National Measurement System

NMS Engineering and Flow Knowledge Base Metrology Programme

Flow Measurement Project Portfolio for Contract Technical Annex

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nel technology for life

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Revision record

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Project No.	EF/2013/01	**Price to NMO**	
Project Title	Enhancing the wet-gas facility to incorporate a third phase	**Co-funding target**	
Project lead		**Stage Start Date**	Oct 2013
Project Team		**Stage End Date**	Oct 2014
		Est Final Stage End Date	Oct 2014
Sector	Energy	**Activity**	Oil & Gas
Project Champion		**Contractor**	

Summary

Most wet-gas flows of hydrocarbon gas and liquid contain some water. The detection and measurement of the water is vital to prevent the formation of ice-like solids that form with natural gas as these can quickly block pipelines causing safety and financial risks. The use of three-phase wet-gas flowmeters has increased significantly due their cost efficiency, enabling the exploitation of economically marginal gas resources and their ability to provide real-time measurements to monitor production and measure the water content.

The UK national wet-gas flow measurement facility can only test flowmeters in two phases which limits the full evaluation of three-phase flowmeters. Modifying the UK national wet-gas flow measurement facility to enable the addition of water to the flows will allow the testing of three-phase wet-gas flowmeters to determine if the meters can detect and correctly measure the water content.

The Need

The use of wet-gas flowmeters for production monitoring, well testing and shared-pipeline allocation in the upstream oil and gas industry is increasing substantially. In addition, meters are being accepted for fiscal-allocation applications. Traditional metering approaches to wet-gas flows relied on periodic measurements using test separators which have high CAPEX and OPEX. The increase in use of wet-gas flowmeters can be attributed to the low-cost and size of meters as well as providing continuous real-time measurement information. The reduced cost can aid the development of economically marginal fields. In the UK untapped reserves of oil and gas under coastal waters may exceed 1400 million tonnes and 1300 billion cubic meters respectively, much of which is in small remote fields and can only be viably measured if using flowmeters rather than traditional separation technologies.

As the majority of wet-gas flow streams contain a mixture of liquid hydrocarbon and water, then many wet-gas flowmeters have been developed to detect and quantify the water content as well as the liquid hydrocarbon content – essentially providing three-phase measurements. The detection and measurement of the water content is extremely important for flow assurance purposes as solid ice-like compounds (hydrates) can form rapidly from the water and natural gas. This can damage equipment, lead to the complete blockage of pipelines and cause health and safety risks. Quick and early detection of water is essential, as the removal of hydrates is costly and time-consuming.

Real-time detection of water using wet-gas flow meters can significantly reduce the risk of hydrates forming if intervention is quick. The measurement of the water content also allows the correct dosing of expensive chemical inhibitors that must to be added to the pipeline to prevent hydrate formation.

Detailed survey of wet-gas industry stakeholders in project FIRE01 highlighted a significant need for a 3-phase wet gas flow measurement capability.

The UK national wet-gas flow measurement facility is only capable of measuring two-phase flows of gas and liquid. The facility is not currently capable of measuring mixtures of water and liquid hydrocarbon to provide three-phase measurements required by industry.

The Solution

Modification of the UK-national wet-gas flow measurement facility to enable the addition of water to the liquid hydrocarbon phase will enable the testing and verification of three-phase wet-gas meters and their ability to detect and measure the water content. This will allow wet-gas flow meters to be tested at realistic conditions encountered by industry.

Project Description (including summary of technical work)

- Detailed design of facility will be finalised (including piping and P&ID), technical specification for critical components including instrumentation, control and services. Risk assessment and hazard &operability study (HAZSOP)
- Design data acquisition and control system to enable 3-phase measurements.
- Procure components and modify the facility
- Commissioning of rig to assess measurement performance and measurement uncertainties

Impact and Benefits

Provision of a wet-gas flow measurement facility capable of measuring three-phase flows with water as one component will provide immediate and provide long-term gains to industry. More stringent evaluation of meters will provide increased confidence in the measurements and reduce industry's exposure to financial and safety risks for effective flow assurance. Evidence of meter performance is required by operators, meter manufacturers, standards organisations, regulators and fiscal authorities to enable the technology to be utilised for the efficient development of economically-marginal fields within the UK by reducing overall exploitation costs. Accurate measurement of the water content can reduce excessive quantities of expensive inhibitor chemicals added to the flows as precautionary safety and production procedures. Three-phase measurements will enable the progression and development of metering technology to reduce measurement uncertainties.

The modified facility will keep the NMS, NEL and the UK at the forefront of wet-gas flow measurement and enable the UK to maintain a pivotal role in measurement for the energy industry

Support for Programme Challenge, Roadmaps, Government Strategies

NMO strategy for developing UK-measurement capability and establishing the UK as a leading force in global metrology development.
European Association of National Metrology Institutes (EURAMET) roadmaps for fluid flow.
Technology Strategy Board – support for production efficiency, development and testing of new technology, energy security, health and safety; including maximizing the potential of existing resources and enhanced oil recovery.
Addresses the programme roadmap challenge 'Ensuring a secure, sustainable energy supply' as well as the target impact 'Industry guidance on advanced flowmetering techniques'
Progressing wet-gas metering to present dry-gas levels – impacts on tax revenues, emissions and maximising recovery of UK oil and gas reserves.

Synergies with other projects / programmes

This project builds on FGRE13 and FHRE10 and will enable future development and evaluation of equations used in wet-gas standards (ISO/TR 11583). Measurement equations developed by NEL are now recommended by the UK regulator (DECC) for wet-gas flow measurement in the North Sea. Modification of the facility forms a synergy with the multiphase rig upgrade (FHDE12) to enable the testing of 3-phase multiphase meters in high-pressure wet-gas conditions. Knowledge gained will assist in the feasibility and concept design for a new high-pressure multiphase facility. The success of project will enable a cost-effective modification of the National Wet-Gas Flow Measurement Facility to meet industry's measurement requirements and in the future will lead to the of development of a Joint Industry Project to evaluate three-phase measurement technology.

Risks

Due to operation of the gas rig at high pressures, the main risk is the identification of safety-related issues that can only be addressed at prohibitively high expensive. This risk will be mitigated by utilizing specialist advice where appropriate. Insufficient separation of the fluid phases leads to increased measurement uncertainty and requires design modification to meet industry requirements.

