Carbon Dioxide Sequestration / Generation and Top Side Equipment in Support of Enhanced Oil Recovery, Enhanced Geothermal Systems, or Both!

SMU Geothermal Conference
4 November 2009

Presented by:
Paul M. Dunn, USN SES (ret.)
COO, Gas Equipment Engineering Corporation

Co-Authors:
Rick Mobley, CEO, Plasma Energy
Greg Gutoski, Technical Director, Fairbanks Morse Engine

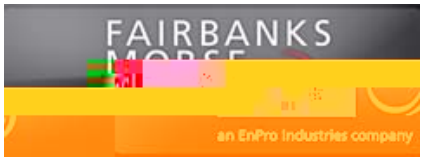
Bottom Line Up Front

- **Next generation Enhanced Geothermal Systems (EGS) and Tertiary Enhanced Oil Recovery (EOR) may have at least one thing in common, supercritical CO2**

- **Gas Equipment Engineering Corporation, founded in 1921 as a producer of CO2, has teamed with Plasma Energy, Fairbanks Morse Engine, and many others in several efforts which pursue the common need of low cost topping systems that enable the research and broader development of EGS-CO2 and Tertiary EOR, as well as new lower or zero emission power generation technology**

NAVY1
85 MW
California
1987
IOC

Introductions

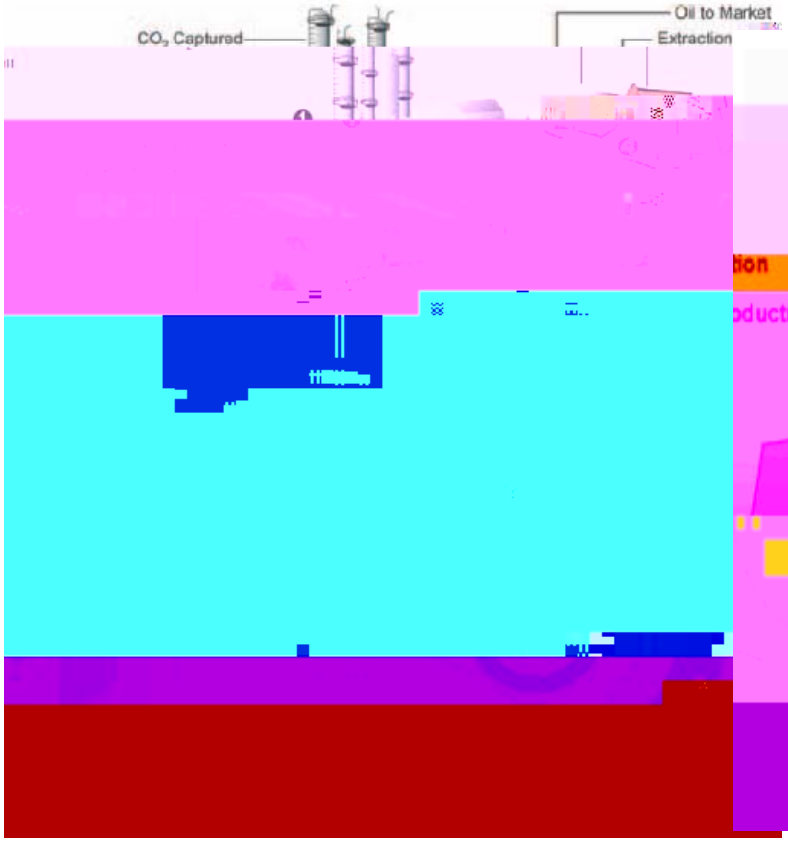


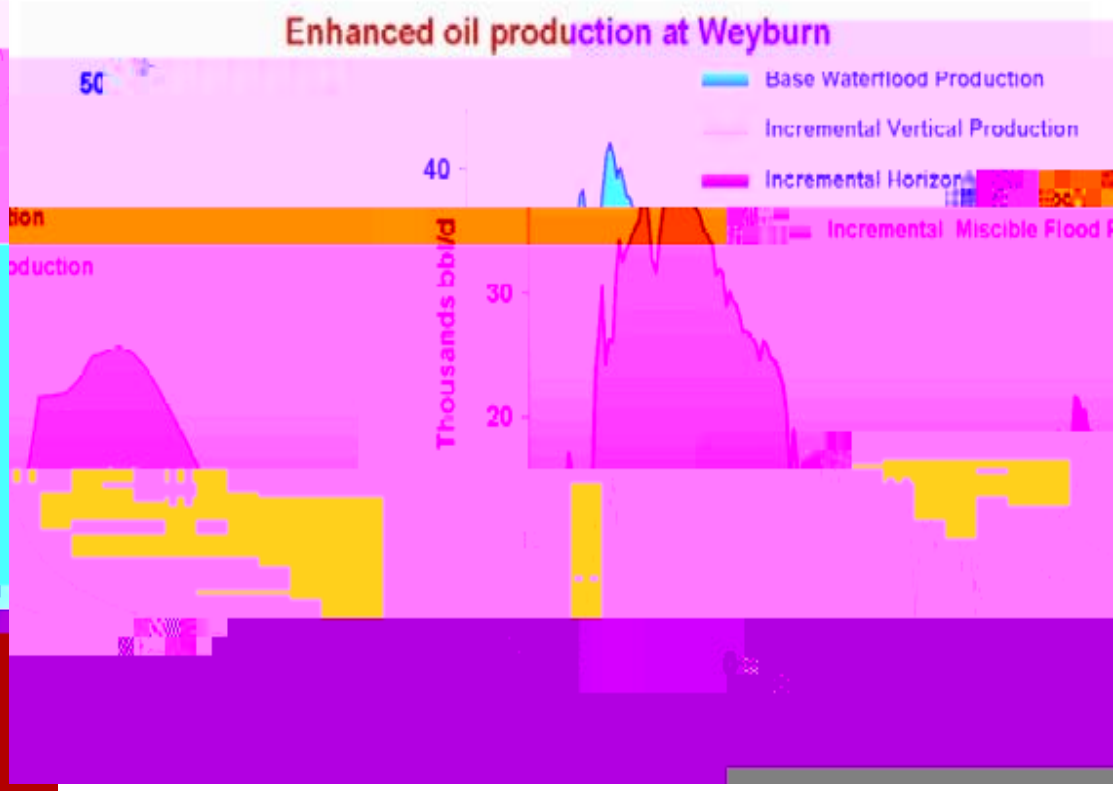
- GEECO is a supplier of custom, high performance Air Separation Units and specialty gas equipment to the US Navy and other very demanding customers

- Fairbanks Morse Engine is the original U.S. manufacturer and today's premier provider of customized medium-speed engine systems and generator sets, diesel or dual

