Technology Assessment– Update Report

Document 10121.4306.01.03

All-Electric Subsea Autonomous High Integrity Pressure Protection System (HIPPS) Architecture
10121.4306.01

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0 PREFACE

The objective of this project, the RPSEA All-Electric Subsea Autonomous High Integrity Pressure Protection System (HIPPS) Architecture (10121-4306-01), is to assess and advance the state of technology concerning subsea all-electric High-Integrity Pressure Protection Systems (HIPPS); a technology enabling extraction from high-pressure fields and expansion of existing low-pressure subsea networks.

In the initial phase, Phase 1, in-depth research has been performed to provide a basis for reducing the risk of environmental impacts resulting from subsea equipment failure through the use of improved failsafe systems and controls. An electric failsafe HIPPS will help ensure the integrity and safety of any subsea equipment not rated for the wellhead shut-in pressure. The first phase of this program addresses the heart of safety, integrity, and reliability of practical subsea facilities. Successful commercialization and utilization of this type of system will result in an added barrier to avoid environmental problems downstream of the system. The Phase 1 research study has three main tasks: an expanded technology assessment, development of a statement of requirements, and defining a basis of design.

In an effort to provide an independent, industry wide, point-of-view, GE Global Research subcontracted all Phase 1 efforts to INTECSEA. Furthermore, a Working Project Group was also assembled that represented a broad range of operators, other manufacturers, and subcomponent vendors.

0.1 Subcontracted Phase 1 - INTECSEA

This report represents a subset of the Phase 1 program deliverables, assessing the current state of all-electric HIPPS technology and incorporating viewpoints from operators, manufacturers, system integrators and subcomponent vendors. Specifically, this document covers the Updated Technology Assessment that was conducted to characterize the current technology beyond the information in the DeepStar study (DS Phase X CTR – 10304), and includes the technical information presented during the workshop attended by current or likely HIPPS manufacturers, along with the RFI issued by INTECSEA intended to assist in gathering current technical information.

[Editor’s Note: The following sections and appendices were created from subsections of a larger final report from INTECSEA, 408024-00348-SY-BOD-0001]
SIGNATURE & DATE STAMP

Weston B. Griffin, Ph.D.
Principal Investigator

March 12, 2014
Date
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ALL-ELECTRIC SUBSEA AUTONOMOUS HIGH INTEGRITY PRESSURE PROTECTION SYSTEM (HIPPS) STUDY – PHASE 1

[Editors Note: The following text was created from subsections of the final report from INTECSEA, with the corresponding document number]

408024-00348-SY-BOD-0001
1 INTRODUCTION

1.1 Project Background

Subsea High Integrity Pressure Protection Systems (HIPPS) have the potential to enable production from high-pressure fields and expansion of existing low-pressure subsea networks to handle newer higher-pressure wells. The use of all-electric technologies within subsea protection systems as HIPPS is considered feasible by the industry, for future subsea developments. All-electric HIPPS installations are seen to be advantageous by eliminating hydraulics and associated environmental concerns as well as potentially enhancing system reliability.

1.2 RPSEA Project Purpose

The Research Partnership to Secure Energy for America (RPSEA) project is intended to assess and advance the state of technology concerning subsea all-electric technology for further usage in the High-Integrity Pressure Protection Systems (HIPPS). The project has two-phases:

Phase 1: In-depth research to provide basis for environmental risk reduction through improved failsafe systems and controls.

Phase 2: Focus on the key component technology gaps currently limiting the realization of all-electric HIPPS through design and sub-scale evaluation.

Successful commercialization and utilization of an all-electric HIPPS system will result in an added barrier to avoid environmental problems downstream of the system.

1.2.1 Document Scope

This document covers the Updated Technology Assessment that was conducted to characterize the current technology beyond the information in the DeepStar study (DS Phase X CTR – 10304), and includes the technical information presented during the workshop attended by current or likely HIPPS manufacturers, along with the RFI issued by INTECSEA intended to assist in gathering current technical information.
2 PROJECT REFERENCES

408024-00348-RFI-001  Request for Information (RFI), RPSEA all subsea HIPPS project

The following references are used to provide consistency with previous work related to subsea HIPPS and “all-electric” subsea HIPPS.

DeepStar CTR 7503  Extreme HPHT Subsea System Study (Boreas 2004 Study)

DeepStar CTR 8303  All-electric vs. EH-MUX Controls: A Technology Study of Readiness and Competitiveness (INTECSEA 2008 Study)

J5920-MMS-RT-U-007  Evaluation of High Integrity Pressure Protection Systems (Granherne 2010 Study)

DS Phase X CTR - 10304  All electric Subsea Autonomous HIPPS Architecture Feasibility Study (DeepStar /Granherne 2011 Study)

OTC 22908  HIPPS- Based Design of Flowlines and Risers. Nikolaos Politis, Hugh Banon, Christopher Curran, BP America (OTC 2008 paper)


OMAE 10668  Reliability Based Pressure Containment Uprating. Elie Dib, Sherif El-Gebaly, and Frank Drennan, INTECSEA (OMAE 2013 paper)
3 UPDATED TECHNOLOGY ASSESSMENT FROM PHASE 1 STUDY

3.1 SUMMARY

The original requirements for the Phase 1 All-Electric Subsea HIPPS Study regarding the technology assessment were to:

- Assess the available technology associated with the all-electric HIPPS application in significant detail, and quantify the Technology Readiness Level (TRL) in accordance with API 17N;
- Identify technology gaps which would need to be closed prior to deployment of all-electric HIPPS; and
- Create a roadmap to address the technology gaps.

Obtaining detailed information in accordance with the above proved to be difficult, if not impossible to obtain; Manufacturers were either unwilling or unable to disclose anything beyond marketing level information of a general nature, due to the information being of a confidential/proprietary nature. Further, while it appeared that technology in certain electric subsea applications is being developed and a substantial amount of subsea electric technology is actually in use, there was general interest in all-electric HIPPS applications. Discussions with operators indicated that applications for all-electric subsea HIPPS are aspirations for the future; no specific near-term installation requirements were identified.

