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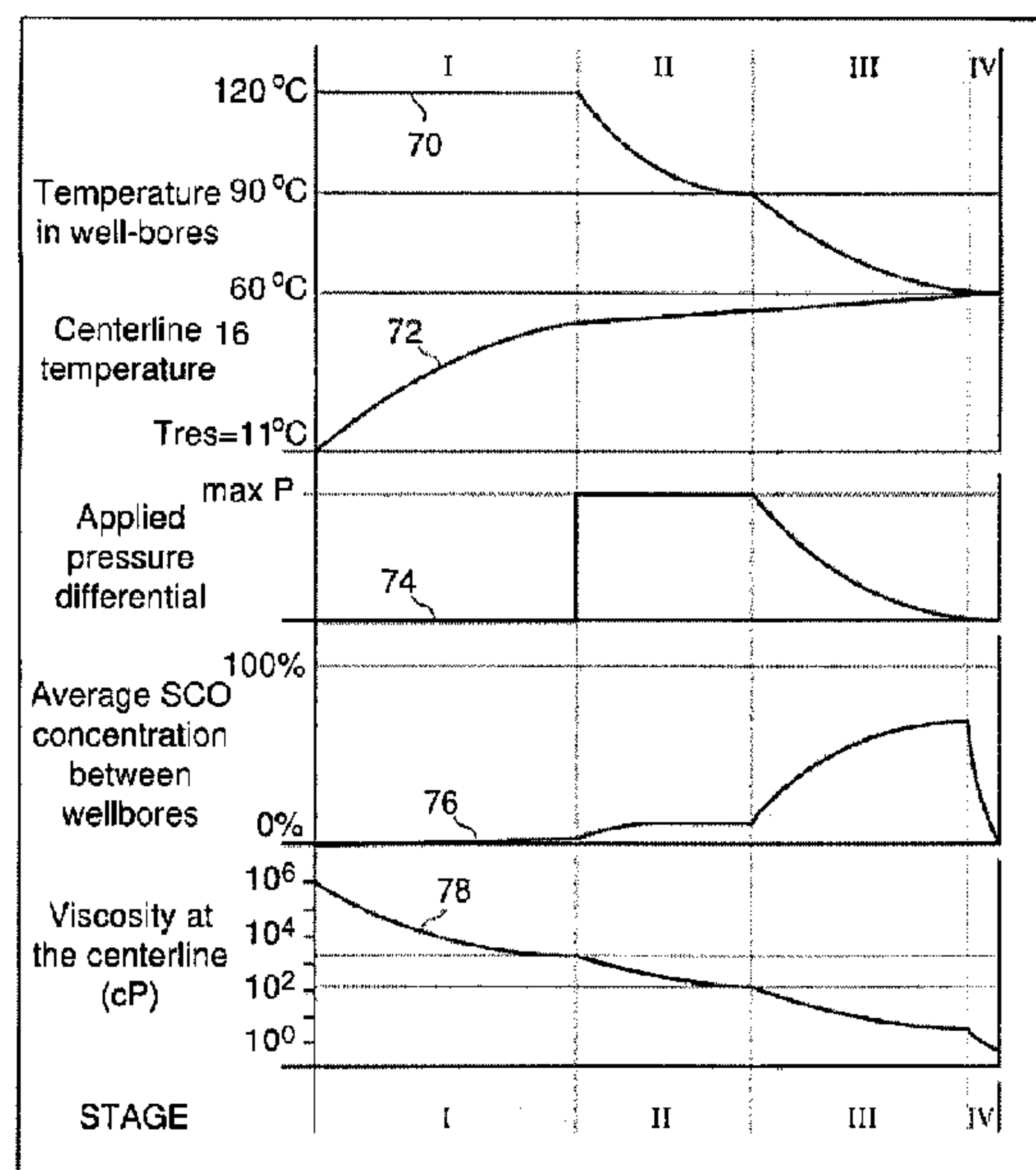
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(54) Titre : PROCEDE ET APPAREIL POUR ETABLIR UNE COMMUNICATION FLUIDE ENTRE DES Puits
HORIZONTAUX

(54) Title: METHOD AND APPARATUS FOR ESTABLISHING FLUID COMMUNICATION BETWEEN HORIZONTAL
WELLS



(57) Abrégé/Abstract:

A method of starting up a well pair for EOR by establishing fluid communication between the wells is disclosed. The method includes the steps of providing a fluid based heat delivery system in each well of said well pair, and circulating a heated non-deasphalting start-up fluid in each well at a first temperature. Then, applying a pressure differential between the wells to encourage start-up fluid displacement across an inter well bore region, and controlling a viscosity of the start-up fluid through one or both of temperature and concentration control, to encourage hydraulically sweeping the inter well bore region, and transitioning from displacing the start-up fluid to a working fluid extraction process.

ABSTRACT OF THE DISCLOSURE

A method of starting up a well pair for EOR by establishing fluid communication between the wells is disclosed. The method includes the steps of providing a fluid based heat delivery system in each well of said well pair, and circulating a heated non-deasphalting start-up fluid in each well at a first temperature. Then, applying a pressure differential between the wells to encourage start-up fluid displacement across an inter well bore region, and controlling a viscosity of the start-up fluid through one or both of temperature and concentration control, to encourage hydraulically sweeping the inter well bore region, and transitioning from displacing the start-up fluid to a working fluid extraction process.

Title: Method and Apparatus for Establishing Fluid Communication Between Horizontal Wells

FIELD OF THE INVENTION

5 This invention relates the field of hydrocarbon recovery or the extraction of oil and the like from underground reservoirs. In particular this invention relates to methods and apparatuses related to in situ extraction of such hydrocarbons and most particularly to processes that use a generally horizontal well pair that includes an injection well and a production well and requires fluid communication between the
10 wells.

BACKGROUND OF THE INVENTION

 The efficient extraction of heavy hydrocarbons from underground reservoirs is challenging. Reservoir conditions are highly variable and pose many unique
15 challenges for extraction due to unique characteristics of the reservoir. Presently, although new discoveries of conventional oil are still being made, there is an increasing need to produce heavy hydrocarbons. The production of heavy hydrocarbons can involve considerable technical challenges that have to be overcome for these resources to be economically, sustainably, and safely recovered.

20 A prime example of an abundant but technically difficult resource is found in the oil sands, for example, in Alberta, Canada. Surface mining is extensively used, but can only economically reach a small fraction of the total known resource.

 Consequently, efforts have been made to develop in-situ technologies to recover the other hydrocarbons within the oilsands. These technologies seek to recover
25 the hydrocarbons from the surface without significant disturbance of the surface soil and the arboreal forest as is required with the surface mining approach. Current in-situ technologies being used commercially or are in development can be classed as thermal, thermal-solvent and solvent only processes, with this classification based on the media or energy source used to mobilize the heavy, or pay hydrocarbons.

Some in-situ technologies use a pair of generally horizontal wells, one generally above the other, which are sometimes referred to as a well pair. The upper well is the injection well used for injecting a working fluid such as water steam and/or solvent vapour, and the lower well is the production well used for pay zone hydrocarbon and working fluid recovery. Recovery processes employing horizontal wells in such a vertically paired configuration may rely on gravity drainage, with the mobilized liquids draining down into the production well from an extraction chamber which is formed around and above the injection well by means of continuous working fluid injection.

10 The start-up phase may be considered to be that part of the extraction process operation after the wells have been drilled and completed, but before an extraction chamber has been developed. In paired horizontal wells of the type used for gravity drainage, the wells are typically drilled in proximity to a bottom of a pay zone containing hydrocarbons. If the bitumen is immobile at initial reservoir conditions, then fluid communication needs to be established between the wells to permit the drainage to occur from the formation to the production well. Fluid communication, in this sense, means that fluids can travel under the influence of gravity, for example, between the upper well and the lower well so that, for example, gases injected through the upper injector well can condense and these condensed liquids can flow down to be removed through the producer well underneath. If the region between the two wells is filled with immobile hydrocarbons drainage is blocked thus limiting production of mobile hydrocarbons to the surface. In essence then, fluid communication involves removing the immobile, or near immobile hydrocarbons from between the well pair in a manner that permits fluids to easily drain down to the production well. If the liquid drainage is obstructed, then the extraction chamber will just fill up with liquid and the ability to deliver working fluid and/or heat to the reservoir is impaired.

In the SAGD process, steam is typically circulated in the well bores to preheat the surrounding reservoir. By means of such heat the hydrocarbons are rendered somewhat mobile and can be removed from between the well pair. This approach has

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some disadvantages for solvent based processes because it introduces a lot of water into the formation and water can be an effective barrier to solvents, and thus impair the contact between solvent and the bitumen. Further, this would require both solvent and steam processing surface facilities which duplicates capital costs.

5 Canadian Patent Applications 2,691,889 and 2,730,680 relate to solvent extraction processes in which a solvent gas is circulated in both the production well and the injection well to warm the near well bore area. However, these patent applications teach the use of a solvent gas at a temperature above its critical temperature. The problem with using gas to establish communication between the
10 well pair is its relatively low sensible heat content; consequently, the start-up process will take a long time to mobilize the pay hydrocarbons between the well pair and require high gas flow rates and pressure drops to establish the desired temperature rise between the two wells even though a high temperature is being used. High pressures can lead to solvent leak off and loss. Further, as taught in these applications, the high
15 heat creates a de-asphalting effect that can lead to deposits. Such deposits, if located between the upper and the lower well can cause a reduction in the formation permeability between the wells, leading to plugging or poor drainage. Lastly, a high heat, high pressure process will likely lead to spot breakthroughs between the well pair or short circuiting, which will establish some, but only very limited, localized
20 hydraulic drainage between the wells. What is desired is a start-up process that will generally mobilize and remove substantially all of the pay hydrocarbon from the entire length of the zone between the well bores thereby permitting the formation to be freely draining for the working fluids without leaving damaging asphaltene deposits behind in the reservoir region used for well drainage. An improved start-up procedure is
25 required.

SUMMARY OF THE INVENTION

What is desired therefore is a start-up method to establish fluid communication by forming a drainage zone between a pair of horizontal wells that are to be used in

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gravity drainage thermal, thermal-solvent, and solvent based extraction processes. Thus, for any process which can create mobile fluids within the formation good drainage rates will lead to good production rates. The preferred start-up method should mobilize and remove the pay hydrocarbon in the inter well bore zone without
5 introducing excess water into the formation or causing other formation damage such as the deposition of asphaltenes. The start-up method should be reasonably quick and reliable to establish good communication along the length of the well pair with a minimum of blocked or impervious regions. The total time for the start-up process should be minimized, be simple and robust, and at the completion of the start-up
10 process, the in situ conditions should be compatible with the desired subsequent working fluid injection conditions. In particular, for example for a heated solvent process, the temperature of the formation between the well bores should be compatible with the operating temperature for the follow on condensing solvent process, for a smooth hand off between start-up and extraction.

