

JOSE LLOREDA CAMACHO & CO.

ABOGADOS

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SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO



No. 10-163533-00004-0000

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Tra. 2 PATENTES Eve: 1 REGDEPOSITO
Act. 444 RESPUESTAREQUE Folios: 51

Señor

SUPERINTENDENTE DE INDUSTRIA Y COMERCIO

DIVISIÓN DE NUEVAS CREACIONES

E. S. D.

Re: PI.-ARCHON TECHNOLOGIES LTD.-Solicitud de Patente de
Invención en Fase Nacional para "PROCESO DE RECUPERACIÓN
DE LA COMBUSTIÓN IN SITU MEJORADO UTILIZANDO UN
SOLO POZO HORIZONTAL PARA PRODUCIR PETRÓLEO Y GASES
DE COMBUSTIÓN A LA SUPERFICIE".-Expediente número
10-163.533.-

1. Me refiero al Oficio No. **02123** dictado por ese Despacho notificado por fijación en lista el 10 de Febrero de 2011.
2. Dando respuesta al mencionado requerimiento y estando dentro del término establecido para ello, atentamente me permito presentar a ese Despacho el documento que acredita el traspaso, que el autor de la patente de la referencia hace a favor de mi representado, de los derechos sobre la misma, debidamente consularizado, junto con su Traducción Oficial número 2011-02-17-102.
3. Adicionalmente, me permito presentar a ese Despacho copia debidamente certificada de la Solicitud de Patente **respecto de la cual reclamo prioridad**, dentro del trámite de la Solicitud arriba referida, a saber, la Solicitud Canadiense número **2698454** de 30 de Marzo de 2010, junto con su Traducción Oficial número 2011-02-18-103, correspondiente a dicho documento.
4. Ruego a usted tomar atenta nota de lo anterior y proceder de conformidad.

Señor Superintendente,


ALICIA LLOREDA RICAURTE

T.P. 53.215

TRADUCCION OFICIAL No. 2011-02-17-102
DE UN DOCUMENTO ESCRITO EN INGLES

CERTIFICADO NOTARIAL

CANADA	)	A TODOS AQUELLOS A QUIENES LOS
PROVINCIA DE ALBERTA	)	PRESENTES LLEGAREN, SEAN VISTOS
A SABER:	)	O CONOCIDOS

Yo, D. Doak Horne, un Notario Público en y para la Provincia de Alberta, por Autoridad Real, debidamente nombrado, residente en la Ciudad de Calgary, en dicha Provincia,

CERTIFICO Y TESTIFICO que el documento adjunto al presente es una copia fiel de un documento producido y mostrado ante mí y que es:

- 1) Un Traspaso Original de Conrad Ayasse a Archon Technologies Ltd., ejecutado por Conrad Ayasse el 26 de marzo de 2010, respecto de la invención del Proceso de Recuperación de la Combustión In Situ Mejorado Utilizando un Solo Pozo Horizontal para Producir Petróleo y Gases de Combustión a la Superficie.

He comparado dicha copia con el documento original, un acto que siendo solicitado he otorgado bajo mi Forma Notarial y Sello de Oficina para servir y ser de provecho según la ocasión lo requiera.

EN TESTIMONIO DE LO CUAL, he suscrito mi nombre y colocado mi Sello de Oficina Notarial en Calgary este día 7 de enero de 2011.

(firma: ilegible)

D. Doak Horne

Un Notario Público en y para la Provincia
de Alberta

Sello Notarial

El Departamento de Asuntos Extranjeros y Comercio
Internacional de Canadá ha autenticado debidamente la
firma anterior de: (ilegible)

Autenticada por el Viceministro de Asuntos Extranjeros
por:

(firma: ilegible) / Michael Gabrario

Ottawa Canadá

Sello

Consularización No. 22 del documento en el Consulado de Colombia en Ottawa,
Canadá.

TRASPASO

POR CUANTO, yo/nosotros, Conrad Ayasse de 3931 Point McKay Road N.W., Calgary, Alberta T3B 4V7, Canadá, he inventado una invención llamada: PROCESO DE RECUPERACIÓN DE LA COMBUSTION IN SITU MEJORADO UTILIZANDO UN SOLO POZO HORIZONTAL PARA PRODUCIR PETRÓLEO Y GASES DE COMBUSTIÓN A LA SUPERFICIE ("Invención"), para lo cual se presentará una solicitud para Patente de Invención en Canadá;

POR CUANTO, Archon Technologies Ltd. (en adelante llamada "CESIONARIO") con oficinas en 1900, 111 – 5th Avenue S.W., Calgary, Alberta, T2P 3Y6, CANADA, desea adquirir y habiéndole asignado a ella el pleno derecho, título e interés en y de la Invención y en y de cualquier Patente de Invención que pudiese otorgarse por lo tanto en cualquiera y todos los países y jurisdicciones; y

POR CUANTO, yo/nosotros he acordado hacer dicho traspaso;

AHORA, POR LO TANTO, en contraprestación de las premisas anteriores, y de la suma de un dólar (\$1.00) y por otra contraprestación buena y valiosa, el recibo y suficiencia de lo cual se reconoce por el presente, yo/nosotros, por el presente vendo, cedo y transfiero completamente al CESIONARIO, el derecho, título e interés completo y exclusivo en y de: (a) la Invención en todo el mundo; (b) cualquiera y toda solicitud de patente para la Invención en todos los países y jurisdicciones y bajo todas las convenciones y tratados, incluyendo el derecho a reivindicar para cualquiera y todas las solicitudes derechos de prioridad a los que dichas solicitudes están facultadas bajo convenciones, tratados o de lo contrario, y todas las divisiones, extensiones, continuaciones, continuaciones en parte, provisionales, no provisionales, sustituciones y renovaciones de ello; (c) toda Patente de Invención que pudiese otorgarse por lo tanto en cualquiera y todos los

países y jurisdicciones, y cualquier renovaciones, reexpediciones, reexámenes o extensiones de la Patente de Invención, y (d) el derecho exclusivo para traer o participar en cualquier procedimiento por infracciones pasadas o cualquier otro derecho accionable bajo todo lo anterior y recibir todos los remedios que surjan de ello, hasta el final del término para el cual dicha Patente de invención sea otorgada, tan completa y enteramente como si la misma hubiese sido tenida por nosotros si no se hubiese hecho este Traspaso.

Yo/Nosotros por el presente autorizo y le solicito a las oficinas de patentes en todos los países y jurisdicciones que expidan cualquiera y toda Patente de Invención, cuando sea otorgada, al CESIONARIO.

Además, yo/nosotros acuerdo que le comunicaré al CESIONARIO o a sus representantes cualquier hecho conocido por mí/nosotros respecto a la Invención, y testificaré en cualquier procedimiento jurídico, firmaré todos los papeles legítimos, ejecutaré todos los papeles relacionados con todas las solicitudes de patente incluyendo toda divisional, continuación, continuación en parte, extensión, renovación, provisional, no provisional o sustituto de la misma, y la Patente de Invención incluyendo cualquier renovación, re-examen, extensión y reexpedición de dicha Patente de Invención, ejecutar todos los papeles de traspaso necesarios para ocasionar cualquiera y toda Patente de Invención que se expida al CESIONARIO, hacer todos los juramentos legítimos, y, en general hacer todo lo que sea posible para ayudar a dicho CESIONARIO, sus sucesores y cesionarios, a obtener y ejecutar la protección apropiada para la Invención en cualquiera y todos los países y jurisdicciones.

El suscrito por el presente autoriza a la firma Gowling Lafleur Henderson LLP para que corrija errores en este traspaso o inserte cualquier identificación

adicional u otra información necesaria o deseable para hacer que este Traspaso sea apropiado para registro en cualquier país.

EEJCUTADO en Calgary, Alberta, Canadá, este día 26 de marzo de 2010.

Testigo:

(firma: ilegible)

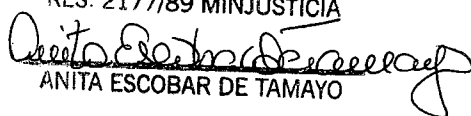
Imprimir Nombre: Susan Johnson

Inventor:

(firma: ilegible)

Conrad Ayasse

Traducido según mi mejor saber y entender, este día 17 de febrero de 2011, en la ciudad de Bogotá, D.C., por Anita Escobar de Tamayo, Traductora Oficial, Res. 2177 de 1989, Ministerio de Justicia, República de Colombia.

TRADUCTORA OFICIAL
RES. 2177/89 MINJUSTICIA

ANITA ESCOBAR DE TAMAYO

NOTARIAL CERTIFICATE

CANADA)
) TO ALL TO WHOM THESE PRESENTS
PROVINCE OF ALBERTA)
) MAY COME, BE SEEN OR KNOWN
)
TO WIT:)

I, **D. Doak Horne**

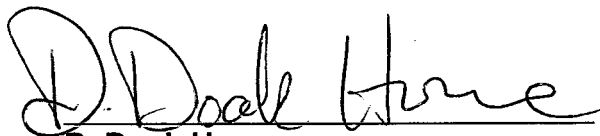
a Notary Public in and for the Province of Alberta, by Royal Authority duly appointed, residing at the City of Calgary, in said Province,

DO CERTIFY AND ATTEST that the paper-writing hereto annexed is a true copy of a document produced and shown to me and purporting to be:

- 1) An Original Assignment from Conrad Ayasse to Archon Technologies Ltd., executed by Conrad Ayasse on March 26, 2010, in respect of the invention to Improved In-Situ Combustion Recovery Process Using Single Horizontal Well To Produce Oil And Combustion Gases To Surface.

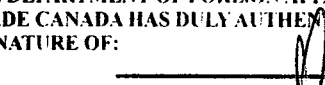
the said copy having been compared by me with the said original document, an act whereof being requested I have granted under my Notarial Form and Seal of Office to serve and avail as occasion shall or may require.

IN TESTIMONY WHEREOF I have hereto subscribed my name and affixed my Notarial Seal of Office at Calgary this 7th day of January, 2011.

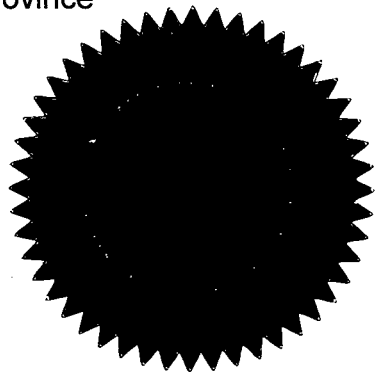


D. Doak Horne

A Notary Public in and for the Province
Of Alberta

THE DEPARTMENT OF FOREIGN AFFAIRS AND INTERNATIONAL TRADE CANADA HAS DULY AUTHENTICATED THE FOREGOING SIGNATURE OF:	
	
LE MINISTÈRE DES AFFAIRES ÉTRANGÈRES ET DU COMMERCE INTERNATIONAL CANADA A DULY AUTHENTIFIÉ LA SIGNATURE QUI PRÉCÈDE:	
AUTHENTICATED FOR THE DEPUTY MINISTER OF FOREIGN AFFAIRS BY:	
	
AUTHENTIFIÉ POUR LE SOUS-MINISTRE DES AFFAIRES ÉTRANGÈRES PAR:	
OTTAWA-CANADA	





CONSULADO DE COLOMBIA

22

En Ottawa, Canadá, a 18 de Ene de 2011

Legaliza la firma de Michael Grobacio

en la fecha ejerce las funciones de Oficial de legalizaciones

\$ 30 = [Signature]

Consul de Colombia

22

En Ottawa, Canada, a 18 de Éne de 2011

Legaliza la firma de Michael Grobacio
 en la fecha ejerce las funciones de oficial de legalizaciones

\$ 30 =

Consul de Colombia

[illegible]

ASSIGNMENT

WHEREAS, IWE: **Conrad Ayasse** of 3931 Point McKay Road N.W., Calgary, Alberta T3B 4V7, Canada have invented an invention entitled: **IMPROVED IN-SITU COMBUSTION RECOVERY PROCESS USING SINGLE HORIZONTAL WELL TO PRODUCE OIL AND COMBUSTION GASES TO SURFACE** ("Invention"), for which an application for Letters Patent will be made in Canada;

WHEREAS, **Archon Technologies Ltd.** (hereinafter referred to as "ASSIGNEE") having a place of business at 1900, 111 - 5th Avenue S.W., Calgary, Alberta, T2P 3Y6, CANADA is desirous of acquiring and having assigned to it the full right, title and interest in and to the Invention and in and to any Letters Patent that may be granted therefor in any and all countries and jurisdictions; and

WHEREAS IWE have agreed to make such assignment;

NOW, THEREFORE, in consideration of the foregoing premises, and of the sum of one dollar (\$1.00) and for other good and valuable consideration, the receipt and sufficiency of which is hereby acknowledged, IWE, hereby sell, assign and transfer absolutely to the ASSIGNEE the full and exclusive right, title and interest in and to: (a) the Invention worldwide; (b) any and all patent applications for the Invention in all countries and jurisdictions and under all conventions and treaties, including the right to claim for any and all applications any priority rights to which such applications are entitled under conventions, treaties or otherwise, and all divisions, extensions, continuations, continuations-in-parts, provisionals, non-provisionals, substitutions and renewals thereof; (c) all Letters Patent which may be granted therefor in any and all countries and jurisdictions, and any renewals, reissues, re-examinations or extensions of the Letters Patent, and (d) the exclusive right to bring or participate in any proceeding for past infringement or any other actionable right under all of the foregoing and to receive all remedies that arise therefrom, to the end of the term for which said Letters Patent may be granted, as fully and entirely as the same would have been held by us had this Assignment not been made.

