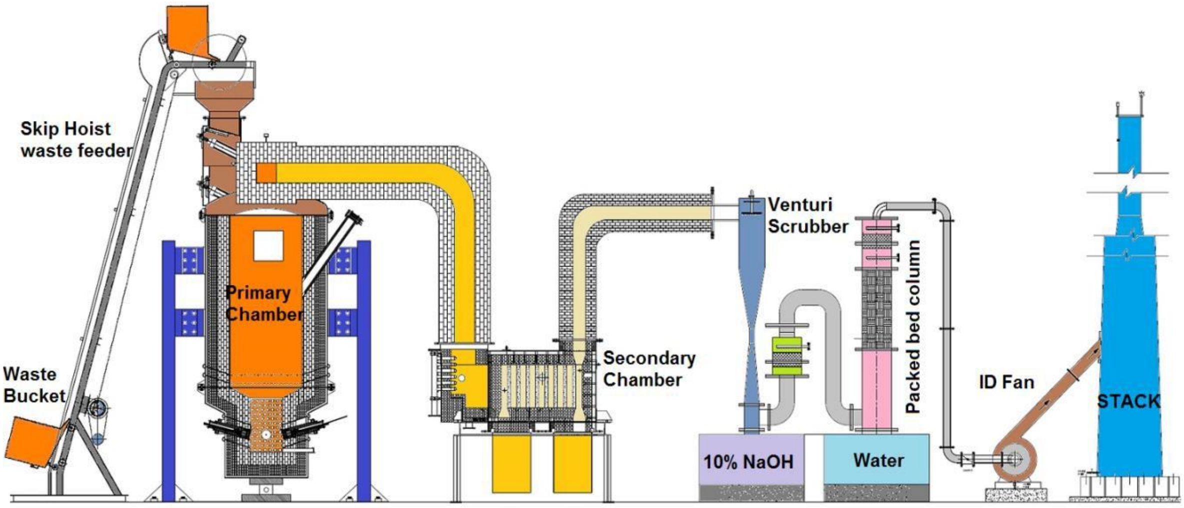
Introduction

Breaking of organic bonds using extremely hot air in an oxygen deficient environment, and conversion of the organic material into fuel gas (called syn gas, similar to CNG used in cars but consisting of mainly CO and H_2) is called gasification. Plasma gasification technology provides an attractive and universal means to treat most types of waste including municipal, nuclear and other solid wastes in an environment friendly manner. Usual low temperature burning has the issues of producing carcinogenic substances like dioxin, furan and other pollutants like NO_X and SO_X. Poor waste to gas conversion, high ash content in residue, slow process rate and no generation of fuel gas are some of the drawbacks of incineration. Gasification is different from incineration as no pollutant is generated and synthesized gas (syn gas) can be used as fuel for heat/electricity generation. The developed technology of Air Plasma Incinerator adopts a judicious combination of the two in which it does high temperature gasification at the bottom of the primary chamber and allows controlled burning of the produced syn-gas at the top to supply energy required for the process. The technique drastically reduces requirement of external supply of energy and mitigates waste in an environment friendly manner extracting energy from the waste itself. Achieved waste process rate in the developed system is of the order of 1-3 ton per day depending on the type of waste.

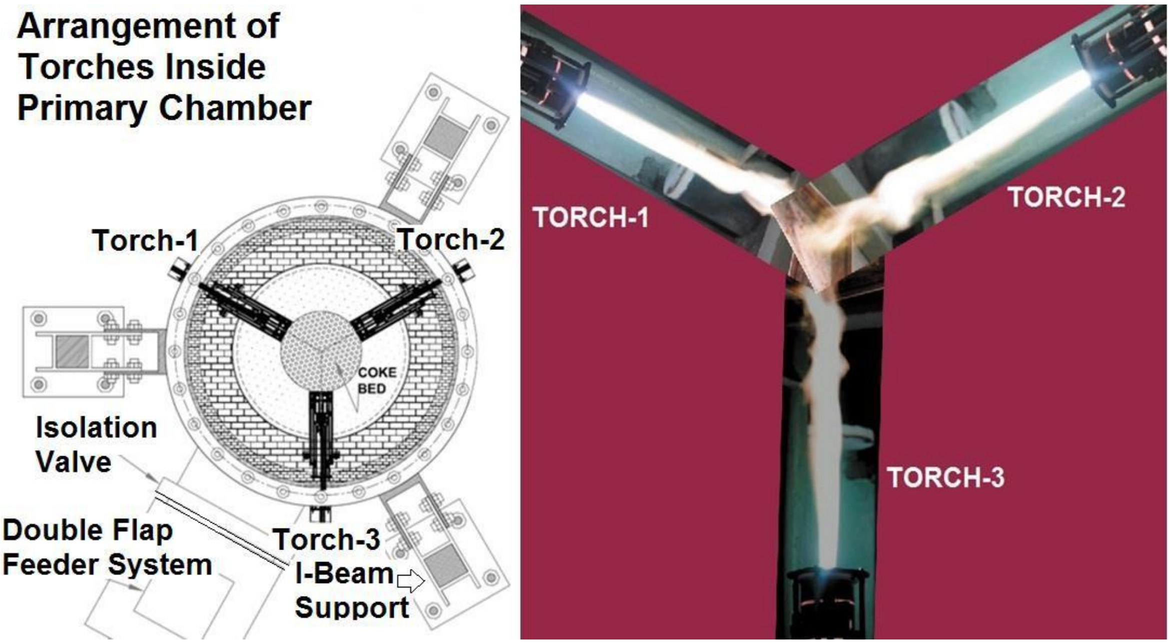
Components



Components of Triple Torch Air Plasma Incinerator

The basic components of the unit include waste feeder unit, primary chamber, secondary chamber, venturi scrubber, packed bed column, id fan unit and a stack. Waste is fed from the side at the top of the primary chamber. The id fan unit maintains a negative pressure throughout the process zone and does not allow any synthesized gas to come out from the process chamber. Three air plasma torches oriented azimuthally 120 degree apart discharge inside a coke bed at the bottom of the primary chamber and form a highly uniform very high temperature process bed of temperature in excess of 1500 ^{o}C. A skip-hoist waste loader drops the wastes at the hopper which eventually reach the bottom of the primary chamber via mechanically interlocked double door compartments, a pusher and a heat blocker gate.

