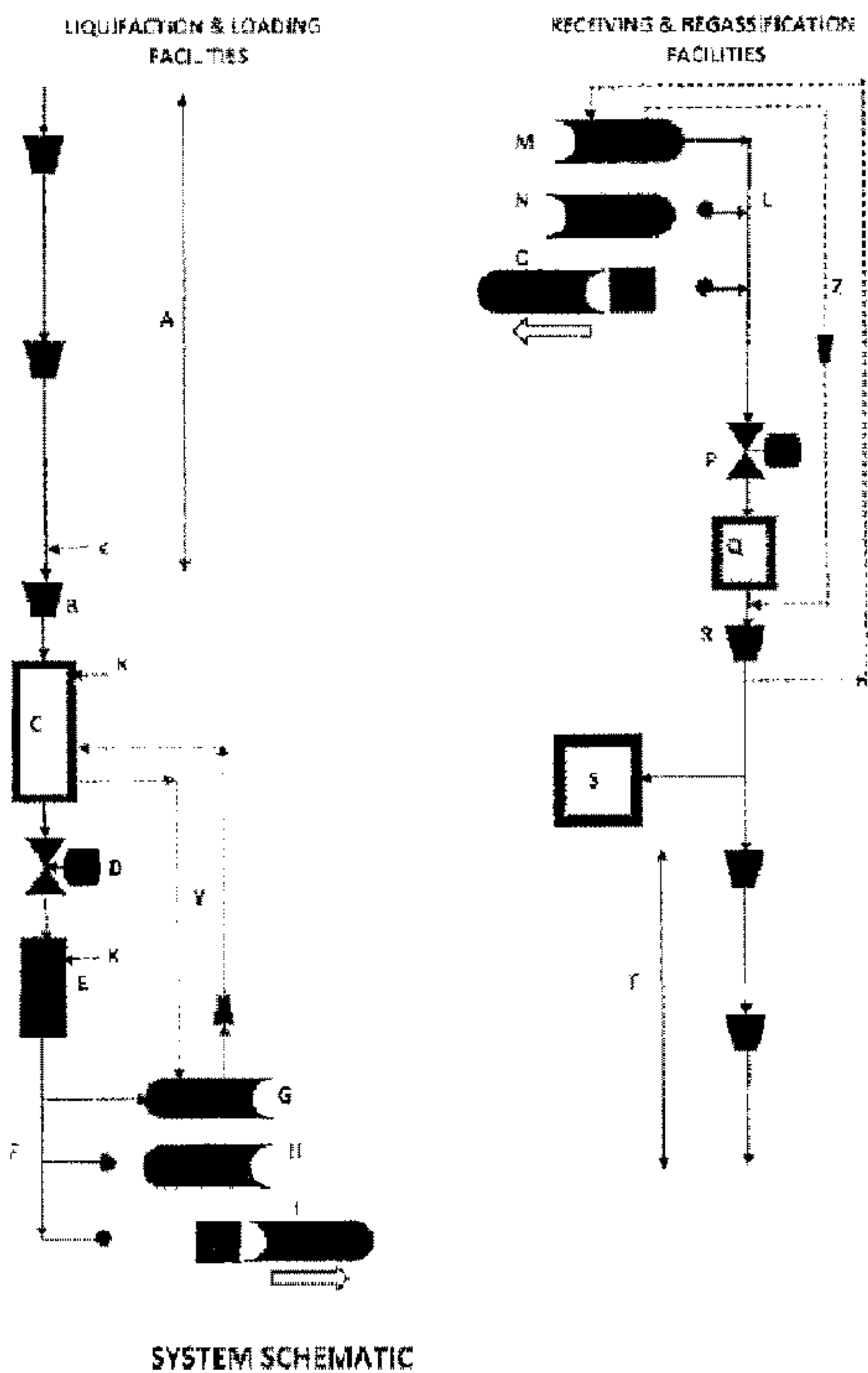




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(72) Inventeurs/Inventors:
MORRIS, IAN, CA;
HOLMAN, DAWN MARIE, CA
(73) Propriétaire/Owner:
MATRIX LNG CORP., CA
(74) Agent: BENNETT JONES LLP

(54) Titre : TRANSFERT DE GAZ NATUREL DIRECTEMENT D'UN PIPELINE VERS UN ENTREPOT DE LIQUIDE
(54) Title: TRANSFER OF NATURAL GAS DIRECT FROM A PIPELINE TO LIQUID STORAGE



(57) **Abrégé/Abstract:**
This invention relates to a method of moving natural gas mixes directly from a high pressure pipeline into a marine or similar liquid containment or transport system. During the loading process a select rich natural gas mixture is transformed into a liquid state without the need for an intermediate traditional LNG processing facility. The liquid mixture results from an induced phase change caused by releasing high pressure NGL enriched natural gas from a pipeline or storage into a lower pressure containment system. The pressures of adjacent gas pipelines are utilized to assist with loading and unloading the stored liquid. Increase in constituent NGLs, chilling or pressurizing can further increase the desired liquid storage density. The work expands beyond existing teachings of the authors and others. The density of the natural gas component held in the liquid here exceeds those of PLNG or CNG under these selected conditions.

TRANSFER OF NATURAL GAS DIRECT FROM A PIPELINE TO LIQUID STORAGE

ABSTRACT

This invention relates to a method of moving natural gas mixes directly from a high pressure pipeline into a marine or similar liquid containment or transport system. During the loading process a select rich natural gas mixture is transformed into a liquid state without the need for an intermediate traditional LNG processing facility.

The liquid mixture results from an induced phase change caused by releasing high pressure NGL enriched natural gas from a pipeline or storage into a lower pressure containment system.

The pressures of adjacent gas pipelines are utilized to assist with loading and unloading the stored liquid. Increase in constituent NGLs, chilling or pressurizing can further increase the desired liquid storage density.

The work expands beyond existing teachings of the authors and others. The density of the natural gas component held in the liquid here exceeds those of PLNG or CNG under these selected conditions.

TRANSFER OF NATURAL GAS DIRECT FROM A PIPELINE TO LIQUID STORAGE

DESCRIPTION

Background Information

Natural gas is primarily moved in a gaseous form by pipeline. Beyond certain distances and by restrictions imposed by remote, scattered or undersea field locations, the movement of natural gas from reserves to market is in many instances not economically viable by existing pipeline or LNG technologies. Advances in Pressurized LNG, CNG and Gas Liquid transportation have been proposed by industry in recent years, but frustrated by the lack of accurate Equation of State methodology for densities in the region adjacent to the Critical Point of natural gas mixes region.

