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(54) Title: STABILIZATION AND REMOTE RECOVERY OF ACID GAS FRACTIONS FROM SOUR WELLSITE GAS

(57) **Abrégé/Abstract:**

A method for the recovery of hydrogen sulphide and other acid gas fractions from sour wellsite gas in hydrocarbon production. The selected acid gas fractions are absorbed into a noncorrosive and transportable solvent solution at the wellsite, the rich solvent solution being transported to a central plant location where it is desorbed from the solvent solution for further handling or processing. The lean solvent solution can then be recycled. Multiple acid gas fractions could be recovered from the sour gas in question using a single appropriate solvent solution. Carbon dioxide could be absorbed and desorbed at the wellsite rather than at the central plant location. Clean gas is yielded at the wellsite for downstream processing or sale.



Application for Letters Patent**REMOTE RECOVERY OF ACID GAS FRACTIONS FROM NATURAL GAS****Iyer et al.****10 Abstract:**

A method for the recovery of hydrogen sulphide and other acid gas fractions from sour wellsite gas in hydrocarbon production. The selected acid gas fractions are absorbed into a noncorrosive and transportable solvent solution at the wellsite, the rich solvent solution
15 being transported to a central plant location where it is desorbed from the solvent solution for further handling or processing. The lean solvent solution can then be recycled.

Multiple acid gas fractions could be recovered from the sour gas in question using a single appropriate solvent solution. Carbon dioxide could be absorbed and desorbed at the wellsite rather than at the central plant location. Clean gas is yielded at the wellsite
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STABILIZATION AND REMOTE RECOVERY OF ACID GAS FRACTIONS FROM SOUR WELLSITE GAS
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This invention is in the field of hydrocarbon recovery and processing, and more specifically deals with a method for the safe and economical recovery of hydrogen sulphide and other acid gas fractions from wellsite gas.

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Background:

Natural gas streams produced from some subterranean formations contain substantial
15 volumes of various acid gas fractions such as hydrogen sulphide (H₂S), carbon dioxide (CO₂) and the like. These natural gas streams, referred to as "sour gas" at the wellsite, must be purified and the acid gas fractions removed before being sent to market. The process of removal of these acid gas fractions is referred to in the industry as "sweetening" the sour wellsite natural gas stream.

20

There are various methods for the sweetening of natural gas streams to remove acid gas fractions therefrom. One of the most basic methods for sweetening a natural gas stream for the removal of acid gas fractions in the past has been to recover those acid gas fractions from the natural gas stream and to simply flare them off at the wellsite, or to

process them in a plant to produce elemental sulphur. Beyond the costs associated with this type of method there is obvious negative environmental impact on a number of levels. In addition, flaring at the wellsite has another significant economic disadvantage namely that the actual acid component of the sour gas insofar as it is flared off or

5 disposed is not in any way used as a positive revenue source. In addition, elemental sulphur is very low market value and with increasing sulphur production around the world the production of elemental sulphur from sour gas is at best only a minor revenue source.

10 The safe handling of sour gas and the removal of acid gas fractions therefrom is a significant economic factor in the feasibility of certain hydrocarbon recovery projects. In cases where it has been desired in the past to remove hydrogen sulphide and other acid gas fractions from a natural gas stream for example, solvent absorption methods have been practiced in the past whereby the gas stream from the wellsite is conveyed to a

15 central processing facility where the hydrogen sulphide or other identified non-desirable acid gas fractions removed by solvent absorption or other similar techniques. The physical plant costs of these types of recovery methods is astronomical however, since in that circumstance it is necessary to pipe the gas stream, containing the acid gas fractions, to the central processing location and the pipeline which needs to be built must be

20 resistant to acid gas corrosion. High cost materials must be used, and even this is not a full insurance against corrosion related failures which almost always result in fatalities or severe health disabilities in humans and livestock apart from the damage to flora and fauna. Hence expensive pipeline inspection and monitoring services are required to be

performed periodically on an ongoing basis. Once a particular well is retired, that pipeline becomes redundant or useless and needs to be abandoned, which is a particular economic concern.

- 5 An alternative which has also been tried in the past, in the place of piping the hydrocarbon stream to a central processing location for recovery or removal of the acid gas fractions there from has been to endeavor to develop on-site acid recovery equipment. Again, the plant costs of installing acid recovery equipment such as this can be staggering on an individual unit basis, and as a producer with hundreds of wells if acid extraction
10 equipment such as this were required at each wellsite the infrastructure cost of distributed acid recovery on this basis becomes impractical.

- Purification or cleaning of sour gas to recover acid gas fractions therefrom, in addition to a major economic consideration in certain oil and gas projects, can also pose a significant
15 safety and environmental concern if inappropriately handled or the recovery process or equipment is breached. In the case for example of piping of the virgin natural gas streams to a central processing location for the removal of acid gas fractions therefrom, if there is a breach in the piping could cause major damage to life and property. In addition to the problem of the actual environmental release of such acid gas fractions there is also
20 the human risk and safety factor associated with maintaining these pipelines and minimizing or avoiding the risk of pipe breaches. Gas releases from such pipeline breaches cannot be controlled or contained in any manner whatsoever and they are left to

the mercy of natural wind and air convection currents to disperse them down to low levels of concentration.

5 **Summary of the invention:**

It would be economically and environmentally desirable and advisable to come up with a method for the removal of acid gas fractions from a natural gas stream, namely sour wellsite gas, which would minimize the physical infrastructure required to effect this
10 removal and recovery at the well site while at the same time significantly minimizing environmental impact and human and other safety risks associated with the recovery of the acid gas fractions. Development of such a method which minimizes the solvent discharge as well as potentially allows for the capture of the acid gas components of the sour gas stream as a potential revenue product is the goal and object of the present
15 invention. A final economic benefit to this type of a method if available would be that clean natural gas would be created at the wellsite which could be immediately presented to the sales pipeline grid.

The first aspect of the present invention is a method of remote recovery of acid gas
20 fractions from natural gas comprising a number of steps conducted a well site before transitioning the final processing steps to a remote central plant location. The first element of this method, conducted at the wellsite, is the preconditioning of the sour natural gas stream to remove any condensates before its further processing. These

- condensates might include water, hydrocarbon condensate etc. Many types of preconditioning equipment and techniques are known in the art and the specific type of preconditioning which would be undertaken into a large degree be determined by the composition or characteristics of the sour gas stream in question. Following
- 5 preconditioning of the natural gas stream, and absorption step would be undertaken using a wellsite recovery apparatus capable of absorbing selected acid gas fractions from the natural gas into a solvent, which solvent upon absorption being a rich solvent could be stably and safely transported and would not be corrosive.
- 10 The next step in the method of the present invention would be the transport of the rich solvent to the central plant location, at which a desorption step would be undertaken to liberate the previously absorbed acid gas fractions from the rich solvent, yielding relatively pure acid gases and lean solvent which could be recycled.
- 15 At any time after the absorption of the acid gas fractions from the natural gas stream, the clean natural gas yielded thereby to be transmitted for sale.

Various chemical compositions or agents could be used in the composition of a solvent which was beneficially able to absorb one or more acid gas fractions is desired in the

20 processing of sour natural gas of a particular profile. Any such solvents, whether they be a single chemical agent or a cocktail of chemical agents are contemplated within the scope of the present invention. The specifics of some of the equipment used in the absorption and desorption steps will vary obviously based upon the design of the solvent

package itself as well as the condition or profile of the preconditioning sour natural gas which is being cleaned.

In one variation on the method of the present invention, there is contemplated the local
5 sequestration of some acid gas fractions and then the transport for remote recovery of
others by their absorption into a rich solvent. It is specifically contemplated that for
example following the absorption of hydrogen sulfide or other acid gas fractions which
was desired to remove from the sour natural gas, the lean solvent which was obtained
from the removal of those acid gas fractions from the rich solvent at the remote central
10 plant location could be recycled for use in a secondary absorption step back at the
wellsite where carbon dioxide could be absorbed, and then immediately desorbed right
there at the well site for disposal or further processing. Removal of carbon dioxide at the
well site rather than transporting rich solvent containing large quantities of carbon
dioxide is desirable simply because of the volume of carbon dioxide which typically
15 needs to be scrubbed from the sour gas.

One or more acid gas fractions could be absorbed from the natural gas stream at the
wellsite by modifying the design of the solvent package and also by potentially
modifying the absorption and desorption equipment used at the well location as well as at
20 the plant location dependent upon what process parameters are required in the
environment in question too often we recovered the desired acid gas fractions from the
sour natural gas.

