# FUSE Application Experiment 25846

**Demonstrator Document**

# Application of Profibus Technology to Oil & Gas Drilling Monitoring Systems

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## Abstract of Application Experiment

*OIL&GASTEK* is situated in Leoben, Austria. The company was founded in 1993 to provide modern electronic process monitoring and control system services for the international oil and gas drilling industry. Currently it employs 12 persons in Austria, 5 of which are master-level graduated engineers.

In this project PROFIBUS technology was introduced for the development of an application for monitoring of deep oil and gas drilling processes ("Mud Logging"). The system previously on the market and still utilising analogue signal transfer was introduced in 1995, and has in the meantime acquired 50% of Austria's drilling monitoring market, with strong interest by companies from Germany, Italy, the Czech Republic, Slovakia and Hungary as expressed during two recent trade show participations (European Petroleum Conference/Milano, Intl. Geothermal Symposium/Bad Kleinkirchheim). It represents, however, a constant source of potential signal transmission problems due to the extensive cabling requirements and repeated D/A and A/D conversion processes, with the obvious impact on overall signal accuracy. Experience with installed systems has shown the vulnerability of a large number of signal cables running through harsh environments like an onshore drilling rig. Currently, no competitor offers digital sensor communication for the applications described here.

Integrating Profibus technology shall increase the flexibility in communicating with decentralized A/D modules distributed over the rig. The new PROFIBUS structure shall in the long run be connected to the overall environment by implementing PROFIBUS functions mapped on Ethernet and TCP/IP.

The new technology definitely provides a market advantage over existing competition. Especially the integration of state-of-the-art sensing systems with latest generation database applications on the MS Windows NT platform provides a powerful sales argument and is viewed as a valuable asset by the client. Due to the oil price collapse this application experiment was necessary to allow the company to survive. This way the operating costs could be reduced significantly and the price of the monitoring services could be decreased.

The experiment started on April 1st 1998 and has been completed by September 6 1998 after a duration of 5 months with AE costs of 38 k€. All equipment has been performing satisfactorily under field conditions being implemented in plant. The increased knowledge on PROFIBUS communication in hazardous envionments represents a significant market advantage. Both sensor availability as well as applicability of this new technology to the oil&gas exploration drilling market can safely be taken for granted.

The expected payback period for this application experiment will be approximately two years. The return of investment over the product lifetime (five years) is expected to be fourfold of the investment been taken. But it has to be mentioned that the product lifetime also depends on the availability of remote controlled sensors. When using remote controlled sensors all wire based systems will be invalid because there is no need for

connecting all sensors. To be competitive *OIL&GASTEK* will have to develop a new product when remote controlled sensors are available.

## Keywords and signature

Keywords: Profibus, bus technology, monitoring system, real-time monitoring, telemetry, intelligent sensor, digital transmission

Signature: 1-0124-551-1420-1-3330-1-23-A

## 1. Company Name and Address

Address : Oil&Gastechnik
Ingenieurbuero f. Erdoel- & Bergwesen GmbH
65-67, Johann Sackl Gasse
A-8700 Leoben/AUSTRIA

## 2. Company Size

The company is part of the *OIL&GASTEK* group currently employing 12 persons in Austria, 5 of which are master-level graduated engineers Group revenues in 1997 were approximately 1.1 M€.

The company Oil&Gastechnik Ingenieurbuero f. Erdoel- & Bergwesen GmbH currently employs 6 persons. Three of those are involved in design.

## 3. Company Business Description

*OIL&GASTEK* was founded in 1993 to provide modern electronic process monitoring and control systems for the international oil & gas drilling industry. As a sideline, the developed process monitoring and data transmission/handling systems have been introduced to environmental applications such as remote monitoring of site remediation and hydrocarbon spill cleanup installations.

The company's scope of products and services was extended in 1995 to include general exploration and drilling data management services, integrating rigsite instrumentation and drilling data acquisition with office-based drilling reporting systems and decentralized database applications. As a result of the innovative line of products, during 1998 the first international contracts (Germany and Libya) could be signed and operations started.

The customers of OIL&GASTEK are mainly oil&gas operating companies, enterprises working in the field of deep geothermal wells, and drilling companies and their contractors. In general all companies drilling deeper than 200 m can be counted as potential clients of OIL&GASTEK.

*OIL&GASTEK* offers its customers data logging and process monitoring systems as well as the lease of all necessary hardware for the measurement.

The company also provides technical consulting, carried out in two steps:

- Conception of the drilling project especially the plant set-up
- 24 hour process monitoring supervised by specialized personnel

## 4. Company Markets and Competitive Position at the Start of the AE

Being a relatively young company, *OIL&GASTEK* has concentrated on developing a strong position on its home market (Austria); customers here include the two local oil&gas operating companies (OMV AG and RAG) as well as some of the local subsidiaries of international major oil companies (Shell Austria, Conoco Austria). During the AE, marketing efforts have been started in Germany (Wintershall, DEA, Mobil) and Libya (OMV Exploration&Production Ltd Tripoli, Zueitina Oil Company).

The Austrian and German mud logging market alone represents a total annual sales volume of some 1.9 M€, with the applicability of the PROFIBUS process monitoring system not limited to oil & gas applications but basically opening the whole industrial sector.

The importance of the product being improved in this application experiment is quite high. Approximately one third of the turnover directly results through this product.

The international mud logging market is dominated primarily by US-based companies, with a few local competitors supplying the non-US markets. This industry is typically reluctant to apply state-of-the-art technology whenever working solutions have been in existence for some time. Typical mud logging systems today are based on DOS environments with conventional analogue signal transmission. Personal computer based data acquisition systems are still fighting to replace dedicated electronics manufactured by the large companies themselves. A trend is however recognizable to develop Windows-based applications primarily to realize real-time transmission of the acquired data via the Internet.

While the US market is characterized by extremely low rental rates for monitoring units, both on- and offshore Europe is still paying adequate rental rates to justify the application of new equipment and continuous upgrades. Western Europe provides a market for approximately 100 monitoring units (including the North Sea), as a small and young company *OIL&GASTEK* is just now starting to actively pursue the markets surrounding Austria (Germany, Italy, Czech Republic, Slovakia, Hungary, Slovenia,

Croatia). At the same time, the realization of a bus-driven monitoring unit can open markets such as the Middle East or South America. Venezuela and Bolivia are currently the most booming drilling market worldwide with the total number of operating drilling units exceeding 300 by mid 1998. All internationally active contractors either are already active in Venezuela or are on the verge of starting their activities there.