Air Plasma Torch Technology



Three plasma torches discharging inside coke bed of primary chamber

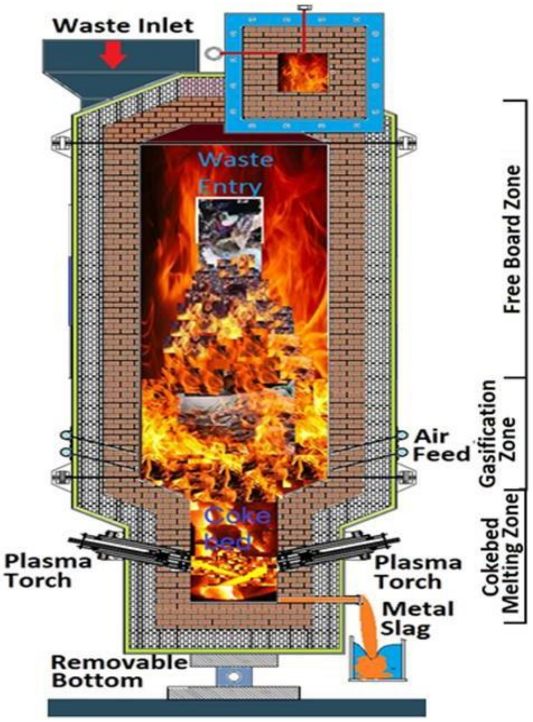
The primary prerequisite for processing waste (organic and inorganic) in an environment friendly manner using gasification technology is the 'availability of high temperature'. Higher the temperature better is the conversion of waste into fuel gas and lower is the harmful emission. Over the years it has been established that an arc plasma jet, a beam of huge concentrated thermal energy at very high temperature consisting of electrons, ions and neutrals, can meet the high temperature requirement of gasification process in a most convenient manner. Air plasma torches are the most suitable in this regard as they take air, freely available in environment and convert that into plasma jet. The offered technology uses three air plasma torches (Patent# 201721012999, Technology transferred), oriented azimuthally 120 degree apart, to produce beams in the form of an intensely luminous extremely hot radiating atmospheric pressure cylindrical plasma jet controlled in terms of its length, diameter, velocity and power content. The three plasma jets meet at the centre of a coke bed to produce uniformly heated very high temperature coke bed process zone for gasification. Low device cost, low operational cost, simple design, use of cheapest gas (air), high efficiency (>60%), high temperature (~8000 K at the anode exit) and ease of control are some of the key features of the air torch technology developed by BARC.

Environment Friendly Mitigation

High temperature of the coke bed immediately breaks all the organic bonds inside the waste material as soon as it interacts with the extremely hot coke bed at the bottom of the primary chamber. Released hydrogen atoms combine to form hydrogen gas. In presence of carbon in coke bed, controlled supply of oxygen through air converts carbon to carbon monoxide and strongly restricts formation of NO_x and SO_x. Formation of carcinogenic dioxin and furan is eliminated first by breaking associated bonds at high temperature coke bed, followed by fast quenching in the quencher unit above the venture scrubber. Particulates are efficiently separated in by the venturi scrubber and eventually deposited as slag at the bottom tank. Residual acidic gases are scrubbed in the spray column of alkaline solution sprayed at the top of the venturi. The cooled off gas is further scrubbed in the packed bed column using water before releasing to the stack.

Design Specialty of the Primary Chamber

The primary chamber is specially designed with an aim to run the system with maximum possible extraction of energy from the waste itself. It has three distinct zones: the very high temperature coke bed zone at the bottom, the gasification zone above it and the free board zone at the top. The chamber is equipped with equi-spaced air injection ports at various levels to facilitate extraction of energy through controlled burning of produced syn gas in the gasification zone. Continuous supply of energy through this mechanism not only has the potential to meet the requirement of energy in the process but also can generate additional energy to be utilized for other processes like generation of steam, production of electricity etc. Presence of plasma torches facilitates assured supply of external energy as and when required. Under self-sustained mode with continuous feed, no supply of external energy is required for wastes like municipal solid waste (MSW).



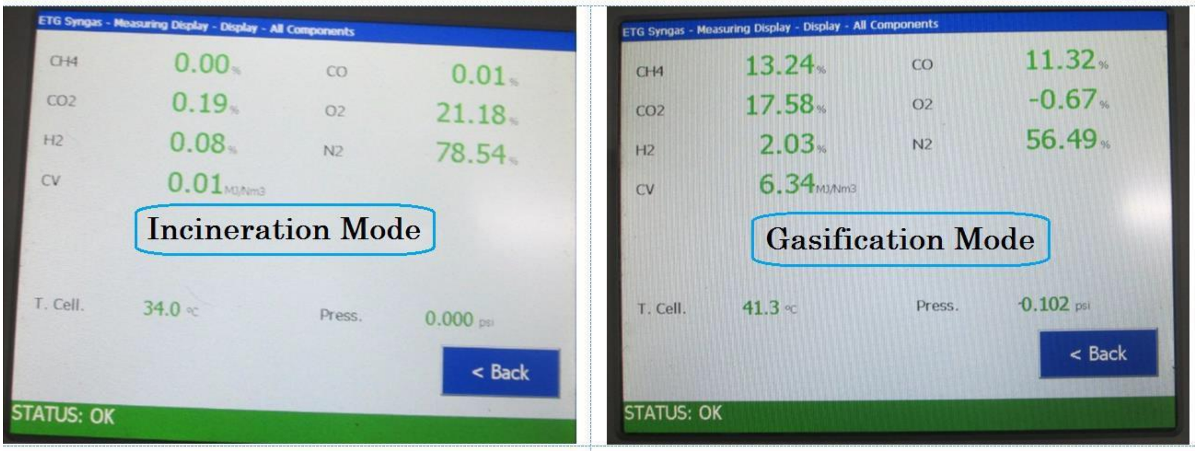
Process zones inside primary chamber

Advantages

- **Oxygen starved environment**: Limits production of harmful gases like NO_x, SO_x,CO_2
- **High temperature plasma and sudden quenching:** Gives ability to break chemical bonds. Does not allow formation of Dioxin & Furan. Makes it suitable for hazardous waste
- **Very high solid to gas conversion efficiency:** Due to vigorous reaction in presence of species in atomic and ionic state. Very little amount of residue. Reduced landfill.
- **Faster conversion:** Higher the temperature better is the concentration of active species (atoms and ions). Faster is the reaction.
- **Syn gas:** Produced high quality fuel gas (CO + H_2) under gasification mode can run gas engine and produce electricity from waste.
- **Low carbon foot print:** No burning of fossil fuel
- **High energy density: Compact reactor**
- **Relatively low device and peripheral cost**: Reduced installation cost.
- **Low operational cost:** Light weight portable compact device: easier handling.
- **Low maintenance cost:** Simpler design, easier maintenance
- **Longer plasma jet (>300 mm):** better plasma waste interaction volume.
- **Low gas flow requirement (~20 slpm in each torch):** Reduced cost of gas delivery and effluent gas treatment.

