Plasma Arc Technology

SOLENA GROUP

AGENDA

- **INTRODUCTION**
- **INDUSTRY OVERVIEW**
- **PPGV TECHNOLOGY**
- **SOLENA GROUP TEAM**
- **SUMMARY**

Who Are We?

- Solena Group, a Delaware Registered US-Italian Corporation founded to Promote Plasma PGV Technology for:
  - Renewable Electric Energy Production from Waste, Coal Waste & Biomass
  - Hydrogen Gas and Syn-Gas Production
  - Shipboard Waste Management

Why Are We Here?

- **Solena Group has :**
  - **A Unique Patented and Proven Technology**
  - **A Consortium of World Leading Energy & Engineering Companies**
  - **A Defined & Growing Market Demand (Contracts > 250 MM US$) for Clean Renewable Energy**
- **Solena Group:**
  - **Designs & Builds Plasma Gasification Vitrification Plants**
  - **Produces Clean Electricity & Cleans the Environment**
  - **Plans To Utilize Coal Waste/Fines as Feedstock**

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Industry Overview

- High Demand for Renewable and Clean Electric Energy
- Lack of Efficient & Safe Waste Disposal Systems
- Increasingly Stringent Environmental Regulations
- Increasing Interest in Fuel Cell and Hydrogen Gas

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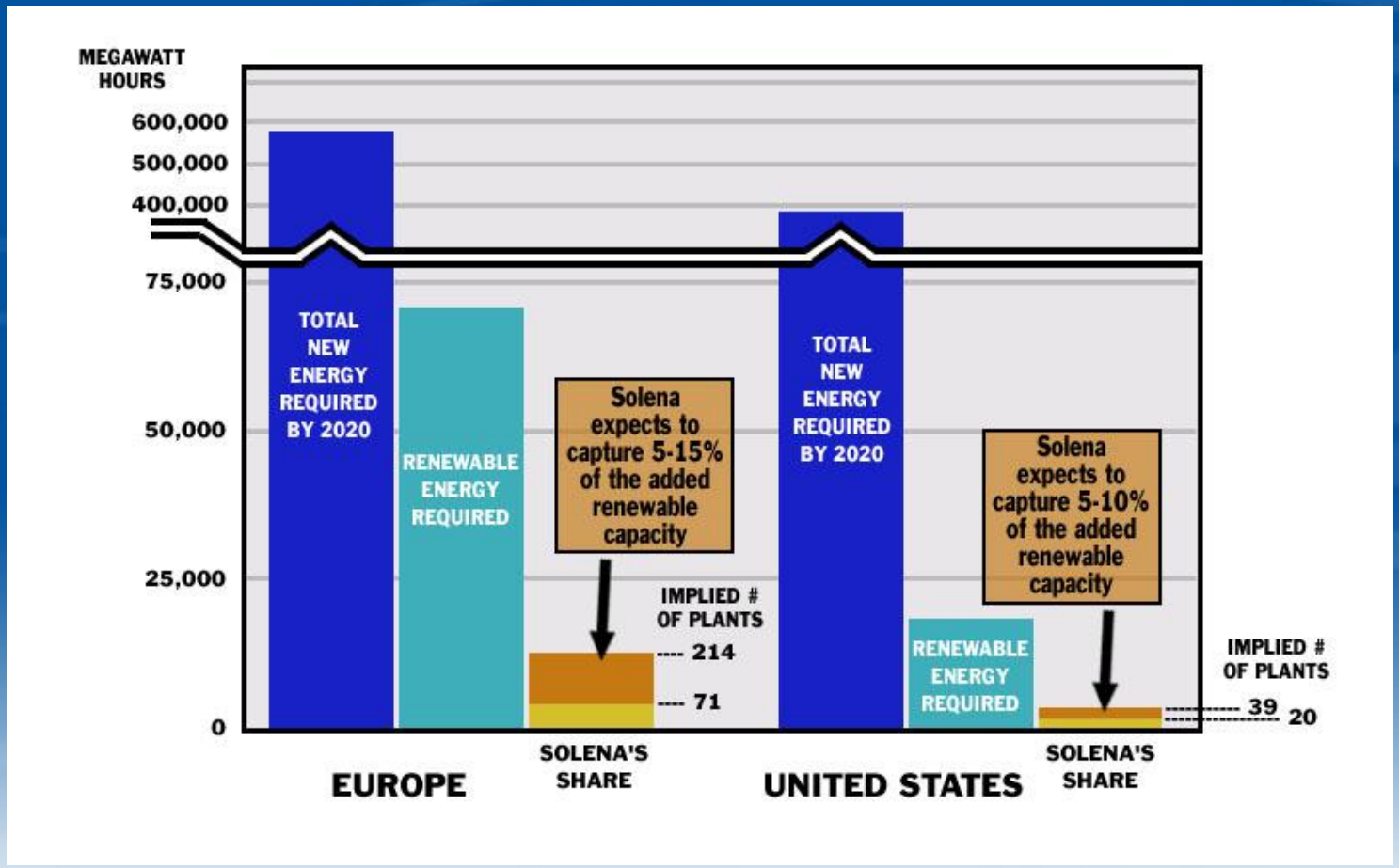
Mandate for Renewable Energy



Source: President Bush Report on Energy, May 2001;
EU Energy Outlook to 2020; EIA Renewable Energy Trends

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Coal Issues: Environmental/Energy Intersection

- Mining/Processing
  - **Large Waste Coal Piles**
  - **Large amounts coal fines**
    - **Silt dams**
    - **Slurry Ponds**
  - **Water Contamination**
    - **Surface**
    - **Ground Water**
- Utilization/Power Plants
  - **Ash Disposal**
  - **Air Emissions**
  - **Water Contamination**
    - **Surface**
    - **Ground Water**

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Magnitude of Coal Waste Problem

- 2 billion tons of bituminous coal fines stored east of the Mississippi
- 50 million tons of coal fines produced annually from existing coal cleaning plants
- Utilities discard millions of tons of unburned carbon as ash waste

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Typical Coal Waste Site

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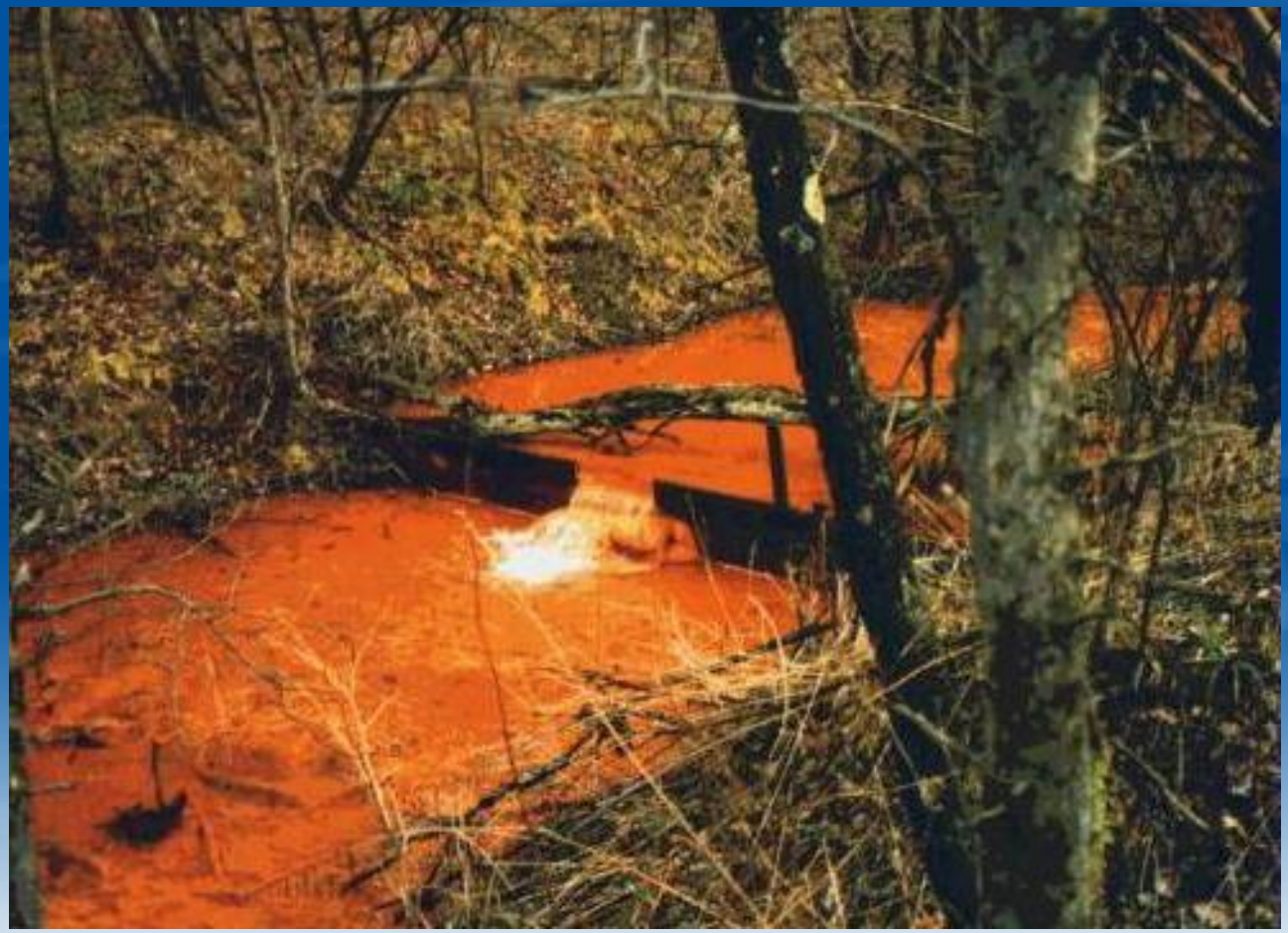
Acid Mine Drainage



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Un-reclaimed Open Pit

What are the Alternatives Coal Wastes?

High Pressure Gasification: Low Availability, Requires specific feed stock preparation and sizing

Plasma Gasification Vitrification: High Availability, Wide range of feed stocks (waste, ash, fines), Environmentally Benign

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Solution: PPGV Technology

- What is PPGV?
- What is Plasma?
- The Plasma torch
- How does it work?
- Why are we better?

