Made to Measure

New upstream control and optimization techniques increase return on investment

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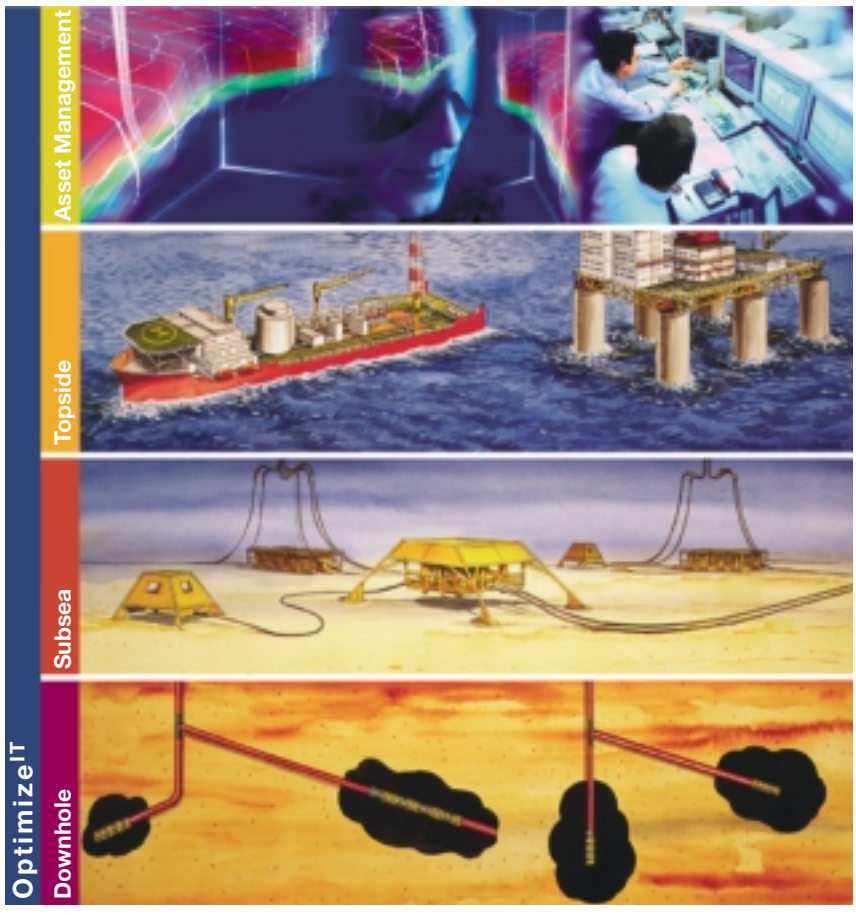
With most oil and gas fields in the western world becoming mature, the industry is having to face a new reality: How to increase, or at least stabilize, production while maintaining available reserves at their present level. One obvious answer is to gain access to new areas of exploitation, but there is another, more cost-effective solution in the form of new technologies that increase oil recovery.

Compared with other process industries, the upstream oil and gas sector has historically been considered 'low-tech', mainly because of its low level of automation. However, products are available today which signal the start of a new era for the industry. Developed to recover more oil and gas as well as achieve better flow constancy and throughput, they are at the forefront of a shift in the upstream industry to a higher level of automation that is fast becoming the standard rather than the exception.

ABB has been developing advanced control and optimization solutions for the upstream oil and gas industry for many years. But unlike its competitors, who for the most part have tried – with limited success – to adapt technologies from the refining and petrochemical industry, like Model Predictive Control (MPC), ABB has used its customers' field



development and operational challenges as the starting point for its product development. Emphasis has been on flow assurance, accurate monitoring, and the optimization of oil and gas flow networks.

