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STORAGE OF GOVERNMENT OIL RESERVES IN SALT CAVITIES

By

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HISTORICAL

In 1947, shortly after the end of World War II, the British Government realised that the war had promoted such an upsurge in the use of petroleum products that there was an urgent necessity to ensure that adequate supplies of refined products could be stored as a precaution against war.

At the same time relationships between the East and the West deteriorated and it was largely as a result of these influencing factors that, following a study, the Government decided that, at minimal cost, significant quantities could be stored in salt cavities.

DEVELOPMENT OF CAVITY STORAGE

For the provision of these cavities, it was natural that the Government should look towards the salt measures of Cheshire as they were in close proximity to a major oil storage and refining area at Stanlow on the River Mersey opposite Liverpool with adequate dock facilities for the import/export of petroleum products, together with easy access to their existing strategic pipeline system.¹ (FIG 1).

In 1949 a small test cavity to hold about 5,000 cubic metres was developed on behalf of the then Ministry of Fuel and Power in the ICI Brinefield at Holford, near Northwich, Cheshire and filled with gasoline and kept under constant observation. In fact testing of this product continued at 6 monthly intervals for 7 years. The tests indicated that there was no deterioration in the quality nor, as far as could be ascertained, any contamination of the brine. This gave the Government confidence by 1951 to approve the development of a series of cavities capable of containing approximately 1.2 million tonnes of oil.

The Ministry acquired from ICI some 200 acres of their salt measures near Plumley, Cheshire, which are about half-a-mile to the west of the M6.

A contract was signed with ICI to develop the actual salt cavities and one with Shell Refining Company to carry out all the necessary engineering works to connect these cavities to the existing Ministry pipeline network and Stanlow Refinery, together with all ancillary engineering works. 34 cavities were constructed at 400 feet centres and with their ceiling some 700 feet below ground level and each capable of holding about 45,000 cubic metres of product.

As first developed, they were about 140 feet in diameter, 170 feet in depth and the final total capacity of the site was about 2 million cubic metres, sufficient for about 1.5 million tonnes of gasoline and middle distillates.

The pipelines from this site connect to an existing installation at Backford, near Chester and then to Stanlow Refinery about 25 miles to the west of Plumley. Backford allowed access to the pipeline system via the North/South line to Avonmouth and also along the West/East line to Killingholme on the eastern seaboard at the mouth of the Humber. In addition, the cavities could be filled directly from a connection on the W/E pipeline from Killingholme which pipeline runs through the Plumley site.

As an additional outlet an installation was built some 6 miles to the east at Goostrey to provide road and rail loading facilities, sidings for the latter being connected to the London - Manchester main line.

Construction of the facilities and leaching out of the cavities occupied some 3 years and it was not until November 1955 that the first oil was introduced into them. The filling continued through the winter until March 1956 by which time some 7 cavities had been filled with gasoline, 4 cavities with gas oil and 2 with kerosene, a total of some 456,000 tonnes of products.

Coincident with this, all oil companies began to realise how vulnerable their crude supplies were from the Middle East because the early part of the '50s saw the building of a number of new refineries in this country and the expansion of existing ones. As these developed the availability of refined products became more and more dependent upon the security of crude supplies. In 1956 came the Suez crisis and before any further significant volumes of Government reserve oil could be moved into the cavities, the major oil companies approached the Government, with a view to using part of the storage for crude oil and thus by the first half of 1958 there was, in fact, 520,000 tonnes of commercially owned crude in the remaining developed cavities.

The Suez crisis and the continuing increase of UK oil refining capacity highlighted the necessity to increase stocks of fuel and storage capacity in the country generally as an insurance against any further peace-time interruption



of supplies. The Ministry subsequently agreed that the capacity of the cavities should be increased.

