

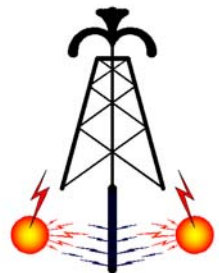
# Past, Present, and Pending Intellectual Property for Electromagnetic Heating of Oil Shale

28<sup>th</sup> Annual Oil Shale Symposium  
Colorado School of Mines  
October 13 – 15, 2008



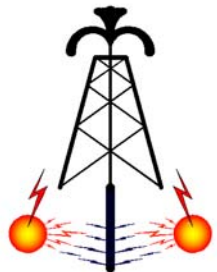
# Objectives

- To provide relevant prior art research
- To show breadth of prior art
- To depict the intensity of electromagnetic heating research prior to the 1980s bust in oil prices
- To illustrate that most R&D was conducted prior to the modern microprocessor, PC software, and sensory input technology
- An overview of Quasar Energy LLC intellectual property



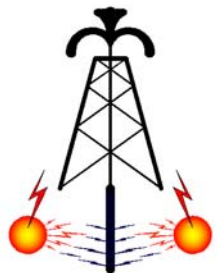
# Definition of a Patent

A patent is a set of exclusive rights granted by a state to an inventor, or his/her assignee, for a fixed period of time, in exchange for a disclosure of an invention.



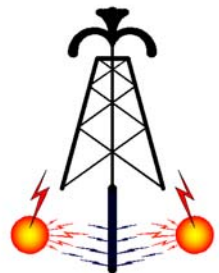
# Scope of Prior Art for this Presentation

In-Situ passage of an electrical current through an oil shale formation, or an apparatus and/or method that is integral or supportive.



# Categories of the Prior Art Search

- Resistive Heating
  - 1 Hz to 300 KHz
  - also known as Joule or Ohmic heating
- Radio Frequency Heating
  - 300 KHz to 300 MHz (Medium, High, Very High Bands)
- Microwave Heating
  - 300 MHz to 300 GHz
- Downhole Tool
- Supportive Apparatus and/or Method



1950

1960

1970

2,757,738  
Radiation Heating  
Union Oil Company



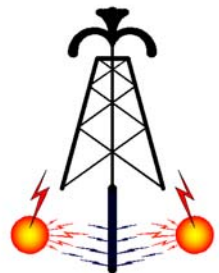
17 Years from Grant

Expiration

2,795,279  
...Underground Electrolinking & Electrocarbo  
Electrotherm Research Corp

Date of Grant

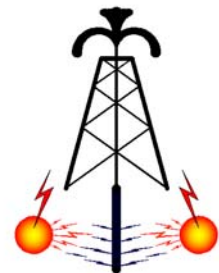
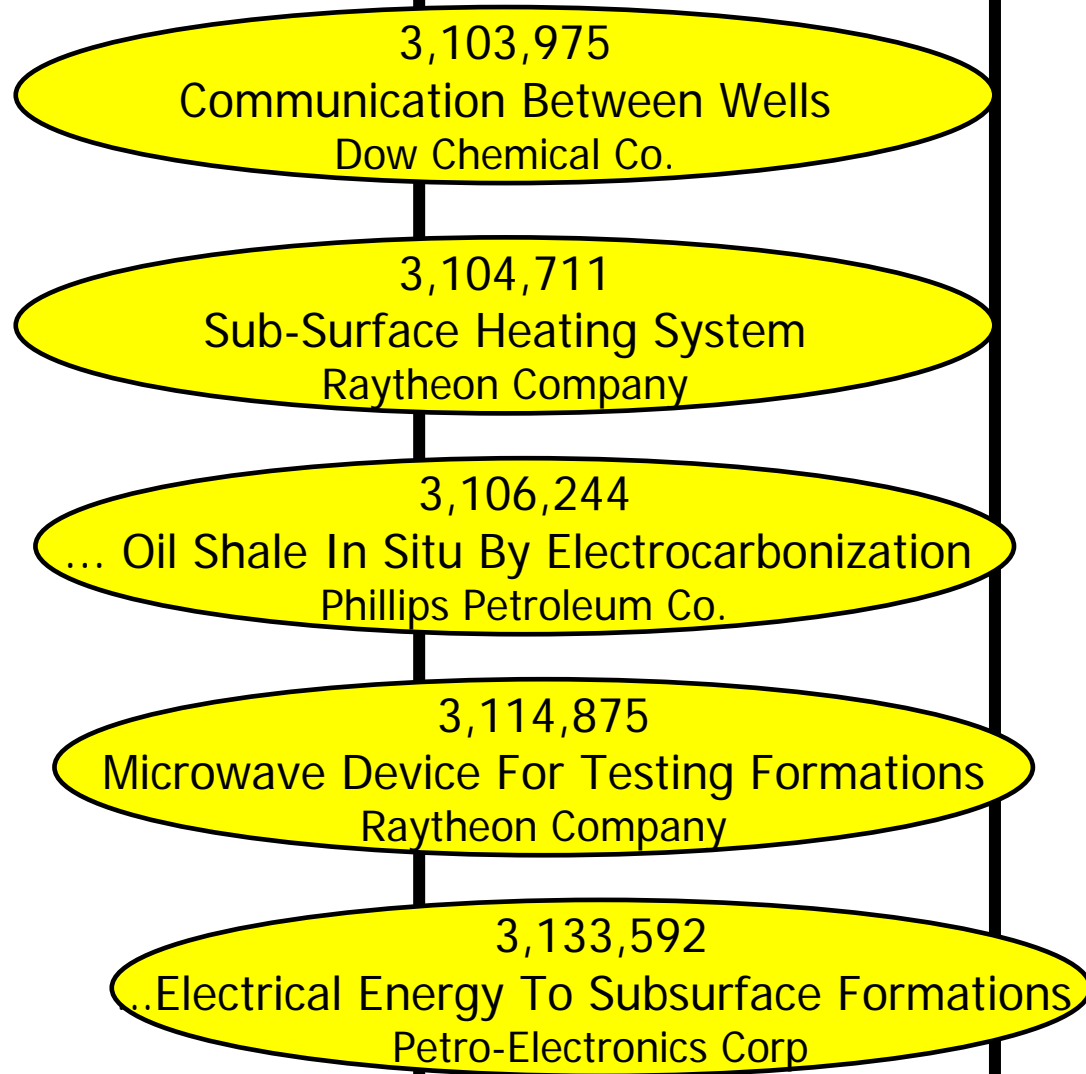
2,799,641  
Electrolytically Promoting The Flow Of Oil  
Thomas Gordon Bell



