Journal of Natural Gas Science and Engineering 37 (2017) 85–105

Contents lists available at ScienceDirect

Journal of Natural Gas Science and Engineering

journal homepage: www.elsevier.com/locate/jngse

A review of the evaluation methods and control technologies for trapped annular pressure in deepwater oil and gas wells

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ARTICLE INFO

Article history:
Received 16 July 2016
Received in revised form
10 November 2016
Accepted 18 November 2016
Available online 19 November 2016

Keywords:
Deepwater well
Trapped annular pressure
Wellbore integrity
Evaluation methods
Control technologies

ABSTRACT

The evaluating methods and control technologies for trapped annular pressure (TAP) are important part of deepwater drilling, completion, testing, production and injection. The casing pipes at the Marlin oil field in Gulf of Mexico were collapsed due to annular pressure buildup (APB) which led to temporary shutdown of the oil field. The incident makes protection of the annular trap casings to be a major consideration in the design of deepwater oil and gas well. In order to solve the problem of APB, an effective way to take is to conduct structure optimization design and develop multiple prevention technologies before the wellbore design and tripping in the casing pipes. The evaluation methods for TAP in deepwater oil and gas wells were summarized and discussed, including: field measurement method, indoor experimental simulation, theoretic model and intelligent monitoring method. Five types of control measures for TAP were reviewed, which contained increasing casing strengths, eliminating the trapped annular, releasing trapped pressure, balancing the expansion volume and blocking heat transfer. The advantages and disadvantages of 12 control technologies were analyzed and compared systematically, such as working principles, critical equipments, applications and key technical indicators. Based on the past development, the controlling program for TAP was devised. Finally, related discussions and recommendations for evaluating and controlling the TAP were carried out, which is a great significance for research on evaluation and control technologies for TAP in deepwater oil and gas wells.

1. Introduction

The investigation of thermal insulation of boreholes can be traced back to the 1960s (Eisenhawer et al., 1981; Aeschliman et al., 1983; O'Brien, 1996; Ravi et al., 1999). Over the past 50 years of research, there are lots of research results for the key problem of TAP. In the 1990s, the 13-3/8″ casing of well A-2 of BP Company at Marlin in Gulf of Mexico was collapsed due to annular pressure buildup (APB; Trapped annular pressure, TAP), as shown in Fig. 1, which discontinued the production of the oil field for one year (Bradford et al., 2002, 2004; Ellis et al., 2002; Gosch et al., 2002; Vargo et al., 2003). Since then, the problem of APB that can lead to great economic loss has begun to draw more attention of oil companies and researchers (Pattillo et al., 2007; Staudt, 2002; Williamson et al., 2003).

When an oil/gas well was being tested or production operated, the downhole high temperature oil/gas will transfer the heat to the production tubing, production casing, intermediate casing, surface casing and conductor casing. The fluid expansion (prepad or drilling mud) in the wellbore occurs because of the increasing of temperature. When the fluid was in the trapped annular A, B and C, fluid expansion will produce tremendous pressure that bears on the tube wall in contact with it (Fig. 2). An oil/gas well with TAP must meet two basic conditions (Oudeman and Bacarreza, 1995; Maldonado et al., 2006): (Adams and MacEachran, 1994) there is trapped annular volume (TAV). When the intermediate casing was cemented, ground formation's break pressure and cost factor should be considered. Therefore, the top of cement (TOC) is usually below the wellhead and the upper casing shoe (Aeschliman et al., 1983). There is a change in the temperature of the fluid in the TAV. In the drilling, testing or production process, mud and downhole oil/gas with higher temperature will transmit the heat to the TAV in the shallow formation. If there are multiple trapped annular volumes, the

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http://dx.doi.org/10.1016/j.jngse.2016.11.042

Fig. 1. The collapsed casings in deepwater oil and gas well (Bradford et al., 2002; Bradford et al., 2004).

