensable products were sent through a demister to make sure that no other condensable products are remaining. The gases travel to an intermediate holding tank via the gas blowers, and then compressed for a storage tank. At this point the gas product can be utilized in the continuation of the reaction in the retort or channeled to make either heat for steam power and or electricity generation.

The lower screw conveyor at the bottom of the heating chamber is designed the same as the upper feed screw conveyor. It has the same slow 1rpm speed and carries the solid matter that is not converted to a gas via the pyrolysis process. The solids are conveyed out the bottom through two of the ACTI designed airlocks and dropped into a holding container. This carbon black material still contains any metals that might be used in the manufacturing of the tire. The carbon solids that were recovered from the unit accounted for about 45-50% of the beginning material with about 7-10% being metals, mainly steel. In another process with the steel removed the carbon black would account for 35-40% of the mass.

ACTI has a process for washing the carbon black to remove the metals. The process involves a hydrochloric acid solution wash, which is very aggressive in dissolving inorganic materials such as metals. The process would produce a solution of ferrous chloride, which has some marketability. Depending on the buyer, the ferrous chloride solution can be controlled by the addition of scrap iron to increase the ferrous chloride percentage or Normality as desired by the buyer. This process was not observed on site the day of the tire combustion, but carbon black products of the said process were observed and appeared to have the quality of carbon black that I have utilized in the chemical processing of oleo chemicals.

Other inorganic impurities will also be found in the solid material recovered. Some of these will be zinc oxide, some calcium, silicon, and other trace inorganic matter. These other inorganic will also be removed effectively by the hydrochloric wash.

ACTI claims that there is a removal of 99.99% of the inorganic matter from the carbon black material. Chemically this is sound, but is dependent on the strength of the hydrochloric solution, temperature of the wash operation, and the residence time of the acid solution on the carbon black material. This process would need to be monitored for the above mentioned variables, as well as the testing of the carbon black material to ensure that it will meet the marketable specifications or the customer chosen.

Figure 2 will give you an idea of the flow of the design.

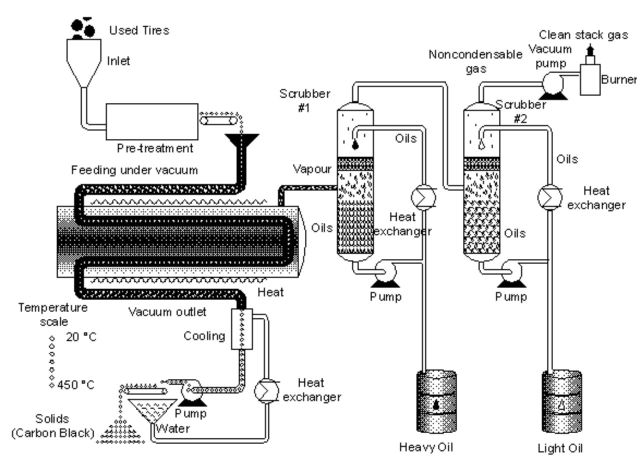

Fig. 2 Schematic of the Process Development Unit

The design of the unit, by ACTI, observed was designed with the following parameters listed in Table 2.

Table 2.

Input	
Capacity	500 lbs/hr
Mass Flow	500 lbs/hr
Output	
Liquid Fuel	225 lbs/hr
Carbon Black	185 lbs/hr
Gas	40 lbs/hr
Metals	50 lbs/hr
Purified Products	
Oil	29.6 gal/hr
Pure Carbon	166 lbs/hr
Power consumption	
Power usage	40 kwhr average
Required inlet	60 kwhr

Results The products that were recovered had a similar percentage that would be expected from the tire pyrolysis as has been documented by other companies and universities. The percentages in Table 3 were derived by a weight percent method and numbers were rounded to the nearest percentage.

Table 3.

Pyrolysis Product Distribution	
Pyro Gas	8.00%
Pyro Oil	46.00%
Carbon Black	40.00%
Steel and other matter	6.00%
Total	100.00%
Pyro-Gas in Pyro Gas Oil	15.00%
Pyro-Oil in Pyro-Gas Oil	85.00%

The analysis of the gas products were run by a third party lab retained by ACTI. The analysis can be seen in Table 4.

Table 4.