1960

1970

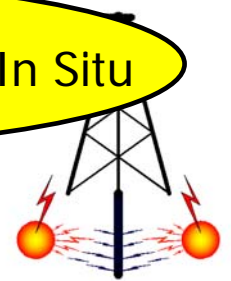
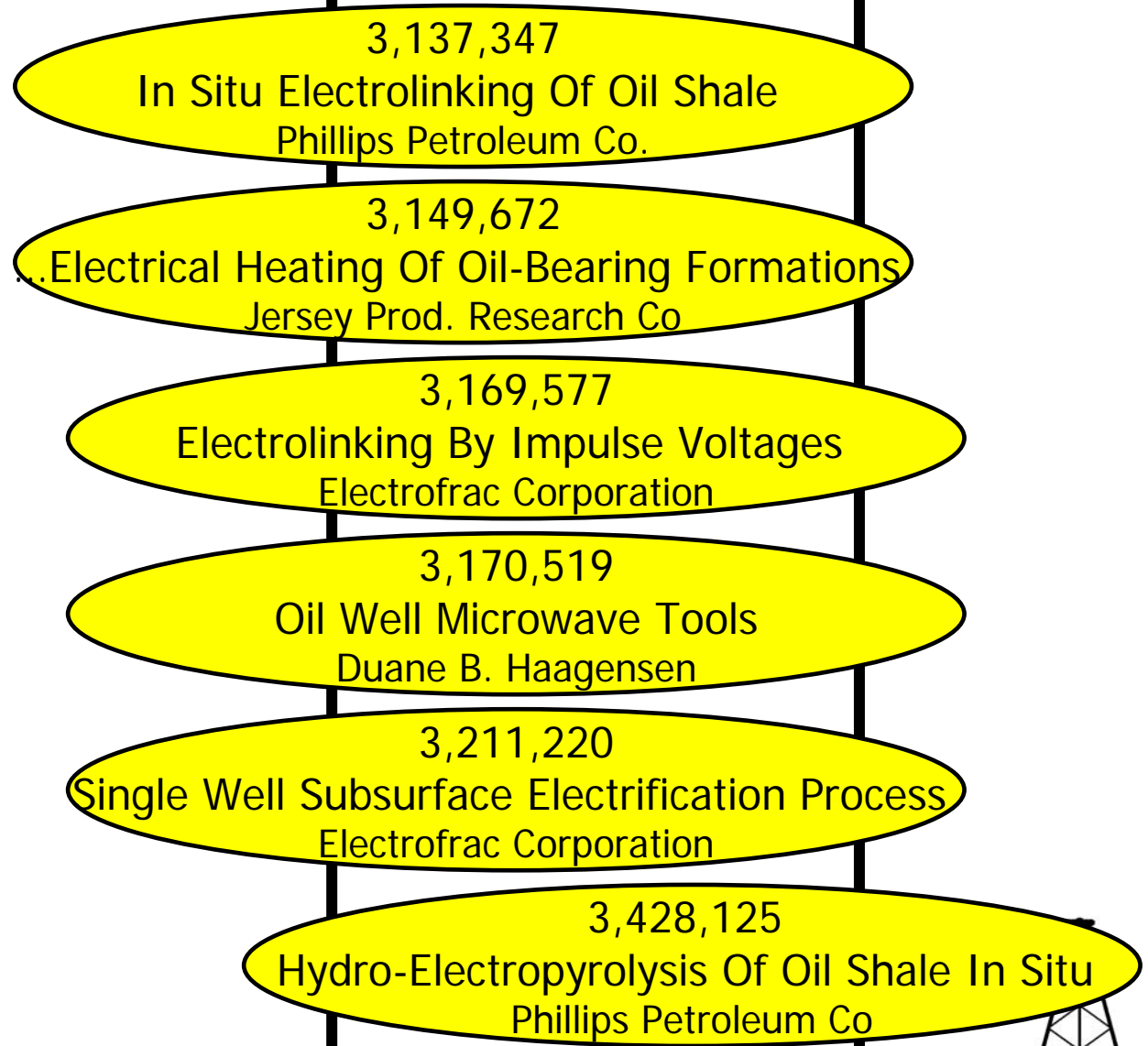
1980