Emission Features

The system can be operated in both incineration and gasification mode. Under incineration mode the measured emission of harmful gases like CO, SO_X, NO_X are found well with the permissible limit by CPCB. The syngas generation mode in the system gets activated once all the external air inlet ports are closed. Obtained syn gas (total of CH_4, CO and H_2) quality meets the energy content of more than 6.3 MJ/Nm^3.



Safe emission in Incineration mode and good syngas quality in gasification mode

Tech Specs

1. Plasma torch

Diameter	Length	Plasma exit bore	Weight	Coolant connector	Gas connector	Electrical connector type
96 mm	250 mm	15 mm	4.5 kg	1/4 inch BSP	1/4 inch BSP	Plate type with central bore (10 mm)

No. of gas connectors	No. of elec. connectors	Current supply	Anode elec. connection	Cathode elec. Connection	Coolant connection
3	4	Dc: 50A to 300 A	Negative of DC Supply	Ground of DC supply	Source: looped Constrictor: separate Anode: separate

Cathode type	Anode type	Cathode cooling	Anode cooling	Constrictor cooling	Maximum coolant temperature
Button type Hafnium in copper matrix	Electrolytic copper	Forced water jet cooling	Annular channel flow	Annular channel flow	50

2. Power Supply

Type & Line supply	Load voltage	Maximum current	Ripple	Control knobs	Indicator
Constant current supply: Electrical line Supply: 400V(±10%), 200A 50Hz(±5%), 3 phase AC	170 V	150 A	<1% of supply current	. Current control . Shut down 3. Emergency stop	. Fault indicator . Line supply status . Load current . Load voltage

3. Air Supply System

Capacity	Discharge pressure	Filter
275 cfm of air at a pressure of 8 bar.	Work: 7 bar Max: 10 bar	Oil content <2 ppm Moisture content < 1ppm

4. Coolant Supply System

Type	Capacity	Inlet & outlet temperature	Control and display
Outdoor, weather proof, Industrial process cooling system	200 liter per minute at 7 kg/cm^2 of pressure	Inlet: 30-50 C Outlet: 15-30 C	. Set temperature . Coolant temperature . Compressor status

5. Arc Ignition, Control and Monitoring System

HF ignition	Spectrometer	RTD sensor	Coolant Flow meter	Gas flow meters
3 kV 3 MHz	Spectral range: 400 nm to 480 nm Resolution: 0.05nm	Range:0-100 C Accuracy: 0.1C	Range: 0-30 lpm Accuracy 0.25 lpm	Range: 0-100 lpm Accuracy: 2.5 slm

Capacity, Investment & Unit Cost of Production

[* Figures given are only indicative and for a rough estimate only. Actual cost may vary depending on market rate.]

Sl.	Subsystem	Component	Subcomponents	Cost (Rs.)
1	Plasma Torch	Plasma source	Hafnium cathode	7000.00
			Cathode holder	5000.00
			Gas Injection ring	3000.00
			Teflon core	7000.00
			SS housing	4000.00
			Copper nozzle	5000.00
			Brass cup for nozzle housing	5000.00
			Electrical and flow tubing	5000.00
			Copper shroud gas injection ring with distributor cavity	6000.00
		Constrictor	Constrictor with coolant channel, electrical and flow connectors	15,000.00
		Anode	Do	15,000.00
		Teflon rings	O-rings with machined grooves 4 Nos.	10,000.00
		SS-Holder plates	2 Nos.	4,000.00
		Holding studs	4 No s with bolts	2,000.00
Plasma source cost (per torch)				93,000.00
Total Source cost for three torches (Rs.)				279,000.00
2.	IGBT Power supply (150A, 170V)x3			20,00,000.00
3.	Air supply system		Air compressor	12,00,000.00
			Electrical networking and star-delta-starter configuration	15,000.00
			Gas supply lining (SS-304, 1 inch NB pipe)	1,00,000.00
Total cost of air supply system				13,15,000.00
4.	Chilled water supply system		Chiller unit	15,00,000.00
			Water piping (SS 304 2 inch NB) with thermal insulation	5,00,000.00
Total cost of coolant supply system				20,00,000.00
5.	Ignition and control system		RF ignitor (3 kV, 3 MHz x3)	75,000.00
			Thermocouple, pressure sensor, control consol, mounting, display and wiring	15,00,000.00
			Gas flow meters (4 Nos.)	40,000.00
			Water flow meters (3 Nos.)	45,000.00
			RTD sensors with mounting (4 nos.) and display	40,000.00
Total cost ignition and control system				17,00,000.00
Total cost primary chamber				25,00,000.00
Total cost secondary chamber				15,00,000.00
Total cost venturi scrubber				14,00,000.00
Total cost packed bed column				11,00,000.00
Total cost i.d. fan unit				6,00,000.00
Total cost stack (fabrication & installation)				10,00,000.00
Net Unit Cost				1,53,94,000.00 (~1.54 Crore)

Energy Consumption Rate under Full Load

Sl No	Particulars	Voltage (V_L)	Current (I_L)	P. F.	Power (KW) $1.732*V_L*I_L*P.F.$	No of Devices	Hrs of Opera -tion	Energy Consumed (KWh) Unit (X) per day	Image
1	Chillier (30Tr)	415	72.7	0.8	**41.8**	01	8	334.4	
2	Air Compressor	415	66.3	0.8	**38.12**	01	8	304.96	
3	Small Chillier (10Tr)	415	22.1	0.8	**12.7**	01	8	101.6	
4	Blower	415	24.4	0.8	**14.03**	01	8	112.24	
5	Packed bed Pump	415	3.2	0.8	**1.84**	01	8	14.72	
6	Venturi Pump	415	9.9	0.8	**5.6**	01	8	44.8	
7	Plasma Torch (P/S @160V*135A	415	41.1	0.8	**26.63**	03	2	159.78	
8	Total		239.7		**140.99**			**1072.5 /Day**	

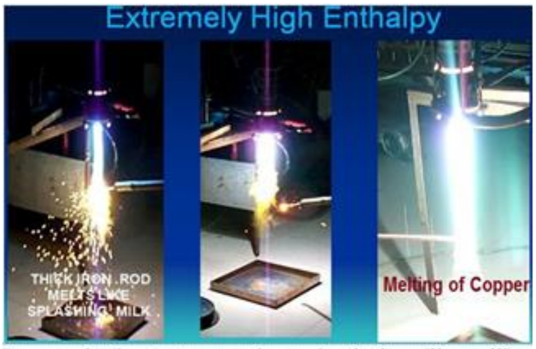
Notes.

