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Use of Nuclear Explosions to Create Gas-Condensate Storage in the U.S.S.R.

I. Y. Borg

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Abstract

The Soviet Union has described industrial use of nuclear explosions to produce underground hydrocarbon storage. Two examples are in the giant Orenburg gas condensate field. There is good reason to believe that three additional cavities were created in bedded salt in the yet to be fully developed giant Astrakhan gas condensate field in the region of the lower Volga. Although contrary to usual western practise, the cavities are believed to be used to store H_2S-rich, unstable gas condensate prior to processing in the main gas plants located tens of kilometers from the producing fields. Detonations at Orenburg and Astrakhan preceded plant construction. The use of nuclear explosions at several sites to create underground storage of highly corrosive liquid hydrocarbons suggests that the Soviets consider this time and cost effective. The possible benefits from such a plan include degasification and stabilization of the condensate before final processing, providing storage of condensate during

periods of abnormally high natural gas production or during periods when condensate but not gas processing facilities are undergoing maintenance. Judging from information provided by Soviet specialists, the individual cavities have a maximum capacity on the order of 50,000 m^3.

Introduction

In exchanges of technical information with the Soviet Union in the past, U.S.S.R. spokesmen have described the use of cavities in salt produced by nuclear explosions for storage of gas condensate.[1,2] Subsequently the Orenburg gas condensate field was designated as the site of the experiments,[3] and indeed two underground nuclear explosions had been detected in that vicinity in 1971 and 1973.[4]

In 1980 and 1981 three underground nuclear explosions were recorded in the Lower Volga area near Astrakhan. This is the site of recent large gas condensate discoveries. The Soviet Union has announced plans to develop the Astrakhan fields and build a gas processing plant during the 11th Five Year Plan (1981-5).[5] In order to understand the role the explosions play in development of the fields and plant we propose to review the information on storage made available by the Soviets and the history of the Orenburg development.

Early Storage Experiments

In 1972 the Soviets reported testing a cavity produced by a nuclear explosion as a prototype underground storage facility for gaseous and liquid hydrocarbons.[1] Surprisingly its effective volume exceeded its geometrical volume by 10%, presumably due to fracture filling beyond the limits of the main void space. Nonetheless it successfully contained the condensate and is reported to be in use at an industrial site.

Orenburg Gas Condensate Field

The Orenburg field (Figure 1) was discovered in 1967 and started production in 1971. It is termed a retrograde gas condensate field because more than 10 MCF (283 m^3) gas are associated with each barrel of