1960

1970

1980

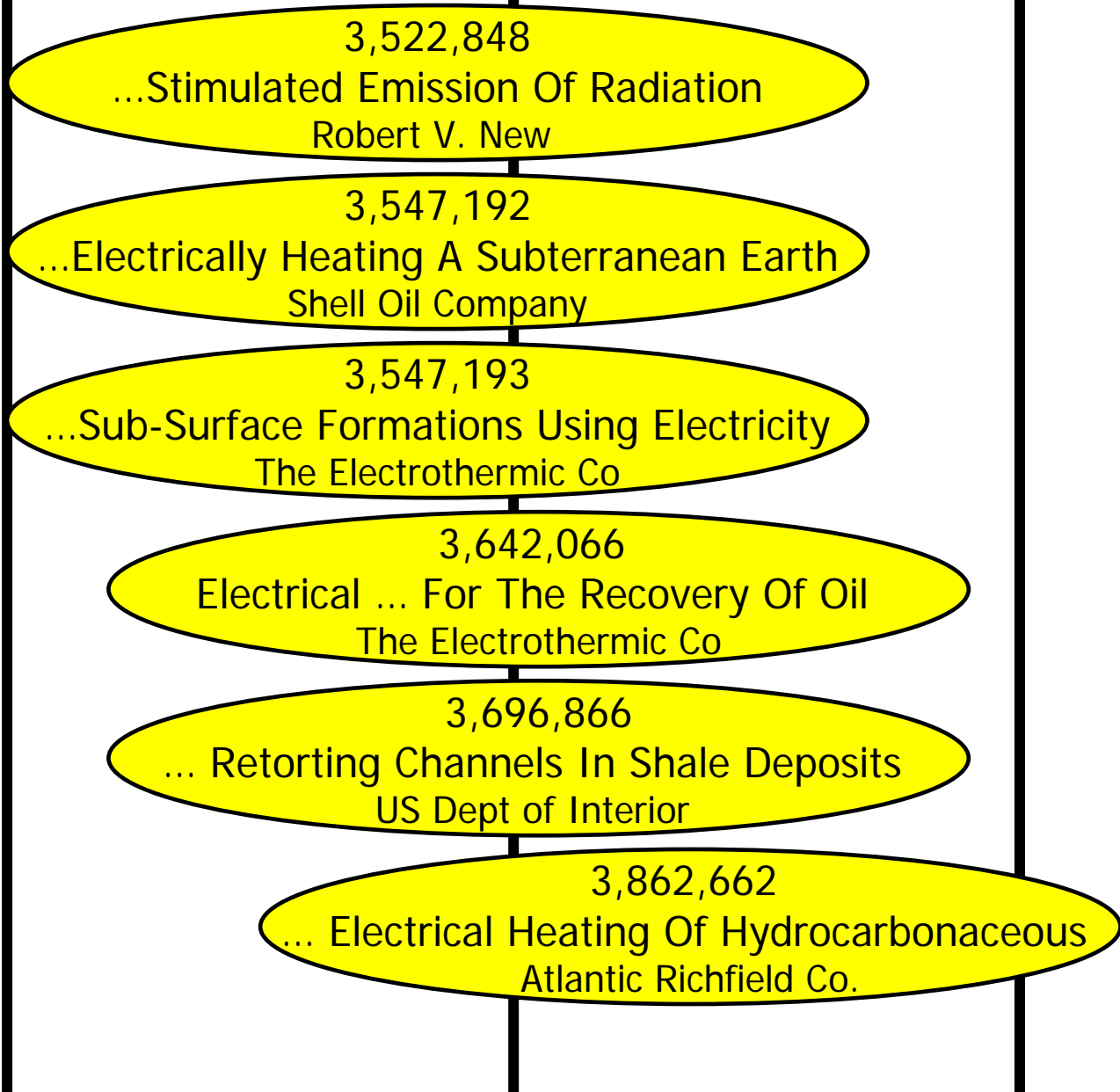




1970

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1990



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3,874,450  
...Electrically Heating A Subsurface Formation  
Atlantic Richfield Co.

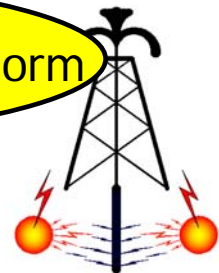
3,931,856  
Method Of Heating A Subterranean Formati  
Atlantic Richfield Co.

3,946,809  
... Steam Stimulation & Electrical Heating  
Exxon Production Research

3,948,319  
...Varying Current Flow ... Source Formation  
Atlantic Richfield Co.

4,008,762  
... In Situ From Underground Deposits  
Sidney T. Fisher

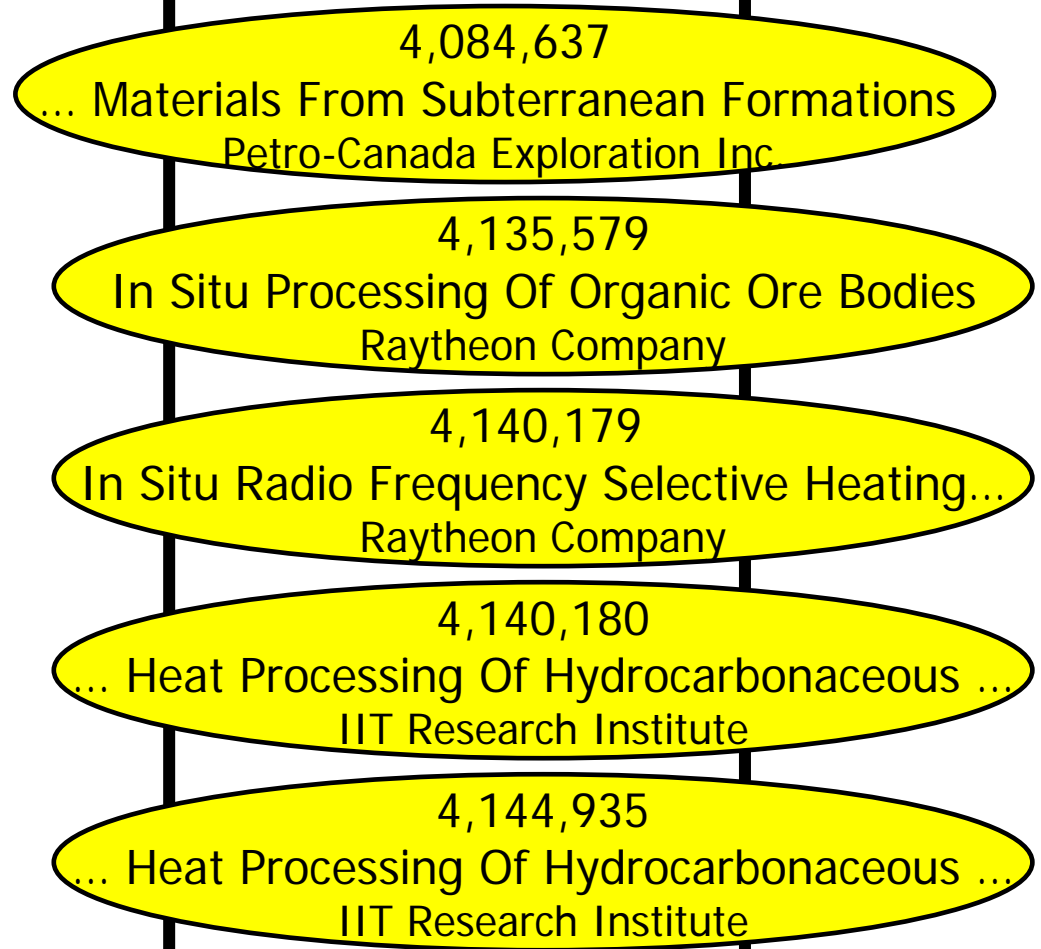
4,010,799  
.. Electrical Heating Of A Subterranean Form  
Petro-Canada Exploration Inc.



