Natural Gas Storage in Caverns in Saskatchewan

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ABSTRACT

Saskatchewan Power Corporation, in common with other natural gas utilities, has a problem of regulating load factor on natural gas transmission lines. This requires the provision of storage or other peak shaving facilities near the load centers. Economic studies indicated that salt cavern storage, if feasible, would be the most advantageous of the alternatives considered. Between 1962 and 1964 a successful experiment was conducted at Melville, Saskatchewan. Other sites at Regina and Prud'homme, Saskatchewan, are now under development.

At Melville, the Prairie Evaporite section consists of a relatively thin zone of anhydrite at the base, overlain by halite with some clay, and minor bands of anhydrite interbedded. This in turn is overlain by a sequence of potassium bearing salts which top at a drilling depth of approximately 3,400 feet (a subsea of -1,520). The lower part of this 530-foot thick Prairie Evaporite section was used to form a 290,000 bbl. cavern, 176 feet high with a maximum diameter of 200 feet. Standard single hole solution mining techniques were used in the cavern formation. Water was obtained from, and the brine disposed of in, the Blairmore Formation at a depth of approximately 1,800 feet.

Three hundred and fifty MMSCF of natural gas at 2,200 psig was stored successfully in the cavern which was used operationally during the 1963-1964 and 1964-65 winters. The cavern has been operated "dry" with a minimum of operational problems to date.

The paper discusses the development and operation of the Melville cavern and conditions at the other two sites.

1. General

Saskatchewan Power Corporation is the utility which distributes natural gas within the Province of Saskatchewan. Figure 1 gives some idea of the system. There are two main sources of supply, the Hatton Many Islands field which is owned and operated by the Corporation and the fields in the Coleville area where we buy gas at the wellhead and operate the field. Some lesser amounts of gas are also provided from the Dollard, Cantuar, Brock, Steelman, and Nottingham area.

As can be readily seen this involves some fairly long transmission lines to the main cities of Saskatoon and Regina. We have at the moment an annual system load factor of about 55-60 percent which presents some very real dispatching problems in the winter time when the temperature can drop to between 45°F and 50°F below zero (Fig. 2).

In 1961 it became apparent that some looping on our Success-Regina line within the next few years would be necessary. The looping cost was of the order of \$7-\$10 million depending upon size and routing. From the point of view of carrying charges alone this is obviously expensive. The possibility of peak shaving with propane was also considered. This meant an approximate cost of 70-80¢ per Mcf. The cost of winter peaking gas at Regina at that time from T.C.P.L. was