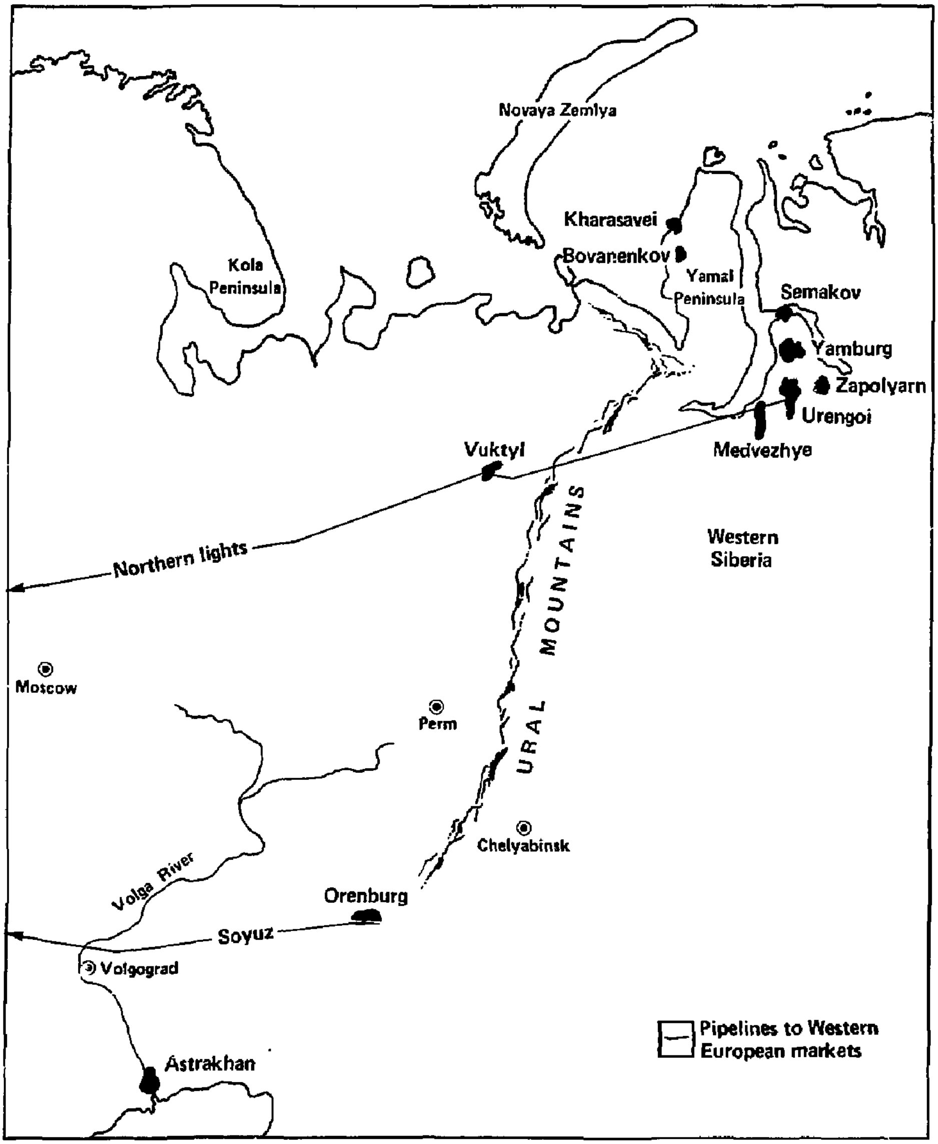
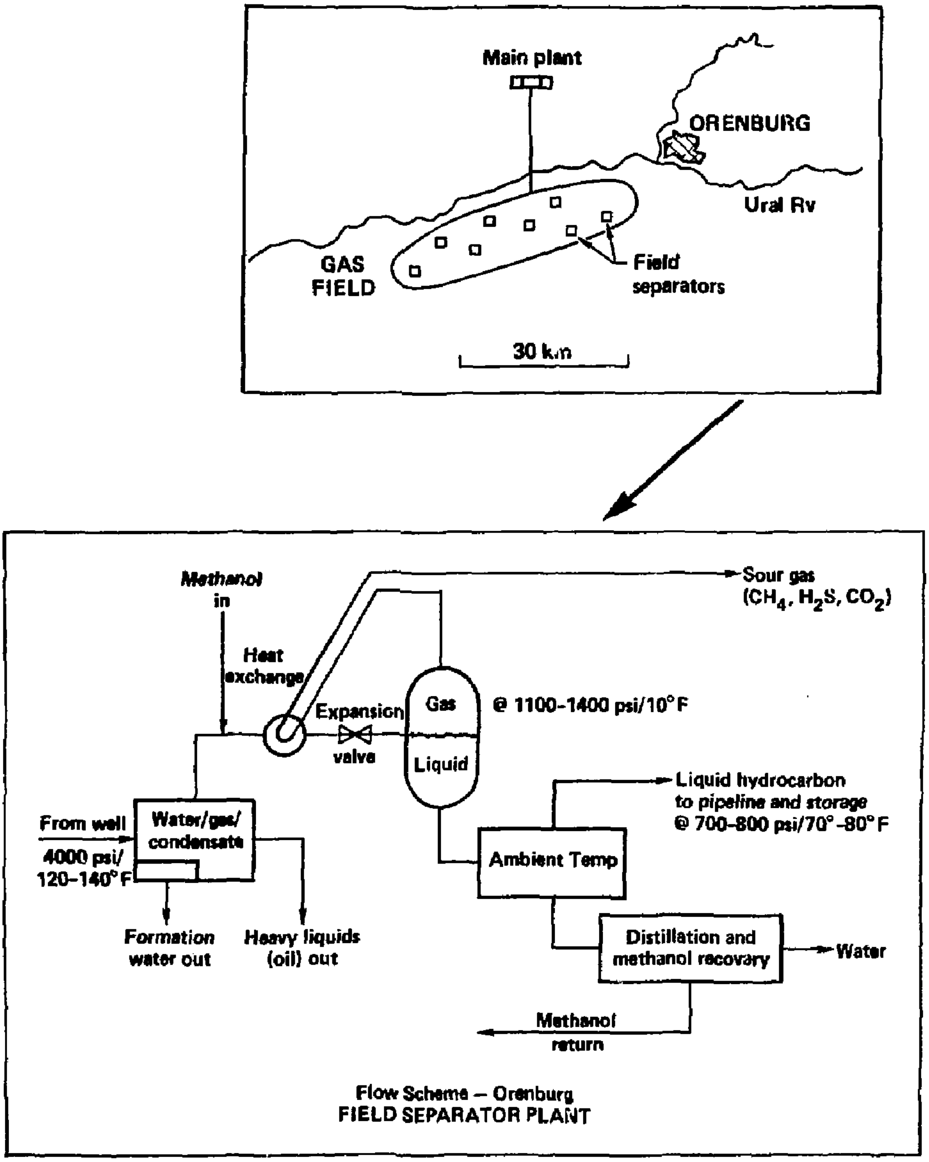