IWE hereby authorize and request the patent offices in all countries and jurisdictions to issue any and all of the Letters Patent, when granted, to the ASSIGNEE.

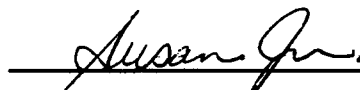
Further, IWE agree that IWE will communicate to the ASSIGNEE or its representatives any facts known to us respecting the Invention, and testify in any legal proceeding, sign all lawful papers, execute all papers relating to all patent applications including all divisional, continuation, continuation-in-part, extension, renewal, provisional, non-provisional or substitute thereof, and the Letters Patent including any renewal, re-examination, extension and reissue of said Letters Patent, execute all necessary assignment papers to cause any and all of said Letters Patent to be issued to the ASSIGNEE, make all rightful oaths, and, generally do everything possible to aid the ASSIGNEE, its successors and assigns, to obtain and enforce proper protection for the Invention in any and all countries and jurisdictions.

The undersigned hereby authorizes the firm of Gowling Lafleur Henderson LLP to correct errors in this assignment or to insert any further identification or other information necessary or desirable to make this Assignment suitable for recordal in any country.

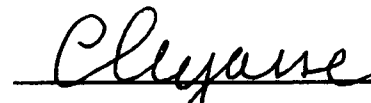
EXECUTED at Calgary, Alberta Canada, this 26th day of March, 2010.

Witness:

Inventor:



Print Name: Susan Johnson



Conrad Ayasse

TRADUCCION OFICIAL No. 2011-02-18-103
DE UN DOCUMENTO ESCRITO EN INGLES

Oficina de Propiedad Intelectual de Canadá
Una Agencia de la Industria de Canadá

Oficina de Patentes de Canadá
Certificación

Por el presente certifico que los documentos adjuntos al presente e identificados a continuación son copias fieles de los documentos en archivo en la Oficina de Patentes.

La especificación y los dibujos, como se presentaron originalmente, con la Solicitud para Patente No. de Serie CA 2698454, el 30 de marzo de 2010, por ARCHON TECHNOLOGIES LTD., cesionario de Conrad Ayasse, para "Proceso de Recuperación de la Combustión In Situ Mejorado Utilizando un Solo Pozo Horizontal para Producir Petróleo y Gases de Combustión a la Superficie".

(firma: ilegible)
Funcionario que Certifica
4 de octubre de 2010

Canadá

(CIPO 68)
07-10-08

OPIC

LO QUE SE REIVINDICA ES:

1. Un proceso de combustión in-situ mejorado para reducir la viscosidad del petróleo contenido en un reservorio que contiene petróleo y recuperar dicho petróleo, desde la reserva, proceso que no emplea uno o más pozos de ventilación de gas separados, que comprende:

(a) proporcionar al menos un pozo de producción que tiene una porción sustancialmente vertical que se extiende hacia abajo en dicho reservorio, y que tiene una porción de extremidad horizontal en comunicación fluida con dicha porción vertical, que tiene un diámetro interno de más de 3 pulgadas y que se extiende horizontalmente hacia el exterior del mismo, dicha porción de extremidad horizontal se completa en una parte relativamente inferior de la reserva;

(b) proporcionar al menos un pozo de inyección vertical posicionado sobre y espaciado en relación con dicha porción de extremidad horizontal y sustancialmente directo sobre dicha porción de extremidad horizontal y aproximadamente en una región intermedia de ella, para inyectar un gas oxidante en dicho reservorio para formar un frente de combustión que avance, que se extienda lateralmente en cada lado de dicho al menos un pozo de inyección;

(c) inyectar un gas oxidante a través de dicho al menos un pozo de inyección e iniciar la combustión de hidrocarburos en dicho reservorio próximo a dicho pozo de inyección con el fin de establecer un par de frentes de combustión que avancen lateralmente en una dirección a lo largo de dicha porción de extremidad horizontal y hacia afuera de dicho pozo de inyección en direcciones opuestas a lo largo de dicha porción de extremidad horizontal, ocasionando dicho frente de combustión que el petróleo en dicho reservorio reduzca su viscosidad y sea drenado hacia abajo dentro de dicha porción de extremidad horizontal;

- (d) permitir que los gases de combustión a alta temperatura junto con dicho petróleo de viscosidad reducida sean recolectados en dicha extremidad horizontal; y
 - (e) producir dichos gases de alta temperatura y dicho petróleo a la superficie; y
 - (f) separar en el talón de dicho pozo horizontal o en la superficie dicho petróleo de dichos gases de alta temperatura.
2. El proceso de la reivindicación 1, en donde dicho gas oxidante es inyectado en dicho pozo de inyección a una presión menor a la presión de fractura.
 3. El proceso de la reivindicación 1 ó 2, en donde dicho más de un pozo de inyección es colocado sobre y a lo largo de una longitud del pozo horizontal.
 4. El proceso de la reivindicación 1, en donde una pluralidad de pozos de inyección vertical se colocan sobre y a lo largo de una longitud del pozo horizontal, y se inicia un frente de combustión en cada pozo de inyección el cual avanza hacia el exterior desde cada pozo de inyección en direcciones opuestas, a lo largo de una línea de dicho pozo horizontal.
 5. El proceso de la reivindicación 1, en donde dichos gases de combustión calientes son usados posteriormente para calentar agua.
 6. El proceso de la reivindicación 5, en donde dicha agua caliente es usada posteriormente para producir vapor para ser usado para producir energía eléctrica usando turbinas.
 7. El proceso de la reivindicación 1, en donde dichos gases de combustión de temperatura elevada se utilizan o se queman posteriormente para producir energía eléctrica usando turbinas de gas o turbinas de vapor.
 8. El proceso de las reivindicaciones 1-7, en donde se ubica una tubería dentro del pozo horizontal que llega hasta un pulgar de dicho pozo horizontal, y se inyecta un

medio seleccionado del grupo de medios que comprenden agua, vapor, gas no oxidante incluyendo CO₂, diluyente hidrocarbonado, y mezclas de los mismos.

9. El proceso de la reivindicación 1, en donde el diámetro interno de la extremidad horizontal del pozo de producción tiene más de 5 pulgadas.

10. El proceso de la reivindicación 9, en donde el diámetro interno de la extremidad horizontal del pozo de producción tiene más de 7 pulgadas.

11. El proceso de las reivindicaciones 1-10, en donde el gas oxidante contiene oxígeno y CO₂.

12. El proceso de las reivindicaciones 1-11, en donde la presión de inyección de gas oxidante se limita a un máximo de menos de 50% sobre la presión del reservorio mediante el ajuste de la tasa de inyección de gas oxidante.

13. Un proceso mejorado de combustión in-situ, proceso que no emplea uno o más pozos de ventilación de gas separados, que comprende:

(a) proporcionar al menos un pozo de producción que tiene una porción sustancialmente vertical que se extiende hacia abajo en dicho reservorio y que tiene una porción de extremidad horizontal en comunicación fluida con dicha porción vertical y que se extiende horizontalmente hacia el exterior de la misma, dicha porción de extremidad horizontal se completa en una parte relativamente inferior del reservorio;

(b) proporcionar una pluralidad de pozos de inyección vertical de gas oxidante posicionados directamente sobre dicha porción de extremidad horizontal y en alineación sustancial con ello;

(c) inyectar un gas oxidante en dicho reservorio por medio de dichos pozos verticales localizados aproximadamente en un punto medio a lo largo de dicho pozo de perforación horizontal;

(d) iniciar la combustión in-situ en dicho reservorio próximo a dichos pozos de inyección vertical para formar un par de frentes de combustión que se extienden verticalmente y avanzan lateralmente en direcciones opuestas a lo largo de dicha porción de extremidad horizontal y hacia el exterior desde cada uno de dichos pozos de inyección vertical, dichos frentes de combustión ocasionan que el petróleo en dicha formación reduzca su viscosidad y sea drenado hacia abajo dentro de dicha porción de extremidad horizontal;

(e) recolectar los gases de combustión de alta temperatura a lo largo con dicho petróleo de viscosidad reducida en dicha extremidad horizontal, y

(f) producir tales gases a alta temperatura y petróleo a la superficie, y

(g) separar en el talón de dicho pozo horizontal o en la superficie, dicho petróleo de dichos gases a alta temperatura.

14. El método como se reivindica en la reivindicación 13, en donde dicho par de frentes de combustión vertical sustancialmente avanzando respectiva y lateralmente a lo largo de dicho pozo de perforación horizontal pasa otro de dichos pozos de dicha pluralidad de pozos de inyección, se inyecta gas oxidante en dicho reservorio en dicho pozo adicional de dichos pozos de inyección.

15. El proceso de la reivindicación 13, en donde el diámetro interno de la extremidad horizontal del pozo de producción tiene más de 5 pulgadas.

16. El proceso de la reivindicación 13, en donde el diámetro interno de la extremidad horizontal del pozo de producción tiene más de 7 pulgadas.

17. Un proceso mejorado de combustión in-situ, proceso que no emplea uno o más pozos de ventilación de gas separados, que comprende:

(a) proporcionar al menos un pozo de producción que tiene una porción sustancialmente vertical que se extiende hacia abajo en dicho reservorio y que tiene una porción de extremidad horizontal en comunicación fluida con dicha

porción vertical y que se extiende horizontalmente hacia el exterior de la misma, dicha porción de extremidad horizontal se completa en una parte relativamente inferior del reservorio;

(b) proporcionar una pluralidad de pozos de inyección vertical de gas oxidante posicionados directamente sobre dicha porción de extremidad horizontal y en sustancial alineamiento con la misma, dicho pozo de inyección vertical situado aproximadamente en un punto medio a lo largo de dicho pozo de perforación horizontal;

(c) inyectar un gas oxidante en dicho reservorio a través de dicho uno de dichos pozos verticales localizados aproximadamente en un punto medio a lo largo de dicho pozo de perforación horizontal;

(d) iniciar la combustión in-situ en dicho reservorio próximo a dicho pozo de inyección vertical para formar un par de frentes de combustión que se extienden verticalmente y avanzan lateralmente en direcciones opuestas a lo largo de dicha porción de extremidad horizontal y hacia el exterior de dicha inyección vertical, dicho frente de combustión ocasiona que el petróleo en dicha formación reduzca su viscosidad y sea drenado hacia abajo dentro de dicha porción de extremidad horizontal;

(e) recolectar los gases de combustión de alta temperatura a lo largo de dicho petróleo de viscosidad reducida en dicha extremidad horizontal, y

(f) producir posteriormente tales gases a alta temperatura y petróleo a la superficie, y

(g) separar en la superficie dicho petróleo de dichos gases a alta temperatura.

