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A study of hydrate plug formation in a subsea natural gas pipeline using a novel high-pressure flow loop

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Abstract: The natural gas pipeline from Platform QK18-1 in the southwest of Bohai Bay to the onshore processing facility is a subsea wet gas pipeline exposed to high pressure and low temperature for a long distance. Blockages in the pipeline occur occasionally. To maintain the natural gas flow in the pipeline, we proposed a method for analyzing blockages and ascribed them to the hydrate formation and agglomeration. A new high-pressure flow loop was developed to investigate hydrate plug formation and hydrate particle size, using a mixture of diesel oil, water, and natural gas as experimental fluids. The influences of pressure and initial flow rate were also studied. Experimental results indicated that when the flow rate was below 850 kg/h, gas hydrates would form and then plug the pipeline, even at a low water content (10%) of a water/oil emulsion. Furthermore, some practical suggestions were made for daily management of the subsea pipeline.

Key words: Natural gas hydrate, blockage, flow assurance, high-pressure loop, water cut, flow rate

1 Introduction

As more and more oil and gas has been discovered and recovered from deep water and ultra deep-water fields, natural gas is transported in subsea pipelines at low temperature and high pressure. The low temperature and high pressure conditions may cause natural gas and water transported in the pipelines to form gas hydrates. Upon formation, hydrate accumulation and agglomeration eventually form a slug, blocking the flow in the pipelines. Therefore, more and more attention has been paid to developing flow assurance strategies to prevent hydrate plug formation (Andersson and Gudmundsson, 1999; 2006; Gaillard et al, 1999; Gudmundsson and Graff, 2003; Ning et al, 2007; Wang et al, 2007; Greaves et al, 2008; Dong et al, 2009; Balakin et al, 2010a; 2010b; 2010c). Unfortunately, little research is focused on the phenomena involved in a hydrate plug formation due to the strict requirements for experimental equipment and conditions, especially on an industrial scale. Since 2003, the Center for Hydrate Research at the Colorado School of Mines had been developing a hydrate formation model-CSMHyK (Turner et al, 2005a; 2005b), available as a plug-in module for the oil & gas analysis package (OLGA), to provide an estimate of where and approximately when a hydrate plug may form in collaboration with the SPT Group. Boxall et al (2008a) performed flow loop tests to verify the hydrate formation model and to investigate the effect of experimental variables on the plugging behavior of hydrate formation in water-in-oil emulsions. Davies et al (2010) developed a model to predict hydrate plug formation by studying the mass and heat transfer resistances to hydrate formation in oil-dominated systems, and the revised hydrate formation model had been validated on both laboratory and industrial scales. Emmanuel et al (2008) presented the effects of key variables on the plugging tendency of model fluids and crude oil systems by conducting tests in the flow assurance loop (FAL) of Tulsa under steady-state and stop-start conditions. Test results indicated that the plugging behavior of oil system is dependent on these variables and the oil-water chemical properties. Nevertheless, up to now there seldom has been systematic work relating experimental research into real plugging practices, and the results are also system dependent, making the reliability of those results to the actual conditions questionable. Therefore, it is necessary and meaningful to perform relevant studies based on real hydrate blockage incidents. In this paper, a typical blockage as below was studied by using a novel high-pressure flow loop.

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