Temperature Sensing Challenges in the Oil & Gas Industry

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Agenda

• Marmon Group and Global Markets
• Oil & Gas Market Segments
  Upstream Applications
  Midstream Applications
  Downstream Applications
• Distributed Fiber Optic Sensing - Global Installations (source: FOSA)
• Temperature Sensor – Market Size
• Summary
The Marmon Group at a Glance

- Marmon Holdings, Inc., part of Berkshire Hathaway, Inc., is a global, diversified industrial organization employing 20,000 people worldwide.
- Marmon comprises four autonomous companies consisting of 16 diverse, stand-alone business sectors and 185 independent manufacturing and service businesses.

Marmon Engineered Components Company
- Engineered Wire & Cable (EWC)
- Distribution Services
- Tubing, Fittings & Wire Products
- Industrial Products
- Engineered Products & Services

Marmon Food, Beverage & Water Tech. Company
- Food Service Technologies
- Beverage Technologies
- Water Technologies

Marmon Energy Services Company
- Rail Products & Services
- Intermodal Containers
- Crane Services

Marmon Retail & Highway Tech. Company
- Retail Science
- Retail Store Equipment
- Retail Products
- Highway Components
- Trailer & Truck Products and Services
Marmon Engineered Wire & Cable - Member Companies

- Marmon (EWC) is a unique group of 15 major cable and sensing companies; design and manufacture of cables and sensors for harsh environments
- North America, UK (CCPI Europe) and India (Radiant-RSCC Joint Venture)

Marmon EWC : 1600 employees

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Marmon Group – Global Markets

End Markets (% of 2016 revenues)

A  Energy, Mining & Petrochemical  27%
B  Construction & HVAC  18%
C  Retail Stores & Restaurants  16%
D  Industrial  10%
E  Heavy-Duty Vehicles (OEM & Aftermarket)  10%
F  Consumer  6%
G  Transportation Providers  5%
H  Food & Agriculture  4%
I  Aerospace & Military  2%
J  Construction & Agricultural Equipment  1%
K  Other  1%

Geographic Markets (% of 2016 revenues)

A  North America  85%
B  Europe  7%
C  Pacific Rim  6%
D  Other  2%

Source: Marmon Holdings Brochure 2016
Oil and Gas Industry - Market Segments

**Upstream**
- Geological Surveys
- Exploration & Production (E&P)
- “Wellbore”

**Midstream**
- Transportation: e.g. Pipeline, rail, tanker, truck
- LNG Terminals
- Storage

**Downstream**
- Refining
- Petrochemical
- Marketing and Distribution
Upstream Application – In-Well Temperature Monitoring SAGD Wells

**Application Outline**

Steam Assisted Gravity Drainage  
Bitumen / Heavy Crude  
Thermal Enhanced Oil recovery method  
Downhole temperatures 235 – 350°C  
Reduce viscosity of Bitumen, pump to surface  
Continuously monitor thermal profile of both Injection & Production well

Key measurable SOR (steam-oil ratio)  
- SOR typically < 2.5  
- 2.5 bbls steam to produce 1 bbl oil

**Challenges**

Permanently installed, long duration (years)  
- Non-retrievable, no access to replace temperature sensor  
Hydrocarbon / Pressure environment; pressure barriers, temperature cycling
Current Temperature measurement methods
Thermocouples (Bundles) – best long term durability

Distributed Fiber Optic Sensing (DTS)
- At limit of Operating Temperatures (300°C)
- Limited life span, hydrogen darkening

Enhanced / New Temperature measurement methods – EMPRESS Projects
- Low Drift, Dual Wall Thermocouples – improved performance for long term installation
- Slimline integrated, self-validating thermocouples, potential development at 300 – 600°C range (EMPRESS 1)
  - Improved temperature measurement over long durations (years)

Traceable Fiber Optic thermometry (ITS-90)
- Standardised calibration techniques for existing and new fiber optic sensors
- Traceable temperature measurements up to 660°C (improved coatings for FO)
- Phosphors, Bragg Gratings & Distributed Temperature Sensing

(Note: IEC 61757-2-2 Ed. 1.en:2016. “defines detailed specifications for distributed temperature measurement by a fiber optic sensor”)

Energy related In-Well Temperature Monitoring - Geothermal Wells (Boreholes)

**Application Outline**
- Renewable – Geothermal Electricity Generation
- California, Philippines, Indonesia, Iceland (tectonic plate boundaries); 20+ Countries
- About 2800 wells, concentrated into ‘fields’
- Current Technique used to monitor downhole temperature;
  - Thermocouples (downhole temperatures typically above fiber optic capability)