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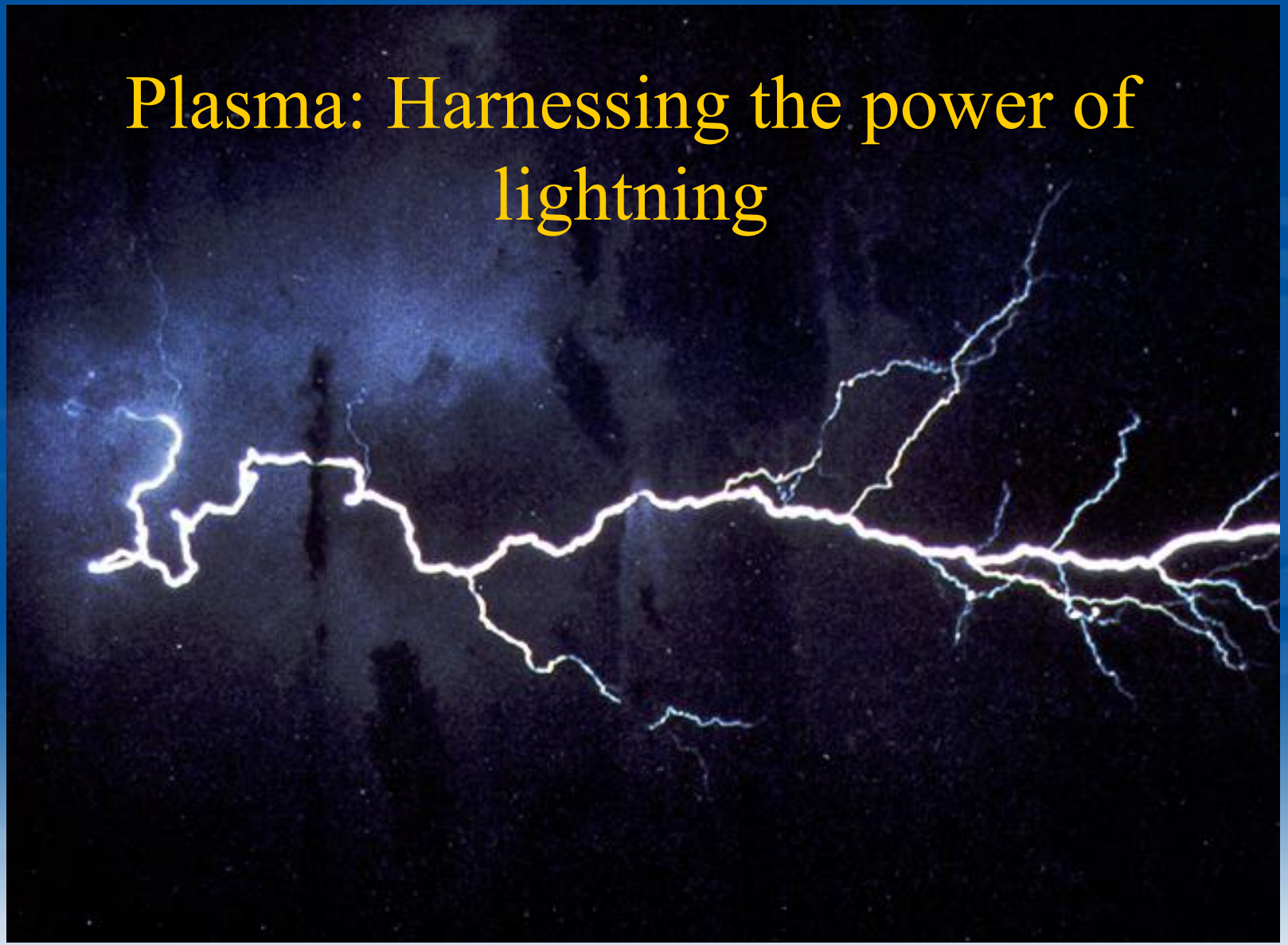
Plasma: Harnessing the power of lightning



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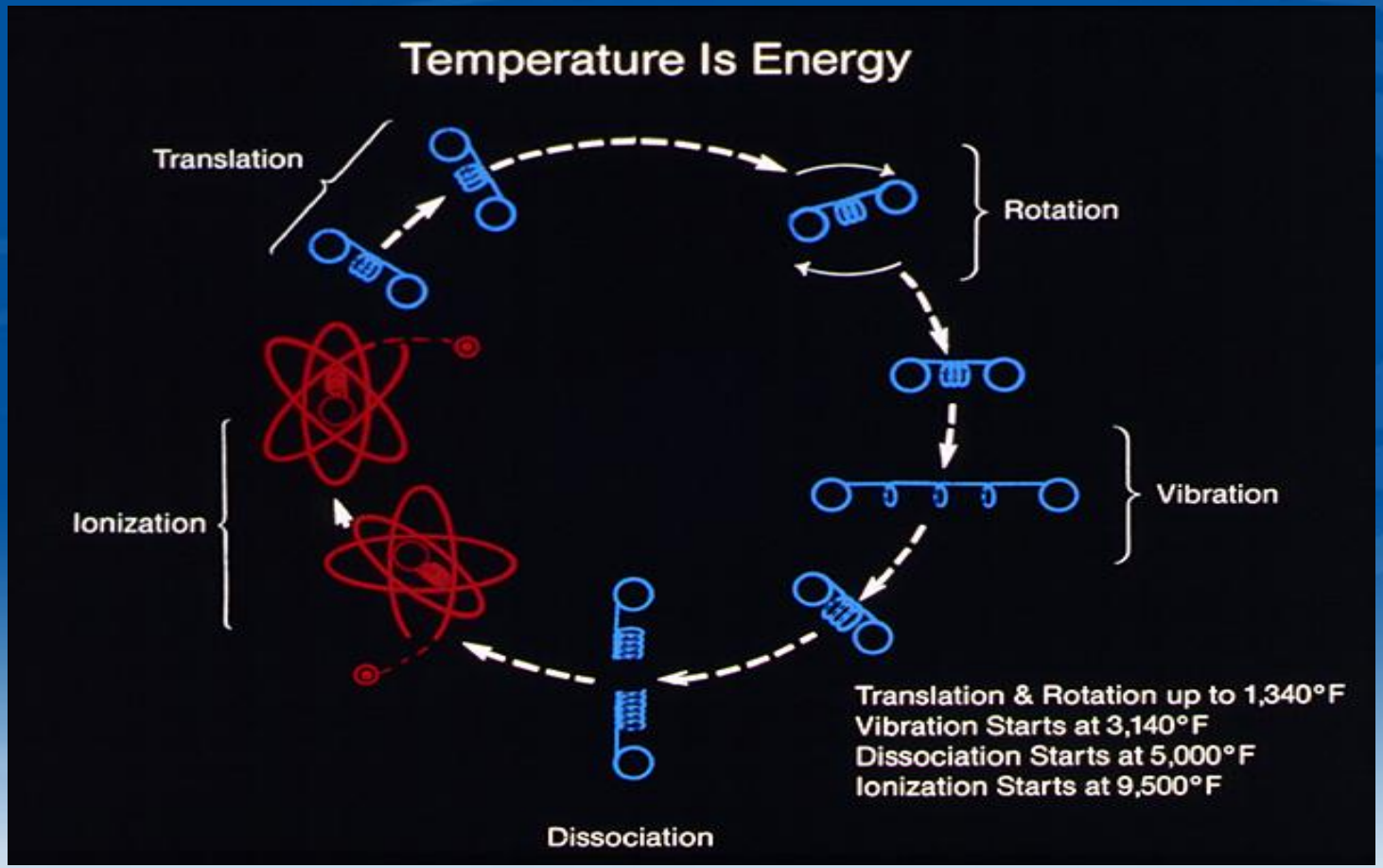
Creation of the Plasma Gas



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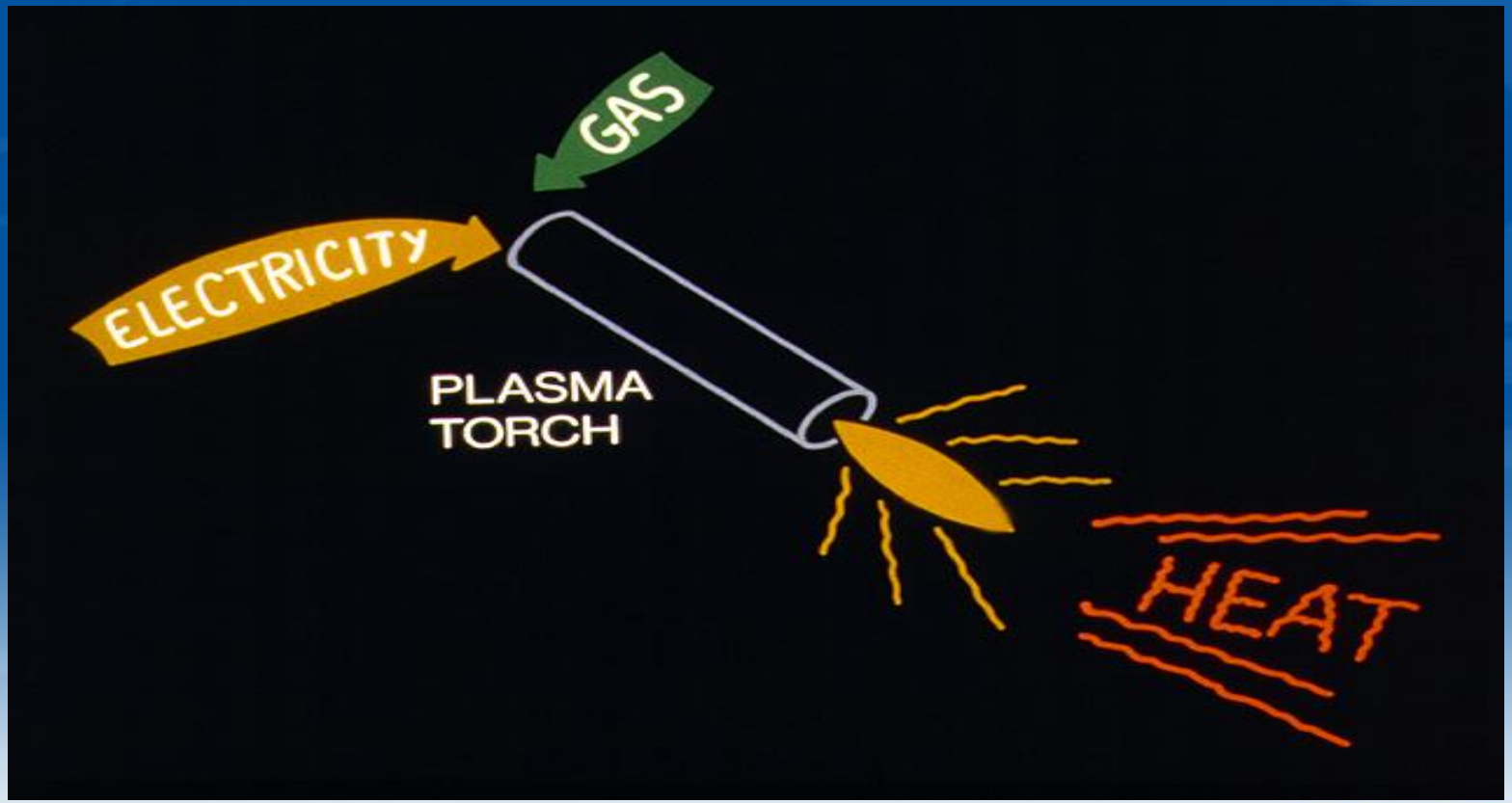
Creating the Plasma Torch and Plasma Heat



