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SUCESSFUL EXPERIENCE WITH VORTEX TUBE TECHNOLOGY AT THE EPE CAVITY STORAGE OF RWE ENERGY

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ABSTRACT

In the year 2000 RWE Energy's cavity storage facility at Epe has received another gas withdrawal train based on vortex tube technology. As far as we know, RWE Energy has the longest experience with the use of the vortex tube technology for dehydration at a natural gas storage facility on a large-scale operational basis.

Due to 5 years of sucessful operation the use of the vortex tube technology has become an economically and technically attractive alternative to conventional dehydration processes.

Within the paper presentation the withdrawal train based on the vortex tube technoloy is described in detail. Furthermore details will be given of the opertaional experiences, including process parameters, operating resources and detailed photographs of the tube.

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1. RWE Energy

RWE Energy is the RWE Group’s sales & marketing and grid company for Continental Europe. In a total of 12 regions, including six outside Germany, RWE Energy offers electricity, gas, water and related services on a one-stop basis. Our customers include households, SMEs, business and industry, municipal utilities and regional suppliers. Within the different regions RWE Energy operates 10 underground gas storage facilities in Germany and the Czech Republic as well as a peak-shaving LNG-plant in Germany.

Due to the liberalisation of energy markets, increased competition, cost cutting measures and environmental protection requirements new challenges arise for the design and operation of underground gas storage facilities.

2. Background - Natural Gas Pressure Reduction and Dehydration Based on Vortex Tube Technology

In the year 2000 RWE Energy’s cavity storage facility at Epe has received another gas withdrawal train based on vortex tube technology. As far as it is known, RWE Energy has the longest experience with the use of the vortex tube technology for dehydration at a natural gas storage facility on a large-scale operational basis.

The design principles of the vortex tube are mainly based on fluiddynamic considerations. The gas is injected into the double-wall vortex tube tangentially via the inlet nozzles at the entry of the tube. Due of the pressure let-down at this point, the flow velocity is accelerated to almost the speed of sound. Owing to the Joule-Thomson effect, the gas is cooled, with some of its components (water and/or higher hydrocarbons) condensing. The flow takes on a pronounced rotationally symmetrical configuration. Due to the centrifugal forces in the vortex field, gas and condensate are pressed against the inside wall of the tube while flowing to the end of the tube. The condensate is drained off via outlets on the tube wall to condensate lines and fed to a condensate tank.

As the gas moves axially along the tube, dissipation occurs near the wall, i.e. the kinetic energy of the gas flow is converted into heat. The ”warm gas” produced this way leaves the vortex tube at the end through a specially designed annular gap, thus leaving the remainder of the gas, which is reflected by a conical element, to return to the entry of the tube. On its way back, the temperature is reduced below the temperature of the warm gas. This “cold gas” is withdrawn at the inlet side of the tube and blended with the warm gas.

The flow inside the vortex tube is three-dimensional; viscous and turbulent. A general analytic description of flow conditions inside the tube is therefore impossible; any description has to be limited to a number of special cases for which boundary conditions have been simplified. In addition the details of the energy exchange between the warm gas flow near the wall and the cold gas flow in centre of the tube are so far only partly understood. [1, 2, 5] Regarding the use of vortex tubes for the dehydration of natural gas, the process is made even more complex by the condensation of individual gas components during the vortex process.

3. Aims: Gas Withdrawal Train Design

In 1999 the need to increase the withdrawal capacity of the storage Epe was identified. As a consequence of a comparison of different dehydration processes like adsorption-process, glycol-absorption-process, glycol-free dehydration-process with salt pellets and the vortex tube technology the vortex-tube process was the most economic solution. In addition to the 3 conventional withdrawal trains the new withdrawal train was therefore based on vortex tube technology. For the design point, defined by an inlet pressure of 175 bar, an outlet pressure of 33 bar, and a dew-point of -10 degrees, the withdrawal capacity of the storage was increased by 140.000 Nm3/h.