NATURAL GAS SYSTEM

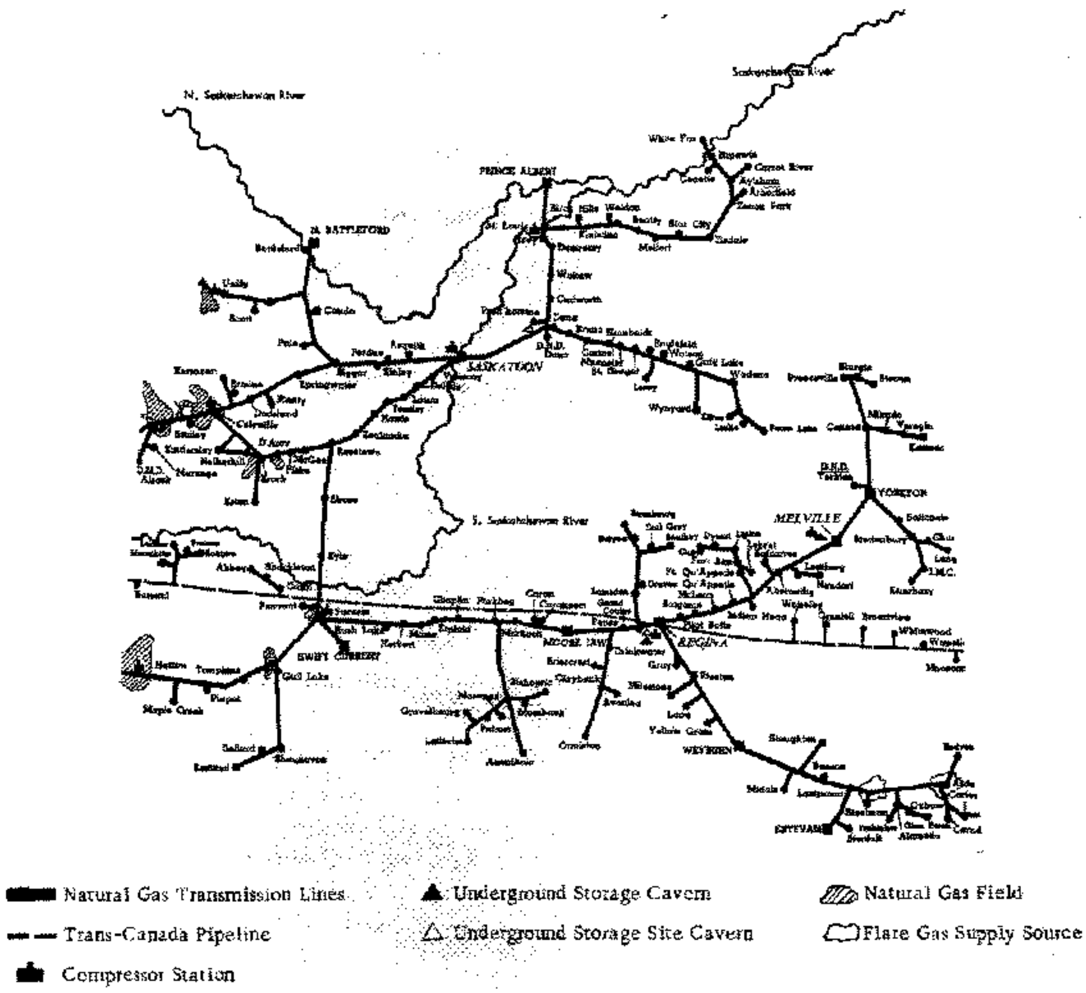


Figure 1

also 75¢. Our rate structure for residential gas gives an average selling price of about 75¢ so there wasn't much profit in any of these alternatives.

Running diagonally across Saskatchewan is a major deposit of Middle Devonian evaporites known as the Prairie Evaporite. This formation varies in thickness from 50 feet near the edge of the basin to over 600 feet in the centre. The base of the formation is generally relatively pure halite interspersed with some clay, shale, and anhydrite layers. Above this are varying amounts of potash salts interbedded with halite and again interspersed with clay, shale, and anhydrite. The whole Prairie Evaporite Formation is overlain by the impermeable Second Red Beds of the Dawson Bay Formation and underlain by the dolomite of the Winnipegosis. In 1961 some solution mining had been done in this area experimentally by Standard Chemical (now Kalium Chemical Ltd.,) for the production of potash, and operationally by Steelman Gas Company for the storage of propane

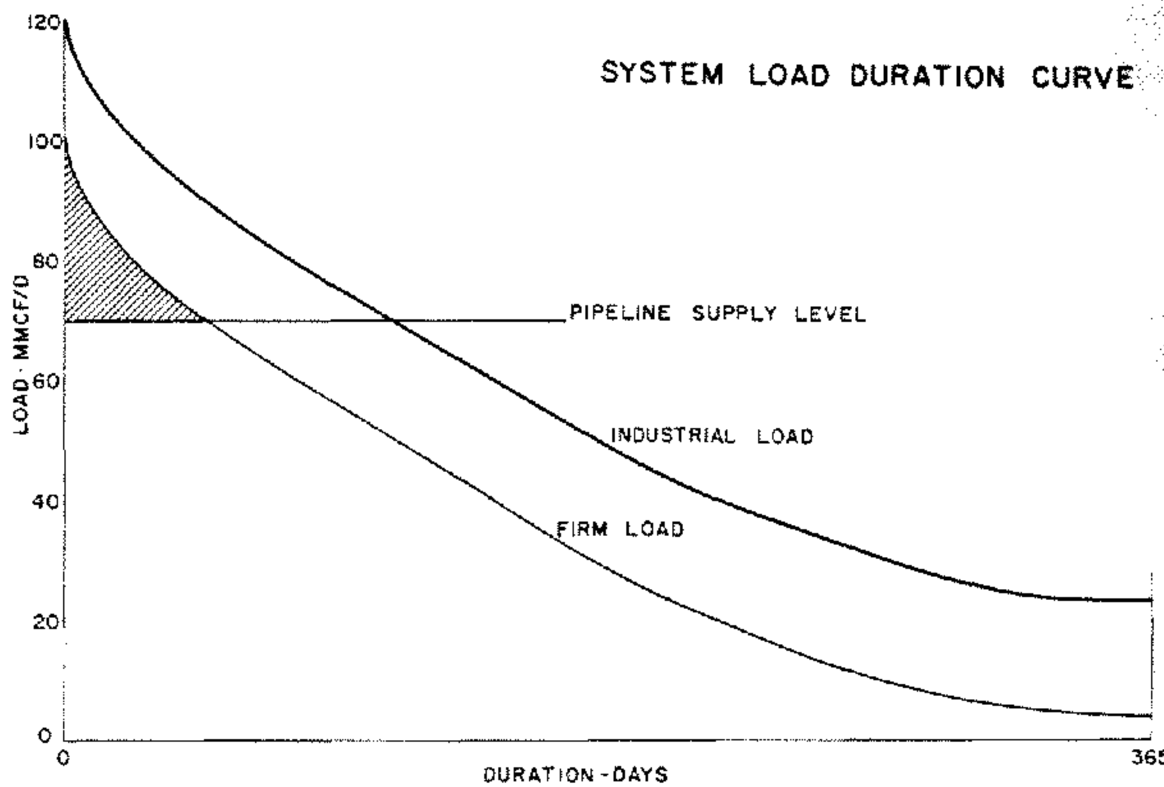


Figure 2

and butane in liquid form. This gave birth to the idea that a similar cavern might be used for natural gas storage.

