

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

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Objectives

- To provide my collection of prior art for those that wish to research *in situ* electromagnetic heating.
- To show the extent of prior art
- To depict the intensity of research and development prior to 1980's bust in oil prices
- To demonstrate that most research and development was conducted prior to the modern microprocessor, software, and sensory input technology as we know it today.
- And, if I keep moving along there will hopefully be time for a quick overview of intellectual property I have developed and assigned to Quasar Energy.

Definition of a Patent

The reason patents, otherwise referred to as prior art, are an excellent source of information is the requirement that the patent application discloses how to build and/or operate an invention. While many patent attorneys and inventors feel they are being clever by keeping their disclosure nebulous as possible with the hopes of making their claims broader, my opinion of the patents we will be reviewing is their inventors and attorney's did an excellent job of describing their inventions – thus making them an excellent resource for the researcher.

Since the vast majority of the inventors are retired or deceased and since the technology was never commercially implemented, if it were not for patents, *in situ* electromagnetic heating would truly be a lost art.

Scope of Prior Art for this Presentation

Although my own personal collection of *in situ* electromagnetic heating of hydrocarbon-bearing formations exceeds what I have included in this presentation, I find it interesting that the vast majority of prior art was solely for oil shale. There are some patents in this presentation that were not developed for oil shale but I included them if my reading of the claims indicated they were broad enough in scope to include oil shale by using terms such as "mineral bearing" instead of directly referring to kerogen or oil shale.

Most of the patents are for an apparatus or method of *in situ* passing an electrical current through an oil shale or hydrocarbonaceous formation, but I have included downhole tools and one patent for a device that provides data for phase angle calculations.

Categories of the Prior Art Search

The patents of this presentation fall into these five categories;

- Resistive heating
- Radio Frequency heating
- Microwave heating
- Downhole Tool
- Supportive Apparatus and/or Method

I am sure someone is going to take exception to the frequencies I have attributed to each category but for the sake of this presentation this is how I have categorized the patents. This is really more for reference than anything else, as I have not assigned each patent to a category, although I would like to do so in the future.

1950s

On June 8, 1995 the USPTO changed the in-force term from 17 years from date of

grant to 20 years from date of filing the patent application. An exception is if the USPTO takes longer than three years to examine the application and then it is adjusted to 17 years from grant.

I will reference the patents by their last three digits. In the case of '655', it does not fully fit our definition of scope because it describes using electricity to heat an element that thermally conducts heat to oil shale for what the inventor terms as destructive distillation of oil shale.

Three patents were issued in the 1950's for *in situ* electromagnetic heating. Patent '738' is the first *in situ* electromagnetic heating patent I found using radio frequencies, but it is directed towards oil and gas wells without any mention of shale or kerosene.

1960s

Patent '711' is the first of 11 patents assigned to Raytheon, this patent being for microwave heating in conjunction with a liquid that has a lower loss transmission path between the radiation source and the subterranean formation.

Patent '244' assigned to Phillips Petroleum Company is the first patent I have located for distilling oil shale by passing an electrical current through an oil shale formation.

Patent '875', also assigned to Raytheon, is notable from the aspect that it teaches a testing device for measuring dielectric characteristics, specifically incident and reflected power to ascertain a voltage standing wave ratio to be used in conjunction with microwave *in situ* heating. As I will discuss later this can be achieved as part of an automatic microprocessor controlled process.

Patent '347', also assigned to Phillips Petroleum Company, is for an improved electrical resistive heating process that is tailored specifically to oil shale. Another patent assigned to Phillips Petroleum Company is patent '125', which is for injecting an electrolyte into an oil shale formation and passing an electrical current through the oil shale via the electrolyte and preventing the

electrolyte from vaporizing by maintaining a sufficient pressure.

1970s

Patent '866', assigned to Dept of Interior, is for creating retorting channels in shale by charring a path with electricity, forcing out the charred remains with pneumatic pressure, and then using the path as a permeable retorting channel.