Knowledge Transfer and Exploitation

The enhanced measurement capability will be discussed and information disseminated at meetings and clubs, for example, at the Oil and Gas Focus Group meeting, international flow conferences (e.g. North Sea Flow Measurement Workshop) and specialised wet-gas conferences. The existing client base will be advised through the NEL Ezine (distribution list of over 7,000 clients).

Co-funding and Collaborators

In-kind contribution of knowledge and experience from wet-gas stakeholders. Provision of a 3-phase wet-gas flowmeter for extensive testing as part of the project commissioning phase.

Deliverables

1	**Start: 01/10/13**	**End: 01/12/13**	
Finalised detailed design of facility modifications			
2	**Start: 01/12/13**	**End: 01/04/14**	
Modified data acquisition and control system			
3	**Start: 01/12/13**	**End: 01/07/13**	
Procurement of components and modified facility capable of 3-phase measurements			
4	**Start: 01/07/13**	**End: 31/10/14**	
Report summarising commissioning of facility.			

Project No.	EF/2013/03	**Price to NMO**	
Project Title	Enhancing the Wet Gas Facility to higher flowrates	**Co-funding target**	
Project Lead		**Stage Start Date**	October 2013
Project Team		**Stage End Date**	April 2014
		Est Final Stage End Date	April 2014
Sector	Energy	**Activity**	Oil & Gas
Project Champion		**Contractor**	

Summary

NEL's wet-gas flow measurement facility is limited in terms of achievable flowrates and therefore ability to test larger meters over their operating range. Modifying NEL's wet-gas flow measurement facility to enable the ability to achieve higher flowrates and operate across a wider range will allow testing of meters across their operating range and the ability to test larger meters which are common in the market.

The Need

The use of wet-gas flowmeters for production monitoring, well testing and shared-pipeline allocation in the upstream oil and gas industry is increasing substantially. In addition, meters are being accepted for fiscal-allocation applications. Traditional metering approaches to wet-gas flows relied on periodic measurements using test separators which have high CAPEX and OPEX. The increase in use of wet-gas flowmeters can be attributed to the low-cost and size of meters as well as providing continuous real-time measurement information. The reduced cost can aid the development of economically marginal fields. In the UK, untapped reserves of oil and gas under coastal waters may exceed 1400 million tonnes and 1300 billion cubic meters respectively, much of which is in small remote fields and can only be viably measured if using flowmeters rather than traditional separation technologies.

NEL's Wet Gas flow measurement facility is only capable of covering a limited range in terms of dry and wet gas flowrates which do not cover the full operating range of many wet gas meters available on the market. There are other wet gas facilities worldwide, such as in the USA, that have the ability to test over a wider operating range. As a result, the UK is falling behind in its metrology capability in this area, to the detriment of UK industry.

The Solution

Modification of the UK-national wet-gas flow measurement facility to higher flowrates. This will require the modification of the facility layout to reduce number of bends and straighten out the test line, review of the gas blower and identification of other, more efficient, alternatives, modification to the liquid pumps to deliver higher liquid flows, implement optimum liquid injection point to reduce pressure drop when operated in wet gas mode.

Project Description (including summary of technical work)

- Industry consultation - a minimum of six active players from the wet-gas flow measurement area will be contacted to determine the critical operating parameters and flow testing envelope required for new and existing meters
- Conceptual design detailing modifications and costs associated. This will generate information required for a decision on modifications to proceed with.
- Detailed design and HAZOP on modifications.
- Implementation of modifications required to enhance the wet gas facility to higher flowrates.

Impact and Benefits

Provision of a wet-gas flow measurement facility capable of testing commercial wet gas flowmeters across their full operating range will provide immediate and provide long-term gains to industry. More stringent evaluation of meters will provide increased confidence in the measurements and reduce industry's exposure to financial and safety risks. Evidence of meter performance is required by operators, meter manufacturers, standards organisations, regulators and fiscal authorities to enable the technology to be utilised for the efficient development of economically-marginal fields within the UK by reducing overall exploitation costs. Independent testing of wet gas meters across their flow range will enable the progression and development of metering technology to reduce measurement uncertainties

Support for Programme Challenge, Roadmaps, Government Strategies

NMO strategy for developing UK-measurement capability and establishing the UK as a leading force in global metrology development.
European Association of National Metrology Institutes (EURAMET) roadmaps for fluid flow.
Technology Strategy Board – support for production efficiency, development and testing of new technology, energy security, health and safety; including maximizing the potential of existing resources and enhanced oil recovery.
Addresses the programme roadmap challenge 'Ensuring a secure, sustainable energy supply' as well as the target impact 'Industry guidance on advanced flowmetering techniques'
Progressing wet-gas metering to present dry-gas levels – impacts on tax revenues, emissions and maximising recovery of UK oil

Synergies with other projects / programmes

This project builds on work performed in FIRE01 and the implementation of the design case following on from FIRE01 from 2 to 3 phase capability.
There are also synergies with upgrade projects on the UK National Standards Multiphase Test Facility and design of a new high pressure multiphase

Risks

The availability of key NEL staff will be invaluable in this project. It is important that there is appropriate communication with industry to ensure that the modified facility fully meets the needs of industry and the UK.
Due to operation of the gas rig at high pressures, the main risk is the identification of safety-related issues that may prove costly to address. This risk will be mitigated by utilizing specialist advice where appropriate.

Knowledge Transfer and Exploitation

The enhanced measurement capability will be discussed and information disseminated at meetings and clubs, for example, at the Oil and Gas Focus Group meeting, international flow conferences (e.g. North Sea Flow Measurement Workshop) and specialised wet-gas conferences. The existing client base will be advised through the NEL Ezine (distribution list of over 7,000 clients) and for wet-gas flow measurement enquires.

Co-funding and Collaborators

Consultation and guidance from key industry players to verify industry's current and future needs – in-kind contribution of knowledge and experience.

