EPF

Zadgaonkars'
Eco-friendly Plastic Fuel

Conversion of Waste Plastic into Liquid Hydrocarbons / Energy

A major breakthrough in the arena Of Non-conventional sources of energy!

Information Brochure
And
Technical Write-Up

Prof. Mrs. Alka Zadgaonkar
Asst. Professor & Head, Dept. of Applied Chemistry,
G. H. Raisoni College of Engineering, Nagpur.

Contact:
9, Buty Lay-out, R.P.T.S. Road, Laxminagar, Nagpur-440 022
09370120111, 09373104991
auzchem@yahoo.com , umeshz@yahoo.com

Table of Contents:
(Press Ctrl + click the topic to go directly to a specific location)

1. Introduction
1.1 Review

Prof. Mrs. Alka Umesh Zadgaonkar, Head of Department of Applied Chemistry at the Nagpur based G.H. Raisoni College of Engineering invented an Environment friendly catalytic process for disposal of waste plastic. The application for the patent has been filed.

The invented process involves degradation waste plastic using `catalytic-additive' and is different from the generally existing pyrolytic processes. The laboratory scale set-up was developed in batch mode in which individual as well as mixed plastics were successfully converted in to fuels. The products obtained in the process are Liquid hydrocarbons, Gas and residual Coke.

INDIAN OIL CORPORATION LIMITIED (RESEARCH & DEVELOPMENT CENTRE) evaluated the process, tested the products and submitted the report to MOP&NG in the month of March 2003. In order to promote research in this area, a MOU was signed on 16th June 03 between IOC (R&D) and Prof Mrs. Alka Umesh Zadgaonkar & Dr. Umesh Zadgaonkar for optimization of process, upgradation of product, design & development of demonstration plant and economic analysis of demonstration plant. Subsequently, experiments were conducted at IOC (R&D) with the objectives to establish the material balance, product quality and to develop the specific areas of improvement, if necessary. Also a report was prepared based on their experiments and detailed product analysis. The Inventor, Prof. Mrs. Alka Zadgaonkar et al and IOC (R&D) have jointly applied for two more patents.

After spending sufficient time with Government and other authorities at New Delhi, inventor felt that this novel invention cannot be materialized just by depending on government and grant.

With complete faith on techno-economical feasibility of the invention, inventor decided to go ahead on her own and approached the biggest banker of India i.e. State Bank of India for financial assistance for first commercial plant based on the invented technology.

After analyzing and scrutinizing the proposal by two different groups viz. 1) Technical 2) Financial, State Bank of India has offered financial assistance for the commercial venture. Erection work of the commercial plant is completed and trials undertaken are also successful as far as quantitative and qualitative parameters are concerned.

1.2 Waste Plastic Disposal: A Grave Problem

- **International status**

Waste plastic problem is an ever-increasing menace for global environment. Because of flexibility, durability and economy, a phenomenal rise is observed in the plastic consumer base. Throughout the world, research on waste plastic management is being carried out at war-footing. In developed countries, few waste plastic disposal / conversion methods have been implemented but are not efficient and economically feasible.

Plastics being non biodegradable get accumulated in the environment. If this problem is not addressed properly, it will lead to mountains of waste plastic. Environment protection Agency U.K. estimates that by the year 2005 the amount of waste plastic throw will be 65% more than that in year 1997.

India has been a favored dumping ground for plastic wastes, mostly from industrialized countries like Canada, Denmark, Germany, UK, the Netherlands, Japan, France and the United States. According to the Government of India import data, more than 59,000 tons and 61,000 tons of plastic waste have found its way into India in the years 1999 and 2000 respectively. (Source: Statistics of Foreign Trade of India. March 2000 and March 2001. DGFT, Government of India).

More than 100 million tons of plastic is produced worldwide each year. Though plastics have opened the way for a plethora of new inventions and devices it has also ended up clogging the drains and becoming a health hazard.

India is the fourth highest Asian importer of plastic waste.