1. Depending on chilling requirement, the usual power consumption rate during operation will be less, once steady state reaches in the system.

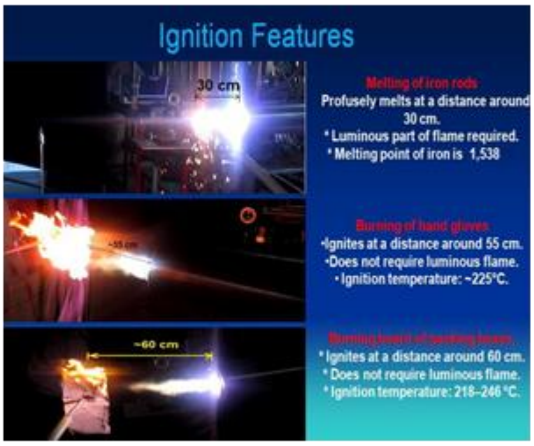
2. The Power consumption by air compressor will depend on the air flow requirement. For lower flow rate, the compressor may stay in idle condition and the power consumption rate will be reduced.

3. Once coke bed reaches very high temperature (>1500K) through plasma discharge, the power coming from the waste found to be sufficient to run the system with requisite efficacy. The plasma power input may be stopped at that time. The energy consumption rate may be directly reduced by 75 kW under steady state operation with continuous waste feed.

Process & Operational Features-I

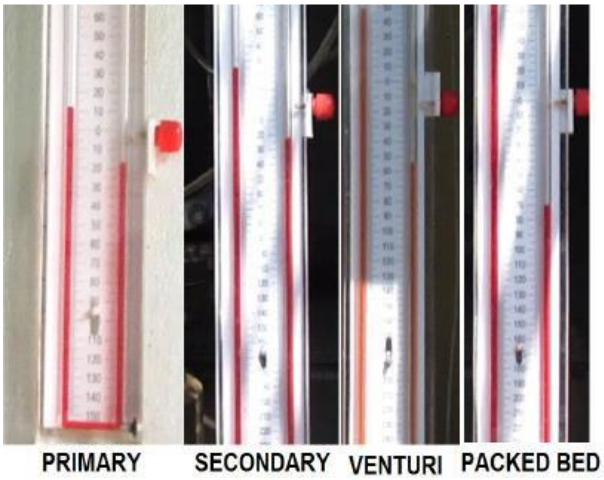


Iron melts instantaneously and splashes like milk; copper melts and even evaporates instantaneously




Clean emission from stack: Only faint white stream of water


The extremely hot coke bed with bed temperature

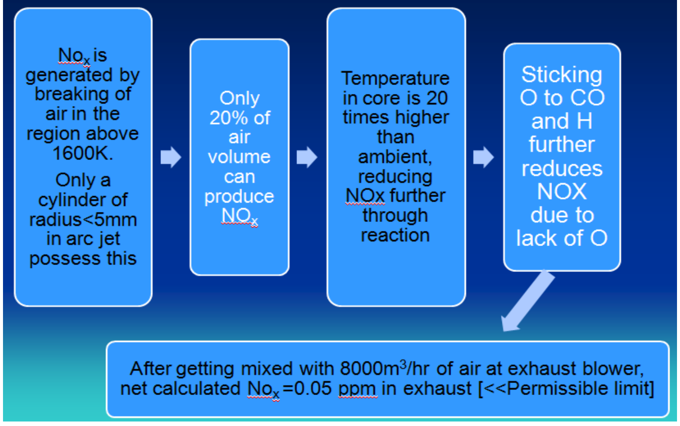


Negative pressure maintained at different units


Fast plasma gasification as waste interacts with extremely hot coke bed

Process & Operational Features-II

Mitigation of NO_x



Mitigation of HC, CO, H_2, CO_2

Off gas is burnt in secondary chamber and gets converted into (99.99%):

$$HC \longrightarrow H_2O + CO_2$$
$$CO \longrightarrow CO_2$$
$$H_2 \longrightarrow H_2O$$

- Design basis of the KOH Scrubber assumes exhaust CO_2 concentration as 10ppm.
- Considering natural value of CO_2 concentration in ambient air as ~400 ppm, ground level emission is permitted

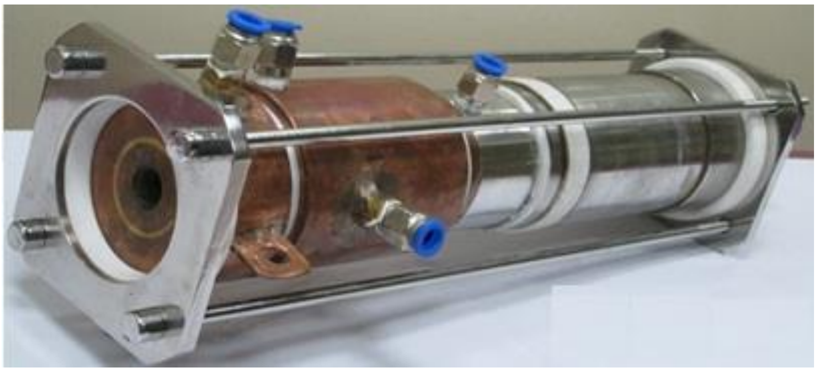
Formation of Dioxin and Furan takes place in the temperature zone 200-600C. The zone is avoided by sudden quenching of syn-gas from ~1200 ºC to 50 ºC in the ventury scrubber. Also, the system generates least amount of fly ash to act as catalyst for formation of Dioxin and Furan.