An economic study of the alternatives indicated that if the cavern was successful then it would be the most advantageous.

In 1962 Mr. Howard Lowe and Dr. Carl Bays gave the opinion that at Melville and Regina such use of a solution mined cavern in the "dry" state was quite feasible. Normally when liquid propane or butane are withdrawn from a cavern the volume is replaced with brine. Our proposal envisaged storing the compressible natural gas initially at or near the formation pressure and then merely withdrawing the gas and allowing the pressure to drop. No brine re-injection to the storage cavern was envisaged.

The plan did not call for a large installation. In terms of the billions of cubic feet of gas handled by some of the major gas companies the S. P. C. system is very small but the climate makes service continuity a very vital matter and introduces many operating problems which are unknown in other sections of the continent.

2. Melville

In spite of the fact that Regina was the load centre, Melville was finally selected as the site of the experimental cavern on the recommendation of Mr. Howard Lowe who was engaged to design and supervise the initial installations. The reasons for this decision were:

1. Better geological information on the Prairie Evaporite Formation was available.
2. A source of water was assured.
3. The Prairie Evaporite was at a lesser depth than at Regina.

The Prairie Evaporite in the Melville storage well starts at a depth of 3, 366 feet and is approximately 530 feet deep. The lower portion of this between 3, 578 feet and 3, 840 feet, consisting of relatively pure halite, was selected for the actual location of the cavern.

Water for solution mining which was about two percent saline was obtained from the Viking and Blairmore formations which at this location exists between 1, 232 feet and 1, 758 feet. Selected sections were perforated to obtain the maximum water flow. The production rates achieved averaged 6, 500 barrels per stream day using a Reda pump set at 1, 165 feet. The brine was disposed of in the same formation at a depth of between 1, 500 feet and 1, 635 feet at a horizontal distance of just under one-half mile from the source well. No interference was experienced. Figure 3 shows an artist's conception of the process.

Special care was taken in the design and installation of the cement job on the 9 5/8-inch casing in the storage cavern well to ensure good bond with a sulphate resistant cement of low ultimate permeability.

The cavern was developed by standard single hole solution mining techniques using freshwater injection at the base of the cavern through 3 1/2-inch tubing and brine withdrawal at the top through a 7- to 3 1/2-inch annulus. The roof of the cavern was controlled by the use of a blanket of diesel oil maintained in the 9 5/8- to 7-inch annulus as shown in Fig. 4. Mr. Thor Brandt who has had wide experience in solution mining was also engaged to advise us on this phase of the operation.