15 According to the present invention these and other objectives can be met by using a multi-step start-up procedure. A first step is to deliver heat into each of the well bores. This can be readily achieved by circulating start-up liquid such as a hot hydrocarbon fluid into the toe of the well and back along the annulus or vice versa into the heel and back down the annulus or by energizing a heating element placed in the
20 well bore or by some combination of both. Heat supplied to each of the well bores will be conducted outward from the well bore and will eventually raise the temperature of the region between the well bores. The start-up procedure involves optionally preheating the near well bore area for example, using a resistance electrical heating device inserted into each of the well bores. Next, a positive pressure differential can
25 be applied between the injection and production wells to displace the start-up liquid into the pay hydrocarbon, to encourage further mixing, warming, and displacement into the one of the production and injection wells where it can be subsequently removed by the recirculating start-up liquid. The temperature may be reduced or increased during this stage and recirculation from both wells is carried on until the pay

hydrocarbon starts to become reasonably mobile, as evidenced by the amount of pay hydrocarbon content produced to the surface in conjunction with the re-circulating liquids. At an appropriate time, the production well is put into production, with artificial lift if required, and the recirculation rate in the injection well is gradually
5 reduced in favour of a displacement between the upper injection well to the lower production well. This displacement is carried on until the mobilized pay hydrocarbon is largely removed from between the wells and clear communication is established by the start-up liquid. Communication completeness is determined by the amount of pay hydrocarbon in the recirculation fluid at the production well. The mobilization and
10 removal of the inter-well bore pay hydrocarbon is accomplished whilst substantially avoiding the creation of potentially harmful asphaltene deposits in the near well bore region since it is a displacement rather than a solvent mobilization. More specifically, this goal is achieved by avoiding the use of known deasphalting solvents such as propane, butane, pentane and others that cause asphaltene precipitation until after the
15 start-up phase is completed. During a following condensing solvent process for example, where de-asphalting may occur, such de-asphalting will occur at the extraction chamber perimeter, will be widely disbursed and will not adversely affect fluid drainage properties to the production well.

According to one aspect, the present invention provides an apparatus for
20 applying a start-up method to an inter well bore region between two vertically displaced horizontal wells, said apparatus comprising:

- a source of non deasphalting start-up fluid above grade;
- a heater for heating said start-up fluid;
- a well head connection from said source to each of said two vertically displaced
25 horizontal wells;

- a fluid delivery and removal system connected to said well head to permit said start-up fluid to be circulated along each of said two vertically displaced horizontal wells;

- one or more circulating pumps for circulating said start-up fluid from said

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source through said heater down into said formation along each of said vertically displaced horizontal wells and then back up to the surface;

a conditioner located above grade to remove solids and water if necessary from said returned start-up fluid, and

5 sensors to measure one or more of a temperature, a viscosity, and a composition of said start-up fluid which is returned to the surface.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference will now be made, by way of example only, to preferred
10 embodiments of the invention in which:

Figure 1 is an illustration of a horizontal well pair located within a pay zone of an underground formation;

Figure 2 is a graph showing the change in viscosity of sample pay hydrocarbon such as bitumen for different temperatures and blends with a liquid hydrocarbon such
15 as synthetic crude oil (SCO);

Figure 3 is a schematic showing the different stages of a start-up procedure according to the present invention;

Figure 4a is a diagram indicating the well bore and midline temperatures over time for a typical well pair for a given initial electrical resistance pre-heating period;

20 Figure 4b is a diagram indicating the well bore and midline temperatures over time for a typical well pair for a given initial start-up liquid temperature and flow rate;

Figure 5 is a graph illustrating the temperature at the well bore midline and the amount of heat energy absorbed by the reservoir over a treatment period for a treatment according to the present invention;

25 Figure 6 is a chart illustrating the effect of well spacing of the well pair on the timing of the start-up phase according to the present invention;

Figure 7 is a schematic view of the bitumen phase on one side and the temperature profile on the other side of at four different times during the start-up procedure according to the present invention;

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Figure 8 shows the effect of spacing between the well pair on the drainage time according to the present invention; and

Figure 9 shows the effect of changing the pressure differential on the drainage time according to the present invention.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is a schematic view of a generally horizontal well pair with an upper well 10 and a lower well 12 that are separated by a well spacing 14. Midway between the wells 10 and 12 is a mid or centerline 16. The wells 10, 12 are located within an underground formation 18 which includes a pay hydrocarbon zone 20, with an overburden 19 and an underburden 21. The well pair 10, 12 are positioned towards the bottom of the pay hydrocarbon zone 20 in accordance with a conventional positioning of the well pair for gravity drainage. The preferred type of pay zone is a heavy hydrocarbon pay zone such as may be found in the oilsands of Alberta, Canada.

15 Although the wells are shown with slanted risers 22, 24, and horizontal casings 26, 28, it will be appreciated by those skilled in the art that these are illustrations only and that in practice the angle of the wells might vary considerably from this. Thus, in this specification, the terms generally horizontal and generally vertical are used to comprehend the field variations that might be encountered from horizontal and
20 vertical. Further, in this specification, the term near well bore area means an area surrounding a well bore in cross section. As well, the term inter well bore area means the space between the well pair.

The present invention comprehends providing the well bores with a pre heating phase which may be electrical resistance heating and or a fluid delivery system to
25 provide a heated start-up liquid to the wells in accordance with a preferred method as described below. In one form of the invention, the resistance heating system includes long electrical resistance well bore heaters 27, 29 that extend along the length of each of the wells having electric power lines 31, 33 which extend to the surface and are connected to a power source. While this is one form of pre-heating device it will be

understood that the present invention comprehends other forms of in situ or downhole heater as well. What is desired is some form of downhole heat that can be used after the wells are completed, but before the surface facilities are ready to circulate the start-up fluid.

5 In Figure 1, the fluid delivery system includes narrow diameter tubes 30, 32, for example 3½-inch coil tubing, which is fed down the riser portion of the well and then fed out towards the toe 34, 36 of each well 10, 12. A second narrow diameter tube 38, 40, such as the 3½ inch coil tubing, is also fed down the riser portion of each well, but preferably extends only to about a heel 39, 42 of each well 10, 12. Each of
10 the narrow diameter tubes 30, 32, 38 and 40 are connected to appropriate above-grade pumps and heaters to allow a circulation of liquid down to the toe, back along the casing and then up through the tubes 38, 40 to the surface again in each well 10, 12 as shown by arrows 44. Although this is shown as extending from the toe and the heel, the present invention comprehends ending the narrow diameter tubes intermediate the
15 ends depending upon the circumstances.

 In the most preferred embodiment of the invention, the start-up liquid is a liquid hydrocarbon that is heated above-grade in an appropriate heat exchanger (not shown) before being circulated through the wells 10, 12, by, for example, a pump. Accordingly, the present invention provides a liquid circulation system for start-up,
20 which permits the start-up liquid to be heated above and / or below grade, pumped down the tubes 34, 36 of each well and out to the toe, where it is released into an annulus formed between the narrow diameter tubing and the well casing. Then the fluid is drawn back along the casing towards the heel, where it enters the second tubes 38, 40, and from there it is brought or pumped up to the surface. The present invention
25 comprehends that the circulation direction could be reversed. At the surface the start-up liquid can be conditioned to remove solids and water if necessary, reheated and then re-circulated back into the wells as described above. Placing the start-up fluid well inflow end at the toe or the heel establishes a countercurrent heat exchange, between the tubing and the annulus. While countercurrent heat exchange is not optimal

and initially produces large thermal gradients along the well bore, calculations show that for the preferred embodiment of the invention, within a week, the counter-current temperature gradient flattens out and the well bore is effectively isothermal, permitting most of the heat in the start-up liquid to be delivered to the formation in the near well
5 bore area through conduction.

The preferred method of the present invention is a multiple step process, as described in more detail below. In an optional first step or phase, which may or may not be appropriate in all circumstances a downhole heat source, such a downhole heater, for example, an electrical resistance heating device can be placed in each of the
10 well bores. Heat from the downhole heater is delivered to the well bore and in the case of a resistance electrical heater is transferred into the reservoir formation by conduction. Electrical power is supplied to the resistance heating device located above grade through an appropriate connection to an electrical power supply. This is considered a pre-heating step or phase and is continued until a desired amount of heat
15 is delivered to the reservoir. Such a preheating step may reduce the time required to transfer heat through start-up fluid circulation alone.

As for the start-up fluid, assuming that no down hole heater has been used, in the next step the start-up liquid is heated above grade, and then simply circulated within each well for enough time to further increase the reservoir temperature in the
20 region surrounding the well bores or the near well bore area. As the start-up liquid's heat is transferred to the formation through conduction, the temperature will gradually rise in the near well bore region in a circular or radial pattern around each well bore. The heat and volume lost from the circulating start-up liquid is made up by a combination of reheating and the addition of fresh, hot start-up liquid at the surface.
25 It will be appreciated that the preferred start-up liquid is one that is compatible with the surface facilities for the extraction process. Thus, in the case of a process that uses a working fluid of a condensing solvent, the preferred start-up liquid is a form of liquid hydrocarbon. Many different start-up liquids are comprehended by the present invention, provided they meet with certain initial criteria. Most preferably, the start-

up liquid is hydrocarbon-based so as to avoid using or introducing water into the formation. Fluids such as SCO, diesel fuel and other refined or upgraded products are suitable. What is most preferred is a liquid that does not cause de-asphalting, will remain a liquid in the temperature and pressure ranges used in the start-up process of the present invention, and which is generally available in the local area. Liquids are preferred over gases due to their greater effectiveness in delivering heat to the reservoir and their greater ability to sweep out or displace in situ hydrocarbons located between the well pair.

Of course, the rate of heating will depend on a number of factors, including the rate of flow and initial temperature of the start-up liquid and the initial temperature of the reservoir. According to well understood engineering principles, the greater the temperature difference between the start-up liquid and the reservoir, the more rapid the heating of the reservoir will be. However, there may be temperature and pressure limits imposed by the conditions present in the reservoir or the desired start-up conditions that must be considered in defining the operating conditions for temperature and pressure. In the event that an initial pre-heat is applied with a downhole heater, the start-up fluid must be warmer than the near well bore temperature to add heat to the formation. However, the start-up fluid is also responsible for hydromechanical effects as set out below, namely the displacement of the inter well bore pay hydrocarbons even if the heating has been adequately done by the electrical heat.

Figure 2 shows a graph that illustrates the calculated change in viscosity of representative bitumen with both change in temperature and change in concentration in a preferred hydrocarbon start-up liquid, specifically SCO, in a bitumen/SCO blend. The curve 50 is the change in viscosity curve of pure representative bitumen. Below that are curves 52, 54, 56, 58 and 60, which represent 90% bitumen/10% SCO to 10% bitumen/90% SCO in changes of 20% on a per line basis. The line 62 represents the change in viscosity for SCO over a range of temperatures. This graph illustrates that there are significant changes in viscosity for the bitumen with both a temperature change and a change in SCO concentration. As can now be understood, the present

invention seeks to take advantage of two ways to reduce viscosity of the bitumen in the inter-well bore zone i.e. by both warming and liquid dilution. In some cases, it may be appropriate to clean out the wells before commencing with the start-up method of the present invention. The clean out of the wells is for the purpose of removing any material that would impede the easy flow of fluids through the well, such as leftover drilling mud or the like, as well as removing any excess free water that might be present. A nitrogen or other gas huff-and-puff optionally is comprehended by the present invention. In this sense a huff-and-puff pretreatment step involves injecting a gas, up to a certain pressure, and then releasing the pressure and removing the gas from the area in which it was applied. In any such clean out preconditioning step, it is important not to use so much pressure as to overpressure the formation. Thus, it is preferred to keep the "huff" pressure well below a formation fracture pressure and most preferably below reservoir pressure during the huff and puff step. By being below the native reservoir pressure it may be possible to prevent a loss of the pressurized gas to the formation. The clean out gas can also be circulated through the well tubes to the toes, then into the annulus and then drawn out again through the well tubes located at the heels as described previously to clean the tubes out if needed or desired.