Country	**No. of Shipments**	**Total (kg)**
Hong Kong	586	1,71,37,118.00
Philippines	58	24,45,200.00
Indonesia	50	22,48,443.00
India	**11**	**9,98,046.00**
Malaysia	7	2,54,935.00
China	6	95,746.00
Taiwan	6	1,56,453.00
Thailand	6	1,23,974.00
Korea	6	1,09,807.00
Japan	5	51,210.00
Singapore	6	71,437.00
Total	**747**	**23,692,369.00**

- **Current status of technology in country**

According to a nation wide survey, conducted in the year 2003, more than 10,000 MT of plastic waste is generated daily in our country, and only 40 wt% of the same is recycled, balance 60 wt% is not possible to dispose off (Reference `The Hindu' dated 25/09/03 and Central Pollution Control Board Study, 2003)

Plastic waste contributes to the solid waste streams by about 8% - 15% by weight and twice that by Volume (GOI 1997). It is projected that annual post-consumer plastic waste will reach 3.6 million tons by the year 2005-2006. At these alarming levels of waste generation, India needs to prepare a lot in recycling and disposing the waste. Several processes and means have been attempted to fight against the alarming levels of waste generation. However each process had its drawbacks and operational, economical & financial limitations for practical implementation.

A large proportion of sheeting materials and molded parts, etc is left out by rag pickers. The small bags /moldings are soiled and are difficult to identify. Also they have no value as recycle feed stocks. These un-utilized waste plastic remain uncollected and spread everywhere, littered in open drains or in garbage dumps, often resulting in choking of municipal sewers and storm water drains. Thus the balance 40 wt% gradually goes on accumulating, thereby leading to:

- Serious environmental problem
- Disposal problems
- Wastage and non utilization of high energy material

In this direction, for the first time in the country, Prof. Mrs. Alka Umesh Zadgaonkar, Nagpur and her team have done significant work to dispose waste plastic material and thereby convert it into hydrocarbons.

1.3 Fuel / Energy Shortage

On the other hand, our country faces the critical problem of fuel and energy deficiency. The fast depletion of petroleum reserves in the world and frequent rise in prices of crude oil affect our economy adversely. India is not self sufficient in case of petroleum and crude oil. The national production capacity is capable of fulfilling not even 30% of the total fuel demand. **The remaining whooping 70% is fulfilled by importing crude.** Most of our precious foreign exchange is spent on importing crude.

Case Study:

Calculation of oil consumption

Crude Oil Consumption in India		115	MMTPA
Crude Imported	80%	92	MMTPA
Waste plastic generated in India (excluding almost equal amount of imported Waste dumped in India)		10000	MT/day
	i.e.	3,650,000.00	MT/annum
	i.e.	3,650,000,000.00	Kg/annum
Liquid Hydrocarbons obtained in the invented process	100% W/V	3,650,000.00	Kilo-litre/ annum
	i.e.	3,650,000,000.00	
Quantity of crude that can be replaced by the output of the Zadgaonkars' Process (Assumption: Only the Waste Plastic generated in India is processed.)		10,950,000.00	Kilo-litre /annum
	i.e.	10,950,000,000.00	Litres /annum
	i.e.	54,750,000.00	Barrels/annum
Average rate of crude oil		*44 USD per Barrel	
Saving on Foreign Currency		2,409,000,000.00	USD
	i.e.	110,814,000,000.00	Indian Rupees

*Current Average rate of crude oil is 60 USD

It is important to note that India generates just 2% of the Global waste.

Similarly India faces Power deficiency also.

2. Alternative Waste Disposal Methods

2.1 Land Filling

Waste Plastic materials are dumped for land-filling and they become "mummified" after decades. It is worth mentioning that the plastic is not a bio-degradable material hence this leads to the soil contamination and in long term serves as a cause of severe environmental hazard such as degradation of soil fertility, pollution of surface & subsoil water. Besides the above drawbacks, the embodied energy present in the plastic is lost.

2.2 Incineration

It is possible to incinerate mixed plastics to recover energy. However it is not possible to do so in a controlled manner to reduce off-gas pollution i.e. dioxins & fleuron to desirable standards. Hence this method of plastic waste management is generally not preferred. The treatment cost of the gases is often more than the energy recovered.