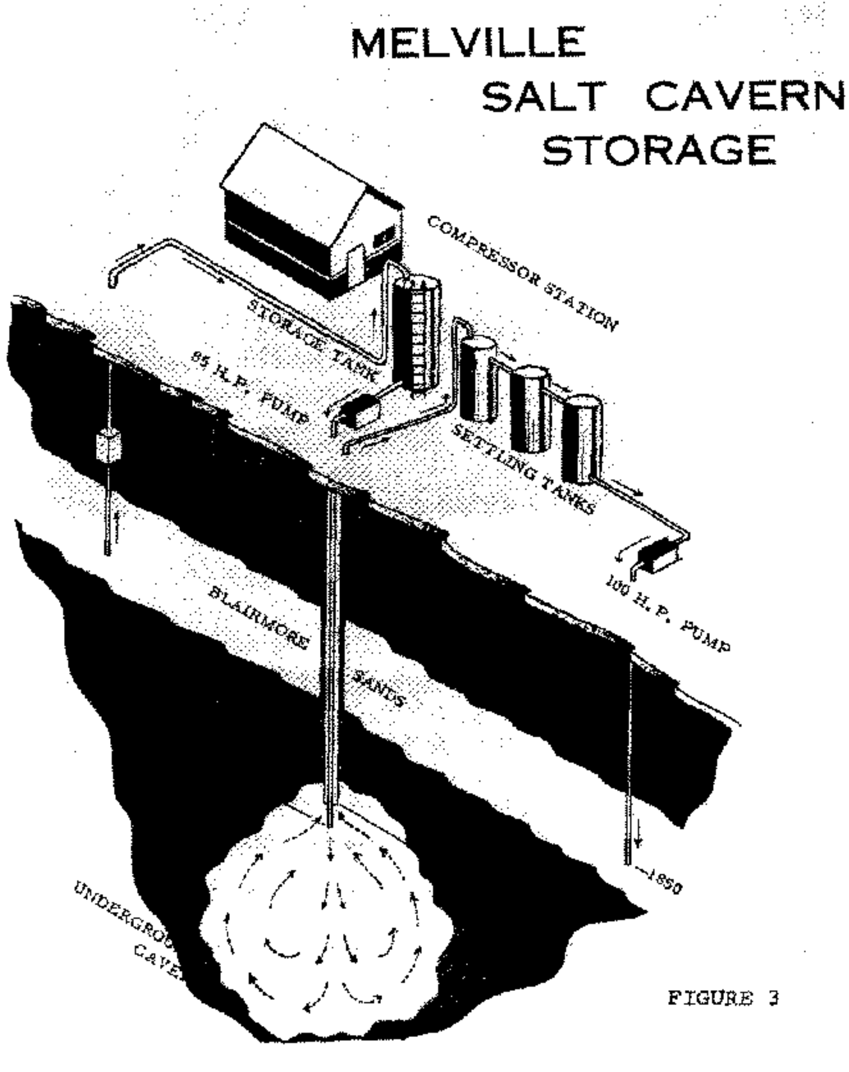


FIGURE 3

Figure 3

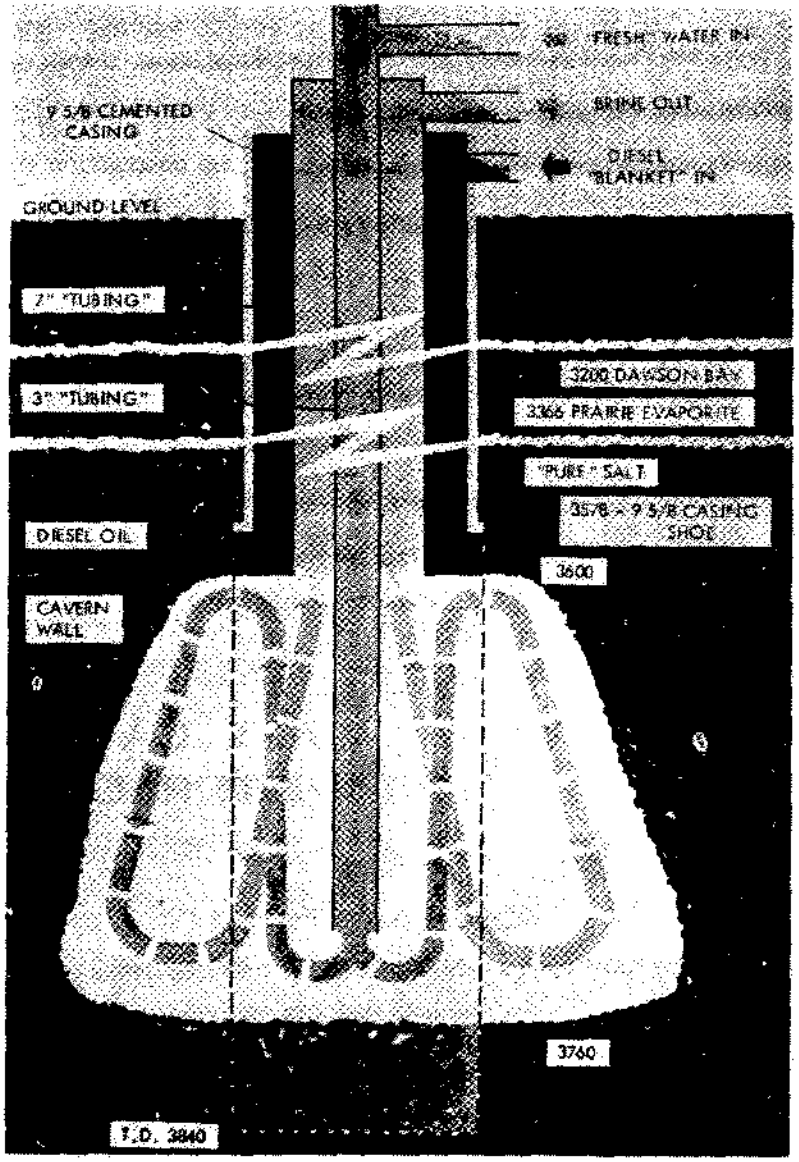
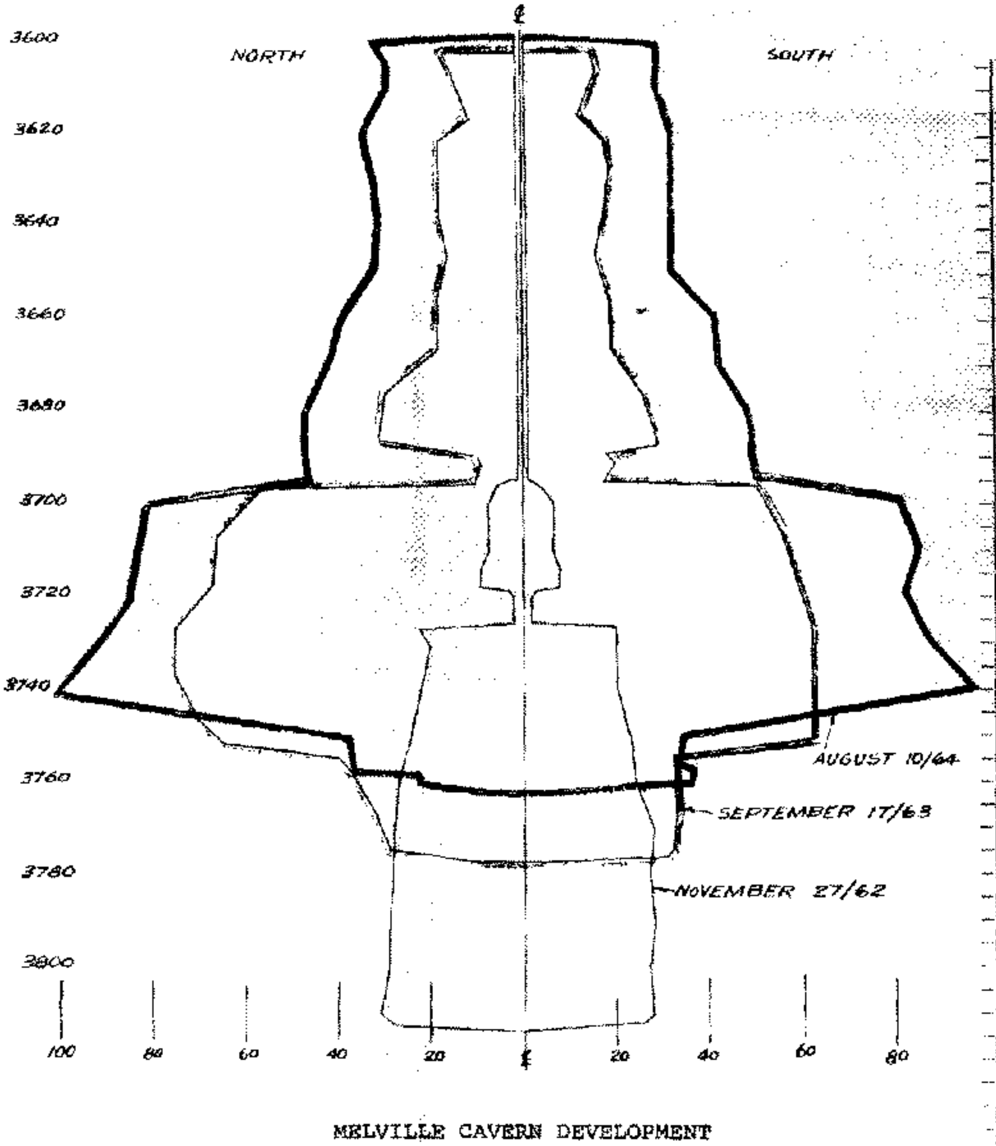


Figure 4

The progress of the cavern development is shown in Fig. 5 which depicts representative cross sections from a Dowell Sonar Survey. In 1962 a sump to take the insolubles from the main cavern was developed; these were estimated to be less than 10 percent of the total volume. The irregularity in the cavern at this time was attributed partially to a shale stringer and partially to some problems associated with the diesel blanket. The irregularity in the 1963 cavern was attributed to an insoluble anhydrite layer which was partially washed out in 1964.

In the spring of 1963 a gas test was run on the cavern to ensure its gas tightness. The brine was displaced with gas and the cavern was pressured up to 2, 200 psig (2, 000 psig wellhead pressure). After an initial stabilization period of about 48 hours, the dead weight pressure results remained constant for one week. It was concluded that the cavern was gas tight and subsequent tests have not indicated any leakage.