Deliverables

1	**Start: 01/10/13**	**End: 01/11/13**	
Industry consultation report			
2	**Start: 01/10/13**	**End: 01/12/13**	
Conceptual design			
3	**Start: 01/01/14**	**End: 01/02/14**	
Detailed design and HAZOP on modification			
4	**Start: 01/01/14**	**End: 01/04/14**	
Implementation of modifications			

Project No.	EF/2013/05	**Price to NMO**	
Project Title	Virtual metering for Subsea applications	**Co-funding target**	
Project Lead		**Stage Start Date**	Oct 2013
Project Team		**Stage End Date**	May 2015
		Est Final Stage End Date	May 2015
Sector	Energy	**Activity**	Oil & Gas
Project Champion		**Contractor**	

Summary

Virtual meters are distributed sensors in combination with software models that are used to infer flow rates. They are being increasingly used in the Oil and Gas sector to supplement and sometimes replace physical flow measurements. They normally occupy less space and cost less than flow meters. The purpose of this project is to evaluate market leading virtual meter product performance across a range of flow conditions against the flow measured by a physical flow meter.

The Need

Virtual flow meters are increasingly being used by many of the major operating companies across the UK sector of the North Sea. They are used to measure flows when direct flow metering is difficult or too expensive. Therefore the accuracy of these measurements will have a significant financial impact on the operator. So far, there has been no independent assessment of their performance under the range of conditions experienced in the UK Continental Shelf.

The Solution

A thorough programme of independent testing of the main virtual metering products would give operators information about their performance across a wide range of flow conditions such as temperatures, pressures, and phase conditions. This would allow these companies to make better informed decisions as to when it is appropriate to use virtual flow meters and how accurate the flow measurements would be under the specified conditions.

Project Description (including summary of technical work)

The project will be broken down into the following stages.

- A full description of virtual metering technology, where it is used and what it is used for.
- A market survey identifying the total market size, the market leaders and the main users.
- Acquisition of a range virtual metering packages from vendors for the purposes of testing.
- Formulation of a generic test programme, covering some 'typical' field conditions.
- Initial testing of the technology using a number of NEL's flow facilities.
- [Subject to successful co-funding - a rigorous programme of field tests, using several operators platforms
- and wells, both sub-sea and top-sides covering a wide range of operating conditions]
- A discussion of potential future developments and areas for improvement.
- Dissemination of the results through reports, guidance notes, and training

Impact and Benefits

The principal benefits of this project will be increased knowledge about the performance of virtual meters over the range of operating conditions in the UK sector of the North Sea. The main effect of this knowledge will be to enable oil and gas operators to make sound and costed decisions about the level of metering infrastructure required to measure produced hydrocarbons. They will be better informed about the pro's and con's of virtual vs. conventional metering in specific sets of circumstances.

Support for Programme Challenge, Roadmaps, Government Strategies

The project supports the Strategy for the National Measurement System: 2011-2015 in respect of *The Energy Challenge* whose priorities with regard to fossil fuels include provision of a "measurement infrastructure that allows fair trading, taxation and regulation". It also addresses the programme roadmap challenge 'Ensuring a secure, sustainable energy supply' as well as the target impact 'Industry guidance on advanced flowmetering techniques' It also addresses, coincidentally, some of the Technology Strategy Board's priorities – in development and testing of new technology, energy security, including maximizing the potential of existing resources.

Synergies with other projects / programmes

Describe how the project proposal would add value to internal and external, previous, current and future projects or programmes. What is the future plan for the work beyond the life of the current project?

This project will have synergies with the project dealing with uncertainties in flow metering arising from uncertainties in the physical properties of fluids. In the assessment of the accuracy of virtual meters, all of the input variables to the virtual meter software will have uncertainties. These will in turn contribute to overall uncertainty in the flow inferred from the virtual meter. Therefore, increased knowledge of the effect of physical property uncertainty on the flow will help characterise the uncertainty in the flow from the virtual meter.

Risks

Set out any significant technical or operational risks that could threaten successful delivery of the project, and what will be done to mitigate them (exclude resource (people and money) risks).

The main risks associated with his project are:

- Non-participation of the main vendors of virtual measurement packages in the market survey and test stage of the project.
- Non-participation of operators to test the packages

The above risks will be mitigated by exploiting existing relationships to extol the benefits of the project to the different interest groups.

Knowledge Transfer and Exploitation

The main mode of dissemination will be a report giving a summary of the main results of the project. Other modes of dissemination will include

- A guidance note – giving operators past practice in the use of virtual meters
- Incorporation of the findings into training packages for off-shore metering
- Production of technical paper and conference presentation

The guidance will be aimed at the Oil and Gas sector as these are the companies that mainly operate Virtual flow meters

Co-funding and Collaborators

This project will require collaboration from both the vendors of the virtual flow metering packages and the operating companies that use them. This could take the form of provision of test equipment, provision of facilities on which to test the virtual meters or direct funding for the tests.

Deliverables

1	**Start: 01/10/13**	**End: 31/10/13**	
Technology description and market survey			
2	**Start: 01/11/13**	**End: 30/04/13**	
Facility based test programme			
3	**Start: 01/05/14**	**End: 31/03/15**	
Field trial test programme			
4	**Start: 01/04/15**	**End: 01/05/15**	
Production of report and dissemination of project findings			

Project No.	EF/2013/06	**Price to NMO**	
Project Title	Calibration range extension methods for measurement of falling flow rates	**Co-funding target**	
Project Lead		**Stage Start Date**	October 2013
Project Team		**Stage End Date**	September 2014
		Est Final Stage End Date	September 2014
Sector	Energy	**Activity**	Oil & Gas
Project Champion		**Contractor**	

Summary

This project will review the issue of operating flow measurement technology at the lower end of its turndown. It will also propose methods to improve upon current measurement performance at these low flow conditions and test these new methods against a flowrate reference system.

The Need

Why is it necessary – Many offshore platforms in operation today were designed and built in the 60's and 70's to extract oil and gas from large fields. Since that time, many fields have declined in production levels and are no longer operating at the same volumetric flowrate. This results in meters operating at close to or below their minimum operating limits. This results in an increased uncertainty in the overall reported flow measurement.

There is a reluctance to strip flow measurement technology out to replace with smaller diameter equipment as this has a large capital cost and may introduce other issues such as installation effects.

Current state of the art – All meters have minimum and maximum operating range with which will achieve their stated uncertainty values. Outside of this range, flow measurement technology will still generally operate successfully but there will be an increased uncertainty in the measurement value. This is because the flowrates are typically at the extremes of the physical measuring capacity of the technology or could simply be due to resolution of the measurement device.