To avoid the formation of gas hydrats all caverns of the underground storage in Epe are connected over a manifold to enable exchange of gas. The different volumes of the individual caverns following the geological parameters are the driving force to keep the gas in motion. The withdrawal trains are attached to the manifold. The main elements of the gas withdrawal train are the separators at the cavern outlet, the natural gas preheaters, the dehydration/pressure let-down plant (vortex tubes), the downstream separators and the gas reheater. After droplets of condensate and solid particles have been removed at the separator, the gas is preheated in the high-pressure heat exchanger. The setpoint for the temperature increase in the heat exchanger requires avoidment of extensive condensation of higher hydrocarbons in the downstream vortex tube process.

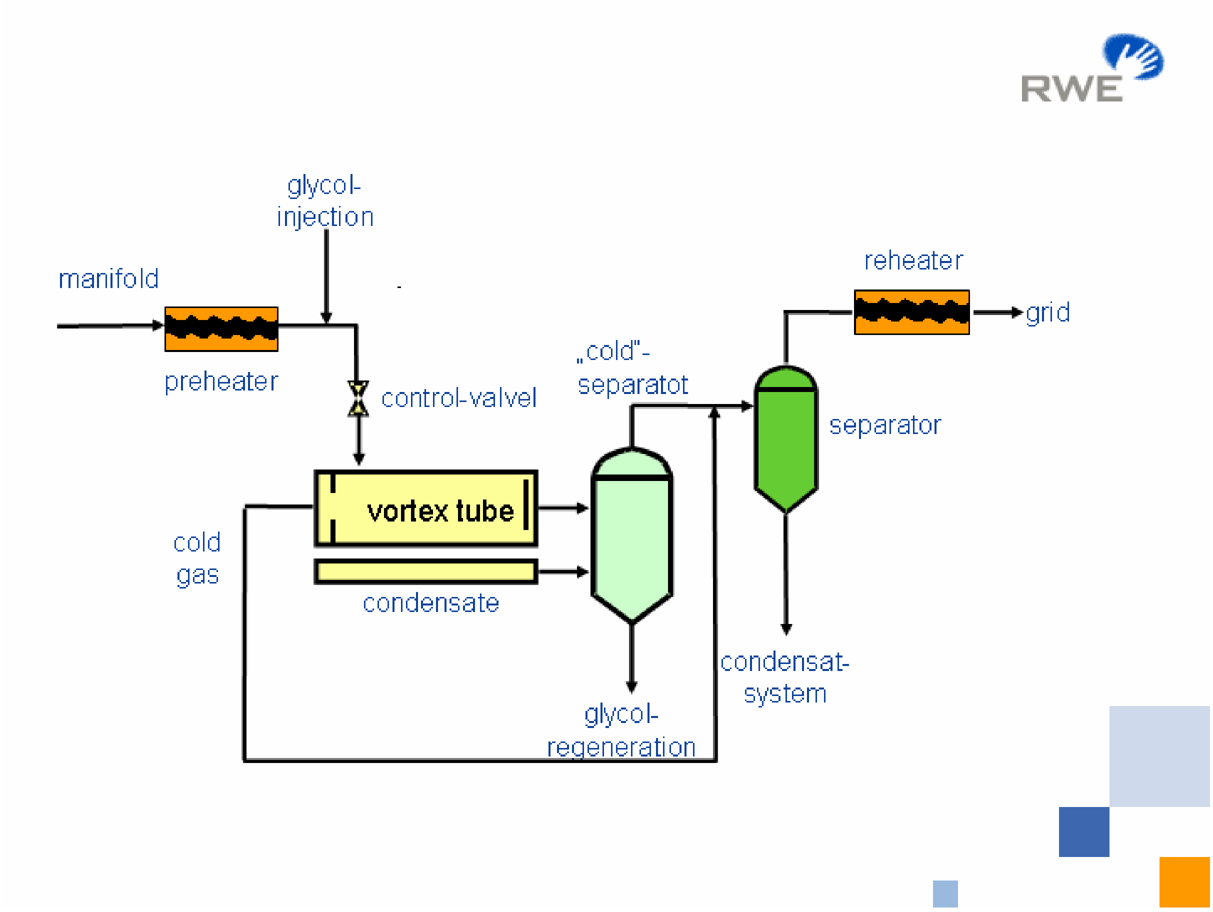
Two vortex tubes are used for pressure reduction and gas dehydration. They are operated in individually or parallel mode depending on gas pressures and flows. Each vortex tubes is fed by two inlet lines. To split the flow, two flow control valves are used. The inlet nozzles of each vortex tube are designed to accelerate the gas flow approx. to the speed of sound while ensuring tangential injection into the tube. Due to the nozzle design, a maximum mass flow is achieved at each nozzle while the gas pressure is reduced. As the gas flow to the vortex tube increases, the control valve regulates the gas flow passing through the nozzles. When the maximum flow has been reached, the second inlet line is completely opened by the respective control valve.