Nevertheless, despite the above findings, it is clear that candidate technologies exist which are feasible for the subsea all-electric HIPPS application, as indicated in the reference DeepStar Report 10304, All Electric Subsea Autonomous HIPPS Architecture Feasibility Study. Given the focus and interest of subsea operators, we are confident that technology at this time is suitable to be considered for subsea HIPPS qualification. Detailed technology assessment, gap identification, etc., could then be conducted on the specific case(s) as part of the qualification exercise.

INTECSEA identified key potential vendors, and used a formal RFI process along with an open workshop to gather information from likely or potential manufacturers of all-electric HIPPS, both full systems and key components. These activities will be described in further detail in a subsequent section of this report.

In spite of the difficulties encountered due to commercial constraints, INTECSEA would like to express its sincere appreciation for the efforts that all the vendors expended in support of this study, including the travel by the overseas vendors.

Below is a summary of the key conclusions drawn regarding the current state of technology from all interactions with the manufacturers.

- Representative technology for subsea electric valve actuation and related controls systems that is directly applicable to an all-electric HIPPS and has been previously deployed subsea in non-safety-
critical rated installations. There are considerable numbers of components representing the above technology that are performing successfully in permanent and temporary installations.

- The electrical actuators for subsea installations are available in a range of configurations and options, and many appear suitable for subsea all-electric HIPPS application.

- The all-electric subsea HIPPS can be developed using either DC or AC technologies, each with its own advantages. The electric subsea technology available can potentially bring the latest in state-of-the-art motion control technology to the HIPPS application. Compact and efficient packaging technology may also be a plus for subsea HIPPS applications, and reliability may benefit from the economies of scale involved in use of the technologies in other applications.

- The range of pressure and size of the subsea valves that can use electrical actuation and control is not limited because the design of the electric actuators can be scaled to accommodate bigger driver trains, gear ratios, and multiple electrical motors.

- Subsea electrical technology can allow electrical actuator designs for rotational or linear motion, and fail-close mechanisms can be mechanical (spring/clutch, reduced power to hold open), electrical (subsea batteries/switch to drive closed) or redundant (spring and electrical power) type. Rotational actuators are possible for 90 degree-turn valves, as well as multiple turn mechanisms that are geared to provide linear motion for non-critical electrical subsea valves.

- The available actuator torques from subsea electrical technology range from inch-lbs to kilo ft-lbs, while stem forces are available from lbf to tons – all within the range of the requirements for subsea all-electric HIPPS valves.

- The subsea HIPPS can further benefit from subsea electric technology due to additional inherent features, such as advanced diagnostics and performance monitoring systems.

- A small number of complete all-electric subsea production systems have been delivered by Cameron and operated by Total in recent years. Oceaneering and FMC have also installed a considerable number of actuated valves and ROV electric operated valve override systems.

- Increasing installation of subsea pumping, compression, and separation systems requires the use of subsea electric technology, with some of the specific applications for this equipment requiring the safety-criticality of subsea HIPPS. Subsea all-electric HIPPS should benefit from the experience derived from increased use of subsea electric technology as it joins the growing trend towards subsea electrification.

### 3.2 Specific Information Requested from Manufacturers

Information was formally requested from manufacturers previously identified in the referenced DeepStar report DS Phase X CTR - 10304, and from additional manufacturers who could potentially supply hardware or systems for all-electric HIPPS. The manufacturers were requested to respond to a written Request for Information (RFI) and were also invited to a one-day workshop to share information in a common forum. The RFI document is contained in Appendix A of this report; the presentation slides from the one-day workshop are contained in Appendix B. The manufacturers considered for this investigation are listed in Table 3.1, indicating their participation.
Table 3-1: RFI and Workshop Participation

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Response to RFI</th>
<th>Attended Workshop</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>OneSubsea</td>
<td>No</td>
<td>Yes</td>
<td>No presentation materials</td>
</tr>
<tr>
<td>FMC</td>
<td>No</td>
<td>No</td>
<td>Declined to participate</td>
</tr>
<tr>
<td>Aker Solutions</td>
<td>No</td>
<td>No</td>
<td>Declined to participate</td>
</tr>
<tr>
<td>GE Oil &amp; Gas</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Dril-Quip</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>BEL Valves</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>PetrolValves</td>
<td>No</td>
<td>No</td>
<td>Provided materials offline</td>
</tr>
<tr>
<td>Techni</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Wittenstein</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Oceaneering</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

Although the information was limited to public-domain data and not all vendors fully participated in either the RFI or the workshop, INTECSEA found the workshop to be productive in opening the discussion about electric technology.

The purpose of the engagements with the manufacturers was to try to assess the industry status regarding the specifics of electric actuation and control of subsea valves for subsea HIPPS, as well as provide an open forum in order to support RPSEA to consolidate the work accomplished by different industry parties covering critical aspects for an acceptable all-electrical subsea HIPPS design for future subsea installation.

Technical discussions were also held with Moog Components Group about their capabilities mentioned in the DeepStar All Electric Subsea Autonomous HIPPS Architecture Feasibility Study DS Phase X CTR – 10304, as well as with Schneider Electric about their power and safety systems. These manufacturers represent potential additional manufacturers of HIPPS or HIPPS related equipment, but neither was invited to participate in the RFI or the workshop.

As mentioned before it was assumed that a subsea all-electric HIPPS will be a standalone system supported by its own topsides and subsea equipment, including its own power, communication, and injection of chemicals, while the subsea field application parameters had been defined by DeepStar All Electric Subsea Autonomous HIPPs Architecture Feasibility Study, document DS Phase X CTR - 10304.

INTECSEA requested manufacturers’ participation in providing technical information in the area of electric actuations and related subsea control systems with direct future applicability in the all-electrical subsea HIPPS. The schematic shown in Figure 3-1 was furnished to the manufacturers to frame the particular items of technology that were of interest in the RFI and the workshop.
The responses to the RFI, including supporting documentation, are regarded as confidential and treated accordingly; hence, the responses to the RFI are not included in this report. For the open workshop INTECSEA stipulated that the information shared in that forum was to be restricted to information that is classified as public domain or marketing-level information, free to be shared publicly. This stipulation was made to ensure appropriate confidentiality would be maintained. No discussion was entertained about commercial aspects of the technology presented. The presentation materials from the workshop can be found in Appendix B of this document.