Many types of acid gas fractions could be absorbed or removed from natural gas as desired at the primary acid gas fraction which is targeted in addition to the on-site removal of carbon dioxide is hydrogen sulfide. The product, hydrogen sulfide gas which is yield by the practice of the method of the present invention is also within the scope of the present invention. In addition to the hydrogen sulfide gas, through another process steps sulfuric acid could be produced in sulfuric acid which was produced using this hydrogen sulfide gas is also contemplated within the scope of the present invention. Finally by one further extension of the processing of the hydrogen sulfide gas in sulfuric acid which are contemplated herein, the sulfuric acid could be used in the production of agricultural fertilizers and any agricultural fertilizer which is produced using sulfuric acid manufactured from hydrogen sulfide gas recovered from sour natural gas in the method of the present invention is contemplated within the scope of the present invention.

Beyond hydrogen sulfide gas, sulfuric acid, and agricultural fertilizers containing the sulfuric acid produced in accordance therewith, various pieces of equipment associated with the practice of the present invention are also contemplated within the scope hereof. For example, a wellsite recovery apparatus is contemplated which is connectable to a lean solvent interface and to a natural gas interface as well as a rich solvent discharge interface. The apparatus itself in addition to these input and output interfaces includes at least one absorption unit which will accomplish the objective of absorbing one or more acid gas fractions from the natural gas into the lean solvent, yielding rich solvent for transport and remote recovery. This apparatus might optionally include natural gas preconditioning equipment as well precondition the natural gas in advance of the

absorption step although it is also possible that the preconditioning equipment might be separately cited at the wellsite.

Various types of rich solvent interfaces are contemplated including simply interfacing the
5 absorption apparatus with a tank or other storage vessel which could store the rich solvent
until it could be transported by truck, train or otherwise for remote recovery. Also in
certain circumstances the rich solvent discharge or interface might actually be a pipeline
connection. Pipeline connection could be used in certain circumstances since the stable
and non-corrosive nature of the solvent package with the acid gas fractions absorbed
10 therein would reduce the cost of materials in the use of those. One pipeline embodiment
of a network of the present invention envisions networking together several wellsite
recovery apparatus units to a single remote central plant apparatus within close enough
proximity and drilling field to make economic sense to run those pipes -- this network is
contemplated within the scope of the present invention.

15

Additionally, the remote or central plant recovery apparatus is also contemplated within
the scope of the present invention the recovery apparatus is interfaced with a source of
rich solvent and basically includes at least one desorption unit which will allow for the
desorption of at least one acid gas fraction previously absorbed at a wellsite from the rich
20 solvent. Once all of the acid gas fractions have been desorbed, lean solvent is capable of
being recycled, and the relatively pure acid gas fractions can be further handled or
processed. For example if the acid gas fraction recovered in this fashion is hydrogen

sulfide gas, the pure hydrogen sulfide which is obtained from the desorption step can be further processed into sulfuric acid.

5 Description of Drawings:

Preferred embodiments are provided in the accompanying detailed description which may be best understood in conjunction with the accompanying diagrams where like parts in each of the several diagrams are labeled with like numbers, and where:

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Figure 1 is a flow chart demonstrating the schematic steps of one basic embodiment of the method of the present invention;

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Figure 2 is a schematic of one embodiment of the portable wellsite capture apparatus of the present invention, showing a single solvent absorption unit;

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Figure 3 is a schematic of one embodiment of an acid recovery apparatus of the present invention, showing two acid recovery units;

Figure 4 is a schematic diagram of one embodiment of a system in accordance with the present invention, showing a single well site capture device and a single acid recovery station, with the rich solvent being transported between those two locations by truck;

Figure 5 is a schematic diagram of one embodiment of the system in accordance with the present invention showing for wellsite capture devices and the single acid recovery station, with the rich solvent being demonstrated being transported
5 between these locations both by truck as well as by pipeline. Recycled lean solvent is also piped back to the wellsite locations from the central plant;

Figure 6 is a schematic diagram of one embodiment of an acid recovery apparatus in accordance with the present invention;

10

Figure 7 is a flow chart demonstrating the schematic steps of an alternate embodiment of the method of the present invention which includes a secondary absorption step at the wellsite to absorb and been desorbed on site at the wellsite carbon dioxide.

15

Detailed Description of Illustrated Embodiments:

As outlined in further detail above, it is the object of the present invention to provide an
20 improved method and apparatus for the stable recovery of acid gas fractions from a wellsite gas stream, removing or minimizing the need for acid gas discharge from well site to a centralized recovery facility.

Acid gas fractions which could be recovered:

Dependent upon the particular subterranean foundation in question there may be different
5 acid gas fractions present within a natural gas stream which may need to be removed to
yield clean natural gas for sale. Two of the primary acid gas fractions which are
particularly plentiful and problematic are carbon dioxide and hydrogen sulphide. Not
only is hydrogen sulphide one of the primary problematic acid gas fractions to be
extracted from sour wellsite gas streams, but the hydrogen sulphide which is recovered
10 can be further processed to obtain sulphuric acid, for resale or use in commercial
applications. However, there are other acid gas fractions which could also be targeted
using the method of the present invention.

For example, either in addition to hydrogen sulphide or as the primary and only target,
15 adopters of the method of the present invention may be primarily concerned with the
extraction and recovery of carbon dioxide from a sour wellsite gas stream, for the purpose
of purification of the gas stream for downstream sale or further processing.

In certain cases there may be other acid gas fractions within the natural gas as well which
20 it was desired to recover either for the purposes of purification or for further economic
benefit or use. Different acid gas fractions of a natural gas stream could be targeted using
the method of the present invention either by changing or adjusting the solvent which was
being used to absorb the acid gas fraction at the wellsite for remote or off-site processing,

or in certain circumstances the same solvent might be used but there might be the need for process parameter adjustments to optimize the absorption of a different acid gas fraction. These changes will be obvious to one skilled in the art of gas sweetening technologies and all such process modifications which do not depart from the central goal of the process of the present invention, namely the on-site absorption of one or more acid gas fractions from a wellsite gas stream into a solvent, for removal and centralized desorption from the solvent for further processing or disposal, are contemplated within the scope of the present invention.

10 It is also specifically contemplated that in certain cases if the appropriate solvent were used, the method of the present invention could actually be used to recover more than one acid gas fraction from the sour gas stream, and that the multiple acid gas fractions could be separately desorbed from the solvent. This is outlined in further detail elsewhere herein.

15

Solvent:

There are various solvents which could be used in the practice of the method of the present invention. The key qualities of the solvent which would be used would be that the solvent, when enriched with hydrogen sulphide or other acid gas fractions absorbed therein, would be a non-corrosive liquid which could be transported in a stable and safe manner.

Depend upon the chemical profile at the acid gas fraction which it was desired to remove from the natural gas stream in question there may be a single chemical agent which could be used as a fluid solvent to absorb that acid gas fraction, or, and as is more likely the
5 case, it may actually be a blend of more than one chemical agents which was used as a solvent in the remainder of the method of the present invention. While this document refers to "solvent" in the singular context, the possibility and in fact the probability of the solvent actually being a multiple chemical cocktail rather than a single chemical is explicitly contemplated to be encompassed within that singular reference.

10

The choice of solvents used would to a degree dictate the type of equipment implemented at the central plant location - for example based upon the type of process which was necessary to be used to desorb the acid gas fraction or fractions from the rich solvent, different types of processing equipment may be required, but will be understood that this
15 type of modification to the equipment that the central plant location is all contemplated within the scope of the present invention insofar as the general concept of the selection of a noncorrosive transportable liquid solvent within which to absorb acid gas fractions from a sour wellsite gas stream, for transport and subsequent recovery of the acid gas fractions at a central plant location is at the heart of the present invention. [Where we speak of the
20 absorbed acid gas fractions in the context of the rich solvent, it will be understood that those acid gas fractions will likely have undergone a phase change and will in fact not be gaseous but rather liquid or suspended solid within the solvent - simply for the sake of clarity and streamlining our language in this document will be understood where we refer

to the acid gas fractions as they have been absorbed into the solvent, in the rich solvent state, that the acid gas reference refers to the component of the rich solvent which went desorbed there from will revert to its gaseous acid phase].