Patent '662' is the first of seven patents issued to Atlantic Richfield, but they are primarily for heavy oil, but the claims use broad verbiage such as "sub-surface formation" so I included them in this presentation.

Patent '762' by Mr. Sidney Fisher is for another method of resistive heating an oil shale formation.

Starting in the 1977 Raytheon, lead by Mr. Raymond Kasevich, and IITR lead by Mr. Jack Bridges began a decade of research and intellectual property protection for the use of radio frequency heating of oil shale that lead to 17 patents between the two organizations.

Patent '579' by Kasevich and assigned to Raytheon is for fracturing an oil shale formation with radio frequency.

Patent '179' by Kasevich and assigned to Raytheon is for selectively heating oil rich shale preferably to the lean oil shale. Selective heating is another prior art that can be dramatically improved upon by incorporating a microprocessor.

Patent '180' by Bridges, Tavfløve, and Snow and assigned to IITR is for uniform heating of large blocks of oil shale formations.

1980s

Patent '307' assigned to Standard Oil teaches rubbleizing the shale oil deposit prior to radio frequency heating to create fractures for efficient recovery of oil.

Patent '581' assigned to Halliburton is based upon observations of IITR field tests that an impedance matching network was needed to correct for variations in load impedance encountered while the formation is

being heated. As I will discuss later, impedance matching can be automated with a microprocessor to increase the energy transfer.

Patent '062' by Dr. Iskander, assigned to University of Utah, is for varying the radio frequency based upon permittivity changes during the heating process. In my opinion this patent is a "must read" for those researching *in situ* radio frequency heating of oil shale as it contains a wealth of information. And once again, the teachings of patent '062' can be significantly improved upon by incorporating a microprocessor.

Patent '459' assigned to Halliburton is for a method of controlling the temperature during the radio frequency heating process. Yet again, this prior art is another prime example of an old technology that can be vastly improved upon by incorporating a microprocessor.

Patent '815' is the first of four patents assigned to Texaco. This particular patent is for insulators on the down-hole tool applicator to eliminate a phase shift during heating.

Patent '592' is another patent assigned to Texaco for an electromagnetic down-hole tool. In this instance it is for protecting the downhole tool device from the expansion of the oil shale during the radio frequency heating process.

Patent '589' assigned to Raytheon is quite interesting in its teachings of a radiating dipole.

Patent '636', is yet another patent assigned to Texaco for a down-hole tool. Obviously Texaco was conducting meaningful *in situ* radio frequency heating field research due to the number of down-hole tool patents they developed. I wish someone could fill me in on the nature and extent of their work.

I am often asked if I have designed a down-hole tool for my intellectual property. Although I have to respond that no I have not yet done so, I do know where there are at least five patents describing how to make one.

1990s

Patent '819' assigned to KAI Technologies, by Mr. Kasevich who previously worked for Raytheon, is for creating steer-able and variable heating patterns.

Patent '039' originally assigned to General Electric, who then assigned the patent to Shell Oil, is for a 'balanced line radio frequency array where adjacent rows of electrodes are 1980 degrees out of phase'.

Patents shaded in yellow have expired. The reason patent '054' is shaded in yellow is because the maintenance fees were not kept up to date. Patents shaded in blue are in-force.

1990s

Patent '399' assigned to KAI Technologies is for a subsurface traveling radio frequency wave that travels in a circular motion.

Patents '460', '457', and '847' by Dwight Kinzer, and assigned to Quasar Energy are for automated impedance matching as will be discussed later.

2000

Patent '428' assigned to Quasar Energy is for computer automated variable frequency. The USPTO always issues patents on a Tuesday. In this case, Tuesday fell on Christmas day, and true to form, the patent was issued on the holiday. I like to say the US government gave me a Christmas present last year.

Patent '385' assigned to ExxonMobil is for injecting an electrically conductive material in fractures then generating electrical current through the material to heat the oil shale.

This concludes our review of past and present intellectual property. Now let's have a quick review of patents pending.