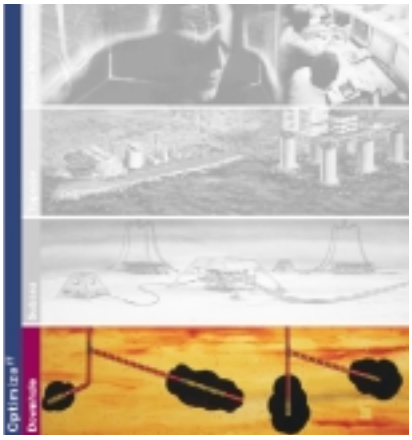
This work has resulted in the *Optimize*IT *Enhanced Oil Production Suite*, a range of systems, solutions and services for increasing oil and gas production. Among the suite's technologies for the upstream industry are *Optimize*IT *Active Well Control* and *Optimize*IT *Active Flowline Control*, two advanced control products for stabilizing slugging wells and slugging pipelines. Both products improve regularity and throughput. Another leading-edge product is *Optimize*IT *Well Monitoring System*, which provides data on the individual flows of gas, oil and water from production wells without having to install expensive multiphase flow meters.

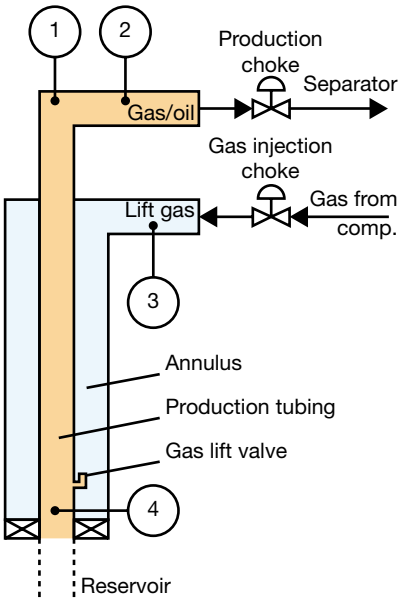
ABB believes that these three products will contribute to the next shift in automation level, in which the upstream oil and gas industry moves from simple control schemes to advanced control products and algorithms.

Stabilization of unstable wells

Oil wells with long horizontal bores, and also gas lift wells, tend to behave erratically under certain operating conditions. Unstable production has many drawbacks. For example, surge hinders smooth operation and calls for safety measures and means of guarding against shutdown. Also, the total oil and gas production must be within the system's design capacity to provide adequate safety margins. Instability can sharply reduce lift gas efficiency, while difficulties with gas lift allocation computation are also common. Well instabilities also make it impossible to distribute the lift gas optimally. All in all, unstable wells are difficult to operate efficiently.

Optimize^{IT} Active Well Control is a unique model-based feedback control solution for the stabilization of unstable production wells. Wells with natural flow are stabilized by automatic actuation of the production choke (in the case of gas lift wells the gas injection choke may also be automatically controlled). Optimize^{IT} Active Well Control holds the well automatically at its optimum operating point and assures stable flow, ie there is no slugging. The cyclic tubing and casing heading in the gas lift wells are also eliminated. More oil is produced by wells equipped with this product since pressure fluctuations and oscillating flows are eliminated.



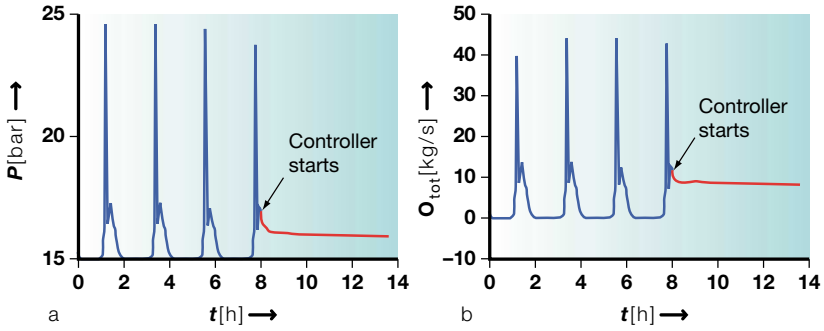


1 Schematic of a gas lift well, with measurements that may be available

1 *Wellhead pressure*
2 *Wellhead temperature*
3 *Casing head pressure*
4 *Bottomhole pressure*

Typically, Optimize^{IT} Active Well Control uses pressure and temperature data from the production tubing, but for gas lift wells measurement data taken from the annulus may also be used **1**. Pressures in the production tubing may be measured anywhere between the bottom of the well and the wellhead. The pressure downstream of the production choke may also be used (For more details on active well control, see [1]).