Figure 1. Location of the Orenburg and Astrakhan gas condensate field.

liquid hydrocarbon (less than 450g of condensate per cubic meter). The field posed production and processing problems because of the relatively high H_2S content of the gas which causes corrosion in transmission and processing facilities. Gas entering the main processing plants averages 2.7% H_2S.

Initially tne raw gas and condensate is treated in one of 10 field separating plants. Their individual capacity is 2.5 and $5x10^9$ m^3/y.[6] These plants separate the sour condensate from the sour gas, dehydrate the gas and lower the hydrocarbon dewpoint of the gas for transmission to the main complex. Such plants are usually not installed at comparable U.S. or Canadian sour condensate fields. For example, at the Ram River Complex in Alberta, Canada the first stage of the main processing plant separates the raw feed into gas and liquid hydrocarbon.[7] A general sketch of these field or satellite plants at Orenburg is given in Figure 2. The gas - separated at 1100-1400 psi and 10^0F - and condensate - at 700-800 psi and $70-80^0F$ - are transmitted to the main processing plants some miles distant in separate lines.

The main gas processing complex (Figure 3) is in three sections each with gas capacities on the order of 1.7 billion CF/day (17×10^9 m^3/y). Table 1 contains a list of products produced. Orenburg, the largest gas processing plant in the world, was built by a consortium of Western firms of which Technip, the French engineering group was most prominent. J.F. Pritchard Company of Kansas City designed and supervised the construction of the second plant. The first plant went into operation in February 1974, the second in September 1975 and the third in late 1978. A helium extraction plant associated with the third stage also went into operation in 1978. It may have a helium potential as high as 4.4 million m^3/y.[9]



Flow Scheme – Orenburg
FIELD SEPARATOR PLANT

Figure 2. Field Separator plant at Orenburg.[10] The liquid stream on the right side of the diagram can be directed to underground storage.