Case for public funding – This research can be focused on individual meter types which means industry has a reluctance to private funding due to the belief they are funding manufacturers R+D. Public funding would be a more beneficial route as it would allow the results to be shared with industry as a whole.

The Solution

The solution to this issue would be to develop an increased knowledge capability on operating meters close to or below their minimum operating limit. This will allow a fuller understanding of why this limit exists and how to improve upon it.

Project Description (including summary of technical work)

Research – Review documents on operating principles of meters and their performance at lower flowrates including reasons why. This document will then suggest the most likely metering technologies that can be improved upon.

Testing – The measurement technologies highlighted as having the most potential to be improved upon will be tested in single phase oil or water. The pipe diameter will likely be 6 or 8 inch with reference meters being 2 or 4 inch (i.e. well within their operating range). The testing will use one fluid at one temperature to remove any temperature or viscosity effects.

Report - A report will be completed on the test data recorded. This report will include a description of the new metrology methods used and an assessment of their suitability with flowrates below the stated minimum limit.

Knowledge Transfer – The information generated as a result of this work will be made available to industry and will be presented at flow conferences and advertised on E-Zines.

Impact and Benefits

The benefit of this work will be in the improved performance of flowmeters in low flowrate applications. Typically, this application occurs in installations with falling production rates. Greater confidence and accuracy in these measurements will allow for more reliable measurement data. The impact of the work can be measured in lower uncertainty values on recorded flow.

Impact of the sector – It is well known that the majority of the off-shore installations in the North Sea are more than 15 years old and designed for much higher flowrates than what is currently being produced. This work will aid in reducing the uncertainty in flow rate measurement leading to more efficient operation.

Impact on the economy/environment - This work will allow for improved optimisation of processing equipment. If the

flowrate is more accurately known and with greater confidence, then this will allow for a greater efficiency in production. This will reduce energy consumption and associated emissions.

Support for Programme Challenge, Roadmaps, Government Strategies

Support for Programme Challenge, Roadmaps, Government Strategies

This project links in well with the NMO strategy. From the strategy document (page 12 section 3.1.2), there is specific reference to “extension of the operational lifetime of fossil fuel plant”.

This project aims to complete this task by improved operability and performance of flow meters at low flowrates. The added confidence in measurement will allow for a reduction in carbon emissions through improved operational efficiency.

Synergies with other projects / programmes

This work would be an initial project that would likely be a starter project for future work. This work could either take the form of additional E&FP projects or JIPs, depending on the outputs from this project.

It is likely that manufacturers/vendors would conduct their own investigations as a result of this work. There would be possibility to work together.

Risks

The main risk from this project is that the technology can not measure below the stated flow rates with any reduced uncertainty. Another risk is in the supply of meters for testing. This risk is alleviated by good relationships with vendors and a wide selection of NEL owned flowmeters.

Knowledge Transfer and Exploitation

The information will be disseminated in the form of conference papers and magazine articles which will be publicised through E-Zines and other electronic based media.

Co-funding and Collaborators

It is expected to receive in-kind contributions in the form of loan of equipment and advisory input from collaborators.

Deliverables

1	**Start: 01/10/13**	**End: 31/03/14**	
Technical review detailing current technology and proposing new measurement methods			
2	**Start: 01/04/14**	**End: 30/06/14**	
Test work evaluating meters in low flows			
3	**Start: 01/07/114**	**End: 30/09/14**	
Technical report detailing experiments undertaken, data analysis and key findings.			

Project No.	EF/2013/07	**Price to NMO**	
Project Title	Methods for Predicting Reynolds Number	**Co-funding target**	
Project Lead		**Stage Start Date**	October 2013
Project Team		**Stage End Date**	September 2014
		Est Final Stage End Date	September 2014
Sector	Energy	**Activity**	Oil & Gas
Project Champion		**Contractor**	

Summary

This project will review the need for accurate determination of Reynolds number inline and propose several ways to accomplish the task using either traditional or novel measurement methods. These methods will be tested to assess their accuracy and potential for use in industries that measure flowing fluid below a Reynolds number of 2×10^5.

The Need

Why is it necessary – Most flow measurement technology is dependent on Reynolds number in some respect and the output value has to be corrected for it. Typically, this dependence is greatest at lower Reynolds numbers and decreases in severity with increasing Reynolds number. With a rising global energy demand and an estimated 70% of the worlds reserves of oil being classed as 'heavy' (with an operating range $Re < 2 \times 10^5$), there is a critical need to monitor Reynolds number in line in order to provide the most accurate correction factors.

Current state of the art – At present, meters are calibrated over a specific range of flowrates due to the fact that inline Reynolds numbers are not known. Calibrations therefore do not take into account changes in physical properties of the fluid and hence changes in Reynolds number. This can lead to errors in the final reported flowrate as the wrong correction factors are used.

High viscosity oils are often blended with lighter fractions that reduce the overall viscosity all the mixture. This is done for a variety of reasons including reduced pumping costs. Another major reason is the improved accuracy and uncertainty of flow measurement at lower viscosities and hence higher Reynolds numbers.

Case for public funding – The sector as a whole could benefit from this early-stage work therefore it should be public funded to prevent the information becoming proprietary. Further development work, if the initial study is promising , could be more applications-focused, therefore possibly JIP or part-JIP funded.

The Solution

The solution to this issue would be an increased knowledge capability and the development of one or more metrology methods for the determination of Reynolds number in line.

Potential methods include the use of in-line physical property measurement devices, like densitometers and viscometers, to enable calculation of Reynolds number. Alternatively, using high frequency pressure transmitters, it may be possible to infer Reynolds number. The pro's and con's of different methods will be weighed up against one another before deciding which method(s) to select for verification testing.

An increased knowledge capability will give a fuller understanding of the potential errors associated with unknown Reynolds numbers. This information will be filtered to industry through various KT initiatives. Any metrology method developed will allow an additional NEL service to help industry overcome issues with unknown Reynolds number corrections.

Project Description (including summary of technical work)

Research – A short literature review and metrology method description will be conducted to find out what information is already in the public domain on this topic. It will also highlight potential solutions to the problem which will be tested in stage two. The deliverable will be an initial report.