In addition to the manufacturers listed in Table 3.2-1, the following additional parties joined in the open workshop to hear the findings:

- ExxonMobil (one representative from the Working Project Group)
- National Energy Technology Laboratory (NETL) - part of U.S. Department of Energy
• Research Partnership to Secure Energy for America (RPSEA Project Manager)
• BSEE was represented during high level discussions emphasizing the requirements of the HIPPS approval process once an application has been identified.

The manufacturers had the opportunity to present their achievements in technology advances and answer questions related to their equipment. They presented a clear message that their intention is to continue their development of such equipment, and to manufacture and deliver this equipment, believing that the subsea development will call for more electric technology implementations in the future.
Appendix A

INTECSEA – RFI Document
ALL-ELECTRIC SUBSEA HIGH INTEGRITY PRESSURE PROTECTION SYSTEM (HIPPS)

REQUEST FOR INFORMATION (RFI)

408024-00348

RFI-0001
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4 INFORMATION NEEDED – SUBSEA ALL-ELECTRIC CONTROL SYSTEM AND INTERFACE COMPONENTS ..................................................................................................................... 5
1 SCOPE OF DOCUMENT

INTECSEA is engaged in a study, together with GE Global Research on a contract awarded by the Research Partnership to Secure Energy for America (RPSEA), to assess the state of current technology of subsea electric systems applicable for a future all-electric subsea HIPPS.

In order to assess the industry status INTECSEA is requesting manufacturer’s participation in providing technical information. INTECSEA’s request has two parts:

- **Provide responses** to the specific technical points listed in this document, within 2 weeks of receipt of this document, by June 21, 2013. In order to expedite the transfer of information, INTECSEA will arrange to contact appropriate personnel, either by phone or in person, to interactively discuss this RFI and obtain information directly in the discussion. Any information obtained in this manner will be documented by INTECSEA and furnished to the originator for verification. It is also anticipated that further information will be identified in the discussion which INTECSEA would like for the manufacturers to furnish in due course. Information is requested in electronic versions of written and/or printed documents, sent via email to: Larry.forster@intecsea.com and 408024-00348@intecsea.com.

  We encourage the subsea equipment providers to answer the questions 1 through 20 in Section 3 and 1 through 9 in Section 4. This will expedite the grouping and interpretation of provided information.

- **Attend an open workshop at INTECSEA’s Houston office** located at 575 N. Dairy Ashford, first floor, on **Tuesday, July 2, 2013, from 9 AM to approximately 4 PM**, for further discussions of the technical information associated with all-electric subsea HIPPS, in a common forum with other participants and subsea systems operators.

For any clarifications and details regarding this Request for Information please contact Larry Forster, INTECSEA, Inc., +1 281-925-2322, Larry.forster@intecsea.com.
2 INTRODUCTION

Subsea High Integrity Pipeline Protection Systems (HIPPS) have the potential to enable production from high-pressure fields and expansion of existing low-pressure subsea networks to handle newer higher-pressure wells. The use of all-electric technologies within subsea protection systems as HIPPS is considered feasible by the industry, for future subsea developments. All-electric HIPPS installations are seen to be advantageous by eliminating hydraulics and associated environmental concerns as well as potentially enhancing system reliability.

The study will assess the status of electric actuations and associated control systems for all-electric subsea HIPPS application identifying the technology gaps and developing a roadmap for future development, qualification and implementation.

INTECSEA study will update and consolidate the work by different industry parties covering critical aspects for an acceptable all-electrical subsea HIPPS design for future subsea installation that will be included in a Statement of Requirements and a Basis of Design for the subsea all-electric HIPPS.

The information compiled in this study will thus form a common industry platform for the design of the all-electric subsea HIPPS.

The specific information listed in this technical query is based on two (2) generic schematics and one (1) table indicating the preliminary subsea HIPPS configuration as well as system design parameters for reference.

The information requested in this document can be summarized:

- Section 3. Technical details of electric actuators and valves, the actual technology readiness level (TRL) per API 17N, for equipment available or under design, manufacture, testing or qualification of assemblies or components, as applicable.
- Section 4. Technical description of the subsea control system and related interface equipment, along with the TRL as described above.

The reference schematic for the all-electric HIPPS is shown in Figure 4-1 while main design parameters are listed in Table 4-1. The schematic, shown in Figure 4-2, contains a proposed interface delimitation between the subsea control system and subsea electric actuators that should be considered for TRL classification of the subsea control systems as well as electric actuators.

Please note that at this stage of the study, it is assumed that the subsea all-electric HIPPS will be a standalone system, supported by its own topsides and subsea equipment, including its own power,
ALL-ELECTRIC SUBSEA HIGH INTEGRITY PRESSURE PROTECTION SYSTEM (HIPPS)
REQUEST FOR INFORMATION (RFI)

communication, and injection of chemicals to the subsea HIPPS equipment. This assumption will provide the flexibility to consider all the possible options of developing the all-electric subsea HIPPS.

This request for information is addressed to manufacturers who provide, or intend to provide, complete systems, as well as, to the manufacturers that are providing the key components that are part of the future all-electric subsea HIPPS.