Optimize^{IT} Active Well Control is currently undergoing extensive field tests. So far, these have validated the well flow stabilization action and shown an increase in production. Also, an extensive simulation program has confirmed the performance of the



2 Stabilization of the wellhead pressure (a) and oil production rate (b) of a vertical gas lift well

P *Wellhead pressure* *t* *Time*

O_{tot} *Total oil production rate*

solution over a wide range of well conditions. 2 and 3 show the results of simulations for a vertical gas lift well. In 2 the results can be seen when the wellhead pressure is used to manipulate the gas injection choke. The two diagrams show the dramatic change in wellhead pressure and total oil production rate that takes place when the well controller takes over.

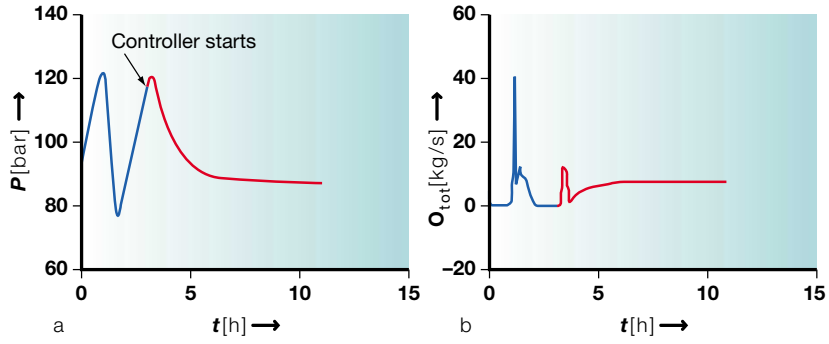
Similarly, in 3, which gives the results of using the casing pressure for active control of the production choke, the controller stabilizes both the casing pressure and the total oil production rate.

4 shows the stabilization of the downhole pressure in a horizontal well where the downhole pressure is measured and used for automatic control of the production choke. The result is a dramatic reduction in pressure variation.

3 Stabilization of the casing pressure (a) and oil production rate (b) of a vertical gas lift well

P *Casing pressure* *t* *Time*

O_{tot} *Total oil production rate*

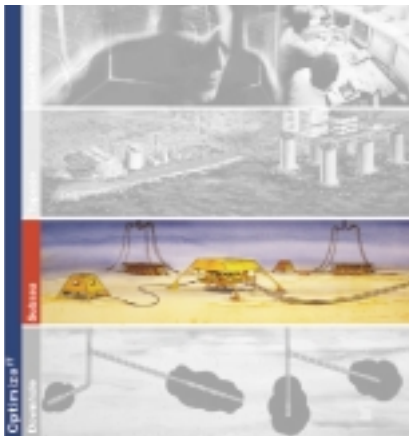


Main benefits of using Optimize^{IT} Active Well Control

- Increased well production
- Well is automatically maintained at optimal operating point
- Increased production uptime
- Disturbances in process and production gathering are avoided
- Possibility of more reservoir drawdown
- Rationalized lift gas consumption
- Pressure surges at payzone sandface are avoided
- Simplified well operation