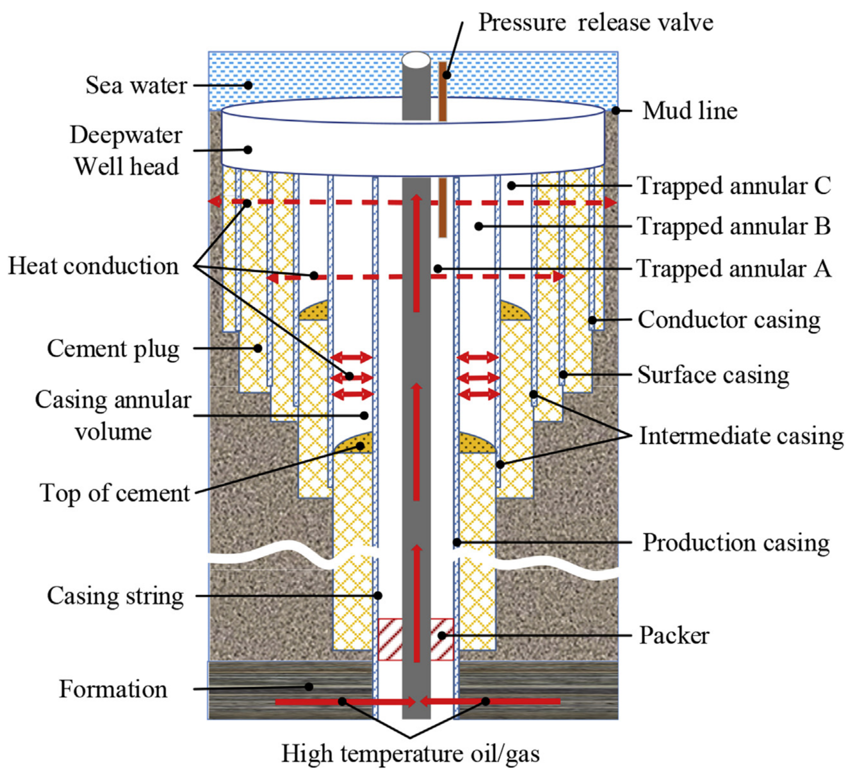

Fig. 2. Typical deepwater well profile and the heat conduction process.

expansion pressure will be larger. In deepwater areas, the temperature near the mud line is low, normally around 1–4.4 °C, while the downhole fluid temperature can be up to 260 °C. Therefore, the TAP in the deepwater areas is larger than shallow water and continental oilfields, as much as 84 MPa (Fig. 3) (Payne et al., 2007; McSpadden and Glover, 2008; Rosland et al., 2013; Kaculi, 2015). If the control technologies are not taken promptly, the high TAP will collapse the casing and cause huge economic loss. As most of the christmas trees in continental oilfields and offshore oilfields are above the sea level, the wellhead can be used to release the trapped pressure (Rivas et al., 2009; June et al., 2010; Willoughby, 2014). In deepwater and ultra-deep water areas, only the trapped pressure on the production tubing and production casing can be released by the relief valve installed on the wellhead, which is not applicable to the annular pressure between the outer casings (Rp, 2012). Therefore, the existence of TAP between deepwater casings can bring huge damages to regular production of oil/gas wells. This factor must be taken into consideration in casing design. Currently, oil and gas reserves are abundant in deepwater and ultra-deep water areas, and a number large of deepwater wells will be constructed (Sun et al., 2011; Yang et al., 2013; Hu et al., 2013; Zou et al., 2013). Consequently, the research and investigation of TAP in deepwater wells is an important and interesting problem. However, there are few science paper focus on the systematic review of APB problem, so we should pay attention to it and systematic researches (Hu, 2012, Hu et al., 2012; Eaton et al., 2006; Tahmourpour et al., 2010; Bellarby et al., 2013; Weideman and Nygaard, 2014; Perdana and Zulkhifly, 2015; Lentsch et al., 2015; Santos et al., 2015; Sathuvalli et al., 2016).

From the above analysis, a broad overview of evaluation and control technologies for TAP can help the researchers and engineers to develop more advanced methods which can applied to mitigate the TAP in deepwater oil and gas wells. The structure of the paper is as follows. The first section mainly summarizes the evaluation