2.3 Blast furnace

Waste plastic may be used in place of coke and pulverized coal after forming into particles of the required size and subsequently injected into the blast furnace. The injected plastic is broken down to form reducer gas ($CO + H_2$), which rises through the raw material in the furnace and reacts with the iron ore. The injection of chlorine-contained plastics such as PVC in the blast furnace generates hydrogen chloride. The limestone used in the blast furnace to control the composition of the slag neutralizes the hydrogen chloride in the furnace and decrease its concentration. But substitution of coke with plastic is limited to approximately 40% wt only. (Ref: Shutov F. "Effective energy and gas emission saving using plastic waste recycling technologies", Expert group meeting, 2-3/ Dec /1999, Vienna international center, Vienna, Austria)

2.4 Gasification

Gasification is essentially thermal decomposition of organic matter under inert atmospheric conditions or in a limited supply of air. If the feed contains chlorinated compound like PVC then it is advisable to do gasification at lower temperature to remove chlorine then the temperature is raised to convert higher hydrocarbons. There are problems in controlling the combustion temperature and the quantity of unburned gases. (Reference US Patent Application No. 20030037714).

2.5 Recycling

Recycling is not the complete solution for disposal of the waste plastic. After third/fourth recycling the plastic is totally unfit for reuse and hence ultimately it ends up in Land filling. Some types of the plastics are not suitable for recycling. However, this method is only suitable for processing segregated plastic materials and is not suitable for assorted municipal waste plastic.

The problems associated with the recycling process are as follows:

- Many types of plastics are used hence it is difficult to segregate them for specific purpose.
- Plastics contain a wide range of fillers & additives.
- Many times plastic is associated with metal, Glass etc.
- Sorting of plastic is technically difficult as well as expensive.
- Recycling of plastic degrades the quality of the end product

3. The Invention: Zadgaonkars' Process

3.1 Introduction

- Principals involved

All plastics are polymers mostly containing carbon and hydrogen and few other elements like chlorine, nitrogen etc. polymers are made up of small molecules called as monomers which combine and form single large molecule called polymer.

When this long chain of monomers breaks at certain points or when lower molecular weight fractions are formed this is termed as degradation of polymer. This is reverse of polymerization. If such scission of bonds occurs randomly it is called as 'Random De-Polymerization'.

In the process of conversion of waste plastic into fuels random De-Polymerization is carried out in a specially designed Reactor in absence of oxygen & in the presence of coal and certain catalytic additive. The maximum reaction temperature is 350°C. There is **Total** conversion of waste plastic into value added fuel products.

3.2 Laboratory Scale / Bench Scale

Inventor Prof. Mrs. Alka Zadgaonkar started the basic research work for elimination of polymer waste in the year 1995. After five years of rigorous research, in the year 2000, 300 gm of plastic waste was successfully converted into liquid hydrocarbons. The reaction parameters viz. temperature, pressure and time for a batch were extremely high in initial stages. Subsequently these parameters were brought down to feasible level by formulating improved catalytic additives.

Inventor was quite aware of the fact that many laboratory scale inventions miserably failed after scaling up. Considering this important fact, inventor decided to scale up the lab-scale unit by 100 times and thus 30 Kg bench scale apparatus was designed.
The Bench Scale Batch Process set-up :

The equipment was upgraded and designed with the controls, feed back and data generation devices for 30 kg of mixed waste plastic as batch feed, which could be conveniently operated in a laboratory setup. A number of experiments were carried out on this set up and the data generated was analyzed for further development. Assorted plastics and coal along with catalyst is heated to about 400 ^{0}C and distilled products are collected.

The brief description of the equipment is as follows-

SN	Particulars	Description
01	Reactor	This is an insulated stainless steel cylindrical reactor heated by electrical heating coils to achieve a maximum heating temperature of 500 ^{0}C. The necessary provision is made on the reactor for mounting the gadgets for measuring pressure, temperature and collection of hydrocarbons from the reactor.
02	Condenser	The gaseous output from the reactor is passed through a double walled condenser with inlets and outlets for cooling water. The gaseous hydrocarbons at a temperature of around 350 ^{0}C are condensed to around 30-35 ^{0}C.
03	Receiver	The condensed hydrocarbon in the liquid form is collected in the receiver. The provision is made for collecting the uncondensed gases in to gas collector. The arrangement to measure the volume & rate of flow of distillate continuously or intermittently at any point of time is made in this section.
04	Control Panel	The complete process is controlled from the control panel. Optionally the process can also be controlled from a Computer. The continuous feed back of the process parameters is available on the Control Panel and the Computer. The data generated is stored in the computer.