Once the clean out step has been completed (if the same is necessary or advisable), the start-up method can commence. Figure 3 shows a schematic of a preferred form of the present invention, which has four main stages identified by numerals I, II, III and IV across the top and, for ease of reference, the bottom of the Figure 3. Plots are provided for the changes in various parameters during each of the start-up phases. At the top, line 70 is a plot of the temperature of the well bores during the four phases for the invention implemented in an oilsands reservoir as found in Alberta, Canada. Below it is a plot 72 of the temperature of the centerline between the two wells for the like implementation, and Line 74 is a plot of the applied pressure differential between the two wells. The plot 76 identifies the average relative pay hydrocarbon concentration that arises between the well bores in the zone to be cleared.

The plot 78 shows the average relative change in the pay hydrocarbon viscosity at the well-pair centerline during the start-up phases. While these values are suitable for the representative bitumen used in this example, the actual values may vary for other bitumen or pay hydrocarbon deposits.

5 The present invention comprehends a further pretreatment step using a means of delivering heat directly to the formation through a downhole heater such as an electrical downhole heater. In a preferred embodiment the heater is in the form of a long heater element that can run the length of the wells. As can be seen from the Figure 3, Stage I involves raising the temperature of the near to the inter well bore
10 area. This may be done by a downhole heater by circulating hot start-up fluid or a combination of both. Regardless of the source of the heating what is desired is to provide an even heat distribution along the length of wells to help warm the inter well hydrocarbons. In the event downhole heaters are used, one form is to use long heating cables that run the length of the wells to provide heat distribution along the length. As
15 the wells are typically drilled prior to the construction of the above grade facilities, the use of a downhole heater with no fluid circulation may enable well bore heating to start before the plant might otherwise be available to begin the start-up fluid circulation phase, thus beginning pre-heating early and potentially shortening the start-up time. It is desirable to top up the well bore with an appropriate fluid like SCO to enhance the
20 uniform transfer of electrical heat to the reservoir and avoid the potential of overheating during the downhole heater heating step. This also encourages some near well bore dilution of the pay hydrocarbon which is required for viscosity reduction as explained in more detail below.

 Another option to deliver heat to the formation in the first stage of the present
25 invention is the circulation of heated liquid, which will further distribute the heat along the well length and also carry heat to the formation without asphaltene precipitation. As can be seen by the temperature graph of the centerline temperature 72, over this phase, the temperature between the wells rises from a native reservoir temperature to anywhere between 40⁰C and 70⁰C, most preferably between about 40⁰C to 50⁰C. As

shown by the plot line 78, the application of heat will reduce the bitumen viscosity by about 99%. This is accomplished primarily through the temperature conduction as there is no appreciable mixing of the start-up liquid and the pay hydrocarbon during this phase.

5 The present invention comprehends providing heat by circulating a heated start-up fluid through each of the producer and the injector wells. Assuming a 500 meter well and a 3½-inch coiled tubing, the start-up liquid can be circulated at a rate of 5000 barrels per day (bpd) per well and an initial temperature of anywhere between 30°C to 300°C, but in this example at about 120°C. In this example, the average
10 spacing between the horizontal wells is assumed to be 5.5 meters. Using these values, the temperature increase in the near-well bore area as a function of time can be calculated. The length of time required to complete this phase is estimated to be about two to six months, with about three months being average, but the time being dependent on the amount of downhole heater pre-heating the start-up fluid
15 temperature, the recirculation flow rate, the length of the wells and the reservoir characteristics. These start-up times are examples of what might be suitable, but other start-up times are also comprehended by the present invention. In choosing the appropriate start-up fluid and temperature, it is preferable to avoid de-asphalting conditions in the inter well bore area that can damage the porosity of the reservoir
20 formation and inhibit the ability to establish communication between the well pair.

 It is also highly undesirable to inject hot hydrocarbon based fluid at pressures well above native reservoir pressures because this can lead to loss of confinement and the start-up fluid can be lost from the inter well bore region. This displacement can be avoided or mitigated by the use of artificial lift, so that the downhole circulating
25 pressure is maintained at or perhaps even below the native reservoir pressure. During the next step, the temperature of the start-up liquid is adjusted to achieve desired operating temperatures for a subsequent formation treatment while still circulating as per Stage I. The main event of phase II is the application of a pressure differential between the two well bores. Most preferably, the pressure is applied from the upper

well to the lower well, so that the pay hydrocarbon flows downward assisted by such pressure differential and the viscosity reduction arising from one or both of a temperature change and dilution. A pressure applied from the lower well to the upper well is also comprehended by this invention. The pressure difference may be applied
5 by increasing the pressure in one well, reducing the pressure in the other well, or both. Adjusting the pressure in both wells allows for the optimization of the pressure differential between the wells without exceeding a desired maximum pressure in the reservoir formation. The benefits of the applied pressure differential can now be better understood, as, for example, as pressure is applied to the upper well, it will displace
10 the start-up fluid outwardly. In turn, the start-up liquid will displace the pay hydrocarbon downwardly into a warmer region of the lower well. This displacement further encourages the dissolution and warming of the pay hydrocarbon so as to reduce its viscosity and enhance the ability to displace it from between the well pair.

As can be seen from the plot line 76 in Figure 3, the increased start-up fluid
15 concentration in the pay hydrocarbon and the increased temperature have the effect of further lowering the pay hydrocarbon viscosity, as shown by the plot 78. Most preferably, this phase is completed with little or no further addition of start-up liquid. This means that the circulating fluid reaching the surface trends towards an increasing concentration of pay hydrocarbon content in the start-up fluid. As can now be
20 appreciated, the rising content of pay hydrocarbon in the circulating start-up fluid in combination with a decreasing temperature increases the viscosity of the start-up fluid and helps to limit the amount of fluid flowing between the two horizontal wells, while still allowing a pressure difference to be sustained. In this manner, the present invention is better able to hydraulically sweep out pay hydrocarbons between the
25 wells. Further, the amount of pay hydrocarbon present in the start-up liquid can be monitored and used as a proxy for how close the process is to establishing communication along the full length of the well pairs. The present invention contemplates that there will be a non-uniform flow rate of start-up fluid between the wells at various locations along its length. However, by continuing the process of re-

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circulating the start-up fluid, with the application of moderate pressures over a sufficiently long enough time frame, the present invention can provide for the gentle physical displacement and removal of the pay hydrocarbon from the inter-well bore area without asphaltene deposition.

5 Now the procedure enters the next stage III of the present invention. As more and more of the inter-well bore pay hydrocarbon is progressively mobilized and displaced, the circulating pumps become rate limited and thus the ability to apply a pressure differential may be reduced. Again, it is desirable to continue to adjust the temperature of the circulating fluid gradually so as to permit the formation to assume
10 the design operating temperature for the extraction process that follows. This can involve a reduction in start-up fluid temperature. Also, the viscosity of the circulating fluids may be increased by allowing a greater pay hydrocarbons concentration or a lower temperature or both. A higher viscosity allows a high pressure differential and a more effective sweep of pay hydrocarbons from the inter well bore region. In the
15 case of a following solvent based extraction process, the design operating temperature may generally be between 20⁰C to 70⁰C, most preferably 40⁰C to 60⁰ C, but again dependent on the reservoir conditions. Ideally, the heated start-up liquid-pay hydrocarbon fluid mixture that is circulating is almost at the same temperature as the centerline by the end of this phase. However, due to the mixing and mobilization of
20 the start-up liquid and the pay hydrocarbon there is a higher concentration of start-up fluid between the well bores. As can be seen from the plot 78, the viscosity of the centerline is still further reduced during this next stage as the centerline fluid (bitumen) is progressively displaced with the bitumen start-up fluid blend. The application of a sustained pressure differential over a sufficiently long time ensures almost complete
25 mobilization of the pay hydrocarbon in the inter well bore region. The completion of this stage III can be predicted by numerical simulation, and/or confirmed by a variety of physical measurements, such as pressure drop, shut in well bore temperature profiles, fluid properties, tracer residence time analysis, etc.

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The last stage is stage IV, and it consists of preparing the chamber for production. At the start of this stage, the centerline temperature is about 60°C or whatever other temperature is desired to achieve optimum temperature for the start of the working fluid injection and the fluid between the two well bores is a diluted
5 mixture of pay hydrocarbon and start-up fluid with a viscosity between 10 cP and 1000cP.

At this point, the fluid recirculation into the wells is stopped and the mobilized fluid is drained. A means for lifting the liquids out of the formation may be required, such as by using an electrical submersible pump on the production well. The pump is
10 operated for long enough to permit all of the fluid to drain out of the near-well bore area so it can be replaced by the working fluid and to thereby establish good hydraulic drainage along the length of the wells. This is shown as a dramatic reduction in start-up liquid concentration between the wells, and a temperature at the centerline which approaches the temperature of the well bores indicating an even temperature
15 distribution in within the inter-well bore region. In some cases it may be necessary to provide working fluid vapour to the chamber to provide voidage replacement as the mobilized pay hydrocarbon is drained. In other cases, the voidage volume may be filled from dissolved gases that may naturally evolve from the pay hydrocarbon. If it is necessary to supply some working fluid then a small amount of, for example, solvent
20 vapour can be injected into the well provide some vapour pressure support without reaching a pressure that causes condensing conditions so as to minimize the risk of deasphalting the mobilized pay hydrocarbon between the well bores.

When the mobilized pay hydrocarbon is largely drained from the well bore region then the injection of working fluid can now begin. The working fluid is injected
25 from the injection well into the heated, drained chamber and it traverses the chamber and condenses on the cooler extraction interface, located at the periphery of the extraction chamber, where it releases its heat and reduces the viscosity of the pay hydrocarbon so that the blend can drain by gravity down to the production well. Achieving this condition is mostly a matter of increasing the working fluid injection

rate so that the chamber pressure is such that condensing conditions are achieved. From this point on, normal gravity drainage production can proceed. The start-up procedure thus displaces pay hydrocarbon from the inter well bore area through the combined effects of dilution with start-up fluid and raises the temperature. Although
5 60° C is used in the example, it will be understood by those skilled in the art that any convenient, condensing vapour temperature could be selected based on the working fluid being used. What is desired is to have the temperature of the near-well bore area compatible with the desired operating conditions once the start-up process is complete.

It can now be understood that the working fluid may result in the deposit of
10 immobile asphaltenes with the formation. However, as the start-up stages have displaced the pay hydrocarbons from the inter and near well bore area, these asphaltenes will be located well away from the well bores, and will be dispersed through the formation. Thus, it can be appreciated that the present invention is intended to reduce the production of the asphaltenes at a location where they could
15 substantially interfere with the hydraulic drainage properties of the formation in the vicinity of the production well.