Testing – The methods highlighted in stage one will be tested in single phase oil that will cover a wide range of Reynolds numbers. The same oil will be used at the same temperature throughout the testing programme to ensure there are no temperature or viscosity effects on the measurement principle.
The result from each method will be compared with calculated Reynolds number from the test facility. This will include accurate flowrate and physical property data giving a reference Reynolds number with low uncertainty.

Report – A report will be completed on the test data recorded in phase two. This report will include a description of the metrology methods used and an assessment of their accuracy and potential future use in industry.

Knowledge Transfer – The information generated as a result of this work will be made available to industry and will be presented at flow conferences.

Impact and Benefits

The benefits of this work will be on the improved accuracy and reduced uncertainty of flow measurement technology. This improvement can be measured through changes in uncertainty budgets and reported flowrates.

Impact of the sector – It is well known that 70% of the world's oil reserves as classed as high viscosity where flow measurement has been shown to be extremely difficult and costly. This work will prepare industry by providing information about potential issues they will face in the future and also by providing solutions to these issues. In the North Sea, one major operator has already started exploration and production on a high viscosity field with more to follow. This work will enable production of these fields with more confidence.

Impact of the economy/environment – This work will allow for improved optimisation of processing equipment. If the flowrate is more accurately known and with greater confidence, then this will allow for a greater efficiency in production. This will reduce energy consumption and associated emissions.

Support for Programme Challenge, Roadmaps, Government Strategies

This project links in well with the NMO strategy. From the strategy document (page 12 section 3.1.2), there is specific reference to the "challenges around the production and transportation of high viscosity fuels".

This will be completed by "reducing carbon emissions" and "maximising the recovery and use of UK natural fuel resources" through improved efficiency and optimisation of flow measurement.

Synergies with other projects / programmes

There have been several previous projects on the measurement of high viscosity fluids which have highlighted Reynolds number effects in flowmeters (FHRE17, FHRE07, FGDE03, FGDE91 and FGDE12). This project can be considered a spin off from these projects as it looks for a way to correct the reported flowrate caused by increased frictional forces within the pipe.

Potentially, this work could lead to a JIP or follow on E&FP projects which would specifically test the performance of the methods alongside current flow measurement technology.

Risks

There is a possibility of a supplier risk in providing technology to test. This has been mitigated through previous projects and the development of good relationships with suppliers. There is also a risk of finding no measurement method capable of completing the task. The probability of this is fairly low.

Knowledge Transfer and Exploitation

The information will be disseminated in the form of conference papers and magazine articles which will be publicised through E-Zines and other electronic based media.

Co-funding and Collaborators

It is expected to receive in-kind contributions in the form of loan of equipment and advisory input from collaborators.

Deliverables

1	**Start: 01/10/13**	**End: 31/03/14**	
Technical review detailing current technology and proposing new measurement methods			
2	**Start: 01/04/14**	**End: 30/06/14**	
Test work evaluating new measurement methods			
3	**Start: 01/07/14**	**End: 30/09/14**	
Technical report detailing experiments undertaken, data analysis and key findings			

Project No.	EF/2013/08	**Price to NMO**	
Project Title	Uncertainties in Flow Metering arising from Uncertainties in Physical Properties of Fluids	**Co-funding target**	
Project Lead		**Stage Start Date**	March 2014
Project Team		**Stage End Date**	August 2014
		Est Final Stage End Date	
Sector	Energy	**Activity**	Oil & Gas, Low Carbon
Project Champion		**Contractor**	

Summary

Knowledge and understanding of thermophysical properties of fluids underpins flow metrology throughout industry. In the Oil and Gas sector in particular, industry moves towards virtual metering systems, sub-sea multi-phase flow metering and the exploitation of marginal fields have all increased the need for high accuracy fluid property data. Through the production of representative uncertainty budgets and quantification of input fluid property uncertainties from various sources (e.g. literature data, measurements, software packages), this project will quantify uncertainties in flow metering arising from uncertainties in physical properties of fluids

The Need

In the Oil and Gas sector the majority of flow metering is still carried out using volumetric techniques but for many applications (including allocation, taxation and custody transfer), the required quantity is mass, thus requiring knowledge of the density of the fluids being metered. Knowledge of fluid viscosity is also essential for the calculation of Reynolds numbers. Whilst good data and reliable methods for estimating these parameters are generally available for traditional oil and gas applications, this is not the case for new applications including sub-sea multi-phase metering, exploitation of marginal resources such as wet-gas fields and the use of virtual metering systems.

Currently the AGA-8 equation is the most widely-used method for calculating thermophysical properties of natural gas mixtures from composition measurements. Whilst acceptable for pipeline quality gas, recent work has shown that its application to compositions now being exploited in the North Sea may lead to errors in density of 0.3 %, which corresponds to a financial exposure of £150,000 per annum for a typical field production. Similarly, whilst the process simulation software commonly used to calculate oil properties generally have robust calculation models, end users may not be aware of the magnitude of the errors that can arise in calculated compositions and properties due to the use of inappropriate model selection.

Whilst methods such as the AGA-8 equation have effectively entered the public domain (through its incorporation in ISO-12213), many of the models and methods used by process simulation software remain proprietary. This has created the situation whereby many users have been locked in to particular methods, based on their choice of software package. Even where options are available within a software package, a general lack of understanding of the limitations of various models has prevented users from fully appreciating the impact on fluid properties and hence on flow metrology.

The Solution

Through the development of a number of case studies, this project will provide end users with information on the effects of uncertainties in fluid properties on flow metering and the importance of using appropriate models. In addition to reinforcing NEL's existing capabilities, this project will provide NEL with additional capabilities for uncertainty analysis projects and the provision of advice on the selection and use of software and models. This will ensure that the necessary knowledge will be in place to address the metrology implications for flow measurement arising from developments such as the exploitation of gas resources with different compositions than conventional reserves and the move to the use of virtual metering systems.

Project Description (including summary of technical work)

At least 3 suitable case studies will be identified, drawing on information from previous NEL projects and new information from discussions with leading flow metering specialists in the Oil & Gas sector.

The case studies will involve the production of representative uncertainty budgets, quantification of input fluid property uncertainties from various sources (e.g. literature data, measurements, software packages) and determination of output uncertainties.

Dissemination will occur throughout the project and beyond - specific details are given in the Knowledge Transfer and Exploitation section.