3.3 Output Yield Data

The major process parameters and product yields are given in Table below. The evolved vapors are condensed to collect gas and liquid products.

Feed	Assorted waste plastic
Catalyst	1 wt% on feed
Coal	10 wt% on feed
Temperature	300-400 ^{0}C
Pressure	Atmospheric
Batch cycle time	3-4 hrs
The product yields	**Quantity (wt%)**
Gas	10-20
Liquid hydrocarbons	60-80
Residue	7-10

Typical analysis of the gaseous product is given in the following table-

S.N.	Component	Quantity
1.	Methane	6.6 % wt
2.	Ethane+ethylene	10.6 "
3.	Propane	7.4 "
4.	Propylene	29.1 "
5.	Iso-butane	1.9 "
6.	n-Butane	0.9 "
7.	C4 (unsaturated)	25.6 "
8.	Iso C5-n-C5	0.1 "
9.	C5+higher	15.3 "
10.	Hydrogen	2.5 "
11.	CO/CO2	< 400 ppm

NB: The gas analysis was done after removal of chlorine as HCl

Typical analysis of the liquid product is given in the following table

Sr.No	Carbon number	Quantity (wt%)
1	Upto C10	61.0
2	C10 to C13	2.4
3	C13 to C16	8.5
4	C16 to C20	4.1
5	C20 to C23	7.6
6	C23 to C30	16.4

3.4 Certified Observations and Conclusions from Indian Oil Corporation (R&D Centre)

Following are the major observations and conclusions from the experiments by INDIAN OIL CORPORATION LIMITIED (RESEARCH & DEVELOPMENT CENTRE)-

- All the types of plastic waste including PVC & PET are converted into gases & liquid hydrocarbons.
- The catalyst enhances the conversion of waste plastic in to hydrocarbons thereby improving quality & quantity of hydrocarbon gas and liquid products. Negligible Conversion was observed in absence of invented catalytic additives
- Increase in the temperature and rate of heating increases the gas yield.
- Introduction of feed at higher temperature substantially reduces the process cycle time.
- Water from wet gas meter indicates presence of HCl in the gaseous fraction.
- Inorganic Chlorine is present in the gas and liquid products.

- **PET bottles as a feed material** – Analytical results of experiments using 100% PET bottles show that yield of liquid hydrocarbon is 60 wt%. There was no formation of carboxylic group. This confirms that it is possible to convert the PET material in to liquid hydrocarbon under the catalytic conditions of the developed process.

- **PVC as a feed material** – Effect of catalytic conversion of pure PVC have been studied and the data shows the liquid yield of about 40 wt%. Further experiments were conducted for removal of chlorine from these products. Here de-chlorination step was incorporated prior to reaction step. It was observed that about 55% weight reduction after removal of Chlorine from the PVC.

4. Commercial Scale 5 MT Per Day Capacity Plant

4.1 Introduction

The lab-scale and the bench-scale units were of Batch Process type. Hence after successfully scaling up the technology, inventor decided to harness the advantages of a continuous process. The 5 MT commercial plant is successfully setup at:
K-13, Butibori MIDC Industrial Area,
Wardha Road, Nagpur.

4.2 Implementation Map

The following table shows the roadmap of the targeted Schedule for construction and implementation of 5 MT per day capacity plant.

<table>
<tr><th colspan="14">Project Implementation Schedule</th></tr>
<tr><th colspan="2"></th><th colspan="12">Number of Months</th></tr>
<tr><td>S.N.</td><td>Description</td><td>01</td><td>02</td><td>03</td><td>04</td><td>05</td><td>06</td><td>07</td><td>08</td><td>09</td><td>10</td><td>11</td><td>12</td></tr>
<tr><td>i.</td><td>Detail Engineering</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>a</td><td>Process</td><td colspan="3">***************</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>b</td><td>Mechanical Engineering</td><td></td><td colspan="5">*********************************</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>c</td><td>Piping</td><td></td><td></td><td></td><td colspan="4">************************</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>d</td><td>Electrical</td><td></td><td></td><td></td><td colspan="4">************************</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>e</td><td>Instrumentation</td><td></td><td></td><td></td><td></td><td colspan="4">***********************</td><td></td><td></td><td></td><td></td></tr>
<tr><td>f</td><td>Civil & Architectural</td><td></td><td colspan="6">***************************************</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>ii.</td><td>Procurement</td><td></td><td colspan="9">***</td><td></td><td></td></tr>
<tr><td>iii.</td><td>Site Preparation & Construction</td><td></td><td></td><td colspan="8">***</td><td></td><td></td></tr>
<tr><td>iv.</td><td>Installation/Erection</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">*******************</td><td></td></tr>
<tr><td>v.</td><td>Trial Runs / Commissioning</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">*********************</td></tr>
</table>