Major competitors in the mud logging field in Central Europe are mainly Geoservices of France and Geodata of Germany, with Halliburton and Schlumberger supplying those clients where they have a strong position due to their other drilling-related service lines. Geoservices has been developing their Windows-based system for the last three years and just now puts it on the market, while Geodata still relies heavily on their DOS-based applications. Especially during recently drilled deep, extended reach wells in Northern Germany, the operator has demanded real-time data analysis and state-of-the-art drilling monitoring, a trend that will continue and that is expected to support *OIL&GASTEK*'s role in the market.

In the last months 80% of the companies competitive to *OIL&GASTEK* had to shut down operations or have a substantial portion of their equipment idling. This was caused by the significant contraction of the market due to the oil price collapse. *OIL&GASTEK* is able to survive in such a condition because of its lower overhead costs (relatively small company!) as well as reduced service costs. The reduced amount of cabling cuts back on the required installation time for each job. Another major advantage of the use of PROFIBUS technology is the ability of remote maintenance which also results in cost reduction.

A complete monitoring unit (container mounted) represents an initial investment of 140 k€ whereat the costs for the used sensors, cabling and other hardware comes to 80 k€. Due to the nature of the market, mud logging units are rarely sold but mainly rented on a per-well or per-month basis. The average per-unit revenue per operating month comes to an amount of 20 to 23 k€, depending on required on-site personnel.

| Competitor | Austrian Market Share | German Market Share | Italian Market Share |
|---|---|---|---|
| Competitor A | 51 % | 0 % | 20 % |
| Competitor B | 12 % | 50 % | 0 % |
| Competitor C | 0 % | 50 % | 10 % |
| Competitor D | 0 % | 0 % | 50 % |
| *Oil&GasTEK* | *37 %* | *0 %* | *0 %* |

***Table 1 Major Competitors and Respective Market Shares***

The following table provides an overview of the economic history of the AE product over the past three years.

| Year | Revenue (k€) |
|---|---|
| 1996 | 30 |
| 1997 | 90 |
| 1998 | 232 |

***Table 2: Economic history***

## 5. Product to be improved and its industrial sectors

*OIL&GASTEK*'s RIM (*Rigsite Information Management*) system combines traditional instrumentation of deep drilling rigs (capable of drilling deeper than 3000 m) with current state-of-the-art electronics and information management. Complete monitoring systems record and control all functions of surface drilling equipment (hook loads, weight applied to the drill bit, torque and rotational speed applied to the drill string, rotational speeds and discharge pressures of mud pumps, mud tank levels, flow rates of drilling fluid into the well and from the well etc.) as well as rheological and chemical parameters of the circulated drilling fluid. Gas components circulated out from the well are sampled and analyzed in standalone gas chromatographs.

While competitors only visualize (e.g. print out) and hardly store the acquired information, the RIM system records all data into an on-site SQL database, thus making it available to all users on the network, both locally (on-site) as well as via Remote Access Service from off-site offices. Operating completely on a Microsoft Windows NT 4.0 platform, the system makes full use of currently available network and shared computing. The intention is to provide an information node on location for all data acquisition services (drilling monitoring, on-site geology, third-party service companies, daily drilling reporting etc.).

In its current configuration, the system consists of various sensors installed inside the explosion hazardous area (15 m around the wellhead) and driven via intrinsically safe barriers that transmit their information via analog signals (typically 4-20 mA) to a central A/D conversion board outside the hazardous area, which communicates with the recording and processing computers via RS485 interfaces. The resulting number of delicate data cables running across the entire drilling rig (in what basically is a heavy construction site environment) has been a continuous source of malfunctions and increases the necessary time for rigging up and rigging down of the system during rig moves (see block diagram in Figure1).

In addition to the already substantial cabling requirements, the current system layout with independent power supplies (device drivers) for each intrinsically safe sensor requires a significant effort in building and operating the central A/D conversion module. Certification processes for each installed component during rig up and acceptance testing account for a substantial part of development, manufacturing and rig-up costs, as

they have to be done by accredited certification authorities (TUV, PTB, KEMA etc.). Therefore the significant parameter and characteristics which influenced the choice for this new technology can be defined as follows: star topology with enormous cabling effort, information transmission via analog signals (RS485) and independent power supplies for each intrinsically safe sensor which also increases the cabling effort.

The reason for innovation is the reduction of the operating costs and that the market has diminished (as described, 80% of our competitors have went out of business).