Certain features of the present invention can now be appreciated. For example, it can be now understood that the present invention warms, dilutes and drains the pay hydrocarbon between a pair of generally horizontal wells without significant
20 precipitation of asphaltenes in the close proximity of the wells. This is intended to ensure good flowability and drainage of the working fluid and produced fluid both around the wells and between the wells. The pressure differential is applied between the wells to encourage mixing, for better heat transfer, and to mobilize the pay hydrocarbon from the well bore area into one of the wells so that it can be removed
25 from the reservoir. The start-up liquid has an ability to deliver heat efficiently to the formation to encourage a reduction in the viscosity of the in situ pay hydrocarbon. Using the toe delivery tube and the heel removal tube in each horizontal well encourages the flow of the start-up liquid along the length of the wells to even out the heat distribution during the process along the full length of the horizontal wells. Figure

4 shows the well bore and center line temperatures, after 3 days, 10 days, 90 days and steady state, for wells with a working fluid supply temperature of 120°C for a 500 meter well pair and a 5000 bpd circulation rate. As shown, the temperature in the wells after one week is about 105°C and it is estimated that the temperatures reach a steady state when the heel is about 110°C and the toe is about 115°C .

The centerline temperature profile (i.e. at the midline 16 of figure 1) is also shown at different times during the start-up process (in this case without a downhole heater pre-heating step). In this same example, the well temperatures are shown at the start, after ten days, after 30 days, after 80 days and after 115 days. As can be seen, the temperature profiles at the centerline are quite uniform despite the large increase in the well bore temperature. This is because it takes time for the heat to be conducted out to the mid-point between the well pair.

Figure 5 is a graph of the total heat supplied to the area and the temperature history over time for this example. The plot line 80 shows the change in temperature and the plot line 82 shows the rate of heat input in kW. As the reservoir surrounding the wells gets warmer, the rate of heat transferred by the start-up fluid gets smaller due to a smaller temperature difference. As shown, after one week the rate of heat input into the ground is about 500kW per well pair, after two weeks it might drop to about 400kW and at the end of the period it has dropped to 300kW.

Figure 6 shows the estimated effect of start-up fluid temperature on the warm-up period. According to the present invention, the warm-up period can be reduced by supplying the start-up fluid at a temperature of 140°C as compared to 120°C , and reduced even further by supplying start-up fluid at 170°C . The reduction in start-up time for a well spacing of 5.5 meters on average is estimated to be to three months for an operating temperature of 140°C as compared to well over four months for a 120°C operating temperature, and two months for 170°C , as shown by plot line 90. Plot lines 92 and 94 show the start-up time for a well pair spacing of 4.5 meters and 6 meters respectively and various operating temperatures. It will be understood, however, that the end of the start-up procedure defines a starting temperature for the beginning of

extraction. The higher the temperature of the extraction process, which in some cases is controlled by selecting an operating pressure and thereby defining a condensation temperature, the greater the overall energy requirement for the extraction. Thus, the present invention is intended to warm the formation up in the near-well bore area to a
5 temperature that is compatible with the extraction process which follows. In a preferred embodiment the hand-off temperature is equal to the extraction temperature, but the present invention comprehends that these two temperatures may also be different, depending upon the extraction process.

Figures 7a to 7d illustrate more clearly the effect on the near- and inter-well
10 bore areas of the start-up method according to one aspect of the present invention. These graphs depict temperature profiles over time, and are estimated at 30, 60, 85 and 93 days for a test case. The test case is a well of 500 meters in length, with a start-up liquid temperature of 120°C, a well separation distance of 5.5 meters, and a differential pressure of 2MPa. On the left hand side of each drawing is the pay hydrocarbon swept
15 areas and on the right hand side is shown the estimated temperature contours 100. As can be seen by the thermal contours, the temperature wave gradually penetrates outward, further away from the wells 10, 12 in a radial pattern. On the other half of the figures, it can be seen that the pay hydrocarbon is gradually swept out of the inter-well bore region over time with the expansion of swept area, shown as 102, 104, and
20 106. The exact time required to displace the pay hydrocarbon and complete the start-up process will vary from reservoir to reservoir and will vary along the wells depending on the spacing of the horizontal wells at a particular location but the foregoing illustrates the effect of the preferred invention on the near-well bore region. For ease of illustration, the swept areas are shown for one half of the well bores 10,
25 12, although it will be understood by those skilled in the art that the swept area will be symmetrically extended on both sides of each of the wells 10, 12.

Figure 8 shows the effect on the sweeping time of the pay hydrocarbon of well pair separation and start-up fluid operating temperature. The y-axis is sweeping time in days and the x-axis is the temperature of the start-up fluid. The plot lines 110, 112

and 114 show that the closer the well pair 10, 12 is together, and the higher the applied temperature, the quicker the sweeping time for this representative example. Figure 9 shows the effect on sweeping time of start-up fluid temperature and applied pressure. In this figure, the y-axis is sweeping time in days and the x-axis is the temperature of the start-up fluid. Additionally, the plot lines 116, 118 and 120 are three different pressure differentials applied between the wells 10, 12. As can now be appreciated, the present start-up method can be varied to be made quicker or slower as needed to suit local reservoir conditions and operating requirements. Generally, the greater the temperature of the start-up fluid, the faster the displacement can occur, sweeping out the pay hydrocarbons. Generally, the closer the well spacing, the faster the pay hydrocarbon is removed from the inter-well bore area. Generally, the higher the pressure applied between the wells, the faster the desired completion of sweeping the inter-well bore region of pay hydrocarbon. However, the individual conditions of the reservoir may provide upper limits to each of these parameters. Closer well spacing requires good inflow control into the production well to avoid flooding the injector well with liquids. Higher pressure differentials require good reservoir integrity to avoid pushing the start-up fluid out, away from the inter-well bore area through high permeability routes.

As can now be appreciated, the present invention comprehends using certain equipment to implement the preferred start-up process. For example, above grade there is a source of liquid start-up fluid, most preferably a non-asphaltene hydrocarbon that can be heated by a heater to a predetermined temperature. Next, there needs to be a pump and a wellhead connection, to permit the heated hydrocarbons to be circulated through the wells. If the reservoir integrity is sufficient, that the pump pressure can be used to also pump the fluids back out of the well, then that is preferred. However, the present invention also comprehends that it may be necessary to use well heel pumps to pump the liquids back up to the surface as a means to reduce the reservoir pressure to match reservoir containment conditions. Such well heel pumps might be any form of suitable pumps for artificial lift such as electrical submersible pumps.

This adds expense and complexity and thus is less preferred except when to do otherwise would invite a loss of liquids owing to a lack of reservoir integrity.

5 The present invention also comprehends using temperature and pressure sensors and the like to instrument the wells during the start-up process to provide monitoring of the progress of the start-up through the different phases. The present invention also comprehends using temperature and pressure sensors and the like to instrument observation wells in order to monitor the start-up process. Sampling facilities located above grade are also required to monitor the pay hydrocarbon content of the circulating fluid.

10 The present invention also comprehends the use of a downhole heat source such as an electrical resistance heater to use in delivering heat as an initial option phase of the start-up process, as noted above.

As can now be appreciated the present invention provides for a warming of the pay hydrocarbon in the near well bore area by contact with a warm start-up liquid, for
15 the purpose of reducing the viscosity of the pay hydrocarbon. In this sense, warm means moderate temperatures as opposed to the high temperature steam at typical reservoir pressures of 1 MPa or higher. Further, the start-up liquid is dissolved into and mixed with the pay hydrocarbon to further reduce the viscosity without being in sufficient quantity or kind that substantive asphaltenes are deposited in the inter well
20 bore region. Essentially the present invention is aimed at mobilizing and then removing the pay hydrocarbon, largely by hydraulically sweeping or displacing the same, from the near-well bore area to establish a working fluid injection and extraction chamber. At the end of the start-up process, the extracted zone is at or near to the desired temperature for the extraction process that follows. The start-up process has
25 been carried out in the absence of any water injection. Also, any residual water in the reservoir that may have been turned into steam by the warm start-up liquid, will re-condense and be removed from the near-well bore region as the liquids are removed in the start-up process. Once extraction commences, the asphaltene deposits that may occur will be formed at a location distant to the near-well bore region at the extraction

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interface and thus will not impede fluid flow in the near well bore region. Further, the start-up liquid is preferably compatible with the surface facility that is located above the reservoir for the purpose of working fluid injection and pay hydrocarbon production. Furthermore, the displacement from injector to producer could be reversed
5 and the circulating and displacement fluid could be injected at other locations besides the toe, and withdrawn at other locations besides the heel, as needed.

While the foregoing describes preferred embodiments of the present invention, it will be understood by those skilled in the art that various modifications and alterations are possible without departing from the broad spirit of the invention as
10 defined in the attached claims. While some of these variations have been discussed above, others will be apparent to those skilled in the art. All such variations and modifications are comprehended by the present specification.

**THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:**

1. An apparatus for applying a start-up method to an inter well bore region
5 between two vertically displaced horizontal wells, said apparatus comprising:
 - a source of non deasphalting start-up fluid above grade;
 - a heater for heating said start-up fluid;
 - a well head connection from said source to each of said two vertically displaced
horizontal wells;
 - 10 a fluid delivery and removal system connected to said well head connection to
permit said start-up fluid to be circulated along each of said two vertically displaced
horizontal wells;
 - one or more circulating pumps for circulating said start-up fluid from said
source through said heater down into said formation along each of said vertically
15 displaced horizontal wells and then back up to the surface;
 - a conditioner located above grade to remove solids and water if necessary from
said returned start-up fluid, and
 - sensors to measure one or more of a temperature, a viscosity, and a
composition of said start-up fluid which is returned to the surface.
- 20 2. The apparatus as claimed in claim 1 wherein said source of start-up fluid is a
source of diesel fluid.
3. The apparatus according to any one of claims 1 and 2 further including a down
25 hole heater to warm said inter wellbore region between said two vertically displaced
horizontal wells.
4. The apparatus according to any one of claims 1 and 2 further including a source
of make-up start-up fluid.

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5. The apparatus according to any one of claims 1, 2 and 3 further including at least one vertical observation well having temperature sensors for measuring a temperature within said inter well bore region.
- 5
6. The apparatus as claimed in claim 1 wherein said fluid delivery and removal system includes a fluid delivery tubular extending into a toe of at least one well.
7. The apparatus as claimed in claim 1 wherein said fluid delivery and removal
- 10 system includes a fluid delivery tubular extending to a toe of both wells.
8. The apparatus as claimed in claim 1 wherein said fluid delivery and removal system includes a fluid delivery tubular extending to a heel of at least one well.
- 15 9. The apparatus as claimed in claim 1 wherein said fluid delivery and removal system includes a fluid delivery tubular extending to a heel of both wells.
10. The apparatus according to any one of claims 6 and 7 further including a fluid removal tubular extending from a heel of each of said wells having a fluid delivery
- 20 tubular in said toe.
11. The apparatus according to any one of claims 8 and 9 wherein said fluid delivery and removal system further includes a fluid removal tubular extending towards a toe of each well having a fluid delivery tubular located towards the heel
- 25 thereof.