All responses to this inquiry, including supporting documentation, shall be considered confidential and shall be treated accordingly.
3 INFORMATION NEEDED – SUBSEA ELECTRIC ACTUATORS ASSEMBLY AND COMPONENTS

1. Actuator size and type (rotary or linear, stroke, force, weight, etc.)
2. Valve size and type (gate valve, ball valve, etc.)
3. Fail safe configuration (spring, subsea electrical batteries, redundancies, pressure-assist, damping, etc.)
4. Actuators main components (electrical motors, gears, clutches/release mechanism etc.)
5. Electrical motor type (permanent magnet, AC/DC, etc.) and possible operating parameters (voltage, current, power consumption, etc.) for the main HIPPS valve actuators
6. Electrical motor type including possible operating parameters for the bypass and chemical injection valve actuators
7. Clutch or other release mechanism parameters (peak/standby voltage, current, etc.)
8. Actuator assembly packaging information (compensation fluid type, etc.)
9. Actuator opening and closing times (as applicable, in accordance with valve size/stroke and maximum valve operating pressure)
10. Electrical actuator interface with the valve (integrated, separate assembly, etc.)
11. Electrical motor controller (actuator integrated/included, separate/included in subsea controls equipment)
12. Electric motor controller type: P, PI, PD or PID.
13. Electrical motor controller feedback type: open or closed loop. If closed loop, specify encoder feedback type (HED, Proximity Sensor, etc.) or back emf.
14. Actuators assembly operation history (surface/topsides as well as subsea)
15. Actuators main components operation history (surface/topsides as well as subsea)
16. Qualification or development status (as applicable for the subsea electrical actuator assembly as well as main components, TRL level per API 17N.
17. Qualification or development targeted parameters for components utilized in other applications, as basis for comparison to requirements of HIPPS application
18. Actuator scalable design options including the assembly and main subassemblies
19. Actuators ROV override strategy and associated parameters (mechanical/electrical parameters, etc.)
20. SIL rating or other reliability supporting data/documentation for electrical actuator assembly or any components – as available
4 INFORMATION NEEDED – SUBSEA ALL-ELECTRIC CONTROL SYSTEM AND INTERFACE COMPONENTS

1. Type of subsea power and control system for electrical actuated subsea valves (AC/DC, power requirements, etc.)

2. System operating ranges for electrical parameters (topsides and subsea power and controls equipment parameters for start-up, operation, stand-by, etc.)

3. Subsea power configuration and interface with subsea controls (electric SCM subsea power conversions type/location, subsea power management, batteries location, etc.)

4. Subsea electrical system communication to topsides (communication rate, protocols, etc.)

5. Electrical actuators drives/controllers (type/location, parameters, subsea communication to control module etc.)

6. Clutches/release mechanism drives/controllers (type/location, parameters, subsea communication to control module etc.)

7. Electrical actuators main assemblies’ instrumentation (type, parameters, subsea communication with controls module etc.)

8. Electrical SCM assembly and components operation history (power as well as communication components etc.)

9. SIL rating or other reliability supporting data/documentation for power and controls system components – as available
ALL-ELECTRIC SUBSEA HIGH INTEGRITY PRESSURE PROTECTION SYSTEM (HIPPS)
REQUEST FOR INFORMATION (RFI)

Figure 4-1: All-Electric Subsea HIPPS Generic Schematic
Table 4-1: All-Electric Subsea HIPPS Main Design Parameters

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host facility</td>
<td>Semi</td>
<td></td>
</tr>
<tr>
<td>Tie-back distance to host</td>
<td>30 miles</td>
<td></td>
</tr>
<tr>
<td>Water depth at host</td>
<td>6,000 ft</td>
<td></td>
</tr>
<tr>
<td>Minimum arrival pressure at host</td>
<td>1,500 psig</td>
<td></td>
</tr>
<tr>
<td>Water depth in field</td>
<td>10,000 ft</td>
<td>Increased from Diablo 7500 ft</td>
</tr>
<tr>
<td>Number of producing wells</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Distance from wells to manifold/flowline hub</td>
<td>150 ft</td>
<td></td>
</tr>
<tr>
<td>Flowline insulation</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Flowline pigging</td>
<td>Roundtrip</td>
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</tr>
<tr>
<td>Product type</td>
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<td></td>
</tr>
<tr>
<td>Gas oil ratio</td>
<td>1700</td>
<td></td>
</tr>
<tr>
<td>Corrosiveness</td>
<td>Sweet</td>
<td>Note sensitivity to CO₂ &amp; H₂S</td>
</tr>
<tr>
<td>Maximum shut in pressure</td>
<td>15,000 psi</td>
<td>Investigate to 20,000 psig</td>
</tr>
<tr>
<td>Minimum pressure</td>
<td>0 psia</td>
<td></td>
</tr>
<tr>
<td>Well head flowing maximum temperature</td>
<td>300 °F</td>
<td></td>
</tr>
<tr>
<td>Producible reserves</td>
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<td></td>
</tr>
<tr>
<td>Average reserves per well</td>
<td>20 M bbl</td>
<td></td>
</tr>
<tr>
<td>Initial production rate</td>
<td>20 kbopd</td>
<td></td>
</tr>
<tr>
<td>Average production rate</td>
<td>10 kbopd</td>
<td></td>
</tr>
<tr>
<td>Hydrate control</td>
<td>LDHI</td>
<td>Allow MEG &amp; MEOH injection</td>
</tr>
<tr>
<td>Valve sizes</td>
<td>5 to 9 in</td>
<td>Components &amp; system</td>
</tr>
<tr>
<td>Safety Integrity Level (SIL)</td>
<td>SIL 3</td>
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</tr>
</tbody>
</table>
Figure 4-2: All-Electric Subsea HIPPS Schematic Highlighting Internal Interfaces
Appendix B

All-Electric HIPPS Workshop Presentations

The following list of companies approved the inclusion of their respective workshop presentations into the Phase 1 report deliverables.