In general the solution mining phase of the operation proceeded without undue problems. The mining was suspended in September, 1963, so that the cavern could be used operationally to help



MELVILLE CAVERN DEVELOPMENT

Figure 5

overcome our peak gas loads during the 1963-64 winter season. At this time the cavern volume was about 162,000 barrels with a gas capacity of 190 MMscf. The 1964 washing period enlarged this to 290,000 barrels with a gas capacity of 350 MMscf. It was originally planned to stop development of this experimental cavern at 300 MMscf so this cavern is now considered as being completed. This figure was arrived at from consideration of the gas transmission line capacity and load characteristics of the area. Figure 6 summarizes the principal statistics of the cavern.

The surface equipment for gas handling at the site consists of:

1. An 800 H.P. electric-driven Cooper-Bessemer two-stage compressor capable of compressing 7 MMscfd from 300 psig to 2,200 psig.
2. A CESSCO glycol type dehydrator, heater, and choke capable of handling 20 MMscfd.
3. A liquid knockout drum.
4. Gas measuring equipment.
5. Provisions for alcohol injection.

MELVILLE GAS STORAGE CAVERN

Principal Statistics

Volume:	Approximately 1.6 million cubic feet or 290,000 barrels		
Capacity:	Approximately 350 MMscf of natural gas		
Dimensions:	Approximate Diameter Maximum	--	200 feet
	Minimum	--	60 feet
	Height	--	176 feet

Figure 6

The general layout is shown in Fig. 7. Figure 8 shows a photograph of the wellhead, heater, and dehydrator.

To date the static wellhead pressure has not been taken above 2,050 psig (2,250 psig cavern pressure) although the formation was originally subjected to a hydrostatic test of 2,550 psig.

During the past winter which was very severe and set many new records in Saskatchewan, extensive use was made of the cavern. Between November 19, 1964, and March 28, 1965, better than 611 MMscf was utilized from this cavern. In other words, it was cycled nearly 1.7 times by taking advantage of breaks in the weather to refill the cavern. The wellhead pressures cycled between extremes of 2,050 psig and 690 psig apparently without any adverse affects.

To say that there have been no problems with the operation would be misleading but so far the problems have been of a relatively minor nature. For convenience these will be split into two groups of problems which take place (A) During Injection, and (B) During Withdrawal.