It is important to note that all the 5 steps indicated in the above chart have been completed by the 09th month i.e. 3 months in advance

4.3 The Process

The subject system is designed indigenously using modular concept for providing flexibility in operations and production. The process is flexible enough to design the end products on-line without changing the feed design. The process is designed for the Waste Plastic sourced from the Municipal Waste stream with a factor of variation at 5.0 % to 10.0 % for normal feed. The process is also suitable for a dedicated feed if required. The process modules, which house the equipment, components, process sensors piping & valves, are designed as follows –

S N	**PARTICULARS**	**DESCRIPTION**	**VOLUME** (lXbXh mt)
01	Feed	Sizing and Feeding	5.0 X 7.5 X 6.0
02	Melting	Removing metallic solids etc.	4.5 X 4.5 X 2.5
03	Reactor	Reacting additives and catalysts	4.5 X 4.5 X 2.5
04	Hydrogenation	Stabilizing the hydrocarbons	4.5 X 4.5 X 2.5
05	Final Product (liq. Hydrocarbon)	Collecting mixed hydrocarbons	5.0 X 7.5 X 6.0

The placement of sections is kept sequential for the convenience of plant operation, process flow and plant layout practices.

4.4 Plant Assembly

- **Feed System**

Feed system consists of sizing equipments for sizing hard, thick flexible and thin flexible materials, which normally constitutes the municipal waste stream. The system essentially consist sorters and sizing equipment like of Crusher, Cutter and Shredder. The various sizes and shapes of the material are sorted into categories suitable for Crushing, Cutting and Shredding. The sorted material is crushed or cut or shredded and graded in to uniform size for ease of handling and melting in the melting/preheating. This process of sizing and grading the waste is semi automatic. The graded feed is stored in a hopper before feeding to the process by a conveyor feeder. The sorted feedstock of known composition is stored separately for proportionate feeding for processing nonstandard feed design or processing special feed designs.

The dust and other fine waste collected from the cyclone filter are disposed through a vent with particle size monitoring system.

Section Specifications: Feeder

Materials of construction	M.S. & SS-316
Waste Plastic Sizing rate	250 kg/hr (consolidated)
Waste material feed rate	200 kg/hr
Pressure	0.0 kg/cm^2
Temperature	10-45 ^{O}C

- **Pre-melting / Feeder**

The graded and air washed particles of Waste Plastic are then introduced into a Melting Vessel through a feeder. The feeder consists of a collecting hopper, driving motor, extruder barrel, screw conveyor, electric heater and control panel. The granular crushed/cut/shredded waste plastic melts and injected in the melting vessel.

- **Melter**

In melter vessel, the feed is heated to 275^0C - 410^0C. The extraneous impurities such as hard metal, clay, sand, glass etc. settles in the bottom of the melter, which will be removed on periodic basis. In future the heating required for the melting of waste plastic shall be provide by the gaseous fuel generated from the plant.

Section Specifications: Melter and De-chlorinator

Materials of construction	SS-316 lined with Duran/Pyrex glass
Feed rate	200 kg/hr
Vessel Pressure	0.0 –1.0 kg/cm^2
Temperature vessel	275 °C
Pre-Melter Extruder	100 kg/cm^2
Process Products	
Gaseous HCl, and other gasses (Hydrocarbons)	20 – 30 kg/hr
Molten Plastic Sludge	150-190 kg/hr
Metals and other extraneous impurities	3.0-5.0 kg/hr
Energy (Electrical Form)	4.0 kW
LPG	20.0-25.0 kg/hr
By product gas	10.0-15.0 kg/hr
Melting Vessel Size	2.0m X 0.6m dia
Material holding time	30 min