1970

1980

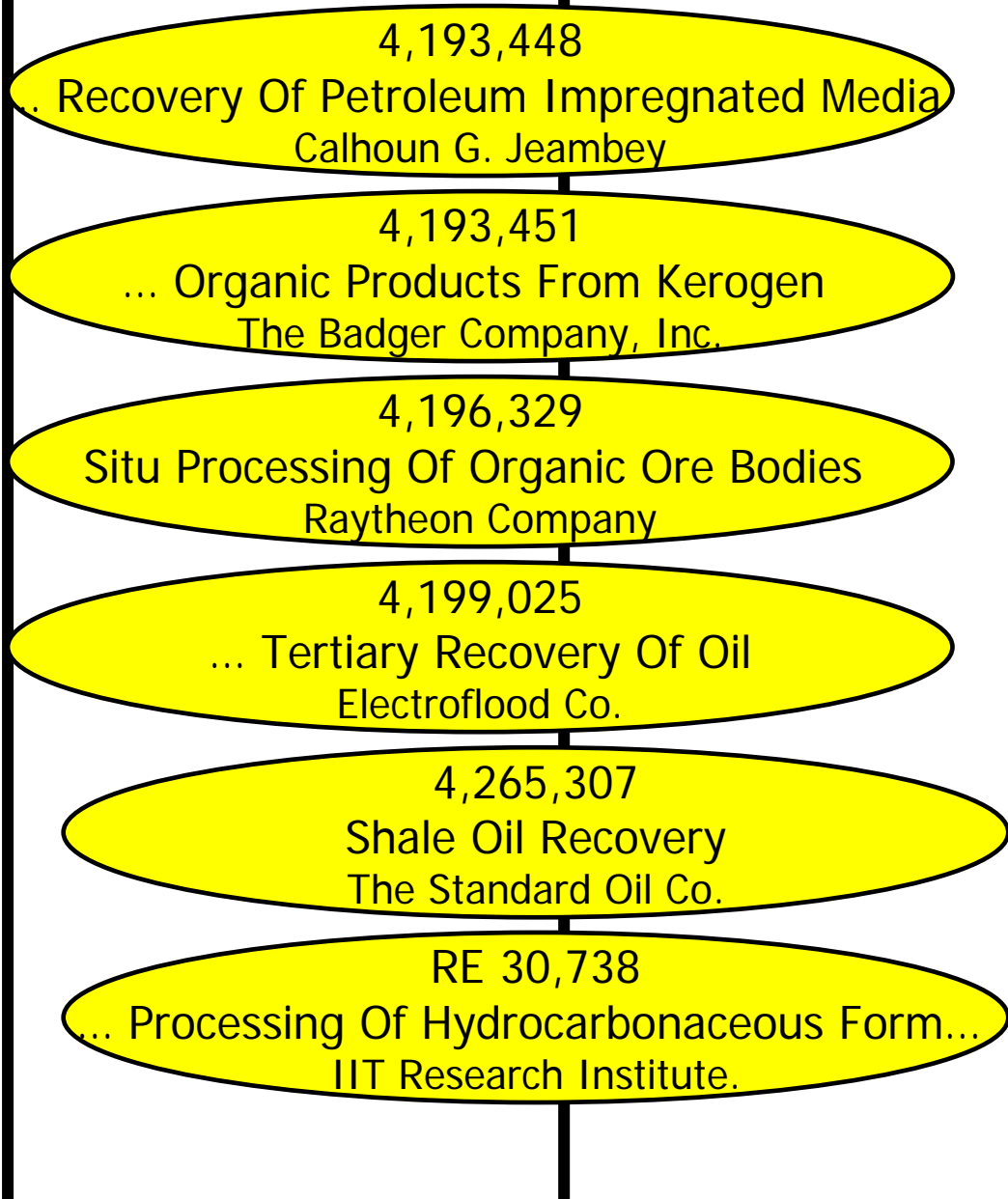
1990



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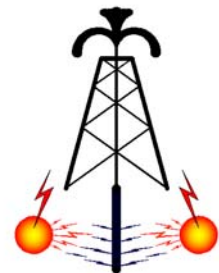
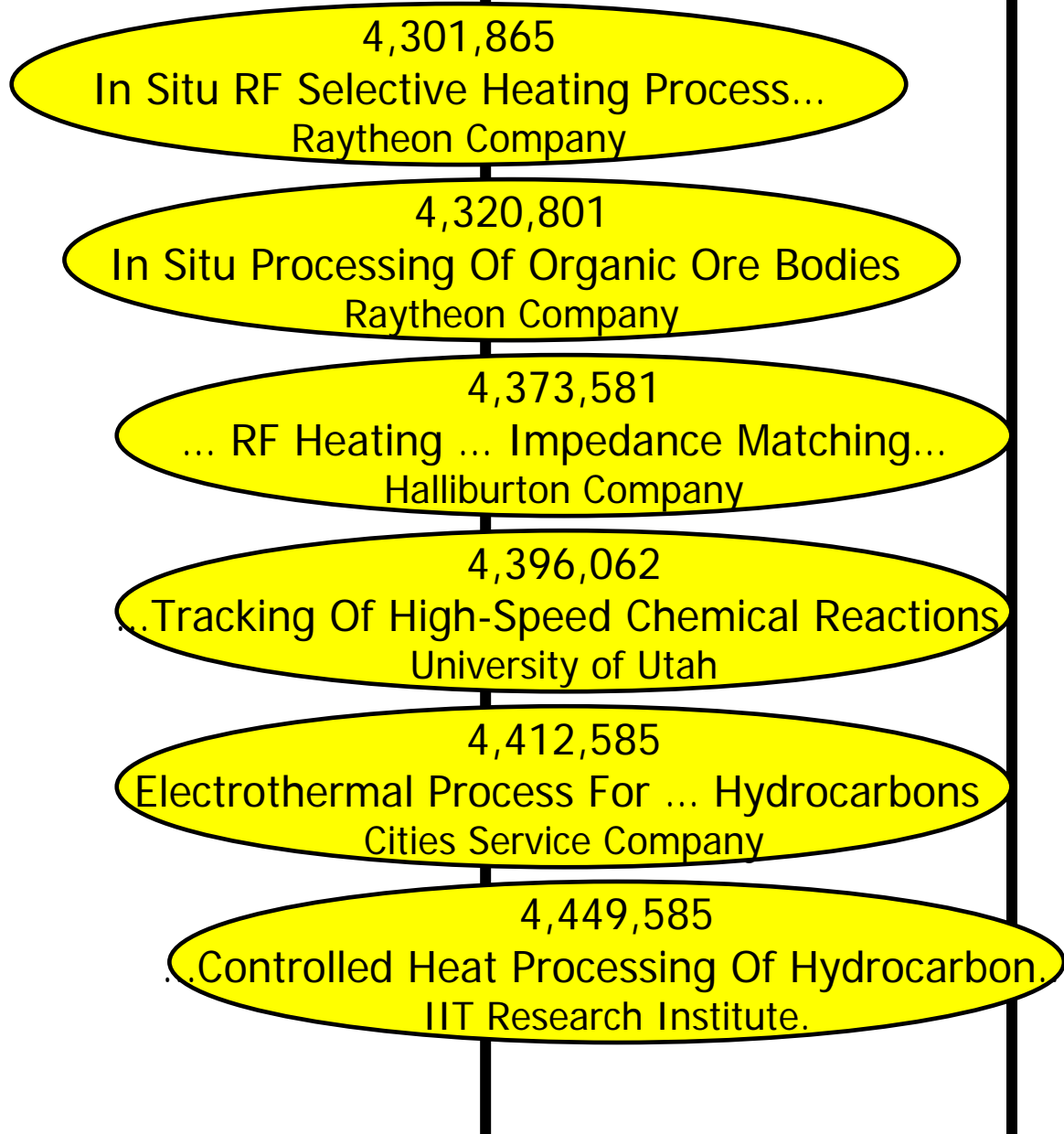
2000