US Patents Pending

Patent applications '857' and '880' assigned to Raytheon are for using radio frequency in conjunction with critical fluids. '857' has been accepted and should issue any day as a patent. '880' is still in the examination

process and is for an apparatus described in the method of application '857'. Raytheon has assigned both of these patent applications to Schlumberger.

Raytheon stated they felt 70% of in-place oil could be pyrolyzed and recovered without the use of critical fluids, but that recovery rates could be extended to 90% to 95% with critical fluids.

Patent application '533' by Mr. Bridges and assigned to Pyrophase does not fit the scope definition because it is for using radio frequency to heat a pipe which then thermally conducts the heat to the formation.

Patent application '912' also by Mr. Bridges and assigned to Pyrophase also does not fit the scope definition because it is for intermittent storage of energy.

Out of my high regard for Mr. Bridges I included patent applications '533' & '912'

Patent application '474' by Raytheon is also for a method and apparatus that combines radio frequency heating with critical fluids. For some reason the USPTO did not indicate Raytheon had assigned this patent application to Schlumberger.

Patent application '566' assigned to Quasar Energy is for the apparatuses of the methods that have been patented and previously discussed. Many of the claims have already been accepted in PCT examination.

Number of US Patents Issued By Year

It generally takes 2 to 3 years for a patent to issue from when it is filed. If one adds another 2 years for the time required for research and writing of the patent application, then one needs to subtract five years from date of patent issue to get a sense of the technology at time of invention conception.

As you can see, if we start subtracting four to five years from the date of issue, then all of the patents issued in the early 1980's were done so before Bill Gates released DOS version 1.0.

Using the same logic the patents issued in the early 1990's would have been developed about when Windows was first being released. My recollection is that PC computer automation really didn't start until the early 1990's about the time the 486 chips and the first Windows operation system was

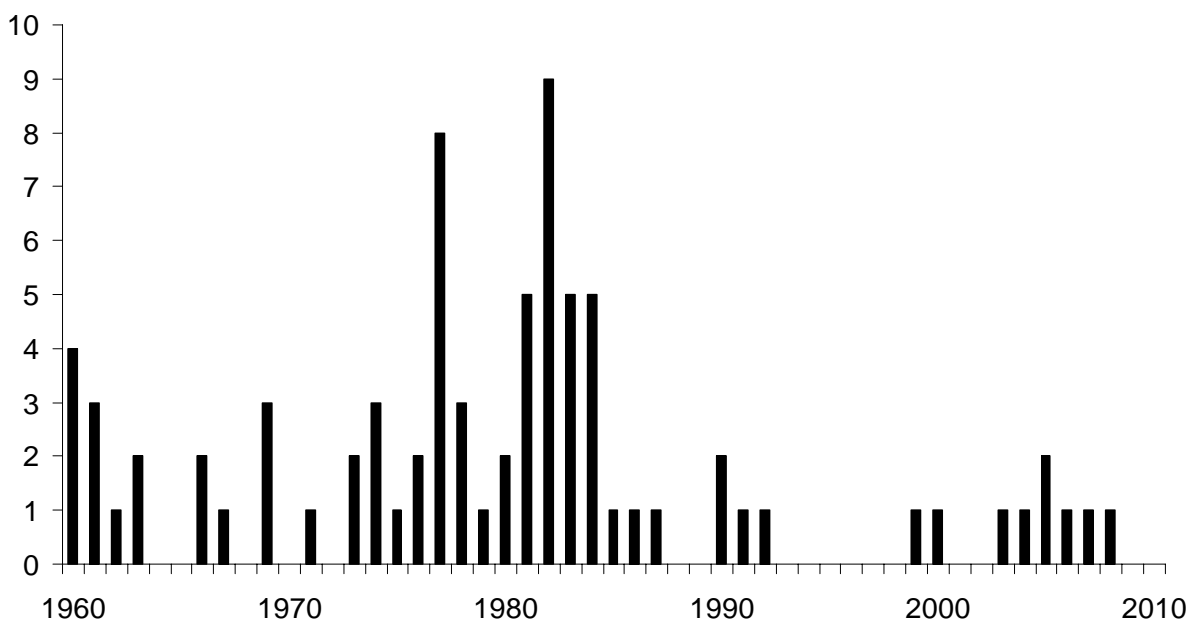


Figure 1: Patents issued by year for electromagnetic heating of oil shale

released.