18. El método como se reivindica en la reivindicación 17, en donde dicho par de frentes de combustión vertical avanzan lateralmente a lo largo de dicho pozo de perforación horizontal pasa otro de dicha pluralidad de pozos de inyección, se

inyecta gas oxidante en dicho reservorio en dicho pozo adicional de dichos pozos de inyección.

19. El proceso de la reivindicación 17, en donde el diámetro interno de la extremidad horizontal del pozo de producción tiene más de 5 pulgadas.

20. El proceso de la reivindicación 19, en donde el diámetro interno de la extremidad horizontal del pozo de producción tiene más de 7 pulgadas.

Traducido según mi mejor saber y entender, este día 18 de febrero de 2011, en la ciudad de Bogotá, D.C., por Anita Escobar de Tamayo, Traductora Oficial, Res. 2177 de 1989, Ministerio de Justicia, República de Colombia.

TRADUCTORA OFICIAL
RES. 2177/89 MINJUSTICIA


ANITA ESCOBAR DE TAMAYO



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Industry Canada

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*Canadian Patent
Office
Certification*

La présente atteste que les documents
ci-joints, dont la liste figure ci-dessous,
sont des copies authentiques des docu-
ments déposés au Bureau des brevets.

This is to certify that the documents
attached hereto and identified below are
true copies of the documents on file in
the Patent Office.

Specification and Drawings, as originally filed, with Application for Patent Serial No:
CA 2698454, on March 30, 2010, by **ARCHON TECHNOLOGIES LTD.**, assignee of
Conrad Ayasse, for "Improved In-Situ Combustion Recovery Process Using Single
Horizontal Well to Produce Oil and Combustion Gases to Surface".

Chris Colyer

Agent certificateur/Certifying Officer

October 4, 2010

Date

Canada

(CIPO 68)
07-10-08

OPIC  CIPO

ABSTRACT

An in-situ combustion process which process does not employ one or more separate gas venting wells. At least one vertical production well having a substantially vertical portion extending downwardly into the reservoir and a horizontal leg portion extending horizontally outwardly therefrom completed relatively low in the reservoir is provided. At least one vertical oxidizing gas injection well, positioned above and in spaced relation to the horizontal well, is positioned laterally along the horizontal well approximately midsection thereof. Oxidizing gas is injected therein and combustion fronts are caused to progress outwardly from such injection well in mutually opposite directions along the horizontal well. Preferably a plurality of injection wells are provided along the direction of the horizontal well, and oxidizing gas is injected in each and combustion fronts caused to progress outwardly and in opposite directions from each, and oil is caused to drain down into the horizontal well, which oil along with hot combustion gases is produced to surface.

5 **IMPROVED IN-SITU COMBUSTION RECOVERY PROCESS USING SINGLE
HORIZONTAL WELL TO PRODUCE OIL AND COMBUSTION GASES TO
SURFACE**

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FIELD OF THE INVENTION

This invention relates to a process for recovering viscous hydrocarbons from a subterranean reservoir using in-situ combustion, a vertical oxidizing gas injection well,
15 and a separate horizontal well, and in particular to an improved process which does not employ separate additional gas venting wells.

20

BACKGROUND OF THE INVENTION

In situ combustion processes for producing oil from viscous underground hydrocarbon formations and various methods for separating hydrocarbons from subterranean formations containing hydrocarbons are well known in the art.

25 By way of example, US Patent 3,502,372 (M. Prats) discloses a process wherein shale oil and soluble aluminum compounds are recovered from a rubbleized or fragmented shale oil formation by top-down burning of the shale oil. The removal of oil is conducted to clean the shale for subsequent solution mining of the aluminum in the shale with alkaline chemicals. The pyrolyzing agent can be a hot mixture of air and water but it must be
30 injected at a temperature over 500 °F and the temperature in the formation must be controlled to 600-950 °F to prevent damage to the minerals. The present invention, as discussed in the Summary of the Invention and thereafter in the Detailed Description does not require rubbleization of the reservoir or utilize top-down burning. Rather, an established combustion front moves laterally along a horizontal well bore.

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US Patent 3,515,212 (Allen et al) discloses an in situ combustion process combining forward and reverse in situ combustion between vertical wells. The region of an injection well is heated with steam to auto-ignition temperature and air is injected from an offset well and flows in the direction of the injection well. As the air enters the heated zone oil

5 zone near the injection well, ignition occurs. Combustion gas is withdrawn at the ignition well and the combustion front grows towards the offset well, in a reverse in situ combustion process. After the front approaches the offset well, air injection is undertaken at that well and the original injector is converted to an oil producer, and a forward in situ combustion process is initiated wherein the combustion front moves
10 toward the original injection well, and is produced from the original injection well.

US Patent 4,566,537 (Gussis) relates to the production of immobile oil, such as the Athabasca bitumen. The problem of communication between vertical wells is overcome by conducting a series of cyclic steam cycles to heat the oil near the injector and create
15 voidage. In a second stage air is injected high in the reservoir at one of the wells and combustion gases are produced at the other well, establishing communication between the wells at the top of the reservoir. This now enables steam injection at the base of one well, with oil production at the other well. This process is different than the process of the present invention, which as discussed below, utilizes gravity drainage into a horizontal
20 producer and does not requiring a steam drive stage. Further, continuous removal of oil and combustion gas occurs in the same well.

US Patent 4,410,042 (Shu) discloses a method of conducting the early stage of in situ combustion that utilizes pure oxygen. Until the combustion front reaches a distance of 30
25 feet from the injector, the oxygen is diluted with carbon dioxide. Thereafter pure oxygen is injected. By way of contrast, as discussed in the Summary of the Invention and the detailed description, the process of the present invention does not employ mixtures of pure oxygen with carbon dioxide at any stage.

30 US Patent 4,418,751 (Emery) discloses an in situ combustion process wherein water is injected into the upper part of an oil reservoir separately from oxygen that is injected near the base. The water and combustion gases mix in the reservoir, vaporizing the water and scavenging heat. The present process does not require or employ the simultaneous injection of oxygen and water. In fact the injection of oxygen near the horizontal well at
35 the base of the reservoir would be very dangerous since oxygen would enter the wellbore

5 and burn oil therein, causing high temperatures that would threaten the integrity of the wellbore and deposit coke that would partially plug the wellbore.

US Patent 4, 493,369 (Odeh et al) discloses essentially the same well and fluid arrangement as '751 with injection of oxidizing gas at the base of the reservoir and water
10 at the top.

US Patent 5,456,315 discloses an in situ combustion process wherein an oxidizing gas is injected into vertical wells that are perforated in the upper part of an oil reservoir. The vertical wells are placed in a row directly above a horizontal well that is situated at the
15 base of the reservoir. This orientation of wells is the same as the present process. However, '315 requires a row of horizontal/vertical gas vent wells that are placed on either side of and parallel to a horizontal producer, but each situated at the top of the reservoir. The purpose of the vent wells is to withdraw the combustion gasses to the surface separately from the liquids that drain by gravity into the horizontal producer. The
20 present process, as more fully described below, does not utilize separate combustion gas vent wells, but produces the liquids and gases together through the same horizontal well, and so it needs only one horizontal producer well, and thus substantially fewer expensive horizontal wells. In addition, the withdrawal of combustion gas separately from the liquids as done in the process of '315 eliminates convective heat transfer in the oil
25 drainage zone, making the process of '315 less energy efficient. Specifically, by inhibiting mixing of combustion gas with liquids, '315 removes produced hydrogen from contact with hot oil so that the degree of in situ hydrocracking and oil in situ upgrading is greatly reduced. The removal of carbon dioxide, which occurs at 16% in the combustion gas, inhibits the solvency benefit which occurs in the present invention as described
30 below, which present invention is thereby better able to further reduce oil viscosity and broaden the oil drainage zone, thereby resulting in higher oil production rates than the method disclosed in '315.

A further major drawback of vent gas withdrawal as disclosed in the '315 patent is
35 process safety since the vent wells must be water-cooled on account of the high

5 temperature attained from the burnt (and sometimes burning) vent gas inside the reservoir. Furthermore, recalling that the air injection wells and the vent wells are all at the top of the reservoir and are in communication, there is likelihood of oxygen mixing with hydrocarbon liquids and gases in the vent wells so as to create an explosive mixture therein or at the surface.

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US Patent 5,339,897 (Leaute) discloses a process similar to '315 for producing hydrocarbons from tar sands wherein a vertical well is placed at the top of the oil-bearing reservoir over a horizontal producer and a second vertical well is emplaced offset from the first vertical well, also at the top of the reservoir, and laterally from the horizontal
15 producer. Communication is accomplished between the vertical wells using hot fluids, then an oxidizing gas is injected in the well over the producer and combustion gas is withdrawn via the offset well. Heated oil drains downward to the producer. Additionally, '897 process of injecting a cracking fluid such as superheated steam into the accumulated oil above the horizontal producer induce cracking reactions.

20

US Patent 5,626,191 (Greaves et al) discloses an in situ process wherein an oxidizing gas injector is placed near the top of an oil reservoir in the vicinity of the toe of a horizontal producer that is emplaced at the base of the reservoir. A combustion front is developed that is quasi-vertical, extends laterally and moves from the toe of the producer towards
25 the heel of the producer. Oil and gas drain together into the same horizontal producer. The present invention, as described below, is a valuable improvement over '191 because by placing the injector midway along the horizontal producer or placing multiple injectors above the producer as in the present invention greatly enhances the oil production rate and degree of oil upgrading at moderate cost. In this configuration, each
30 injector sustains two combustion/drainage fronts instead on only one using '191. Surprisingly, the combustion/drainage fronts advance at equal rates toward the toe and the heel of the producer. US Patent 5,626,191 is incorporated herein in its entirety.

US Patent 6,412,557 (Ayasse et al) is an improvement on '191 wherein a catalyst is
35 emplaced in, on or around the horizontal producer well to enhance oil upgrading. US

5 Patent 6,412,557 is incorporated herein in its entirety.

US Patent 7,493,952 (Ayasse) discloses an improvement on '191 and '557 wherein a non-oxidizing gas is injected within the horizontal producer at the toe to prevent oxygen entry and enhance process safety by controlling temperature and pressure within the wellbore. US Patent 7,493,952 is incorporated herein in its entirety.

US Patent Publ. 20090308606 (US Pat. Appl. 12/280,832) (Ayasse) discloses an improvement to '191 and '952 wherein a diluent such as naphtha or other hydrocarbon solvent, or CO₂ is injected in a long tubing extending to the toe of the horizontal producer well in order to control wellbore pressure and temperature and to facilitate flow of wellbore oil by density and viscosity reduction.

US Patent Pat. Pub. 20090200024 (US Appl. No. 12/068,881) (Ayasse et al) discloses a new process, similar to '191, wherein oxidizing gas is injected near the heel of a horizontal well, having a tubing extending to the toe. A combustion front develops with movement from the heel to the toe. The advantage of the process of the present invention, as more fully described below, over US '191 is that unlike US '191 the drilling of a distant vertical injector near the toe is not required. Rather, in the present invention, the injector could be drilled away from the toe, such as midway along the horizontal leg. The advantage of the present process over US Application '881 is that a single injector well may be placed midway between the toe and heel of the horizontal producer well and dual combustion fronts will move towards the toe and heel without concern about burning up the vertical segment of the horizontal producer as could happen with '881 wherein the air injection point is nearby or at the vertical segment. The present invention, as with '881, also has the advantage of placing a vertical air injector well back from the toe of the horizontal well (for example at 500 meters from the toe for a 1000meter horizontal producer leg) so that surface inaccessibility, such as caused by a bog or lake at the toe region, will not prohibit the drilling of a vertical injector there and inhibit reservoir exploitation.