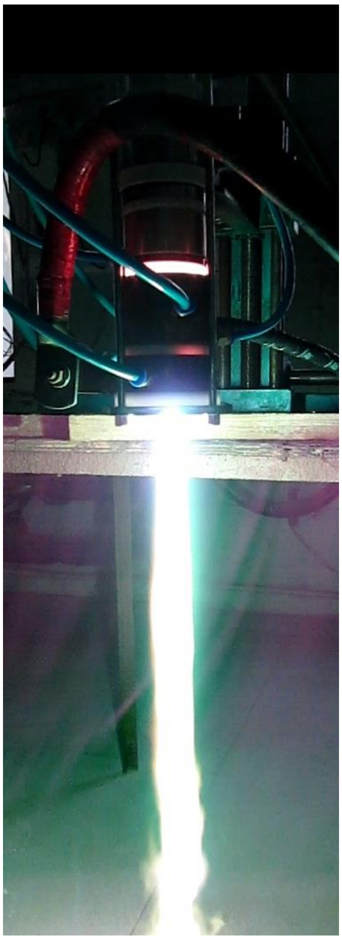
Safety Aspects

- Operation at negative pressure, allows no syn-gas to reach outside.
- Dual gate feeder unit prohibits release of obnoxious gas
- Suction hood on top of scrubber and secondary chamber takes care of release of syn gas if any
- Inline temperature sensors at multiple locations monitors thermal health
- Pressure sensor for chamber and duct monitors process health
- Continuous area motoring for NOx, CO, CO2, HC for safe operation
- No thermal runway. Automatic trip for any electrical instability, as arc characteristics do not support.
- Coolant flow is interlocked with the power supply through flow switch

Air Plasma Torch

A thermal plasma jet is a beam of huge concentrated thermal energy at very high temperature consisting of electrons, ions and neutrals. Such plasmas are naturally formed in atmosphere during thunderbolt and observed as a bright flash in the sky. Similar plasma is produced by the offered technology in the form of an intensely luminous extremely hot radiating atmospheric pressure cylindrical plasma jet controlled in terms of its length, diameter, velocity and power content using a small device called air plasma torch. The novel technology offers a compact device that takes air from the atmosphere and converts it into a controlled well defined jet of air plasma at an electrical power level of many tens of kW with efficiency greater than 60%. Low device cost, low operational cost, simple design, use of cheapest gas (atmospheric air), high efficiency (>60%), high peak temperature (~9000 K at the anode exit) and ease of control are some of the key features of the technology.





ADVANTAGES

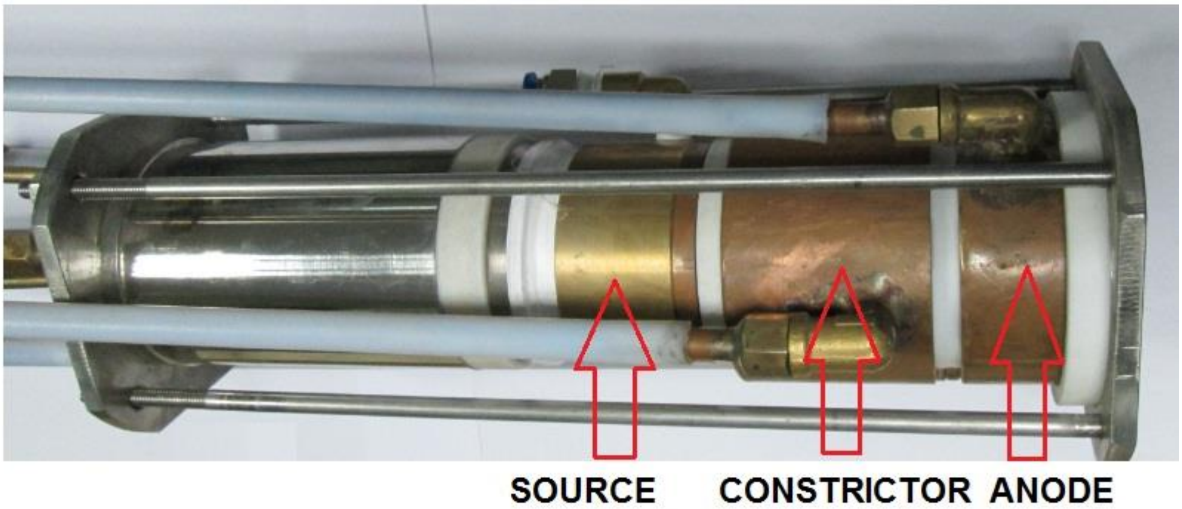
1. Low device and peripheral cost: reduced installation cost.
2. Use of air from atmosphere as plasma gas: low operational cost.
3. Light weight portable compact device: easier handling.
4. Simple design, easier maintenance: low maintenance cost.
5. High efficiency (>60% in non-transferred mode and >95% in transferred mode): better performance
6. Extremely low cathode erosion: long electrode life and low operational cost
7. Very high plasma temperature (at the exit >8000K): more efficient heat transfer.
8. Very long plasma jet (>300 mm): better plasma matter interface.
9. Low gas flow requirement (~20 slpm): reduced cost of gas delivery and post treatment section.

POTENTIAL APPLICATION AREAS

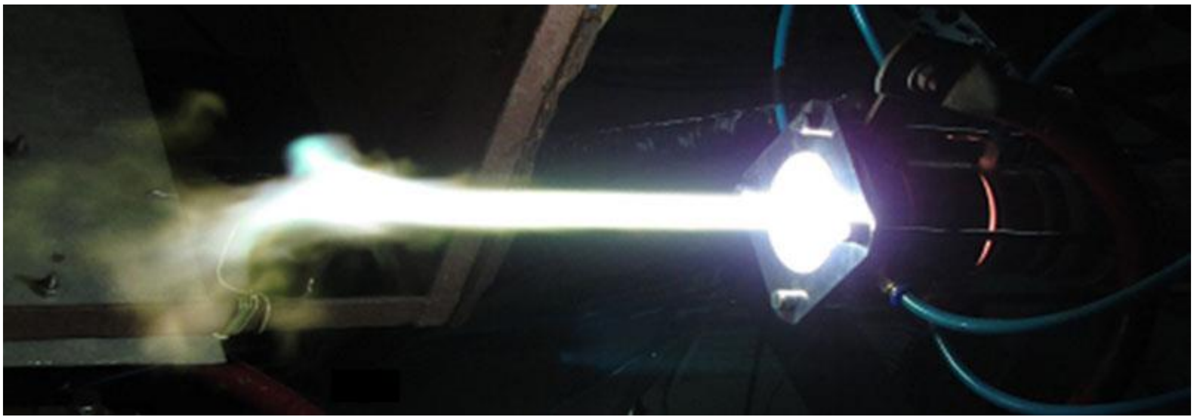
1. Conversion of waste into energy through plasma gasification
2. Municipal and medical waste treatment through plasma gasification
3. Hazardous waste destruction
4. Nuclear waste immobilization through melting and volume reduction
5. Chemical processing industries
6. Thermal barrier coatings
7. Steel and iron making industries
8. Metallurgical alloy making industries
9. High temperature testing of heat shield materials
10. R& D Applications

DESIGN AND OPERATION

Internal components of the device are shown in below figure.