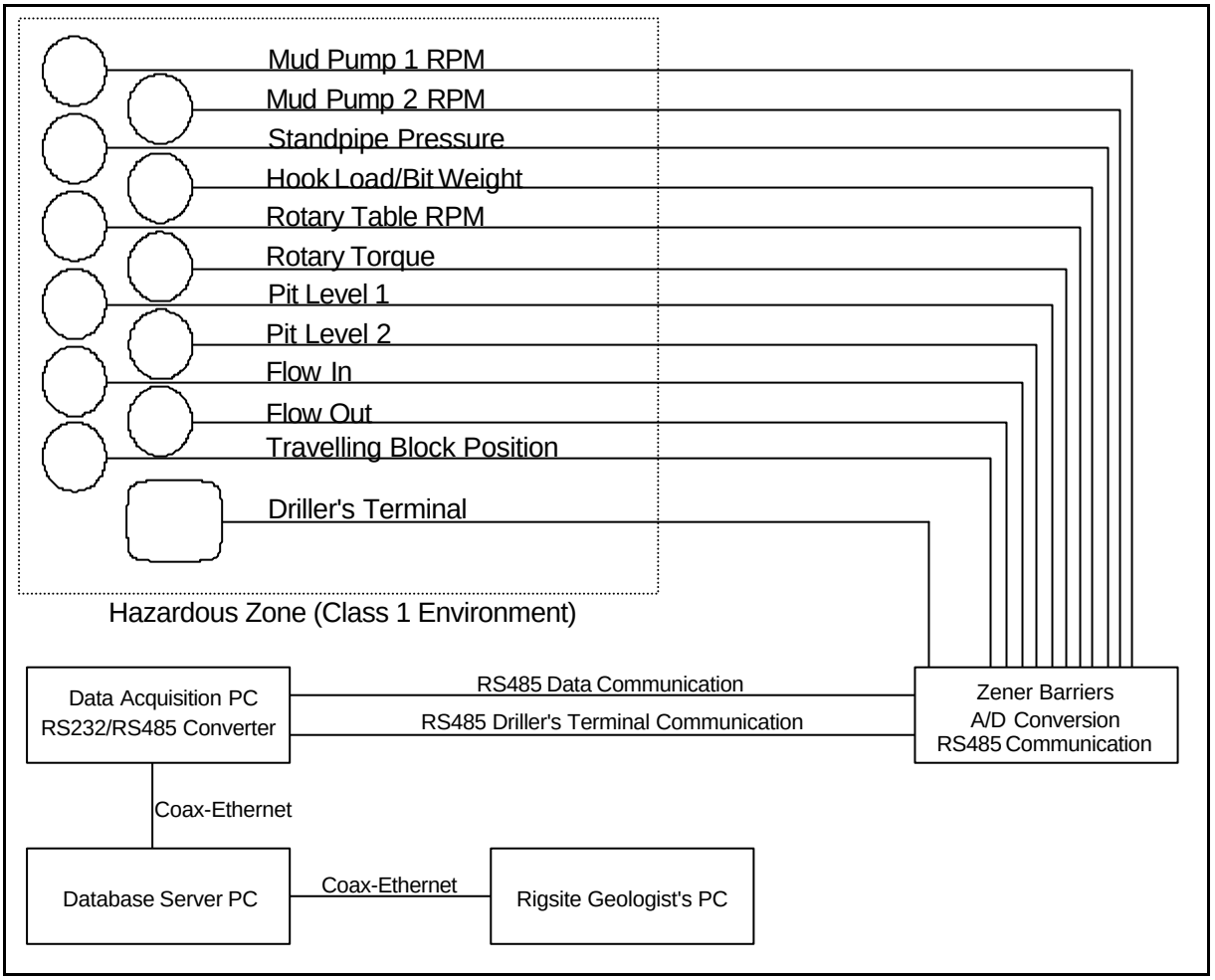


***Figure 1: Block Diagram Rigsite Information Management System***

## 6. Description of the technical product improvements

The task of the project was to design and build an integrated monitoring array accommodating a wide range of different sensors into a PROFIBUS PA communication system driven by a local Microsoft Windows NT4.0 workstation. Rather than loading the workstation with all communication, calibration and signal conditioning routines, the system decentralizes as much of the actual data acquisition tasks into intelligent sensor modules. All installed sensors (12 for the AE) were connected to a single bus, ranging from the monitoring unit into the hazardous area around the wellhead and up into the drilling derrick. Installed sensor technology has to be able to withstand rough operating environments (-30°/+50°C, IP65 or higher) as encountered in oilfield drilling operations.

*OIL&GASTEK* has designed the bus architecture and overall system layout, while the individual sensor components such as pressure transducers and position/movement encoders were purchased from leading suppliers as “off-the-shelf” products.

By changing from RS485 communication with centralized A/D conversion boards to PROFIBUS communication directly with the sensor, the whole system became smaller and faster where short response times together with the complete elimination of any A/D conversion enhanced information quality. At the same time, class 1 certified PROFIBUS components reduced the currently necessary effort for intrinsically safe drivers for each sensor component as only one power supply can provide the necessary voltage to all installed sensors and still fulfill intrinsic safety requirements (see Fig.2).

Decentralizing calibration and signal conditioning tasks directly into the respective sensor modules and utilization of the sensor module's intelligence greatly reduces the load on the central data acquisition processor and makes it available for more complicated engineering simulation tasks to be run in real time.

By full utilization of the PROFIBUS structure as well as the sensor’s intelligence, all calibration can be done directly in the sensor. Physical access to the sensor can be limited to necessary sensor replacement in case of mechanical damage, sensor troubleshooting is greatly simplified by the built-in memory and the possibility to access sensor status information via the PROFIBUS protocol.

While current sampling rates (2 Hz) can hardly be increased any more due to necessary response times on the RS485/ASCII protocol, the PROFIBUS solution allows sampling rates of 5 Hz or more, thereby increasing data resolution and accelerating response times for the real-time monitoring screens.

A large part of the project was the definition of availability of class 1 certified intelligent transducers supporting direct PROFIBUS communication (pressure, frequency/counters, fluid flow, weight etc.). By the time the AE has been completed it can safely be stated that for all applications required under the presented monitoring system (except for the encoder to monitor block position), adequate sensor technology is available that supports PROFIBUS PA technology :

- Pressure (0-6000 psi working pressure, 8700 psi burst pressure)
- Temperature (all conventional thermocouples and PT elements)
- Proximity (high frequency inductive proximity switches for rotational speed pickups)
- Proximity (low frequency inductive proximity switches for safety switches)
- Encoder N/A
- Fluid Flow (magneto inductive meters up to 12” diameter)
- Fluid Level (ultrasonic tank level sensors)
- Conductivity (fluid conductivity; sensor to be introduced 09/98)
- pH/Redox (sensor to be introduced 09/98)