INTECSEA Workshop introduction
BEL Valves
GE Oil and Gas
Techni AS
Wittenstein Motion Control
8:30 AM  Coffee and Pastries

9:00 AM  Workshop Opening
- Welcome
- Introductions
- One-Way Moment
- Review of Agenda
- RPSEA Program Overview
- Workshop Overview
  - Background
  - Objectives of Current Study
  - Purpose of this Workshop
  - Terms & Conditions: Confidentiality/Commerciality

Break
Presentations by Manufacturers – Integrators
- Dril-Quip
- OneSubsea
- GE Oil & Gas

Presentations by Manufacturers – Components
- Bel Valves
- Techni
- Wittenstein
- Oceaneering (iFokus)
- Moog (to be confirmed)
- Others (presented by INTECSEA)

10:00 AM
Lunch (Brought In)
1:00 PM ➤ Summarization
- Development of Industry Platform for Electric HIPPS Technology (Facilitated Interactive Session)
- Development of Summary Presentation (To Deliver to Operators/BSEE)

2:00 PM ➤ Operator/Regulatory Input
- Welcome and Introductions of BSEE and Operator Personnel
- Presentation of Summary of Electric HIPPS Technology
- Open Discussion (Facilitated/Scribed)

Break
- Acknowledgements, Next Steps
- AOB
- Adjourn
Background
- HIPPS has been in the works for some time, basic requirements addressed in API 17O
- All-electric subsea, also in the works
- DeepStar conducted All-Electric HIPPS Feasibility Study
- RPSEA study taking All-Electric HIPPS a step further

Objectives of Current Study
- Expanded Technology Assessment
- Statement of Requirements
- Basis of Design

Purpose of this Workshop
- Elaborate on technology status
- Develop industry platform for all-electric HIPPS
- Obtain initial regulatory and operator input
Terms & Conditions: Confidentiality & Commerciality

- Marketing-Level Information to be Shared
- Only Information Available in the Public Domain
- No Discussion of Prices, Costs, or Anything Commercial
- Careful about New Technology – only public domain info, nothing proprietary
- Discussion shall be managed, meeting shall be minuted
  - No discussion on inappropriate areas.
- Other Issues?
All-Electric HIPPS Study
Open Workshop #1
“Valve & Actuator Elements”

Richard Dodd
BEL Group Product & Engineering Director
• Company
• HIPPS Experience
• HIPPS – Valve & Actuator Element
• Replacing Hydraulic with Electric
BEL Valves Ltd

1922
1950s

Turnover > $200m
Circa 1200 employees
International Installed Base

Excellence in valve engineering
Where Do We Operate?

- Head Office
- Sales Locations
- Installed Regions
HIPPS and HP/HT experience

High Pressure => 10,000 psi

High Temperature => 121°C

High Integrity Pressure Protection System

Over 5,000 installed
Basic Subsea HIPPS Valve Criteria

- SIL 3 Capable (3rd party TUV Certification required)
- Valve must close on demand
- Valve must close in time required
- Valve design/leakage – API 6A/6DSS/17D/17O
- Integrity maintained over 30+ years field life
- Through conduit gate valve choice for Subsea HIPPS
- Horizontal Installation
Shah Deniz HIPPS Valve Parameters

Through Conduit Gate Valve

Weight 18 Tonnes

10” (254mm) ID Full Bore

Height 3.4m

Seat test pressure 990 Bar

Fail-Safe-Close

Closure Time <15 seconds

Test depth 660m

Early life gas flow 163m$^3$/s
Extended PR2
Hyperbaric
Addl Qualification Scope
Closure time testing
TUV Certification
Addl Qualification Scope

- Quick Closing Test
- Broken Spring Test
- Pinch Test
- Pin on Disc Test
- Open Compensator Test
- Oil Compatibility Test

TRL 4 now achieved on Valve Actuator Assembly
Many Years Experience supplying HPHT & HIPPS
Future – Replace Hydraulic with Electric

Image Courtesy Framo Engineering AS
Subsea Isolation Ball Valve (SSIV)

14” 900 Bar Subsea HIPPS Gate Valve

Future – Replace Hydraulic with Electric
Subsea Electric Actuator

Looking to the future of the All Electric Oil Field.
Design
(For Fail Safe)
Use of Existing Components

Electric Thrust Unit (ETU)

Existing Field Proven Actuator & Valve
Standard roller screw technology

The drive mechanism is a set of simple spur and helical gears.

Conventional Helical Spring
Differential Gear Drive

• Self Locking
• Spring Return
• Low Power Hold Open
• Proven Technology
• Inherently Fail Safe
Ball Valve ROV Override

- Standard rotary interface
Gate Valve ROV Override

- Standard rotary or linear interface
• No hydraulic fluid to displace
• Closure time <1 Second
• Use of variable orifice damper
• Attractive for use as HIPPS or SSIV
• Suitable for Partial Stoke Test
10% Partial Stroke Testing – Hydraulic Spring Return

- overshoot difficult to control
- greater control of quick closing valves
10% Partial Stroke Testing – Electric Spring Return

- Reduced Overshoot
- Reduced Lag
- Immediate Re-open or constant pause
QUESTIONS

RICHARD DODD
BEL GROUP PRODUCT & ENGINEERING DIRECTOR
RD@BEL.CO.UK
Ball Valve Actuator

- Valve size 7,1/16” 5,000psi (345 Bar)
- Testing Temperature: -10°C to +65°C (Actuator)
- Water Depth 3000m
- Voltage 415 VAC 3PH
- Motor Power 1.5kw
- Hold open power <10w
Gate Valve Actuator

- Valve size 5,1/18” 10,000psi (690 Bar)
- Testing Temperature: -10°C to +65°C (Actuator)
- Water Depth 3000m
- Voltage 415 VAC 3PH
- Motor Power 10kw
- Hold open power 34w
Differential Gear Drive

• Self Locking
• Spring Return
• Low Power Hold Open
• Proven Technology
• Inherently Fail Safe
Electric HIPPS – what does it involve?

Martin Stokes – Lead NTI Engineer
RPSEA Workshop 2013, Houston US.
Agenda

• Brief HIPPS Description
• Development History
• Electric HIPPS Motivation
• Electric vs. Hydraulic HIPPS
• Standards & Regulation
What Function Does HIPPS Perform?