- **De-chlorinator**

The molten plastic sample will be drawn from the overflow end of melter vessel to De-chlorinator. Here the waste plastic is heated with catalytic additive which helps in removal of chlorine. The gaseous products from the molten plastic shall be subjected to separation of HCl gas. HCl gas is separated by absorption in a water column. The hydrocarbons free from

HCl shall be used for heating purpose. The samples for analytical testing shall be drawn from the water column for checking the presence of HCl in the gases. The sample of molten plastic is taken out for analytical testing of chlorine content of the plastic, accordingly the quantity of scavenger is added to the reactor vessel, before subjecting to Depolymerisation

- **Reactor Section**

The reactor section of the plant consists of the reactor, which together with other equipment constitutes a continuous conversion of waste plastic in to hydrocarbons. The molten waste plastic free of chlorine, nitrogen and other organic impurities is fed in to the reactor and allowed to flow over a heated surface at 300 - 350 ^{O}C in the presence of the coal and patented additives. A small amount of Calcium Hydroxide is also added in this reactor if the molten plastic contains chlorine compounds.

The breaking of chemical bonds under the influence of heat is the result of overcoming bond dissociation energies. Organic substances such as polymers are highly heat sensitive due to the limited strength of the covalent bonds that make up their structures. Scission can occur either randomly or by a chain-end process, often referred to as an unzipping reaction.

The reaction breaks complex hydrocarbons into simpler molecules in order to increase the quality and quantity of lighter, more desirable products and decrease the amount of residuals. All the reaction equipment and interconnecting transfer lines are heated. The heat is supplied in a number of individually controlled heating zones.

Section Specifications: Reactor Section

Materials of construction	SS-316/310
Waste material feed rate	150-190 kg/hr
Temperature	300-350 °C
Pressure	
Reactor vessel	0.0 to 1.0 kg/cm^2
Pre-Reactor extruder	50-100 kg/cm^2
Process Products	
Gaseous Hydrocarbons	148-185 kg/hr
Coke	12-16 kg/hr
Calcium Chloride	5.0-7.0 kg/hr
Others	4-5 kg/hr
Energy Electrical	50-60 kW
Melting Vessel Size	2.0m X 0.6m dia
Material holding time	30 min

- **Hydrogenation**

The gaseous unsaturated hydrocarbons are treated with the hydrogen under pressure at 20-25 kg/cm^2 and 200-300 ^{0}C temperature in a small reactor.

- *Sectional Specifications:* Hydrogenation

Materials of construction	SS-316/310	
Waste material feed rate	148-185	kg/hr
Vessel Pressure	20-25	kg/cm^2
Temperature	200-300	^{O}C
Process Products		
Gaseous Hydrocarbons	198-340	kg/hr
Energy LPG	20.0-25.0	kg/hr
Byproduct gas	10.0-15.0	kg/hr
Melting Vessel Size	160cm X 20cm dia	
LHSV	5/hr	

- **Final Product (Liquid Hydrocarbon Storage)**

The condensed fractions are collected here and the uncondensed gases are colleted and stored separately which can be used for heating requirements of the vessels.

Sectional Specifications: Liquid Hydrocarbon Storage

Materials of construction	SS-316	
Feed rate	110-185	kg/hr
Pressure	0.0	kg/cm^2
Temperature	30	^{O}C

4.5 Planned Control System

The COMPUTER CONTROL UNIT supervises the functioning of

a) Smooth Operation of Plant
b) Safety Management
c) Co-ordination and Control
d) Intelligent monitoring and Energy Saving

The control system consists of a control station interface electronics, supervisory control and data acquisition software. 1 kVA, on line, Un-interrupted Power Supply (UPS), with 30 minutes backup. The control station shall be IBM compatible PCAT , P-IV, 40 GB hard disk, VGA colour monitor. The control station is loaded with DOS based Supervisory control and Data Acquisition (SCADA) software. The parameters, which are to be monitored/controlled through computer, will be displayed on CRT and values of set point, auto/manual selection, direct/reverse action selection, engineering units can also e changed through the computer. The interface electronics consists of programmable logic controller (Allen Bradley) or Equivalent). The signal from the field will be accepted by interface electronics.

The input/output cards of the programmable logic controller carry out signal conditioning of the field signals and pass on the data to the CPU of the programmable logic controller. The PID algorithm, interlock logic sequencing etc is carried out by the PLC. The supervisory PC is loaded with DOS – based SCADA software which reads the data from PLC and displays it.