5 The absorption and desorption approach to a particular natural gas source would depend upon the composition of the sour well gas or the natural gas source, as well as the pressure and temperature of that gas source. Finally another factor which could also be in the mix in terms of determining the nature of the process which would be undertaken or the selection of the lean solvent which would be employed would be the purity of the
10 separation which was required. At present it is specifically contemplated that one or more of the following currently available solvents would be used in the development and practice of the apparatus and method of the present invention:

- Any primary, secondary or tertiary amine like, MEA (Mono Ethanol Amine), Di
15 Ethanol Amine, Di Isopropyl Amine, Di Glycol Amine, MDEA (Methy Di Ethanol Amine)
- Morphysorb™ (Krupp-Uhde Process)
- Genosorb™ (Krupp-Uhde Process)
- Selexol™ (UOP Process)
- 20 ● Sulfinol™ (Shell Process)
- Rectisol™ (Methanol based Lurgi Process)
- Purisol™ (NMP based Lurgi Process)

It will be understood that this grouping of solvent options is only demonstrative of the types of lean solvents, or solvent components, which could be selected or considered for use in the practice of the method of the present invention depending upon the factors outlined above in terms of the particular acid gas fractions which were desired to be
5 extracted etc. Inclusion of this demonstrative list of solvent possibilities is not intended to be limiting upon the scope of the present invention outlined herein.

General method:

10

Reviewing first the general method we turn to Figure 1 which demonstrates at a schematic level steps involved in one embodiment of the method of acid recovery of the present invention. As outlined in general above, the concept of the present invention for the recovery of acid gas fractions from a natural gas stream at the wellsite, is to absorb
15 the desired acid gas fractions into an appropriate solvent at the wellsite, which solvent in its rich form containing absorbed desired acid gas fractions or gases is transportable and noncorrosive and to then transport that rich solvent to a central plant location at which the acid fractions will be desorbed or removed from the solvent for further processing or disposal, and the solvent at that point, being lean and having had the acid fractions
20 removed there from can be recycled for reuse at the wellsite in the ongoing practice of the method of the present invention.

Where the gas stream which is being purified in accordance with the method of the present invention is a wellsite natural gas stream, the first step in the method of the present invention is to precondition the natural gas to remove the first series of condensates from the natural gas either for the purpose of cleaning the gas or for the purpose of the economic recovery of those condensates. For example in traditional or conventional natural gas sweetening applications, the preconditioning of natural gas will yield potentially water from the subterranean formation which can be disposed or pumped back down a well, as well as a hydrocarbon condensate which is economically viable and separately salable, and results in a cleaner natural gas stream for the next steps in the process. Referring to Figure 1, the preconditioning of the natural gas stream is shown at step 1-1. Conventional preconditioning methods for natural gas sweetening can be used. Also shown at block 1-8 in this Figure is the actual removal of the condensate recovered from the preconditioning process.

Once the natural gas stream which it is desired to recover the acid gas fractions from has been preconditioned in this way, the next step which will be undertaken is the absorption of the selected acid gas fraction or fractions into the solvent. The absorption step is shown at 1-2. The absorption step would be carried out using a wellsite absorption apparatus as is described elsewhere herein -- the selected acid gas fraction or fractions would be absorbed into the solvent bypassing the natural gas stream through the solvent under a predetermined set of parameters.

The key aspect of this step of the present invention is to understand the qualities of the solvent which will be used. Specifically, the solvent which will be selected will depend upon the specific acid gas fraction or fractions which are desired to be removed from the natural gas stream since certain solvents will beneficially absorb certain gases but not
5 others. The specific process steps involved in this acid absorption step will depend upon the gas stream, the acid gas fraction in question as well as the solvent insofar as certain solvents will have varying process requirements to accomplish the absorption of the desired acid gas fractions into the solvent. The necessary equipment will be provided at the wellsite or at the natural gas stream to accomplish the objective of connection of the
10 solvent absorption equipment to the natural gas stream and perform the necessary process steps to yield the transformation of the bare or lean solvent [being the solvent in its clean form not having absorbed the desired acid gas fractions], to a rich solvent into which the desired acid gas fractions have been absorbed. For example where the acid gas fraction which is desired to be removed is hydrogen sulphide, a solvent could be used to
15 selectively absorb pure hydrogen sulphide from a hydrocarbon sour gas stream to yield a benign liquid form rich solvent which can be safely transported and is noncorrosive.

Following the passage of the through the solvent, at the absorption step, will be "clean". The transmission of the clean gas from the wellsite is shown in this case at step 1-3. It
20 will also be understood that the transmission of the clean gas could logically be understood to take place at the end of this block diagram but that one where the other following the absorption of the selected acid gas fraction or fractions from the natural gas in question, clean gas will be available for transmission to the sale grid.

The clean gas transmission step would potentially include treating the clean natural gas devoid of the selected acid gas fractions for moisture removal in advance of its conveyance for sales into the clean gas pipeline grid which is typically available at close
5 proximity to the well site.

At step 1-4 the transportation of the rich solvent, containing the selected absorbed acid gas fractions, to a central plant location is shown. At the central plant location, the acid gas fractions will be desorbed from the rich solvent, shown at 1-5, to yield lean solvent
10 which can be recycled back in the process, shown at step 1-7, and the desorption of the acid fractions from the rich solvent 9 will result in the availability of relatively pure acid gas which can be processed or otherwise disposed of further, shown at step 1-6. In the example of the selected acid gas fraction being extracted from the natural gas and hydrogen sulphide, the recovered acid gas fraction which will be desorbed from the
15 solvent would be basically pure hydrogen sulphide which could be processed further into sulphuric acid or for other purposes. The specific mechanics of recovery of those acid gas fractions from the rich solvent, and the necessary equipment to accomplish this, will depend upon the solvent which is being used as well as the behavior of the acid gas fraction or fractions in question -- this step in the process will need to be tailored to
20 include the necessary specific process steps to liberate the acid gas fraction or fractions in question from the solvent, yielding a pure acid gas fraction and a lean solvent, the lean solvent being the solvent with the absorbed acid gas fractions having been removed there from. The lean solvent, being the one result of this process step, can then be recycled

back to one or more wellsite absorption locations for reuse in the method of the present invention, and the liberated pure acid gas fractions can be further processed or disposed at the central plant location. The ability to recycle the solvent which is chosen, yielding zero or minimal solvent discharge from the method of the present invention is one

5 significant benefit both in terms of environmental impact as well as cost of the process, since by recycling the solvent not only is it possible to minimize the ongoing purchase amount but also to minimize environmental impact by the discharge of even relatively inert spent solvents.

10 By recovering one or more selected acid gas fractions from the sour natural gas at the wellsite, the remaining sweet gas at the wellsite following absorption of the acid gas fractions there from can be immediately forwarded on for sale or further processing. Absorption of the acid gas fraction or fractions into a solvent for remote acid recovery also reduces the amount of equipment required at the wellsite to remove these acid gas

15 fractions and as such will be economically beneficial to well operators. Even in circumstances where the wellsite location was not connected to any kind of a pipeline for transport of the rich solvent and the rich solvent was stored in a tank or the like pending transport by truck or otherwise to the central plant location, the noncorrosive and safe nature of the rich solvent will mean that even the storage equipment such as tanks and the

20 like can be manufactured of regular materials rather than the need to use higher cost and noncorrosive materials.

As will be specifically outlined in more detail below, it is contemplated that the equipment which would be used at the wellsite to absorb the selected acid gas fractions into the selected solvent for transport to the central plant location could be containerized or could otherwise be rendered relatively portable so that it could be moved from location to location as certain wells were either retired or even shut down on a periodic basis, so that the equipment utilization by the operator could be maximized and even the waste of consumable or equipment and materials at wellsites would be minimized such that upon closure of a well would not be such a significant sunken cost in wasted materials or equipment abandoned that the wellsite or otherwise no longer of use. Similarly in certain circumstances it is contemplated that even the central plant location equipment could be rendered portable so that the central plant location could be moved or beneficially located in relation to a plurality of wellsites within a proximal drilling area. The central plant location could also of course be a permanent installation, and this would just require some modification to the length of transportation required to transport the rich solvent for processing into extract of acid gas fractions and lean solvent which could then be recycled back to the wellsite.

Preconditioning of the sour gas:

20

As was mentioned above the first step in the general method of the present invention of the capture and remote recovery of acid gas fractions from natural gas

is the preconditioning of the natural gas stream. As outlined, preconditioning the natural gas in a conventional context consists of removing certain condensates from the gas before it's further processing. For example, water might be removed as natural gas coming from a certain type of a subterranean formation would be more heavily laden with water. The water typically is other disposed or pumped back down an empty well. In any event it needs to be removed before the natural gas can be further processed and transmitted. In addition to the removal of water the other type of condensate which may be desired to remove the preconditioning step would be hydrocarbon condensate. The hydrocarbon condensate actually can have many types of specific hydrocarbon contents including gasoline etc., and the hydrocarbon condensate which is removed during traditional natural gas sweetening processes commands a strong economic value. On that basis as well as for the fact of rendering or yielding clean natural gas, the preconditioning step would be undertaken in advance of the absorption of the selected acid gas fractions out of the natural gas into the solvent cocktail.