Protects downstream equipment from over-pressure by continuously monitoring line pressure and automatically closing an isolation valve if it rises above a pre-set level.
Anatomy of a Generic HIPPS

- PT1
- PT2
- PT3

HIPPS BARRIER VALVE 1

HIPPS BARRIER VALVE 2

PIPELINE SPEC BREAK

HIPPS SCM / SEM
Risk Reduction / Reduced Demand Rate

Layered Protection

For rising pressure the following sequence would result:

1. High pressure alarm – manual intervention
2. Autonomous tree shut-down
3. Autonomous manifold shut-down
4. HIPPS trip

Although 1, 2 & 3 above are not SIL rated, their combined effect will be to reduce the demand rate on the HIPPS and so assist in achieving the required SIL rating.
Selection of the logic solver

Traditional (Hardwire) Logic Solvers

- Solid state logic
- Magnetic core logic

Simple verification & validation

Failure modes, simple to identify and analyse

Or...

Software PLC logic solvers have started to gain acceptance
## HIPPS Project History - GE Oil & Gas

<table>
<thead>
<tr>
<th>Operator</th>
<th>Project</th>
<th>Date</th>
<th>Depth (m)</th>
<th>Press (bar)</th>
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</table>
Electric HIPPS – What is the Motivation?

- All Electric gaining momentum - slowly
- Technical limits of Hydraulic systems
- Commercial Limits of Hydraulic systems
- Possible Enabler for Marginal Fields
  - GoM expected to have many of these fields.
- Can the PFD be improved?
All Electric vs Electro Hydraulic HIPPS

- Development Discussion Topics?
  - Sensors
  - Logic Solver / Safety Controller
  - Actuator
  - Valve
  - Electrical Distribution
Standards & Regulations

IEC: 61508
Functional Safety of Electrical / Electronic / Programmable Electronic Safety-Related Systems

IEC: 61511
Functional Safety – Safety Instrumented Systems for the Process Industry Sector

OLF 070
Recommended Guidelines for the application of IEC 61508 and 61511 in the petroleum activities of the Norwegian Continental Shelf

API 17-O
Recommended Practice for Subsea High Integrity Pressure Protection Systems
All electric Subsea HIPPS
“OEM Components”

Dag Almar Hansen, TECHNI, Norway
HIPPS Open Workshop July 9 2013
Some defining projects

-1997
Parallell DC control

1997 -
XMT

1997 -
XMT

2000 -
Direct drive Gyro

2000 -
Aerospace actuator

2003 -
Kværner XMT & SSS

2006

ABB Industri AS
Some defining projects

2006

- Complete XML based control system
- 4-way valve actuator
- KAL_EL all electric for gate valve
- Gas lift valve
- Servo driven turret
- Actuator & overrides
Linear and rotary actuators

• Techni provides both rotary and linear types of actuators
• Stroke from one inch up to three feet
• Force from 12 lbf to more than 90 metric tons
• Rotary actuator designs from 50 ft. lbf to 25k ft. lbf.
The extreme in speed and force challenges
Inherent safety through design

Roller screw
Linear guide
Motor
Emergency-stop spring
Interface
Bearing
Over torque protection
Subsea and Well Technology

Sensors
Controllers
Drive Systems
Valve Position Monitoring; for LWI. Can be applied for HIPPS

TTRD Riser

VLI
Used for measuring the position of the looking pin, normally verified by ROV.

Inductive adapter
Converts inductive sensors to Modbus communication.

Inclinometer
Used to align the TTRD riser to the EDP during drilling operations.

Strain rms
Measures the strain on the riser.

EDP
Stress joint
Strain gauge based structural monitoring; Special gauges with virtually no creep factor. Can be utilised as safety device on HIPPS. Applied in GoM.
Through barrier, passive, wireless gauge
B annulus monitoring. retrievable processing component.

Enables pressure and temperature gauge without compromising barrier
qualification programme Q3-Q4 2013
Can be implemented as standard in HIPPS
POSIROD
Accurate, fast positioning technology for hydraulic actuators
Sub sea, topside heave compensation systems

Operators control desk

Controller

Motion sensing device

Valve block
Lab model
Proved concept/patent works. HIPPS worthy? Depends.
All electric linear actuator;
Improved fail safe mechanism
Expelled industry known seal tech
Permanent magnet motors
Smart controller, possibility to set up for autonomously correcting certain valve issues
All electric linear actuator;
As deployed in the award winning pump.
Rotary actuators;
ROV assisted actuation
Override with dampened brake return
70 units delivered
Rotating actuator; Chemical injection setup

Permanent magnet motors
Network node design
Each w/ Master/slave controller
50 units delivered
Rotating actuator; ROV installable subsea actuator

ROTATING VALVE ACTUATORS

CO-OP WITH BEL VALVES UK, PRODUCT NOW TECHNI IP

MULTI-USE CONTROLLER, NOW BEING IMPLEMENTED ALSO IN LWI SYSTEMS AS VALVE CONTROLLER
Controller

Parameters for the main HIPPS valve controller and logic solver device. (5 to 9 inch)
We suggest a 3 phase AC
• Voltage: 690 VAC, 50/60Hz
• Current: TBD
• Power: Dependent of voltage and current, efficiency usually better than 96%.
• Other voltages and DC current solution can also be provided.
Control system

- The fail to safety units are planned to be directly powered by an integrated or local eSCM. The eSCM can communicate with other eSCMs or directly to topside. Logic solving will be, to achieve SIL 3, fault tolerant and include redundancy based on the 2oo3/n election system or similar.