In 1984 a patent was issued to Dr. Iskander for varying frequency based up elapsed time. Today, 24 years later, it is unconceivable to do anything less than incorporate sensory inputs for measuring every conceivable operating parameter that are feed to a microprocessor with sophisticated software and quite possibly an algorithm to instantaneously adjust the frequency to the optimum setting.

I once heard that the oil and gas industry has the longest time frame from conception to implementation – 27 years. If we were to use 1980 as our baseline for conception then one could suggest that the time has come for *in situ* electromagnetic heating to become a disruptive technology. This premise certainly correlates with advances in technology and petroleum economics.

Patents By Company

The list of highly respected companies in Table 1 clearly shows a concerted effort to utilize electromagnetic heating on oil shale. Obviously many of the best and brightest of their time felt that the chemistry and physics of *in situ* electromagnetic heating had significant potential.

Out of this list there are only two companies with in-force patents; KAI Technologies and Quasar Energy.

Patents By Inventor

As you can see, Mr. Bridges is the most prolific inventor of the group.

Mr. Kasevich and myself are the only individuals on this list whose patents are in-force.

Quasar Energy LLC

To make a long story very short, my four patents assigned to Quasar Energy are for automated computer controlled radio frequency and microwave optimized heating.

Patent '460' is for automatic impedance matching using a wide spectrum of process parameters.

Table 1: 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

Patent '457' is for automatic impedance matching in conjunction with variable frequency.

Table 2: Patents by Inventor

#	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	Sresty, Guggilam C.
3	Sarapuu, Erich

Patent '847' is for automatic impedance matching based on a relationship to temperature.

Patent '428' is for automatic variable frequency adjustments based on a relationship to temperature.

Advantages of Quasar Energy Intellectual Property

By monitoring variations in load properties during the heating process and selecting the resonant frequency, also known as the Debye frequency, in conjunction with automatic impedance matching, real time optimization of energy transfer can be achieved.

Microprocessor controlled impedance matching automatically matches the effective adjusted load impedance to the output impedance of the signal generating unit to achieve a maximum heating rate.

Characterization of dielectric properties based upon frequency, temperature, and control parameters are key elements in the design of an optimized Radio Frequency dielectric heating system. Specific dielectric properties are determined and/or used directly as process control parameters, or indirectly as by reference to a model used in the process.

This slide lists eleven process control parameters that can be continuously monitored and adjusted with a microprocessor to provide real time optimization, selective heating, and a highly efficient energy transfer from an antenna to one or more selected compositions targeted for heating.

The Debye resonance frequency is the frequency at which lattice limitations occur which in turn is the frequency at which maximum heating can be imparted for a given electric field.

Automatic real time optimized impedance matching combined with automatic real time optimized variable frequency provides the technology to continuously maintain the signal generator setting to the Debye frequency to one or more selected compositions targeted for heating.

What's Next?

The signal generating equipment to perform the automated tasks I have described is "off-the-shelf-technology". However, spectral analysis simulating reservoir conditions to characterize the changing dielectric properties at different temperatures and pressures has never been conducted. This research is required to develop the algorithms needed to provide real-time automated radio frequency controls.

In situ electromagnetic heating has been a promising technology now for over 50 years and I believe its time has come. The advantages and efficiencies are too beneficial to be ignored.