Prior work by Morris et al has shown that under certain storage conditions through the addition of light-hydrocarbon and other solvents, it is possible to store natural gas as a dense phase gas (US Patent 6,217,626) or a liquid matrix phase of sufficient packing density to be economically attractive alongside LNG (liquid natural gas), PLNG (pressurized LNG), and CNG (compressed natural gas) modes of transportation (US Patent 7,607,310). The light-hydrocarbons referred to here as solvents are ethane, propane and butane, or mixtures of all three components in the form of NGL (natural gas liquids) or propane and butane in the form of LPG (liquid petroleum gas). Again this work too was limited by the available Equation of State methodology of the day. This invention now ventures closer to the critical point of the mixtures, into the realm of better densities for storage of natural gas below -62C previously attributed to the warmer reaches of PLNG. Here we obtain more competitive densities of natural gas containment roughly two thirds that of LNG without resorting to the high energy demands of its processing.

The increased densities for the gas mixes are achieved by addressing their properties and seeking lower levels of compressibility (Z) factor associated with the gas behavior equations. The reduction in the compressibility factor is brought about through the addition of the light hydrocarbon solvent which introduces an order of more intense intermolecular attraction forces that result in the denser packing of natural gas under the selective conditions of storage. APRD methodology by the VMG organization began to filter into use from 2007 onwards. This method

improves on the milestone work of the Peng Robinson Equation of State and methods of Costald determining liquid densities.

It is on this basis that more accurate investigations were able to be carried out in the region approaching the critical points of rich gas mixes examined here. This work showed the existence of a band of temperatures and pressure storage conditions for a liquid phase of natural gas and NGLs referred to here as Matrix Gas that offers superior Net Storage Densities for the natural gas component hitherto not available to the industry.

It is also important to note that the conditions favorable to enhanced storage of gas in this manner are limited as defined by this invention, and only attainable using the stated light hydrocarbon solvents. Other heavier hydrocarbons with larger molecules require much higher pressures to achieve similar behavior characteristics of high density packing of the natural gas component in fuel mixes at/near ambient temperatures - ref. Hibino, (US Patent 6,584,780). However, the use of such heavier solvents is not part of the claims of this invention. Their vehicle fuel service conditions also run contrary to the objectives of light weight, low pressure containment components sought by this invention to achieve economies of scale in storage and transport of bulk quantities of natural gas.

The stored density values of this invention are predicated on attaining storage conditions in the liquid region at or near the inflection points of graphic representations of the bubble curves of the particular phase envelope of the storage mix as described in US Patent Application 11/750,942. The present invention further defines its limiting boundaries of Pressure /Temperature shown in tabular form in the Figures.

Adjustment of the mol percentage of the solvent at each storage point to a best performing level was an additional requirement, to further identify the ideal liquid mix at each coordinate of pressure and temperature shown in the Figures. This is a critical requirement, to achieve the listed maximum volumetric ratio of the stored natural gas at each of the specified conditions.

Summary of the Invention

In accordance with a broad aspect of the invention, there is provided a method of accelerating the formation of a liquid storage mixture comprising natural gas emerging from transmission pipeline or accumulator chamber without the intermediate need for LNG processing, the mixture

further comprising: methane and one or more light hydrocarbons that are ethane, propane, butane or combinations of these light hydrocarbon as "solvents"; the storage mixture then being liquefied by Joule Thompson effect as it leaves the pipeline or storage chamber; with additional chilling if required, then being done under bulk storage pressure conditions of 3080 kPa to 7190 kPa and temperature conditions of -63C to -84C of the mixture.

The method of storing natural gas in a liquid matrix may comprise of the mixture, maintained by pressure and temperature conditions such that the mol percentage of light hydrocarbon solvent ranges from 1 to 9% mol., where the mixture in storage has a net density greater than that which would the case for natural gas alone under the same conditions in the form of CNG or PLNG.

The method of storing natural gas in a liquid matrix may comprise of the mixture, maintained by the pressure and temperature conditions, such that the mol percentage of light hydrocarbon solvent ranges from 1 to 26% mol. and where the storage yields greater net density of the stored mixture, compared to that which would the case for natural gas alone under the same conditions in the form of CNG or PLNG.

For mixed service, the method of storing natural gas in a liquid matrix comprised of the mixture, maintained by the pressure and temperature conditions, such that the mol percentage of light hydrocarbon solvent ranges from 26 to 90% mol.

The method of storing natural gas in a liquid mix comprised of the mixture of natural gas emerging from transmission pipeline or accumulator chamber without the intermediate need for LNG processing, with methane and one or more light hydrocarbons that are ethane, propane, butane or combinations of these light hydrocarbons, as solvent, maintained by the pressure and temperature conditions, such that the mol percentage of light hydrocarbons solvent is preferably in the range of 5 to 25% mol, yielding net densities of the natural gas component in the range of 350 to 425 times the density of the natural gas component in the mixture under standard conditions of 15C, and 1 atmosphere.

In accordance with another broad aspect of the invention, there is provided an accumulator extension apparatus to a natural gas pipeline having an increase in diameter and/or additional runs of pipe specifically configured to hold a greater density of the carried product by virtue of its operation at higher pressure than the MOP (Maximum Operating Pressure) of the pipeline, the operating pressure within the range of 14825 kPa to 22360 kPa.

In a process chamber and valve apparatus downstream of the accumulator the pressure in the accumulator may be relieved to 7190 kPa to 3080 kPa, causing a Joule Thompson cooling effect sufficient to bring about a phase change to cause formation of the liquid form of the carried product.

The accumulator may include a pre-loading chiller and optional pump combination to further increase the density of the carried fluid which is then loaded into a bulk storage vessel/transportation system, where transport can be rendered by land, sea, or air within composite carbon, Kevlar, aluminum and steel vessels.

The accumulator may include a plurality of process injection equipment specifically for increasing the density of the liquid matrix mixture through the introduction of additional NGLs upstream or downstream of the process in a process chamber.

The accumulator may include a plurality of process and containment equipment specifically for loading and unloading the liquid matrix mixture in combination with the pressures and natural gas displacement mixtures available from interconnecting pipelines at each end of the transport route.

This invention is primarily intended to seek a less capital intensive and quicker means of implementing the movement of natural gas from transmission pipeline in the production field to one in a distant marketplace. Traditional use of LNG infrastructure is avoided, and in its place a less dense fluid carrying the natural gas component is created between high pressure pipeline and low pressure carrier. The fluid is simpler to produce from the field, transport, and convert back to a gas stream at the market.

This invention seeks to illustrate the finite limits of temperature and pressure where the densest storage of natural gas within a light hydrocarbon solvent can be achieved. These processes are based on temperature/pressure/constituent specifications not previously defined by prior art. In addition, this invention aims to respect the work of others in the field, and intrude with improved performance on boundaries established by these technologies. Nevertheless, limits to the invention are shown in tabulations in Figures 2, 3 and 4.