- Most of our actuators combines one or more of the following initiators, sensors and instruments:
  - Multiple temperature transmitters
  - Pressure transmitters
  - Flow meters
  - Position indicating initiators, like resolvers or proximity sensors.
WITTENSTEIN – being one with the future

More intelligent
More efficient
More secure
Milestones in the Company's Development

- **1949**: DEWITTA Spezial-maschinenfabrik established
- **1979**: Manfred Wittenstein takes over DEWITTA
- **1983**: First low-backlash planetary gearhead
- **1989**: Start of international expansion
- **1992**: Portfolio extended with electromechanical products
- **1996**: Company relocates to Harthausen
- **2001**: WITTENSTEIN AG established
- **2008**: WITTENSTEIN talent arena opens
- **2011**: "Urban Production" officially opened in Fellbach
- **2012**: Construction work begins on Harthausen Innovation Factory
WITTENSTEIN International

Santa Clara CA
Tech Centre

Bartlett IL

... in more than 40 countries worldwide

January 2013
Company Headquarters in Igersheim / Harthausen
Group Sales

5-year actual (in million EUR)

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Mechanical & Mechatronic Drive Solutions

WITTENSTEIN alpha

WITTENSTEIN electronics

WITTENSTEIN motion control

WITTENSTEIN cyber motor

WITTENSTEIN intens

WITTENSTEIN bastian

WITTENSTEIN aerospace & simulation

attocube systems
Quality Control Program

- WITTENSTEIN Company strategy and Quality philosophy
- Q-Organization WMC-S
- Quality Engineering Process
- Quality Test Concept
- Quality Tests
- Quality Test Facilities
- Quality Assurance and Control
- Deviation management
- Q-Documents and -management
- Q-Standards & Certifications

Quality system to **DIN EN ISO 9001**
certified supplier of aviation equipment acc. to **EASA 21G & EASA 145**.
certification acc. to **EN 460** (medical technology)
<table>
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<tr>
<th>General Test</th>
<th>Configuration</th>
<th>Mechanical Test</th>
<th>Electrical Test I</th>
<th>Electrical Test II</th>
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<td>Heatup Run</td>
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<td>Configuration status</td>
<td>Motor feedback</td>
<td>Breakaway Torque</td>
<td>High voltage Test</td>
<td>Resolver Field</td>
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<td>Brake/Clutch manual unlock</td>
<td>Friction Torque</td>
<td>Leaking Current</td>
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<td>Manual Drive Torque</td>
<td>Winding resistance</td>
<td>CAN impedance Terminal</td>
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<td>Cogging Torque</td>
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<td>CAN Communication</td>
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<td>Additional Parts</td>
<td>Brake/Clutch Torque</td>
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<td>Burn-In Cycle</td>
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MTBF  MIL-STD 217F calculations

MTBF Calculation

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Extended failure rate per operating hour *10E-6

Failure rate: 2.2440

MTBF in hours: 445.633
Structure of WITTENSTEIN AG

Customers

Generating Process Management (GPM)

Service Centre (DLZ)

WITTENSTEIN Component Manufacture
Igersheim (D), Fellbach (D), Grüssch (CH), Sibiu (RO), Ueda (J), Chicago (USA)

Supply Chain Management (SCM)

Value Partners

WITTENSTEIN innovative technology
WITTENSTEIN alpha
WITTENSTEIN cyber motor
WITTENSTEIN electronics
WITTENSTEIN motion control
WITTENSTEIN aerospace & simulation
WITTENSTEIN intens
attocube systems

WITTENSTEIN servos
WITTENSTEIN cyber motors
WITTENSTEIN electronics
WITTENSTEIN motion control
WITTENSTEIN aerospace & simulation
WITTENSTEIN intens
attocube systems

Source: WITTENSTEIN
WITTENSTEIN motion control

Solutions for special applications among extreme conditions...
Market Segments

WMC Specialty Technology serves the following technology markets:

- Defence
- Energy, Oil & Gas, Subsea
- Railway
WITTENSTEIN motion control – Special Applications

Mechatronic Drive Technology on the Sea Bed

Redundant actuator system for extracting oil & gas guarantees trouble-free operation at a depth of 3000 m

Valve / pump actuators and position switches made by WITTENSTEIN

- Maximum availability and functional reliability
- Safety certified on request (SIL 3) electronics

Extreme requirements on the sea bed

- Used at a depth of up to 3000 m
- Pressure resistant up to approx. 350 bar
- Vibration resistant
- Robust and durable
- Lifetime: 25 years. MTBF 395,000 hours
Control Electronics – Motor – Gearbox

Perfectly Harmonised Components for Closed Loop Motion Control

o/p interface:
- Speed
- Torque
- Temperature
- Position
Integrated Systems from a Single Source

Planetary Gearheads

Electronic Modules

Brushless DC-Servo Motors
Actual photo of subsea control electronics and motor/gearbox prior to assembly in housing.

Integrated Systems from One Source:

WITTENSTEIN motion control
From Single Components to Integrated Systems

Characteristics of Power & Control Electronics

- Product range from 18 V up to 900 V DC bus voltage
- Output current from 15 A up to 400 A
- Customized housings and connections
- Analog and digital interface or CAN Bus
- EMC-qualified
- Resistant against shock and vibrations
- MTBF 100,000 hours
Characteristics of Brushless DC-Servo Motors

• Motor power from 10 W to 200 kW & 18v to 900v
• Extremely high power density
• Extraordinary overload capacity
• Ambient temperature -56°C … +250°C
• Optional operation in oil and other fluids environment
• Several feedback options
• Full redundancy, optional

• MTBF 395,000 hours
From Single Components to Integrated Systems

Characteristics of High-Precision Planetary Gearheads

• Standard backlash < 1 arcmin
• Output torque up to 40,000 Nm (10,000Nm subsea)
• Ratios from 1:1 to 1:10,000
• Extraordinary overload capacity
• High mechanical stiffness
• Ambient temperatures -56°C … +125°C
• MTBF 372,000 hours
TPM+ basis for subsea applications

An integration of motor and gearhead…

…for more compactness…

⇒ smaller space requirements
⇒ less weight (moved axes)

⇒ smaller power amplifier
⇒ less heat dissipation

⇒ and lower internal inertia!