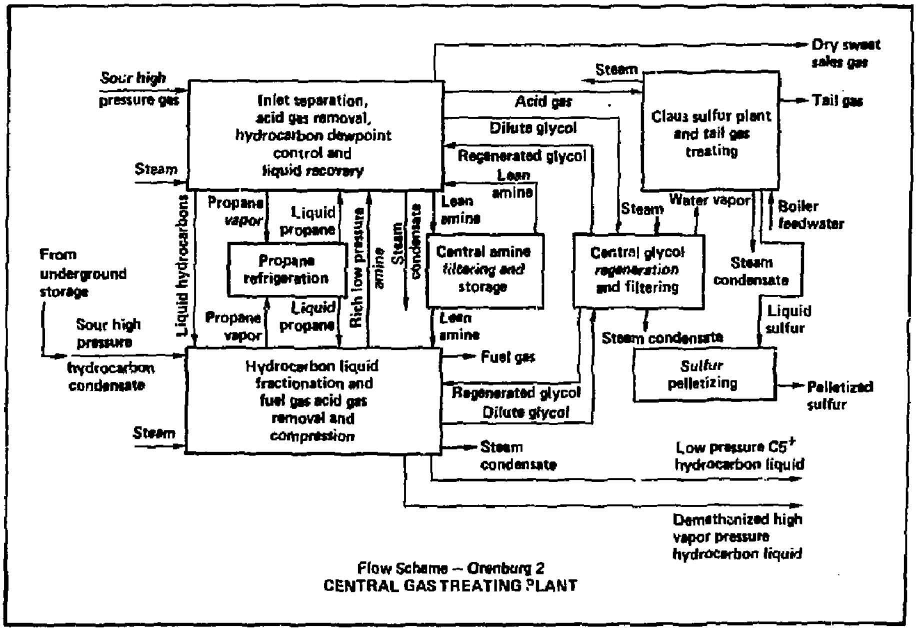


Figure 3. Main gas processing plant at Orenburg 2.[6]

Table 1. Products at Orenburg [8]

Products	Unit of measurement	Stages		
		I	II	III
Commercial gas	10^9 m^3/year	14.6	14.6	14.6
Sulphur	Thousand tons/year	432.0	432.0	432.0
Light hydrocarbons	-"-	267.0	267.[illegible]	267.0
Stable condensate	-"-	937.0	543.0	66.0

The two underground nuclear explosions in vicinity of Orenburg field preceded the construction of the complex. Western engineers at the site were in fact unaware of the existence of the large standing underground cavities. Their location in the vicinity of the field as opposed to the main plant environs some kilometers distant suggests that they were not intended for product storage.

Kedrovskiy in describing an underground nuclear explosion in salt, (Figure 4) now believed to be at the Orenburg site, states that there was need for storage of "separated" condensate before transporting it and for "degasification (stabilization)."[2] Some of the requirements were