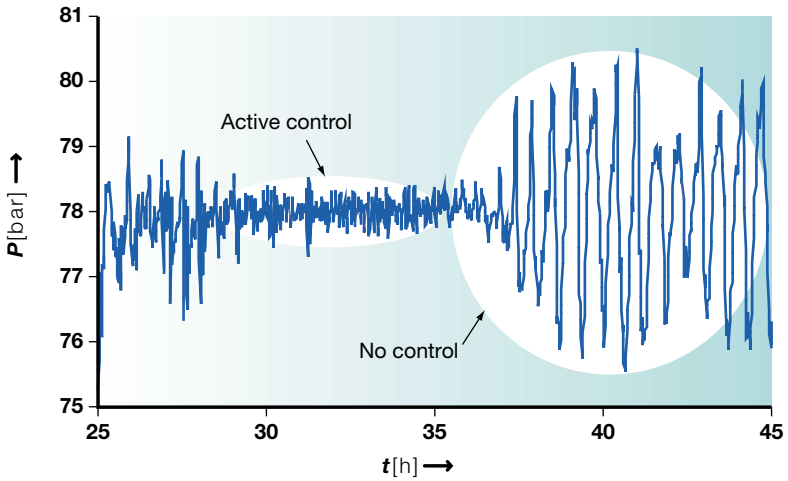
Stabilization of slugging flowlines

Multiphase pipelines connecting remote wellhead platforms and subsea wells are an increasingly common feature of offshore oil production. More than 2000 lines of this kind exist worldwide, with another 2000 scheduled to be added over the next five years. In addition, long-distance pipelines are likely to be used in the future to connect subsea processing units directly to onshore processing plants.



4 Stabilization of the downhole pressure *P* in a horizontal well

t Time



One of the biggest challenges confronting operators of offshore processing plants and subsea separation units is how to control disturbances in the feed to the separation process, ie how to smooth or avoid flow variation at the outlet of the multiphase pipelines that connect wells and remote installation to the processing unit.

One common form of flow variation is *slug flow*, in which the liquid flows intermittently along the pipes in a concentrated mass, called a slug.

The unstable behavior of slug flow in multiphase pipelines has an adverse effect on the operation of offshore production facilities. Severe slugging can even cause platform trips and plant shutdown. Frequently, compressors trip due to large, rapid variations in the feed rates to the separators caused by unstable multiphase fluid flows.

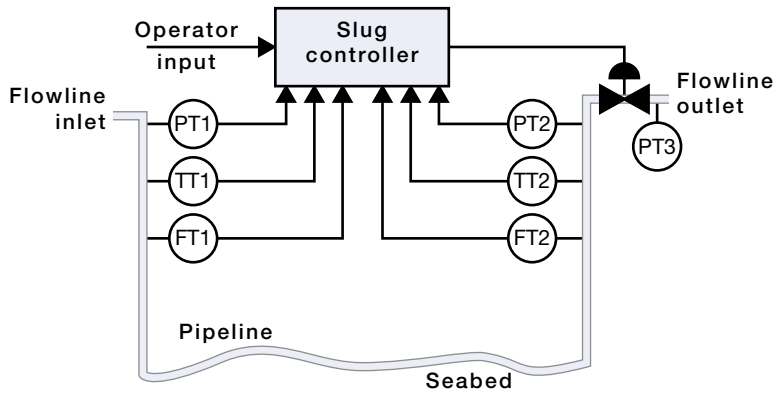
A lot of effort has gone into trying to avoid the operational problems associated with severe slugging. The two main approaches are:

- Design the system in a way that avoids the problems.
- Find ways to tolerate the unwanted behavior, eg through operational changes or control.

Each of these approaches is usually very costly since, in modern field developments, the operating conditions vary widely and can be hard to cope with without multiple production lines and parallel processing.

Teamwork is key

Optimize[IT] *Active Flowline Control* is the result of multidisciplinary research at ABB in the fields of fluid mechanics and cybernetics, but builds on earlier theoretical and practical work [2–4]. Recently, several papers have also been published that show the feasibility and potential of applying feedback control techniques to unstable multiphase flow (see [5] for an overview). However, to ABB's knowledge there are only four installations in operation which have stabilizing controllers installed. These are the Dunbar-Alwyn pipeline [6], the Hod-Valhall pipeline [7], the Heidrun-Nordflanken tie-in pipelines, and the Tor-Ekofisk pipeline. One reason for this might be that cybernetics and fluid dynamics are usually treated as separate technical fields, In other words, the control engineers have limited knowledge of multiphase flow, and the fluid dynamics experts limited insights into what can be achieved with feedback control.



5 Typical configuration for Optimize^{IT} Active Flowline Control. The pipeline instrumentation includes flow transmitters (FT), pressure transmitters (PT) and temperature transmitters (TT).

With Optimize^{IT} Active Flowline Control, ABB has now introduced a third approach:

Avoid the problems by using appropriate instrumentation and control.