Insofar as preconditioning of natural gas is a conventional process step known in the art it will be understood to those skilled in the art the different types of preconditioning techniques and apparatus which could be used. Any preconditioning step or apparatus which could be used to accomplish the objective of the removal of water, hydrocarbon or other condensates from the natural gas stream is contemplated within the scope of the present invention.

Wellsite capture apparatus:

In addition to the general concept and method of the present invention it is also specifically contemplated that the invention encompasses the actual wellsite capture apparatus used to absorb the selected acid gas fraction or fractions into the solvent for transport and further processing. A portable wellsite capture apparatus which can be operably connected to a natural gas stream as well as to a source of a selected lean solvent into which one or more selected acid gas fractions can be absorbed is contemplated within the scope of the present invention. In addition to the operable connections to the natural gas stream and the source of the selected lean solvent, the wellsite capture apparatus would include at least one solvent absorption unit, comprising the equipment necessary to effect the absorption of the selected acid gas fraction or fractions into the selected lean solvent. Specific equipment which would comprise the at least one solvent absorption unit would vary dependent upon the selection of the lean solvent, the acid gas fraction or fractions which were desired to be absorbed, and the necessary process or parameters which would be required in order to effect that absorption. The final component of the wellsite capture apparatus, in addition to the gas source interface, lean solvent source interface and solvent absorption unit or units would be a rich solvent discharge interface. The rich solvent discharge interface would either be a connection to a tank or other storage vessel, or a pipeline or the like, through which the rich solvent containing the absorbed acid gas fraction or fractions could be stored or transported for eventual downstream processing at the central plant location.

The selected solvent source could be integral with the remainder of the wellsite capture apparatus such as a tank or the like, or it could be a pipeline connected to a remote source of the selected solvent.

- 5 The portable wellsite capture apparatus might also optionally include the necessary equipment for the preconditioning of the natural gas stream. The preconditioning equipment could be incorporated into the wellsite capture apparatus, or insofar as conventional or prior Art preconditioning methods are contemplated or might be used the preconditioning equipment could also be separate and the natural gas stream could
- 10 basically be preconditioned in advance of its entry into the portable wellsite capture apparatus.

For the sake of demonstration of the general concept of the portable wellsite capture apparatus of the present invention we refer to Figure 2. The portable wellsite capture

15 apparatus 23 would include at least one solvent absorption unit 8 which would comprise the necessary equipment to effectively absorb one or more selected acid gas fractions from a natural gas stream into a solvent. The solvent absorption unit 8 might comprise one or more actual physical pieces of equipment regardless of the number of acid gas fractions which were desired to be absorbed into the solvent in question. It may also be

20 the case that if more than one acid gas fraction were desired to be absorbed from the natural gas source that more than one type of process would need to be employed to absorb the respective acid gas fractions into the lean solvent in question and on that basis it may be the case that if more than one acid gas fraction were contemplated to be

absorbed into the lean solvent in question, more than one solvent absorption unit 8 may be required.

The at least one solvent absorption 8 would be connected to a natural gas stream 7 by a
5 natural gas stream interface 11. The natural gas stream interface 11 may be simply a connection directly to the sour gas stream at the wellsite, or there may be additional preconditioning taking place of the sour gas in advance of its introduction into the apparatus 23. In any event, a natural gas stream interface 11 would be the source of sour
10 gas from which it was desired to remove or absorbed the one or more selected acid gas fractions. As outlined, it is likely that the sour natural gas which was interfaced to the apparatus at 11 would be preconditioned to remove certain condensates in advance of the acid gas fraction absorption step.

In addition to the natural gas stream interface 11, the at least one solvent absorption unit 8
15 would be connected to a source of a lean solvent 6. The lean solvent would be a solvent which was capable upon the application of certain process parameters in contact with the natural gas stream 7 to result in the absorption of one or more selected acid gas fractions from the natural gas stream 7. The lean solvent source 6 might be a tank, pipeline or otherwise, and it would be operably connected to the at least one solvent absorption unit
20 8 by a lean solvent interface 10.

Lean solvent 6 and the sour natural gas stream 7 are the two product inputs to the at least one solvent absorption unit 8 which conducts the step of absorption of one or more

selected acid gas fractions from the sour gas stream 7 into the lean solvent 6, yielding rich solvent 9 containing the selected acid gas fractions in a benign and transportable liquid form. Rich solvent 9 would be discharged from the at least one solvent absorption unit 8 by a rich solvent discharge 12, which could again be a connection to a tank, directly to a transport vessels such as the trailer or a train car, or to a pipeline in a local or longer distance application of the system and method of the present invention.

Finally shown in Figure 2 is the sweetened gas discharge 25. Following absorption of the selected acid gas fractions from the natural gas stream 7, the remaining gas stream would be sweetened natural gas 24 which could simply be piped, stored or otherwise transported or processed in accordance with conventional handling practices.

As outlined elsewhere above, the specifics of the solvent absorption unit or units 8 will be dependent upon the lean solvent 6 which is selected for use in the absorption of whatever the selected acid gas fraction or fractions might be. Dependent upon the solvent selection and the acid gas fractions in question, different types of solvent absorption equipment or techniques might need to be practiced and any equipment which will accomplish the objective of absorbing the selected acid gas fractions from the natural gas stream 7, via the natural gas stream interface 11, into the lean solvent 6 via its interface with the remainder of the unit 10, to yield a rich solvent 9 and a sweetened natural gas 24 are contemplated within the scope of the present invention.

The wellsite capture apparatus, as outlined, could either be portable and/or containerized so that it could be moved between wellsites or natural gas source locations, or it could be a permanent installation. Either circumstance is contemplated within the scope of the present invention.

5

Transport of rich solvent:

Once the one or more acid gas fractions have been absorbed into the solvent at the wellsite, yielding a rich solvent, the rich solvent is transported to a central plant location where the acid gas fractions can be removed from the solvent for further processing or disposal. The primary benefit to recovery of the acid fractions at a central plant location is that rich solvent for more than one wellsite location can be processed in a single central plant location, substantially reducing the infrastructure investment which is required to properly handle the recovery of these acid gas fractions in a drilling field or in respect of a drilling field insofar as the solvent would be benign and transportable, various methods of transport or movement of the rich solvent can be contemplated, including by truck, train, pipeline or otherwise. The specific mode of transport of the rich solvent from the wellsite location to the central plant location will be understood to encompass all of these varying types of transportation, and any type of a transportation method which would allow for the movement between locations of the rich liquid solvent are contemplated within the scope of the present invention.

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Acid recovery step:

The next step in the method of the present invention, following the transport of rich
5 solvent from one or more wellsite capture locations to a central plant location, is to
recover the absorbed acid gas fractions from the rich solvent. The acid recovery step
would be conducted at a central plant location, being a location different from the wellsite
capture location where the at least one desired acid gas fraction has been absorbed into
the lean solvent 6, to create the benign transportable rich solvent 9.

10

The acid recovery step as would be conducted at the central plant location would
comprise the conduct of whatever predetermined set of acid recovery steps or process
parameters were required to be conducted or applied to the rich solvent to recover the
absorbed acid gas fractions there from. The specifics of the acid recovery process would
15 be dependent upon the choice of the lean solvent as well as the acid gas fractions
sequestered therein, since depending upon what was required to desorb the acid gas
fractions from the solvent those would be the steps, parameters or equipment required to
accomplish this process step.

20

Acid recovery apparatus:

The acid recovery step of this process of the present invention would be conducted using an acid recovery apparatus at the central plant location. One embodiment of the general schematic of acid recovery apparatus in accordance with the present invention is shown in Figure 3.

5

The first element of the acid recovery apparatus 27 is a connection or interface 19 with a source of rich solvent 9. The rich solvent 9 would be the solvent which had absorbed the at least one selected acid gas fraction at one or more wellsite capture locations, and the rich solvent interface 19 of the acid recovery apparatus 27 might either comprise a
10 connection to a storage tank or storage vessel where trucks or other transport vessels had been used to deposit the rich solvent 9, or might also comprise depending upon the configuration of the remainder of the system and method of the present invention a pipeline connection to a pipeline carrying the rich solvent 9 or even a direct connection to a truck trailer etc. a loading facility whereby trailers or train cars etc. could be attached
15 temporarily for the sake of unloading and then removed and used to go and transport more rich solvent 9, perhaps also with a load of lean solvent 6 being conveyed back to the wellsite.