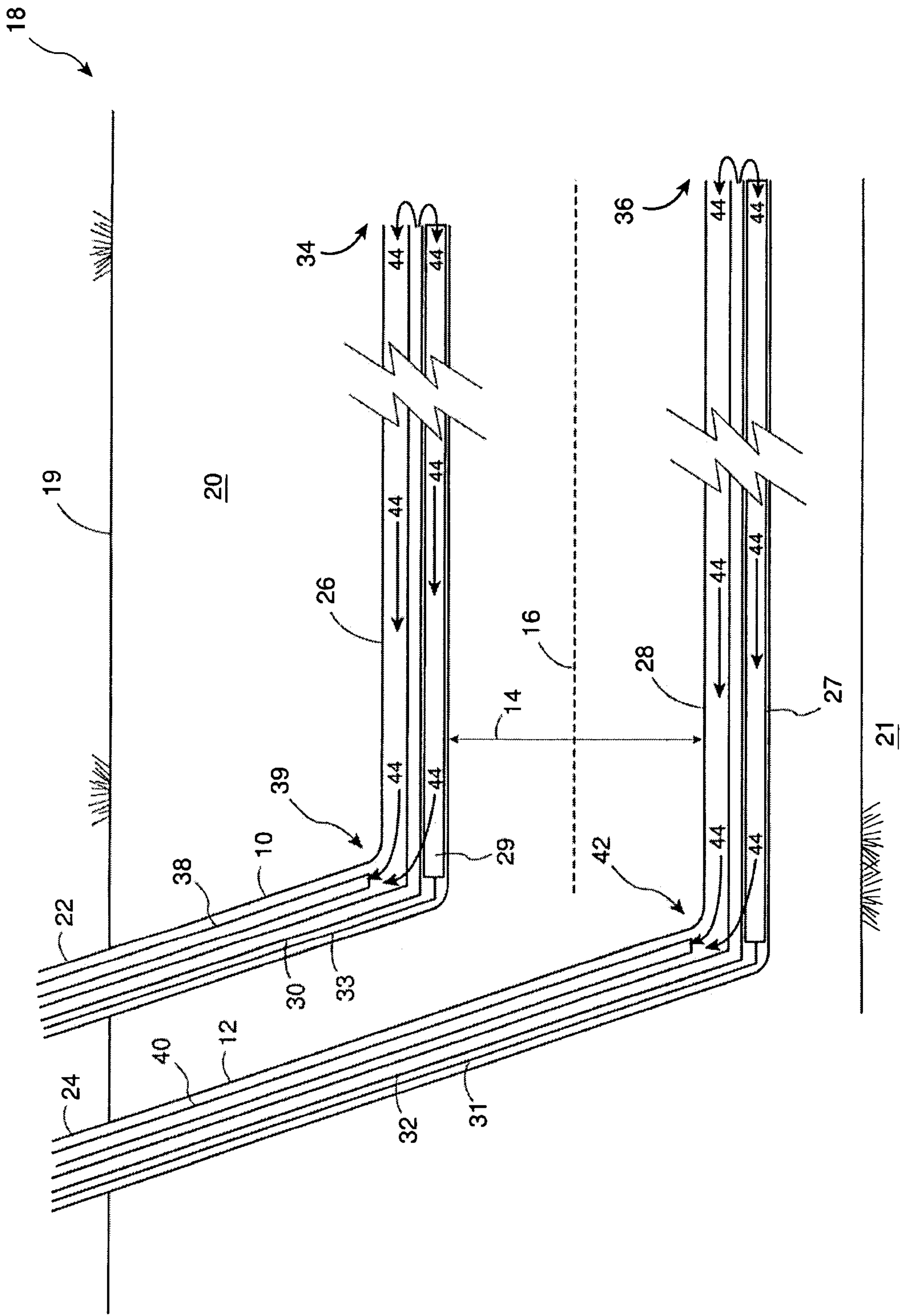
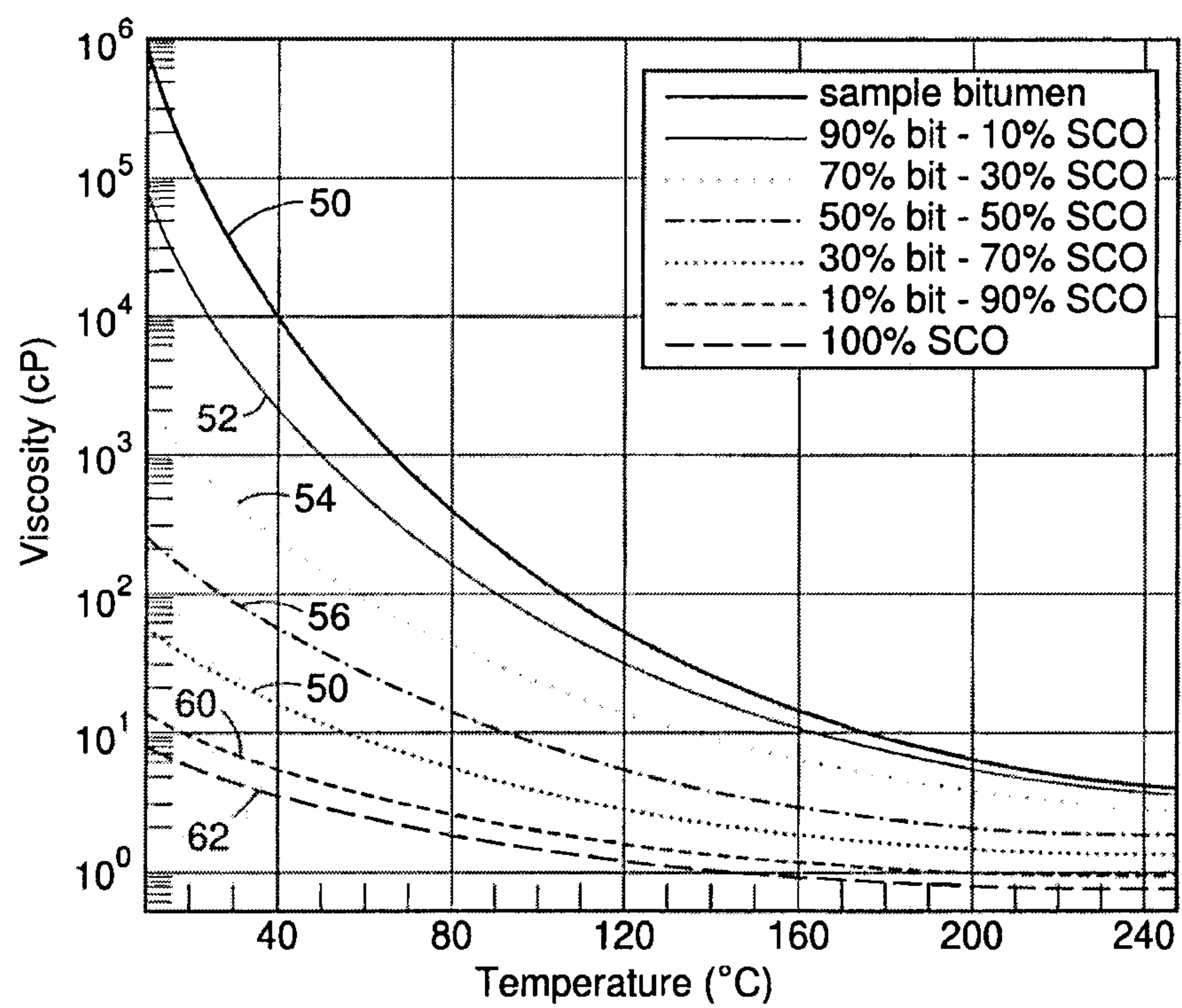