a) an internal volume of the cavity of 50,000 m^3

b) a cavity that could be maintained at 80 atm

c) a capability of bringing condensate to the surface without pumping

d) radioactive contamination below permissible limits

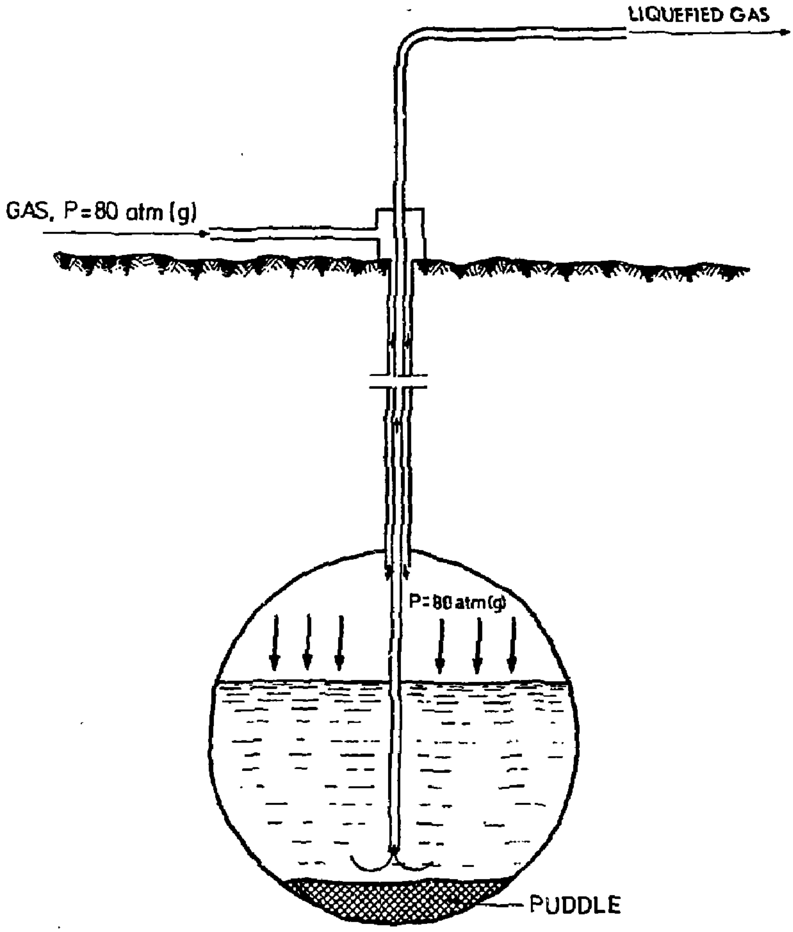


Figure 4. Underground gas condensate storage created by nuclear explosion.[2]

According to the Soviets these objectives were met. The explosion at 1140 m in bedded salt had a yield of 15 kt. The second explosion had a similar seismic magnitude and is assumed to be of the same size. Hence the maximum capacity of the two underground storage units is believed to be 100,000 m^3.

The advantages of the underground storage facilites of gas condensate fields have been described by the Soviets in broad terms.[1,3] Preservation of agricultural land and safety issues are cited as important considerations; however, the lower capital costs of underground cavities created by nuclear explosions constitute the principal arguments. The underground facilities are estimated to be three to five times cheaper than surface storage. Savings are in construction costs and elimination of the need for expensive corrosive-resistant steel tanks and related equipment.

In view of the almost unique use of underground storage in the Orenburg field with respect to usual Western practise some additional issues must have been of concern. According to a Pritchard engineer who worked on the second plant the three plants have excess gas capacity (normal flow is 17.4 billion m^3/d versus maximum flow capability of 20.0 billion m^3/d).[10] Presumably during periods of high gas demand, e.g., during winter months, the plants could not process all of the associated sour condensate. Thus storage of the liquid hydrocarbon until such time as it could be processed would seem to be desirable. From the size of the two cavities it is possible to estimate that about 10 days of surge, sour condensate could be stored. The estimate is based on normal gas production of 45 billion m^3/y, sour condensate production of 300 g/m^3[2] and capability to increase gas processing by 15%; thus about 5,550 tonnes/day of excess sour condensate are produced. If it is assumed that the working volume of each cavity is 75% of the total volume and the density of the sour condensate is 0.7 gm/m^3, the total amount that can be accommodated is on the order of 26,250 tonnes per cavity.

Astrakhan Gas Condensate Field

Three nuclear explosions have been recorded in the Lower Volga River area in the Astrakhan arch. One was registered on October 8, 1980 and the other two within four minutes of each other on September 26, 1981. The latter two may have been detonated closely in time to minimize local disturbance. All had a seismic magnitude (5.2-5.4) similar to those near Orenburg. Because the Astrakhan area is underlain by several thousand meters of Kungurian salt, it is reasonable to assume that the detonations occurred in salt and like Orenburg produced standing cavities of approximately the same size, viz. 50,000 m^3 each.

Astrakhan is a heretofore partially explored but undeveloped gas condensate field (Figure 1). The discovery well was drilled in 1973. Gas flowed from Middle Carboniferous limestones below the salt at depths of approximately 4250 m.[11] Subsequent discoveries delinated a large field containing particularly sour gas from formations with abnormally high pressures. Approximately 25% of the gas is H_2S and 12% is CO_2. Thus the field will be considerably more troublesome to develop than the Orenburg gas condensate field whose gas contained only 2.7% H_2S and 1.4% CO_2.[6] The gas-condensate ratio is probably about the same or somewhat smaller than observed at Orenburg. Reserves at Astrakhan are claimed to be 6 trillion cubic meters; however in the limited development of the field precludes accurate assessment. If this estimate were accurate, Astrakhan would have three times the explored gas reserves of Orenburg.[12]