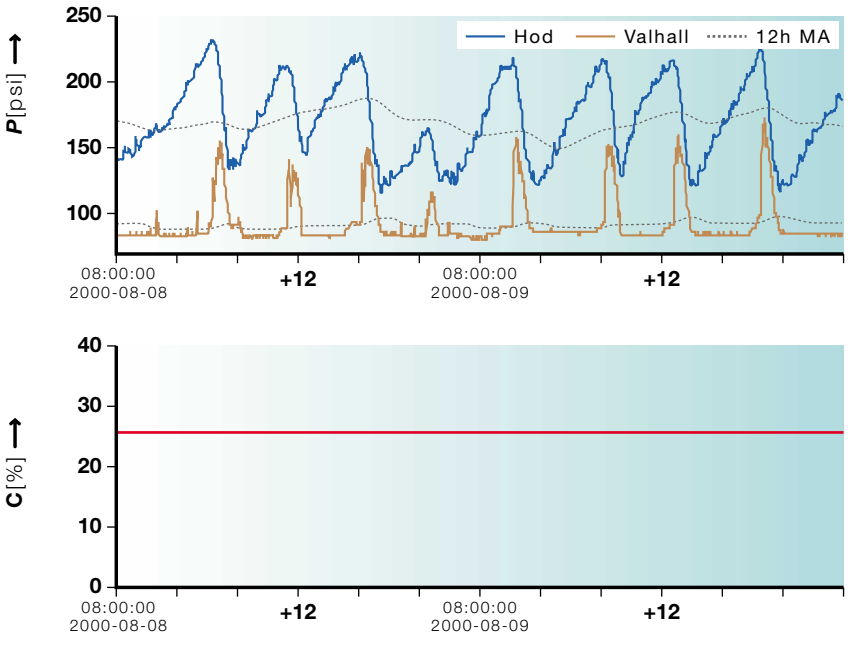
Optimize^{IT} Active Flowline Control is a feedback control solution for stabilizing terrain-induced slug flow in multiphase pipelines. By removing the slug flow, severe process facility upsets are avoided, which improves process flow regularity. Installing Optimize^{IT} Active Flowline Control is several orders of magnitude cheaper than installing slug catchers. Field-tested and confirmed fit-for-purpose, it has already been sold to several offshore fields in the North Sea. Tests and first installations alike have provided remarkably good results for pipeline flow stabilization.

The core of the system is the feedback control algorithm, for which patents are pending.

5 shows how Optimize^{IT} Active Flowline Control utilizes pressure and temperature measurements at the inlet

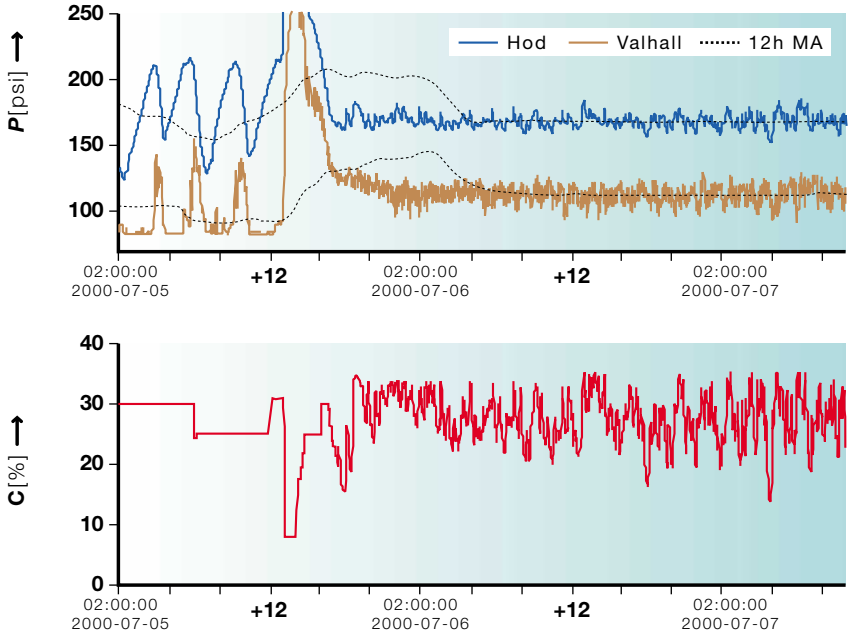
6 Hod-Valhall pipeline pressure fluctuation without active control.