One Example of the Benefit of CO2 EOR…

Weyburn, SK Canada – Enhanced Oil Recovery CO_2 Flood Model



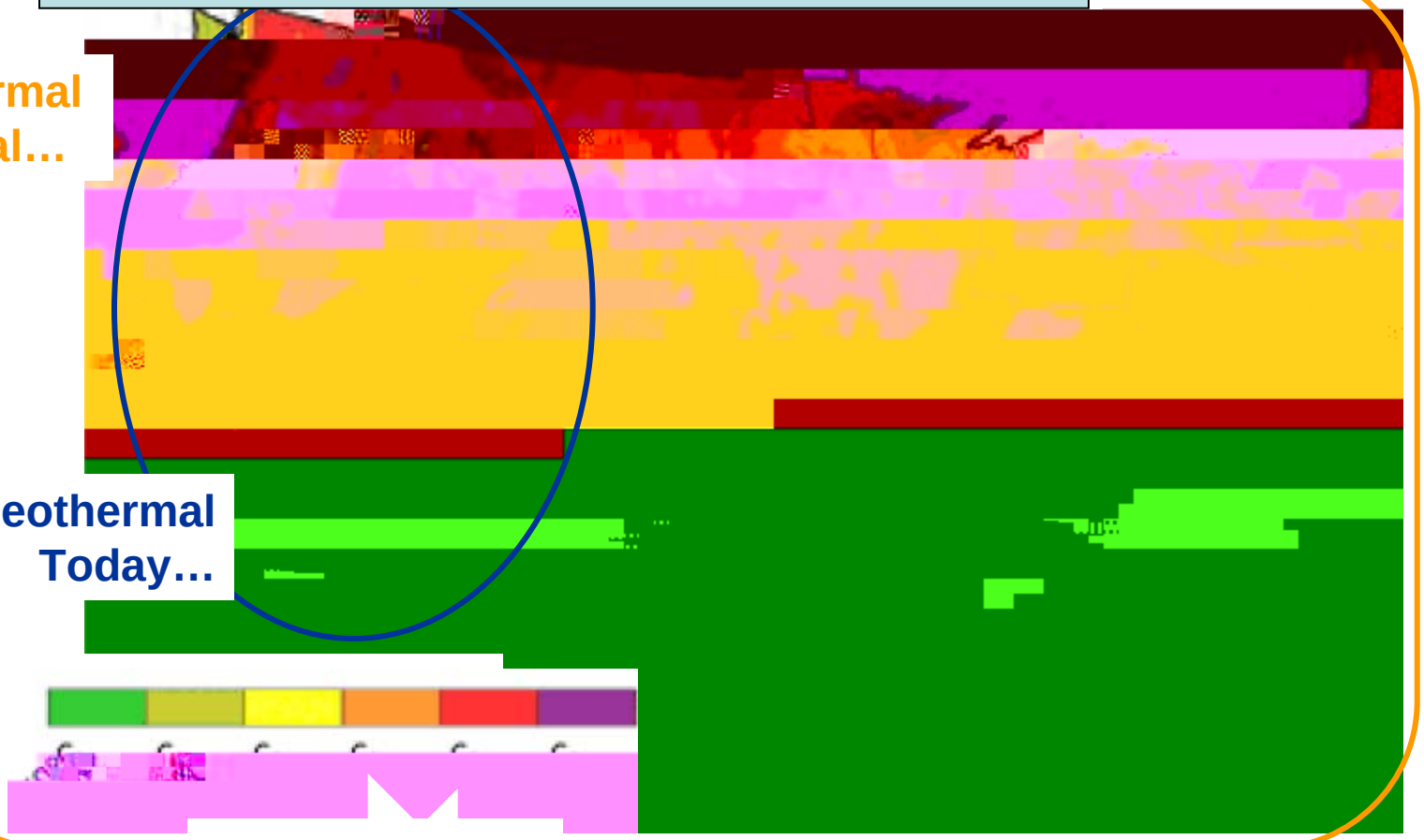


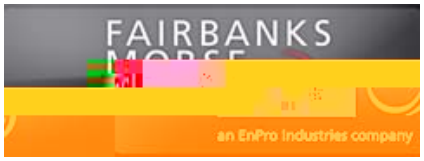
And… CO2 EGS Enables Greater Exploitation Of Geothermal Energy

Geothermal today is exclusively in areas of high heat flow. Exploitation of geothermal is possible nearly anywhere in the lower 48, but lower reservoir temperatures will increase the pumping power burden. CO2 EGS thermal siphon eliminates the "pumping penalty".

