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An Alternative Approach to Wellhead Flowline Pressure Protection

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Abstract

For many years, owner/operator pipe specification standards have required that wellhead downstream piping be adequate to sustain a full wellhead shut-in. This inherently safer design practice ensured that the flowline pipe was specified with a maximum allowable working pressure (MAWP) equal to or greater than the maximum pressure expected to be produced by the well. This practice has been proven to provide adequate protection in thousands of wellhead installations throughout the world.

Inherently safer practice has been challenged recently with the introduction of electric submersible pumps (ESPs) in existing wells. The maximum discharge pressure under block-in conditions is greater than the MAWP of existing flowline pipe. A safe alternative to replacing the pipe is the use of a high integrity protective system (HIPS) designed and managed as a safety instrumented system (SIS) with a safety integrity level (SIL) 3. This presentation explains how the HIPS approach can be applied as a layer of protection against flowline overpressure in single and multiple wellhead installations.

Introduction

When the price of crude oil started to rise above $50 per barrel, oil producing companies aggressively pursued efforts to increase or renew production in existing oil wells at a reasonable capital expenditure. An enhanced oil recovery solution, especially in ultra deep (4,000 ft.) subsea applications, is to utilize electric submersible pumps (ESP) to boost well pressure. A major challenge in developing these deepwater enhanced oil recovery solutions is the maximum allowable working pressure (MAWP) limitation of the downstream flowline pipe. A solution gaining in popularity is the implementation of a high integrity protective system (HIPS) to close block valves located prior to the pipe specification break, protecting the lower rated piping downstream.

Conventional wellhead piping practice requires that downstream piping be adequate to sustain a full wellhead shut-in. These practices have proven effective in thousands of wellhead installations throughout the world. However, the introduction of high pressure ESPs in many off-shore fields has increased the maximum shutr-in pressure beyond the MAWP of the downstream flowline pipe. Reasons given for installing an ESP include:

- Older, sometimes abandoned, wells still contain valuable oil reserves but insufficient pressure for efficient recovery,
- Connecting wells with different production pressures to common manifolds,
- Desire to increase production rates, and
- Existing production wells are being connected to more distant processing facilities.

The design of the instrumented system response is complicated by the need to respond quickly. On wellhead shut-in, the ESP typically produces pressure sufficient to challenge the mechanical integrity of the flowline very quickly. The pressure rise is related to the compressibility of the material, but the pressure rise is generally rapid, resulting in a very short process safety time, e.g., in liquid service, the time may be less than 5 seconds.

In typical on-shore process industry applications, an overpressure hazard, such as the one presented by the ESP well flowline, would be addressed by a pressure relief device (PRD) and a disposal system, such as a flare or scrubber to safely process the material relieved during an overpressure event. When PRDs are installed in conventional flowline designs, they are typically sized to mitigate only thermal expansion of the material when the flowline is blocked-in. For HIPS flowline designs, the PRD sizing should also consider possible block valve leakage.

On-shore, the operator has time to respond to the PRD operation by manual isolating the pressure sources. The holding or disposal system is sized for the rate and duration of relief expected to occur, considering the time required for the operator to take action and for the process to achieve a safe state. This approach is impractical and uneconomic for wellhead applications. If the material could be safely held or disposed of, the holding or disposal system would be large, costly and would pose its own environmental and safety risks.

A safe and reliable alternative to replacing the existing wellhead flowlines relies on the use of a HIPS to detect unacceptable operating pressure and initiate closure of block valves. HIPS (Figure 1) is a special class of safety