**Challenges**
Permanently installed, long duration (many years)
- Non-retrievable, no access to replace temperature sensor, up to 3 miles deep
Temperature range 300°C up to 600°C; vibration

**New / Enhanced Temperature Measurement techniques**
- Low drift / slim-line self-validating thermocouples
- Traceable Fiber Optic Thermometry (ITS-90), higher temperature up to 660°C
Application Outline (Leak detection; temperature)

- Very efficient transport mode for hydrocarbons
- Leaks can be caused by ground movement, corrosion, material failure, 3rd Party intervention and also improper operating procedures
- Continuous monitoring required for pipeline integrity
- Many different monitoring technologies; corrosion, pressure wave analysis etc and temperature measurement along pipeline

Challenges
- Permanently installed, long distance
- Retrofit monitoring difficult and expensive
- Underground and over ground pipelines
- Expansion, contraction, vibration during operation
- Ground movement over time
- Rapid indication of leak (small temperature change)
- Pipeline Leak Detection legislation
  - API RP 1175
Midstream Application – Pipeline Temperature Monitoring

Current Temperature Measurement Methods
• DTS – Distributed Temperature Sensing in conjunction with DAS (acoustic) and DSS (strain)
• In excess of 200 pipelines monitored using DTS
• Leaks – catastrophic to environment and reputations (HSE and shutdown costs)
  - Linear Asset Monitoring
    - Gas pipeline leak; Joule-Thomson effect
    - Oil pipeline leak; temperature changes (a few °C for oil) external to the pipe

Enhanced / New Temperature Measurement Methods
Traceable Fiber Optic Thermometry (distributed Temperature sensing) ITS-90
  Gas Pipeline monitoring (J-T effect)

Temperature measurement is at the core of pipeline monitoring however additional techniques are required for Oil Pipelines – Entire Surface monitoring, Electromagnetic / Wave propagation etc for Pipeline leak detection
Application Outline

Transporting and storing liquefied natural gas (LNG) as a liquid \((-162^\circ C) 111 \text{ kelvin}\)
- Temperature monitoring of LNG Plant, LNG Pipelines, LNG Storage tanks
- Distributed Fiber Optic Temperature Sensing for LNG Pipeline monitoring; LNG Tank monitoring helically wrapped around inner tank (annulus)
- Fiber acts as a passive sensor; no electronics or power; sensing immune to EMI

Challenges

- Primary threat to safe LNG operation is tank / pipeline leakage
- Continuous real-time monitoring of entire LNG surface area (tanks / pipelines)
- Rapid indication of small temperature change required
Current temperature measurement methods

• Distributed Temperature Sensing (DTS) widely used in LNG Plants at cryogenic conditions (\(-162^\circ C\))
• Fiber Optic sensing safe operation in explosive environments
• Leaks catastrophic - people, environment and reputations
• Single point temperature measurements also used in LNG Plants

Enhanced / new temperature measurement methods

• DTS temperature measurement, (Raman, Rayleigh and Brillouin scattering); temperature becomes non-linear at low temperatures (little data on this)
• Traceable (ITS-90) fiber optic thermometry at very low temperatures (cryogenic); standardised calibration techniques
• Phosphor based temperature sensors for 2D Surface measurement of LNG tanks / pipelines (as opposed to current linear DTS measurement)
Application Outline

- Refinery / Petrochem vessels where high temperature processes require a refractory lining
- Gasifier - gasification of petroleum coke, bitumen and other heavy residues
- If the refractory lining fails, hot spots occur on the outer surface, which could result in catastrophic failure
- Fiber acts as a passive sensor; no power; attached externally, sensing immune to EMI, vessel skin temperature measurement (fiber limit ~300°C)

Challenges

- Cost effective and complete coverage of the asset, within the limits of the fiber optic sensing cable (bend radius, time to install, longevity, spatial resolution)
- Refinery / Petrochem Gasifier skin temperatures up to 300°C
Current temperature measurement methods
• Thermocouples (internal temp. measurement)
• Thermal imaging cameras, fixed and survey
• In low cost applications heat sensitive paint
• Distributed Fiber Optic Temperature Sensing (DTS) helically wrapped around the reactor vessel

Enhanced / new temperature measurement methods
• Low drift Thermocouples
• Traceable (ITS-90) Fiber-based thermometry, single point and distributed up to 660°C - Higher temperature Fiber Optic Sensing Cable required 300°C to 660°C range
• Surface Temperature Monitoring (100% reactor vessel surface coverage)