⇒ more dynamic
⇒ faster duty cycles
⇒ less energy

TPM+ : Highest dynamics in the most compact design.
Subsea Electric actuator schematic
ESRO-80A-24V-CAN-RES

Control and power electronics for AC-servo motors with resolver

Technical data

- Output current
  - 155 A peak
  - 68 A nominal

- Supply voltage
  - 18 VDC … 32 VDC

- Interface
  - CAN open

- Dimensions
  - (242x235x214) mm

- Weight
  - 8,2 kg

- Operating temperature
  - -18 °C … +70 °C

- Article code
  - 40023143

- Installation drawing
  - 4007-D033769
### MBSO-178-045R-024V

**AC-servo motor with resolver, operating in oil**

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<th>Technical data</th>
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<tr>
<td>Speed</td>
<td>1000 rpm (at nominal torque)</td>
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<td>Supply voltage</td>
<td>24 V DC nominal</td>
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<tr>
<td>Input current</td>
<td>160 A maximum</td>
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<td>120 A nominal</td>
</tr>
<tr>
<td>Diameter/ Length</td>
<td>(228/ 172) mm</td>
</tr>
<tr>
<td>Weight</td>
<td>14 Kg</td>
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<td>-18°C … +70°C</td>
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Proprietary information
Specialty Technology, J. Mark, May 24, 2013 02-13
MBSO-178-045R-024V
AC-servo ... 172) mm
Weight 14 Kg
Operating temperature -18°C … +70°C
Article code 40023144
Installation drawing 4007-D033063
TPMA050S352R-400N-OH0-045XX000

Technical data

- Backlash: ≤ 1 arcmin
- Gear ratio: 352
- Output torque:
  - Peak: 2700 Nm
  - Nominal: 950 Nm
- Brake torque: No brake
- Output speed:
  - Maximum: 2.5 rpm
  - Nominal: 4.5 rpm
- Supply voltage: 600 V nominal
- Input current:
  - Maximum: 5.8 A
  - Nominal: 1.8 A
- Diameter / Length: 180 mm / 310 mm
- Weight: 29 Kg
- Operating temperature: -18°C … +70°C

Product Information

Redundant AC-servo actuator for operation in oil

Article code: 40022001
安装图: 4007-D030140
TPMA050S066R-400N-OH0-045XX000

Technical data

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
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<tbody>
<tr>
<td>Backlash</td>
<td>≤ 1 arcmin</td>
</tr>
<tr>
<td>Gear ratio</td>
<td>66</td>
</tr>
<tr>
<td>Output torque</td>
<td>500 Nm peak</td>
</tr>
<tr>
<td></td>
<td>150 Nm nominal</td>
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<tr>
<td>Brake torque</td>
<td>No brake</td>
</tr>
<tr>
<td>Output speed</td>
<td>7.6 rpm maximum</td>
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<tr>
<td></td>
<td>20 rpm nominal</td>
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<tr>
<td>Supply voltage</td>
<td>600 V nominal</td>
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<tr>
<td>Input current</td>
<td>5.8 A maximum</td>
</tr>
<tr>
<td></td>
<td>2.6 A nominal</td>
</tr>
<tr>
<td>Diameter / Length</td>
<td>180 mm / 283 mm</td>
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<tr>
<td>Weight</td>
<td>27 Kg</td>
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<tr>
<td>Operating temperature</td>
<td>-18°C … +70°C</td>
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<td>Article code</td>
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<tr>
<td>Installation drawing</td>
<td>4007-D030112</td>
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Redundant AC-servo actuator for operation in oil
### Deployments since 2001 >> 200 units

<table>
<thead>
<tr>
<th>Project</th>
<th>Year</th>
<th>Solution</th>
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<tbody>
<tr>
<td>Statfjord</td>
<td>2001</td>
<td>controls-motor-gearbox</td>
</tr>
<tr>
<td>Elwis</td>
<td>2002</td>
<td>controls-motor-gearbox</td>
</tr>
<tr>
<td>Orman Lange</td>
<td>04/05</td>
<td>Spring return safety actuators concept study</td>
</tr>
<tr>
<td>Norne</td>
<td>2006</td>
<td>controls-motor-gearbox</td>
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<tr>
<td>Gjoa</td>
<td>07/08</td>
<td>controls-motor-gearbox</td>
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<tr>
<td>Tyrians</td>
<td>08/09</td>
<td>SIL controls/Triple redundant motors (not installed)</td>
</tr>
<tr>
<td>Asgard</td>
<td>2011</td>
<td>controls- Dual redundant motor-gearbox (not installed)</td>
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<tr>
<td>PLUTO</td>
<td>07/08</td>
<td>controls-motor-gearbox</td>
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<tr>
<td>Albacora</td>
<td>2007</td>
<td>controls-motor-gearbox</td>
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</table>
WMC Speciality technology Personnel

- 31 People in the Group

- 5 Program/Project Managers
- 5 Specialist Industry Development Engineers
- 2 Mechanical Engineers
- 3 Electronic Engineers
- 5 Core Technology Engineers
- 2 Quality Assurance
- 6 Sales and Marketing & Commercial
- 3 Management

Includes two TUV accredited **FSP - Functional Safety Professionals**

- The Functional Safety Professional dealing with functional safety on a per project basis.
“PCB Design Award 2012” for Innovative Circuit Board Design

WITTENSTEIN electronics GmbH carried off first place in the 3D / Form Factor category with this novel design for a 3D pub for medical applications.

Dr. Manfred Wittenstein is “Entrepreneur of the Year 2011”

“The visionary among machine builders”

Dr. Manfred Wittenstein is “Entrepreneur of the Year 2011” in the “Industry” category. In addition to outstanding entrepreneurial commitment, the criteria assessed also included a clear employee focus, proven innovative vitality and future viability.

As Germany’s representative of the “World Entrepreneur of the Year 2012” awards, Dr. Wittenstein was admitted to the “World Entrepreneur of the Year Academy”.

“Axia Award 2010” for Strong Innovation Culture

WITTENSTEIN AG is winner in the “Culture of innovation – a Success Factor for SMEs” category in Baden-Württemberg.

“WITTENSTEIN’s innovation strategy creates an ideal breeding ground for creativity and innovation”, proclaimed the jury at the award ceremony in January 2011.

WITTENSTEIN AG makes the “TOP 100” in 2010

WITTENSTEIN AG is one of Germany’s top 100 innovators among small and medium-sized enterprises.

“Resourceful staff, the courage to tread new paths and an open mind have propelled this particular SME to the top”, explained the organizer in the official press release.
WITTENSTEIN – being one with the future

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More secure