In addition to the rich solvent interface 19, the acid recovery apparatus 27 would
20 comprise at least one acid extraction unit 14. The acid extraction unit 14 would comprise whatever equipment was necessary to effect the removal or recovery of at least one of the absorbed acid gas fractions from the rich solvent 9. In this particular case, two acid extraction units 14 are shown, to demonstrate the concept of the capture and/or removal

of more than one acid gas fraction, by the conduct of more than one acid extraction step. Specifically, there is shown a first acid extraction unit 14 which would comprise whatever equipment or process was necessary to recover a first recovered acid gas fraction 15. The first recovered acid gas fraction 15 is in this case shown as well as a first recovered acid gas fraction discharge interface 20 which would basically be an interface to a storage tank or other apparatus into which the recovered acid gas fraction 15 would be conveyed. In this particular case there is then also shown a second acid extraction unit 14 which is intended to demonstrate the recovery of at least two acid gas fractions using this acid recovery apparatus 27. There is shown connected to the second acid extraction unit 14 a lean solvent discharge interface 21, as well as the lean solvent 6 being shown-as outlined elsewhere herein it is contemplated that at the conclusion of the acid recovery step the original lean solvent 6 would be fairly clean if not purified of the presence of any residual acid gas fraction there from and could be reused at wellsite in the practice of the method of the present invention. Also shown in respect of that second acid extraction unit 14 is a second acid gas fraction discharge interface 22. For the sake of demonstration of additional equipment which could optionally be included in the acid recovery unit 27, there is also shown an additional acid gas fraction processing step 16. Additional acid gas fraction processing equipment 16 could actually be a part of the acid recovery in the 27 or else the acid gas fraction discharge interface 22 could simply be connected to additional but separately containerized or separately mounted acid gas fraction processing equipment 16. In any event following the acid gas fraction processing step and equipment shown at 16, there is shown a processed acid gas fraction 17 and a discharge 23.

As mentioned above, the acid recovery equipment which would be used in accordance with the method of the present invention could be containerized or manufactured in such a way that it could be moved between locations, so that either is fed by local pipelines or
5 even if so as to allow for relatively short haul local transport of rich solvent from the wellsite to the central plant location, the acid recovery equipment of the present invention could it will be understood either be manufactured in a portable fashion, or in a permanent installation, and either such approach is contemplated within the scope of the present invention.

10

Central plant location:

One of the key elements of the method of the present invention is that the recovery and
15 downstream processing of the acid gas fractions from the rich solvent will take place at a central plant location, different from the wellsite. By development of a method for the recovery of acid gas fractions from a sour wellsite gas source which allows for the aggregation of certain portions of the process, equipment costs are minimized and in the system and method of the present invention the absorption of the desired acid gas
20 fractions into a benign transportable liquid solvent also has environmental and safety benefits.

As outlined elsewhere herein the central plant location which could be used in accordance with the method of the present invention could either be in fairly close proximity to one or more wellsite locations, where for example that was desired to use a containerized or portable acid recovery apparatus which was connected by low cost local pipelines to a plurality of acid absorption locations, or it may be the case that it was desired to aggregate the rich solvent 9 from a larger number of natural gas stream originating points and transported longer distances to a larger central plant location. Either approach is contemplated within the scope of the present invention.

Figure 4 demonstrates a first hardware configuration of the system of the present invention, comprising at least one wellsite capture unit 23 and at least one acid recovery unit 27 at a central plant location. In this particular case there is shown a wellsite 1 to which the wellsite capture apparatus 23 is connected via a natural gas stream interface 7. The details of the wellsite capture equipment 23 are discussed elsewhere herein. Shown in this particular figure is a tank for the storage on-site of lean solvent 6 as well as another tank for the capture and storage of the rich solvent containing absorbed acid gas fractions 9. In this particular case the interface or mode of movement to the rich solvent 9 between the wellsite capture apparatus 23 in the central plant location and apparatus 27 is a truck. It will be understood that in an embodiment such as this the infrastructure costs are minimized as no pipeline is used between the wellsite capture 23 in the central plant location 27. Multiple wellsite capture locations 23 could be transported to a single central plant location 27 for desorption. As well, presumably lean solvent which was

recovered at the central plant location 27 could be transported back from the central plant location 27 to the wellsite 14 use again by the wellsite capture 23.

Another specific embodiment of the present invention which is contemplated would be to
5 create on a local drilling field basis a network of temporary pipelines, which could be manufactured of relatively inexpensive material since it would not need to be noncorrosive, which would feed to a locally installed temporary central plant location. For example the absorption equipment to be used at the wellsite would likely be containerized in some way so that it could be moved between different locations, and it
10 could similarly be the case that the acid recovery equipment could also be containerized but configured in such a way that for example one set of acid recovery equipment on a skid could be used to process rich solvent from a plurality of central plant locations.

In the embodiment of the network of the present invention where the central plant
15 location was connected by relatively low cost pipeline to the well heads, in addition to piping the rich solvent 9 to the central plant location it would also be possible to pipe the lean solvent 6 once the absorbed acid gas fractions were removed therefrom back to the wellsite locations for reuse.

20 Figure 5 demonstrates one embodiment of this type of a local acid recovery network, comprising at least one wellsite capture device 23 capable of absorbing at least one acid gas fraction into a lean solvent 6, yielding a rich solvent 9, which can be transported to a central plant location and unit 27 for liberation of the acid gas fractions therefrom. The

central plant location 27 would in turn contain the necessary equipment to these orb or
remove the absorbed acid gas fractions from the rich solvent 9, yielding at least one
recovered acid gas fraction 15, and lean solvent 6 which could be reused. In the
embodiment of Figure 5 there are shown four wellsites 1, 3 of which are connected by
5 way of pipeline from their respective wellsite capture unit 23 to the acid recovery device
27. The fourth wellsite 1 and related wellsite capture apparatus 23 is shown with a truck
representing the ability to in this type of a network configuration encompass various
modes of transport of rich solvent.

10 Also shown in Figure 5 is a plurality of pipelines from the central plant location back to
the wellsite locations 21, which represent the piping back of cleaned lean solvent to the
wellsite recovery apparatus too be reused.

15 ***Recycling of solvent:***

One of the key benefits to the method of the present invention is that upon extraction or
desorption of the acid gas fractions from the rich solvent at the central plant location, the
lean solvent can be reused in the method of the present invention by transporting it back
20 to a wellsite or gas source location. The ability to recycle solvent will have a great
economic benefit but will also result in significant environmental improvements since
there will be no solvent discharge, or at the very least very little or minimal solvent

discharge, employing the method of the present invention in comparison to a method where the solvent would be disposed.

It will also be understood that upon removal of the absorbed acid gas fractions from the rich solvent 9, the recovered lean solvent 6 could also be stored or repurposed for other use. The only limitation on the ability to reuse the lean solvent 6 for purposes other than reuse in the method of the present invention would be the level of purification which was achieved at the central plant location but it is believed that a clean lean solvent 6 can be yielded. Slight impurities in the lean solvent 6, being inclusions of small amounts of residual acid gas fractions, would not be problematic in terms of the reuse of the solvent in the method of the present invention, since the lean solvent 6 would effectively just be transported back to a wellsite location for use.

15 ***Recovery of multiple fractions using a single solvent:***

It is specifically contemplated that by choosing the correct lean solvent solution 6 for use in accordance with the remainder of the system and method of the present invention that more than one acid gas fraction might be recovered from the natural gas stream 7. As outlined elsewhere herein it is contemplated that the solvent, per se, would consist of a plurality of chemical agents designed to provide beneficial absorption characteristics for the selected acid gas fractions under field operation parameters. There exist solvents 6 which could individually take up more than one acid gas fraction from the natural gas

stream, perhaps based upon the application of different absorption techniques to accomplish the absorption of each such selected acid gas fraction into the lean solvent 6. For example it is specifically contemplated that in the case of hydrogen sulphide and carbon dioxide, solvents exist which could absorb both of these acid gas fractions for the benign transport of the rich solvent containing both products, and that these individual acid gas fractions could then also be desorbed or removed from the rich solvent at the central plant location.