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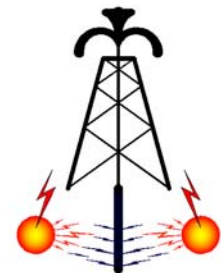
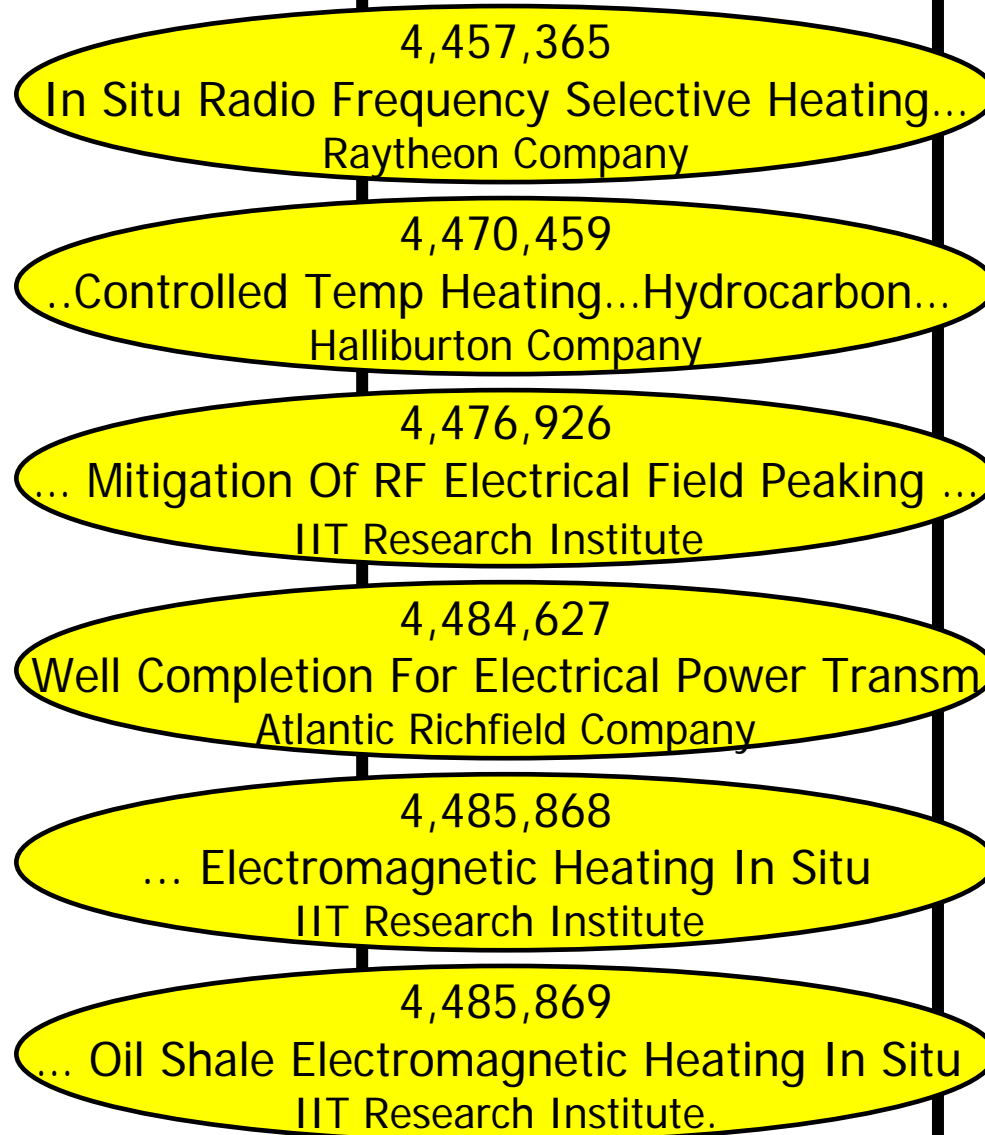
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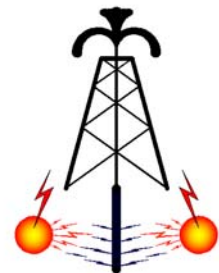
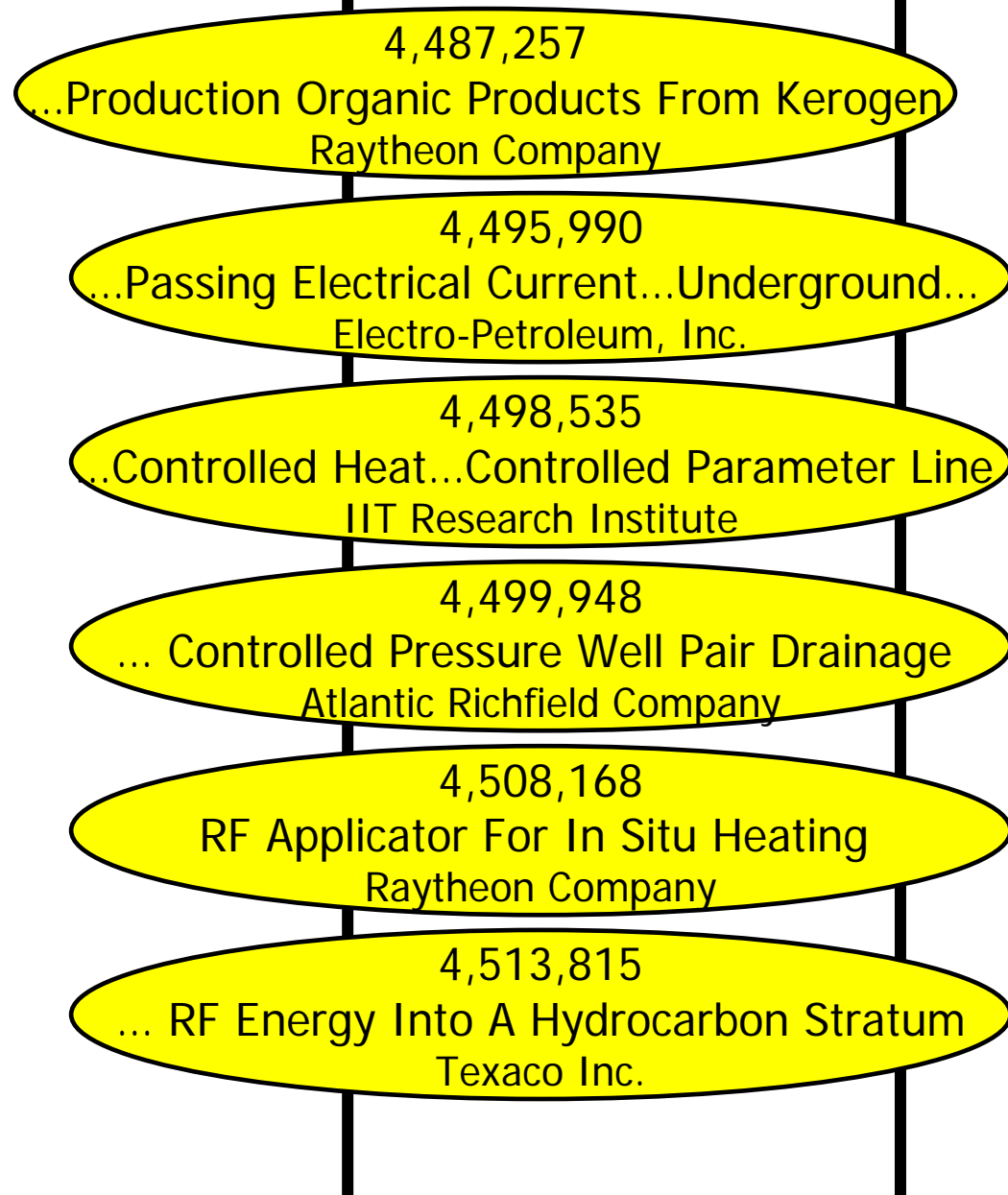
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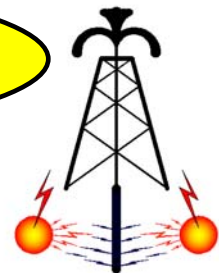