Other Refinery Applications (refractory lined reactors);
• Hydrotreaters / Hydrocrackers (400°C skin temperature)
• Fluid Catalytic Cracking Units (300°C skin temperature)
• Delayed Cokers (530°C skin temperature)
• Sulphur extraction Plants (150°C skin temperature)
Application
Large refineries have 100’s of PDC’s (Power Distribution Centers) and MCC’s (Motor Control Centers)
3,000 Refinery / Petrochemical plants worldwide
Condition Monitoring (temperature measurement); Fire Detection Application

Recent Incident
Pump malfunction caused electrical breaker issue that initiated fire in PDC area
• Safety, Environmental and Plant Shutdown

Customer Request
Ability to continuously monitor temperature of PDC / MCC equipment real-time with historical thermal data (hotspots) comparison over time;
• Improve Safety and Operational Uptime
• Improves predictive maintenance
• Drives preventative maintenance schedules
Current temperature measurement methods

- Periodic (weekly) inspection of PDC’s with handheld Infrared Cameras
- No real-time continuous temperature monitoring
- Inconsistent surface location for inspection, Operator dependent
- No historical comparison of Thermal data for early indication of hotspots

Potential Solution

- Surface temperature measurement / Quantitative Thermal Imaging (identification of hotspots)
- Thermal Fingerprinting
- Continuous real-time Surface thermal monitoring
- Comparison of Thermal data over time, CM and Fire Detection

“Protection of both People and the Asset”
Distributed Fiber Optic Sensing Installations (Source: FOSA)

Map showing the distribution of fiber optic sensing installations around the world. The map highlights regions with different numbers of installations, ranging from 1 to 149.

Surveyed Companies:
- AP Sensing (Greg McElveen, info@apsensing.com)
- Asymmetric Technologies (Brian Borowski, info@asymmetric.com)
- Fotech Solutions (Kent Varley, info@fotechsolutions.com)
- LIOS Technology (Wieland Hill, info@lios-tech.com)
- Omnisens (Geoffrey Lacroix, info@omnisens.com)
- OptaSense (John Williams, contact@optasense.com)
- OZ Optics (Yesim Sizerman, sales@ozoptics.com)

The surveyed companies also referenced 142 installations in undisclosed locations, including 84 perimeters, 37 pipelines, 8 international borders and 13 other installations.
Distributed Fiber Optic Sensing Installations (Source: FOSA)

- FOSA: Fiber Optic Sensing Association (non-profit, founded 2017)
- 1300+ distributed fiber optic sensing installations worldwide (member companies)
- 75 Countries / 20,000 miles of Fiber Optic sensing cable
- Predominantly Distributed Temperature Sensing (DTS); also includes DSS (distributed strain) and DVS / DAS (distributed vibration / distributed acoustic)
- Primary Applications
  - Power Cable Monitoring (22%)
  - Tunnel Monitoring (Fire Detection) (20%)
  - Pipeline Monitoring (13%)

- Accelerated Market Growth through traceability to ITS-90 for fiber optic sensors / measurement and development of standardised calibration techniques

- Distributed Fiber Optic Sensing – Market Size
  - 2016, $600M Sales
  - 2025, $2B forecast Sales

(Note: IEC 61757-2-2 defines specifications for distributed temperature measurement by a fiber optic sensor)
“The temperature sensors market was valued at USD 4.99 Billion in 2016 and is expected to reach USD 6.86 Billion by 2023, at a CAGR of 4.5% between 2017 and 2023.

The chemicals and petrochemicals industries are likely to hold major shares of the temperature sensor market for process.....by 2023”

Source : Markets and Markets, July 2017

• Customer needs in the Oil and Gas Industry are driving both enhanced and new temperature measurement technologies

• Oil & Gas Industry drivers are Safety and Environmental together with improved process control

• Oil & Gas Operators (IOGP) support and drive International Standards (IEC, ISO, API)
**Upstream (SAGD, Geothermal)**
Low drift thermocouples (dual-wall)
Slim-line integrated, self-validating thermocouples
Traceable (ITS-90) Fiber-based thermometry up to 660°C (single point and distributed)

**Midstream (Pipelines, LNG)**
Traceable (ITS-90) Fiber-based thermometry, distributed down to -162°C
Surface Temperature monitoring (phosphor-based)

**Downstream - Refinery (gasifiers, reactor vessels) and PDC (Electrical distribution)**
Low drift thermocouples (dual-wall)
Traceable (ITS-90) Fiber-based thermometry up to 660°C (single point and distributed)
Surface Temperature monitoring (phosphor-based)

**Oil & Gas Temperature Applications ranging from -162°C to 660°C**
Questions