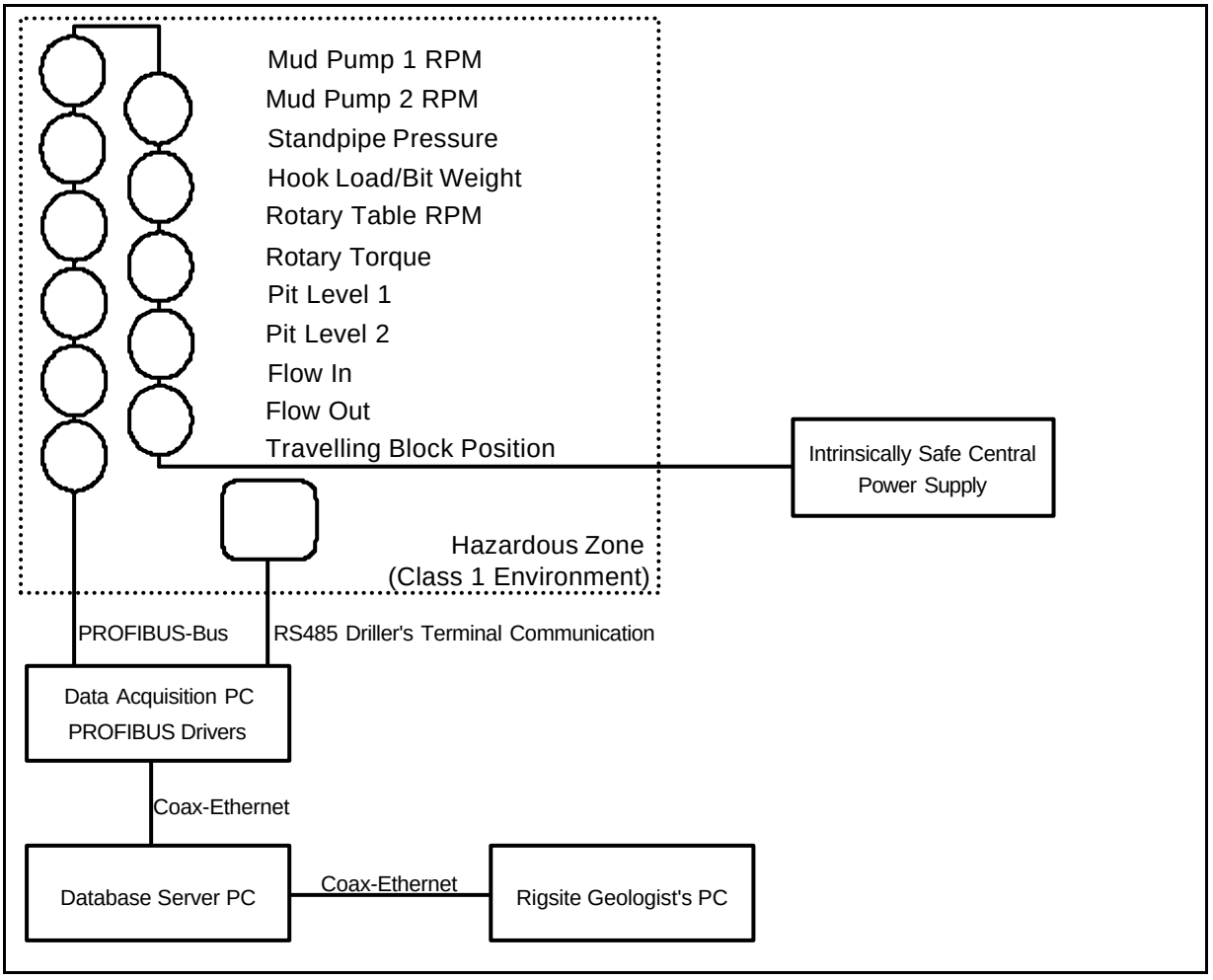


***Figure 2: Block Diagram Enhanced Rigsite Information Management System***

The following description shall give an overview of the improved parameters.

By introducing the PROFIBUS technology instead of using a star topology the manufacturing costs for the needed hardware, sensors and cabling effort can be reduced by 11,4 %.

The functionality was improved by integration of state-of-the-art sensing systems with latest generation database applications on the MS Windows NT platform as well as the new featured possibility to access sensors and A/D-conversion systems from remote via Internet or Intranet solutions.

A speed improvement was made possible through using the PROFIBUS solution with a sampling rate of 5 Hz instead of the former used RS485/ASCII protocol with a sampling rate of 2 Hz.

Due to the reduced cabling effort the reliability of the whole monitoring system was significantly improved. This reduction results also in a weight and size reduction of the system.

The possibility to access each sensor from remote offers an enhanced maintainability.

These parameters collectively contribute the 15-20% operating cost reduction.

The new technology definitely provides a market advantage over existing competition. Especially the integration of state-of-the-art sensing systems with latest generation database applications on the MS Windows NT platform provides a powerful sales argument and is viewed as a valuable asset by the client. The possibility to even access sensors and A/D-conversion systems from remote via Internet or Intranet solutions is a novelty that is regarded as a quantum leap in system monitoring applications.

## 7. Choices and rationale for the selected technologies, tools and methodologies

Due to experience gathered by operating the existing system leads to new requirements which the product of the application experiment will have to fulfil. One of the major requirements was the reduction of the cabling effort which is mainly responsible for approximately 50% of the rig-up/down time and more than 50% of all system downtime. Therefore another cabling topology had to be found to increase the operating costs as well as the reliability. Another important requirement was an increase in maintenance, quality and accuracy of the sampled signal. Additional the transmission speed also had to be improved. The sampled data should be stored in a SQL-database running on the data acquisition PC using the operating system Windows NT which will give a crucial advantage over *OIL&GASTEK's* competitors. The requirement for the availability of the used sensors as well as their supplier support can be seen as more economic rationale for selecting the right technology.

To fulfil the requirement for decreasing the cabling effort it was decided to develop a bus solution rather than a conventional "star" wiring layout.

Rugged cable connectors that are able to withstand the rough environment reflect a substantial portion of each installation's capital investment, yet are still prone to moisture or mechanical damage.

There were three possible technology options: POFIBUS, serial data transmission via RS485 and the MODBUS. Serial data transmission via RS485 is currently used in the existing product, MODBUS was not considered because of it's limited field of application.

It was decided to pursue a PROFIBUS solution because PROFIBUS technology is a well supplier-supported architecture. *OIL&GASTEK* has repeatedly been approached by sensor suppliers to realize field applications of PROFIBUS sensors, but the necessary capital investment associated with changing from existing system layouts to PROFIBUS architectures had discouraged this development.

The design of the new product started with the determination of the product requirements based on the existing system. After selecting the right technology, in this case PROFIBUS, the determination of the PC hardware and the bus communication was carried out. Finally *OIL&GASTEK* gathered information on the availability of the required measuring components with PROFIBUS support.

## 8. Expertise and Experience in Microelectronics of the company and the staff allocated to the project

*OIL&GASTEK* has developed its current scope of hard- and software products in-house and thus can rely on in-depth know how on the applicability of electronic measurement (sensor) equipment to on-shore drilling rigs as well as the underlying data acquisition, transmission and handling system requirements. The *OIL&GASTEK* suite of data management products has been built around the MS Windows NT platform, while the applied sensor technology reflects the state of the art in process parameter acquisition. Previous field installations have been based around a "star" cabling design concentrating the analog sensor signals in a central A/D conversion unit before sending the information via RS485 bus to the data acquisition station.

The main strength of the company lies in the in-depth understanding of and experience with implementing electronic sensor and telemetry installations in hazardous environments, which are defined as routinely having a potentially explosive atmosphere (US : class 1, Europe : Zone 1) and require all electric installations to conform to CENELEC standard EEx IIB T3 or higher. It is *OIL&GASTEK*'s commitment to realize all explosion proofing through intrinsic safety rather than utilize conventional pressurization or incapsulation technology. Thus, the applicability of PROFIBUS systems to intrinsically safe process monitoring systems has become a prime target for further in-house R&D efforts.

*OIL&GASTEK* allocated one university graduate (University of Leoben) with 5 years of plant design and engineering experience in measurement technology, explosion proofing as well as data transmission and data administration.