Figure 1

**Figure 2**

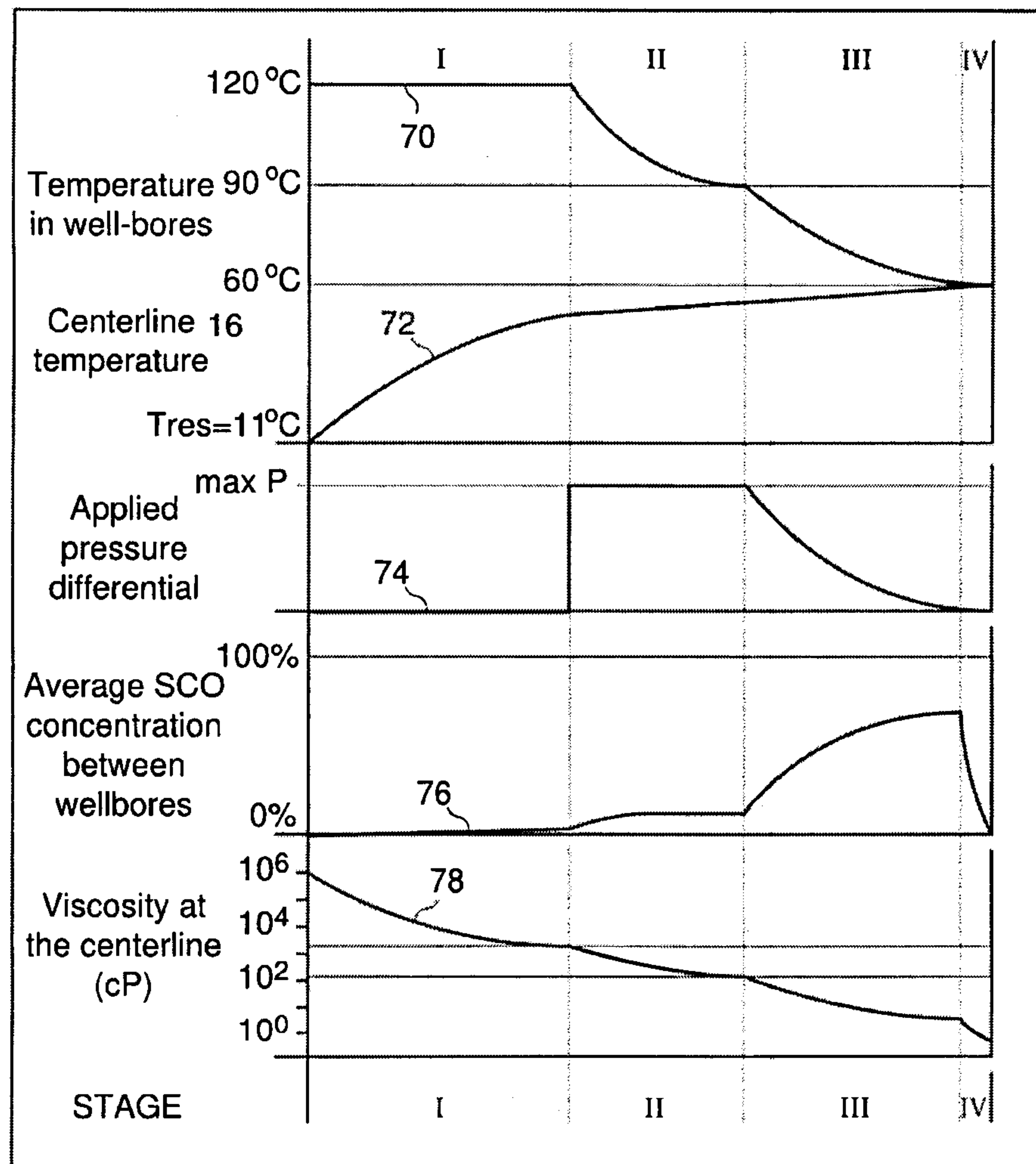
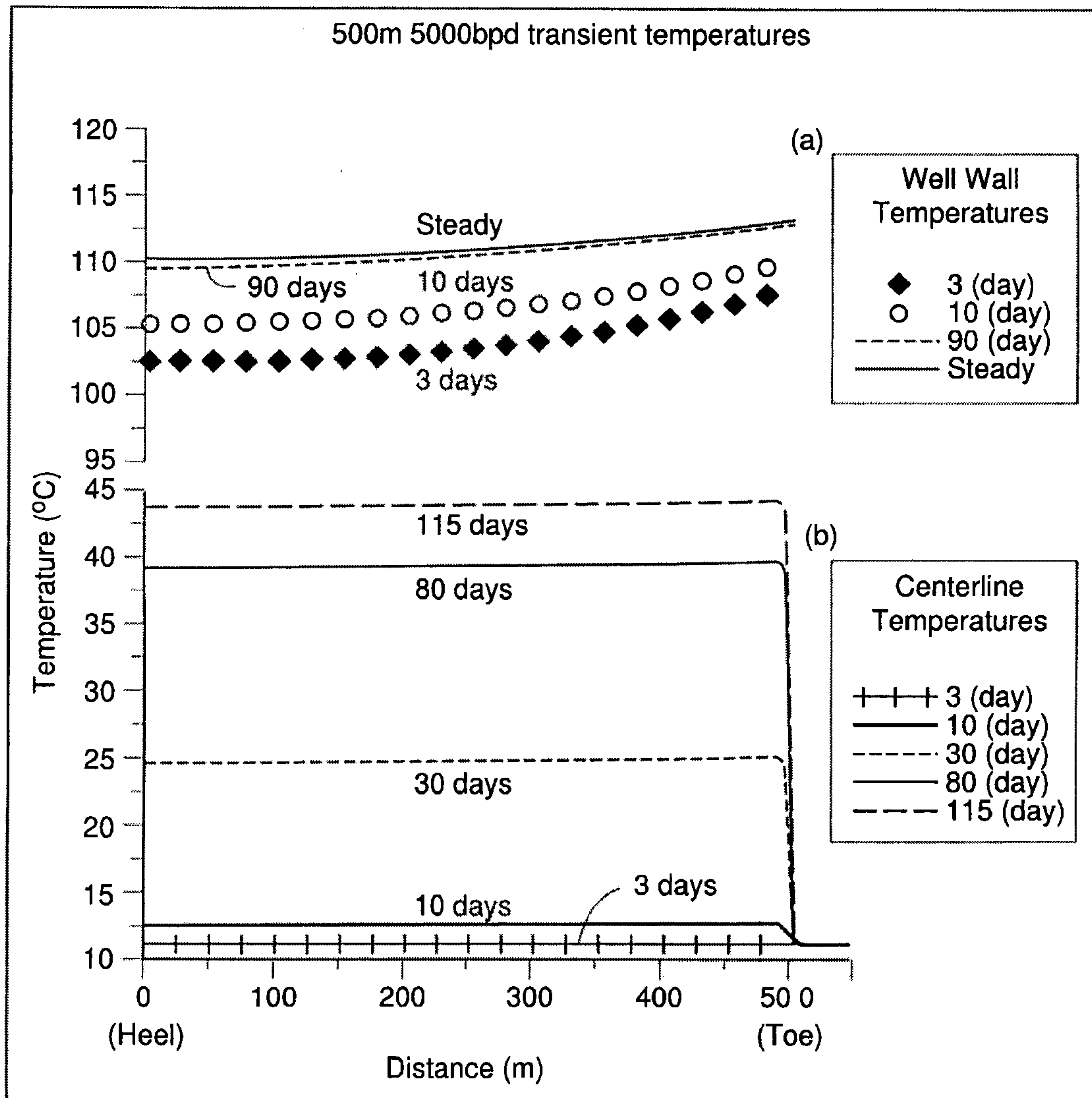
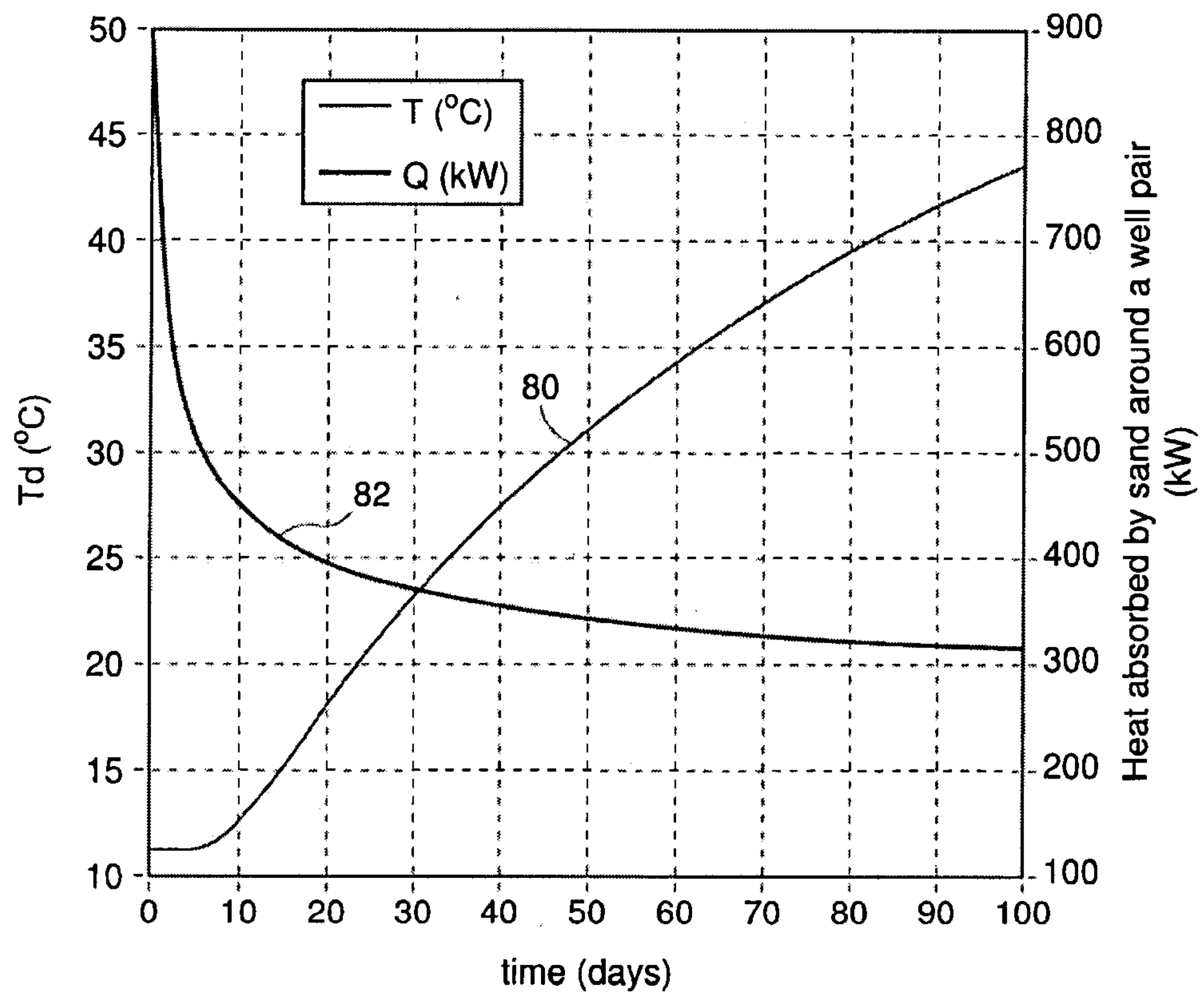
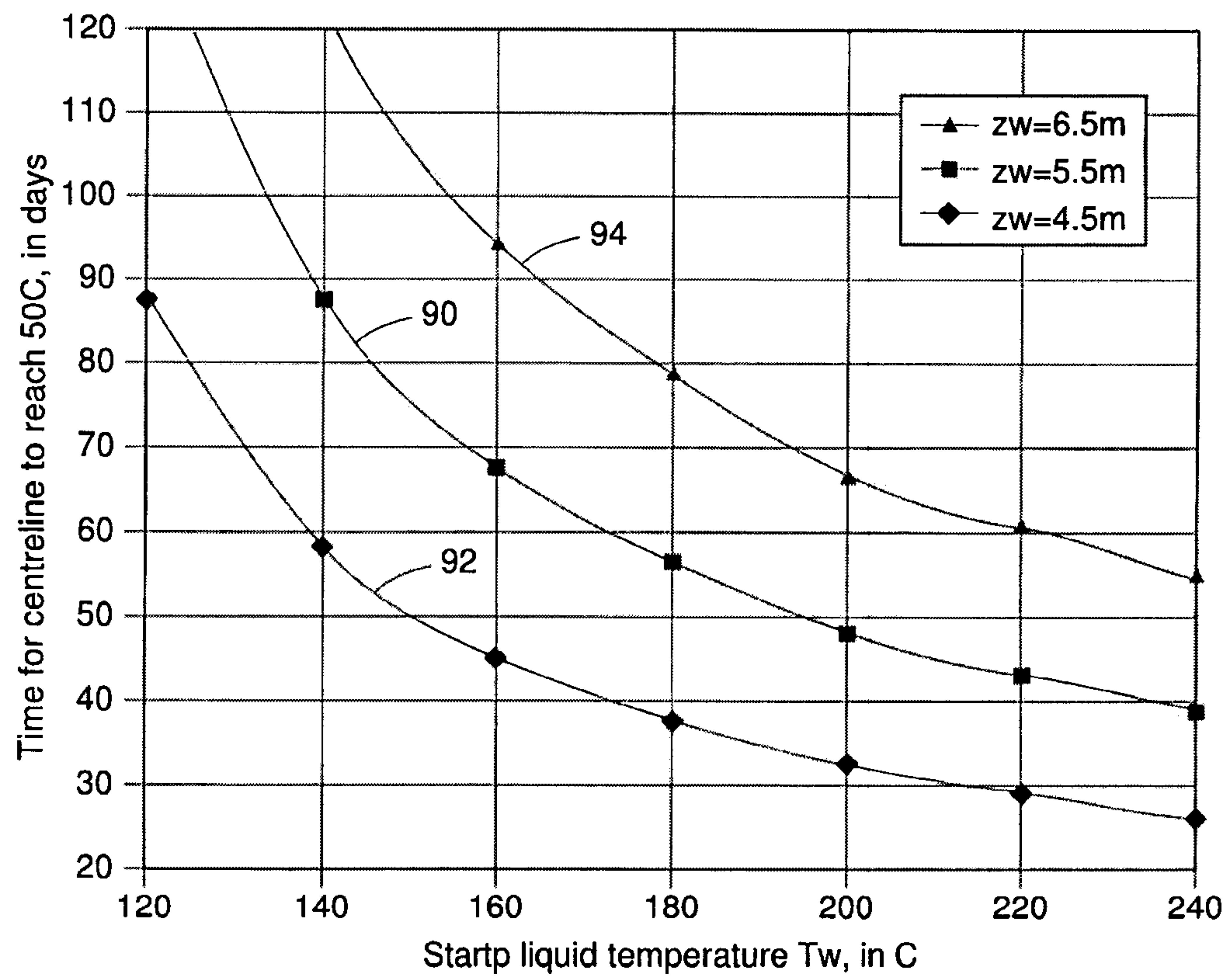