Inside the vortex tube, the flow energy of the gas is used to reduce the temperature of the gas still further. During this process, the temperature drops below the dewpoint, allowing condensation of water and higher hydrocarbons already dissolved in the gas. Apart from condensation, the centrifugal forces generated by the vortex cause the gas components to move towards the tube wall, thus enabling gas/liquid separation.

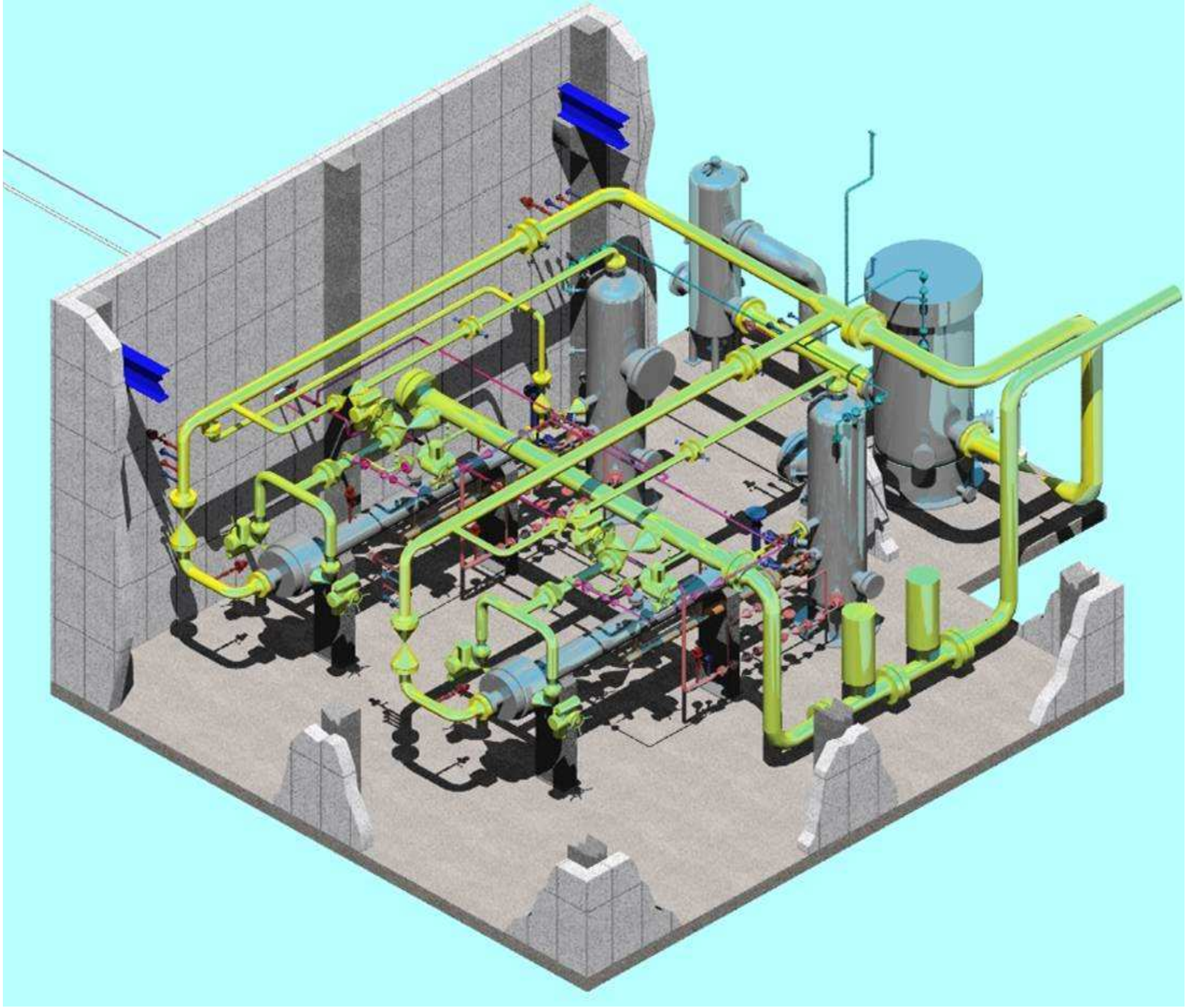
To avoid hydrate formation, glycol is injected, upstream of the vortex tubes and subsequently removed from the condensate recovered from the vortex tube system and returned to the process.