The final report will present the case studies, clearly identifying the impact of uncertainties in fluid properties on flow metering.

Impact and Benefits

The uptake of innovative techniques such as virtual flow metering and the exploitation of previously marginal resources will play an important role in ensuring the continued security of the UK's energy supply. However, the UK's upstream oil and gas regulator, DECC, has identified a number of issues that must be resolved; this project will help to ensure that NEL has the necessary knowledge and expertise to address those specific to the effects of fluid properties on flow metering.

Significant uptake of virtual flow metering systems has the potential to reduce operating costs, making hitherto marginal resources commercially viable. In addition, by reducing the need to install flow meters then regularly remove them for re-calibration, virtual metering will reduce environmental and health & safety impacts. However, this will require user and regulator confidence in the technology, in turn requiring confidence in the fluid property models.

Support for Programme Challenge, Roadmaps, Government Strategies

Through its support of the enabling science (underpinning metrology, traceability and standards plus increasing knowledge of physics, chemistry and fluid dynamics of single phase, multiphase and complex fluids), this project addresses a key aim of the Energy Challenge which is to 'maximise the recovery and use of UK natural fuel resources'.

Synergies with other projects / programmes

Several recent facility build projects at NEL (in particular those related to CCS activities, including FGDE06, FHRE16 and FGRE94) have depended on NEL's thermophysical properties expertise and this will continue to be the case as existing facilities are upgraded and new ones developed.

Knowledge capability projects also depend on this expertise. This project will both directly support and benefit from two project proposals, NEL-10032 (Subsea virtual metering) and NEL-10034 (Reynolds No prediction) since these both depend heavily on knowledge and understanding of thermophysical properties of fluids. NEL-10032 will provide case study material for this project whilst this project will provide the fundamental information on fluid properties required by projects NEL-10032 and NEL-10034.

Risks

No significant technical or operational risks have been identified**.**

Knowledge Transfer and Exploitation

The main dissemination routes will be through e-zine articles, presentations at NEL's Oil and Gas Focus Group and papers at relevant conferences such as the North Sea Flow Measurement Workshop

Co-funding and Collaborators

NEL's extensive contacts amongst the flow metering community in the Oil & Gas sector will be used as a source of material for case studies and to ensure that representative values are used for key parameters.

Deliverables

1	**Start: 01/03/14**	**End: 31/03/14**	
Identification of case studies			
2	**Start: 15/03/14**	**End: 15/07/14**	
Development of case studies			
3	**Start: 01/03/14**	**End: 31/08/14**	
Dissemination			
4	**Start: 01/08/14**	**End: 31/08/14**	
Final report			

Project No.	EF/2013/09	**Price to NMO**	
Project Title	Flow Metrology Knowledge Transfer	**Co-funding target**	
Project Lead		**Stage Start Date**	October 2013
Project Team		**Stage End Date**	September 2014
		Est Final Stage End Date	
Sector	Energy, Environmental sustainability, Advanced Manufacturing & Services	**Activity**	All
Project Champion		**Contractor**	

Summary

This project is a vital part of the programme since it ensures that the outputs from current & previous flow research projects are effectively communicated and made available to industry. This project brings together the research work and sector and technical knowledge to ensure targeted dissemination. Each technical project has its own dissemination plan, so a key aspect of this project is to provide a supporting framework from which to co-ordinate these dissemination activities to the flow community.

The project supports well established sector-based flow networks that involve industry, regulatory bodies, and academia. It also uses existing networks such as academic networks, trade associations and institutions to provide even greater outreach. Targeted dissemination meetings within companies or local areas and the flow helpline are also used.

This project also provides a co-ordinating role to promote ongoing collaboration both with the flow-related research as a whole and also with individual research projects.

The Need

The effective dissemination of NMS engineering and measurement related information will support industry and government with current and potential future measurement challenges. Dissemination will better inform industry, academia and UK government. The KT plan underpins the practical impact of Engineering & Flow Programme projects.

A 2008 report assessing KT activities of the Engineering & Flow Programme identified areas for improvement. Findings suggested that there was poor industry awareness of the NMS and the National Measurement Institutes (NMIs).
It is anticipated that greater awareness of the NMS will improve impact. Further findings suggested the preferred method for KT was face to face activities. The plan aims to address these issues combining traditional and innovative KT approaches.

Current state of the art

The balance of KT delivery techniques has shifted to a more personable approach. Following the success of interactive sessions in the last programme and feedback from the 2008 report, this programme will concentrate on face to face activities including guest lectures and lunch and learn sessions with stakeholders.

The Solution

This KT programme has been developed to address the key needs identified in the 2008 report. The proposal combines several elements (see project description) to strike a balance between face-to-face and traditional dissemination activities. Impact will also be assessed through the use and analysis of stakeholder and client feedback.
A collaborative approach between NMIs will be adopted where appropriate.

Project Description (including summary of technical work)

Existing vehicles will be utilised to disseminate the research in this Programme. The “Flow Tidings” newsletter is an excellent vehicle for disseminating information on flow related research projects.

Awareness of current issues, NMS projects, activities and industry impact is also raised through the inclusion of topical articles.

The TUV NEL website provides a hub for NMS KT activities. It is a vital communication tool providing information on the NMS, the NMO and NMIs, networks and clubs and helpline contact details. The site provides a wealth of information for industry and academia. Stakeholder feedback will be analysed to help provide useful information which can potentially be used to direct future development and continuous improvement and support impact related KT activities.

The existing networks including the CCS and the Oil & Gas networks will continue to be managed and run by TUV NEL.

The ‘lunch and learns’ sessions provide companies with a bespoke agenda covering a variety of client selected flow measurement and metrology topics.

Guest lectures work primarily with universities and provide an introduction to the NMS, the role of the NMIs and the importance of correct measurement. TUV NEL will continue to identify appropriate contacts and plan and deliver presentations.

Technical guidance documents will be produced and disseminated.

Case studies on the impact of research will be developed and disseminated

Impact and Benefits

What benefits will result from this work and how will their impact be measured? This section should include evidence, when relevant, about the project's impact on the economy (short term, 1 – 5 years), quality of life, and innovation, as well as the project's scientific value and its contribution to developing or maintaining the NMI's measurement capability.