1980

1990

2000

- 4,524,826  
Method Of Heating An Oil Shale Formation  
Texaco Inc.
- 4,524,827  
..Well Stimulation...From Subsurface Format  
IIT Research Company
- 4,545,435  
Conduction Heating Of Hydrocarbon Form  
IIT Research Institute
- 4,553,592  
Method Of Protecting An RF Applicator  
Texaco Inc.
- 4,576,231  
... Encroachment By In Situ Treated Format  
Texaco Inc.
- 4,583,589  
Subsurface Radiating Dipole  
Raytheon Company

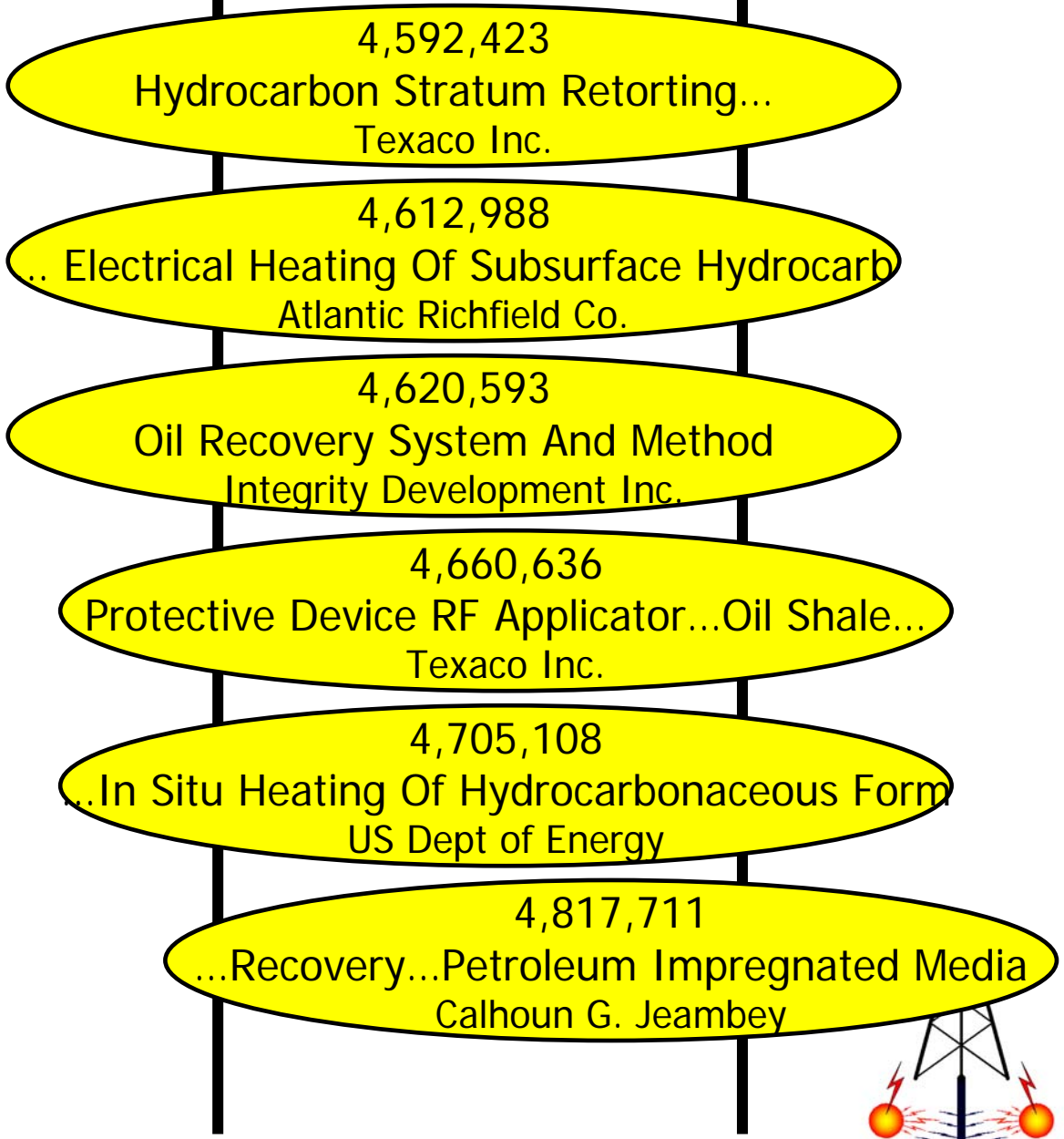




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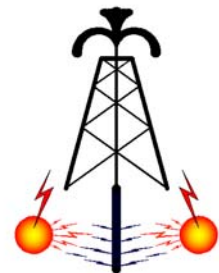
2008 2010

5,055,180  
...Fractions From Hydrocarbon Materials ...  
Electromagnetic Energy Corp.

5,065,819  
Electromagnetic...In Situ Heat & Recovery...  
KAI Technologies

5,082,054  
In-Situ Tuned Microwave Oil ... Process  
A. I. Kiamanesh

5,236,039  
Balanced-Line RF Electrode...Oil Shale  
General Electric to: Shell Oil



2000

2008 2010

2020

6,189,611  
Radio Frequency Steam Flood & Gas Drive ...  
KAI Technologies, Inc.