Supporting Information: US Patents related to Electromagnetic Heating of Oil Shale

Patent Number	Title	Application Number	Inventor(s)	Filed	Assignee	Date of Patent	Notes
1,269,747	Method Of And Apparatus For Treating Oil Shale		L. H. Rogers	April 8, 1918		June 18, 1918	
1,269,747	Method Of And Apparatus For Treating Oil Shale		L. H. Rogers	April 8, 1918		June 18, 1918	
1,372,743	System For Removing Obstructions To The Flow Of Fluid In the Earth Strata Adjacent To Wells	393,436	Benjamin Fulton Garder	July 1, 1920		March 29, 1921	
1,510,655	Process Of Subterranean Distillation Of Volatile Mineral Substances	602,462	Cornelius Clark	November 21, 1922		October 7, 1924	
1,784,214	Method Of Recovering And Increasing The Production Of Oil	313,458	Paul E. Workman	October 19, 1928		December 9, 1930	
2,472,445	Apparatus For Treating Oil And Gas Bearing Strata	575,859	Severn D. Sprong	February 2, 1945	Thermactor Company	June 7, 1949	
2,634,961	Method Of Electrothermal Production Of Shale Oil	756,625	Fredrik Ljungstrom	June 24, 1947	Svenska Skifferolje Aktiebolaget	April 14, 1953	
2,757,738	Radiation Heating	50,152	Harold W. Ritchey	September 20, 1948	Union Oil Company	August 7, 1956	
2,795,279	Method Of Underground Electrolinking And Electrocarbonization Of Mineral Fuels	282,922	Erich Sarapuu	April 17, 1952	Electrotherm Research Corporation	June 11, 1957	
2,799,641	Electrolytically Promoting The Flow Of Oil From A Well	505,005	Thomas Gordon Bell	April 29, 1955		July 16, 1957	
3,001,776	Method Of Preparation For And Performance Of In Situ Retorting	805,396	Hendrik K. van Poolen	April 10, 1959		September 26, 1961	
3,103,975	Communication Between Wells	805,410	Alden W. Hanson	April 10, 1959	The Dow Chemical Company	September 17, 1963	
3,104,711	Sub-Surface Heating System	99,442	Duane B. Haagen-sen	March 30, 1961	Raytheon Company	September 24, 1963	
3,106,244	Process For Producing Oil Shale In Situ By Electrocarbonization	37,451	Harry W. Parker	June 20, 1960	Phillips Petroleum Company	October 8, 1963	

Patent Number	Title	Application Number	Inventor(s)	Filed	Assignee	Date of Patent	Notes
3,114,875	Microwave Device For Testing Formations Surrounding A Borehold Having Means For Measuring The Standing Wave Ratio Of Energy Incident To And Reflected From the Formations	107,785	Duane B. Haagen-sen	May 4, 1961	Raytheon Com-pany	December 17, 1963	
3,133,592	Apparatus For The Application Of Electrical Energy To Sub-surface Formations	815,415	Bill M. Tomberlin	May 25, 1959	Petro-Electronics Corporation	May 19, 1964	
3,137,347	In Situ Electrolinking Of Oil Shale	27,627	Harry W. Parker	May 9, 1960	Phillips Petro-leum Company	June 16, 1964	
3,149,672	Method And Apparatus For Electrical Heating Of Oil-Bearing Formations	192,565	Joseph Orkiszew-ski, James L. Hill, Preston S. McReynolds, Tho-mas C. Boberg	May 4, 1962	Jersey Produc-tion Research Company	September 22, 1964	
3,169,577	Electrolinking By Impulse Voltages	41,418	Erich Sarapuu	July 7, 1960	Electrofrac Cor-poration	February 16, 1965	
3,170,519	Oil Well Microwave Tools	28,340	Duane B. Haagen-sen	May 11, 1960		February 23, 1965	
3,211,220	Single Well Subsurface Elec-trification Process	103,429	Erich Sarapuu	April 17, 1961	Electrofrac Cor-poration	October 12, 1965	
3,272,261	Process For Recovery Of Oil	330,497	Richard A. Morse	December 13, 1966	Gulf Research & Development Company	September 13, 1966	
3,377,266	Electrothermal Pyrolysis Of Oil Shale	403,315	Ivan S. Salnikov	October 12, 1964		April 9, 1968	
3,428,125	Hydro-Electropyrolysis Of Oil Shale In Situ	567,530	Harry W. Parker	July 25, 1966	Phillips Petro-leum Company	February 18, 1969	
3,522,848	Apparatus Production Amplifi-cation By Stimulated Emission Of Radiation	641,823	Robert V. New	May 29, 1967		August 4, 1970	
3,547,192	Method Of Metal Coating And Electrically Heating A Subter-ranean Earth Formation	813,502	Elmond L. Claridge, Michael Prats	April 4, 1969	Shell Oil Com-pany	December 15, 1970	