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5 SUMMARY OF THE INVENTION

This invention is directed to an improved process for recovering viscous hydrocarbons from a subterranean reservoir using in-situ combustion, utilizing at least one vertical oxidizing gas injection well and a separate horizontal well, and in particular to an improved process which does not employ separate additional vent gas wells and instead
10 uses a horizontal well bore situated low in a formation to collect not only heated oil but also hot combustion gases, and to thereafter produce both to surface, where the oil is thereafter separated from the high temperature combustion gases.

In the embodiment of the invention where only one vertical injection well is utilized, the
15 vertical injection well is disposed and completed in the upper part of the reservoir, for injecting oxygen-containing gas into the reservoir to support in-situ combustion therein. Such vertical injection well is situated above the horizontal well and approximately at a midpoint along said horizontal well, and upon injection of an oxidizing gas into the reservoir via the injection well and upon ignition of hydrocarbons in such reservoir
20 proximate such vertical injection well a combustion front is generated proximate the vertical injection well which combustion front propagates outwardly from the injection well in mutually opposite directions each mutually opposite direction being along the horizontal well, as well as laterally to the horizontal well. Both high temperature combustion gases and heated oil are drawn downwardly from the hydrocarbon
25 formation and collected within the horizontal well, and thereafter are together produced to surface via such horizontal well, where at surface the hot combustion gases are separated from the oil using a multi-phase separator, vortex separating techniques or other techniques well known to persons of skill in the art, and further where desired the hot combustion gases are used to heat water so as to produce steam, preferably for use in
30 powering steam turbines for the production of electrical power. Alternatively, the combustion gases, which contain flammable components such as methane, ethane, propane, carbon monoxide, hydrogen and hydrogen sulfide, may be combusted at the surface to produce electricity with a steam turbine or gas turbine. In processes with gas vent wells, these gases are combusted in the upper reaches of the reservoir and must be
35 cooled to protect the vent wells from thermal damage, so that the energy is wasted.

5 Similarly, in a preferred embodiment of the process of the present invention employing multiple vertical oxidizing gas injection wells aligned and extending in a direction of the horizontal well, each vertical oxidizing gas injection well is completed above and appropriately spaced along the horizontal well bore, and dual combustion fronts of hot combustion gases and draining oil are created at each injector, which combustion fronts
10 propagate along the horizontal wellbore substantially orthogonal to the horizontal well bore and through the hydrocarbon formation, in mutually opposite directions from the vertical injection well bore as well as towards the toe and the heel of the horizontal well. For example, for 5-oxidizing gas injectors there will be generated ten (10) fluid drainage fronts, which provides high oil production rates an low extra cost.

15 Notably, if the inner diameter of the horizontal leg of the producer well is too small, then wellbore hydraulics interfere with the symmetry of combustion front advancement-the front advancement in the direction of the heel of the horizontal producer will be faster than toward the toe, thereby reducing efficiency of the process, and the symmetry of
20 simultaneously proceeding equally in mutually opposite directions along the horizontal producer will be lost, and more importantly slowed in the direction progressing towards the toe.

Consequently, in a further preferred embodiment of the process of the present invention,
25 where the horizontal well may have in the neighborhood of approximately 400 meters of reservoir above it, with corresponding wellbore hydraulics at such depth, the inner diameter of the horizontal leg of the producer well should be greater than 3-inches so as to maintain frontal advancement symmetry, preferably greater than 5-inches and most preferably greater than 7-inches to permit sufficient diameter in the producer well.

30 Also contemplated within this invention is a process whereby a plurality of vertical oxidizing gas wells may be initially completed above the horizontal well bore along a line thereof, and an oxidizing gas is injected initially into the formation at one of said vertical injection wells located approximately midsection of the horizontal well and a combustion
35 front is formed proximate thereto, which advances in mutually opposite directions along

5 the horizontal well. After the combustion front has advanced a given distance in mutually opposite directions past additional vertical oxidizing gas injection wells, on respective opposite sides of such initial injection well, further oxidizing gas may then be injected into one or each of said additional injection wells so as to sustain combustion and permit the combustion front(s) to continue to advance along the horizontal well bore.

10

Advantageously, by using a horizontal well bore to draw down both heated oil and hot combustion gases and then producing both oil and hot combustion gases (depleted of oxygen) to surface, the following advantages are cumulatively realized, namely:

15

(i) the hot combustion gases which are drawn into the horizontal production well along with the heated oil serve to keep the oil continuously heated and thus improve not only collection rates of such oil from the hydrocarbon formation but also ensures the viscosity of the heated oil remains low and thus such oil may be lifted to surface using gas "lift", eliminating the use and necessity of pumps;

20

(ii) fewer wells need be drilled, and in particular no gas vent wells need be drilled to separately collect and vent hot combustion gases, as was necessary with certain prior art processes; and

25

(iii) hot combustion gases may be thereafter be used at surface to heat water so as to produce steam, which may be used for heating and/or to power steam turbines so as to generate electrical power, and thus energy which otherwise which would have been lost is thereby able to have been made use of in this process.

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(iv) oil upgrading will be achieved because of higher oil temperatures and the comingling of oil in the reservoir with hydrogen generated in this process

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Specifically, with regard to advantage (ii) above, by situating a vertical injection well proximate the midsection of a horizontal well and by propagating the combustion front in two mutually opposite directions along such well bore, such allows more rapid

- 5 collection of oil than by the method disclosed in either US 5,626,191 ("toe to heel" propagation of combustion front) or US 7,493,952 ("heel to toe" propagation of combustion front) which merely causes the combustion front to advance in a single direction along the horizontal well bore.
- 10 Moreover, by injecting an oxygen-containing gas at less than fracturing pressure through the injection well and establishing a zone of oxygen-containing gas around the injection well that extends upwards to the reservoir cap rock and downward (but not reaching) the horizontal production well, and establishing a water, oil and combustion gas drainage front that grows along the horizontal well in directions both towards the toe and towards
- 15 the heel of the horizontal well and also grows perpendicularly to the strike of the horizontal well, the heated oil and water and the heated combustion gas may all drain under the influence of gravity and pressure forces and further be collected in the horizontal well free of oxygen or oxidizing gas, which greatly reduces the chance of explosion. Compared with the process of vent gas withdrawal by separate vent wells, the
- 20 present process preserves the valuable flammable components for production to the surface rather than burning them in the reservoir where the heat is wasted, and it utilizes some of the generated hydrogen to hydrocrack the hot oil, thus producing a stable partially upgraded oil.
- 25 Accordingly, in one broad aspect of the process of the present invention such process comprises an improved in situ combustion process for reducing the viscosity of oil contained in an oil-bearing reservoir and recovering said oil of reduced viscosity from the reservoir, which process does not employ one or more separate gas producing wells, comprising:
- 30 (a) providing at least one production well having a substantially vertical portion extending downwardly into said reservoir and having a horizontal leg portion in fluid communication with said vertical portion and extending horizontally outwardly therefrom, said horizontal leg portion completed relatively low in the reservoir;

- 5 (b) providing at least one vertical injection well positioned in spaced relation to said horizontal leg portion and substantially directly above said horizontal leg portion and approximately in a midsection thereof, for injecting an oxidizing gas into said reservoir to form an advancing, laterally extending combustion front on each side of said at least one injection well;
- 10 (c) injecting an oxidizing gas at less than fracturing pressure through said at least one injection well and initiating combustion of hydrocarbons in said reservoir proximate said injection well so as to establish a pair of combustion fronts advancing laterally in mutually opposite directions along said horizontal leg portion and outwardly from said injection well, said combustion front causing oil in said reservoir to become reduced in
- 15 viscosity and to drain downwardly into said horizontal leg portion;
- (d) allowing high temperature combustion gases along with said oil of reduced viscosity to be collected in said horizontal leg; and
- (e) producing such high temperature gases and oil to surface; and
- (f) separating at surface or at the heel of said horizontal well said oil from said high
- 20 temperature gases.

Alternatively, in another broad aspect of the method of the present invention, such method comprises an improved in-situ combustion process for reducing the viscosity of oil contained in an oil-bearing reservoir and recovering said oil of reduced viscosity from the formation, which process does not employ one or more separate gas venting wells,

25 further comprising:

- (a) providing at least one production well having a substantially vertical portion extending downwardly into said reservoir and having a horizontal leg portion in fluid communication with said vertical portion and extending horizontally outwardly therefrom, said horizontal leg portion completed relatively low in the reservoir;
- 30 (b) providing a plurality of oxidizing gas vertical injection wells positioned directly above said horizontal leg portion and in substantial alignment therewith;

- 5 (c) injecting an oxidizing gas into said reservoir via each of said vertical wells located along said horizontal wellbore;
- (d) initiating in situ combustion in said reservoir proximate each of said vertical injection wells so as to form a pair of vertically-extending combustion fronts advancing laterally in opposite directions along said horizontal leg portion and outwardly from each of said vertical injectors, said combustion front causing oil in said formation to become reduced
10 in viscosity and to drain downwardly into said horizontal leg portion;
- (e) collecting high temperature combustion gases along with said oil of reduced viscosity in said horizontal leg; and
- (f) simultaneously producing such high temperature gases and oil to surface; and
- 15 (g) separating at surface or at the heel of said horizontal well said oil from said high temperature gases.

In a further refinement, where combustion is only initiated at an injection well located midpoint along the horizontal well, upon the substantially vertical combustion front advancing laterally along said horizontal well bore past further vertical injection wells,
20 oxidizing gas is injected into said reservoir at said further vertical injection wells to accelerate movement of the vertical combustion fronts in both directions along said horizontal well.

In a still further embodiment, such improved in-situ combustion process (which process does not employ one or more separate gas venting wells) comprises:

- 25 (a) providing at least one production well having a substantially vertical portion extending downwardly into said reservoir and having a horizontal leg portion in fluid communication with said vertical portion and extending horizontally outwardly therefrom, said horizontal leg portion completed relatively low in the reservoir;
- (b) providing a plurality of oxidizing gas vertical injection wells positioned directly
30 above said horizontal leg portion and in substantial alignment therewith, said one of

5 said vertical injection wells situated approximately at a midpoint along said horizontal well bore;

(c) injecting an oxidizing gas into said reservoir via said one of said vertical wells located approximately midpoint along said horizontal wellbore;

(d) initiating in situ combustion in said reservoir proximate said one of said vertical
10 injection wells so as to form a pair of vertically-extending combustion fronts advancing laterally in opposite directions along said horizontal leg portion and outwardly from said one vertical injection, said combustion front causing oil in said formation to become reduced in viscosity and to drain downwardly into said horizontal leg portion;

15 (e) collecting high temperature combustion gases along with said oil of reduced viscosity in said horizontal leg; and

(f) thereafter producing such high temperature gases and oil to surface; and

(g) separating at surface said oil from said high temperature gases.

In a further refinement of such immediately-preceding process, said substantially
20 vertical combustion front advancing laterally along said horizontal well bore past a further one of said plurality of injection wells, oxidizing gas is injected into said reservoir at said further one of said injection wells.

Optionally, cyclically or directly stimulating the reservoir with steam through the injection well and the production well may be initially conducted prior to initiating in situ
25 combustion, in order to establish fluid communication between the injection well and the horizontal oil production well, to better ensure the flow of heated combustion gases and heated oil once in-situ combustion is initiated. Optionally, oil ignition may be enabled or assisted by the known technique of injecting linseed oil or other fluid which is easily ignited into the reservoir through the air perforations.