These figures provide an overlay of the results of the present methodology on claim areas of this invention and of others abutting this invention. The density trends of this invention and others clearly establish the superiority of the invention within the sweep of a band of pressure/temperature coordinates outlined in heavy lined borders on the diagrams. Under these

conditions there is a reduction in the energy requirement to produce the stored liquid and compress and chill it to containment conditions compared to CLNG and CNG processing. Favorable ratios of material intensity and the fiscal capital needs per the unit of contained gas are attainable in this region.

The invention seeks to achieve in an energy efficient manner, at pressures below 5820 kPa, and through the use of light hydrocarbon solvents to achieve packing densities of natural gas components that are an order of magnitude ahead of prior art, raised to two thirds that of LNG. (This yields a net storage density gain of the order 400:1 compared to 600:1 for LNG). Investigation of higher pressures above the critical pressures of most mixes (about 6850 psig) revealed declining benefits in volumetric ratio for this technology over those of simple natural gas storage (as CNG or PLNG).

No benefits were found at temperatures below -85C, where the performance band tails off with higher percentage mol mixes required to sustain better net densities of the stored natural gas.

Beyond a certain point of concentration of these solvents, it is noted that their addition becomes ineffective in improving the yield of natural gas from the gas matrix. The maximum density of this matrix mix that yields gains in improved storage packing of the natural gas component beyond that of simple natural gas lies in the region of 336 kg/m³.

High density mixes with high concentration of heavier hydrocarbons do not yield optimal densities of the natural gas component as is found when using the lighter hydrocarbons as in this invention.

This invention creates a superior storage region abutting claim areas of earlier industry practices, using ethane, propane and butane based solvents or mixtures thereof classified as NGLs or LPGs. The base natural gas mixes used are consistent with practical clean burning levels promoted by N. American gas specifications. The method is equally applicable to leaner and richer base mixes, with adjustments made to the solvent mol percent to achieve a balanced storage mix.

Description of the Invention

The invention enables the bulk storage of natural gas to be efficiently rendered within a liquid light hydrocarbon matrix, which is then maintained in liquid form under conditions of pressure and temperature, yielding a packing net density of the natural gas component that is greater than

those previously discovered for Compressed Natural Gas or Compressed LNG mixes under these conditions in earlier developments in this field. The solvent components comprise of ethane, propane and butane based hydrocarbon mixes or combinations therein as found in the form of NGL and LPG blends.

The natural gas or rich natural gas blends delivered from the production field exit the transmission pipeline to be compressed into a gas phase accumulator configuration of pipeline or dedicated storage chamber operating at a higher pressure than the MOP of the transmission pipeline.

From gaseous storage the NGL enriched mix is de-pressured into a process chamber where it undergoes a phase change to a liquid form suited for bulk storage and transportation without having to undergo processing in an LNG Plant. Depending on ultimate storage density, the liquid mix may require additional additive, chilling or compression. This product state is achieved using less energy and capital expenditure than is required for the production of a bulk storage and transport mix of traditional LNG.

The liquid matrix mix is held in phase and loaded onto the bulk storage/transport vessel against a backpressure provided by the storage accumulator or transmission pipeline.

For marine transportation an articulated tug barge configuration of the vessel is the preferred means of providing quick turn-round and transitory storage for the bulk liquid at each end of the voyage. The Tug section uncouples and latches from one barge to the next at each terminal minimizing port charges, and having the voyage fuel preloaded and available on the newly coupled barge.

On arrival at its destination, the natural gas matrix mix is offloaded either in its transport composition that could be an enhanced form to directly meet particular market specifications, or be subject to processing whereby the solvent component can be extracted as a market specific feedstock form of ethane, propane, butane, NGL, or LPG or even recycled into the containment vessels for reuse on a subsequent delivery trip.

The invention enhances the acquisition of natural gas from so called remote "stranded" reserves not able to be economically served by LNG vessels or undersea pipeline technology, on or offshore. It enables the delivery of natural gas mixes to market for storage or onward pipeline transmission. Notwithstanding, these mixtures can be conveyed to their destination by land or air modes considering the light pressure containment requirements.

BRIEF DESCRIPTION OF THE FIGURES

In the detailed description of the invention reference is made to the accompanying illustrations:

FIG 1. SYSTEM SCHEMATIC

Schematic Representation of Method Showing Direct Pipeline to Ship Transfer of Liquid Cargo

FIG 2. VOLUMETRIC STORAGE RATIOS OF METHANE MIXES CONSTITUENT mol% OF ETHANE IN BEST MATRIX MIX

Regions of Optimal Volumetric Ratio of Natural Gas Storage in an Ethane Based Solvent, Defined by Best mol% Ethane for Each Temperature and Pressure Point.

FIG 3. VOLUMETRIC STORAGE RATIOS OF METHANE MIXES CONSTITUENT mol% OF PROPANE IN BEST MATRIX MIX

Regions of Optimal Volumetric Ratio of Natural Gas Storage in a Propane Based Solvent, Defined by Best mol% Propane for Each Temperature and Pressure Point.

FIG 4. VOLUMETRIC STORAGE RATIOS OF METHANE MIXES CONSTITUENT mol% OF BUTANE IN BEST MATRIX MIX

Regions of Optimal Volumetric Ratio of Natural Gas Storage in a Butane Based Solvent Defined by Best mol% Butane for Each Temperature and Pressure Point.

DETAILED DESCRIPTION OF THE INVENTION AND FIGURES

FIG. 1 shows in schematic form the step by step handling of the gas emerging from a transmission pipeline **(A)**. The gas can be either burner tip thermal rating or enriched mixes boosted with NGLs. At various points in the process enrichment can be injected at points labeled **(K)**.

The gas flow-stream is compressed from pipeline MOP conditions (typically 6500 to 14725 kPa) to storage conditions of the order of 20550 kPa using compression facilities **(B)**. This storage pressure is limited by the avoidance of fall out of NGL liquids in the specific gas composition.

The storage space **(C)** is in the form of a final leg of parallel pipelines or one of increased diameter, or cavern type facility to provide several days of production capacity.

From the storage the product flows through a turbo expander or pressure reducing valve **(D)** into a cold temperature chamber **(E)**. Here it experiences a drop to the range of 7190 to 3085 kPa bulk storage pressures, dependent on the behavior of the specific gas composition. Here it undergoes a phase change to the liquid state by virtue of the Joule Thompson effect. At this point a touch of additional chilling can be provided if needed to reach the desired liquid density.

The loading rack **(F)** provides for loading a vessel **(G)**, holding an empty vessel **(H)** or dispatching a loaded vessel **(I)**. An ocean going Articulated Tug-Barge type vessel is the preferred means of conveyance shown here, as it minimizes the turn round time at the terminus ends of the voyage. This does not exclude the use of conventional ships. Purging lines and draw-down compression **(Y)** of purge gas from the storage system are illustrated here.

At the delivery end of the voyage the Unloading rack **(L)** is equipped with the ability to unload the vessel **(M)** using the higher back pressure from the transmission pipeline and draw down the resulting heel gas using the interconnects **(Z)**. Provision is made for a standby loaded vessel **(N)** and departing empty vessel **(O)**. The departing vessel can be fuelled by sufficient heel gas left in its storage system.

The offloaded product flashes back to a gas after leaving the vessel passing through a pressure control station **(P)** into a heat exchange chamber **(Q)** where it is warmed to a gas state suited to recompression **(R)** to storage **(S)** or transmission pipeline entry pressure.

FIG. 2 shows in tabular form the conditions, expressed as coordinates of temperature and pressure, where the matrix mix of an **ethane C2 solvent** and methane C1 (Natural gas) yield the best net volumetric values of storage for the methane (natural gas) component.

The lower number in each box shows the storage value V/V for methane in the form of CNG or PLNG as a ratio relative to methane (natural gas) at standard conditions. The middle figure shows the mol % rounded to the nearest whole number where the best performance from a gas matrix mix of this methane and ethane can be obtained under these same storage conditions. The value

of the volumetric ratio for the matrix mix is shown as a net value of the contained methane on the upper line of each box.

Where the best performance volumetric ratio numbers of the matrix mixture far exceed the CNG/PLNG performance volumetric ratio under the same conditions, the box is defined by thicker lines.

It will be noted that the best performing conditions sweep in an arc from a condition at 3425 kPa and -84.5C to a condition at 6850 kPa and -51 C. The coordinate boxes on the higher pressure side of this arc require a lower % mol of ethane to achieve these higher volumetric ratios than do their counterparts positioned on the lower pressure side of the arc.

Of note is the net volumetric ratio of 387 for the matrix mix achieved over a ratio value of 112 for PLNG, at conditions of 3425 psig, -84.5C. Mol % solvent here is only 9%.

Within the scope of the invention is the coordinate condition of 6365 kPa and -67.8C. The matrix mix yields a net volumetric ratio here of 330 compared to the PLNG figure of 202. A mol% of 14 is required for the ethane.

Dropping down to 4110 kPa for the matrix mix at -67.8C yields a net volumetric ratio of 299 against what is now CNG which yields a volumetric ratio of 95. The mol% of solvent involved here is a higher figure of 27 percent.

Surrounding the heavy box region are coordinate boxes defined by lighter lines. These areas are regions where PLNG and CNG technologies begin to outstrip the matrix mix volumetric performance.

Adding solvent to natural gas is ineffective for these outer conditions, indeed the best numbers come from adding a minimal 1% mol of solvent to the methane (natural gas).

FIG. 3 shows in tabular form the conditions, expressed as coordinates of temperature and pressure, where the matrix mix of a **propane C3 solvent** and methane C1 (Natural gas) yield the best net volumetric values of storage for the methane (natural gas) component.

The lower number in each box shows the storage value V/V for methane in the form of CNG or PLNG as a ratio relative to methane (natural gas) at standard conditions. The middle figure shows the mol % rounded to the nearest whole number where the best performance from a gas matrix

mix of this methane and propane can be obtained under these same storage conditions. The value of the volumetric ratio for the matrix mix is shown as a net value of the contained methane on the upper line of each box.

Where the best performance volumetric ratio numbers of the matrix mixture far outstrip the CNG/PLNG performance volumetric ratio under the same conditions, the box is defined by thicker lines.

It will be noted that the best performing conditions sweep in an arc from a condition at 3425 kPa and -84.5C to a condition at 6850 kPa and -51C. The coordinate boxes on the higher pressure side of this arc require a lower % mol of ethane to achieve these higher volumetric ratios than do their counterparts positioned on the lower pressure side of the arc.

Of note is the net volumetric ratio of 388 for the matrix mix achieved over a ratio value of 112 for PLNG, at conditions of 3425 kPa, -84.5 C. Mol % solvent here is 11%.

Within the scope of this invention is the coordinate condition of 5480 kPa and -67.8C. The matrix mix yields a net volumetric ratio here of 349 compared to the PLNG figure of 202. A mol% of 11 is required for the propane.

Dropping down to 4110 kPa for the matrix mix at -73.0 yields a net volumetric ratio of 327 against what is now CNG which yields a volumetric ratio of 109. The mol% of solvent involved here is a higher figure of 22 percent.

Surrounding the heavy box region are coordinate boxes in defined by lighter lines. These areas are regions where PLNG and CNG technologies begin to exceed the matrix mix volumetric performance. Adding solvent to natural gas is ineffective for these outer conditions.

FIG. 4. shows the behavior of **butane C4 solvent** matrix mixes. Equal parts of i-butane and of n-butane were used in calculations for butane mix and the tabulated values represent an average of the differing values of the critical temperatures and critical pressures of these two forms of this light hydrocarbon. Overall the critical properties of butane exhibit a higher critical temperature and a lower critical pressure than the aforementioned ethane and propane components of a matrix mix.

Once again the best values for superior volumetric performance begin at the coordinate condition of 3425 kPa psig pressure and -84.5C and assume an arc rotating counter clockwise towards the higher pressure region of the table.

The best performing condition here is at 4110 kPa and -81.7C where the volumetric ratio of the matrix mix is 395 for 5% mol solvent content. This compares to a volumetric ratio of 265 for CNG under the same conditions.

At a condition of 900 psig pressure and -65C temperature a matrix mix with butane based solvent requires 9% mol of solvent to achieve a volumetric ratio of 351 that compares to a volumetric ratio of 241 for CNG under the same conditions.

At a condition of lower pressure of 3425 kPa psig and the same -65C temperature the matrix mix requires 21% mol of solvent to achieve a volumetric ratio of 312. The same conditions yield a volumetric ratio of 170 for CNG.

The use of NGL compositions that have constituent parts of ethane, propane and butane and LPG compositions that also include propane and butane in their make-up is also considered for suitable solvent mixes. The use of these solvents will straddle the same general pressure/temperature arcs presented in FIGS. 2, 3 and 4, the exact positioning being dependent on the composition of the solvent.

All Matrix storage mixes are suited to transportation and fixed location storage. The mixes having lighter % mol in the form of solvent are particularly suited for transport modes for natural gas mixes where the solvent does not take up an undue portion of the tonnage allocated for cargo in the design of the vessel.

The Matrix mixes having a heavier % mol in the form of solvent are more suited to fixed storage such as bulk reserves and smaller peak shaving plants where utilities supplement transmission pipeline deliveries during times of high demand. More costly LNG plants are presently employed by over 50 utilities in the US and Canada for peak shaving purposes.

The concept of enhancing volume ratio storage through the addition of a solvent is also suited to recycling of the solvent on release of the natural gas. Commercial demands might dictate the sale of all or part of the solvent - this is possible by simple diversion of the return flow, downstream of the offloading process train that splits the natural gas from the solvent.

The recent development in low temperature steels, fiber composite technology, and aluminum alloys for use at temperatures of -73.5C, coupled with advances in low temperature fluids example, makes this invention feasible in a number of process areas. Should costs of stainless steel or high nickel steels become excessive for the fabrication of containment vessels on the scale envisaged for this technology, the lower pressures suggested here will minimize the impact.

The invention stems from the dense phase technology of natural gas achieved by an increase in light hydrocarbon constituents. This natural gas rich liquid state is achieved either by the addition of the light hydrocarbons or the reduction of natural gas methane concentration employing commonly used industry technologies. These process systems are not as complex or costly as LNG trains. By selective positioning of storage conditions of temperature /pressure it is possible to contain the storage mix in a state where its compression factor "Z" is decreased to the levels of 0.2 or lower.

Beyond this optimal point there is little benefit in increasing the relatively incompressible density with greater expenditure of work, either by further decreasing temperature or increasing pressure.

IN CONCLUSION

This invention establishes a niche technology wedged between CNG and PLNG.

It requires a simple means of field preparation producing the stored fluid comprising minimal gas conditioning in respect of removal of water, nitrogen, carbon dioxide and acid gas such as H₂S. Liquid formation, direct from a pipeline adjunct storage system, and without the use of extensive equipment trains or LNG processing comes about through simple static mixing of the chilled flow-streams of solvent and solvent followed by final cooling and compression of the formed liquid to storage conditions.

Placing the liquid into containment is done at storage pressure against the back pressure of a reusable slug of natural gas mix or suitable non miscible displacement medium in a similar manner to the salt water method commonly applied in storage caverns. In this manner the liquid is prevented from flashing to the vapor stage during loading.

Containment in vessels designed specifically for the storage conditions is provided with a backflow of pipeline gas or alternate displacement medium acting against controlled pressure outlet valves to empty the fluid. In this way maximum evacuation of the containment system is

possible, any "heel" gas as is common to LNG and CNG systems that is left behind is measured and used for fuel gas on the return voyage of delivery vessels.

Gas mixes can be customized at the loading side of the voyage to suit the GJ heat rating at the market end of a voyage. Leaner N. American spec transmission gas can be enhanced to a higher GJ heat rating by enhancement of the NGL content to balance both the liquid storage needs and the export market specifications. On arrival it requires only to be warmed and unloaded directly into market transmission pipelines following compression of the re-established gas phase.

Alternatively, straddle plant process systems can separate portions of the NGL solvent from the offloaded flow to yield the local specification natural gas and feedstock according to local market conditions for both products.

The overall process of this invention requires common gas field equipment, and little in the way of exotic materials and process technology. It requires less energy from field to market delivery compared to the complexity of LNG systems or compression energy and attendant cooling and evacuation of CNG systems. This enables a greater portion of field reserves to be available for the end market.

Coupled with less costly capital and operating costs the invention offers the market a broad range of NGL solvents as well as natural gas mixes. Additionally, improved volumetric ratios are offered beyond the prior art for transport of natural gas mixes with compressed liquid hydrocarbons, exceeding or comparable to those sought for the lower reaches of PLNG systems at lesser cost.

CLAIMS

We claim:

1. A method of accelerating the formation of a liquid storage mixture comprising natural gas emerging from transmission pipeline or accumulator chamber without the intermediate need for LNG processing, the mixture further comprising: methane and one or more light hydrocarbons that are ethane, propane, butane or combinations of these light hydrocarbon as "solvents"; the storage mixture then being liquefied by Joule Thompson effect as it leaves the pipeline or accumulator chamber; with chilling to meet temperature conditions of -63C to -84C, then being kept under bulk storage pressure conditions of 3080 kPa to 7190 kPa and temperature conditions of -63C to -84C of the mixture.
2. A method of storing natural gas in a liquid matrix comprised of the mixture of Claim 1, maintained by pressure and temperature conditions such that the mol percentage of light hydrocarbon solvent ranges from 1 to 9% mol., where the mixture in storage has a net density greater than that which would be the case for natural gas alone under the same conditions in the form of CNG or PLNG.
3. A method of storing natural gas in a liquid matrix comprised of the mixture of Claim 1, maintained by the pressure and temperature conditions of Claim 1, such that the mol percentage of light hydrocarbon solvent ranges from 1 to 26% mol. and where the storage yields greater net density of the stored mixture, compared to that which would be the case for natural gas alone under the same conditions in the form of CNG or PLNG.
4. For mixed service, a method of storing natural gas in a liquid matrix comprised of the mixture of Claim 1, maintained by the pressure and temperature conditions of Claim 1, such that the mol percentage of light hydrocarbon solvent ranges from 26 to 90% mol.
5. A method of storing natural gas in a liquid mix comprised of the mixture of Claim 1, maintained by the pressure and temperature conditions of Claim 1, such that the mol percentage of light hydrocarbons solvent is preferably in the range of 5 to 25% mol, yielding net densities of the natural gas component in the range of 350 to 425 times the density of the natural gas component in the mixture under standard conditions of 15C, and 1 atmosphere.

6. A plurality of process and containment equipment specifically for loading and unloading the claimed liquid matrix mixture of Claim 1 in combination with the pressures and natural gas displacement mixtures available from interconnecting pipelines at each end of a transport route.

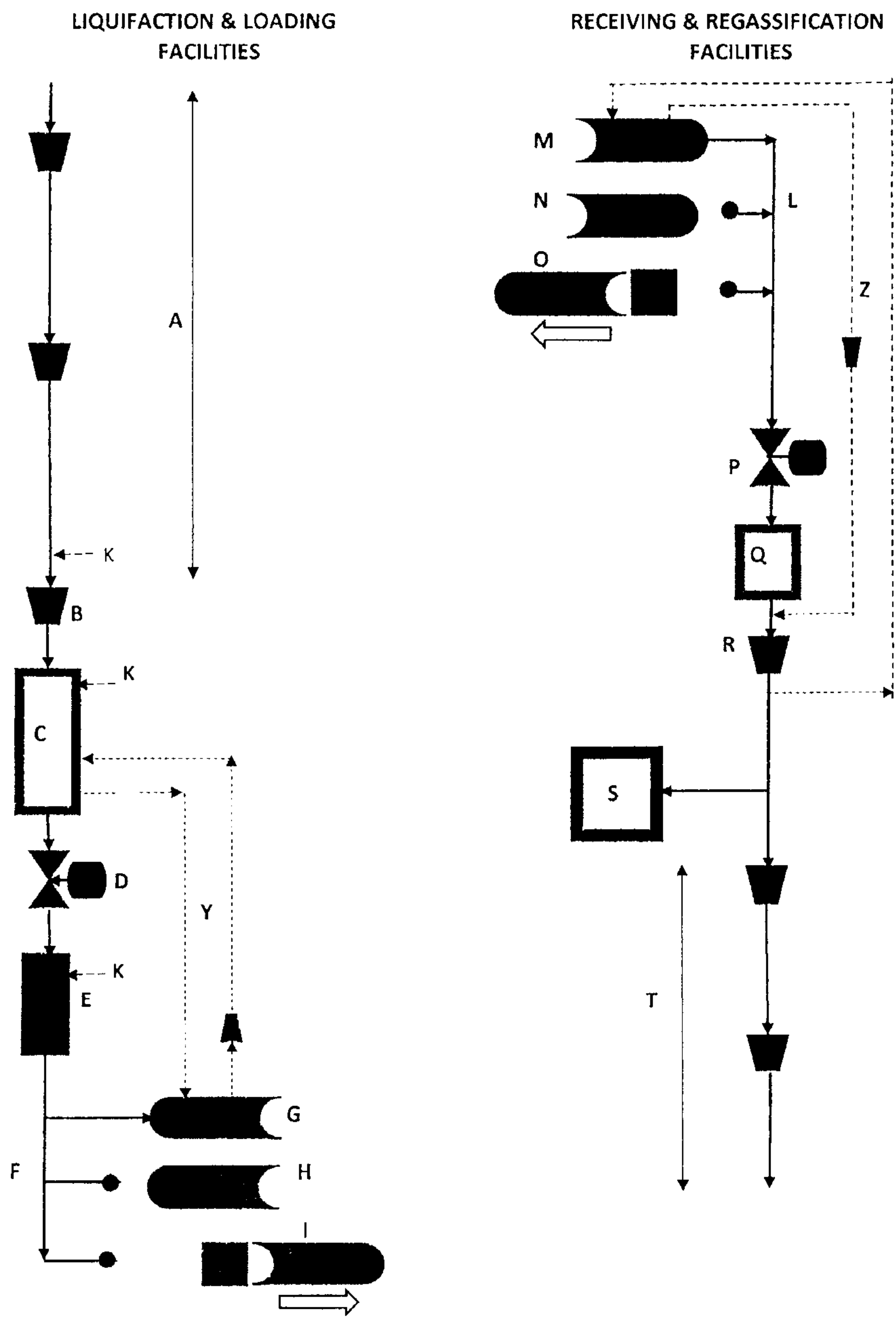


FIG 1 SYSTEM SCHEMATIC

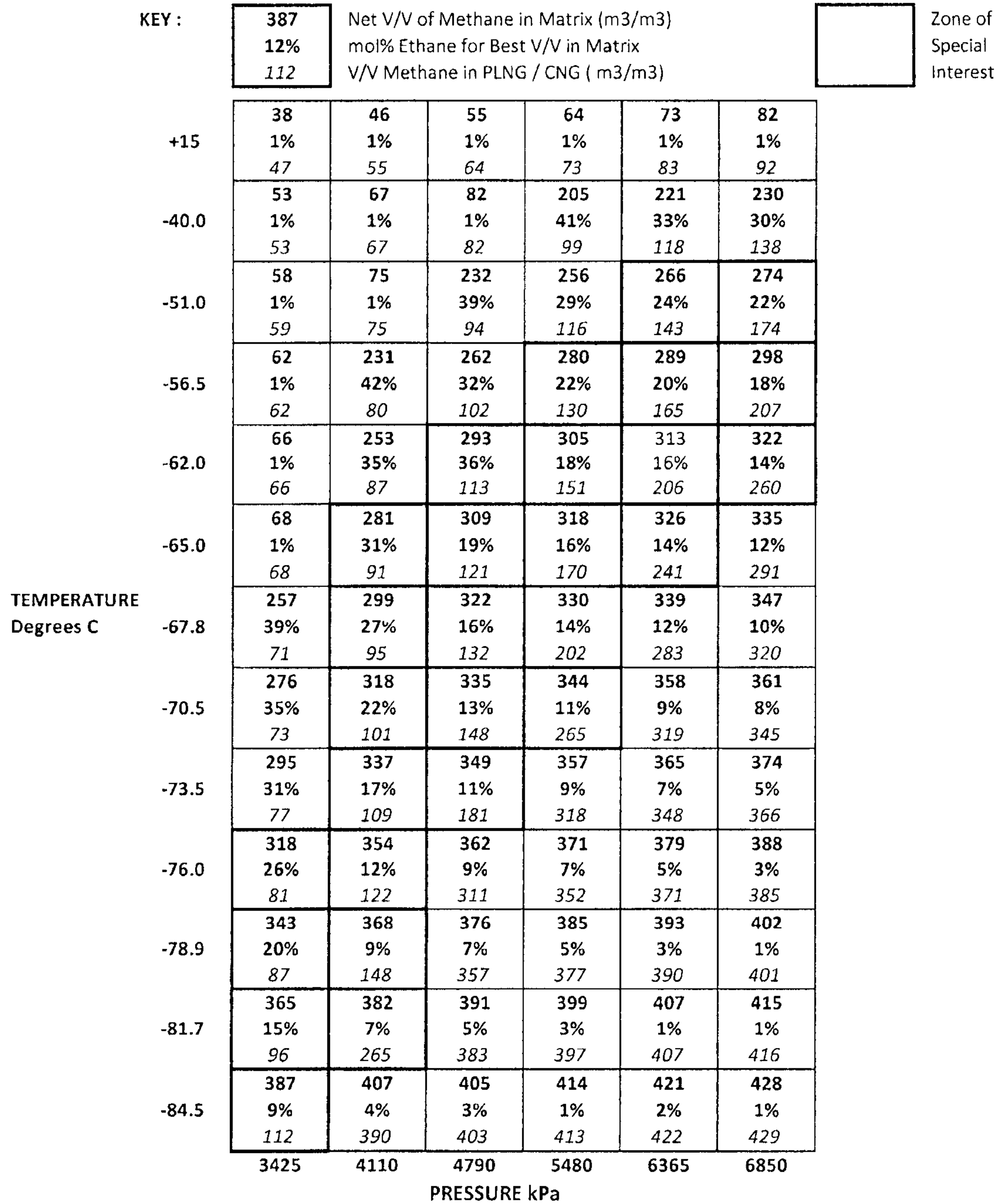
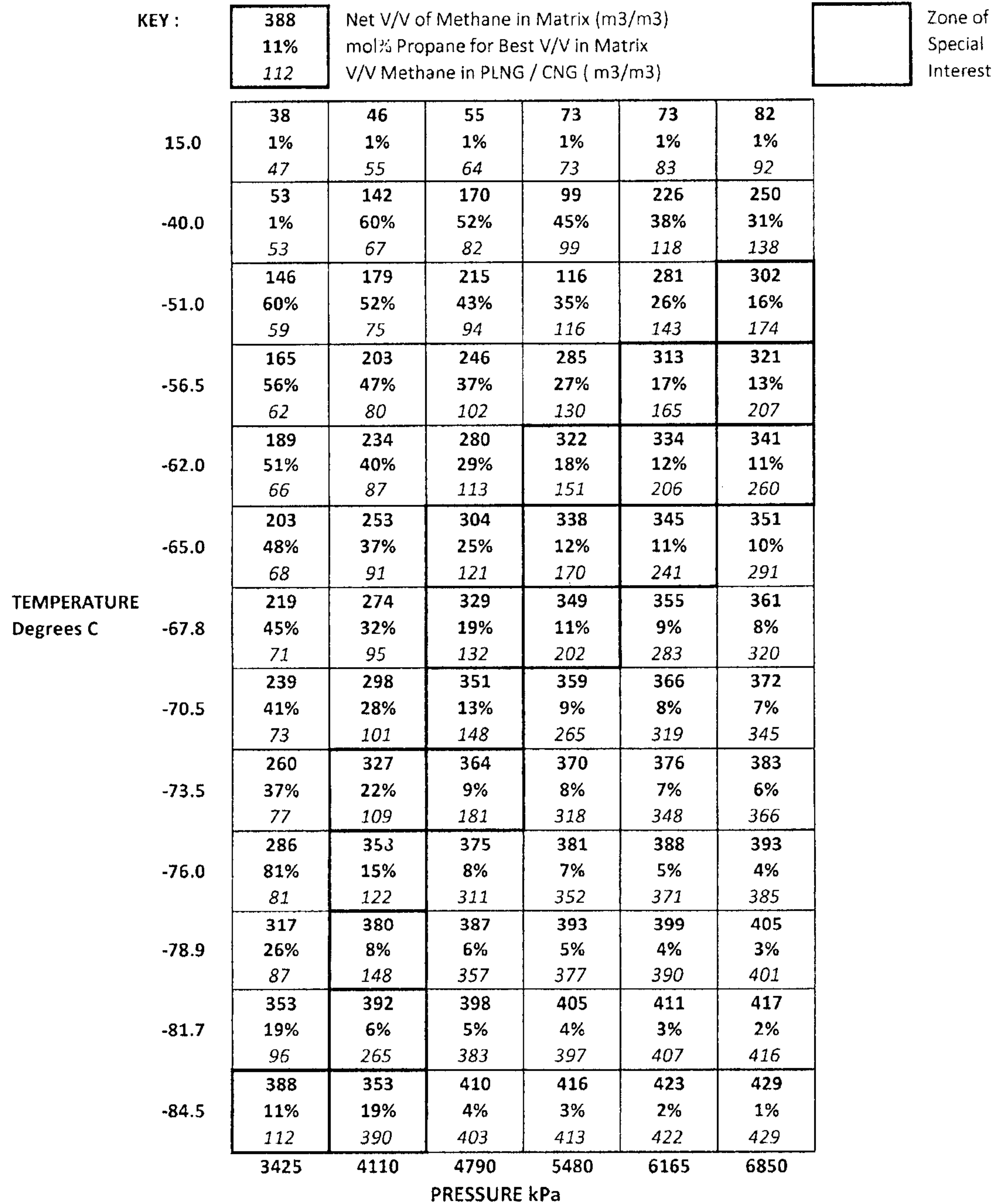


FIG 2

VOLUMETRIC STORAGE RATIOS OF METHANE MIXES
CONSTITUENT mol% of ETHANE in BEST MATRIX MIX



VOLUMETRIC STORAGE RATIOS OF METHANE MIXES

CONSTITUENT mol% of PROPANE in BEST MATRIX MIX

FIG 3

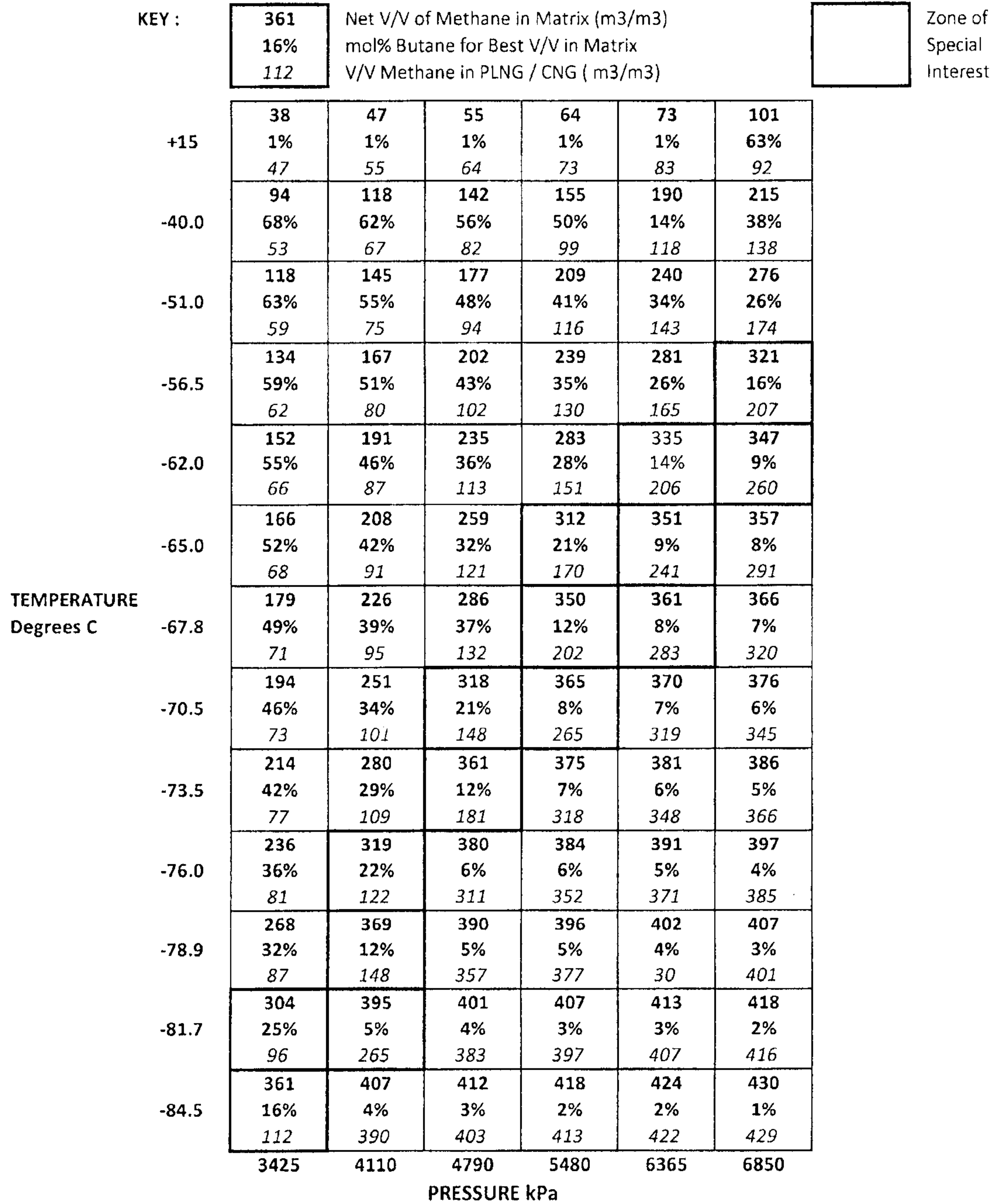
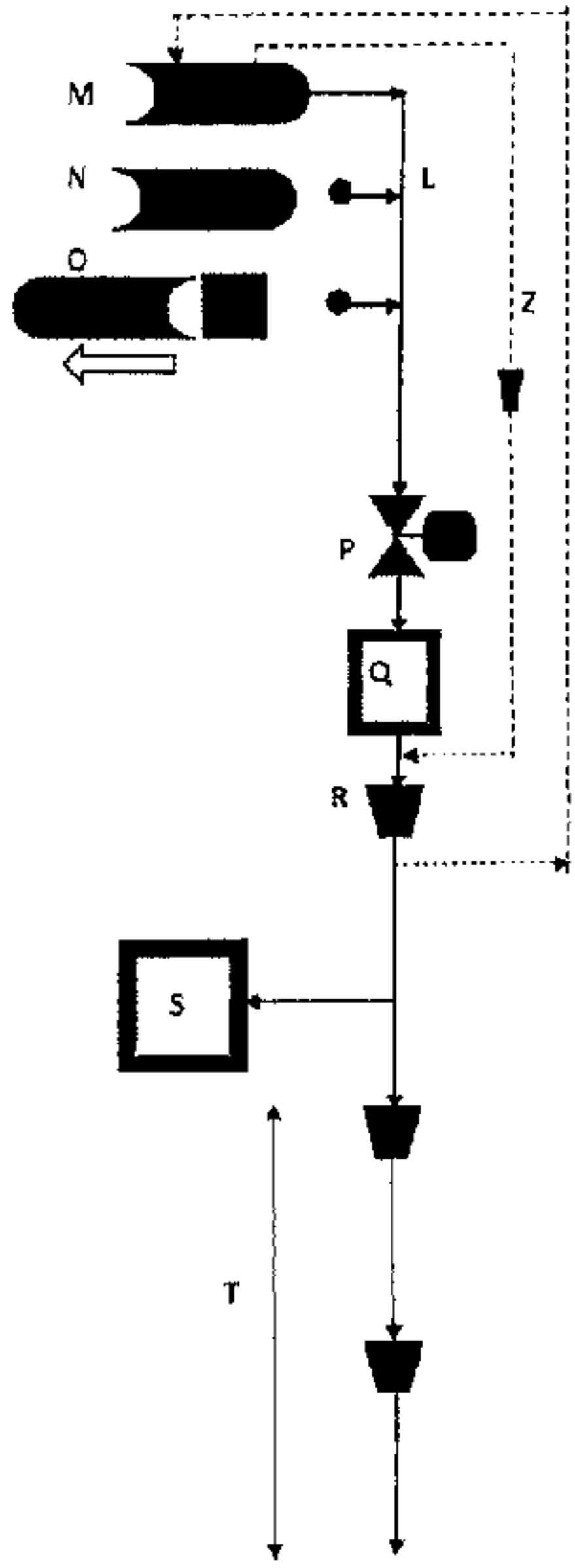
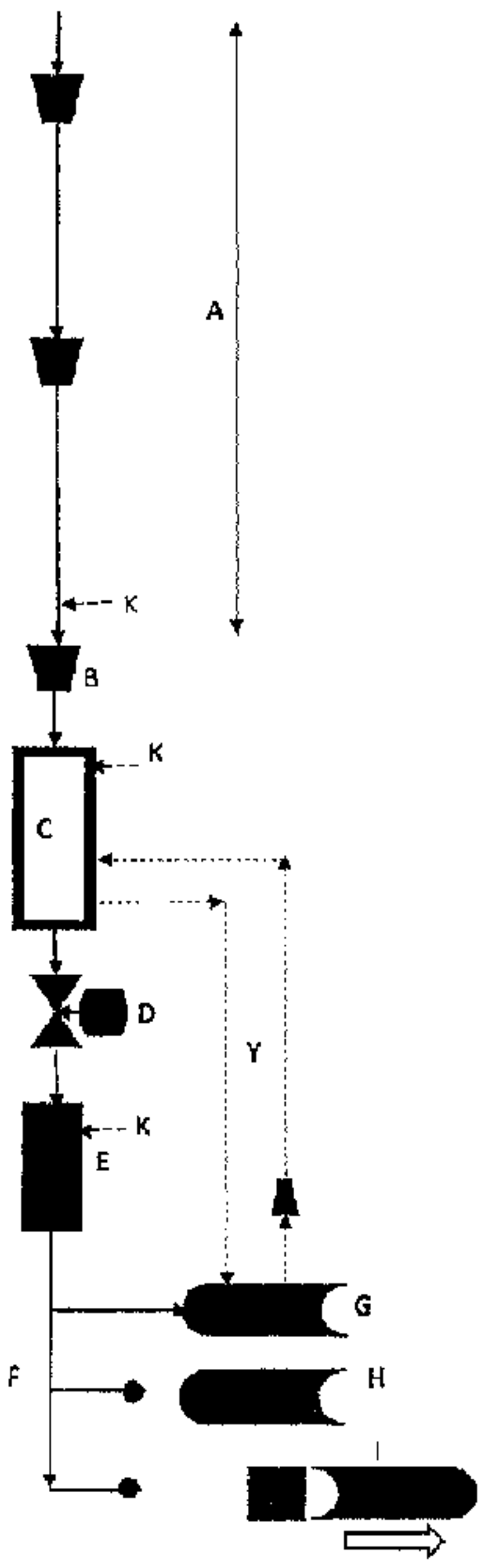


FIG 4

LIQUIFICATION & LOADING FACILITIES

RECEIVING & REGASSIFICATION FACILITIES



SYSTEM SCHEMATIC