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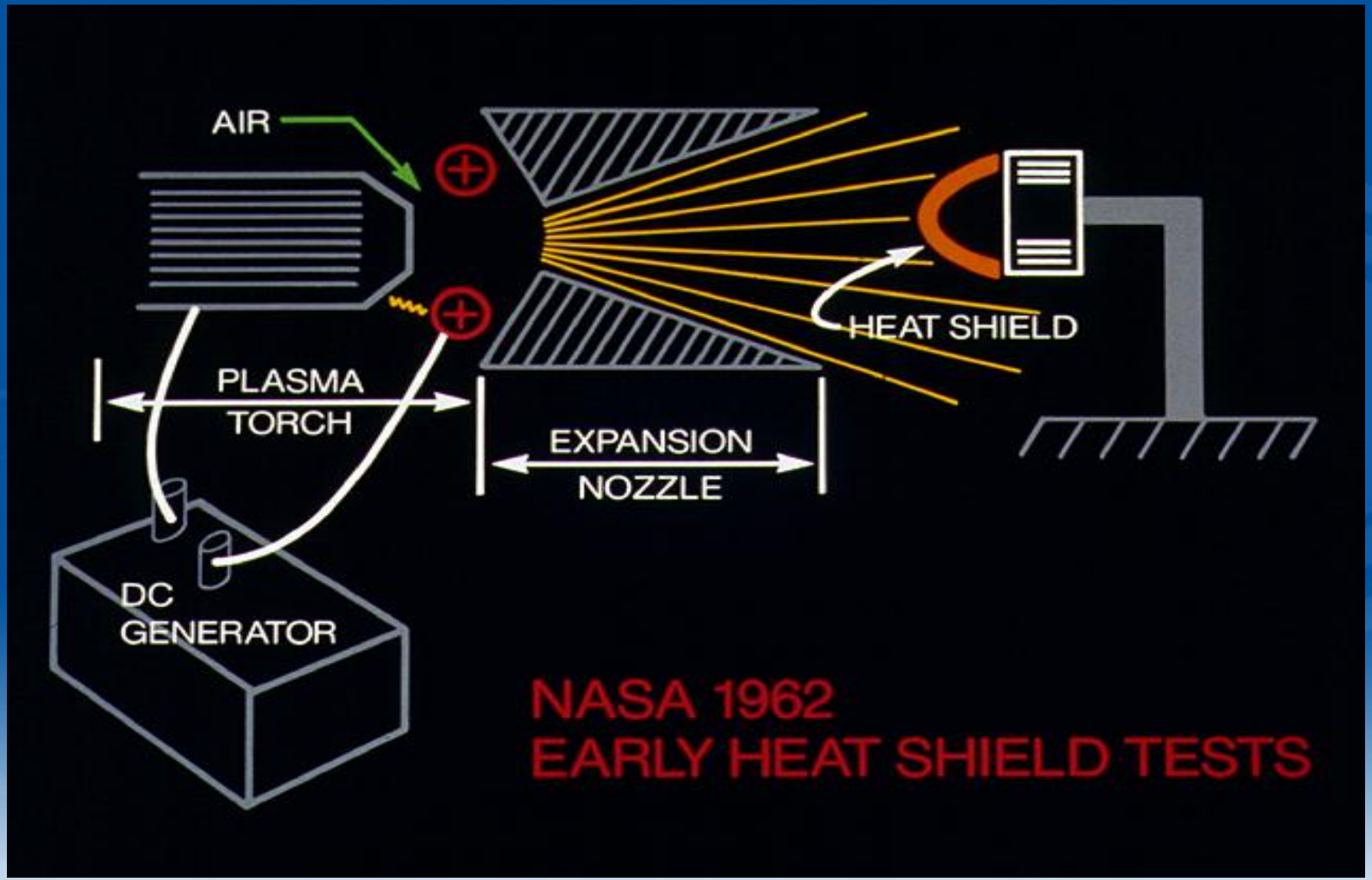

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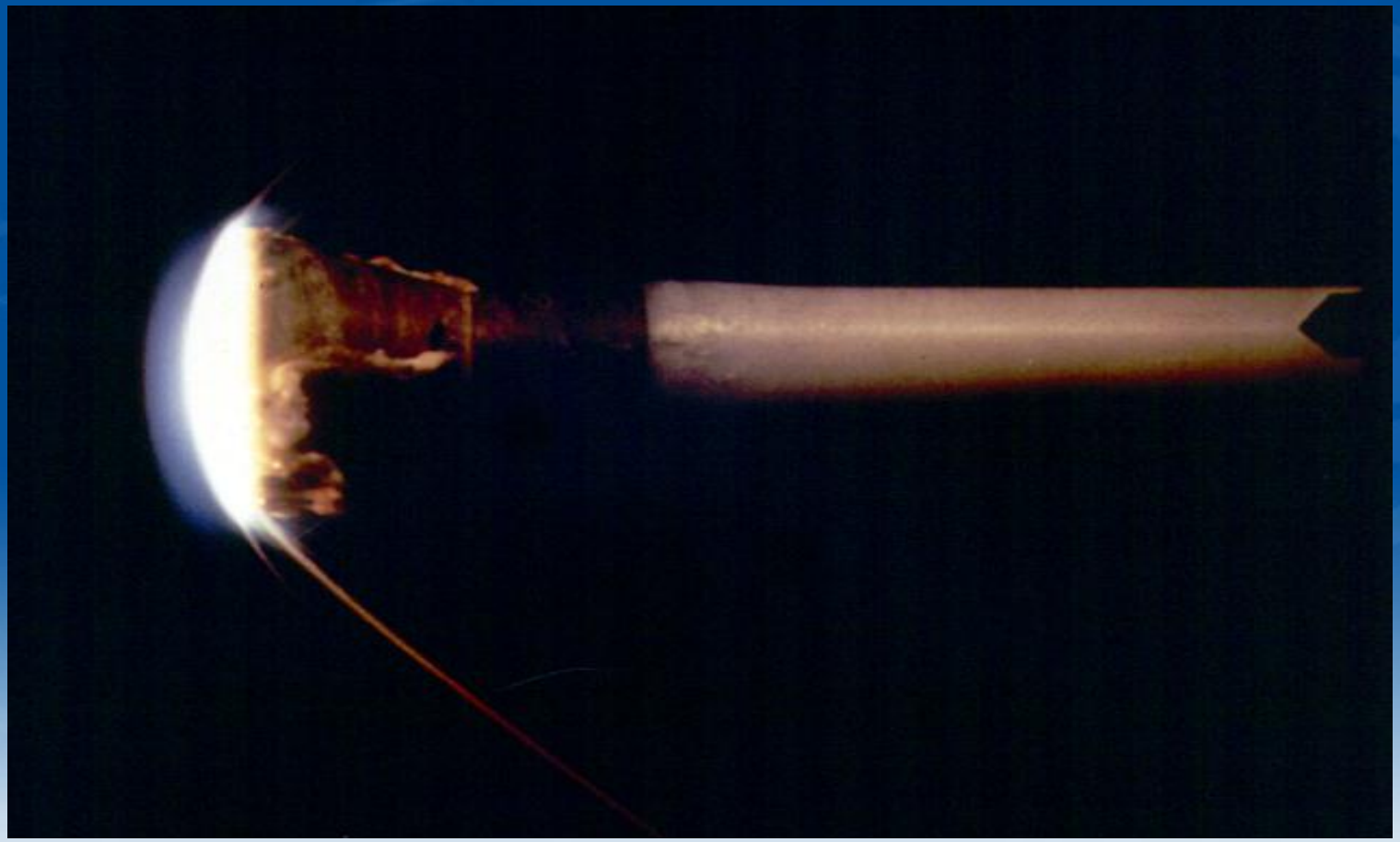
NASA Plasma Torch Testing



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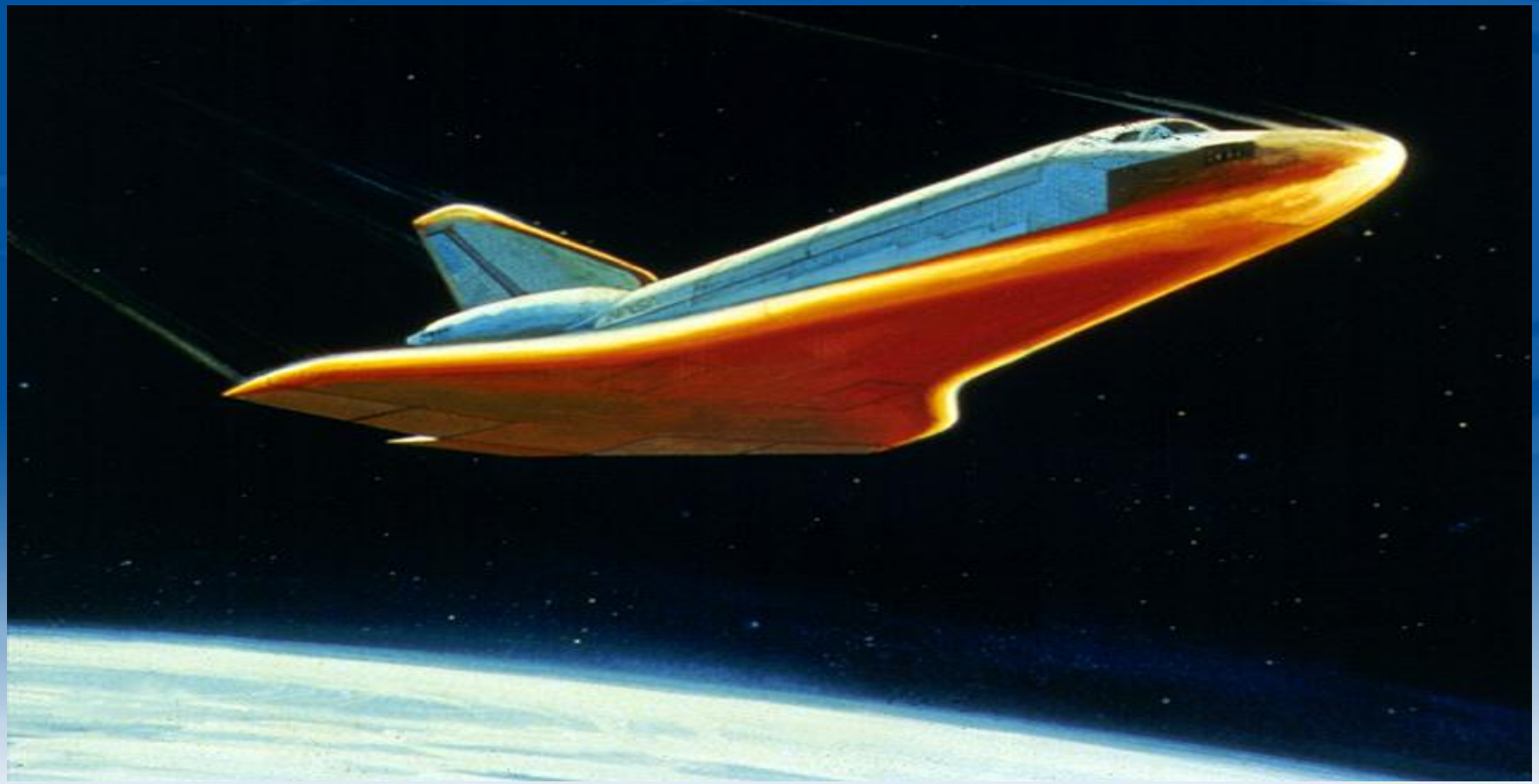
Plasma Technology: NASA's success story