Geothermal Potential…

Geothermal Today…

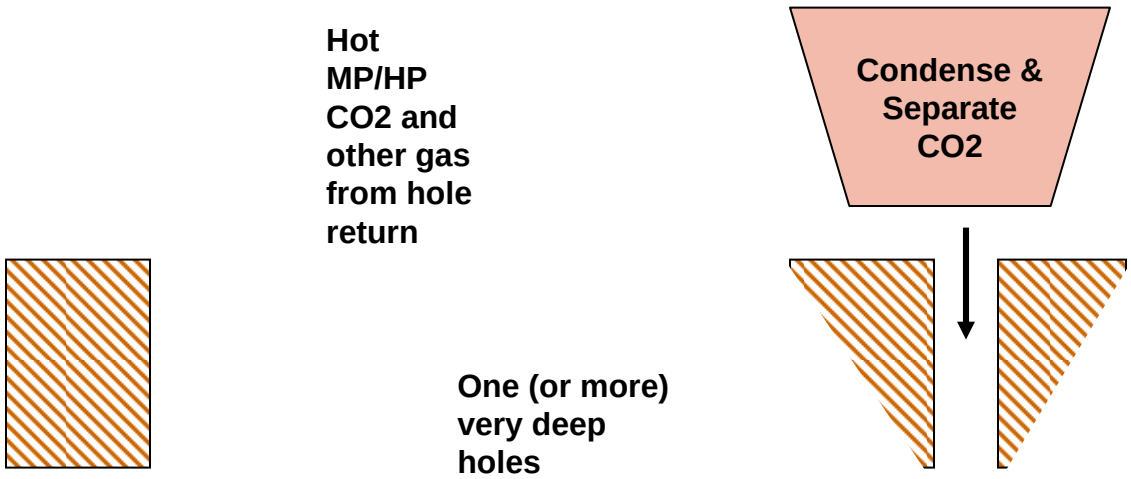



FAIRBANKS
an EnPro Industries company

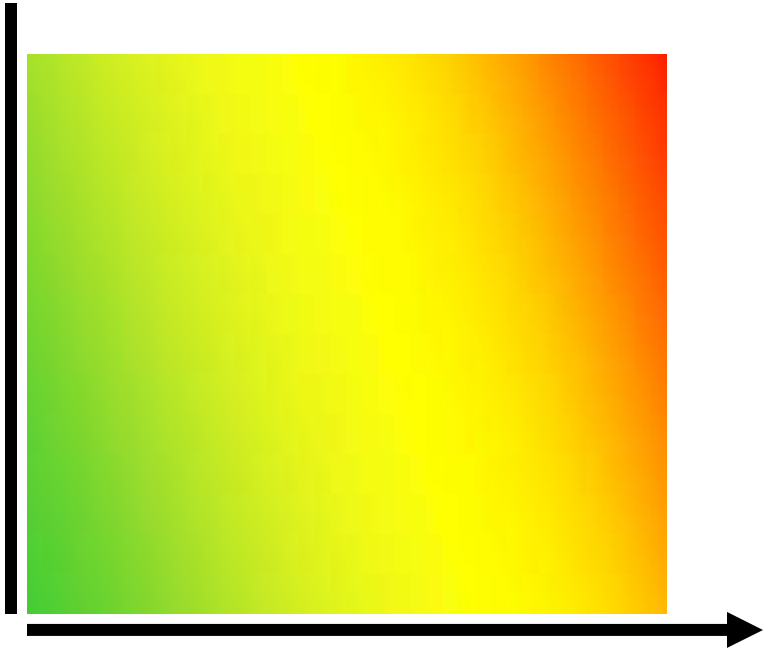

PLASMA

Development of Top Side Equipment Concept

- **Basic CO2 EGS Thermal Siphon with Optional Power Turbine**



How Much CO2?
EOR Will in General Use More (per acre) than EGS, but even EGS Uses a Lot…



- The mass of CO2 required to charge a given reservoir is a function of the density (average at temperature and depth), volume, and porosity
- The "dot" is at ~$4M per MWe, e.g.
  - 50 MW, 1 km^3
  - 0.1% porosity
  - 700 ktons CO2
  - $210M @ $300/ton

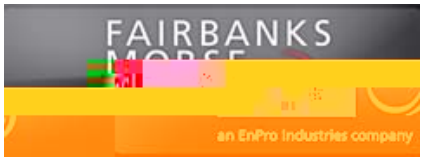
A big barrier for early implementation of EGS-CO2 is CO2 cost / technical risk

Removing the CO2 Cost Barrier

- **Highly efficient, and highly non-emissive power systems can be operated with enriched air (or pure oxygen)**
  - **The NOx emission problem can essentially go away; enabling higher combustion temperatures / greater efficiency**
  - **From refined fuels, using a FME Dual Fuel genset, modified for closed cycle with EGR, the exhaust stream can be essentially pure CO2 and water**
  - **From unrefined fuels, using a Plasma Energy process, the same pure gaseous exhaust exists, and metal / salt particulates are captured**

- **Since both concepts generate net power, and power can be sold or used in lieu of purchased power, the effective cost barrier for CO2 is removed**

Removing the CO2 cost barrier enables (reduces cost of) EGS-CO2 research & demonstration work now and ultimately enables broader deployment of EGS-CO2 and Tertiary EOR