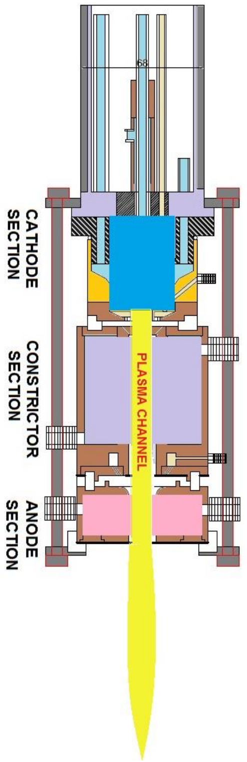


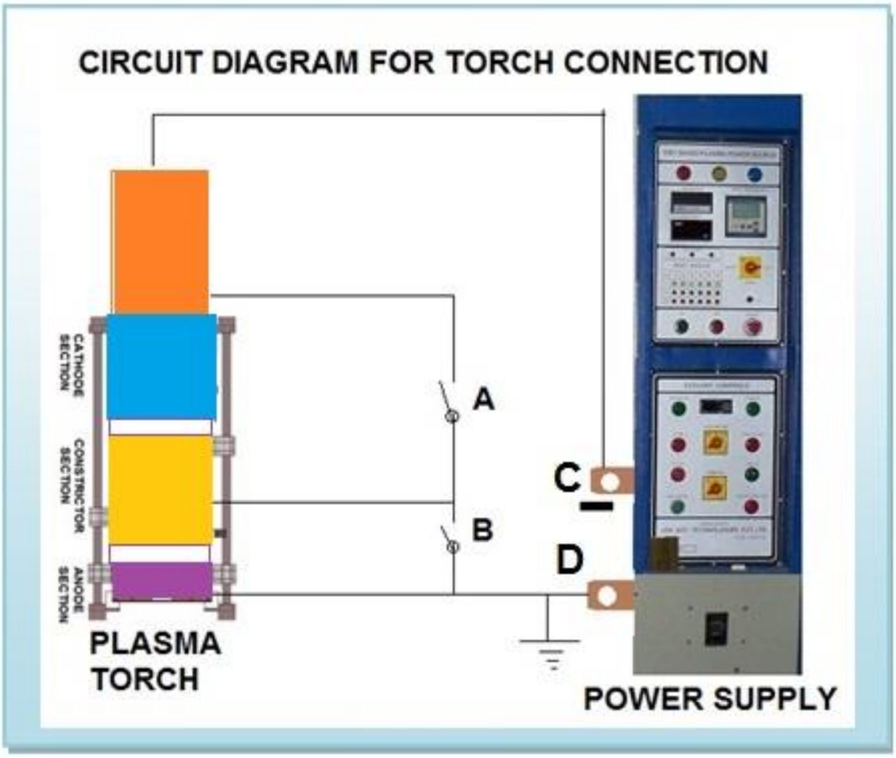
It has three major sections: (1) plasma source (2) constrictor and (3) main anode. The plasma source section consists of a specially designed hafnium based cathode, gas distributor and coolant distributor. A single coolant loop caters to all the sectors in this section. With the help of a radio-frequency igniter, the plasma (arc) is initiated in this section between the cathode and the nozzle. Once the source is on, the arc is transferred to the constrictor section at low power. The role of the constrictor is to streamline the plasma jet as well as develop appropriate voltage in the plasma column for operation at a given power level. For a given current and gas flow rate, the power of the plasma jet can be adjusted just by changing length of this constrictor section. The power of the plasma is gradually increased to medium level. Next, the arc is transferred the main anode and full power of the jet is achieved. An extremely bright well-formed huge jet comes out from the device as shown in figure below.



ASSEMBLY AND ELECTRICAL CONNECTIONS

The section of the assembled plasma torch and electrical connection with power supply for operation is shown in figure below. Initially both the connectors "A" and "B" are connected and an arc is initiated between the cathode and the nozzle. The connectors are sequentially opened to make a gradual transfer of the arc from the cathode to the constrictor and finally to the main anode. While in operation at full power, both the connectors remain open.





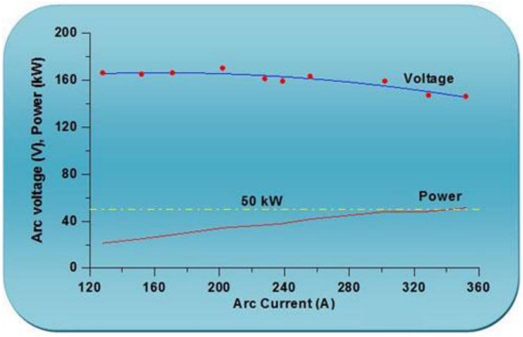
SUBSYSTEMS

The complete plasma system consists of the following five subsystems:

1. **Plasma torch**
   The air plasma torch serves as the key device for the entire system. Rests of the units are the supporting units for the torch.
2. **Power supply system**
   An IGBT based DC power supply delivers the necessary power for the torch operation.
3. **Air supply system**
   The air supply system, consisting of a compressor and a storage tank, supplies the necessary airflow for the torch operation.
4. **Water supply system**
   The chilled water supply system provides necessary cooling for the thermally stressed components of the plasma torch.
5. **Arc ignition and control system**
   The ignition and the control system consists of an HF (high frequency) unit, two contactors and a power supply control unit. The HF unit (included in the power supply) ignites the arc, the contactor units transfer the arc to the main anode, and the power supply control unit controls the delivered power to the torch through control of arc current.