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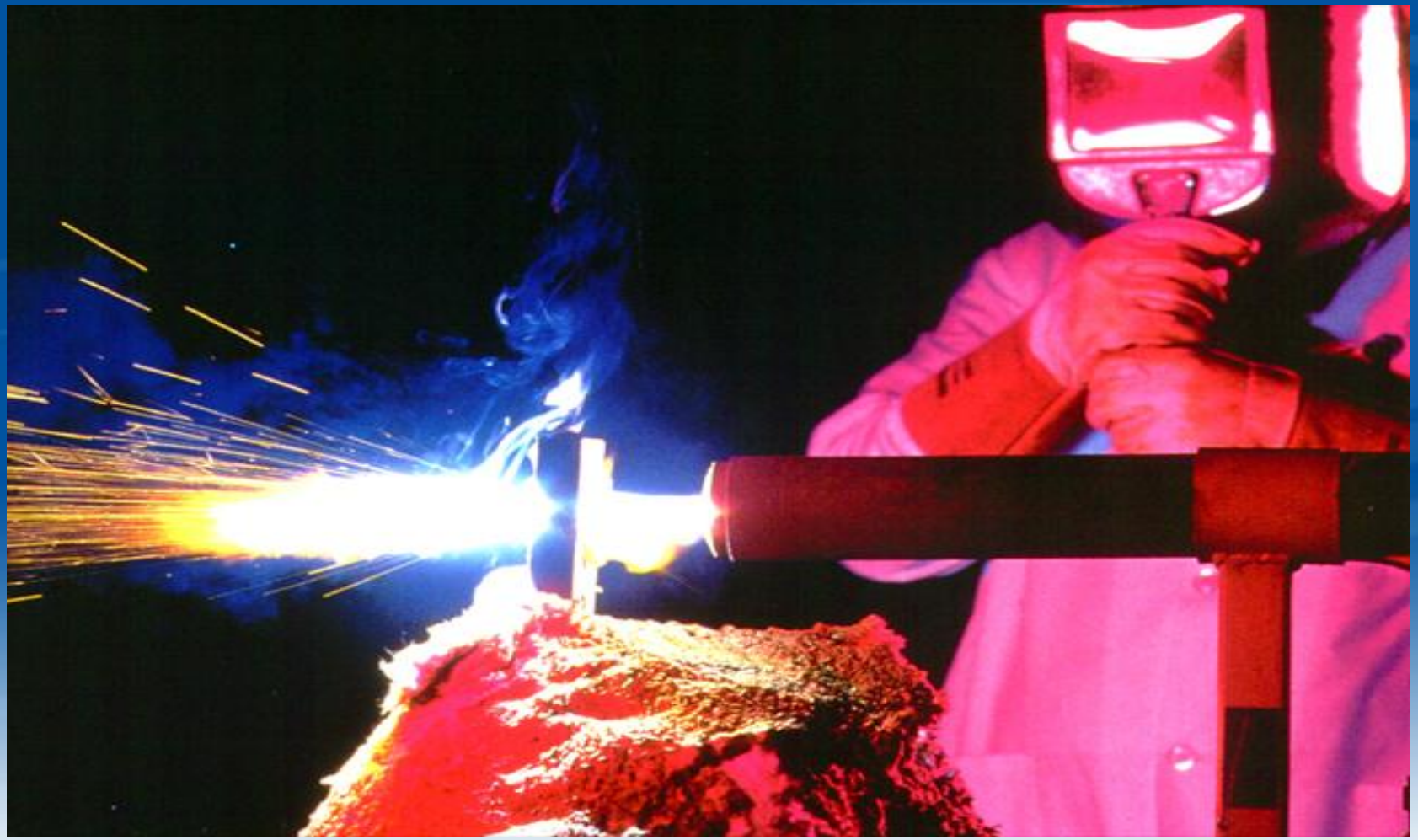
Plasma Torch Power



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Plasma Torches

- Developed into industrial tools for heating
- Variable size and capacity (50 KW and 2500 KW)
- Has performed at large scale (50 tons to 100 tons per hour) commercial facilities in US (GM), Canada (AlCan) and Japan (Kobe, Kawasaki)

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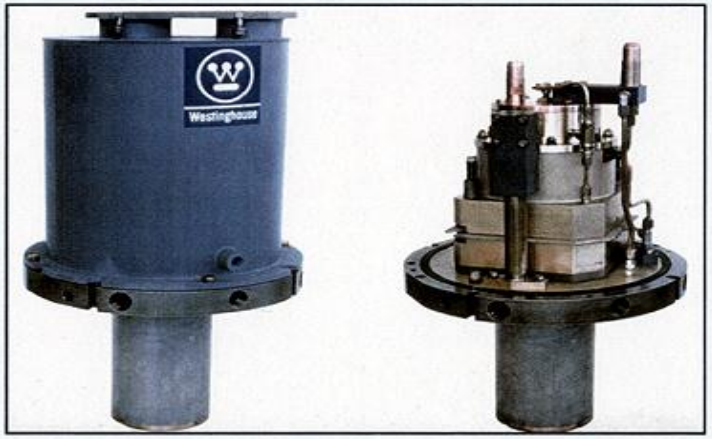
The MARC-11 Plasma System

- Self-Stabilized Arc
- Mode of Operation: Non-Transferred Arc
- Nominal Power:
  - 600 – 2500 Kw
- Cathode: Cold



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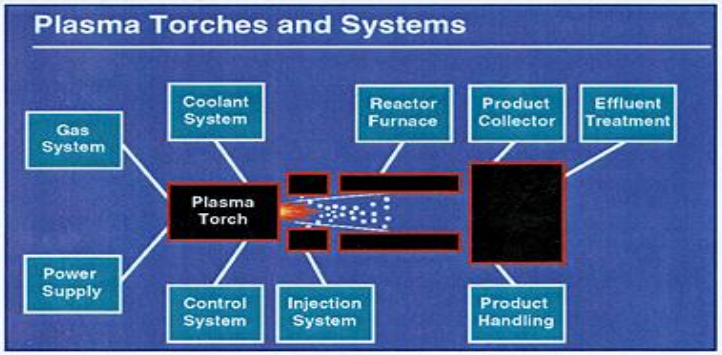
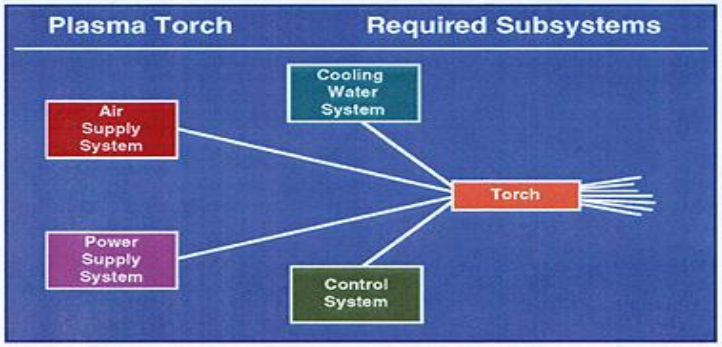
Plasma System Components

- Torch
- Arc Power Supply
- Field Power Supply
- Ignitor
- Gas Supply System
- Deionized Water Supply System
- Control System