Patent Number	Title	Application Number	Inventor(s)	Filed	Assignee	Date of Patent	Notes
3,547,193	Method And Apparatus For Recovery Of Minerals From Sub-Surface Formations Using Electricity	868,277	William G. Gill	October 8, 1969	The Electrothermic Company	December 15, 1970	
3,642,066	Electrical Method And Apparatus For The Recovery Of Oil	876,462	William G. Gill	November 13, 1969	The Electrothermic Company	February 15, 1972	
3,696,866	Method For Producing Retorting Channels In Shale Deposits	110,090	Julian R. Dryden	January 27, 1971	US Department of Interior	October 10, 1972	
3,862,662	Method And Apparatus For Electrical Heating Of Hydrocarbonaceous Formations	424,103	Loyd R. Kern	December 12, 1973	Atlantic Richfield Company	January 28, 1975	
3,874,450	Method And Apparatus For Electrically Heating A Sub-surface Formation	424,099	Loyd R. Kern	December 12, 1973	Atlantic Richfield Company	April 1, 1975	
3,931,856	Method Of Heating A Subterranean Formation	535,162	Allen L. Barnes	December 23, 1974	Atlantic Richfield Company	January 13, 1976	
3,946,809	Oil Recovery By Combination Steam Stimulation And Electrical Heating	534,261	Alton R. Hagedorn	December 19, 1974	Exxon Production Research Company	March 30, 1976	
3,948,319	Method And Apparatus For Producing Fluid By Varying Current Flow Through Subterranean Source Formation	515,205	William C. Pritchett	October 16, 1974	Atlantic Richfield Company	April 6, 1976	
4,008,762	Extraction Of Hydrocarbons In Situ From Underground Deposits	661,770	Sidney T. Fisher, Charles B. Fisher	February 26, 1976		February 22, 1977	
4,010,799	Method For Reducing Power Loss Associated With Electrical Heating Of A Subterranean Formation	540,434	Loyd R. Kern, Thomas K. Perkins	September 15, 1975	Petro-Canada Exploration Inc., Imperial Oil Limited, Canada-Cities Service, Ltd.	March 8, 1977	

Patent Number	Title	Application Number	Inventor(s)	Filed	Assignee	Date of Patent	Notes
4,084,637	Method Of Producing Viscous Materials From Subterranean Formations	751,058	John C. Todd	December 16, 1976	Petrol Canada Exploration Inc, Canada-Cities Services, Ltd, Imperial Oil Limited	April 18, 1978	
4,135,579	In Situ Processing Of Organic Ore Bodies	838,265	Howard J. Rowland, Joseph T. deBettencourt	September 30, 1977	Raytheon Company	January 23, 1979	
4,140,179	In Situ Radio Frequency Selective Heating Process	756,165	Raymond S. Kasevich, Myer Kolker, Arthur S. Dwyer	January 3, 1977	Raytheon Company	February 20, 1979	
4,140,180	Method For In Situ Heat Processing Of Hydrocarbonaceous Formations	828,904	Jack Bridges, Allen Taflove, Richard Snow	August 29, 1977	IIT Research Institute	February 20, 1979	
4,144,935	Apparatus And Method For In Situ Heat Processing Of Hydrocarbonaceous Formations	828,621	Jack Bridges, Allen Taflove	August 29, 1977	IIT Research Institute	March 20, 1979	
4,153,533	Shale Conversion Process	831,171	Chalmer G. Kirkbride	September 7, 1977		May 8, 1979	
4,193,448	Apparatus For Recovery Of Petroleum Impregnated Media	941,122	Calhoun G. Jeambey	September 11, 1978		March 18, 1980	
4,193,451	Method For Production Of Organic Products From Kerogen	845,504	Thonet C. Dauphine	October 25, 1977	The Badger Company, Inc.	March 18, 1980	
4,196,329	Situ Processing Of Organic Ore Bodies	838,264	Howard J. Rowland, Joseph T. DeBettencourt	September 30, 1977	Raytheon Company	April 1, 1980	
4,199,025	Method And Apparatus For Tertiary Recovery Of Oil	807,739	Neil L. Carpenter	June 17, 1977	Electroflood Company	April 22, 1980	