Work on enlarging the cavities began in January 1959. With the necessity to transfer existing stocks from one cavity to another, and the inevitable time factor of leaching out the salt, the enlargement programme was not completed for almost 4½ years until June 1963 - finally providing a total capacity of about 3.2 million cubic metres, sufficient for about 2.6 million tonnes of oil. Their enlarged capacity made them onion shaped, about 250 feet in diameter at the widest section but maintaining a depth of about 170 feet.

The storing of commercial crude volumes in these cavities eliminated the necessity for the Government to make any substantial addition to their own reserves which levelled off at about 0.5 million tonnes at the completion of the enlargement programme.

During this period the Ministry took under its control 2 very large worked out ICI salt cavities which had been in use by the Navy for storing bunker fuel and had become redundant. These were filled with about 0.43 million tonnes of Government crude oil.

It is of interest to note from Government records that the total cost of constructing these cavities and their associated facilities (with the exception of the Goostrey distribution terminal) was approximately £3.6 million and the total maintenance cost for the 6 years from 1960 to 1965 inclusive amounted to about £310,000. The revenue from the commercial use of the cavities at that time far exceeded the maintenance and movement costs. It is to be regretted that the continued expansion of refineries and the provision of additional surface tankage, much of it due to the oil companies' obligation to hold up to 90 days stocks in accordance with various international undertakings, together with the declining demand for oil products since the 1973 oil crisis, has reduced the need to make use of this facility.

OPERATION

On completion of the leaching of the salt in the production of the cavity, they are full of saturated brine. The 7" O.D. brine main which finishes about 25 feet above the bottom of the cavity is surrounded by a 10%" O.D. lining, terminating 2 metres approximately above the ceiling of the cavity and this

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is cemented into 13%" O.D. casing running from the wellhead down through the over burden into the 200 feet approximately of salt measure which lies above the cavity ceiling.

Oil is introduced into the annulus between the 7" pipe and 10%" lining, displacing the same volume of brine, via an interceptor, to a surface reservoir from which it is pumped into the ICI brine field mains and forms part of the volumes they supply by pipeline to the various works in the industrial zone around Runcorn south of the Mersey.

To recover the oil, brine is pumped from ICI into the surface reservoir and thence, by the same pumps, into a ring main connected to the brine pipe of the cavity, the oil being displaced up the annulus and into the suction side of on-site pumps for onward pumping either to the Goostrey distribution depot or through the cross country pipelines to Backford and Stanlow Refinery.

ICI are contracted to HMG to supply 7,200 cubic metres of brine per day but they are capable, by arrangement, normally of supplying about 12,500 cubic metres per day.

In order to ensure security of operation of these facilities, the 34 cavities are connected by a combination of individual pipelines and ring mains to two separate manifolds and pipeline pump stations of a similar design and size. The manifolds are provided with headers, tees and spectacle flange connections whereby great flexibility of operation may be obtained in allocating the cavities to segregated products to be pumped through the 4 pipelines from this site to Backford and Stanlow, employing the 3/300 cubic metres/hour pumps at each station, which can be allocated to any of the cavities or a combination of them.

To ensure security of power supply the site is fed by two separate 11 KV feeders into separate sub-stations and switchrooms connected by a ring main with interlocks on the main breakers so that either sub-station can carry the full site load. In addition, further security of pumping is maintained by the provision of two diesel driven pumping units which are coupled into the manifold system.

To allow for the possibility of failure of the brine supply, two pumphouses each housing two electric pumps, together with two diesel driven pumps, have been provided at the River Weaver some 6 miles to the north west and connected to the site brine mains by two 15" cross country pipelines. This facility can, of course, only be used to a limited extent as it is considered likely that about 4 displacements of the contents of the cavities by fresh water would, as a result of the ensuing leaching of the salt, increase the cavity size to a level where the separation distance between the cavities would reach a minimum thickness for safety.

The temperature in the cavities is about $11^{\circ}c$ (50°f) and this means, therefore, that they are unsuitable for the storage of the more viscous fuel oils and the heavier crudes.

As will be realised from the foregoing, the oil/brine circuit is hydraulically continuous but the gravity of the oil being in the order of .8 average and brine 1.2, there is a differential head between the brine and the oil at the wellhead, resulting in the oil pipe being, when not in operation, at a pressure of about 110 p.s.i. Any maintenance on the oil lines, therefore, requires the brine head to be reduced and this is achieved by introducing an air line down the brine pipe and blowing sufficient of the brine clear to surface to reduce the oil pressure to atmospheric.

MEASUREMENT

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There is no provision on the cavities for sampling or for dipping in order to ascertain the volume contained as is the normal practice with conventional above ground tankage. The only sample that can be taken is from the wellhead and if there has been no movement since the last cargo, testing this only indicates what the quality is of the last gallon pumped into the cavity.

The cavities are not provided with individual flowmeters, although modifications that have taken place in recent years have provided orifice plate flowmeters (of unproven accuracy) which can be reconciled against a similar type of brine meter in the brine pumphouse to assist in computing the volume stored in any one cavity. This in turn can be reconciled against the dips taken of the tanks supplying product to or receiving it from the cavities at Backford or Stanlow.

It will be readily realised that since dipping cannot take place and there is no physical access to the cavities, it is impossible to accurately assess the balance left in the cavity after a product movement during the last 25 years unless at some time in those operations the cavity has been completely emptied. Experience has shown that a fair measure of accuracy can be obtained on white

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oil product movements but in regard to crude, the stock books show generally a considerable residual volume in the cavities which is unpumpable due to the settling out of the heavy ends increasing the viscosity to a point where the friction losses in pumping are up to a level in excess of the head duty of the brine pumps.

Downhole sonar equipment has been developed for use in these cavities which can provide a profile of the cross section, at say, 1 foot intervals, from which can be computed approximately the volume per foot vertically of the cavity. In addition, ICI have developed an oil/brine interface detector employing gamma ray absorption techniques which can be lowered down the brine tube by an umbilical cable. The cable is connected to equipment which gives a digital read out from the detector head and an electric winch records the footage of cable in the well.

By plotting the change in absorption the brine/oil interface can be determined to about the nearest foot and from this, in conjunction with the profile of the cavity, the volume of residual oil floating on the brine can be approximately calculated.

EXPERIMENTAL WORK

During the course of the operation of these cavities, the opportunity has been taken to investigate the use of a downhole pump for increasing the output from them in time of war or national emergency.

A small multi-stage electrically driven centrifugal pump has been in operation for some years carrying out a test programme on behalf of the Department of Energy and in association with this, the opportunity has been taken to introduce a nitrogen blanket to prove that the cavities can safely be operated without the use of brine for lowflash products and could be capable of storing LPG.

The advantages of this type of storage is that the volumes are large and the maintenance very low - in fact apart from painting and ensuring no physical deterioration of the wellhead equipment, there is no expenditure involved in maintaining the integrity of the cavity except, as has been done on this site recently, carrying out a downhole sonar check to ensure that the cavity

profile has been maintained and to run a cement log to ensure the validity of the casing. Recent tests employing this equipment have indicated no deterioration in the profile of the cavities since their enlargement was completed some 20 years ago in June 1963.

Whilst individually the cost of maintenance is very low, there is nevertheless a very high standing charge in providing all the infrastructure associated with keeping this cavity facility in operation and therefore its commercial viability does depend on a relatively high utilisation. Regrettably, as already stated, the current recession has seriously affected this.

In conclusion it may be said that HMG's experience is that salt cavity storage is a proven method of providing large capacity storage for minimum investment. This applies to both strategic and commercial capacity, providing the latter has a relatively high utilisation. This is supported by a U.S. consortium decision in 1971 to provide large capacity importation and storage facilities in the Gulf employing the salt measures of the Mississippi delta and resulted in the LOOP (Louisiana Offshore Oil Port) project which was commenced in 1977.²

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