As there was no experience availabe [3, 4] in the engineering phase on a large-scale operational basis the decision was made to include 2 seperators in the downstream process for safety reasons. The glycol / water separators consists of multicyclons and demister packages. Leaving the vortex tube, the warm gas and the condesate stream flow into the cold separator, where the phase separation takes place. In the next process step cold gas and the warm gas streams are brought together entering the second separator. The total gas stream is reheated to the specified pipeline temperature in a downstream reheater. From here, it passes through the metering system before being fed into the transmission pipeline.

The process scheme is visualised in picture 1.



Picture 2 shows a 3-dimensional view of the installation.



4. Results / Summary: Operational experiences

Due to 5 years of successful operation the use of the vortex tube technology has become an economically and technically attractive alternative to conventional dehydration processes.

All guaranteed performance parameters have been fulfilled. In addition to that, the performance of the train have exceeded the guaranteed parameters, resulting in extra-flexibility for the storage-operator. During the 5-year operation period of the vortex tube withdrawal train no unplanned maintenance occurred. The inspection of the vortex-tube after 5 years shows no mechanical wear. (see picture 3 and 4).

Picture 3 gives a internal view of the vortex tube entrance.

Picture 4 shows the annular gap of the vortex tube.

However a problem with the automatic rejection of the liquid phase in the cold separator was identified. Due to foam production the liquid level was not exactly detected, so that the automatic rejection system didn’t work accurately. As a consequence the detection system was modified, i.e. the ultra-sonic technology was replaced by conventional technology. To reduce the amount of foam production the demister packages of the cold separator were altered.

In the 5-year operation period, the expected advantages of the vortex-tube technology in comparison to the conventional dehydration processes have been confirmed. In consequence of the functionality of the vortex tube the added glycol serves only as a measure to avoid the formation of gas hydrates. In relation to the conventional process the volume of glycol is reduced by approx. 90%, resulting in a smaller glycol regeneration plant. The recirculated quantity of glycol is about 200 l / 100.000 Nm3/h. Additionally to that, the demand for the selectivity level is only 95%. On a whole, the impact of the emissions of the burnt vapours to the environment is lower. Therefore the total demand of process energy (heating and electrical energy) for the glycol regeneration process is reduced. A very positive aspect of the decribed process from the operational point of view is the short start-up time for the withdrawal process.

At the end of the withdrawal period the pressure differences between the caverns and the transport pipeline are smaller, i.e. the driving force of the vortex-tube process vanishes. For very small pressure differences, the vortex-tube process switches over to a spray drying process. The situation in Epe is determined by the minimum pressures inside the caverns in the range of 45-50 bar and the fact that the Epe storage feeds into a transport system with a maximum operating pressure of only 38 bar. As a consequence, the operating method of spray drying is very unlikely. Furthermore, the conventional withdrawal trains would be operated under these conditons with a higher priority.

Currently the ratio of cold and warm gas flow is equal 70:30. In future we would like to investigate a flexible ratio to optimise the process.

The decision to use the vortex tube technology has been confirmed due to sucessful operation for 5 years. The advantages of the process were demonstrated on a large-scale operational basis. Furthermore the advantages of this process due to the conditions at the Epe-site (min. pressure of caverns, max. pressure of transport pipeline), far outweigh the disadvantages.

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