Pyro Gas Analysis	
	Mole %
(H_2) Hydrogen	14.60%
(CO_2) Carbon Dioxide	7.84%
(C_2H_4) Ethylene	8.07%
(C_2H_6) Ethane	7.62%
(CH_4) Methane	31.17%
(CO) Carbon Monoxide	3.59%
C_3+, as C_4H_{10}, others	27.11%
Total	100.00%

The analysis that was conducted on the pyro oil products were conducted by the ACTI laboratory on their gas chromatograph equipment, and the results can be seen in Table5.

Table 5.

Pyro Oil Analysis	
	Weight %
(C_5H_{12}) n-Pentane	1.75%
(C_6H_{14}) n-Hexane	3.25%
(C_7H_{16}) n-Heptane	7.25%
(C_6H_6) Benzene	9.50%
(C_7H_8)Toluene	9.50%
(C_8H_{10})Ethyl Benzene	7.50%
(C_8H_{10}) Xylene	8.00%
(C_8H_8) Styrene	10.50%
(C_9H_{20}) Nonane	2.00%
($C_{10}H_{22}$) Decane	2.75%
($C_{10}H_{16}$) Limonene	13.30%
($C_{11}H_{24}$) Undecane	4.00%
($C_{10}H_8$) Napthelene	1.00%
($C_{11}H_{10}$)Methyl Napthelene	3.00%
($C_{12}H_{26}$) Dodecane	3.00%
($C_{13}H_{28}$) Tridecane	4.00%
($C_{14}H_{10}$)	2.70%
Wax, as C_{19}	7.00%
Total	100.00%

The oil products that were tested for boiling point for classification as flammable, combustible, or heavy fuels. The percentages are listed in Table 6 as to the products boiling point.

Table 6.

Percentages of Oil Products by BP	
	Weight %
Pyro oil with bp <180C	75.30%
Pyro oil with bp>180C	24.70%
Pyro oil with bp >250C	9.70%
Pyro oil with bp <150C	59.25%

Conclusions and Discussion I have had the opportunity to observe the pyrolysis unit at ACTI facility in Paramount, California on multiple occasions. Each occasion was to observe the pyrolysis of different feedstocks as well as tires. Each time I have watched the unit operate it has functioned just as ACTI had stated it would, and I have to date to see any malfunctions with the unit or the design. I have seen this unit used to make pyro oil from tires with and without water in the feedstock, which has an effect on the amounts of aromatic compounds there are in the light fuels, to being used solely for the use of syngas production at the higher temperatures. The same unit has run tires at 850ºF and other feedstocks at 1250ºF, which demonstrates the robust construction and the flexibility that is built into the design. This flexibility makes the unit very useful if the economics and markets change allowing the use of different feedstocks to be used, and to determine what type of product that you need to make, either liquid or gas.

Based on observations and data received thus far, this unit by ACTI does do what they state it can do. With that said the product output and operational costs will vary with the quality of the feedstocks used in the process, the parameters that the unit is operated at and the location the unit is set in. Control of the feedstocks used is a controllable factor by the operating company, as well as the parameters of the unit while in process mode. And, these should be reviewed and adjusted as the feedstocks arrive or if suppliers change. The site where the unit will be operated will dictate the operational costs such as labor and electrical costs. These above variables are outside the scope of this review, but will determine if the unit is run successfully or not.

Author Background

BS Chemistry
BAS Business and Finance
AAS Industrial Management
22 years in Oleo Chemicals Production and Design, 18 of which were in Biofuels production and Design
Certified Hazardous Materials Manager
Registered Environmental Manager
ASTM D02 Petroleum Fuels Committee Member
Governing Board Member of National Biodiesel Board

References

1. Materials from American Combustion Technologies, Inc., Paramount, California, as supplied by Latif Mahjoob.
2. "Vacuum Pyrolysis of Used Tires", C.Roy, h.Darmstadt, B.Benallal, A. Chaala, and A.E. Schwerdtferger, Departement de Genie Chimique, Universite Laval, Quebec, Canada G1K7P4, May 1995.
3. "Pyrolysis Oil", Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/wiki/Pyrolysis_oil .
4. "Factors Influencing the Quality of Pyrolytic Oil from Used Tires", Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, Volume 30, Issue 9, June 2008, pp 833-841.Q.Cao, L.E. Jin, W.R.Bao, Y.K. Lu, Taylor& Francis Group publisher.
5. "Pyrolysis of Scrap Tires: Can it be Profitable?", Marek A. Wojtowicz, Michael A. Serio, Marketplace section, Chemtech, October 1996.
6. Organic Chemistry, John McMurry Cornell University, Fourth Edition, Brooks/Cole Publishing Company, 1996.