It will be understood that those skilled in the art will be able to conceive of particular combinations of lean solvent materials 6 and solvent absorption units 8 and absorption parameters or processes which will result in the ability to absorb more than one acid gas fraction into a single lean solvent 6 yielding a rich solvent containing more than one acid gas fraction which can in turn be individually removed at the central plant location and all such changes are again contemplated within the scope of the present invention.

15

Combined local and remote recovery:

It is further contemplated that the method of the present invention might be altered to allow for the combination of local gas fraction capture or segregation from the natural gas stream of certain acid gas fractions, while the solvent absorption and remote recovery of certain other acid gas fractions might still be conducted in accordance with the remainder of the method of the present invention as described herein. It is specifically contemplated

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for example that it may be possible to locally segregate carbon dioxide in the hydrocarbon application, the carbon dioxide being one acid gas fraction, while hydrogen sulphide or other acid gas fractions could still be absorbed into a solvent for transport and remote removal. In a case such as this it is believed that body modification of the solvent
5 absorption unit 8 to add whatever other necessary equipment was required, and perhaps by adjusting the selection of lean solvent 6 which was used, it would be possible to recover some acid gas fractions simply at the wellsite which do not require significant infrastructure or hardware investment [such as in the right embodiment the recovery of carbon dioxide for local storage, segregation, sequestration or resale] while still providing
10 for the remote recovery of other acid gas fractions which are more difficult to handle or require more extensive equipment etc.

Figure 6 is provided to demonstrate an alternate schematic for a wellsite capture unit 23 which shows a locally captured fraction 30 and a local capture fraction interface 29. It is
15 contemplated that by selecting an appropriate lean solvent six and making appropriate revisions to the wellsite capture unit 23 it would be possible to capture and segregate at the wellsite carbon dioxide for example as a target acid gas fraction, while other acid gas fractions such as hydrogen sulphide etc. were absorbed into the lean solvent 6 for inert transport and subsequent desorption or liberation from the solvent at a central plant
20 location.

The necessary equipment modifications which would be required to the wellsite capture equipment 23 to allow for this type of a hybrid local and remote acid recovery method

will be understood by one skilled in the art and are all contemplated within the scope of the present invention.

Referring to Figure 7 there is shown a schematic of one embodiment of the method of the present invention which incorporates a local capture step for the local segregation of one acid gas fraction and the absorption of another acid gas fraction or fractions into a solvent for remote recovery. It is specifically contemplated that this type of a method would be used to the location of the well site separate carbon dioxide, being one acid gas fraction, from the sour natural gas and following the absorption of that carbon dioxide on-site to simply desorbed it again right away for release or for sequestration.

The first number of steps shown in Figure 7 are similar to those of the method of Figure 1. The first step in the process is the preconditioning of the sour natural gas stream, to remove condensates there from. The preconditioning step, and the removal of the condensates from the natural gas and for further processing, sale or otherwise is shown at steps 7-1 and 7-11. Following the preconditioning of the natural gas stream there would again be an absorption step in the process, shown at 7-2, in which it is contemplated that one or more acid gas fractions which were desired to be remotely processed and removed would be absorbed into a solvent, yielding a rich solvent. The rich solvent would then be transported at 7-3, to a remote central plant location at which the acid gas fractions would be desorbed from the rich solvent to yield acid gas fractions in a purified state and lean solvent for recycling. It is then contemplated that the lean solvent would be reused back at the well site to absorb carbon dioxide, being another acid gas fraction which would be

desorbed on site so that it could be processed or disposed of on site without the need for transport. It could be the case that the same solvent could be used or designed which would absorb both the other acid gas fractions desired to be liberated from the natural gas as well as the carbon dioxide, or it will also be understood that different solvent could be used. The preferable embodiment here is that the same solvent will be designed to be used in the absorption or removal of all of the desired acid gas fractions including hydrogen sulfide, carbon dioxide or optionally any other acid gas fractions with the necessary adjustments to the process parameters to activate or enhance the behavior of that solvent package with respect to the particular acid gas fractions in question. Shown and then finally in this Figure is the transmission of clean natural gas, which again may also include traditional or conventional moisture treatment steps etc.

The product, sulphuric acid:

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Where the acid gas fraction which was absorbed from the sour natural gas for remote recovery was hydrogen sulfide, the next process step which can be added at the central plant location is the processing of that hydrogen sulfide gas into sulfuric acid. It is explicitly contemplated that sulfuric acid which is created as a result or in accordance with the method of the present invention, namely the absorption of hydrogen sulfide gas from sour well gas at the wellsite into a safe transportable solvent from which the hydrogen sulfide can then be desorbed at the plant location, followed by processing of that desorbed or liberated hydrogen sulfide which will be relatively pure into sulfuric acid

is contemplated within the scope of the present invention. Any sulfuric acid which is produced from or using hydrogen sulfide liberated from sour well gas in accordance with the method of the present invention is contemplated within the scope hereof.

5

The product, agricultural fertilizer

In addition to the product sulfuric acid processed or manufactured from hydrogen sulfide recovered from sour natural gas in accordance with the method of the present invention,
10 another product which is explicitly contemplated as well as a method extension, is agricultural fertilizer containing sulfur which is manufactured using the sulfuric acid of the present invention. Following production of sulfuric acid from the hydrogen sulfide which is relatively pure and which is recovered from the rich solvent at the plant location [which sulfuric acid could be manufactured at the plant location or could also be
15 manufactured following transporter transmission of the hydrogen sulfide gas although safety would be enhanced or maximized by on-site or combined location manufacture of the sulfuric acid in addition with the extraction of the hydrogen sulfide from the rich solvent] it is explicitly contemplated that the sulfuric acid produced in accordance with the remainder of the present invention could be used in the production of agricultural
20 fertilizers. Any agricultural fertilizer which is manufactured using sulfuric acid prepared in accordance with the present invention were prepared using hydrogen sulfide gas recovered from sour natural gas in this way is contemplated within the scope of the present invention. Various types of fertilizers are contemplated including a moan he

aided or phosphate fertilizers. Any agricultural fertilizer which uses sulfuric acid manufactured from hydrogen sulfide which is the product of the method of the present invention as a feedstock is contemplated to be covered within the present invention.

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The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous changes and modifications will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all such suitable changes or modifications in
10 structure or operation which may be resorted to are intended to fall within the scope of the claimed invention.

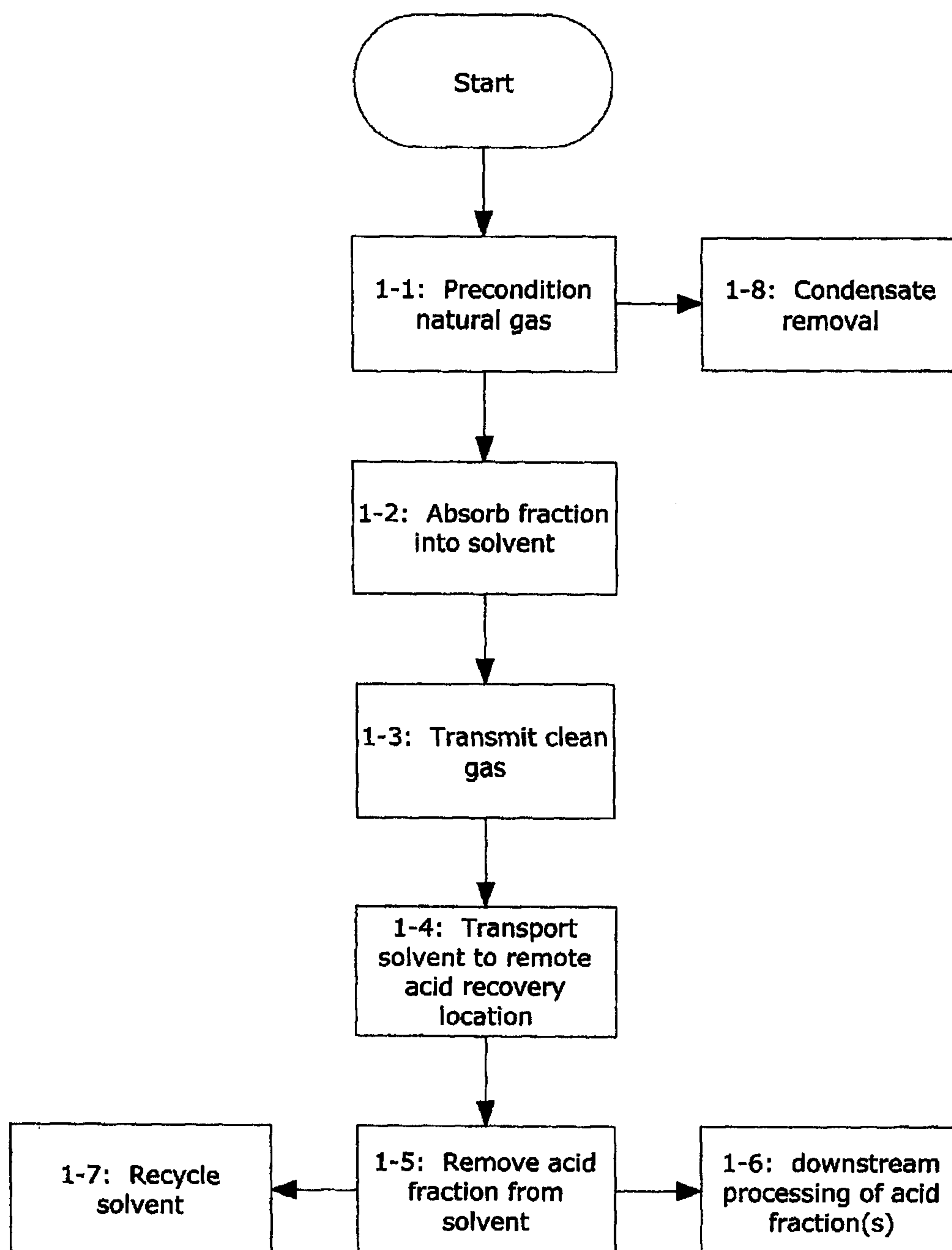
FIGURE 1:

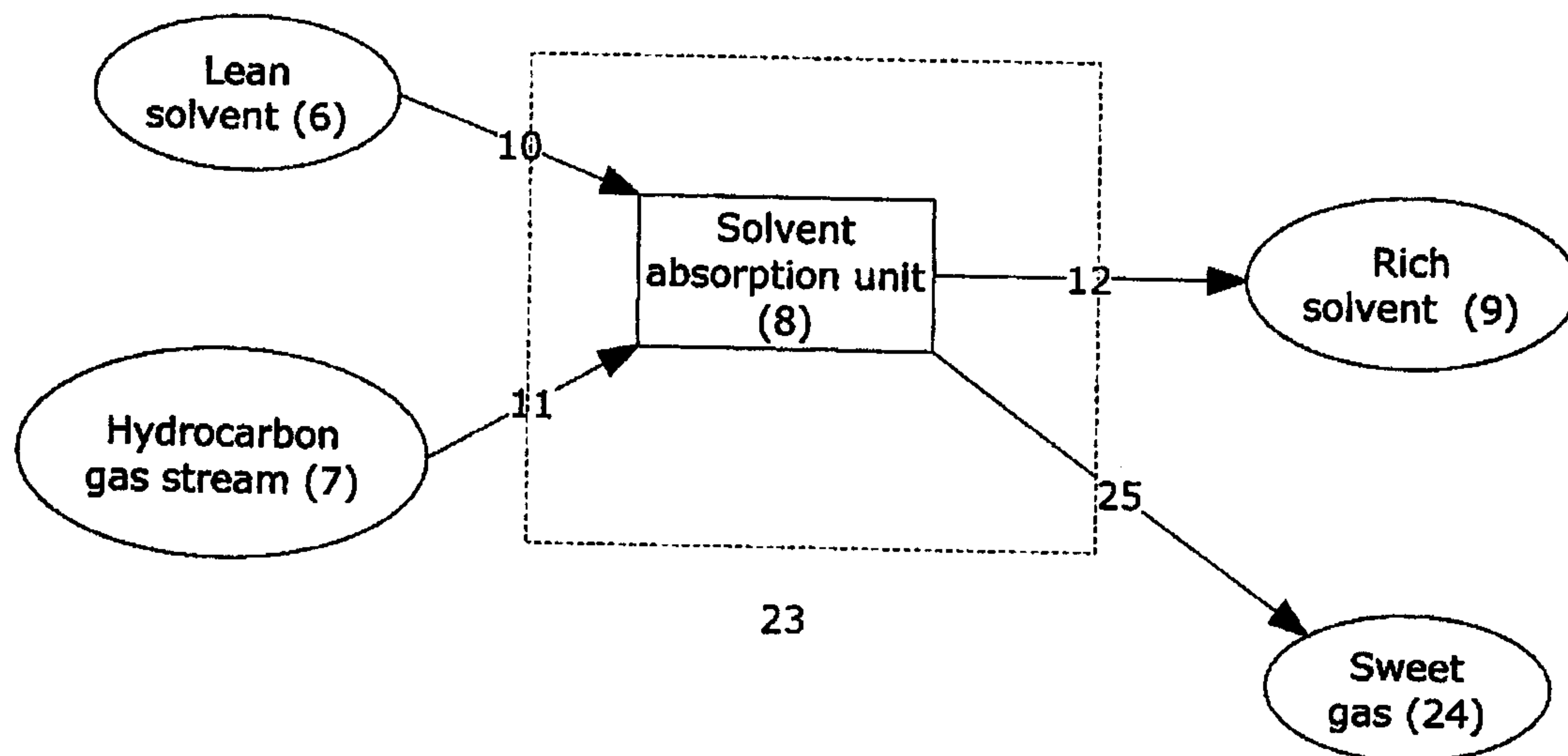
FIGURE 2:

FIGURE 3:

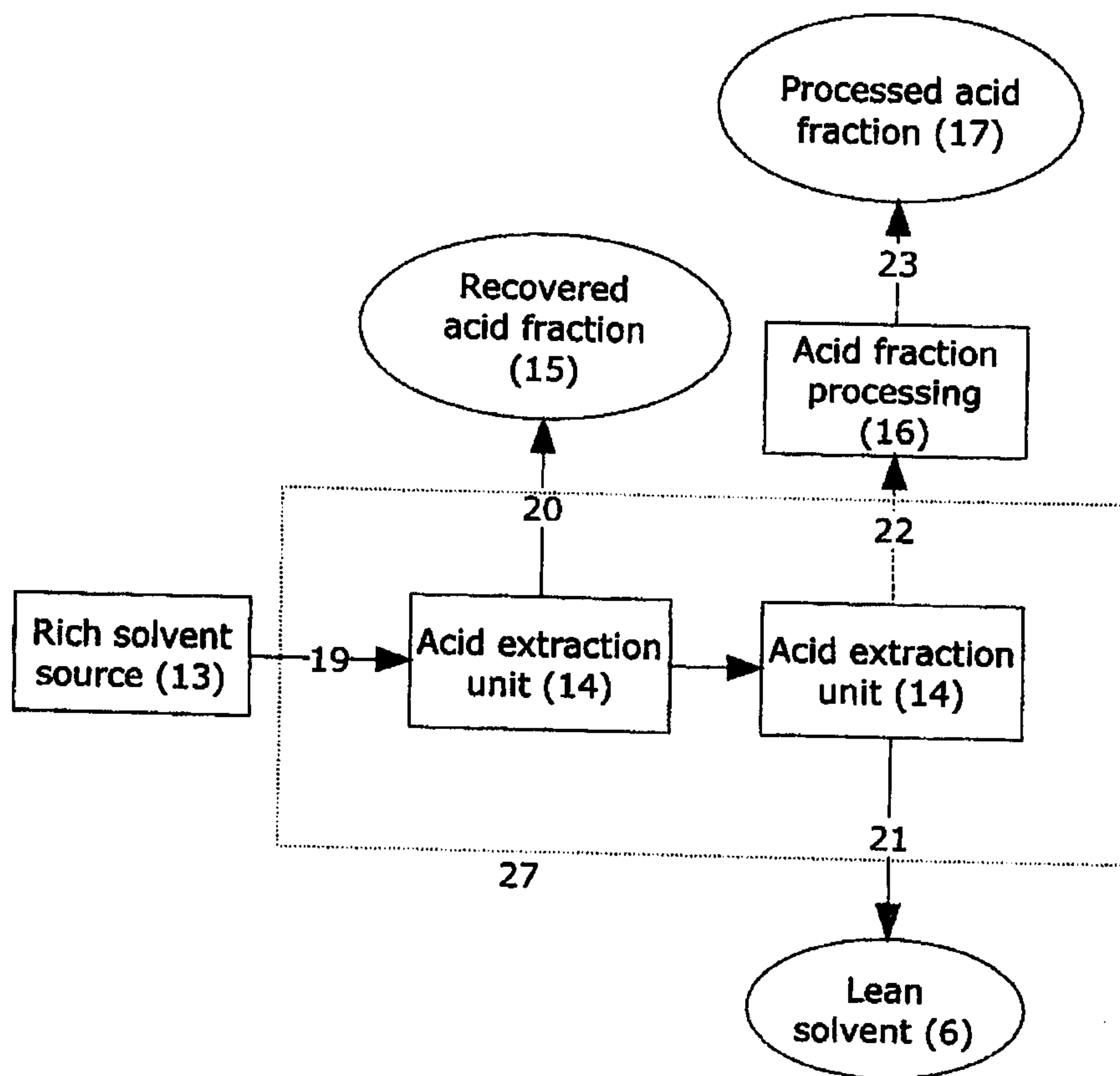


FIGURE 4:

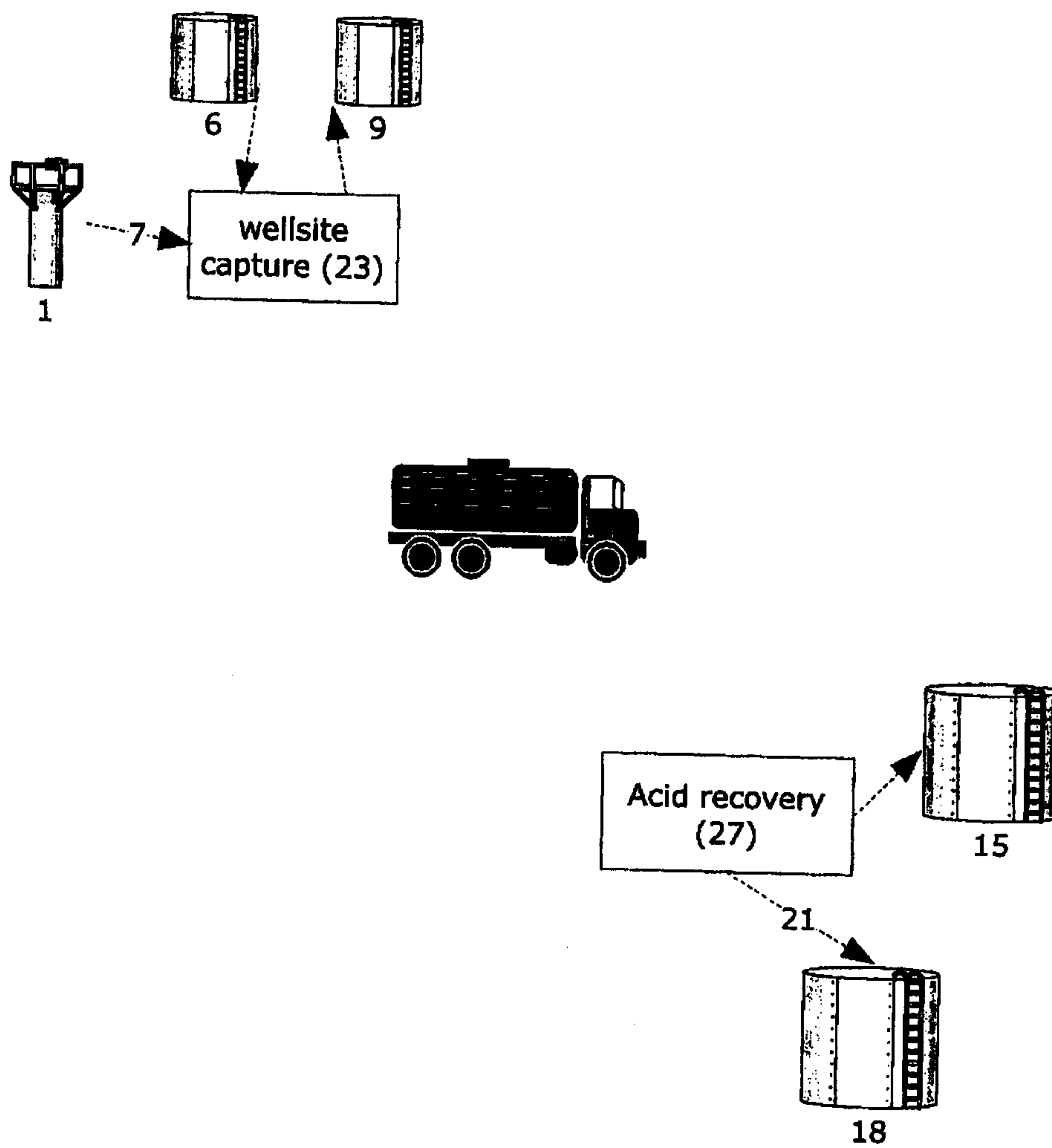


FIGURE 5:

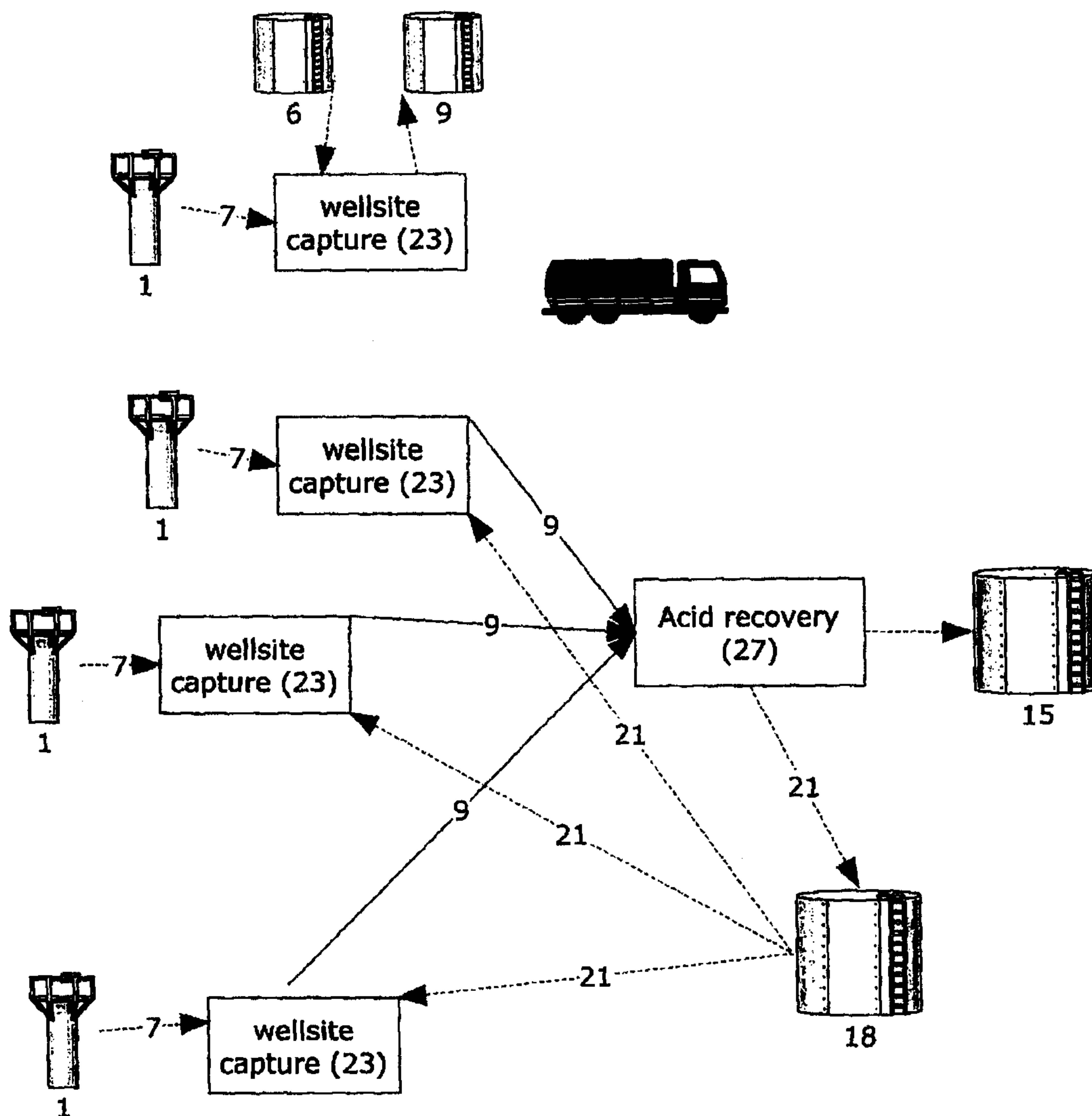


FIGURE 6:

