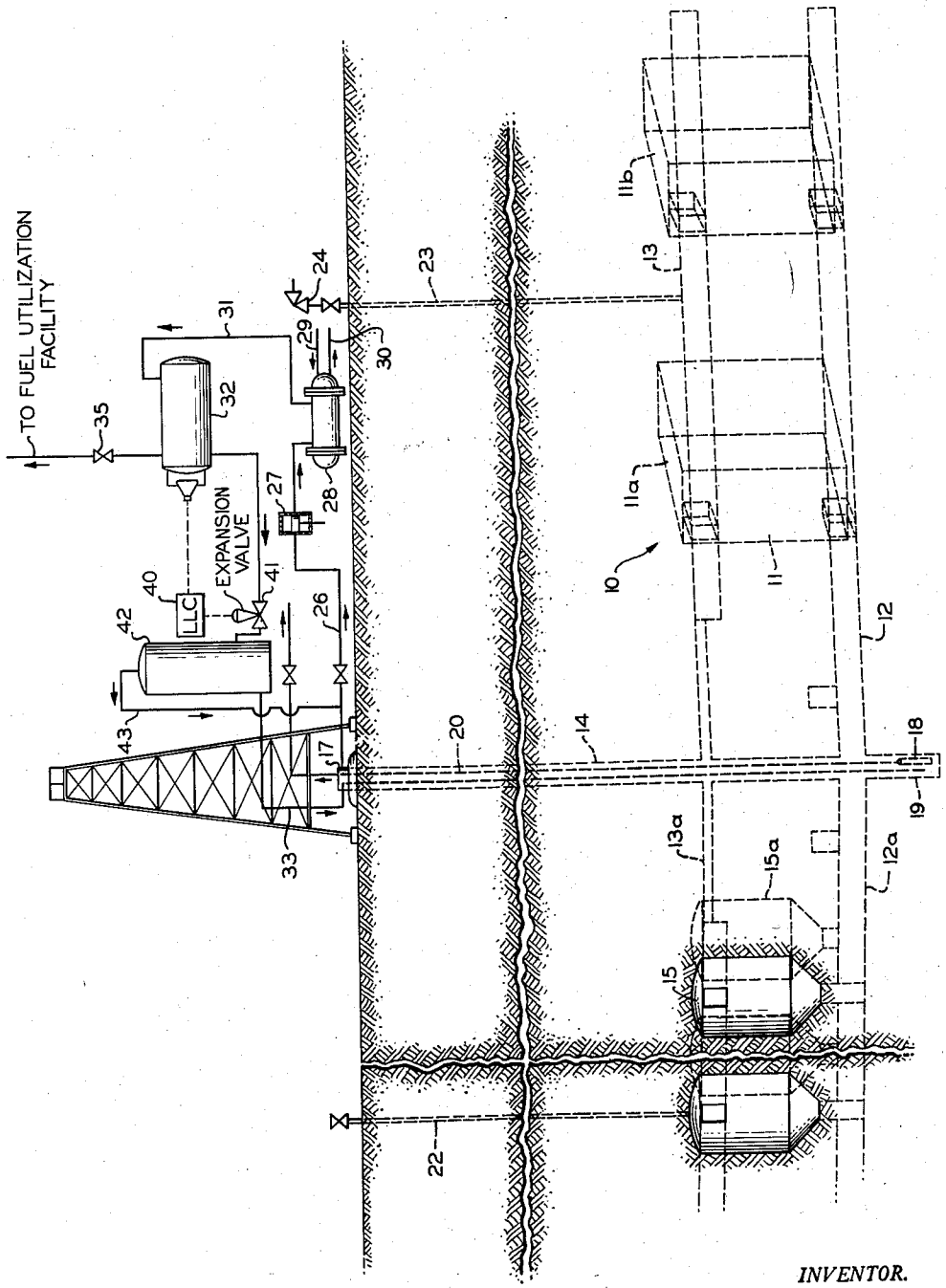
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UNDERGROUND STORAGE

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UNDERGROUND STORAGE

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3 Claims. (Cl. 62—54)

This invention relates to underground storage.

In such systems, a portion of the vapors can be continuously or intermittently withdrawn from the cavern, compressed, condensed and returned to the cavern. The return of the condensed mtaerial to the cavern dissolves a portion of the more volatile components in the vapor space, thus reducing the cavern pressure, as does the refrigeration effect produced by the vaporization and condensation cycle. Preferably and advantageously, at least a portion of the more volatile materials, such as ethane, methane and the like, can be separated from the condensed material and diverted from the underground storage system. For example, these light materials can be used as fuel. This results in a further lowering of the pressure within the cavern. Also, it is possible to reduce the cavern pressure to a point where it is substantially equal to the formation pressure. Under these circumstances, surface tension of the water in the formation effectively prevents flow of stored material out of the cavern or flow of fluids from the surrounding formations into the cavern.

In the system just described, the rate at which pressure can be reduced for one filling of the cavern or the pressure reduction which can be maintained continuously with intermittent or continuous injection and removal of product is determined by the efficiency of separation of the light ends.

In accordance with this invention, the efficiency of separation of the light ends is substantially increased so that the rate of pressure reduction can be increased with a given compressor size. Alternatively, the pressure can be lowered, the size of the compressor can be reduced, or the amount of power supplied to the compressor can be decreased.

This increased efficiency is obtained by passing the compressed, cooled liquid from an accumulator, wherein light gases are removed, through an expansion valve to a separator vessel having its vapor space connected to the compressor inlet, and its liquid space connected to a return line to the cavern.

Accordingly, it is an object of the invention to provide a system for operating an underground storage cavern at a reduced pressure.

It is a further object to provide a system for continuously or intermittently separating more volatile components from the vapors present in the cavern with increased efficiency of separation of the light ends.

It is a further object to provide a simple, economical and efficient method of operating an underground storage installation.

Various other objects, advantages and features of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawing, in which:

The figure is a schematic flow diagram of an underground storage system constructed in accordance with the invention.

Referring now to the drawing in detail, I have shown

an underground storage cavern **10** which includes, by way of illustration, a plurality of rooms **11***a*, **11***b* in the form of parallelepipeds, each room being connected at the lower portion thereof to a tunnel **12** and at the upper portion thereof to a tunnel **13**. These tunnels communicate with a vertical shaft **14** extending to the surface of the earth. Another set of tunnels **12***a* and **13***a* are connected to the respective bottom and top portions of a plurality of silo-shaped excavated caverns **15**.

The top of the shaft is sealed by a head **17**, and a downhole pump **18** is suspended in a sump **19** at the bottom of the shaft by a string **20** of tubing which extends through the head **17**. This pump is used to withdraw the stored material from the cavern.

The cavern is filled through a drill hole **22** which communicates with the cavern **15**. Another drill hole **23** communicates with the tunnel **13** and is provided with a pressure relief valve **24**.

The cavern illustrated herein, as more fully described in the copending application of Leonard P. Meade, Serial Number 314,541, filed October 13, 1952, now abandoned is one suitable type of cavern adapted for the practice of this invention. However, the system of this invention can also be utilized in various other types of excavated caverns and to caverns formed in salt or other types of soluble formations.

Vapors are withdrawn from the cavern through a line **26**, either continuously or intermittently, and fed through a compressor **27** to a condenser **28** through which a cooling medium is circulated by lines **29** and **30**. The condensed material passes through a line **31** to an accumulator **32**. A liquid level controller **40** connected to the accumulator permits liquid to flow through an expansion valve **41** to a separator vessel **42** where liquid flows back to the cavern through a line **33** which extends down to the liquid in the cavern while the vapor from the separator vessel **42** is recycled by a line **43** to the inlet of the compressor **27**. It is preferred to spray the condensed material down shaft **14** to effect contact with the rising vapor and thereby improve the separation of light components from the heavier ones.

It will be apparent that the vaporization and subsequent condensation of the vapor produces a refrigeration effect within the cavern, and that the condensed material dissolves lighter components such as ethane or methane present in the gas or vapor space within the cavern. This substantially reduces the cavern presure and due to the fact that the liquid in accumulator **32** is lighter than the liquid in the cavern, the vapor which flashes in separator **42** is lighter than the vapor removed from the upper part of the cavern so there is a higher concentration of light ends in the compressor, condenser, accumulator circuit with more efficient removal of these light ends.