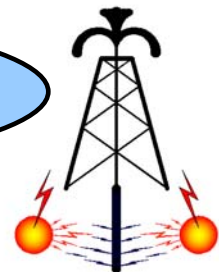
6,413,399  
Soil Heating...Rotating Electromagnetic Field  
KAI Technologies, Inc.

7,048,051  
Recovery Of Products From Oil Shale  
Gen Syn Fuels

7,091,460  
... Variable Frequency Automated ... RF..  
Quasar Energy LLC

7,109,457  
...Automatic Impedance Matching RF...  
Quasar Energy LLC

7,115,847  
... Variable Frequency Dielectric Heating  
Quasar Energy LLC



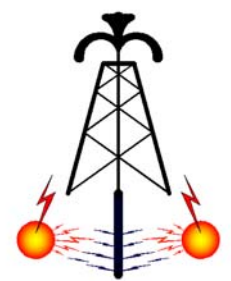
2000

2008 2010

2020

7,312,428  
Processing Of Hydrocarbons ... Frequencies  
Quasar Energy LLC

7,331,385  
Organic Matter Into Producidble Hydrocarbons  
ExxonMobil



# US Patents Pending

11/314,857

Method...Using Electrical Energy And Critical Fluids  
Raytheon Company – Assigned to: Schlumberger  
August 07, 2008: Notice of Allowance Mailed

11/314,880

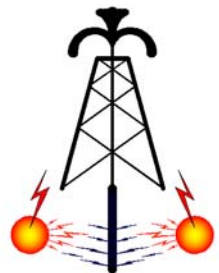
Apparatus...Using Electrical Energy And Critical Fluids  
Raytheon Company – Assigned to: Schlumberger  
July 16, 2008: Non-Final Rejection mailed

11/600,992

Method And System For Extraction Of Hydrocarbons From Oil Shale  
SASOR – Assigned to: Shale And Sands Oil Recovery LLC  
September 29, 2008: Publications -- Issue Fee Payment Received

11/610,823

Microwave-Based Recovery Of Hydrocarbons And Fossil Fuels  
Mobilestream Oil, Inc. (Global Resources Inc.)  
April 11, 2007: Docketed New Case - Ready for Examination



# US Patents Pending

11/655,533

Radio Frequency Technology Heater For Unconventional Resources  
Pyrophase, Inc.

August 14, 2008: Response to Non-Final Office Action Entered

11/708,912

Electro Thermal In-Situ Energy Storage ...  
Pyrophase, Inc.

September 19, 2008: Response to Non-Final Office Action Entered

11/678,614

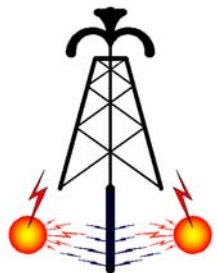
In-Situ Extraction Of Hydrocarbons From Oil Sands  
HCE, LLC

September 11, 2008: Response to Non-Final Office Action Entered

11/682,171

Stimulation And Recovery Of Heavy Hydrocarbon Fluids  
HW Advanced Technologies, Inc.

May 29, 2007: Docketed New Case - Ready for Examination



# US Patents Pending

11/786,474

Method And Apparatus ... Using Energy And Critical Fluids

Raytheon Company

August 06, 2008: Non-final office action mailed

11/805,906

Microwave Process For Intrinsic Permeability Enhancement ...

Peter M. Kearl – Assigned to Geoscience Services

March 16, 2008: Docketed New Case - Ready for Examination

12/011,456

Methods Of Treating A Subterranean Formation To Convert Organic ...

ExxonMobil Upstream Research Company

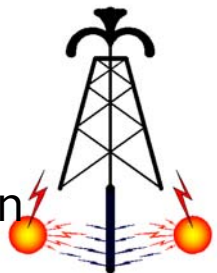
May 12, 2008: Docketed New Case - Ready for Examination

10/591,566

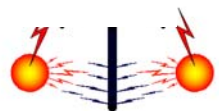
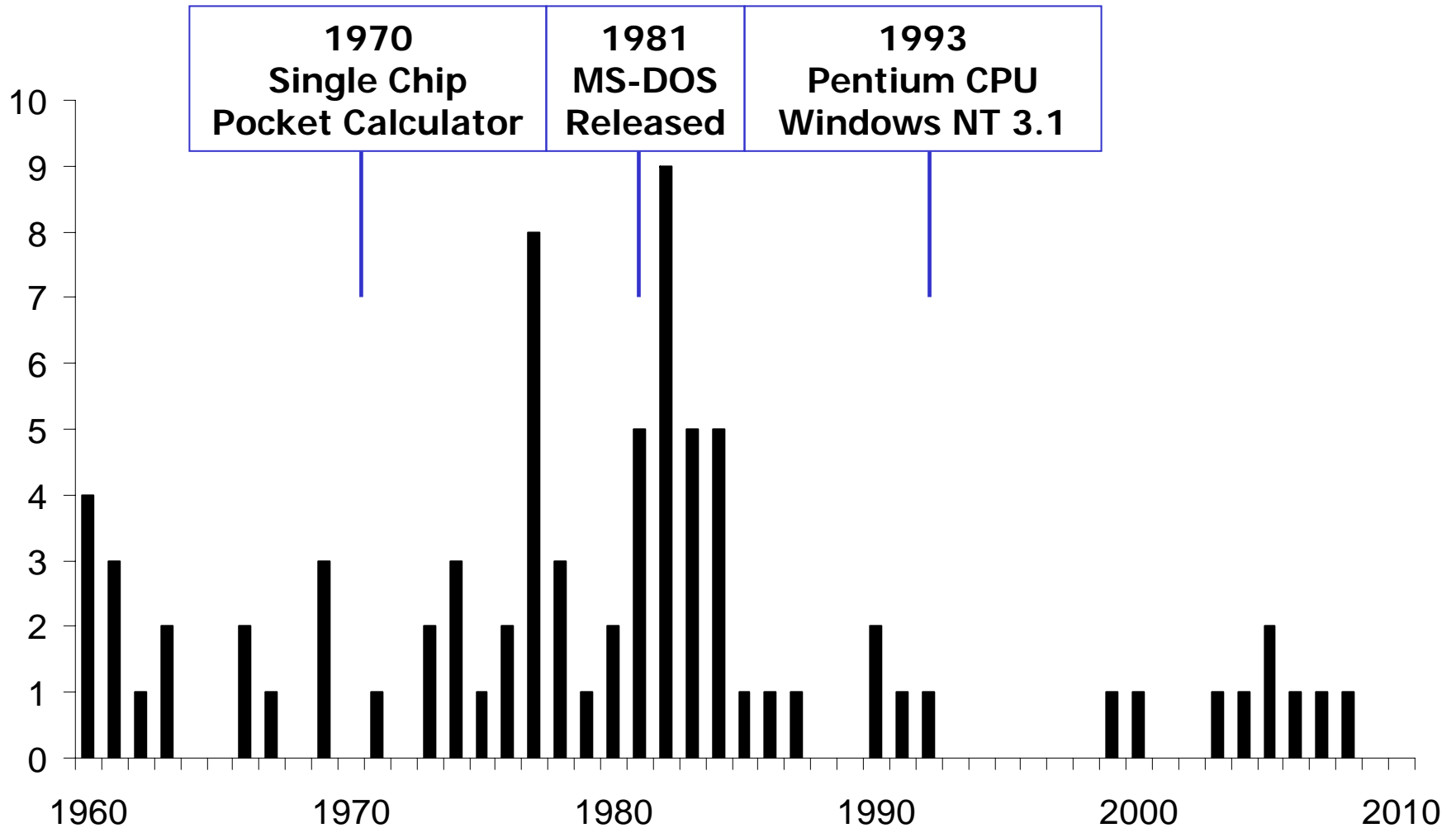
Extracting And Processing Hydrocarbon-Bearing Formations