P Pipeline pressure *C Choke position*



Main benefits of using Optimize^{IT} Active Flowline Control

- Increased oil and gas flows through the pipeline
- Improved separation in the inlet separator
- Lower operating costs for compressors due to lower energy consumption and reduced wear
- Smaller investments in mechanical and structural equipment



7 Optimize[IT] Active Flowline Control goes into action 30 minutes after one of the big wells begins producing. The Hod-Valhall pipeline is immediately stabilized.

P *Pipeline pressure* C *Choke position*

and outlet of the pipeline to adjust the pipeline choke valve. If pipeline flow measurements are also available, these can be used to adjust the nominal operating point and the tuning parameters of the controller.

ABB has shown that installing Optimize[IT] Active Flowline Control on production pipelines increases oil and gas production. After its installation on the Tor-Ekofisk pipeline, it was estimated that oil and gas production increased by about 10% and 5%, respectively.

Optimize[IT] Active Flowline Control also improves separation in the customer's inlet separator and reduces the cost of compressor operation by lowering energy consumption and reducing wear.

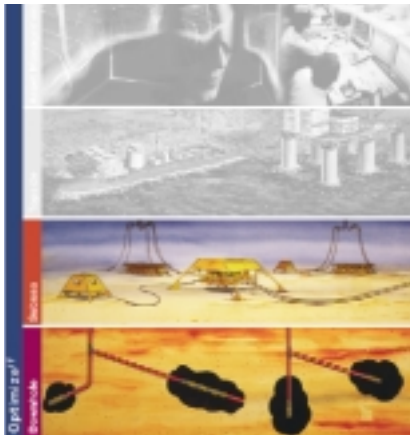
6 gives results from the Hod-Valhall pipeline operating without active control, and shows clearly the characteristic pressure oscillations for terrain-induced slug flow. **7** shows the same pipeline with Optimize[IT] Active Flowline Control in action. The controller stabilizes the pipeline and the mean pipeline pressure drop decreases as soon as the slug cycles are eliminated.

Monitoring of well production

The Optimize[IT] Well Monitoring System provides real-time estimations of the flow rates for oil, gas and water from all the individual wells in an oil field, based on data from sensors in the wells and the flowlines. The model-based system may be used as a Software Multiphase Flowmeter, as a Reliability Tool or as a Production Allocation System.

The Optimize[IT] Well Monitoring System simulates all the flows in the production system simultaneously, using every available data point. This field-wide approach guarantees maximum accuracy and also offers redundancy, making the system independent of individual sensors and therefore more reliable and robust.

All calculations performed by the Optimize[IT] Well Monitoring System are based on a state-of-the-art, mechanistic model for multiphase flow and a full, compositional model of the fluid (PVT model). Using the full model to calculate all the fluid properties ensures that the analysis of blended fluids from different zones in the reservoir is just as accurate as the simulation of a single fluid from a single well. This approach is superior to the method based on interpolation of tabulated data, which is the one most



commonly found in commercially available multiphase fluid simulation programs.

Application areas

Software multiphase flow meter

For daily operations, the Optimize^{IT} Well Monitoring System may be thought of as a distributed software multiphase flow meter. It estimates the flow rate of oil, gas and water based on data from standard well instrumentation and handles every configuration of well instrumentation. In addition, it detects instant changes, such as water and gas breakthrough, in the composition downhole. By performing these functions it provides the basis for automatic well control or choke setting optimization.

Reliability tool

Where equipment might fail, or when redundancy is needed for other reasons, the Optimize^{IT} Well Monitoring System can be used as a reliability tool for the installed instrumentation. By validating specific measurements, it introduces redundancy to the system. Measured data are estimated whenever the measuring equipment fails, reducing unscheduled maintenance and increasing uptime.