30 It will be noted that the process of the present invention advantageously comprises and is characterized by the following features:

- 5 (i) There is no split production of the liquid and gas phases since they both enter the same production well (i.e. the horizontal well) completed low in the reservoir near the base thereof;
- 10 (ii) The high gas/liquid ratio in the horizontal well, when using air as an oxidizing gas, due to depth of the well and ingress of high temperature gases into the production well, assures that natural gas lift will be effective in a reservoir that is not pressure-depleted so that the use of pumps is unnecessary, reducing process complexity and cost;
- 15 (iii) As a direct consequence of the oil and combustion gas (and sometimes water and/or steam) flowing together into the horizontal well bore, high energy efficiency is achieved because all the combustion heat energy is transferred convectively to the oil inside of and ahead of the drainage zone in the reservoir, which thereby due to the energy transfer from combustion gases to the oil provides the greatest viscosity decrease of the fluids and maximizes the oil production rate. The air-oil ratio is also decreased, reflecting increased energy efficiency compared with the case of split gas and liquid production with different wells;
- 20 (iv) Co-production of combustion gas and hydrocarbon liquids also improves the oil production rate because CO₂ present in the combustion gas permeates the oil ahead of the drainage front and acts as a solvent to further reduce oil viscosity and facilitate oil drainage into the horizontal well. Also, CO₂ in the combustion gas has its highest solubility in cold oil, so that the drainage zone is made wider as a consequence of CO₂ dissolving in cold oil;
- 25 (v) Hydrogen entrained with the flowing hot oil in the drainage zone and in the wellbore enables hydrocracking and partial upgrading of the oil
- 30 (v) Low air injection pressure is required in the present process because the combustion gas is in direct communication with the nearby horizontal production well, being distant at most by the thickness of the oil zone.

5 BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings which illustrate exemplary embodiments of the present invention:

10 **Figure 1** is a cross section through an oil-bearing reservoir, showing the arrangement of wells used to carry out the method of the invention, such cross section cutting through both the vertical injection well and horizontal/vertical production well pair. A layer of overburden lies over the oil-bearing reservoir, into which are placed a vertical oxidizing gas injection well and a vertical/horizontal well pair for producing the oil;

Figure 2 is a cross-sectional through the oil-bearing reservoir shown in **Figure 1**, taken along plane B-B, with the horizontal production well shown in cross-section;

15 **Figure 3** is a partially-transparent top view of the oil-bearing reservoir shown in **Figure 1** from numerical simulation;

Figure 4 is a cross-section through an oil-bearing reservoir similar to **Figure 1**, showing a variation of the method of the present invention, where a plurality of oxidizing gas injection wells are used to advance a combustion front in two mutually opposite
20 directions; and

Figure 5 is similar to **Figure 1**, but employing 5- oxidizing gas injection wells as simultaneous injectors.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to **Figure 1**, an oil-bearing reservoir 20 shown in **Figure 1** is typically covered
25 by an overburden 1, preferably constituted of shale or cap rock sufficiently thick to be substantially impermeable to gas flow so that the injected oxygen-containing gas 22 will be contained within the oil-bearing reservoir 20.

In accordance with the method of the present invention, at least one vertical oxidizing gas injection well 6a is drilled from the surface 30 downwardly into an upper portion of

5 the reservoir 20, and is perforated so as to permit injection of oxidizing gas 22 into reservoir 20 proximate the top of the oil-bearing reservoir 20.

A horizontal/vertical production well pair 9 is provided, having a vertical well portion 10 and a horizontal portion 8. The horizontal well portion 8 is completed low in the reservoir 20 and preferably extending substantially across a length of an oil-bearing reservoir 20 or a portion thereof from which oil is desired to be recovered by the process of the present invention. The casing of the horizontal well, is perforated as shown in Figures 1 and 4, or may consist of porous screens, as shown and taught in PCT/CA to the assignee herein, Archon Technologies Ltd., narrow slots or FacsRite™¹ screen plugs and the such to permit ingress of hot oil 3 and hot combustion gases 5 from the reservoir 20 into the horizontal well 8, for subsequent production to surface 30. The inner diameter of the horizontal producer well is preferably greater than 3-inches so as to maintain frontal advancement symmetry, and preferably greater than 5-inches and most preferably greater than 7-inches (ie an inner diameter of approximately 9 5/8 inches in typical current standard wellbore size) to permit sufficient diameter in the producer well.

20

The at least one oxidizing gas injector well 6a, in accordance with the method of the present invention, is located above and approximately midway along horizontal well bore 8 (i.e. wherein distance "d₁" is approximately equal to distance "d₂" as shown in Figure 1), although the precise position may be altered based on known reservoir heterogeneity or other factors.

25

The first step in starting and conducting the oil recovery process of the present invention, in a preferred embodiment, is to establish fluid communication between the vertical injection well 6a and the horizontal production well 8 so that oxidizing gas 22 can more easily be injected into the reservoir 20 and heated oil 3 and combustion gas 5 can be removed from the reservoir 20 via horizontal/vertical well pair 9. Initially, steam (not shown) may be injected cyclically or continuously in the vertical well 6a, and also injected from surface into horizontal well 8 and circulated therein to heat the horizontal well 8 and increase mobility of heated oil 3 therein. The pressure of the initially-injected

30

¹ FacsRite™ is a trademark of Shlumberger Inc. for producing well sand screens.

5 steam is not to be so great so as to force large volumes of steam directly through
reservoir 20 and into horizontal well 8, but merely sufficient to assist viscous liquids in
reservoir 20 to be assisted under such assisting pressure to drain downwards in reservoir
20 to an area of lower pressure, namely the region of horizontal well 8 which horizontal
well 8 removes fluids from such region and thereby creates an area of relatively lower
10 pressure, and thus establishes fluid flow in such direction). For oil 3 that is immobile at
reservoir conditions, steam may also be injected via the injection well 6a in a continuous
manner, relying on reservoir dilation to achieve steam injectivity. When the oil 3 is so
viscous that it is immobile in the reservoir 20, pre-heating the horizontal production well
8 prevents oil 3 from solidifying in the horizontal well 8 and inhibiting production,
15 especially when the production well 8 must be shut-in, as may happen should difficulties
occur with the surface oil-treating facilities. Such pre-heating may be conducted by
circulating steam in the horizontal leg 8 from the toe 40 to the heel 42 of the horizontal
well 8. The circulation is achieved by placing a long tubing (not shown) within the
horizontal well 8 for injecting steam that flows via the tubing to the toe 40 and returns
20 back the heel 42 via the annular space between the tubing and horizontal well casing 8
and thereafter to surface 30. Once fluid communication is established between the
injector well 6a and horizontal producer well 8, an oxygen-containing gas, for example
air, oxygen-enriched air, CO₂-enriched air or an oxygen-CO₂ mixture, is injected into the
reservoir 20 via injector well 6a as shown in Figure 1. At first, relatively moderate air
25 rates are used, but these rates are ramped up to the target maximum while keeping the
wellbore temperature below about 350 °C as measured by a string of thermocouples
placed in the wellbore. After initiating injection of oxidizing gas, combustion by-products
such as CO₂ will appear at the surface in the produced gas, indicating that combustion has
been achieved in the reservoir.

30 Pre-heating the reservoir 20 near the vertical injector well 6a serves a second important
purpose because oil at steam temperatures is usually able to auto ignite and start the
burning and oil production processes. It also reduces the oil saturation in the sand near
the vertical injector, which serves to reduce the strength of the combustion exotherm and
prevent over-heating the injector well.

5 At the beginning of the in-situ combustion process, when oxidizing gas 22 contacts oil 3
 in formation 20, burning reactions occur and coke is created in region 4 immediately
 following the combustion fronts 50, as shown in **Figures 1-4**. Thereafter, coke is the only
 fuel consumed, which after consumption leaves a burned-out zone 2, as shown in **Figures**
 1-4. Coke, in region 4 (see **Figures 1-4**), is constituted of small carbonaceous particles
 10 dispersed on the sand grains. The hydrogen/carbon ratio is typically 1.13 as measured in
 laboratory reactors and refinery cokers involving Athabasca bitumen. The sands
 containing coke particles remain substantially permeable to gas, so that the oxidizing gas
 22 and the produced combustion gas 4 can readily flow through, contacting cold oil and
 transferring heat. The convective oil heating is so extensive that oil hydrocracking occurs
 15 on account of high temperatures produced during coke combustion and the presence of
 generated hydrogen. The present process will operate similarly to the THAI²™ (Toe-to-
 Heel Air Injection) process with regard to the burning mechanism and drainage front.
 Petrobank Energy and Resources Ltd., operating the THAI™ process at Conklin, Alberta
 has reported reservoir temperatures over 600 °C, up to 8 volume percent hydrogen in the
 20 produced gas and 3-4 points of bitumen upgrading. Consequently, the produced oil 3
 from the present invention will be substantially upgraded.

Advantageously, in the method of the present invention which provides for removing hot
 combustion gases 5 via horizontal/vertical well pair 10, such allows significant
 advantages to be achieved over the prior art such as the process of US patent 5,456,315,
 25 which relied on extra wells 4 (see Fig. 2 of US 5,456,315) placed in the upper reaches of
 the reservoir to remove such combustion gases. Disadvantageously, such prior art
 methods as shown in U.S Patent 5,456,315 greatly reduce the ability to provide
 convective heat transfer from the hot combustion gases to the oil, and further
 disadvantageously such prior art methods remove produced hydrogen needed for
 30 hydrocracking, as well as CO₂ solvent which further serves to advantageously reduce the
 viscosity of the oil. Such prior art processes, by relying mainly on conductive heat
 transfer, are less energy efficient and have lower oil rates than the present process. In the
 present process, a fluid drainage zone 15 is established and the hot upgraded oil 3, (as

² THAI™ is a registered trademark of Archon Technologies Ltd, of Calgary, Alberta, for the services of
 licensing of a particular patented method/technology for enhanced oil recovery from petroleum formations.

5 well as water/steam (not shown) and combustion gases 5 flow downward and into the horizontal well 8 for conveyance together to the surface 30. As the process proceeds, the outer part of the coke layer 4 nearest the injected oxygen-containing gas 22 burns away and fresh coke is laid down where the hot combustion gas first contacts oil. In this operation, reservoir oil 3 never meets oxygen, so that oxygenated organics are not made
 10 and the produced oil emulsions are easy to break in oil treating facilities at the surface. The oil 3 beyond the fluid drainage zone 15 remains substantially un- heated until the drainage zone 15 and combustion front 50 advances. For reservoirs 20 containing mobile oil, un-heated native oil 3 away from the combustion drainage front 15 mixes with hydrocracked oil 3 in the horizontal well 8 to reduce the overall degree of upgrading.
 15 However, for mobile-oil reservoirs the oil production rate is increased because the entire horizontal wellbore is productive throughout the life of the well. In all reservoirs 20, the zone of injected oxidizing gas remains isolated from the horizontal well by a layer 24 of oil 3, preventing entry of oxidizing gas (e.g. oxygen) into the horizontal well 8. This layer 24 is fed by hot upgraded oil 3 that drains from the laterally expanding combustion
 20 front 50 and flows at the base of the reservoir 20 into the horizontal well 8. As the process of the present invention proceeds, the volume of oil 3 entering the horizontal well 8 from the protective layer 24 increases relative to the volume of oil 3 draining along with combustion gases 5 (cf Figure 1 and Figure 4 as to increased volume of layer 24).

25 **Figure 2** is a cross-sectional view along plane B-B of the oil-bearing reservoir 20 and present method shown in **Figure 1**, with identical components identically itemized to those of **Figure 1**. This figure shows how the protective oil layer over the horizontal well is formed.

30 **Figure 3** is a top-down view of the present process showing the oil-bearing reservoir 20, the burned zone 2, the coke fuel deposit zone 4 and the fluid drainage zone 15. The oxygen-containing gas injector well 6a is located in the upper part of the oil-bearing reservoir 20 and the horizontal segment 8 of the production well pair 9 is at the base of the reservoir 20. The vertical segment 10 of the horizontal/vertical well pair 9 is connected to the horizontal segment 8 at the heel 42 of the production well 9 and

5 connects to the surface oil treating facilities (not shown). While the fluid drainage zone 15 intersects the horizontal well 8 at two points, 17 and 18, nevertheless all produced oil 3 moves inside the horizontal well 8 towards the heel 42 of the horizontal well 8. Surprisingly, the distance between the projection of the injector well 6a and the drainage entry points 17, 18 into the horizontal well 8 remains substantially equal throughout the operation of the process. One would have expected that portion (entry point) 18 of the drainage zone 15 moving towards the heel 42 of the horizontal producer well 8 would advance much faster than that portion (entry point) 17 of drainage zone 15 that moves towards the toe 40, since portion (entry point) 18 is nearer the low pressure heel 42- however that is not the case.