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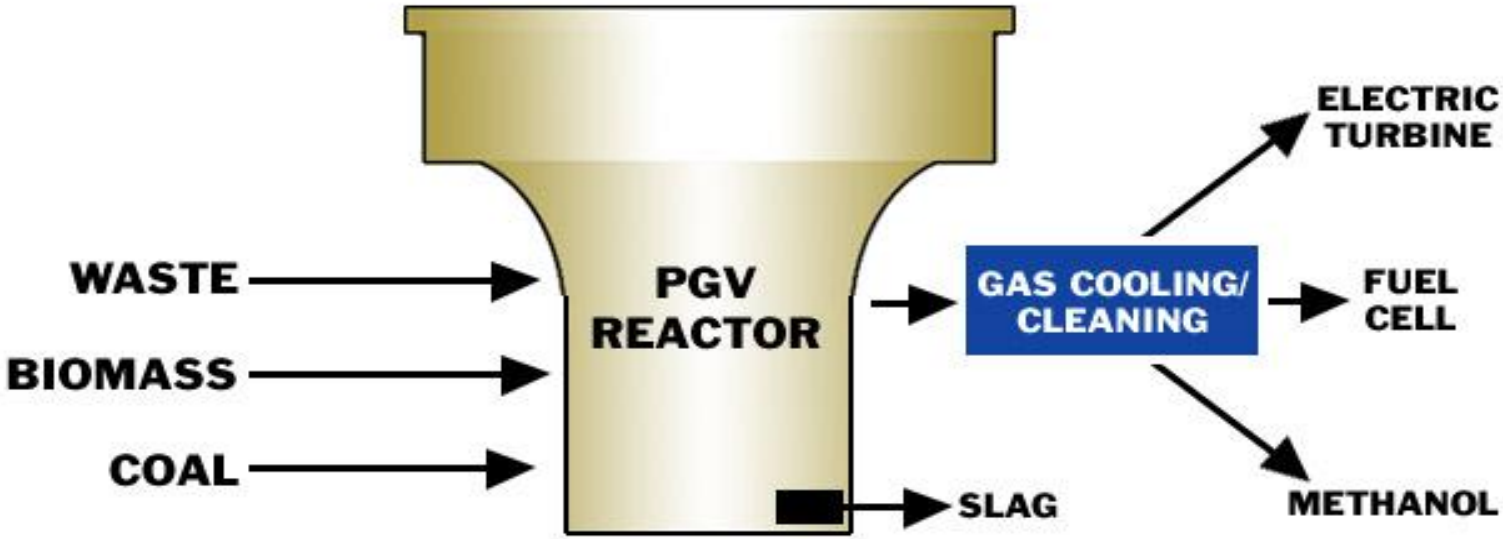
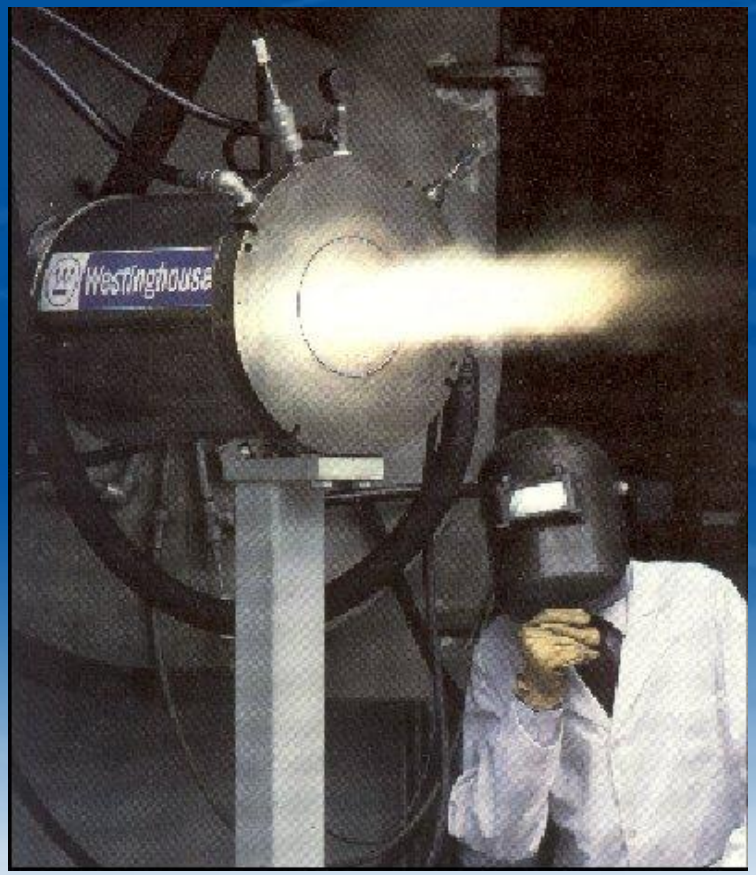
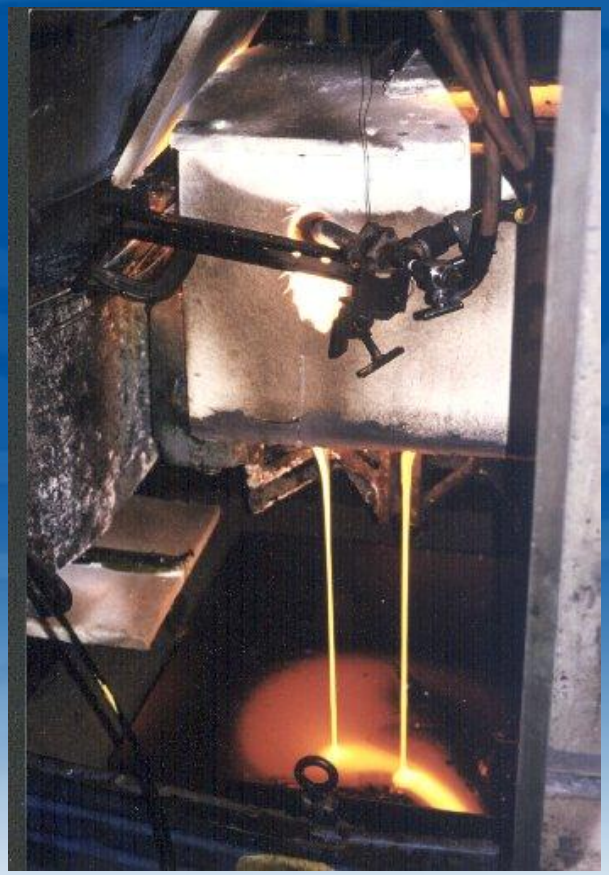
The Patented PGV Process



1. Mixed Materials Fed Into System → 2. Organic Materials Gasified Into H2 / CO…….. Inorganic Materials Vitrified Into Inert "Slag" → 3. Gases Converted Into Energy

Plasma Gasification and Vitrification





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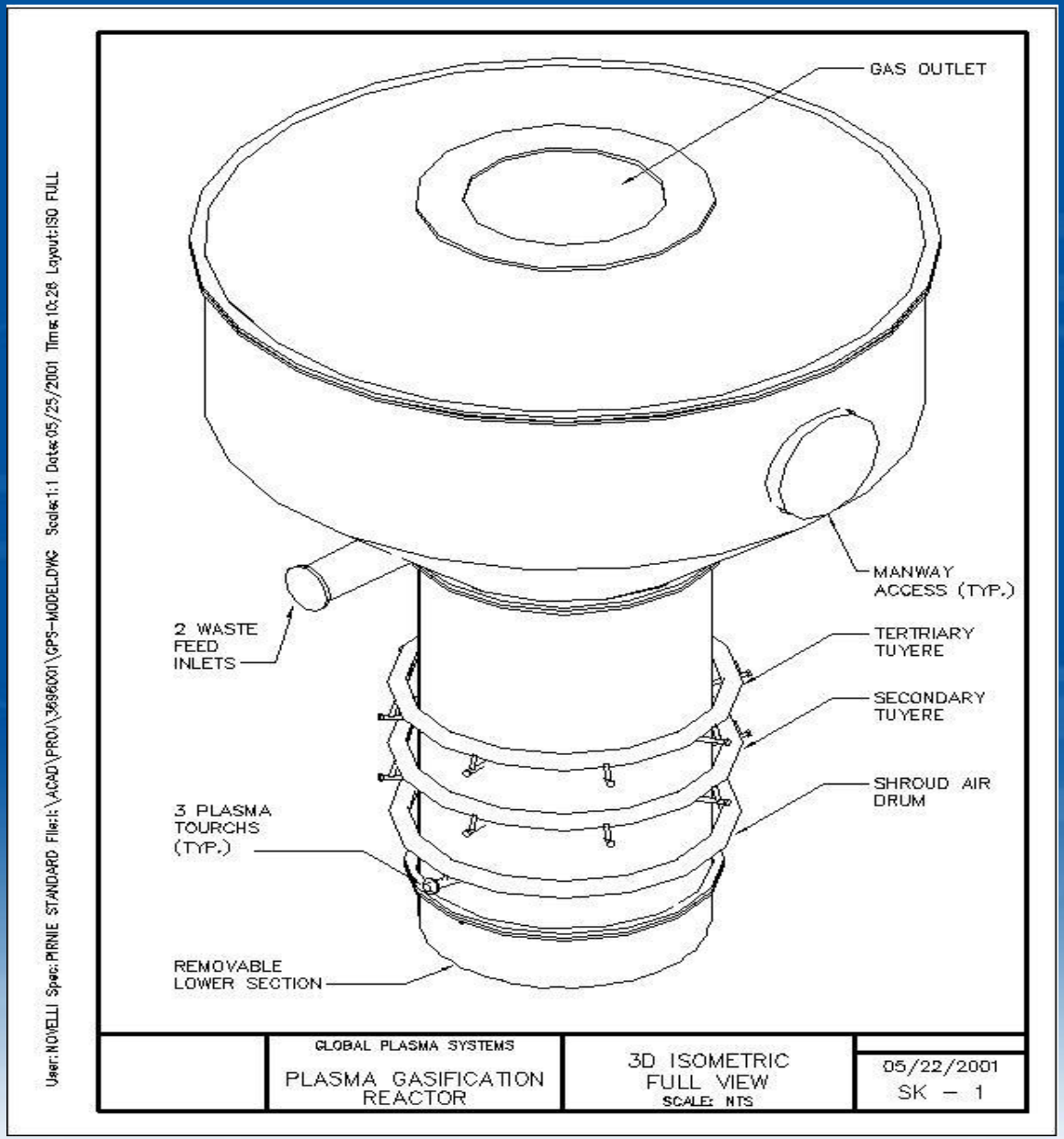
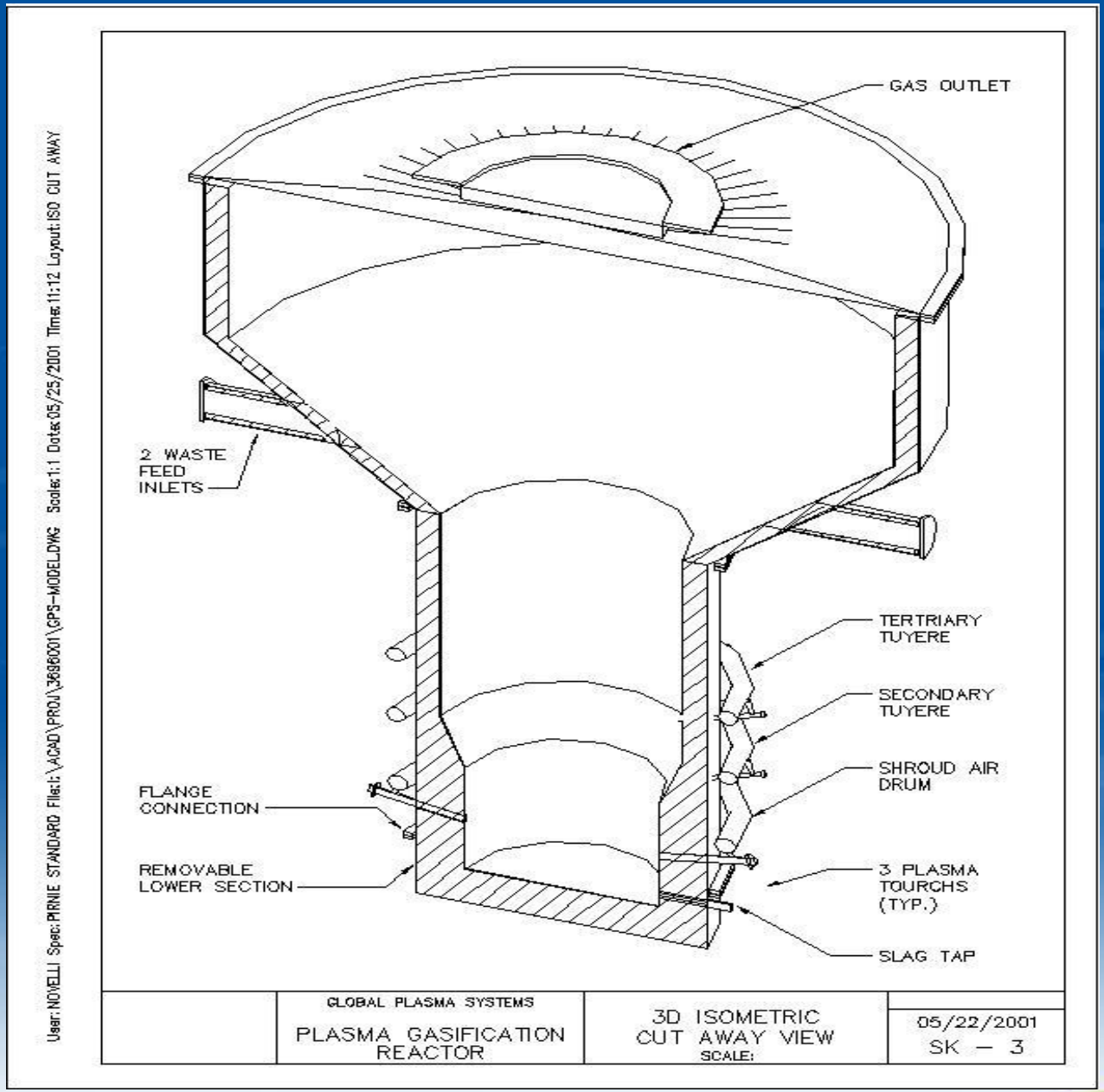
Solena Group Patented PPGV Process