## 9. Work plan (Planned vs. Actual)

The workplan of the project was divided into six workpackages each containing one or more tasks. The following table gives a short overview of this:

| WP | Task | Description |
|---|---|---|
| 1 | | Project Management |
| | 1 | Project management |
| 2 | | Personnel Training |
| | 1 | Pers. training/courses |
| 3 | | Prototype Unit Design |
| | 1 | Unit design |
| | 2 | Sensor/Bus hardware selection |
| | 3 | Cabling/Communication design |
| 4 | | Prototype Unit Building |
| | 1 | Container preparation |
| | 2 | DAQ Processor installation |
| | 3 | Profibus communication installation |
| | 4 | Cabling/Sensor installation |
| 5 | | Prototype Unit Lab Testing |
| | 1 | Individual sensor testing |
| | 2 | Complete unit test-run |
| 6 | | Project Evaluation |
| | 1 | Final evaluation/reporting |

The first workpackage provided the management of the complete project. The second concerned the training carried out. The next four workpackages were chronologically ordered as carried out in the project, starting with the design and ending with the evaluation of the project. Each of these four workpackages (i.e. 3, 4, 5, and 6) contained a separate unit of the project (design, building, testing, evaluation) which could be finished before kicking off the next one.

### *Project Management*

| ***Phase*** | ***Project Management*** | | | |
|---|---|---|---|---|
| Personnel Involved | Manager | | Technician | |
| | Planned | Actual | Planned | Actual |
| Personnel Time Required | 22 person days | 22 person days | - | - |
| Personnel Cost | 7,0 k€ | | - | |
| Remarks | Personnel time is allocated as one day per project week to provide ongoing project management | | | |
| Hardware Cost | - | | | |
| **Total Phase Cost** | **7,0 k€** | **7,0 k€** | | |
| MILESTONE | no milestone (ongoing management) | | | |

Management of the complete project has been provided by the project manager (budgeted at 7.0 k€) and could be kept within the estimated one day per week requirement. Since the project has been completed in the estimated time, the projected budget of this section was met.

### *Personnel Training*

| ***Phase*** | ***Personnel Training*** | | | |
|---|---|---|---|---|
| Personnel Involved | Manager | | Technician | |
| | Planned | Actual | Planned | Actual |
| Personnel Time Required | 10 person days | 7 person days | 10 person days | 8 person days |
| Personnel Cost | 3,2 k€ | 2,24 k€ | 1,82 k€ | 1,46 k€ |
| Remarks | - | | | |
| Hardware Cost | - | | | |
| Other | 4,6 k€ (Training Courses) | 0 | - | - |
| **Total Phase Cost** | **9,62 k€** | **3,7 k€** | | |
| MILESTONE | PROFIBUS familiarization | | | |

Due to problems in scheduling the training course originally planned to be held by Siemens Austria (July/August vacation period together with field service calls of scheduled *OIL&GASTEK* personnel), the training course was finally cancelled altogether, because the required PROFIBUS know how had already been obtained through assistance by Endress+Hauser, leading hardware supplier for the project. As a result of the dropped training course, the total time spent on this activity has been slightly below the estimated time requirement, and the cost budgeted for training course fees has been avoided.

### *Prototype Unit Design*

| ***Phase*** | ***Prototype Unit Design*** | | | |
|---|---|---|---|---|
| Personnel Involved | Manager | | Technician | |
| | Planned | Actual | Planned | Actual |
| Personnel Time Required | 10 person days | 10.5 person days | 30 person days | 33 person days |
| Personnel Cost | 3,2 k€ | 3,36 k€ | 5,46 k€ | 6,01 k€ |
| Remarks | - | | | |
| Hardware Cost | - | | | |
| **Total Phase Cost** | **8,66 k€** | **9,37 k€** | | |
| MILESTONE | Completion of system design | | | |

Contacting the major sensor suppliers for availability of class 1 certified equipment supporting direct PROFIBUS communication protocols took slightly longer than anticipated, being reflected in the overrun of the project manager's (5%) and project engineer's (10%) allotted time. At the end of the design phase, the complete unit layout, necessary system developments and complete part inventories have been defined and the necessary orders placed with the suppliers.

### *Prototype Unit Building*

| ***Phase*** | ***Prototype Unit Building*** | | | |
|---|---|---|---|---|
| Personnel Involved | Manager | | Technician | |
| | Planned | Actual | Planned | Actual |
| Personnel Time Required | 5 person days | 9 person days | 20 person days | 31 person days |
| Personnel Cost | 1,6 k€ | 2,88 k€ | 3,64 k€ | 5,64 k€ |
| Remarks | Procurement of equipment, unit assembly | | | |
| Hardware Cost | 4,01 k€ | 1,14 k€ | | |
| **Total Phase Cost** | **9,25 k€** | **9,66 k€** | | |
| MILESTONE | Unit Completion and Startup | | | |

A slight delay in the project progress was due to increased delivery times on certain hardware components. The reduced hardware cost for procurement of the whole system on the one hand reflects the constant reduction of electronic component cost (PROFIBUS components: -0,18 k€) as well as the substitution of the two electromagnetic flow meters by only one unit of applicable pressure rating (-1,1 k€), as the electronics package is generally the same on both units, and the scope of the AE could be met by staying with one meter. Due to the same rationale, only 2 pressure transducers (one high-pressure one low-pressure unit) have been purchased instead of the originally intended 5 transducers (-0,71 k€), while the two purchased ultrasonic tank level meters were cheaper than originally planned (-0,2 k€).

Personnel requirements for the building phase exceeded the planned time schedule by two weeks, reflected in the overrun of the project manager's (80%) as well as project technician's (55%) budget. This was mainly due to unexpected problems when first connecting the integrated power/signal cabling, which required several days of

troubleshooting with Pepperl&Fuchs, the suppliers for the intrinsically safe barriers utilized in the PROFIBUS PA system. This phase has been completed by starting the whole sensor configuration on the network and successfully accessing each individual sensor from *Oil&GasTEK*'s proprietary software package.

### *Prototype Unit Lab Testing*

| ***Phase*** | ***Prototype Unit Lab Testing*** | | | |
|---|---|---|---|---|
| Personnel Involved | Manager | | Technician | |
| | Planned | Actual | Planned | Actual |
| Personnel Time Required | 1 person day | 3 person day | 10 person days | 16 person days |
| Personnel Cost | 0,32 k€ | 0,96 k€ | 1,82 k€ | 2,91 k€ |
| Remarks | - | | | |
| Hardware Cost | - | | | |
| **Total Phase Cost** | **2,14 k€** | **3,87 k€** | | |
| MILESTONE | Unit released for field testing | | | |

Prior to releasing the unit for field service, the intended lab testing period has been slightly extended due to some minor data transmission problems during the early testing phase. *OIL&GASTEK*'s system has been successfully debugged, and a continuous 72-hr test run resulted in a completely error-free operation. At the end of this phase the unit has been pronounced fit for field application and has been shipped to an initial field job on the deep geothermal well "Geinberg Th2".