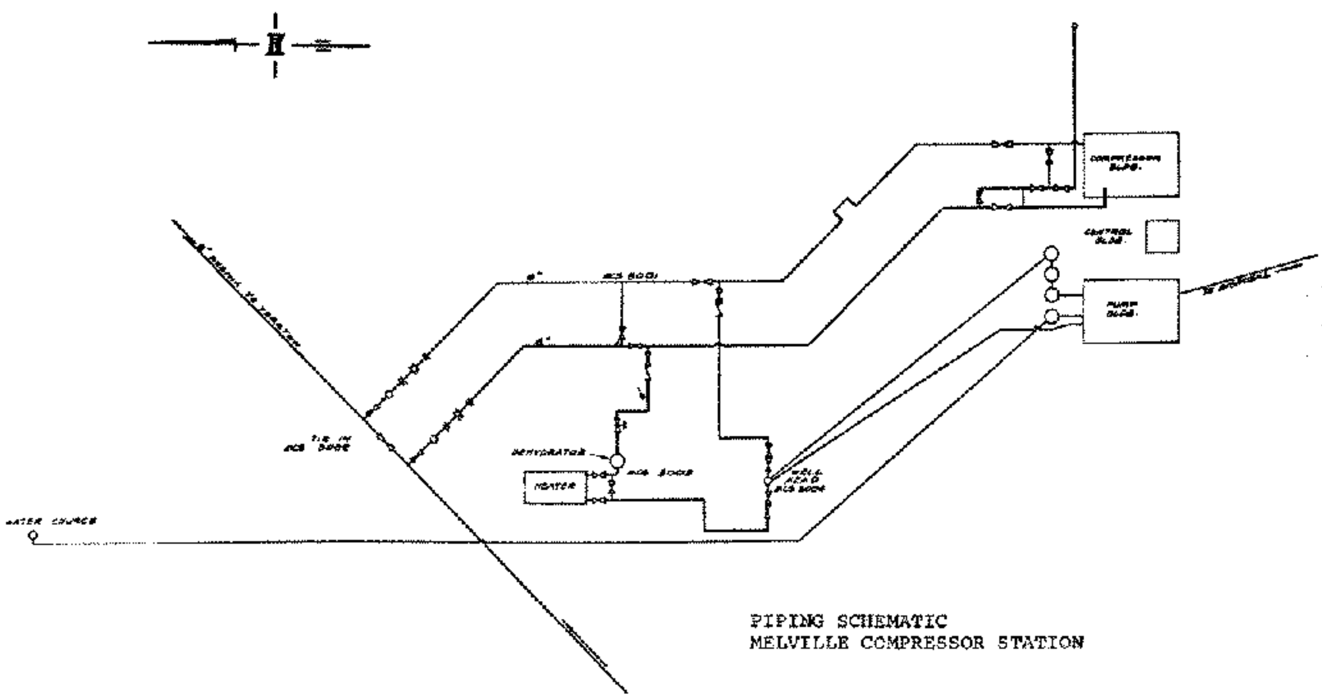


Figure 7

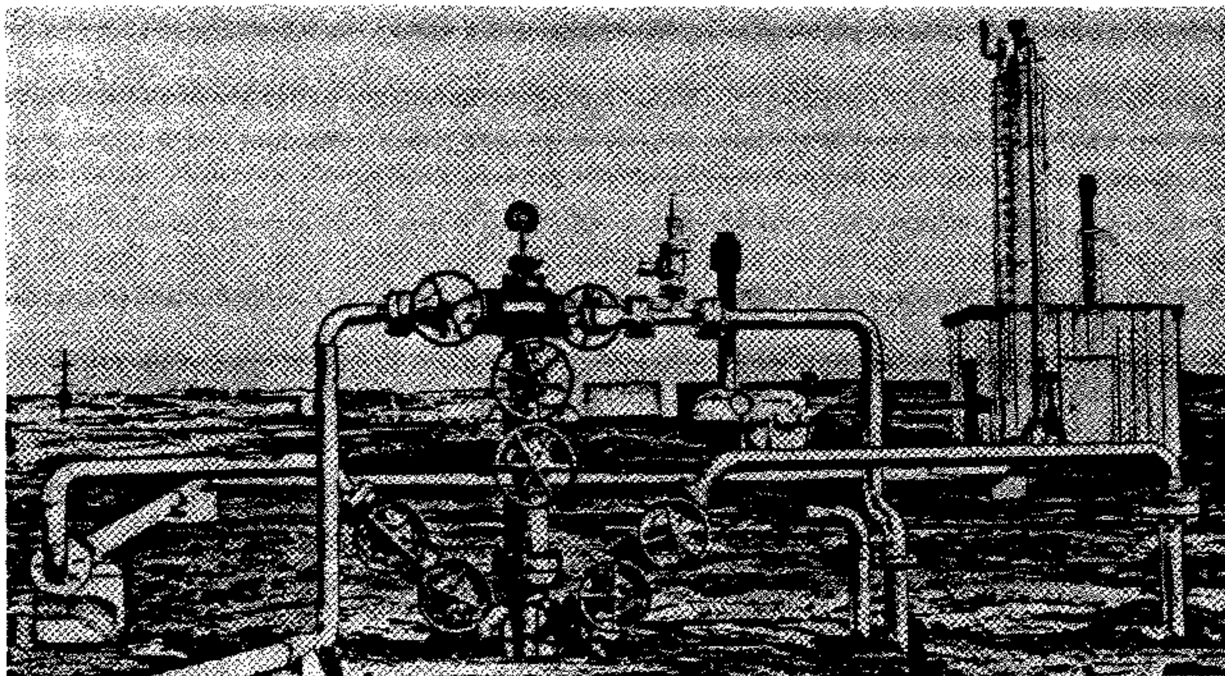


Figure 8

A. During Injection

The main problem during an initial cavern filling, when it is full of brine, is to accurately forecast the point at which the gas breaks through and starts coming up the brine return tubing. At this time the pressure in the brine return lines rises very rapidly and if the operation is not shut down quickly a dangerous situation could develop.

After the initial filling of course this problem does not arise again and the operation becomes fairly routine. It is merely necessary to keep injecting gas until the desired wellhead pressure is reached.

The principal unknowns during the initial filling are the exact capacity of the cavern and a precisely accurate measurement of the brine and/or the gas.

B. During Withdrawal

It was anticipated that for the first few years of operation the gas coming from the cavern would be saturated with water vapour and that hydrate problems would result between the wellhead and the heater. To date, however, this problem has not been experienced.

Carry over of diesel oil which presumably was coating the 9 5/8-inch casing and was being picked up by the flowing gas has been experienced. When the test of the cavern in the spring of 1963 was conducted, nothing more serious than glycol contamination in the dehydrator for a short time was encountered. During the 1963-64 winter, however, the oil started showing up in the gas transmission lines. Last year a scrubber was installed to catch this oil and no recurrence of the trouble has occurred.

3. Regina

As soon as there was evidence that the experimental cavern at Melville was successful, plans were immediately made to build a larger installation near the load centre of Regina 100 miles to the southwest. Here the problems were more severe. There was a shortage of geological information about the Prairie Evaporite and the location of a suitable water source.