- Utilize Plasma torch heating up to 5000 Degrees Celsius to Produce Clean Renewable Energy
- All organic materials are Gasified into a H2/CO Fuel gas (“Syn-Gas”)
- All Inorganic materials are Vitrified into inert “slag”
- Syn-gas is recovered as electricity/methanol or H2


GAS OUTLET
MANWAY ACCESS (TYP.)
2 WASTE FEED INLETS
TERTRIARY TUYERE
SECONDARY TUYERE
SHROUD AIR DRUM
3 PLASMA TOURCHS (TYP.)
REMOVABLE LOWER SECTION
GLOBAL PLASMA SYSTEMS
PLASMA GASIFICATION REACTOR
3D ISOMETRIC FULL VIEW
SCALE: NTS
05/22/2001
SK – 1
User: NOVELLI Spec: PRNIE STANDARD File: i:\ACAD\PROJ\3696001\GPS-MODEL.DWG Scale: 1:1 Date: 05/25/2001 Time: 10:28 Layout: ISO FULL


User:NOVELLI Spec:PRNIE STANDARD File:I:\ACAD\PROJ\3696001\GPS-MODEL.DWG Scale:1:1 Date:05/25/2001 Time:11:12 Layout:ISO CUT AWAY
GAS OUTLET
2 WASTE FEED INLETS
TERTRIARY TUYERE
SECONDARY TUYERE
SHROUD AIR DRUM
FLANGE CONNECTION
REMOVABLE LOWER SECTION
3 PLASMA TOURCHS (TYP.)
SLAG TAP
GLOBAL PLASMA SYSTEMS
PLASMA GASIFICATION REACTOR
3D ISOMETRIC CUT AWAY VIEW
SCALE:
05/22/2001
SK – 3

Temperature Profile

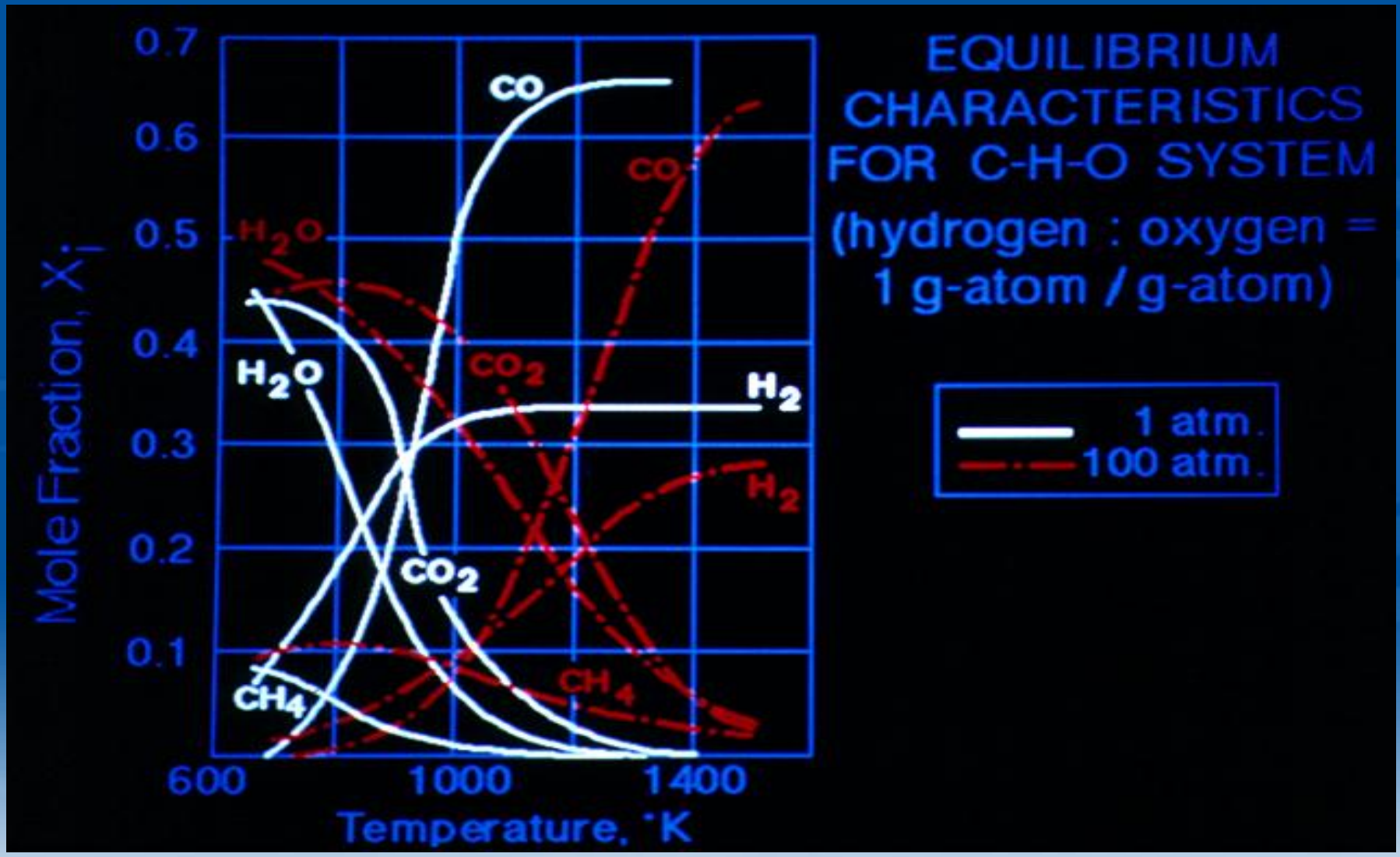
- Exit Gas, 1700 C
- Coke Bed, 1800 – 4000 C
- Torch Plume, > 5000 C
- Slag Pool, 1700 – 1800 C

Gasification Reactions

$C_xH_y + O_2 = 2CO + H_2$ Exothermic

$2C + O_2 = 2CO$ Exothermic

$C + H_2O = CO + H_2$ Endothermic


EQUILIBRIUM CHARACTERISTICS FOR C-H-O SYSTEM
(hydrogen : oxygen = 1 g-atom / g-atom)
1 atm.
100 atm.
Mole Fraction, X_i
0.7
0.6
0.5
0.4
0.3
0.2
0.1
600
1000
1400
Temperature, °K
CO
H_2O
CO_2
H_2
CH_4

PPGV Process Description

- Process Control by Computerized DCS
- Defined Start up, Steady State and Shut Down Procedure
- Control of All Process Variables including:
  - Feed Rate
  - Catalyst Feeding & Flux Feeding
  - Process Air/O2 Enriched
  - Torch Power
  - Catalyst and Waste Bed Height

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PPGV Process Description

- Process Control Variables:
- Variation in Feed:
  - High Moisture Content: Lower Top Gas Temp
  - Lower Carbon Content: Lower HHV of Top Gas
  - Higher Inorganic Content: Increase Slag Flow & Decreased Temp
- Process Control Independent Variables:
  - Adjust Torch Power & Air Flow
  - Higher Temp in PGR : Higher Top Gas HHV & slag

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PPGV Process Description

- Process Parameters Monitored & Controlled:
  - Exit Top Gas Composition, Temp & Flow Rate
  - Reactor Temp & Pressure @ 36” section
  - Refractory Temp at Bottom with Slag Flow and Basicity
  - Catalyst and Waste Bed Height

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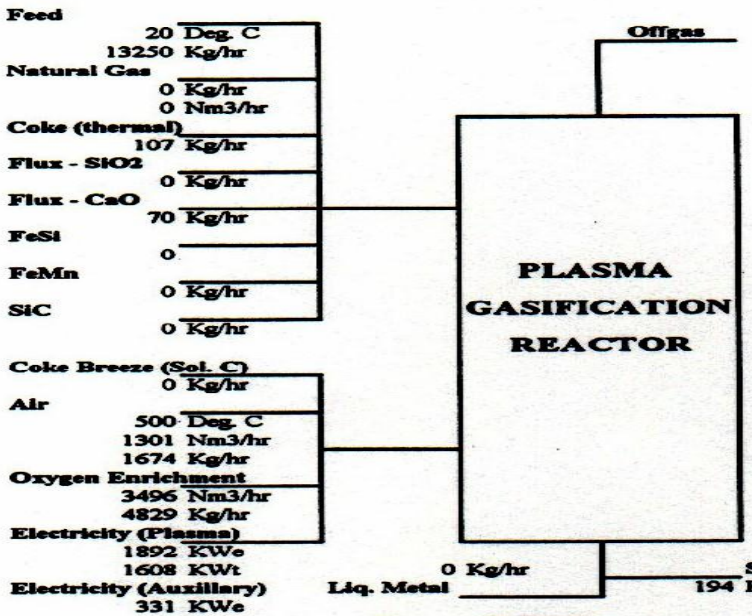

1700 Deg. C
26136 Nm3/hr (gas only)
19735 Kg/hr
11.89 meters/sec

	Wt %	Vol % (gas only)	Kg/hr
CO	70.36%	42.53%	13885
CO2	11.06%	4.25%	2182
O2	0.00%	0.00%	0
N2	8.60%	5.20%	1698
H2	5.35%	45.29%	1056
C2H4	4.24%	2.56%	836
CdO	0.00%		0
ZnO	0.06%		12
PbO	0.00%		0
HCl	0.10%	0.05%	19
H2S	0.23%	0.11%	45
H2O	0.01%	0.01%	2
Total	100.00%	100.00%	19735

Power Generation Option

OffgasDelta H =	8.52E+07	Kcal/hr
Blast Recuperator =	1.50E+05	Kcal/hr
Available Delta H =	8.50E+07	Kcal/hr
Cycle Efficiency @	45.00%	
Electricity Production	44.49	MWe
MW =	16.91	(gas species only)
CO/CO2 =	10.00	(by volume)
HHV =	3258	Kcal/Nm3 (incl. sensible heat)
HHV =	2942	Kcal/Nm3 (without sensible heat)
HHV =	3899	Kcal/Kg (without sensible heat)
LHV =	2718	Kcal/Nm3 (without sensible heat)
LHV =	3601	Kcal/Kg (without sensible heat)