### *Project Evaluation*

| ***Phase*** | ***Project Evaluation*** | | | |
|---|---|---|---|---|
| Personnel Involved | Manager | | Technician | |
| | Planned | Actual | Planned | Actual |
| Personnel Time Required | 10 person days | 12 person days | - | 2 person day |
| Personnel Cost | 3,2 k€ | 3,84 k€ | 0 k€ | 0,36 k€ |
| Remarks | - | | | |
| Hardware Cost | - | | | |
| **Total Phase Cost** | **3,2 k€** | **4,20 k€** | | |
| MILESTONE | Project completion and final report preparation | | | |

Project completion in time allowed preparation of the final report as planned, with two additional days charged for the project technician as he was required to submit an interim report on the lab testing results as well as on the experience gained during several short field applications of individual items during the lab testing phase. No modification to the original unit layout have been found necessary, and the unit will be marketed immediately subsequent to project completion.

The following table provides an overview about the forecast vs. actual effort and cost

Original Time Line Chart and Labor Cost Split

| | Task | Duration | PM | PT | Cost |
|---|---|---|---|---|---|
| 1 | Project Management | 22 weeks | 22 d | - | 7 |
| 2 | Personnel Training | 2 weeks | 10 d | 10 d | 5.02 |
| 3 | Prototype Unit Design | 8 weeks | 10 d | 30 d | 8.66 |
| 4 | Prototype Unit Building | 6 weeks | 5 d | 20 d | 5.24 |
| 5 | Prototype Unit Lab Testing | 2 weeks | 1 d | 10 d | 2.14 |
| 6 | Experiment Evaluation | 2 weeks | 10 d | - | 3.2 |
| | ***Total Labor Cost :*** | | | | ***31.3 kECU*** |

Actual Time Line Chart and Labor Cost Split

| | Task | Duration | PM | PT | Cost |
|---|---|---|---|---|---|
| 1 | Project Management | 22 weeks | 22 d | - | 7 |
| 2 | Personnel Training | 1 week | 7 d | 8 d | 3.7 |
| 3 | Prototype Unit Design | 7 weeks | 10.5 d | 33 d | 9.37 |
| 4 | Prototype Unit Building | 7 weeks | 9 d | 31 d | 9.66 |
| 5 | Prototype Unit Lab Testing | 2.5 weeks | 3 d | 16 d | 3.87 |
| 6 | Experiment Evaluation | 2.5 weeks | 12 d | 2 d | 4.2 |
| | ***Total Labor Cost :*** | | | | ***38.0 kECU*** |

discussed in detail in the sections above.

***Table 3 : Original and Actual Time Line Chart and Labor Cost Split. This table also shows the forecasted vs. actual effort and cost of each task.***

The technology transfer was provided at no costs by Endress+Hauser the supplier of the PROFIBUS sensors.

## 10. Subcontractors Information

One reasons for choosing Siemens AG Austria was that they are an international operating company with many years of experience in the field of PROFIBUS technology. Siemens AG Austria produces and sells a complete PROFIBUS product range including the appropriate network components. Furthermore Siemens offers their customers complete solutions meeting the customer's requirements. Another requirement fulfilled by Siemens is the experience in the field of explosion proof PROFIBUS systems.

Therefore it was planned at the start of the project to attend a training course on PROFIBUS technology at Siemens AG Austria. They had a couple of problems with scheduling their courses. Due to this and to preserve the successful progress of the project it was finally decided to cancel the course.

Requirements and selection criteria applied when choosing the supplier was reliability, technical capability as well as the willingness for a joint development respectively technical co-operation and support.

Due to the cancellation of the training course it was necessary to get the needed information regarding PROFIBUS technology from an other source. Therefore Endress+Hauser become the new subcontractor, which is one of the two leading suppliers for this kind of sensors, suggested to carry out at no cost, the knowledge transfer through a very close co-operation during the project.

## 11. Barriers Perceived by the Company in the First Use of the AE Technology

The following barriers were perceived to be the most difficult to overcome during realization of the AE :

- Market availability of sensor equipment suitable for harsh environments and certified for application in hazardous areas (CENELEC EEx IIB T3).
- Necessary capital investment associated with changing from the existing system layout (star) to PROFIBUS architecture was a barrier prior to this development.
- Know-how and implementation risk of changing from a star wiring layout to a PROFIBUS system.
- Upgrading of in-house system to include PROFIBUS communication modules to completely interact with sensor equipment

## 12. Steps Taken to Overcome the Barriers and Arrive at an Improved Product

- Market availability of sensor equipment suitable for harsh environments and certified for application in hazardous areas (CENELEC EEx IIB T3) :

Preliminary market analysis even before embarking on the AE promised a rapidly developing supplier structure for PROFIBUS sensors and telemetry. Intensive communication with the two leading suppliers (Endress+Hauser and Pepperl&Fuchs) through their Austrian subsidiaries indicated that for the range of sensors required under the AE, suitable solutions would be available. The AE timing coincided with several new market releases, especially for analytical sensor products from E+H, namely conductivity and pH/Redox measurements. Starting the project with an in-depth market analysis on the availability of required PROFIBUS components both sparked interest on the part of the suppliers and gave *OIL&GASTEK* the confidence to go ahead as planned.

- Necessary capital investment associated with changing from the existing system layout (star) to PROFIBUS architecture was a barrier prior to this development :

For a company the size of *OIL&GASTEK*, any R&D investment of the magnitude of this project could only be considered with confirmed strong interest into the final product from international clients. Supported by the EU-funding decision, the company has broadened its capital structure by accepting new partners as well as combined the development and field testing of the developed products with existing field service contracts.

- Know-how and implementation risk of changing from a star wiring layout to a PROFIBUS system.

During preparation of the AE as well as in the initial project phases it became apparent that by closely cooperating with the main hardware suppliers the perceived barrier of lacking PROFIBUS know how could be overcome fairly easily. While initially one of the main drivers for PROFIBUS development (Siemens AG Austria) was intended to be the provider for personnel training and initial PROFIBUS standards familiarization, the project timing (running through the summer vacation period) as well as schedule problems finally resulted in the cancellation of the Siemens training course, to be replaced by a more intensive co-operation with the sensor supplier (E+H). By strongly communicating with E+H, the implementation of PROFIBUS protocol options into the existing *OIL&GASTEK* system could finally be realized, and the AE be brought to a successful completion. Personnel already experienced in network data transmission and implementation of other protocol standards (RS485) could adapt rapidly to the new environment. Sound planning of the new star wiring layout prior to its first field implementation ensured trouble-free introduction of the new system and limited “teething problems” to a minimum.