The Prairie Evaporite Formation at Regina is situated between the 5, 320-foot and 5, 648-foot levels. This meant deeper drilling, increased circulating pressures, increased pressure rating of the gas handling equipment for 3, 600 psig and generally increased costs of construction. In 1963, after careful study of the available data and test drilling one hole, it was established in consultation with Mr. Brandt that a cavern could be built with the casing set at 5, 370 feet and the bottom of the sump at 5, 590 feet. The Blairmore Formation between 2, 543 feet and 2, 817 feet was tested and gave indications of being a suitable water source and disposal formation. Two storage wells, a water and a disposal well were drilled and solution mining commenced. In midsummer 1964, the well was tested with gas and found to be gas tight. This cavern, 72 feet high with a maximum diameter of 110 feet and a minimum diameter of 72 feet and a capacity of 155 MMscf, was used operationally during this past winter. One hundred and twenty-six MMscf was used throughout the winter principally for hourly peak shaving at the Regina load centre. In the meantime, the second storage well was being developed throughout the winter. It is planned to alternately develop each of the caverns while using the other one operationally each winter. The ultimate size of each cavern is planned to be 135 feet in diameter and 200 feet high. The volume will be 500, 000 barrels with a gas capacity of 800 MMscf per cavern at 3, 500 psig cavern pressure (3, 000 psig wellhead pressure).

The surface equipment installed at Regina was all similar to that used at Melville with the exception that higher pressure ratings were necessary.

No new operating problems were encountered at the new site during last winter's experience.

4. Prud'homme

In 1963 it also became apparent that a storage site could materially assist our Northern System and the load centre of Saskatoon (Fig. 1). Plans were laid and by early 1964 preliminary drilling had commenced at Prud'homme 40 miles east of Saskatoon. It was established that 450 feet of Prairie Evaporite existed at similar depths to those at Melville but the Blairmore Formation, although suitable for disposal, would not produce the required 10, 000 barrels per day of water. Eventually after considerable exploratory work a source of glacial drift water was established and solution mining commenced late in February 1965. Work on the surface installations is proceeding now. The cavern will be tested this summer and put into operational use with a capacity of 120 MMscf at 2, 200 psig next winter. Throughout next winter solution mining will continue on a second cavern at this location in the same manner as at Regina. Because of the lower pressures it will be necessary to mine three and possibly four caverns here to reach our planned ultimate capacity of 1. 5 Bcf. At Prud'homme a relatively thick layer of anhydrite was encountered 190 feet from the top of the Prairie Evaporite. It was felt that with this layer in the centre of the cavern considerable difficulty in obtaining satisfactory results would be experienced, consequently, our casing point was established below this band. This reduced the cavern height, washing area, and potential volume and is substantially reducing the cavern production rate.

5. Costs

The 290, 000 barrel Melville project including all the surface equipment has cost about $700, 000 or $2. 41 per barrel to date. As this was originally an experimental project the control is completely manual with the exception of certain safety shutdowns. It is planned to add automatic controls with the ultimate idea of establishing supervisory control from the Regina Dispatch Centre.

It is anticipated that the Regina and Prud'homme unit costs will be lower because of the larger capacities.

Using last winter's experience and amortizing the cavern life over 20 years, it can be shown that fully developed storage costs in caverns of this kind will be about 20¢ /Mcf which compares very favorably with propane air even at a minimum of 50¢ /Mcf (the price of propane has dropped very significantly in our area in the last year) or purchasing peak shaving natural gas at 75¢ /Mcf.

6. Unknowns

Although our somewhat limited experience indicates that the "dry" operation of salt caverns for the storage of natural gas is not only feasible but economical there are still some questions which remain unanswered in our minds:

1. What effect is dry natural gas going to have on the salt formation over a period of years? Is the plasticity of the salt bed sufficient to prevent any serious effects from possible drying out and spalling of the cavern walls?
2. What are the thermodynamic and structural implications of dropping the pressure in a cavern of this nature at a fairly rapid rate? At one time the pressure in the Melville cavern was dropped down to nearly atmospheric pressure for a short period without apparent ill effect. Operationally at Melville the pressure was dropped by over 1,000 psig in a period of less than two weeks. Is this likely to have any effect? If so, what?
3. Some difficulty has been encountered in correlating our results with the published data on supercompressibility. Unfortunately, continuous gas sampling facilities have not been available at the storage sites and as the gas can come from any one or more of four sources, all radically different, the solution to the problem may be very simple.
4. How large a cavern for this use is it possible or practical to develop? So far a more or less arbitrary limit of 500,000 barrels has been set. Is this a realistic figure? Obviously the unit costs can be reduced with increased size and the overall economics made even more attractive provided stability can be maintained.

Further information or experience on any of these points would be extremely welcome.

7. Conclusion

Even though the method is limited by the availability of salt and water, present indications are that the "dry" use of caverns in salt beds can be a successful and economic method of handling gas load peak shaving which is a major problem with nearly all gas companies.