15 Referring to **Figure 1**, the cap rock overburden 1 prevents fluids, including oxidizing gas 22, from escaping the oil-bearing reservoir 20. **Figure 1** also shows the burned zone 2, the coke fuel deposit zone 4, the fluid drainage zone 15, the oxygen-containing gas injector 6a, the horizontal leg 8 of the production well pair 9, and the vertical segment of the horizontal producer 9.

20 As the process of the present invention shown in **Figure 1** proceeds, each of the coke zones 4 and fluid drainage zones 15 move laterally outwardly from the injection well 6a, in two mutually opposite directions, firstly towards the toe 40 and secondly towards the heel 42 of the production well pair 9, as do the fluid entry points 17, 18, and the burned zone 2 expands. (cf **Figure 1**, and **Figure 4**) This process continues until the fluid drainage zones 15 reach the toe 40 and the heel 42, which will occur at approximately the same time if the injector well 6a is placed midpoint along the horizontal well 8 of the production well pair 9. Importantly, the oil bank 24, protecting the horizontal well 8 from exposure to oxygen, thickens with oil 3, as shown in **Figure 4** that drains from the drainage regions 15 into the horizontal well at points 17, 18. Once the toe 40 and heel 42 endpoints are reached by the drainage points 17, 18, the oxidizing gas injection rate must be reduced or halted to prevent over-pressuring the reservoir which would either cause fracturing of the reservoir, or force oxygen entry into the horizontal well 8.

5 Specifically, ingress of oxygen or oxygen-containing gas into the horizontal well 8 or
vertical well 8 is to be prevented because otherwise oil 3 therein will be capable of
burning or exploding thus causing very high temperatures that could damage the
production well pair 9 and cause extensive coke formation that could plug the production
well pair 9. One way of controlling temperature and pressure in horizontal well 8 (and
10 thus also vertical well 10) is to continue the circulation of steam or non-oxidizing gas
through wellbore tubing (not shown, but described above) that was used for pre-heating
the horizontal well 8. Very low steam rates, typically 1-10 m³/d are adequate. A
thermocouple string (not shown) placed alongside the tubing (not shown) in the
horizontal well 8 will alert operators that the steam rate needs to be increased to reduce
15 temperature of horizontal well 8.

Provision of tubing in horizontal well 8, in addition to allowing provision of steam to
pre-heat horizontal well bore 8 and surrounding areas of horizontal well bore 8 and to
initiate fluid communication between reservoir 20 and horizontal well 8, may also
advantageously be used to supply a diluent to oil 3 in horizontal wellbore 8, and in
20 particular a hydrocarbon diluent such as VAPEX, hydrocarbon solvents or naphtha, or
alternatively CO₂, as suggested in co-pending US patent application 20090308606 (US
Pat. Appl. 12/280,832), hereby incorporated herein by reference in its entirety, and
commonly assigned to the assignee of the within invention. Advantageously, injecting
CO₂ into tubing within horizontal well 8 has the advantages of not only acting as a
25 diluent to the oil 3 being collected within the horizontal well 8 and in pool 24
surrounding horizontal well 8, but further serves to slightly pressurize the horizontal well
8 and thereby assist in preventing any ingress of oxidizing gas 22, which if permitted to
enter the horizontal well 8 after drawdown of oil layer 24, could create a potentially
explosive mixture with the oil 3 therein.

30 After the toe 40 and heel 42 of horizontal well 8 are simultaneously reached by the
drainage fronts 17, 18, a new stage of operation begins- the drawdown stage.
Specifically, at this point in time there will no longer be sufficient quantities of high
temperature gases 5 produced to provide natural gas lift of oil 3 to surface 30 because
the entire length of the horizontal well 8 will be covered by layer 24 and sealed with oil

5 3. Therefore, liquid pumping or artificial gas lift is required to recover the large pool of
 hot upgraded oil 3 remaining at the base of the reservoir 20. The oxidizing gas 22
 injection rate into the injector well 6a is then adjusted to maintain an injection pressure
 substantially below reservoir fracture pressure. A maximum oxidizing gas injection
 pressure of less than 70% over the reservoir pressure is preferred, and less than 50% over
 10 reservoir pressure is most preferred during the drawdown stage. The drawdown stage is
 advantageous because compressed gas requirements are low and output of the
 compressor 71 providing compressed air as the oxidizing gas 22 can be substantially re-
 directed to new operations that initially require large volumes of oxidizing gas 22. The
 gas/oil ratio is much lower during the drawdown stage which boosts the overall energy
 15 efficiency of this process. For Athabasca tar sands, the cumulative air oil ratio can be as
 low as 715:1 ($\text{m}^3 \text{ air/m}^3 \text{ Oil}$).

The process is characterized by smooth and consistent operation with oil recovery factors
 up to 80 %, and it minimizes thermal cycling of the producers which leads to frequent
 wellbore failures in steam processes such as steam-assisted gravity drainage (SAGD).

20 In situations where poor reservoir permeability exists, it may be necessary to use a
 plurality of oxidizing gas injector wells 6a, 6b, as shown in Figure 4 and adapt the
 method of the present invention accordingly. Accordingly, in a further refinement of the
 present invention, upon combustion fronts 50 proceeding a specified distance from
 original oxidizing gas injector well 6a, additional oxidizing gas injector wells 6b,
 25 (completed on mutually opposite sides of injector well 6a) may further be, after
 combustion fronts have progressed outwardly past them as shown in Figure 4, each
 provided with oxidizing gas (air) 22 via compressor 71 for injection into the reservoir 20
 to ensure combustion fronts 50 continue to advance outwardly in the direction of toe 40
 and heel 42 of horizontal well and do not fail to advance and/or become extinguished.

30 Additional injector wells 6b, as shown in Figure 4, may be completed on opposite sides
 of initial injector well 6a prior to initial commencement of the process of the present
 invention, or alternatively may be drilled and completed upon the process being initiated
 for a period of time and it becoming apparent that the combustion fronts 50 have

5 advanced to a point where they are too remote from original injector well 6a and require more immediate and proximate supply of oxidizing gas 22 in order for the combustion fronts 50 to progress outwardly along horizontal well 8 and the process thereby continue . The further step of utilizing or completing additional gas injection wells 6b may be repeated, as necessary, each on respective outward sides of earlier-completed injection wells 6b, until such time as points of intersection 17, 18 of drainage zone 15
10 respectively reach toe portion 40 and heel portion 42 of horizontal well 8.

In the most favored embodiment of the present process, multiple oxidizing gas injectors are employed from the outset.

Referring to Figure 5, there are 5-oxidizing gas injectors, 6a-6e, in a bitumen reservoir 20
15 and spaced as indicated in positions as indicated where $x = \text{well length divided by the number of injectors}$. This arrangement assures that the burning fronts, whose direction of movement is indicated by arrows, all join or reach the toe and heel all at the same time. If the injectors are misplaced the process will operate the same way with all the benefits, but the energy efficiency will be somewhat compromised. The oil 3 covering over the horizontal well isolates it from the oxygen. At approximately the time that the combustion fronts reach the toe and heel the drainage points 17a-17e and 18a-18e will merge and the horizontal well will be covered entirely with oil. If the air injection rate is kept high, the reservoir will over-pressure: Therefore, operational control is switched from gas flow control to gas pressure control. Consequently, from then onwards the gas
20 injection rate becomes much diminished while the drained oil spread over the lower section of the reservoir flows into the horizontal producing well. Because of the low gas-oil-ratio during this drawdown stage the oil must be produced by pumping or artificial lift.

As compared with the use of a single oxidizing gas injection well, the use of multiple
30 wells reduces the amount of air that can be safely injected into a single injector, but increases total injectable over all the injectors, which greatly increases the oil production rate.

5

EXAMPLE 1

Table 1 below gives a list of list of Numerical Model Parameters used in this Example.

Numerical simulator: STARS™ 2009.1, Computer Modelling Group Limited

Model dimensions:

Length: 540 meters, 216 grid blocks at 2.5 meters each

10 Width: 50 m, 20 grid blocks of 2.5 meters each with an element of symmetry, giving a wellbore spacing of 100 m

Height: 20m, 20 grid blocks of 1-meter each

Horizontal production well

15 A discrete horizontal wellbore of 500 m extended from grid blocks 9 to 208, leaving a 20-meter buffer zone on either end of the horizontal well. The inner diameter of the horizontal leg was 9 5/8 inches. A steam rate in the horizontal well tubing of 10 m³/d (water equivalent) was maintained throughout all the tests, although this procedure is optional.

Steam and oxidizing gas injector(s)

20

A number of models were run having from 1- 5-vertical injectors placed over the horizontal producer and perforated in grid blocks 6-9 for steam pre-heating (for 3-months) and at the top 4-grid blocks for air injection. Air rates per injector started at 10,000 m³/d and increased to a maximum of 100,000 m³/d.

25

5 **Table 1. Reservoir properties, oil properties and well control.**

Reservoir Properties		
		Reservoir
	Units	Rock
Pay thickness	m	20
Porosity	%	33
Oil saturation	%	80
Water saturation	%	20
Gas mole fraction	%	0
H. permeability	mD	6700
V. permeability	mD	5360
Reservoir temperature	°C	12
Reservoir pressure	kPa	2600 20
Rock compressibility	/Kpa	3.5E-5
Conductivity	J/m.d.C	1.5E+5
Heat capacity	J/m ³ .c	2.35E+6
Oil Properties (Athabasca bitumen)		25
Density	Kg/m ³	995.7
Viscosity	cP	200,000
Molecular weight	AMU	508
Mole fraction		0.886
Heat capacity		50
Combustion enthalpy	J/gmole	6.29E+7
The wells were controlled using the following parameters:		
Air injection pressure max.	kPa	6075
Producer BHP Minimum	kPa	2600
Air rate max. per injector	m ³ /d	20k-100k

Test Runs

40

Seven numerical simulation runs were conducted: The results are provided in Table 2. Run 1 was for the THAI process of US Patent'191 and is for comparative purposes only. Runs 2-7 are with oxidizing gas injectors placed over the horizontal producer well along its length so that the distance between the midpoints between adjacent injectors or the

45 ends of the producer are equal. The grid block numbers for the air injector locations were as follows:

- 5 Run 1- 9
 Run 2 -109
 Run 3- 59, 158
 Run 4 -42,109, 175
 Run 5 -29, 69, 109, 149, 188
 10 Run 6- 29, 69, 109, 149, 188

It was found that the oil drainage over the horizontal well 8 from each injector well was complete at the same time with this configuration. However, such a configuration of injectors is not imperative. The combustion also worked well with highly asymmetric injector orientations. Compared with the well configuration of US Patent '191 (the "THA™" process), where a single injector is placed near the toe of the horizontal producer and has a single drainage front, Runs 2-7 had two drainage fronts for each air injector.

20 Runs 1-6 all had the same total maximum air injection rate, 100,000 m³/day, so that the efficiency of each Run could be compared with the same air compressor capacity. For the Runs with multiple air injectors, the total air was divided evenly between the injectors. For example, Run 2 the single injector 6a received all of the available air, 100,000 m³/d, while Run 6, with 5-injectors, received only 20,000 m³/d of air per injector. In order to

25 quantify the benefit of increasing total air compressor capacity, in Run 7 it was increased from 100,000 to 300,000 m³/d total, providing 60,000 m³/d of air in each of the 5-injectors. The air rate per injector well was ramped-up with the following monthly schedule until the targeted maximum air rate was achieved: 10,000 m³/d; 20,000; 33,333; 50,000; 70,000 and 100,000. After all of the desired maximum air rate was the reached

30 this rate was continued until the burning front simultaneously reached the toe and heel of the horizontal producer. At that point, the exit points for the combustion gas into the horizontal well became sealed by the oil layer covering the horizontal well and it was necessary to control the air rate by injection pressure, otherwise, fracture pressure would have been exceeded. An injection pressure of 4000 kPa was selected, and this was

35 sufficient to fill the voidage from producing oil. The air requirements after the front reached the toe and heel of the producer were greatly reduced from the targeted maximum and so the air/oil ratio became reduced.