- Upgrading of in-house system to include PROFIBUS communication modules to completely interact with sensor equipment

Because the complete data acquisition and transmission/storage system had been developed in-house, the necessary adaptations to accommodate new PROFIBUS components into the system could be realized at reasonable efforts. This point had originally been perceived as a barrier because it was difficult to estimate the problems and workarounds required during the realization phase of the AE.

## 13. Knowledge and Experience Acquired

*OIL&GASTEK* provides modern electronic process monitoring and control systems for the international oil&gas drilling industry. This includes general exploration and drilling data management services, integrating rig site instrumentation as well as drilling data acquisition with office-based drilling reporting systems and decentralized database applications.

*OIL&GASTEK* wanted to expand its knowledge in the application of powerful bus communication technology to enhance data/signal transmission between field sensors and central recording units. Specifically, the application of PROFIBUS systems in hazardous environments is expected to strengthen the company's position both within the oil&gas exploration industry as well as in related industry sectors.

As the personnel training course with Siemens AG Austria was cancelled, the co-operation with the sensor supplier (Endress+Hauser) was intensified thus providing the *OIL&GASTEK* staff with the initial PROFIBUS standards.

*OIL&GASTEK* broadly expanded its knowledge in the application of bus communication technology in hazardous environments. *OIL&GASTEK* is now capable of building and programming the interface between in-house developed software package and the PROFIBUS sensor technology.

Successful implementation of PROFIBUS technology in hazardous environments will increase its acceptance in all other large-scale industrial applications where class 1 requirements so far have discouraged the transition from analogue (intrinsically safe or purged) signal transmission to fully digital bus designs.

A market analysis of Zone 1 PROFIBUS PA sensors availability lead to a general overview of PROFIBUS sensor suppliers. For the presented monitoring system all required sensors are readily available except the encoder to monitor block position.

A continuous 72-hr test run in the lab and a field job on the deep geothermal well "Geinberg Th2" in upper Austria showed that both the hardware and the system layout are functionally for practical use.

Finally it has to be mentioned that the difference between the goals and the actual acquired knowledge was relatively low because of the thoroughly planned application experiment.

## 14. Lessons Learned

Preliminary market analysis even before embarking on the AE promised a rapidly developing supplier structure for PROFIBUS sensors and telemetry. Intensive communication with the two leading suppliers (Endress+Hauser and Pepperl&Fuchs) through their Austrian subsidiaries indicated that for the range of sensors required under the AE, suitable solutions would be available. The AE timing coincided with several new market releases, especially for analytical sensor products from E+H, namely conductivity and pH/Redox measurements. Starting the project with an in-depth market analysis on the availability of required PROFIBUS components both sparked interest on the part of the suppliers and gave *OIL&GASTEK* the confidence to go ahead as planned.

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Every interested replicant should spend considerable time and effort in assessing the personnel and time requirements for the AE. Time requirements as experienced during implementation of this AE were very closely matched to the initial assumptions, with minor discrepancies due to third-party delivery delays and additional unforeseen problems in software adaptation and development.

It has been noticed that large/multinational suppliers (e.g. Siemens) are not necessarily the best choice to support such an AE, because due the relatively small size of the AEs, their interest is naturally smaller than that of regional/mid-sized supply companies.

It should generally be attempted to interest one or more potential clients in participating already during the implementation phase of the AE (e.g. by allowing or even supporting field testing of the new products on their systems) to realize as much feedback as possible from the ultimate judge of the product's worth : the client.

## 15. Resulting product, its industrialization and internal replication

The system has been successfully debugged, and a continuous 72-hr test run resulted in a completely error-free operation. At the end of this phase the unit has been pronounced fit for field application and has been shipped to an initial field job on the deep geothermal well “Geinberg Th2” in August 98. Therefore the current status of the product can be seen as well introduced to the market.

The internal goal is a total replacement of the currently still used analogue system by PROFIBUS communication technology. As it could be shown in the AE this will lead to an enormous reduction in rig-up/rig-down time and costs.

An encoder to monitor block position is still needed to complete the digital system.

Completely unmanned applications for mud logging and drilling monitoring should be possible by utilizing the PROFIBUS sensor functionality together with GSM embedding of the monitoring station to the main office network.

At the time of this assessment (March 1999), there is still no encoder available to pick up rotational movement of the drawworks shaft. Thus, a combination of conventional digital encoder with third-party PROFIBUS-electronics package (Gantner Electronics of Schruns/Austria) has been selected to fill that gap until suitable integrated PROFIBUS technology will be available. At the moment, no manufacturer has announced a definite date for market availability of such an encoder.

No problems were encountered in transferring PROFIBUS-originating data into the SQL database, as for the database the mechanical/electronic origin of the digital data is inconsequential. The advantage of changing to PROFIBUS sensor systems is the capability to directly access the sensors, transfer as much of the signal processing as possible into the sensor and use the sensor intelligence itself for calibrating and quality control of the measured parameter.

Due to the highly modular system design, industrialization is not automatically coupled to mass production or “standardization” of units. Because such mud logging units as the system developed for this AE are typically not sold but rented as part of a general service contract, industrialization of the product is tightly coupled to the overall scope of services and will remain embedded in *OIL&GASTEK*’s general service suite. Thus the cost for industrialization of the product will be fairly low to nonexistent.

Following successful project completion, *OIL&GASTEK* intends to develop a single "ring-line" wiring layout, connecting the data acquisition PC directly (via only one intrinsically safe barrier) to the sensors and thus reducing the possibility of sensor signal distortion across cables and connectors. By converting the sensor signal into digital form right in the sensor, a significantly enhanced data quality can be reached.

## 16. Economic impact and improvement in competitive position

The product has been introduced to the market in early 1999 (as most of the drilling projects were in tendering stage during the winter season 1998/99), and three contracts are currently under negotiation. The new technology definitely provides a market advantage over existing competition. Especially the integration of state-of-the-art sensing systems with latest generation database applications on the MS Windows NT platform provides a powerful sales argument and is viewed as a valuable asset by the client. The possibility to even access sensors and A/D-conversion systems from remote via Internet or Intranet solutions is a novelty that is regarded as a quantum leap in system monitoring applications.