Patent Number	Title	Application Number	Inventor(s)	Filed	Assignee	Date of Patent	Notes
4,265,307	Shale Oil Recovery	971,452	Lincoln F. Elkins	December 20, 1978	The Standard Oil Company	May 5, 1981	
RE 30,738	Apparatus And Method For In Situ Heat Processing Of Hydrocarbonaceous Formations	828,621	Jack E. Bridges, Allen Taflove	February 6, 1980	IIT Research Institute	September 8, 1981	
4,301,865	In Situ Radio Frequency Selective Heating Process And System	967,446	Raymond S. Kasevich, Myer Kolker, Arthur S. Dwyer	December 7, 1978	Raytheon Company	November 24, 1981	
4,320,801	In Situ Processing Of Organic Ore Bodies	98,584	Howard J. Rowland, Joseph T. deBettencourt	November 29, 1979	Raytheon Company	March 23, 1982	
4,373,581	Apparatus And Method For Radio Frequency Heating Of Hydrocarbonaceous Earth Formations Including An Impedance Matching Technique	226,308	Robert L. Toellner	January 19, 1981	Halliburton Company	February 15, 1983	
4,396,062	Apparatus And Method For Time-Domain Tracking Of High-Speed Chemical Reactions	194,153	Magdy F. Iskander	October 6, 1980	University of Utah Research Foundation	August 2, 1983	
4,412,585	Electrothermal Process For Recovering Hydrocarbons	374,582	Larry S. Bouck	May 3, 1982	Cities Service Company	November 1, 1983	
4,449,585	Apparatus And Method For In Situ Controlled Heat Processing Of Hydrocarbonaceous Formations	343,903	Jack E. Bridges, Allen Taflove	January 29, 1982	IIT Research Institute	May 22, 1984	
4,457,365	In Situ Radio Frequency Selective Heating System	291,667	Raymond S. Kasevich, Myer Kolker, Arthur S. Dwyer	August 10, 1981	Raytheon Corporation	July 3, 1984	

Patent Number	Title	Application Number	Inventor(s)	Filed	Assignee	Date of Patent	Notes
4,470,459	Apparatus And Method For Controlled Temperature Heating Of Volumes Of Hydrocarbonaceous Materials In Earth Formations	492,975	George V. Copland	May 9, 1983	Halliburton Company	September 11, 1984	
4,476,926	Method And Apparatus For Mitigation Of Radio Frequency Electrical Field Peaking In Controlled Heat Processing Of Hydrocarbonaceous Formations In Situ	363,765	Jack E. Bridges, Allen Taflove	March 31, 1982	IIT Research Institute	October 16, 1984	
4,484,627	Well Completion For Electrical Power Transmission	509,839	Thomas K. Perkins	June 30, 1983	Atlantic Richfield Company	November 27, 1984	
4,485,868	Method For Recovery Of Viscous Hydrocarbons By Electromagnetic Heating In Situ	428,081	Guggilam C. Sresty, Harsh Dev, Richard Snow, Jack E. Bridges	September 29, 1982	IIT Research Institute	December 4, 1984	
4,485,869	Recovery Of Liquid Hydrocarbons From Oil Shale By Electromagnetic Heating In Situ	435,979	Guggilam C. Sresty, Richard H. Snow, Jack E. Bridges	October 22, 1982	IIT Research Institute	December 4, 1984	
4,487,257	Apparatus And Method For Production Of Organic Products From Kerogen	307,132	Thonet C. Dauphiné	September 30, 1981	Raytheon Company	December 11, 1984	
4,495,990	Apparatus For Passing Electrical Current Through An Underground Formation	427,708	Charles H. Titus, John K. Wittle, Christy W. Bell	September 29, 1982	Electro-Petroleum, Inc.	January 29, 1985	
4,498,535	Apparatus And Method For In Situ Controlled Heat Processing Of Hydrocarbonaceous Formations With A Controlled Parameter Line	445,672	Jack E. Bridges	November 30, 1982	IIT Research Institute	February 12, 1985	