Promotion of the NMS and the importance of correct measurement will help better inform industry and will provide appropriate information to support industry with measurement challenges. Improved understanding in this field will lead to improved measurement practices and associated economic benefits for the UK.

Support for Programme Challenge, Roadmaps, Government Strategies

Describe how the project links in with the relevant programme roadmaps and strategy and supports current Government strategies or initiatives.

This proposal will directly support the delivery section of the National Measurement Office (NMO) strategy document. Effective dissemination of NMS information has the potential to reach a large number of UK sectors.

Synergies with other projects / programmes

Describe how the project proposal would add value to internal and external, previous, current and future projects or programmes. What is the future plan for the work beyond the life of the current project?

This project will support the National Measurement Office's (NMOs) strategy (2010-2014) particularly on energy and environment which is in line with Government strategy.

This project will provide coordinated dissemination for all flow related Engineering and Flow Programme projects.

Where applicable, information and input will also be sought from the NMO, NPL and LGC. In these instances, the TUV NEL KT will also have synergy with the applicable NMI projects. This will support a collaborative approach to KT and help promote the NMS.

Risks

The most significant risk to the project is the UK Government's current publicity ban.

Knowledge Transfer and Exploitation

TUV NEL indirectly provides substantial co-funding to this project via their own activities such as the TUV NEL website, networks and self-funded events such as seminars and workshops.

NPL, LGC, NMO, UK universities, UK professional institutions, companies hosting lunch & learns and providing input to case studies.

Co-funding and Collaborators

Description of nature and estimated value of co-funding e.g. EMRP, and the percentage chance of success.
For collaborators, assess the likelihood of project commitment

Deliverables

1	**Start: 01/10/13**	**End: 30/09/14**	
Dissemination of research through existing web & e-zine channels.			
2	**Start: 01/10/13**	**End: 30/09/14**	
Dissemination of research through existing networks such as the Carbon Capture & Storage Club and the Oil & Gas network.			
3	**Start: 01/10/13**	**End: 30/09/14**	
Deliver 'lunch and learn' dissemination activities to industry.			
4	**Start: 01/10/13**	**End: 30/09/14**	
Disseminate the importance of good measurement to academia via guest lectures.			

Project No.	EF/2013/10	**Price to NMO**	
Project Title	Dissemination of Flow Metrology projects into documentary standards	**Co-funding target**	
Project Lead		**Stage Start Date**	October 2013
Project Team		**Stage End Date**	September 2014
		Est Final Stage End Date	
Sector	Energy, Environmental sustainability, Advanced Manufacturing & Services	**Activity**	All
Project Champion		**Contractor**	

Summary

The objective of the project is to influence the direction of UK and International fora. This project will facilitate a group of world-wide recognised technical experts to disseminate the outputs of Programme research via representation on committees at chair, convener and member levels in International (e.g. ISO, OIML, EURAMET), national (e.g. BSI), sector-based (e.g. Energy Institute) and industry standards and regulations.

The Need

To ensure that documentary Standards relating to flow measurement are relevant and applicable to UK industry, and that the interests of the UK are represented across a wide range of sectors and technologies in the international arena.

The harmonisation of international Standards (particularly OIML, ISO and CEN standards).

To aid wider industrial acceptance of new technologies through standardization to reduce potential barriers to trade.

To support UK policy interests in documentary Standards making.

Case for public funding – the work is undertaken for the benefit of industry as a whole, hence the case for public funding is based on market failure resulting from *knowledge overspill*

The Solution

This project ensures that flow measurement knowledge derived from previous and current Engineering and Flow Programme flow research projects is widely disseminated to industry through standardisation at both UK and International level (for example through an amendment to ISO/TR 15377 to cover orifice plates with drain holes). Applications are in multiple industry sectors including energy, environmental, petrochemical, utilities, chemical, pharmaceutical, food & drink, general process, transport, aerospace, nuclear.

Project Description (including summary of technical work)

Providing leadership and technical support at both UK and International levels will ensure that maximum value is obtained from presenting scientific research information worldwide for acceptance and standardisation.

Leadership in flow standards.

- Chair the ISO top-level technical committee on flow measurement and other key committees and sub-committees.
- Convene appropriate Working Groups e.g. that for water meters, which is planning to publish a harmonised OIML/ISO/CEN recommendation/standard during this period.
- Start the process of completing ISO's set of generic flow measurement standards by expanding the scope of the ISO standards for liquid turbine and positive displacement meters and revising them.
- Play a leading role in the new UK National Standards Committee on CCS (BSI/PSE 265).

Production of new standards and revision of current standards

- Progress new flow measurement standards such as those in EI, BSI and ISO, e.g. the ISO standard on Cone meters.
- Significant revision of ISO/CEN/OIML/EI standards, e.g. the EI Uncertainty standard.

Leadership in European and world flow metrology.

- Provide active UK involvement in the EURAMET Technical Committee for Flow and the BIPM Working Group for Fluid Flow.

Impact and Benefits

Supporting the on-going development of international standards ensures that UK industry obtains standards relating to flow measurement that as far as possible reflect British practice.

Avoiding inaccuracy through adequate specification and avoiding excessive cost caused by over-specification are vital.

An NMI is able to take fair account of the measurement interests of all parties, users, manufacturers and government as well as take an international perspective.

Standards support Innovation by the sharing of best practice, ensuring products and processes are compatible across international borders, while reducing cost and risk.

Standards enable business to trade in competitive markets ensuring industry is able to offer services and products that are cost-effective and time-efficient, commercially viable and safe.

Support for Programme Challenge, Roadmaps, Government Strategies

To fulfil UK obligations on fair trade it is essential to be involved with the European Metrology Research Programme (EMRP) and to support its overall goal of accelerating innovation and competitiveness in Europe whilst continuing to provide essential support to underpin the quality of our lives.

This project supports continued leadership in Europe via the EURAMET TC Flow committee.

Good standards reduce disputes between companies and across borders, hence saving costs and time. By allowing work to progress more quickly, UK companies can do business more efficiently. SMEs and other sectors not directly engaged with the standards making process or the specific research also benefit from the standards development. The Mutual Recognition Arrangement is essential to international trade as it will reduce barriers to trade as the level of agreement between national laboratories is demonstrated.

In addition, maintaining a very visible presence in all standards-forming arenas promotes a high UK status in world flow measurement, which indirectly provides commercial advantages to UK industry through opportunities for sales of both consultancy and products.