As the international mud logging market is dominated primarily by US-based companies with a few local competitors supplying the non-US markets, this industry is typically reluctant to apply state-of-the-art technology whenever working solutions have been in existence for some time. Competitor's mud logging systems today still are based on DOS environments with conventional analogue signal transmission. Personal computer based data acquisition systems are still fighting to replace dedicated electronics manufactured by the large companies themselves. A trend is however recognizable to adopt Windows-based applications to realize real-time transmission of the acquired data via the Internet.

Due to the nature of the market, mud logging units are rarely sold but mainly rented on a per-well or per-month basis. By the end of 1998, *OIL&GASTEK* operated three units, with an average per-unit revenue of 20 to 23 k€ per operating month (depending on required on-site personnel).

| Unit Type | Conventional RIM-System | Number of units | Advanced PROFIBUS/RIM-System | Number of units |
|---|---|---|---|---|
| 1995 *OIL&GASTEK* RIM Revenue | 15 k€ | 1 | 0 k€ | 0 |
| 1996 *OIL&GASTEK* RIM Revenue | 30 k€ | 1 | 0 k€ | 0 |
| 1997 *OIL&GASTEK* RIM Revenue | 90 k€ | 2 | 0 k€ | 0 |
| 1998 *OIL&GASTEK* RIM Revenue (estimated) | 232 k€ | 3 | 0 k€ | 0 |
| 1999 *OIL&GASTEK* RIM Revenue (estimated) | 250 k€ | 3 | 45 k€ | 1 |

***Table 4: RIM System Revenues/Units***

Unit depreciation is based for three years, due to the short evolution cycles in computer developments. While a complete monitoring unit (container-mounted) represents an initial investment of 140 k€. The payback of the costs spent for the application experiment is attempted to be reached within two years. ROI can reach up to 400% over lifetime of the product. This is mainly depending on the overall situation in the oil&gas-industry, since profit margins in low-oil-price phases are near to zero to allow the company to survive.

While initial product cost is not substantially affected by the application of bus technology, operating cost of the unit is reduced by 15-20 % due to shorter rigging-up/down times whenever the drilling unit is moved to another location. At the same time, operational reliability of the unit is increased due to less cabling exposed to mechanical damage while required service calls to the rig can be reduced due to enhanced remote maintenance possibilities.

| Cost Item | Unit Cost PROFIBUS system | Unit Cost conventional system |
|---|---|---|
| Processing Hardware | 13 k€ | 13 k€ |
| Sensor Hardware | 34,6 k€ | 34,6 k€ |
| A/D Conversion | 0 k€ | 4,6 k€ |
| Cabling | 1 k€ | 4,6 k€ |
| Gas Chromatography | 23 k€ | 23 k€ |
| Total Unit Cost | 71,6 k€ | 79,8 k€ |
| Savings | 11,4 % | |

***Table 5: Manufacturing Cost (excl. Labor Cost) per RIM-System Unit***

The economic impact of the AE's results cannot easily be de-coupled from complete monitoring unit cost, as the field implementation of the new design is both linked to investing into the complete data acquisition, management and storage environment as

well as impacts general market success of the system by enhancing its technical competitiveness.

Thus the economic impact of the AE's results are reflected in the reduced operating cost of the system together with the reduction in hardware investment for A/D conversion and cabling. However, this cost reduction alone will not represent the total value of the innovation, as its technological advancement increases its potential market reception. Therefore the ROI was computed over the savings reported in the paragraph above as well as additional profit out of new market opportunities which can be acquired because of the extended capabilities of the new system.

The profitability improvement due to the AE innovation can be quantified through the reduced operating costs of the unit caused by the shorter rigging-up/down times whenever the drilling unit is moved to another location. The operating costs reduction varies between 15 and 20 % based on the operating costs of the existing system.

The following table provides an overview of the estimated increase in profit. But it has to be mentioned that this calculation is based on the assumption that the oil price will be stable over the calculated period.

| Year | 1 | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|
| Increase in profitability (k€) | 70 | 5 | 30 | 25 | 20 | 150 |

***Table 6: Estimated increase in profit***

As described above such mud logging systems are mainly rented, *OIL&GASTEK* is now in the position to offer their customers lower prices for installation and operation costs for the new system.

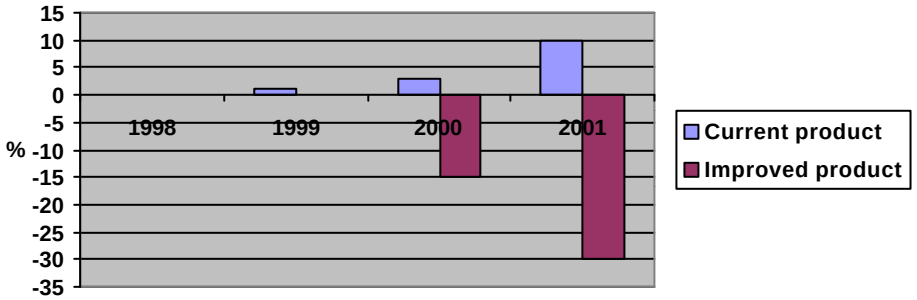


***Diagram 1: Changes in turnover for new and old product relative to 1998***

## 17. Target Audience

*OIL&GASTEK* gathered knowledge in the application of powerful bus communication technology to enhance data/signal transmission between field sensors and central recording unit. Especially the application of PROFIBUS systems in hazardous environments could be of interest for other companies. Another topic of interest is how to deal with suppliers especially with arising problems and delivery delays.

The target audience should be the upstream petroleum industry in general as well as drilling contractors and oil companies regarding mud logging, rig instrumentation and drilling monitoring. Additional the mining industry as well as refineries for explosion proof monitoring should be targeted.

Since *OIL&GASTEK* is also heavily involved in geothermal drilling, this AE should be of interest for enterprises in this area. Additionally, this AE could be of interest for all companies involved in drilling, with holes deeper than 200 m.

Last but not least, for companies which are in need of implementing a bus system this demonstrator document should be of a big assistance in deciding whether a PROFIBUS system would be the right solution.

*OIL&GASTEK* will present the results of the AE at the 1998 European Petroleum Technology Conference (EUROPEC) in The Hague from October 20-22 to an international audience.

The following table shows the Prodcom codes of the industry sectors that may benefit from this document:

| Description | Prodcom code |
|---|---|
| Extraction of crude petroleum and natural gas | 111 |
| Service activities incidental to oil and gas extraction excluding surveying | 112 |
| Other mining and quarrying | 14 |
| Manufacture of refined petroleum products | 232 |
| Manufacture of explosives | 2461 |

***Table 7: Prodcom codes of the industry sectors***