5

'Peak oil rate' refers to the highest oil rate achieved in a Run. For Runs with 1 or 2-air injectors.

Table 2. Numerical simulation results

Run number	1	2	3	4	5	6	7
# Air Injectors	1* THAI	1	2	3	4	5	5
Max. Air per injector, m ³ /day.well	100k	100k	50k	33.3k	25k	20k	60k
Max. Total Air injected, m ³ /day	100	100	100	100	100	100	300
Oil rate after first year, m ³ /d	28	47	57	68	81	90	156
Peak oil rate, m ³ /d	183	141	141	134	130	121	176
Days to 60% Oil Recovery Factor	2948	2067	2045	2019	1992	1990	1923
Recovery factor at 30m ³ /d oil rate, %	72	77	78	77	77	78	78
Minimum Cumulative Air/Oil ratio	1291	1023	1021	923	819	764	924

10 * Results for the THAI process- not part of the present invention.

Comparing Runs 1 and 2, there were two major benefits. Firstly, Run 2 gave a much higher oil rate after the first year of operation: 47 m³/d versus 28 m³/d for THAI, for the same injector capital cost and the same rate of air compression cost. This is very important to the economics of oil production and was achieved by simply moving the air injector to a different location relative to THAI. Secondly, the air/oil ratio was substantially lower in Run 2, 1023 instead of 1291. A major operating cost of combustion processes is the air compression energy cost and this was accordingly lower by 20% [i.e. (1291-1023)/1291] using a single central injector compared with THAI. Additionally to the benefits of high early oil rates and low energy cost, the use of a central injector provided a higher oil recovery factor (percent of original- oil- in -place that is recovered).

The use of multiple air injectors placed over the producer horizontal well is represented in Runs 3-6. As the number if injectors are increased, further benefits of high early oil production rates are achieved, reaching 90 m³/d with 5-injectors. Also the energy

- 5 efficiency of the process is substantially improved with multiple injectors, reaching 764 m³ air/m³ oil for a 25% improvement compared with a single central air injector.

Comparing Run 6 and Run 7, both Runs have 5-injector wells and the only difference is in the air injection rates. By increasing the air rate from 20,000 m³/d-well to 60,000 m³/d-well, a large benefit in early oil rate and peak oil rate is achieved, although at a slight reduction in energy efficiency. Comparing Run 7 with Run 1 (prior art), employing 5-air injectors and 3-times the peak air rate increased the first-year oil rate 5.57-fold.

- 15 Those skilled in the art will be able to select the optimum combination of air rate and the optimum number of air injectors for a specific reservoir and business environment, factoring in parameters such as electricity rates (for air compression) and vertical well drilling costs. It should be noted that a so-called "SMART" well horizontal could be drilled from the same drilling pad as the horizontal well in the present process for air injection at various points in the upper portion of the reservoir. In SMART wells there are individual perforated sections and each is isolated with packers and has its own separate tubing string from the surface that enables specific air volumes to be delivered to each perforated section. A SMART well could be advantageous for instances where there is a lake or other impediment on the land surface over the reservoir that would impede drilling vertical air injector wells.

- While a number of particular embodiments of the present invention have been described above, it is to be understood that other embodiments are possible within the scope of the invention and are intended to be included herein. It will now be clear to any person skilled in the art that various modifications to this invention, not shown, are possible without departing from the scope of the invention as exemplified by the examples herein. For a complete definition of the scope of the invention, reference is to be had to the appended claims.

WHAT IS CLAIMED IS:

1. An improved in-situ combustion process for reducing the viscosity of oil contained in an oil-containing reservoir and recovering said oil from the reservoir, which process does not employ one or more separate gas venting wells, comprising:

(a) providing at least one production well having a substantially vertical portion extending downwardly into said reservoir and having a horizontal leg portion in fluid communication with said vertical portion, having an internal diameter of greater than 3-inches and extending horizontally outwardly therefrom, said horizontal leg portion completed relatively low in the reservoir;

(b) providing at least one vertical injection well positioned above and in spaced relation to said horizontal leg portion and substantially directly above said horizontal leg portion and approximately in a midsection thereof, for injecting an oxidizing gas into said reservoir to form an advancing, laterally extending combustion front on each side of said at least one injection well;

(c) injecting an oxidizing gas through said at least one injection well and initiating combustion of hydrocarbons in said reservoir proximate said injection well so as to establish a pair of combustion fronts advancing laterally in a direction along said horizontal leg portion and outwardly from said injection well in opposite directions along said horizontal leg portion, said combustion front causing oil in said reservoir to become reduced in viscosity and to drain downwardly into said horizontal leg portion;

(d) allowing high temperature combustion gases along with said oil of reduced viscosity to be collected in said horizontal leg; and

(e) producing such high temperature gases and oil to surface; and

(f) separating at the heel of said horizontal well or at the surface said oil from said high temperature gases.

2. The process of claim 1, wherein said oxidizing gas is injected into said injection well at less than fracturing pressure.

3. The process of claim 1 or 2, wherein more than one vertical injection well is placed above and along a length of the horizontal well.
4. The process of claim 1 wherein a plurality of vertical injection wells are placed above and along a length of the horizontal well, and a combustion front is initiated at each injector well which progresses outwardly from each injection well in opposite directions, each along a line of said horizontal well.
5. The process of claim 1, wherein said hot combustion gases are subsequently used to heat water.
6. The process of claim 5, wherein said heated water is subsequently used to produce steam for use in producing electrical power using turbines.
7. The process of claim 1, wherein said high temperature combustion gases are used or further burned to produce electricity using gas turbines or steam turbines.
8. The process of claims 1-7 wherein a tubing is emplaced within the horizontal well reaching to a toe of said horizontal well, and a medium selected from the group of mediums comprising water, steam, non-oxidizing gas including CO₂, hydrocarbon diluent, and mixtures thereof, is injected therein.
9. The process of claim 1 wherein the inner diameter of the horizontal leg of the producer well is greater than 5-inches.
10. The process of claim 9 wherein the inner diameter of the horizontal leg of the producer well is greater than 7-inches.
11. The process of claims 1 -10 wherein the oxidizing gas contains oxygen and CO₂.
12. The process of claims 1-11 wherein the oxidizing gas injection pressure is limited to a maximum of less than 50% over the reservoir pressure by adjusting the oxidizing gas injection rate.

13. An improved in-situ combustion process which process does not employ one or more separate gas venting wells, comprising:

(a) providing at least one production well having a substantially vertical portion extending downwardly into said reservoir and having a horizontal leg portion in fluid communication with said vertical portion and extending horizontally outwardly therefrom, said horizontal leg portion completed relatively low in the reservoir;

(b) providing a plurality of oxidizing gas vertical injection wells positioned directly above said horizontal leg portion and in substantial alignment therewith;

(c) injecting an oxidizing gas into said reservoir via each of said vertical wells located approximately midpoint along said horizontal wellbore;

(d) initiating in situ combustion in said reservoir proximate each one of said vertical injection wells so as to form a pair of vertically-extending combustion fronts advancing laterally in opposite directions along said horizontal leg portion and outwardly from each of said vertical injection wells, said combustion front causing oil in said formation to become reduced in viscosity and to drain downwardly into said horizontal leg portion;

(e) collecting high temperature combustion gases along with said oil of reduced viscosity in said horizontal leg; and

(f) producing such high temperature gases and oil to surface; and

(g) separating at the heel of said horizontal well or at the surface said oil from said high temperature gases.

14. The method of claim 13, whereby upon said substantially vertical pair of combustion fronts advancing respectively and laterally along said horizontal well bore past a further one of said plurality of injection wells, oxidizing gas is injected into said reservoir at said further one of said injection wells.

15. The process of claim 13 wherein the inner diameter of the horizontal leg of the producer well is greater than 5-inches.

16. The process of claim 13, wherein the inner diameter of the horizontal leg of the producer well is greater than 7-inches.

17. An improved in-situ combustion process which process does not employ one or more separate gas venting wells, comprising:

(a) providing at least one production well having a substantially vertical portion extending downwardly into said reservoir and having a horizontal leg portion in fluid communication with said vertical portion and extending horizontally outwardly therefrom, said horizontal leg portion completed relatively low in the reservoir;

(b) providing a plurality of oxidizing gas vertical injection wells positioned directly above said horizontal leg portion and in substantial alignment therewith, said one of said vertical injection wells situated approximately at a midpoint along said horizontal well bore;

(c) injecting an oxidizing gas into said reservoir via said one of said vertical wells located approximately midpoint along said horizontal wellbore;

(d) initiating in situ combustion in said reservoir proximate said one of said vertical injection wells so as to form a pair of vertically-extending combustion fronts advancing laterally in opposite directions along said horizontal leg portion and outwardly from said one vertical injection, said combustion front causing oil in said formation to become reduced in viscosity and to drain downwardly into said horizontal leg portion;

(e) collecting high temperature combustion gases along with said oil of reduced viscosity in said horizontal leg; and

(f) thereafter producing such high temperature gases and oil to surface; and

(g) separating at surface said oil from said high temperature gases.

18. The method of claim 17, whereby upon said pair of substantially vertical combustion fronts advancing laterally along said horizontal well bore past a further one

of said plurality of injection wells, oxidizing gas is injected into said reservoir at said further one of said injection wells.

19. The process of claim 17 wherein the inner diameter of the horizontal leg of the producer well is greater than 5-inches.

20. The process of claim 19 wherein the inner diameter of the horizontal leg of the producer well is greater than 7-inches.