Figure 3

**Figure 4**

**Figure 5**

**Figure 6**

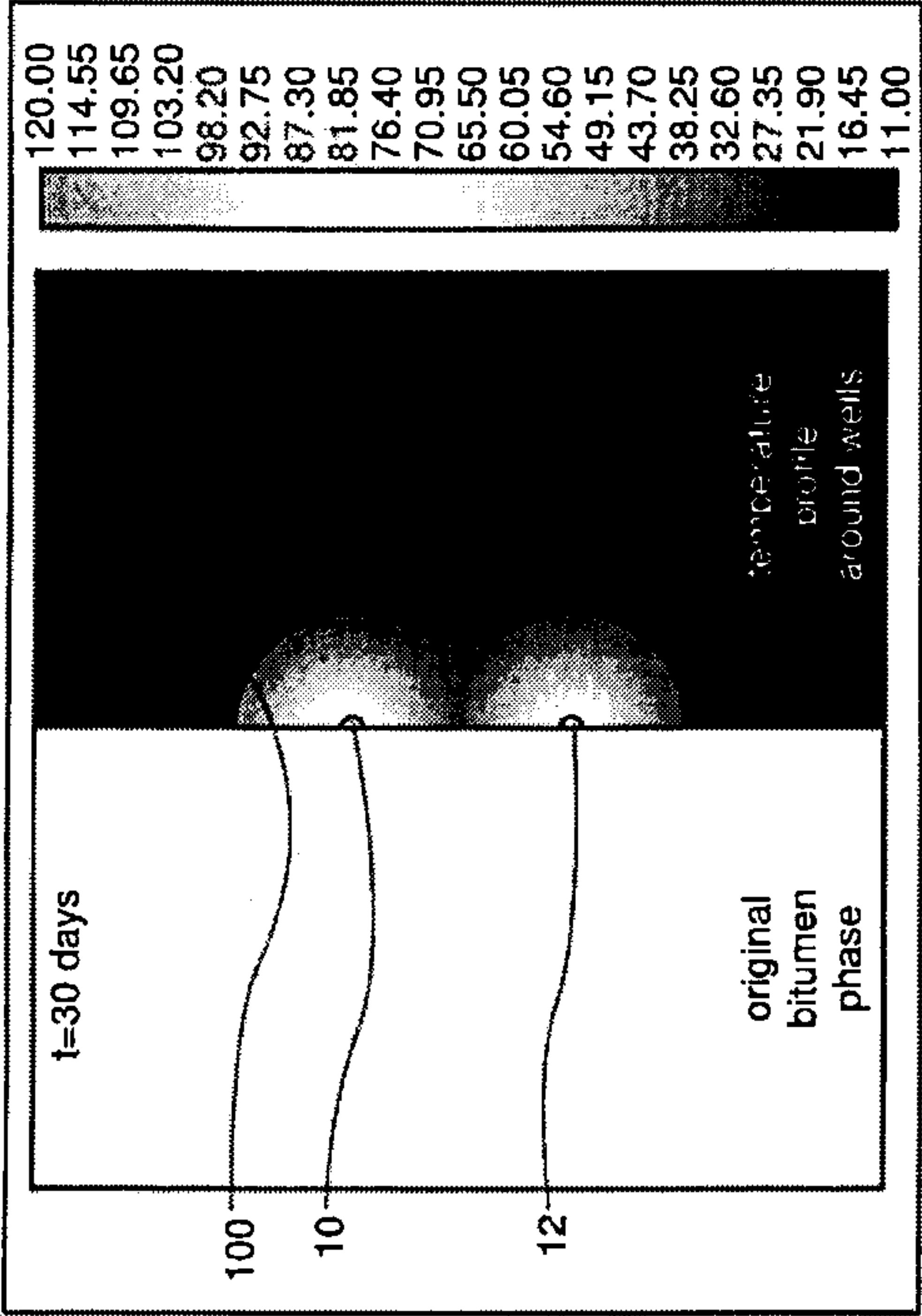


Figure 7a

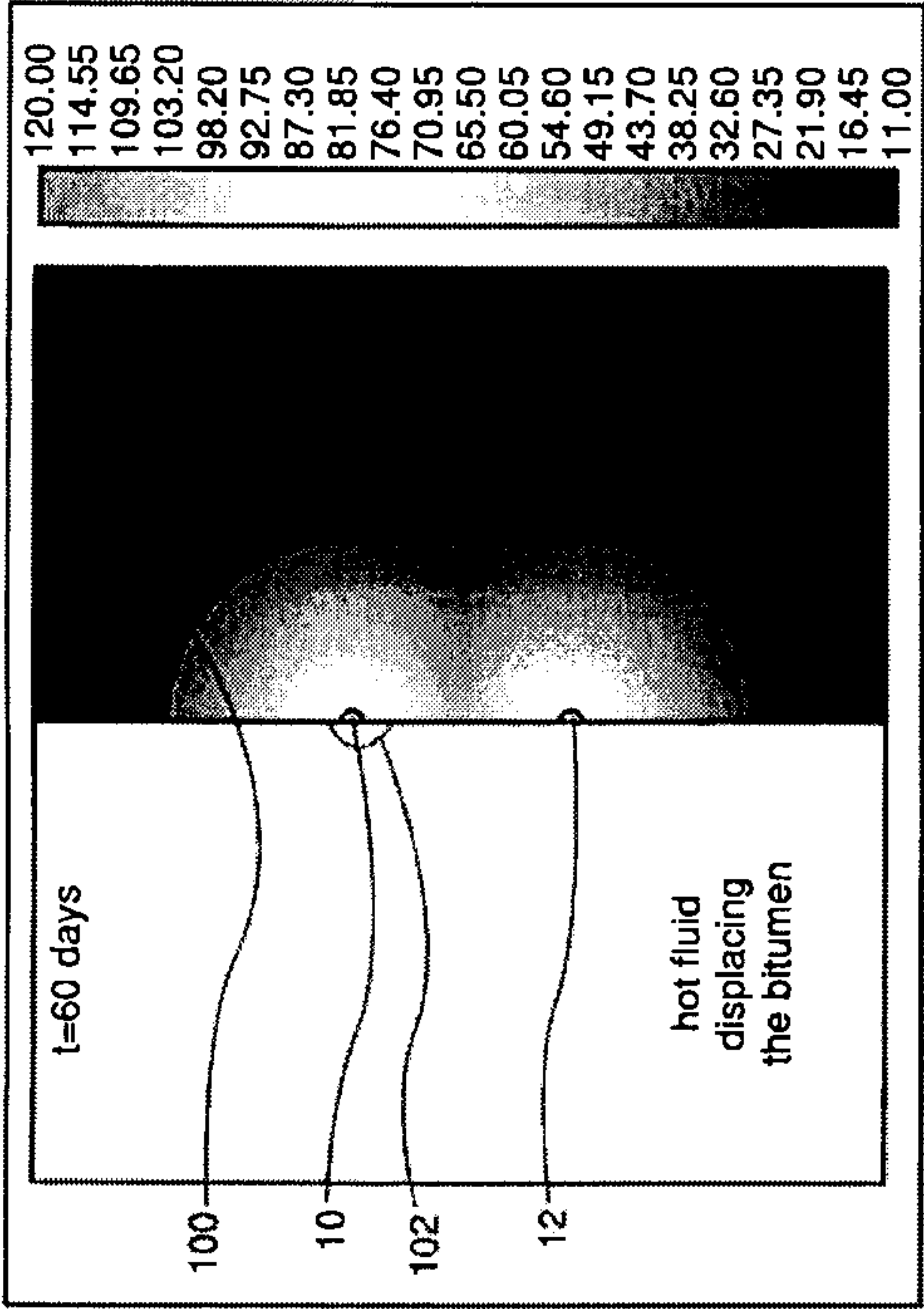


Figure 7b

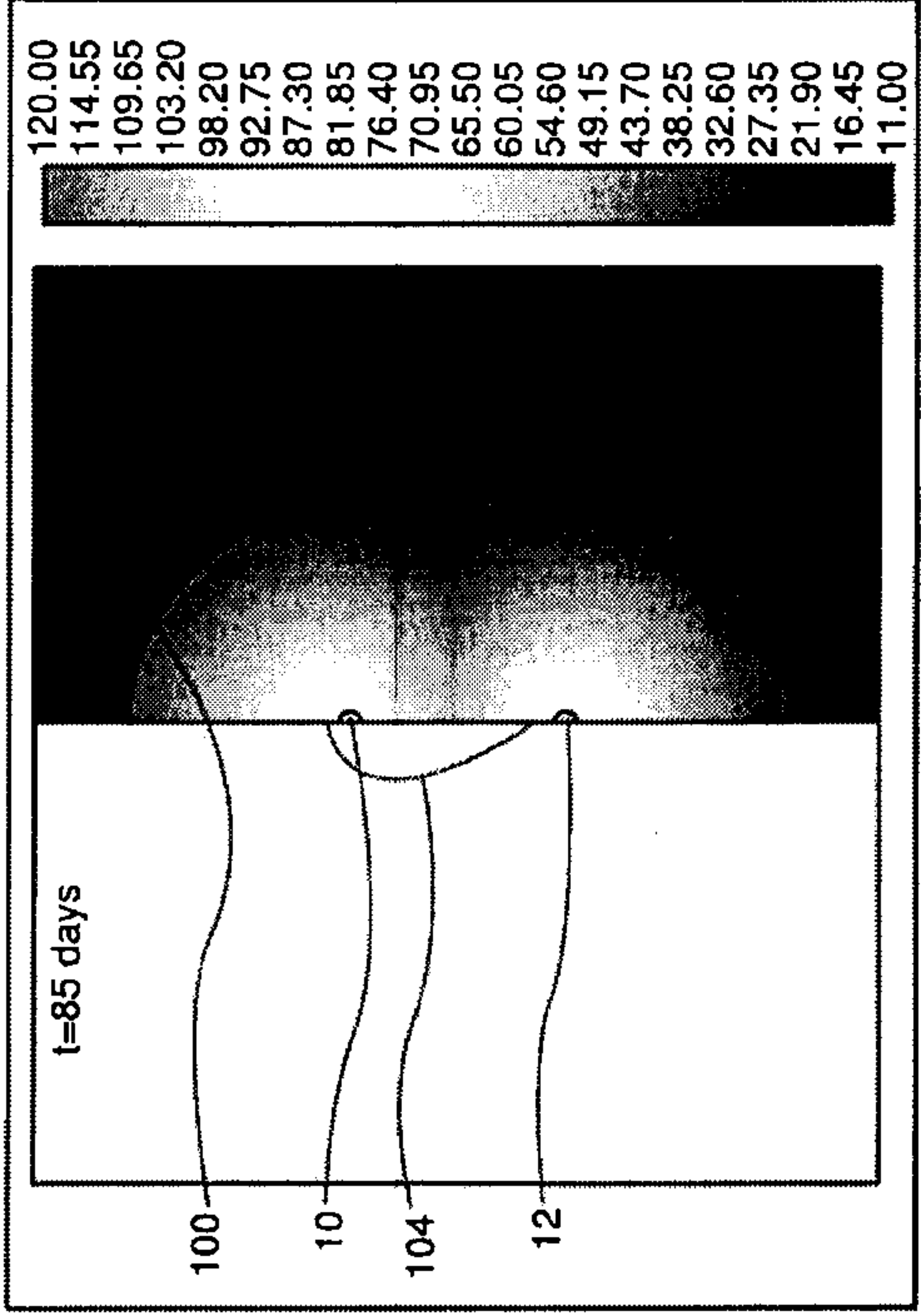