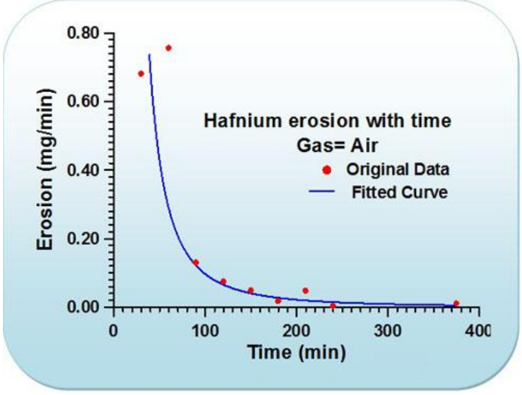
PERFORMANCE CHARACTERISTICS

V-I characteristics



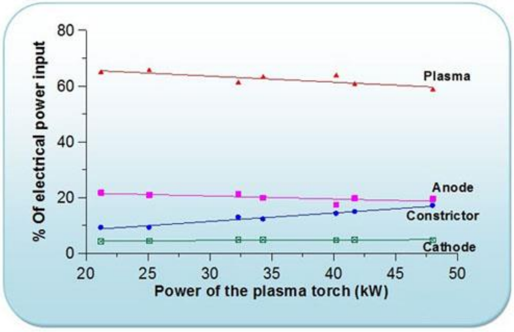
Typical V-I characteristics for the plasma torch is shown in figure above. The arc voltage remains nearly constant over a range of currents. A slight drop in the voltage is observed at higher currents. Increase in power with increase in current is slightly non-linear. For operation around 50 kW the torch operates near current 350 A and voltage 156 V.

Cathode performance



As shown above extremely low electrode loss due to erosion is observed for the cathodes. For new electrodes, the loss is relatively high at the start but decreases fast with time and stays at that extremely low level. The electrode loss reduces with increase in current.

Efficiency and Thermal Losses



Power delivered into the plasma by the power supply is partly dissipated in heating the anode, constrictor and the cathode system. Rest of the delivered power goes into the plasma. As seen in figure, less than 5 % of the total input electrical power is dissipated by the cathode. The torch efficiency is nearly 65% around 20 kW and around 60% at 50 kW. In transferred arc mode, only loss is due to the cathode and efficiency goes above 95%.

25 kW, 150 A IGBT based power source for thermal plasma application

Description

The power source of 25 kW, 150A DC for Thermal Plasma torch consists of a main arc DC power supply and a trigger unit. The trigger unit initiates arc and main arc power supply gives energy to maintain it. The main arc power supply have fast response to enable stabilizing the plasma. The main arc power source is based on 25 kHz IGBT inverter operating in constant current mode. 3kV, 3 MHz trigger unit is based on capacitor discharge through spark gap. Trigger unit is inductively coupled with main arc power supply.

Salient Features & Technical Specifications

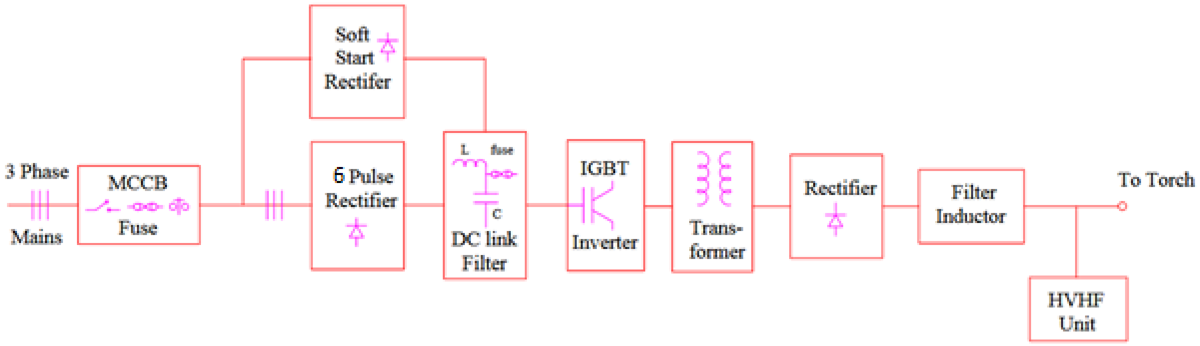
- 25 kW power @150A DC
- Current ripple less than 1%
- Suitable for air plasma torch
- 25 kHz IGBT inverter based design
- User friendly GUI (Graphical User Interface) with 10" touch screen display
- Rugged and light in weight
- Fits into a very compact size of 21.5" x 27.5" x 42"
- Low cost indigenous product
- Compatible with SCADA system

Applications
This power source is used to energize air/argon plasma torch used in gasification/incineration plants. The plasma based incinerator/gasifier used for wide range of application in the field of MSW, Biomass, and Nuclear waste. The user of this power source can be BARC, other units of DAE or any industrial plant. This power source can be used in other industrial application of thermal plasma, viz. cutting etc..

Theory and Operation

A high voltage high frequency (HVHF) supply is required for initiation of the discharge between the cathode and anode without moving the electrodes. Since the electrical resistance of the gas in the plasma torch is high enough that the low voltage of the main arc power supply cannot bridge the inter electrode gap, a high voltage of 3 to 5 kV at a 3 to 4 MHz frequency easily produces the breakdown between the electrode gap and produces ionization of the gas causing a plasma gap discharge. Once the plasma discharge is initiated, its low electrical resistance enables the main arc power supply to take over and maintain the plasma discharge.

The block diagram of a typical power source for thermal plasma application is given in below. The major blocks of this power source are front end rectifier & DC link filter, Soft start rectifier, IGBT inverter, High frequency link transformer output rectifier & filter and HVHF unit.



Conceptual block diagram of typical DC plasma power source

A soft start rectifier is required to charge DC link capacitor in the controlled manner when conventional uncontrolled front end rectifier or high pulse rectifier is used. This is to avoid the over stressing the diodes of main front end rectifier.

IGBT based single phase high frequency ac link inverter is used, which feed to a ferrite core transformer. In the power source the operating frequency of inverter is 25 kHz. The output of inverter is coupled to HF transformer through coupling capacitor for DC blocking. The output of transformer is rectified using fast rectifier and filtered using balanced T filter.

Feedback current taken for control as well as display is sampled through high speed DC CT. Voltage limit is insured by taking an output dc voltage feedback through resistor divider network and feeding to control circuit.