Patent Number	Title	Application Number	Inventor(s)	Filed	Assignee	Date of Patent	Notes
4,499,948	Viscous Oil Recovery Using Controlled Pressure Well Pair Drainage	560,695	Thomas K. Perkins	December 12, 1983	Atlantic Richfield Company	February 19, 1985	
4,508,168	RF Applicator For In Situ Heating	323,212	Vernon L. Heeren	November 20, 1981	Raytheon Company	April 2, 1985	
4,513,815	System For Providing RF Energy Into A Hydrocarbon Stratum	542,870	Herbert A. Rundell, Kerry D. Savage	October 17, 1983	Texaco Inc.	April 30, 1985	
4,524,826	Method Of Heating An Oil Shale Formation	387,996	Kerry D. Savage	June 14, 1982	Texaco Inc.	June 25, 1985	
4,524,827	Single Well Stimulation For The Recovery Of Liquid Hydrocarbons From Subsurface Formations	489,756	Jack E. Bridges, Allen Taflove, Guggilam C. Sresty	April 29, 1983	IIT Research Company	June 25, 1985	
4,545,435	Conduction Heating Of Hydrocarbonaceous Formations	489,849	Jack E. Bridges, Allen Taflove	April 29, 1983	IIT Research Institute	October 8, 1985	
4,553,592	Method Of Protecting An RF Applicator	578,453	Mark D. Looney, Kerry D. Savage	February 9, 1984	Texaco Inc.	November 19, 1985	
4,576,231	Method And Apparatus For Combating Encroachment By In Situ Treated Formations	650,140	Donald J. Dowling, Harold A. Palmer	September 13, 1984	Texaco Inc.	March 18, 1986	
4,583,589	Subsurface Radiating Dipole	602,278	Raymond S. Kasevich	April 24, 1984	Raytheon Company	April 22, 1986	
4,592,423	Hydrocarbon Stratum Retorting Means And Method	610,072	Kerry D. Savage, Hans J. Paap	May 14, 1984	Texaco Inc.	June 3, 1986	
4,612,988	Dual Aquafer Electrical Heating Of Subsurface Hydrocarbons	747,752	Daniel J. Segalman	June 24, 1985	Atlantic Richfield Company	September 23, 1986	
4,620,593	Oil Recovery System And Method	656,753	Duane B. Haagen	October 1, 1984		November 4, 1986	

Patent Number	Title	Application Number	Inventor(s)	Filed	Assignee	Date of Patent	Notes
4,660,636	Protective Device For RF Applicator In In-Situ Oil Shale Retorting	265,263	Herbert A. Rundell, Richard H. Vinton, Kerry D. Savage	May 20, 1981	Texaco Inc.	April 28, 1987	
4,705,108	Method For In Situ Heating Of Hydrocarbonaceous Formations	867,125	William E. Little, Thomas R. McLendon	May 27, 1986	US Department of Energy	November 10, 1987	
4,817,711	System For Recovery Of Petroleum From Petroleum Impregnated Media	55,412	Calhoun G. Jeambey	May 27, 1987		April 4, 1989	
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