Ni	97.9995%
Mo	0.0000%
V	0.0000%
Ti	0.0000%
Mn	0.0000%
Cu	0.0000%
Cr	0.0000%
Fe	0.0005%
C	2.0000%
Si	0.0000%
Total	100.00%

CdO	0.00%
MgO	0.08%
MnO	0.00%
NiO	0.00%
MoO2	0.00%
V2O5	0.00%
TiO2	0.00%
CuO	0.34%
Cr2O3	0.48%
Al2O3	38.89%
SiO2	8.24%
FexOy	9.57%
ZnO	0.00%
PbO	0.00%
CaO	36.23%
CaCl2	0.00%
CaSO4	0.00%
SnO	0.00%
Na2O	6.10%
Inert	0.00%
Total	99.93%

$$\text{Slag Basicity} = \frac{(CaO + CaCl2 + CaSO4 + MgO + Na2O)}{Al2O3 + SiO2} = 0.90$$

Specific Energy = 168 Kwhr/mt of Feed

Material Balance Closure

	Total	Oxygen	Carbon	
Input	19929	12811	7263	Kg/hr
Output	19929	12817	7263	Kg/hr
Delta	0	-5	0	Kg/hr

Average Tuyere Tip Temp. C	1396			
Primary Tuyere Tip Temp. C	1396	assuming	3 torches &	3070 Nm3/hr of total air through each tuyere.
Design Primary Tuyere Tip Temp. C	1372			
Actual PGR inside diameter (cm)	237			
Actual Blast Rate (Scfm/sq.in)	0.44			
Design PGR inside diameter (cm)	202			
Design Blast Rate (Scfm/sq.in)	0.60			

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Plasma Syn-Gas Composition

- Dependent on Feed Composition
- CO and H2 – Predominant and Stable
- Acid Gas H2S, HCL to be Scrubbed
- CO2 not stable in presence of Solid Carbon
- Minimum Soot and Particulates
- No Precursors to SVOCs

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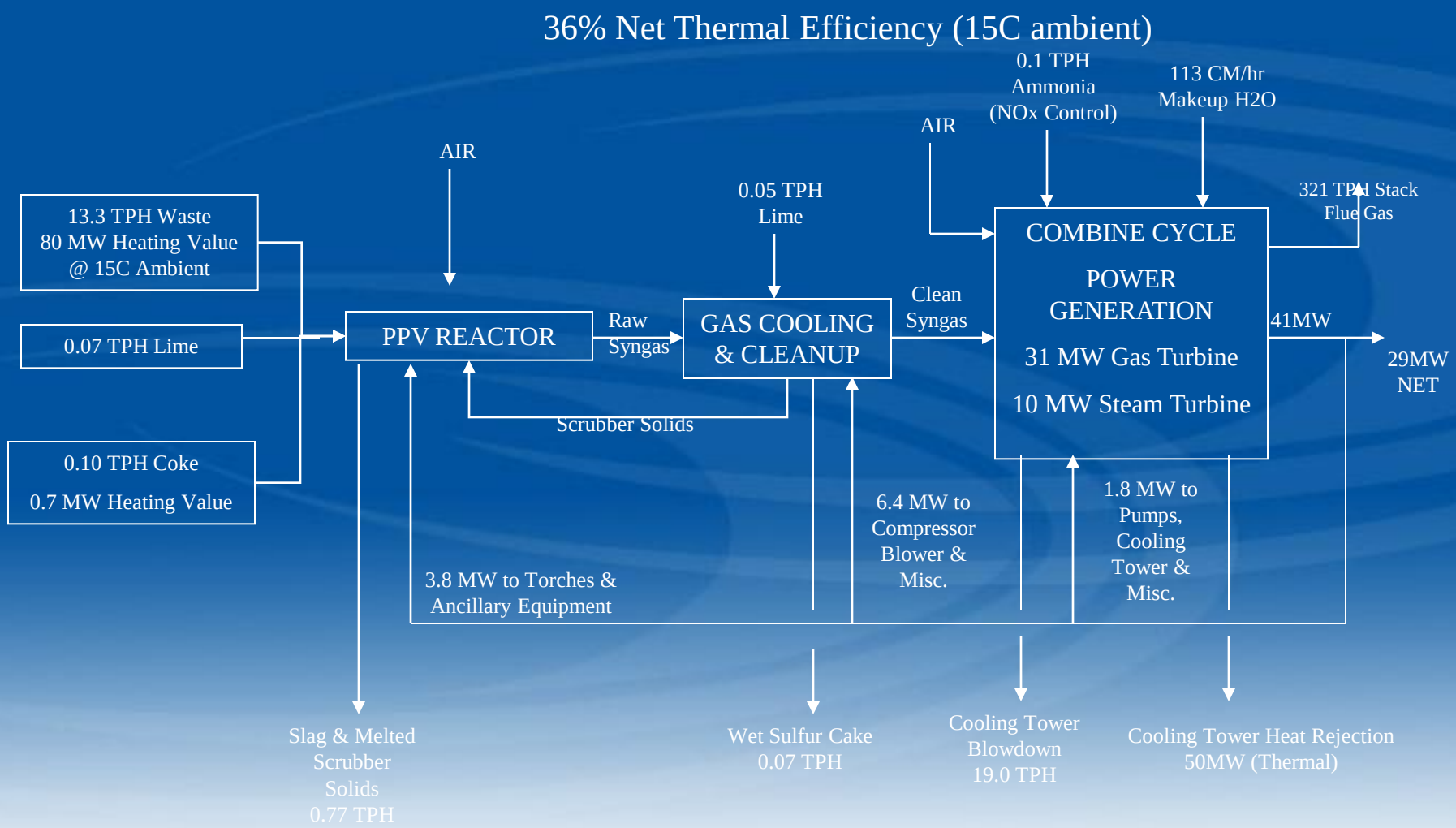
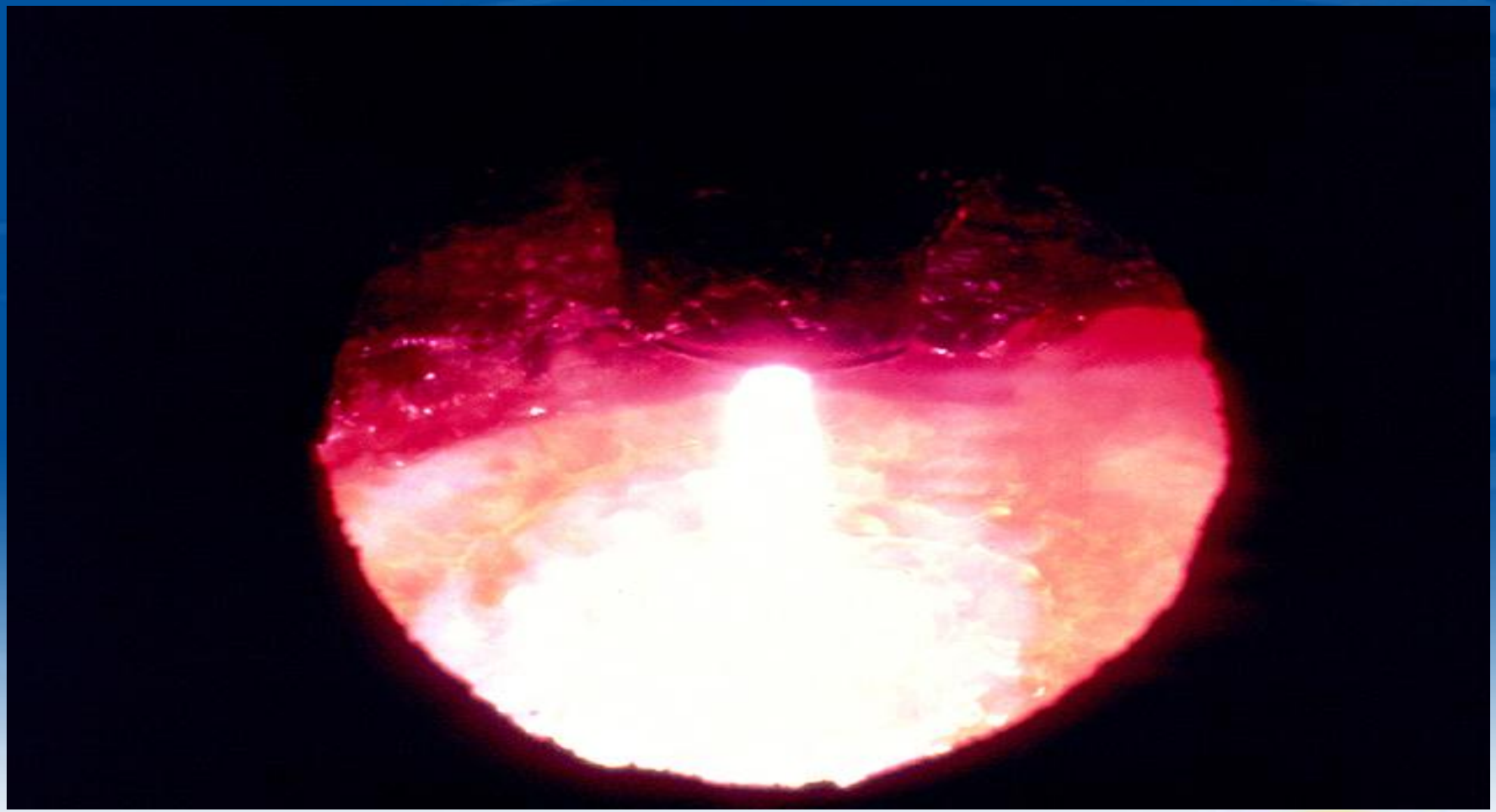
Vicenza Project Overall Heat/Mass Balance



All inorganic waste are vitrified in the plasma molten slag pool



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Plasma Vitrification Provides Both Organic Destruction and Heavy Metal Immobilization

- New York Harbor Sediment Contains a Variety of Hazards:
  - Petroleum Residues, PAH's, and Solvents
  - PCB's, Dioxins and Furans
  - Pesticides
  - Heavy Metals (Pb, Cd, As, Zn, Cr, etc.)
  - Microbiological agents (fecal *coliform*, etc.)
- Plasma Vitrification Provides High Temperatures for Organic Destruction
- Glass Product Immobilizes Heavy Metals

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Environmental Testing Showed Excellent Product Performance

- Molten Glass Poured Easily at 1250°C
- TCLP Meets all EPA Regulatory Limit
- High Destruction Efficiency for All Organics
  - 99.9999999% Overall
  - > 99.98% for PCB's (< detection limit)
  - > 99.81% for PAH's
  - > 99.99% for Dioxins (< detection limit)
  - > 99.98% for Furans (< detection limit)

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Vitrified Sediment Is Re-Usable for a Variety of Applications