The SCADA software enables the operator to monitor and control the process enable/disable alarm action, change the loop set-points and effect the auto-manual and direct-reverse actions. All the parameters for the unit are provided with real-time trends. For Historical time trending, minimum/maximum/average points values can be logged. There is practically no limitation on the number of tags that can be trended.

However, maximum history days are limited by the PC disk capacity. A versatile alarm management system is available through which multi-level alarms can be generated. As many as 300 alarm points can be made available as history. In addition to the above, the following advanced features are also provided through the software-

a) free format script driver reporting support
b) event/conditional reporting
c) alarm logging
d) operational diagnostics
e) access levels definition
f) calculations based on any of the I/O points
g) fault reporting which is on great help for the preventive Maintenance activity.

4.6 Salient Features

a) Generally the municipal plastic waste contains about 3-5 wt% PVC, 5-8 wt% PET, 15-20 wt% PP, 20-25 wt% LDPE, 15-20 wt%, HDPE 10-15 wt%, 7-10 wt% of ABS, Nylon, etc. (Reference – P Vasudevan, Seminar on Recycling & Management of Plastic Waste, Maa Amrita Institute of Technology, Coimbtore). The product output product does not change either qualitatively or quantitatively irrespective of any input changes or proportions.

b) Batch Process has been successfully converted into Continuous Process.

c) Effects of feed variation collected from municipal waste have been studied and offers a complete solution for Waste Plastic disposal.

d) Improvement in product quality from variety of feed generated from municipal plastic waste has been achieved.

e) Optimisation of process parameters have been identified.

f) Generation of reliable design data for 500 MT Waste Plastic per day capacity plant using municipal plastic waste is ready.

4.7 Benefits to the Nation

- This Invention shall lead to the development of simple and economically viable technology for environment friendly disposal of waste plastic.

- **The developed technology will prove to be beneficial to the country for the purpose of catering increasing demand of fuel / energy and will save millions of foreign exchange.**

- With the experience gained from the demonstration plant, full-scale unit could be designed with confidence and it is expected that such plant shall be self-sustaining without any penalty for processing the hazardous plastic waste.

- This technology could be implemented in the various places of our country especially in **PURA** concept.

5. Test Reports

a. Comparative Data of various chemical properties of Regular Petrol and Fuels extracted from plastic

	Regular Gasoline	Fuel Extracted from Plastic Waste
Colour, Visual	Orange	Pale Yellow
Specific Gravity at 28°C	0.7423	0.7254
Specific Gravity at 15°C	0.7528	0.7365
Gross Calorific Value	11210	11262
Net Calorific Value	10460	10498
API gravity	56.46	60.65
Sulphur Content (present by mass max)	0.1	<0.002
Flash Point (Abel) °C	23.0	22.0
Pour Point °C	< -20°C	< -20°C
Cloud Point	< -20°C	< -20°C
Existent Gum, (gm/m^3 max.)	40	36
Reactivity with SS	Nil	Nil
Reactivity with MS	Nil	Nil
Reactivity with CI	Nil	Nil
Reactivity with Al	Nil	Nil
Reactivity with Cu	Nil	Nil

Driving Test on Bajaj Pulsar (150cc)		
	Regular Gasoline	Fuel Extracted from Plastic Waste
Mileage	52.4	63.0
Time for 0-60 Km/Hr	22.5 Sec	18.1 Sec.
CO % at 400 RMP/ HC	2.8	2.3
(Permissible range up to 4.5)		

Note: Above mentioned tests were carried out by State Bank of India's Technical team

Note: In spite of the above mentioned facts, the fuel extracted from plastic waste will be utilized strictly as Non-Motorized fuel to start with.

6. IOC (R&D) Certified End Uses & Applications

The products obtained by this process have been tested at IOC (R&D) and end uses, are as follows:

End uses for liquid hydrocarbon:

a) D.G Sets for Generation of Electricity
b) Fuel for Agricultural pumps
c) Fuel for Boiler
d) Marine Fuel (Bunker fuel)
e) As input feed for Petroleum Refineries
f) Fuel oil etc.

End uses for Gas:

a) Any near by industries using LPG
b) For in-house consumption

For solid fuel:

a) Thermal power plants
b) Metallurgical Industries.