In 1979, the U.S.S.R. trade officials solicited bids from western firms for construction of a gas processing plant at Astrakhan able to handle 6 billion m^3/year.[13,14] The project entails a sulfur recovery unit designed to produce over 2 million tonnes per year of elemental sulfur, half in liquid and half in solid form, for use as a fertilizer. Somewhere between 1.5-2 million tonnes of CO_2 are expected to be extracted and used in tertiary oil recovery in Gur'yevskaya Oblast.[15] Product condensate will be used in the petrochemical industry as at Orenburg and purified natural gas will be used to supplement supplies in southern areas of the U.S.S.R. Ultimately plans call for expansion to 18 billion m^3 annually. In addition to the first gas processing plant, the solicitation invites bids on drilling and well head equipment, scrubbing plants and control systems, thereby pointing up the inability of U.S.S.R. factories to produce corrosion-resistant drilling pipe needed to handle the highly corrosive gas and associated condensate.

Because of the restrictions on export of U.S. technology and goods to the U.S.S.R. following the Afghanistan invasion and the more recent limitations imposed by the Reagan administration, U.S. companies are not expected to participate in the Astrakhan project. Because of their contracts at Orenburg, French engineering firms are considered to be likely participants. However experience with sour gas and gas condensates similar to Astrakhan's are limited in the Western world to the U.S. and Canada. Canada has protested the Reagan administration's attempts to block foreign subsidiaries and U.S. licensees from use of U.S. technology on the Trans-Siberian pipeline.[16] Although no Canadian firms are involved in the pipeline project, a consortium of companies is bidding on the Astrakhan plant.

Summary and Conclusions

Three underground storage projects involving use of nuclear explosives have been described by the Soviets in exchanges of information concerning peaceful uses of nuclear explosives. The one described in a gas condensate deposit has subsequently been identified as at the giant Orenburg deposit that supplies purified natural gas to the Soyuz (Brotherhood) pipeline extending to the Czechoslovakian border. There it is joined by other gas lines from other parts of the U.S.S.R. which feed gas supplies to Eastern and Western Europe. Two nuclear explosions were recorded in the Orenburg field in 1971 and 1973. From Soviet descriptions of the condensate storage experiments and the similar seismic magnitude of the explosions, both are believed to have been detonated in bedded salt and to have created standing cavities with maximum volume of 50,000 m^3 each.

Apparently the use of these cavities in connection with the Orenburg gas processing complex is considered to be a success. In 1980 and 1981 three more underground nuclear explosions were detected in a heretofore undeveloped gas condensate field near Astrakhan. Similarity in subsurface geology and seismic magnitudes indicates that they are of similar size to those at Orenburg. At Astrakhan as at Orenburg the explosions preceded field development and construction of gas processing facilities. The three Orenburg plants were constructed by Western engineering firms (French and U.S.). Recently the U.S.S.R. trade officials have solicited bids from consortium of Western engineering firms for the development of the gas condensate field and construction of the plants at Astrakhan. The raw gas at Astrakhan with its very high H_2S content (25%) is corrosive and requires special steels for all aspects of field and plant development.

The information provided by the Soviets indicates that at Orenburg the cavities produced by the explosions are used for gas condensate storage prior to transport to the main gas plants for "re-processing." This points up an unusual feature of the Soviet gas condensate systems, namely the use of numerous field or satellite gas processing plants in the field in addition to the main plants. They make an initial separation of gas, water and unstable, sour condensate near the wellhead. The gas and unstable condensate are then moved by pipeline to the main plant some kilometers away in two streams for further processing.

According to American engineers involved with design and construction at Orenburg, the main plants were designed with some surge capacity for handling the incoming gas but with no corresponding surge capacity for the condensate streams. Assuming that the excess gas capacity is on the order of 15%, it is possible to calculate that the two cavities at Orenburg could handle at a minimum 10 days' production of the excess unstable condensate that could not be processed at the main plants. It is likely that the three cavities at Astrakhan could be put to similar use. The underground storage in the fields also could be utilized during short periods of maintenance or break-down of the condensate processing portions of the plants without hampering gas processing. Degasification or stabilization of the sour condensate coming from the field separation plants has been given as a reason for their use by the Soviet representations. In similar U.S. or Canadian plants interim storage is not considered necessary.

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