- Architectural Tile Manufacture
- Glass Fiber (Rock Wool Insulation)
- Sandblasting Grit (Black Beauty®)
- Roadbed Aggregate ("Glasphalt")
- Roofing Granules (Shingle Manufacture)
- Recycle Glass Cullet
- Environmentally Innocuous Fill Material

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"*Black Gold*" Tile Proved Superior to Recycle Glass Tile Product

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Limitations of PPGV System

- Seen As A New Technology
- Seen As An Expensive Technology
- Lack of Strict Environmental Legislative Framework
- Land Disposal Cheaper in short term
- Not Seen As Energy Production
- Not a “Black Box”

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Advantages of PPGV System

- Gasification Technology Performing at Atmospheric Pressure, Elevated Temperature and High Plant Availability
- Capable of Utilizing Integrated Mixed Waste and/or Coal Fines/Waste as Feed
- Compact and Modular
- Non-Polluting and Environmentally Safe
- High Recovery of Clean Renewable Energy as Electricity and/or H2
- Economically Competitive
- Proven Technology

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Solena Group Coal Waste Gasification

- Fines, Coal Waste, and Ash as potential Feed Stock
- Modular Plant Design
  - **From 50 MWe (Gross)/ 42 MWe (Net)**
  - **Excellent Gas Quality with minimal fly ash**
  - **Produces non-leachable slag as useful by-product**
  - **Small land requirements- Approximately 7 acres or less pending storage requirements**

Emissions: Comparative Analysis

Technology	SOx Lb/Mwh	Nox Lb/Mwh	Ash Lb/Mwh
Traditional Coal Burning	0.2 - 2.7	1.11 - 7	14
Fluidized Gasification	2.7	4	14
Texaco Gasification	0.1 – 0.5	0.56 - 4	0
Plasma PGV	0.1 – 0.5	0.5 - 2	0

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Solena Offers a Cost-Effective Base Load

Energy Generation Cost Comparison

	Geothermal	Solena	Solar	Coal	Clean Coal (Gasification)	Natural Gas (Combined Cycle)	Wind	Fuel Cell
Availability in %	80%	85%	30%	85%	40%	85%	31%	NA
Installed Cost / kW	$ 1,415	$ 1,333	$ 4,083	$ 1,000	$ 1,300	$ 463	$ 742	$ 4,000
Adjusted for Availability	$ 1,769	$ 1,568	$ 13,610	$ 1,176	$ 3,250	$ 545	$ 2,394	NA
Operating Cost / kWh	$ 0.009	$ 0.011	$ 0.005	$ 0.015	$ 0.015	$ 0.021	$ 0.009	$ 0.140
Adjusted for Availability	$ 0.011	$ 0.013	$ 0.015	$ 0.018	$ 0.038	$ 0.024	$ 0.030	NA

Note: Solena operating costs do not include receipt of tipping fees. Tipping fees outweigh operating costs by 2:1.

Source: Department of Energy, UBS Warburg, Goldman Sachs, Solena Management

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Solena Group Project Business Model

- Project Options
  - BOO
  - BOT
  - Turn Key
- BOO/BOT Requirements
  - ROI/ROE must be attractive to Investment Community (20%/30% target)
  - Payback 5-7 years
  - Guaranteed Revenue Streams

Potential Revenue Streams

- Tipping Fee on Feed Stock
- Electricity Sales
- Sale of vitrified product
- Alternative Revenue Streams
  - Tax Relief/Incentives
  - Subsidized Electric Purchase for Renewable Energy
  - Environmental Remediation Subsidies

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Solena Group Current Projects

- Valencia, Spain: 130,000 tpy WTE 75 MUS$
- Kualiti Alam, Malaysia: 50,000 tpy 45 MUS$
- Vicenza, Italy: 130,000 tpy 75 MUS$
- Rome/Malagrotta: 24,000 tpy 12 MUS$
- CFF, France: 150,000 tpy 75 MUS$
- Ibie, Spain: 150,000 tpy 75 MUS$

Plasma Equipment, Design and Integration Partner

- **Westinghouse Plasma Corp.**
  - Exclusive Teaming Partner
  - Leading Engineering Services and Expertise in the Plasma field
  - Commercially Proven Plasma Equipment

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Process Design and Engineering Partners

- **Stone & Webster/CH2MHill**
  - Leading US High Tech Engineering Firms
  - World leading reputation in engineering & construction for land based and ship board system
  - Guaranteed Process Design and Performance

Gasification/APC Engineering Strategic Partner

- Le Gas Integral
  - World Leading Process Engineering in Gas cleaning system
  - Provide APC systems on TK basis
  - Provide APC systems for over 300 gasification plant worldwide
  - Provide complete performance guarantees

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Development & Financial Partner

- **ElectroAmbiente-ENEL Group**
  - Project Development
  - Marketing & Financial Partner
  - Operations & Maintenance of Project

The Solena Group Team

- Has Participated in all major research, industrial and commercial plasma projects in the world
- Capacity to provide complete plasma solution:
  - Project Development, Project Financing Arrangement
  - Design, Engineer, Build
  - Plasma Equipment
  - Operate and Maintain
  - Complete Performance and Project Guarantees

The Solena Group Team

- Only Group in the World with Operating Plasma Industrial Plants
- Only Group in the World with Industrial Plasma Torches with Electrodes Life from 1000 to 3000 hrs.
- Only Group in the World with Plasma Experience in Handling MSW, Toxic Waste, Sludge at Industrial Capacity

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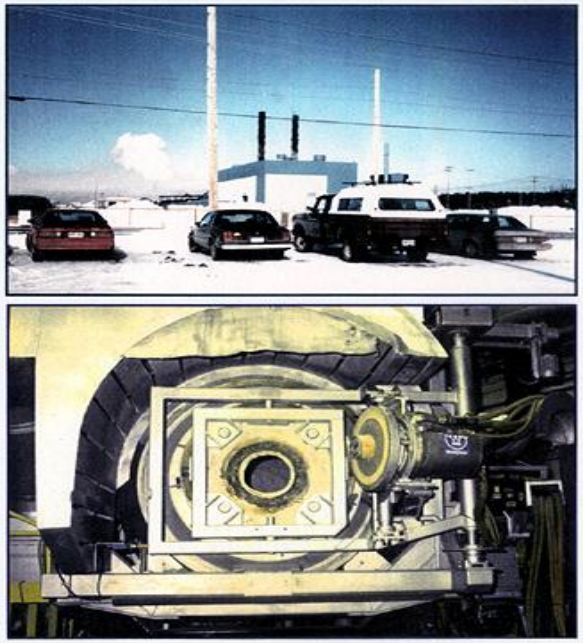
Operating Experience – Commercial Project
Plasma Torch used in Recovery Project in Jonquiere, Canada

- ALCAN Project Started in 1992
- Aluminum Dross Recovery
- MARC-11H Torch
  - 2 active, 1 spare
- Nominal Power:
  - Total System: 3.4 MW
  - Individual Torch: 800 – 1700 KW
- Process Gas: Air
- Electrode Life:
  - Anode: 3500 Hours
  - Cathode: 1500 Hours



ALCAN Pilot Plant Project

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Operating Experience – Commercial Project

Plasma Melter used at General Motors Plant in Defiance, Ohio

- Commissioned in 1987
- Grey Iron Foundry Process
- MARC-11H Torch
  - 6 active, 4 spares
- Nominal Power:
  - Total System: 10.2 MW
  - Individual Torch: 800 – 1700 KW
- Process Gas: Air
- Electrode Life:
  - Anode: 1000 Hours
  - Cathode: 500 Hours

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Operating Experience – Commercial Projects
Plasma Torch used in Kinuura, Japan for Ash Vitrification

- Waste-to Energy Ash Vitrification Commissioned in 1995
- MARC-3A Torches
  - 4 active, 1 spare
- Nominal Power:
  - Total System: 640 KW
  - Individual Torch: 60 – 160 KW
- Process Gas: Air
- Electrode Life:
  - Anode: 900 Hours
  - Cathode: 300 Hours

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Operating Experience – Commercial Project
Plasma Cupola for Geneva Steel in Provo, Utah

- Commissioned in 1996
- Supplemental Hot Metal Production
- MARC-11H Torch
  - 9 active, 2 spares
- Nominal Power:
  - Total System: 18MW
  - Individual Torch: 800 – 2400 KW
- Process Gas: Air
- Electrode Life:
  - Anode: 1500 Hours
  - Cathode: 750 Hours

Plasma-Fired Cupola at Geneva Steel in Provo, Utah is largest in the world and is designed to produce up to 1 million tons of molten metal per year.

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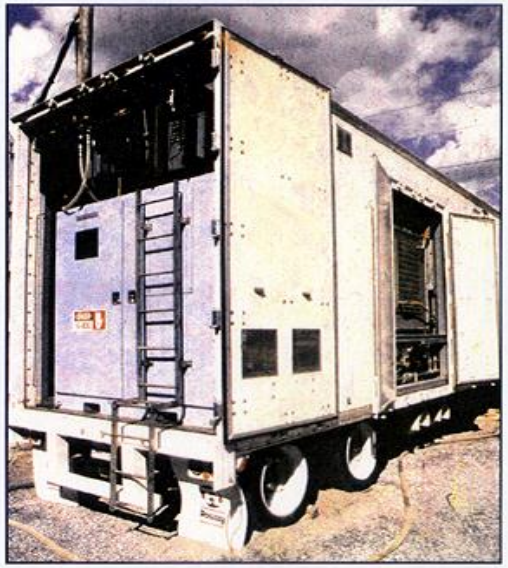
Operating Experience – Commercial Project

Toxic Waste Destruction Project at Plasma Center, Madison, PA

- Project using Pyroplasma Trailer Commenced in 1986
- Destruction of Liquid Toxic Waste
- MARC-11H Torch
  - 1 active, 1 spare
- Nominal Power:
  - Total System: 800 KW
  - Individual Torch: 600 – 800 KW
- Process gas: Oxygen
- Electrode Life:
  - Anode: 900 Hours
  - Cathode: 200 Hours



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Operating Experience – Pilot Plant Project

Plasma Cupola used for Landfill Reclamation at Plasma Center/Madison

- **Treatment of Contaminated Landfill Project – 1987 to 1990**
- **MARC-11H**
- **Power: 750 – 1550 KW**
- **Process Gas: Air**

Plasma Cupola Test Facility–state-of-the-art high temperature process development pilot plant.

Highlights:

- **Non-hazardous slag produced containing heavy metals**
- **Metals recovered by byproduct (Iron, Copper)**
- **Steady state operation maintained for 72 hours**

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Project Guarantees

- Performance Guarantees
  - Plasma Heating Systems Guarantees
  - Complete Equipment Guarantees (All equipment is “off the shelf” industrial equipment)
  - EPC Contractor Guarantees
- All Guarantees wrapped and covered with Complete System Performance Insurance from Hartford Steam Boilers (AIG) and MARSH