Robust hybrid (Analog & Digital) control circuit not only ensures smooth implementation of proportional integral control but also takes care of system interlocks for safe operation, interfacing with other devices. User friendly GUI is implemented through 10” touch screen display.

Facilities & Manpower required for commercial production

- Material handling equipment such as Chain pulley, hydraulic trolley etc.
- Electrical test and measurement equipment such as Multimeter, Clamp on meters, Oscilloscope, Megger etc.
- Floor space of 150 sq. ft. (15ft x 10ft) is required for integration and testing
- Utilities like 3 phase electrical power.
- One electrical engineer with bachelor's degree, one electrician/wireman and one helper is required for wiring and assembly of the power source

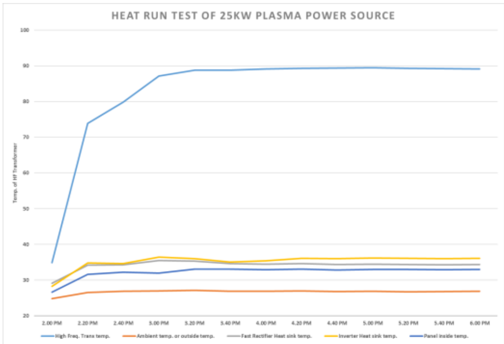
Technical Data Sheets

Sr. No.	Description	Rating
1	Input Voltage	415V ± 10%, 3Ph, 50Hz± 3%, 4 WIRE SYSTEM
2	Input kVA	Approx. 35kVA at 85% efficiency
3	Class of Insulation	Class H
4	Power Factor	>0.9
5	System Frequency	25 kHz
6	Mode of Control	Constant Current Control (PWM Technique)
7	Open Circuit Voltage	700V
8	Max Output voltage	170V
9	Max Output Current	150A
10	Max output Power	150A at 170V (Power will be limited to 25kW)
11	Cooling	Forced air Cooling for IGBT and Rectifiers
12	Input Current	THD as per latest IEEE std 519
13	Ripple factor	<1%
14	Feed Back System	DC CT & Voltage divider
15	Filtration	LC Filters
16	Max. Ambient temperature	40 Deg.C

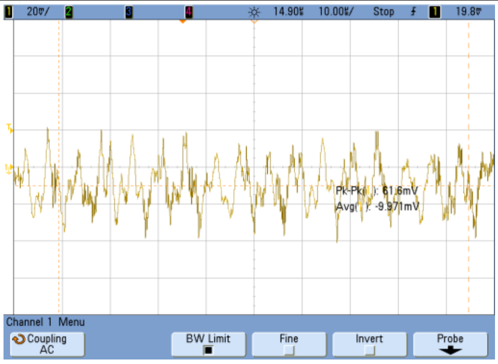
Sr. No.	Control/Indication	Description
1	Input 3-Ph R,Y,B indicators	It shows the input 3-ph power supply availability.
2	Input Fault indication on HMI	(UV/OV/PR/PF) It shows the input supply monitoring and fault status.
3	System over temperature indication on HMI	It Shows the IGBT/rectifier over temperature indication.
4	Output over voltage indication on HMI	It shows the output over voltage indication.
5	Output over Current indication on HMI	It shows the output over current indication.
6	EXT-Trip indication on HMI	It shows the External-Trip Indicator.
7	Emergency stop indication on HMI	It shows the Emergency stop indication.
8	Set Current input from HMI	To adjust the output current minimum to maximum.
9	Mains on/off button and indication on HMI	To switch on the mains contactor.
10	DC on/off button and indication on HMI	To switch on the output dc.
11	Reset button on HMI	It resets the all the latched faults in the system.
12	Emergency Stop Push Button	It is used to stop the system in emergency condition.
13	Output Voltage indication on HMI	It shows the output voltage.
14	Output Current indication on HMI	It shows the output current.

Testing of power source

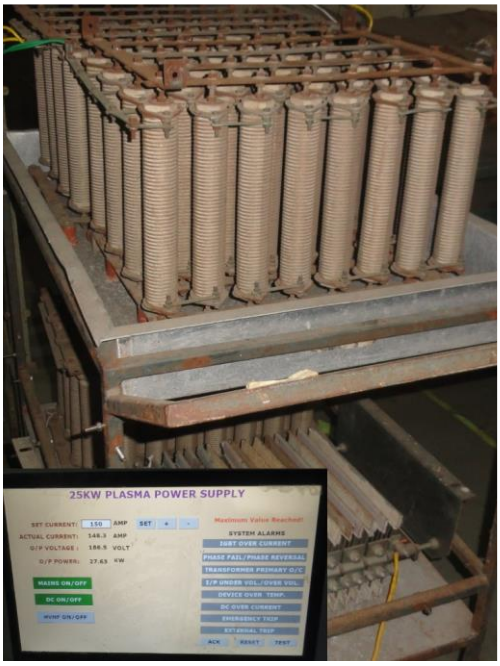
Routine test	Type test
Sub-assembly/ components test	Heat run test
Functional test	Water load test
Light load test	Graphite rod plasma/spark test
Rated load test	Air plasma torch test



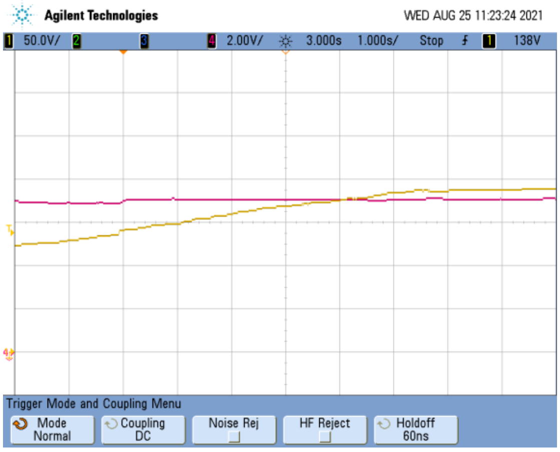
Heat run test



Ripple factor with resistive load is 0.3%, output voltage 170V, 140A.



Rated load test : V=170V, I=150A
Power source is also tested at 110% of full load



Water load test

Sr. No.	**OUTPUT VOLTAGE**	**OUTPUT CURRENT**	
		SET	**ACTUAL**
1	125	140	138.7
2	130	140	138.2
3	140	140	138.7
4	150	140	139.6
5	160	140	139.4
6	170	140	139.7
7	180	140	139.5