In some cases, a heat exchanger is provided to exchange heat between lines **26** and **33**.

Light ends are withdrawn from the accumulator **32** and passed through a valved line **35** to any suitable disposal, such as fuel. This removal of light ends from the storage system causes a still further reduction in the cavern pressure.

In a cavern having a capacity of about 260,000 barrels, propane is fed in at an average weekly input of 25,000 barrels from a pipeline, the feed having a vapor pressure intermediate that of pure propane and propylene, say 90 to 95 pounds per square inch gage at 55° F. The formation pressure is approximately 85 pounds per square inch gage while the vapor pressure within the cavern varies within 100–105 pounds per square inch gage due to concentration of light ends in the vapor space resulting from alternating product filling and withdrawal cycles. By the compression and condensation of vapor from the cavern in the manner described herein, the pressure is

readily reduced to the hydrostatic pressure of the formation which in this instance is 80 to 85 pounds per square inch gage within the cavern, with the result that the surface tension effect of the water in the formation at the wall surfaces, such as 15*a*, 11*b*, effectively prevents flow of any material into the surrounding formation out of the cavern or out of the surrounding formation into the cavern. This surface tension effect is valuable in preventing leakage where the pressure differences between the formation and cavern vapor space is less than the pressure required to overcome the effect of surface tension.

It is a further advantage of the invention that operation of the present vaporization and condensation system denudes the effluent recovered from the cavern of the light materials, such as methane and ethane, so that the stored product withdrawn is actually purified, as compared to the product introduced into storage.

While the invention has been described, in connection with present, preferred embodiments thereof, it is to be understood that this description is illustrative only and is not intended to limit the invention.

I claim:

1. In a system for underground storage wherein a body of liquid is stored in an underground cavern with a vapor space overlying said liquid, in combination, a compressor, a line connecting the inlet of said compressor to the vapor space of said cavern, a condenser, means for supplying a cooling medium to said condenser, a line connecting the outlet of said compressor to said condenser, an accumulator, a line connecting said condenser to said accumulator to transfer condensate thereto, a vapor-liquid separator vessel connected to the lower portion of said accumulator, means for maintaining said separator vessel at a substantially lower pressure than said accumulator, a line connecting the vapor space of said separator vessel to the inlet of said compressor and a line for passing the liquid from said separator back to said underground cavern.

2. In a system for underground storage wherein a body of liquid is stored in an underground cavern with a vapor space overlying said liquid, in combination, a compressor, a line connecting the inlet of said compressor to the vapor space of said cavern, a condenser, means for supplying a cooling medium to said condenser, a line

connecting the outlet of said compressor to said condenser, an accumulator, a line connecting said condenser to said accumulator to transfer condensate thereto, a vapor-liquid separator vessel, a line having an expansion valve therein connecting said accumulator to said separator vessel, a liquid level controller controlling said expansion valve and having a sensing element in said accumulator, a line connecting the vapor space of said separator vessel to the inlet of said compressor and a line for passing the liquid from said separator back to said underground cavern.

3. In an underground storage system, a vertical shaft extending to the surface of the earth, an upper tunnel and a lower tunnel connected to said shaft, a plurality of storage units formed in a subterranean formation defining a cavern, each unit having its lower portion connected to said lower tunnel and its upper portion connected to said upper tunnel, means for introducing material to be stored into said cavern, means including a downhole pump for withdrawing stored material from said cavern and passing it through the shaft to the surface, a compressor, a line connecting the inlet of said compressor to the vapor space of said cavern, a condenser, means for supplying a cooling medium to said condenser, a line connecting the outlet of said compressor to said condenser, an accumulator, a line connecting said condenser to said accumulator to transfer condensate thereto, a vapor-liquid separator vessel, a line having an expansion valve therein connecting said accumulator to said separator vessel, a liquid level controller controlling said expansion valve and having a sensing element in said accumulator, a line connecting the vapor space of said separator vessel to the inlet of said compressor and a line for passing the liquid from said separator back to said underground cavern.

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