Gas Handling, Pumping & Control

Air Enrichment is the Key

Effect of Enriched Air, Diesel Hybrid System

Effect of
Enrichment
Enrichment

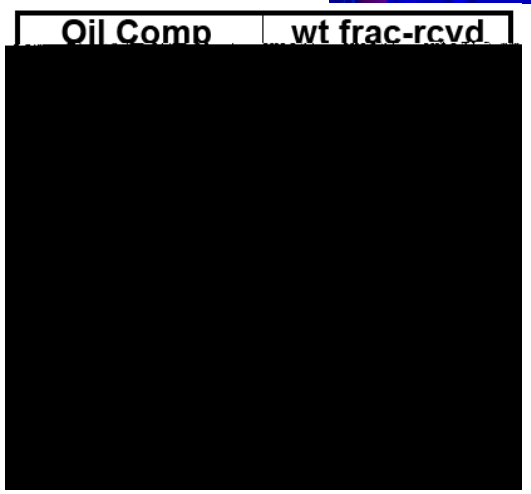
FME Dual Fuel Example with Natural Gas (70 psi)

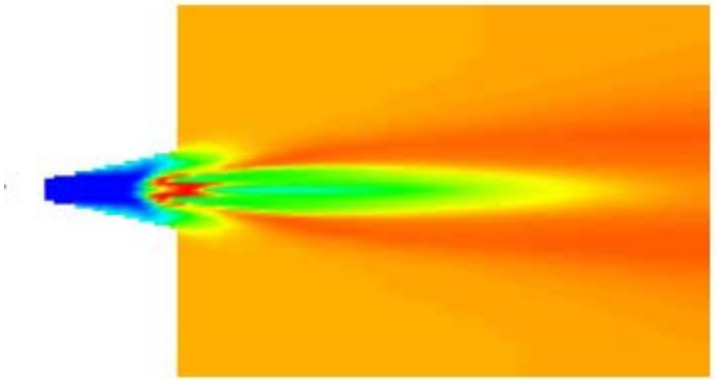
Net Cost of CO2, Diesel Hybrid System

Power and Net Cost of CO2 per Ton	Output (kWe)	Comp. (hp)	PVSA (hp)	CHP (kWe)	Power (kWe)	($ per kW-hr) $0.05	$0.10	$0.15	$0.20
Case 1, 180% Excess Air, 0% N2 / Inert Adsorbtion	3000	5888		540	-620	$210.62	$226.85	$243.07	$259.30
Case 2, 180% Excess Air, 60% N2 / Inert Adsorbtion	3000	1098	940	540	2080	$140.02	$85.64	$31.27	($23.11)
Case 3, 180% Excess Air, 78% N2 / Inert Adsorbtion	3000	773	940	540	2307	$134.07	$73.73	$13.40	($46.94)
Case 4, 180% Excess Air, 97% N2 / Inert Adsorbtion	3000	448	940	540	2535	$128.11	$61.82	($4.47)	($70.76)

Plasma Energy Thermal CO2 System Flexibility…

- High temperature oxygen combustion system with the flexibility to combust lower-cost, lower rank solid or liquid fuels
- Provides high quality thermal inputs with zero greenhouse gas emissions
- Pure CO2 stream with complete carbon and sulfur capture
- Modular in-field cogen system designed to operate in harsh field condition
- The net result will usually be a lower break even point with respect to local electric rate than with refined fuels





Outlook / Plans

- **GEECO and our partners plan to demonstrate these capabilities, including ultimately the EGS / EOR portion**
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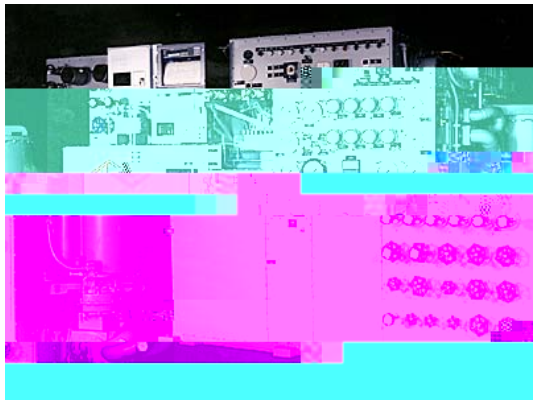
Summary



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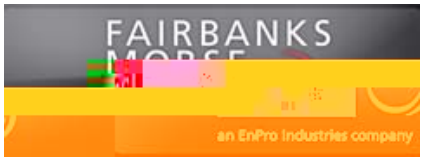

- **Paul M. Dunn, COO, GEECO**
  - **(203) 874-6786**
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