Quasar Energy LLC

October 17, 2007: Docketed New Case - Ready for Examination



# Number of US Patents Issued By Year





# Patents by Company

Raytheon Company - 11

IIT Research Institute - 10

Atlantic Richfield Company - 7

Texaco, Inc. - 6

**Quasar Energy LLC - 4**

KAI Technologies - 3

Phillips Petroleum Company - 3

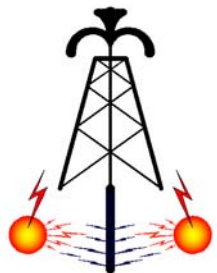
Electrofrac Corporation - 2

The Electrothermic Company - 2

Gulf Research & Development Company - 2

Halliburton Company - 2

Petro-Canada Exploration Inc - 2



# Patents by Inventor

10 - Bridges, Jack E.

7 - Kasevich, Raymond S.

7 - Taflove, Allen

5 - Savage, Kerry D.

4 - Haagensen, Duane B.

**4 - Kinzer, Dwight Eric**

3 - DeBettencourt, Joseph T.

3 - Dwyer, Arthur S.

3 - Kern, Loyd R.

3 - Kolker, Myer

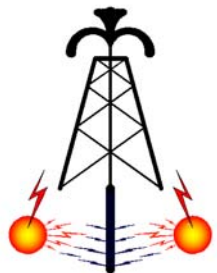
3 - Parker, Harry W.

3 - Perkins, Thomas K.

3 - Rowland, Howard J.

3 - Sarapuu, Erich

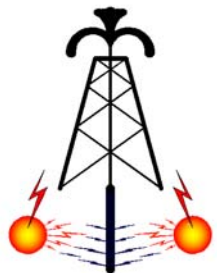
3 - Sresty, Guggilam C.



# Quasar Energy LLC

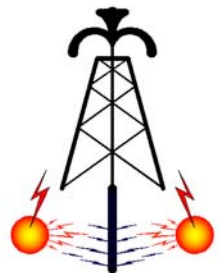
Optimized radio frequency heating typically combines:

- Automatic impedance matching based upon multiple process parameters – Patent 7,091,460
- Automatic impedance matching with variable frequency – Patent 7,109,457
- Automatic impedance matching based on temperature – Patent 7,115,847
- Computer controlled variable frequency based on Temperature – Patent 7,312,428



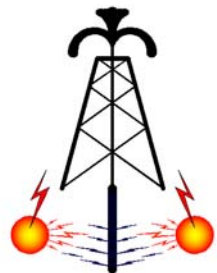
# Advantages of Quasar Energy IP

- **Optimized Energy Transfer**
  - Real time optimization of energy transfer by monitoring variations in load properties during heating and selecting optimal frequency(s) and controlling impedance match
- **Automatic Impedance Matching**
  - By matching the impedance, maximum power is supplied to the load, and the maximum heating rate is achieved.
    - Electrical “impedance”: a measure of the total opposition that a circuit or a part of a circuit presents to electric current for a given applied electrical voltage, and includes both resistance and reactance
    - Matches effective adjusted load impedance to the output impedance of the signal generating unit



# Advantages of Quasar Energy IP

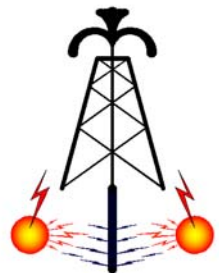
- Characterization of dielectric properties vs. frequency, temperature, and control parameters assists in the design of an optimized Radio Frequency dielectric heating system
- Specific dielectric properties are determined and/or used, either
  - directly as process control parameters, or
  - indirectly as by reference to a model used in the process that includes relationships based on the properties



# Advantages of Quasar Energy IP

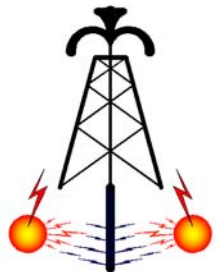
## ■ Process Control Parameters

- Resistance
- Voltage
- Electric field
- Current
- Measuring voltage and current and determining a phase angle
- A reverse power level of RF reflected from an effective load
- Calculating a voltage standing wave ratio (SWR) from a reverse power level
- Automatically adjusting an effective load impedance until SWR is about 2:1, and preferably 1:1
- Adjusting selected frequency (Variable Frequency)
- Tuning a tunable impedance matching network
- Measuring temperature then automatically adjust effective load impedance to match output impedance



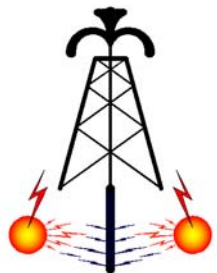
# Advantages of Quasar Energy IP

- Resonance Frequency
- Debye resonance frequency:
  - frequency at which lattice limitations occur;
  - frequency at which maximum heating can be imparted for a given electric field



# What's Next?

- Spectral analysis simulating reservoir conditions has never been conducted!
  - Spectral analysis of each constituent residing in an oil shale formation under reservoir conditions
  - Spectral analysis of each constituent at various temperatures as they increase in temperature
  - Determining Debye resonance frequency for each constituent at various temperatures and pressures
  - Measuring and characterizing dielectric properties as functions of frequency, temperature, and pressure





# Thank You

For a CD of the patents (in pdf format) presented, which pertain to in-situ electromagnetic heating of oil shale and hydrocarbon-bearing formations, contact:

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Quasar Energy LLC  
413 29<sup>th</sup> Ave N  
Fargo, ND 58102  
701.388.3645  
[process@fmtc.com](mailto:process@fmtc.com)