Figure 7c

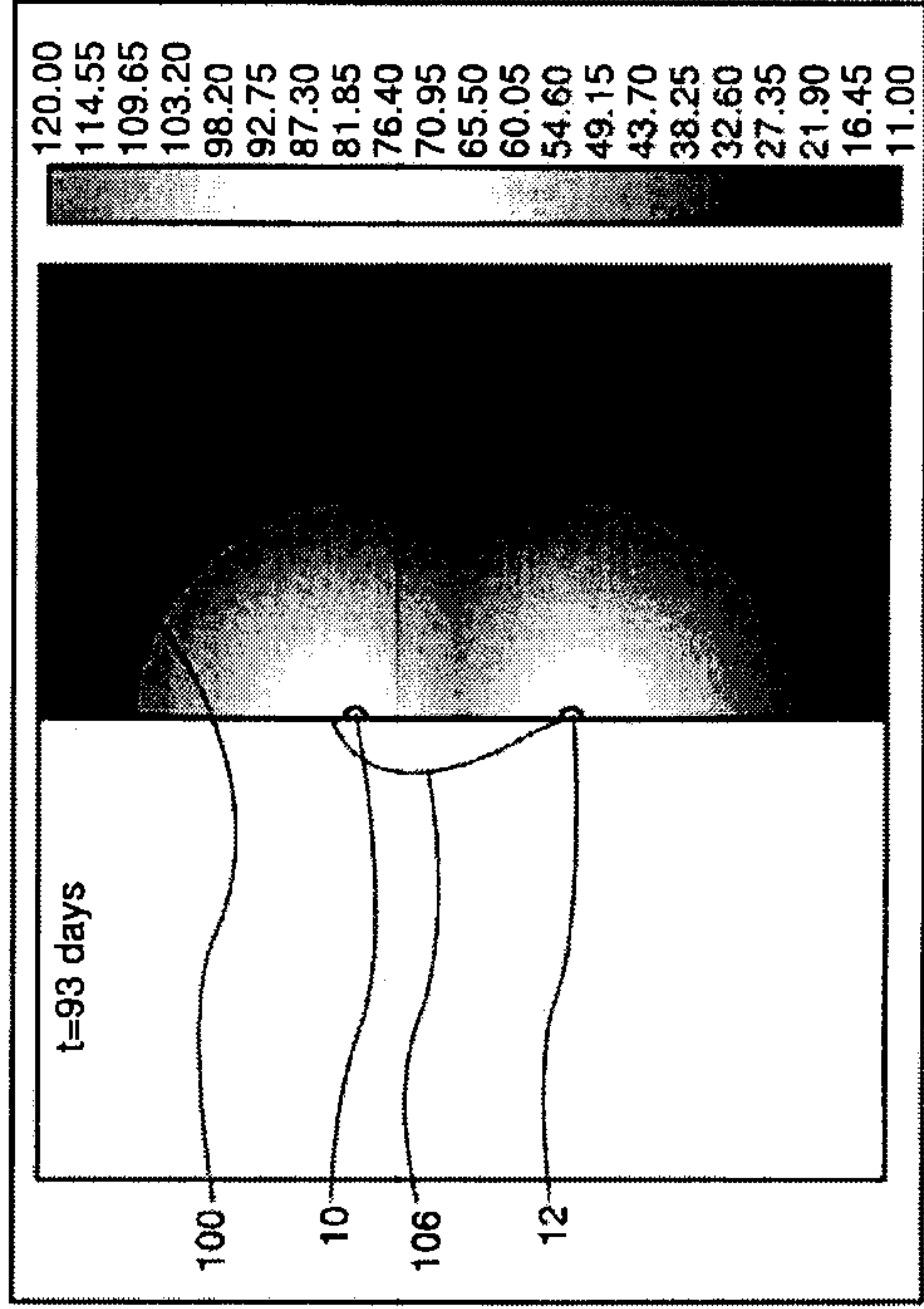
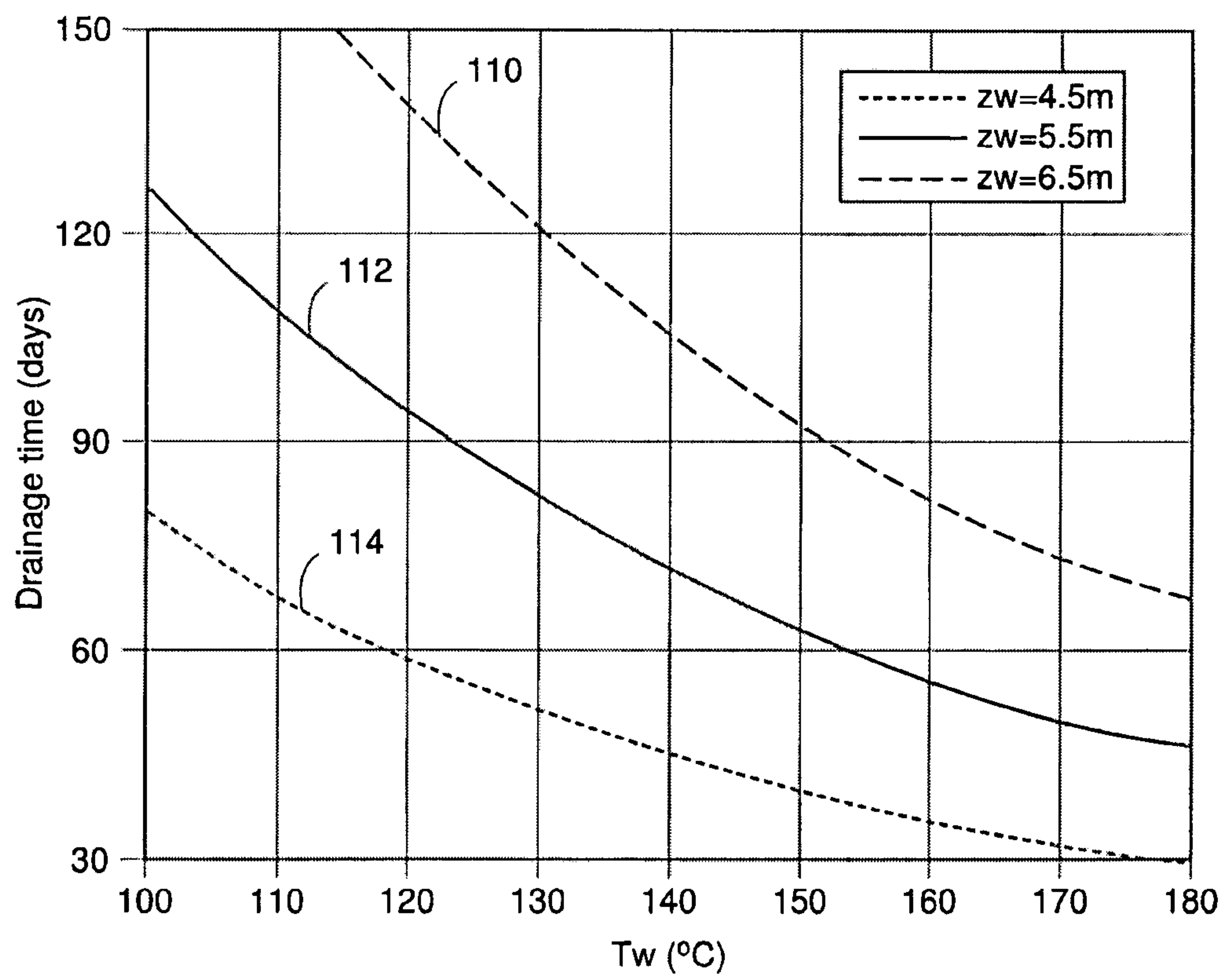
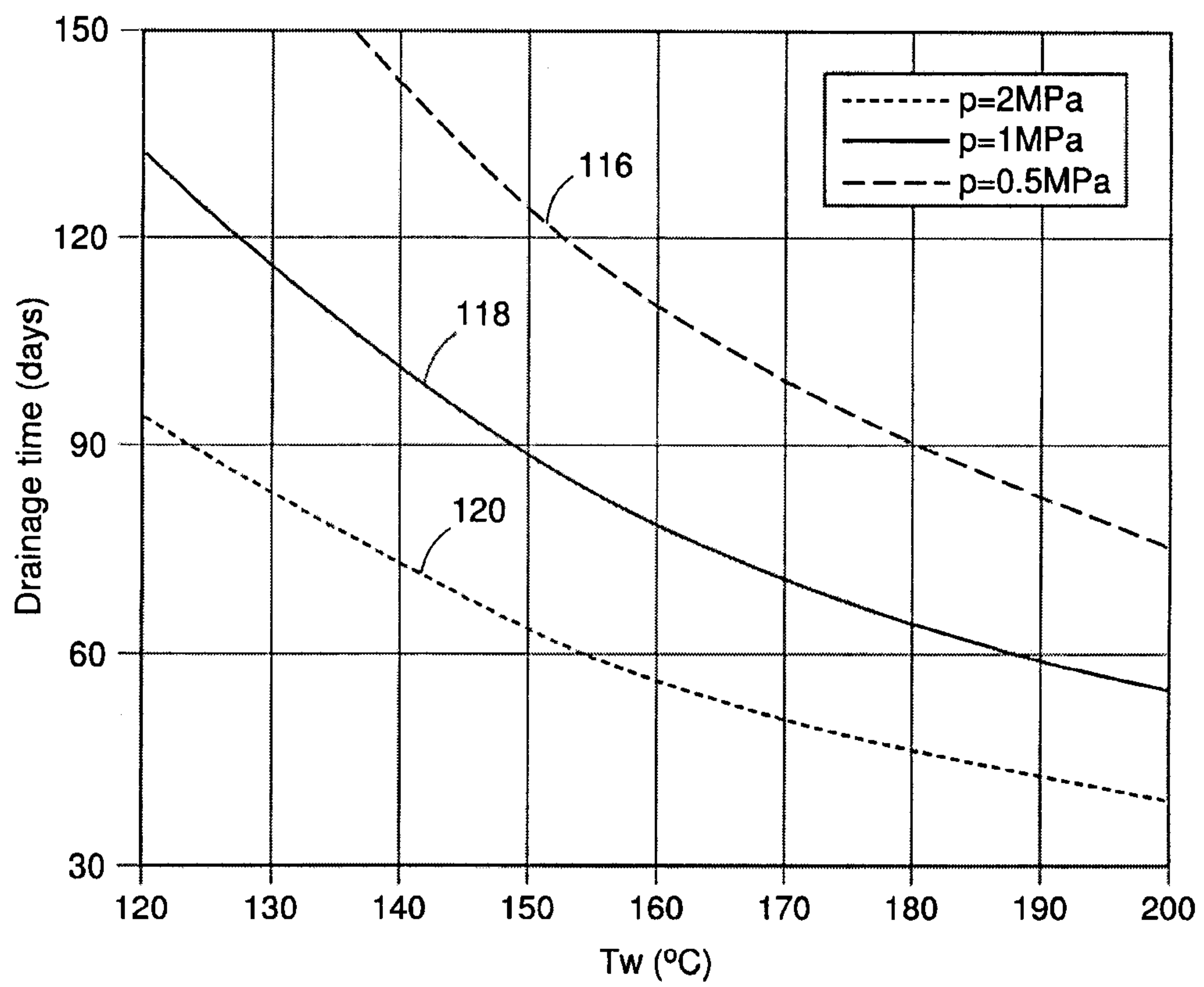


Figure 7d

**Figure 8**

**Figure 9**