Figure

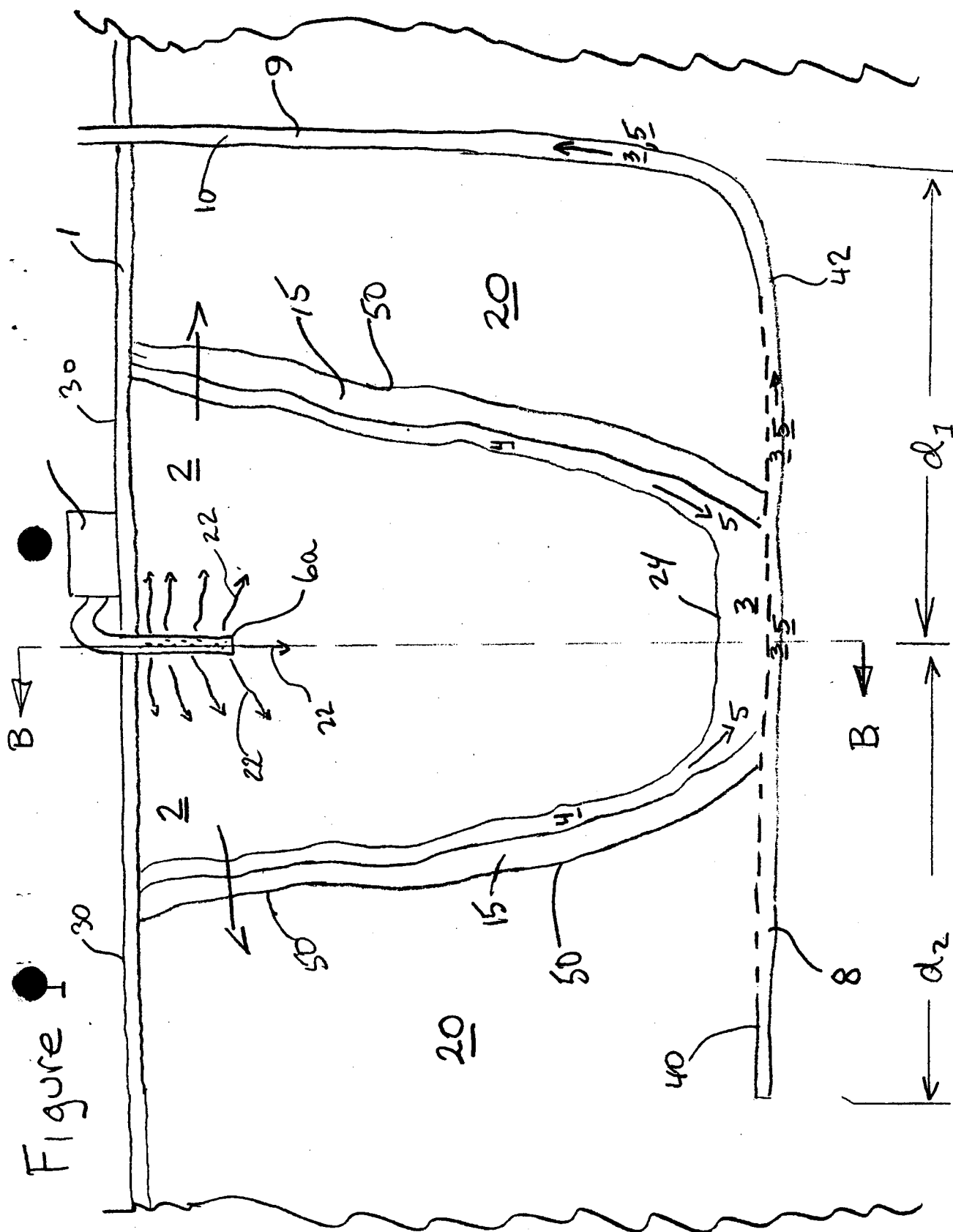


FIGURE 2

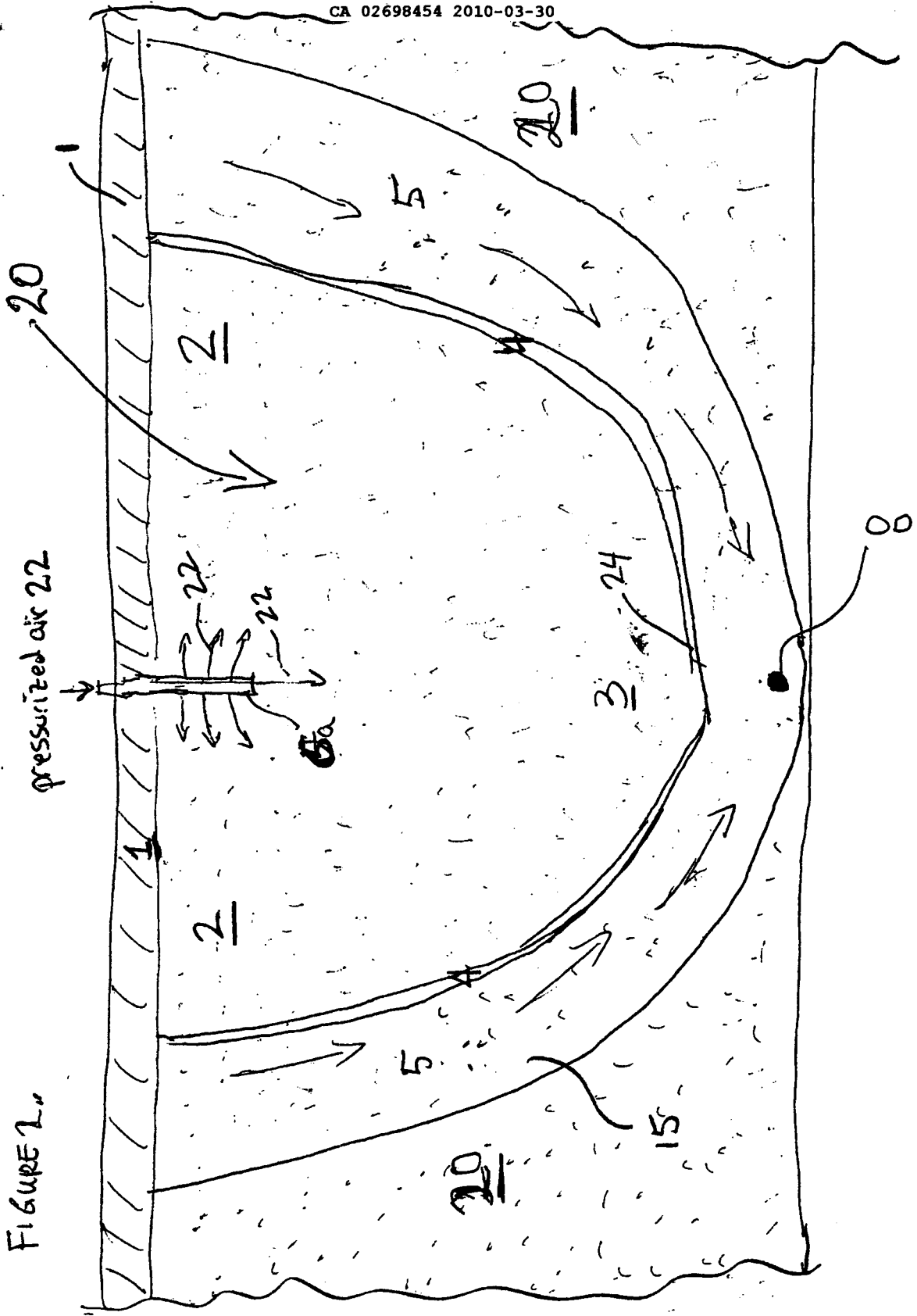


FIGURE 3

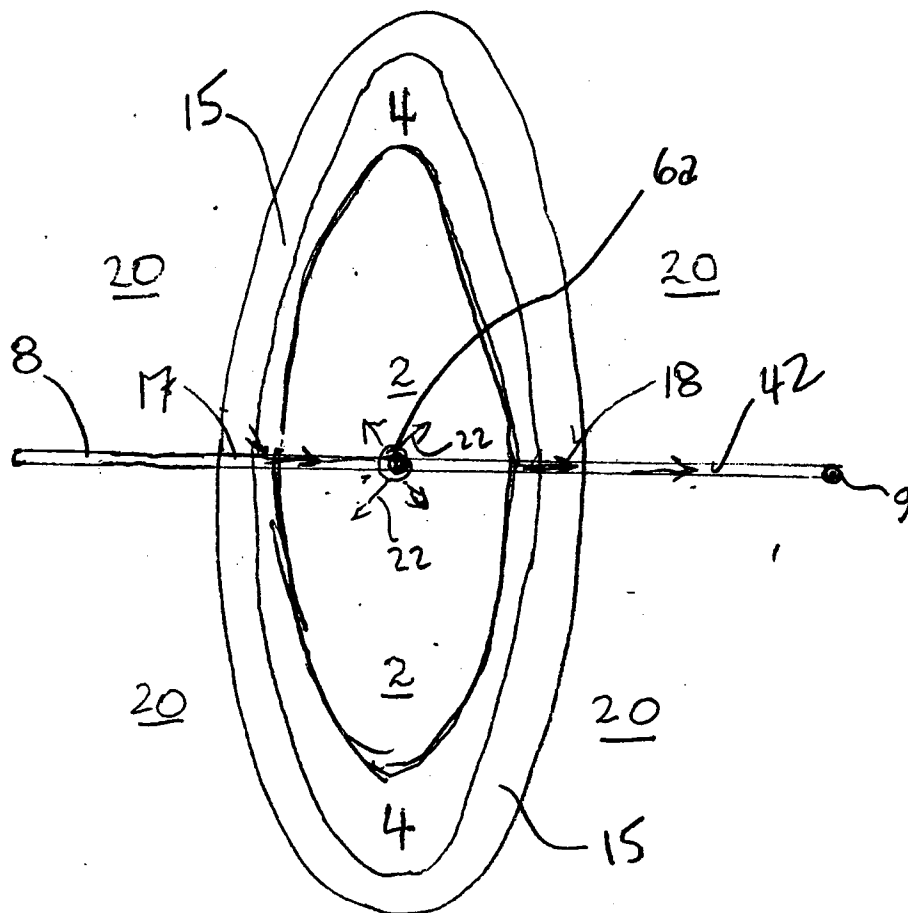


Figure 4

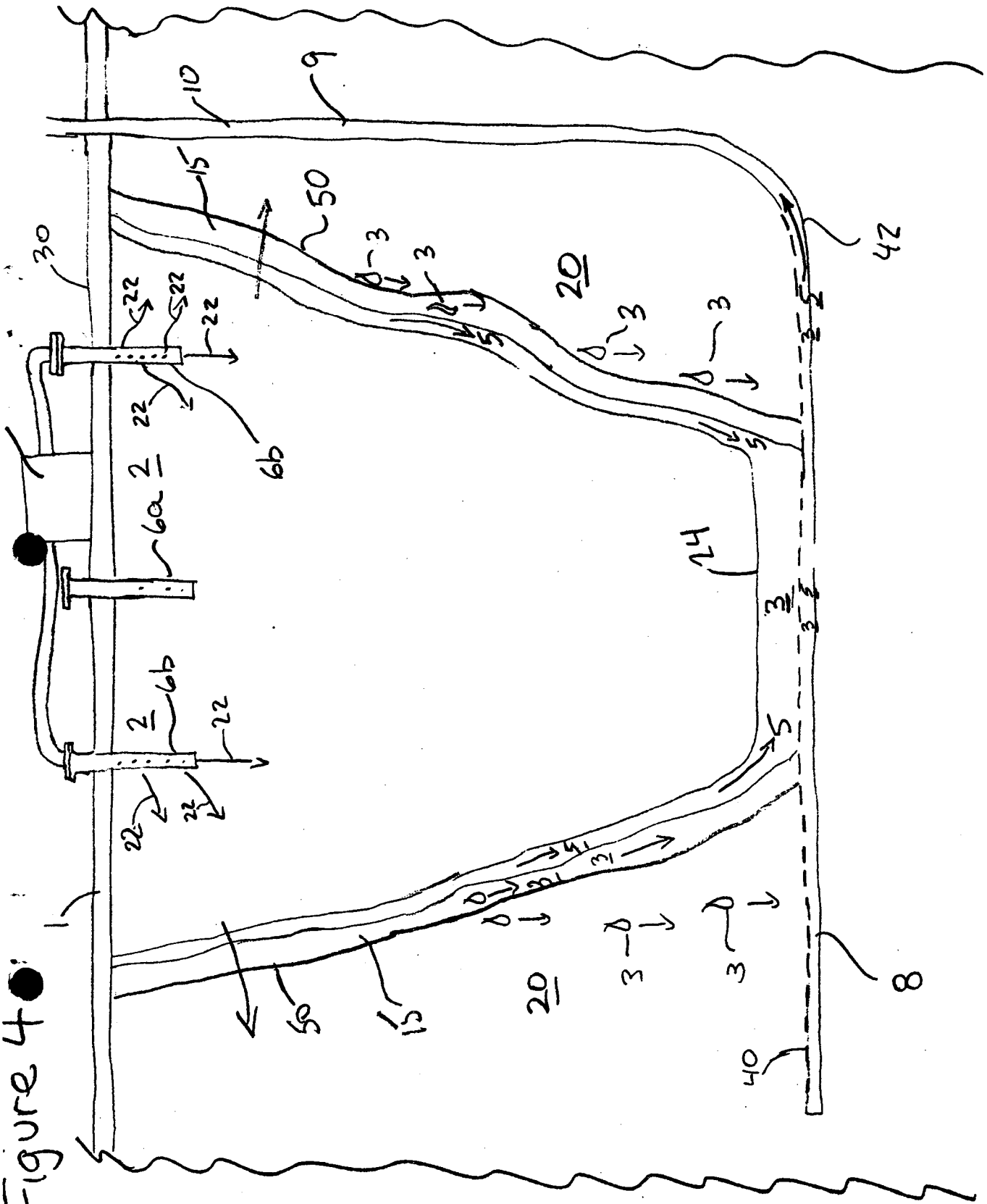


FIGURE 5.