Production allocation system

The Optimize^{IT} Well Monitoring System can be used with every well configuration and directs production from the field to the various zones in the reservoirs. Thus, it provides input for the reservoir simulation and improves reservoir management 8. The system provides a basis for production optimization and allows a higher reservoir recovery factor.

The intelligent oil field

The vision that drives ABB's program to develop advanced control and optimization technologies for multiphase flow is that of the *intelligent oil field.*

The intelligent oil field features enhanced production based on a sound knowledge of the behavior of the reservoir, the wells, the gathering systems and the production systems. New technologies for reliable sensing under and over the mud line are an important prerequisite for such a field. However, efficient utilization of all this extra information depends on information technology being used for active control and on-line optimization. Through the use of various technologies the industry has already managed to increased recovery from 10–20% in the early seventies to 30–60% today. It is ABB's belief that, by using active control and optimization technologies, this recovery factor can be improved still further. The results obtained by ABB so far point clearly in this direction.

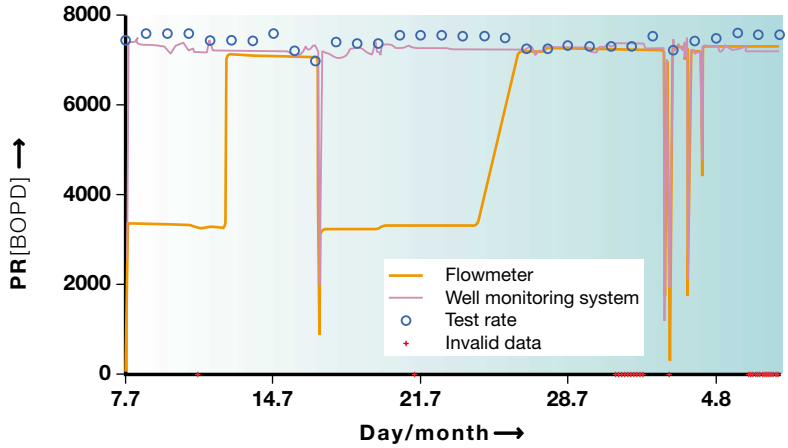
Customized solutions

It is important to note that Optimize^{IT} Active Well Control, Optimize^{IT} Active Flowline Control and the Optimize^{IT}

Main benefits of using the Optimize^{IT} Well Monitoring System

- Increased uptime, due to less-frequent well-testing and early detection of gas or water breakthrough
- Better management of production on a daily basis, thanks to overview of flows in production system, component-by-component
- Increased instrumentation redundancy and validation of measurements
- Redundancy reduces unplanned maintenance
- Improved reservoir management due to total field production being allocated to different zones, which can lead to a better oil recovery factor
- Lower installation and maintenance costs than with any hardware solution
- Functionality scaling possible due to use of standardized software and hardware

8 The Optimize[IT] Well Monitoring System predicts the production rate PR with high accuracy and regularity in a field in the Gulf of Mexico, July 2000.



Whether for customer projects or technology development projects, ABB deploys multi-disciplinary teams whose members have experience in the design *and* operations area. The overall goal is to expand ABB's ability to add value for our customers through an increase in recovery, production rate and reliability. By focusing on enhanced production, ABB will play a leading role in boosting productivity in the oil and gas industry in the years to come.

Well Monitoring System are not general-purpose information and control technologies, but *tailor-made* products. Just as important as the products themselves are the engineering tools and methodologies for design and customization that have been developed alongside them. A skilled multidisciplinary team of experts from ABB is needed to execute projects in which these products are used, but, once installed, the customer finds them easy and straightforward to operate.

The described on-line control and optimization products are among the first to be developed by ABB especially for oil and gas production. All belong to ABB's Optimize[IT] total asset management family and are part of its *Optimize[IT] Enhanced Oil Production Suite*. More dedicated on-line products with a direct positive impact on our customers' bottom-line are to come. There will also be an emphasis on information technology that eases our customers' work processes. And ABB wants to support customers more actively in optimizing the operation of critical processes. This will entail setting up world-class research programs, adopting new control and information technologies as they emerge, and putting new sensing systems to optimum use.

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