Synergies with other projects / programmes

This project provides coordinated dissemination into standards of the flow-measurement-related research projects from the current programme and previous programmes.

Risks

There is minimal technical risk as experts are established. Draft Standards are reviewed and approved by a National or International Committee prior to publication.

Knowledge Transfer and Exploitation

The key dissemination route is through the use of the published standards within industry. Standards development work is also disseminated by the KT project via lunch-and-learn sessions, the website and regular newsletter and journal articles.

Co-funding and Collaborators

Key collaboration will be with other European NMIs particularly related to the European Metrology Research Programme.

This project involves very significant collaboration nationally with BSI members and other users of standards and internationally with standards-makers throughout the world. The standards bodies each collaborate in this project through the dissemination of standards via their own networks.

This project includes significant in-kind contribution through collaboration with users of standards in industry and nationally with BSI members and internationally with standards-makers including ISO, OIML, EI, API, EURAMET, and BIPM.

Deliverables

1	**Start: 01/10/13**	**End: 30/09/14**	
Leadership in flow standards.			
2	**Start: 01/10/13**	**End: 30/09/14**	
Production of new standards and revision of current standards			
3	**Start: 01/10/13**	**End: 30/09/14**	
Leadership in European and world flow metrology**.**			

Project No.	EF/2013/11	**Price to NMO**	
Project Title	Management and formulation of flow metrology projects	**Co-funding target**	
Project Lead		**Stage Start Date**	October 2013
Project Team		**Stage End Date**	September 2013
		Est Final Stage End Date	
Sector	Energy, Environmental sustainability, Advanced Manufacturing & Services	**Activity**	All
Project Champion		**Contractor**	

Summary

The NMS and key stakeholders require a high quality, high impact responsive programme of work that delivers the metrology to enable world leading engineering measurement in the UK. A programme must be formulated to provide the required metrological output that enables the industrial measurement outcomes that will deliver the maximum possible scientific, social or economic impact for the United Kingdom.

The aim of this project is to manage the engineering portion of the NMS Engineering and Flow Programme and formulate its future scope of work. The rationale is to orientate the programme to achieve the maximum possible impact for the UK economy and society, in a cost-effective way.

The Need

In terms of management, the programme is a large and complex collection of individual projects that require regular monitoring, co-ordination, management and formulation, to deliver the desired outputs. The advent of continuous formulation, with the potential for projects to be brought in and others to be terminated, places a much greater emphasis on responsive, visible and decisive management.

Additionally, with the changing nature of the NMS programmes in terms of a greater emphasis on collaboration, and much more external focus on impact and benefits, the programme management has changed in recent times to take a much wider perspective than just the programme itself. Interaction with NMO and other interested stakeholders on strategic direction, cross-programme activities, new programmes, and the development of collaborative joint industry projects, are all now significant aspects of the management and formulation.

The Solution

Addressed in individual project proposals

Project Description (including summary of technical work)

Projects will be scoped out in 2-page format, collated and presented to the Working Group via electronic means to undertake a formal process of prioritisation.

Projects will be monitored on a regular basis to highlight any changes that may be required to facilitate the delivery of the project; there will also be monthly progress reviews and reporting.

Produce intelligent responsive quality proposals that accurately reflect the needs of the key stakeholders and that will deliver maximum impact for the UK. Other activities include:

- Produce annual report and present to working group
- Invoice the NMS on a monthly basis in an accurate and timely manner.
- Liaison with other NMS programmes to ensure co-ordination of input and export of technology to and from other science programmes through monthly/quarterly meetings.
- Produce monthly invoices and attend monthly/quarterly meetings
- Formulate proposals and present to Working Group.
- Manage the process of linking in with EMRP projects and proposals

Impact and Benefits

In terms of management, experience has adequately demonstrated that there will be some projects that require strengthening, others that may require termination, and others that require to be brought into the programme at short notice.

Rolling formulation has now been established. The ability to have a more flexible approach to the introduction of projects to the programme will provide more opportunities to develop co-funding options with industry and academia.

These can be slow to develop because of the cyclical nature and inflexibility of budget setting. By having the opportunity to introduce projects on an annual basis should, for example, allow more joint industry projects to be brought into the programme.
The benefits of an effectively managed and formulated program are as follows:

- The maximum possible impact of the programme is obtained
- The outputs of the programme are delivered on time and within budget
- Participants are committed to delivering the benefits of the programme
- NMO will be well informed of progress, successes and good new stories from the programme
- Risk will be managed to ensure the smooth running of projects.

Support for Programme Challenge, Roadmaps, Government Strategies

To help improve the quality and comparability of measurements made in the UK to improve competitiveness and support regulatory needs.

Synergies with other projects / programmes

Describe how the project proposal would add value to internal and external, previous, current and future projects or programmes. What is the future plan for the work beyond the life of the current project?

Risks

The main risk is associated with the formulation and selection of R&D projects that will be of benefit to the UK. To mitigate the risk, a continuous collection of project ideas and sifting will be undertaken, from which to build a library of project proposals for prioritization.

Networks, conferences, seminars, workshops, training courses and direct one-to-one contact will be the primary routes of data gathering.

Knowledge Transfer and Exploitation

KT generally is addressed within a separate proposal. Activities associated with the management and formulation will include producing and updating a programme level Roadmap, together with the generation of proposals for working group review.

Meet regularly with stakeholders, including:

- UK industry (direct industrial visits)
- UK science base (visits and interaction with academia etc)
- NMO and OGDs (e.g. DECC)

Co-funding and Collaborators

The formulation process will be supported through other activities of NEL including a completely self-funding programme of technical workshops, conferences, seminars and training courses that provide valuable input into the formulation process.

With regard to specific R&D projects co-funding from any source will be explored and incorporated in project proposals.

Deliverables

1	**Start: 01/10/13**	**End: 31/01/14**	
Annual review report**.**			
2	**Start: 01/10/13**	**End: 30/09/14**	
Presentation and information for two Working Group meetings.			
3	**Start: 01/10/13**	**End: 31/07/14**	
Prepare & submit project proposals for review by Working Group.			
4	**Start: 01/10/13**	**End: 30/09/14**	
Hold monthly internal project reviews. Provide supporting narrative for monthly invoices			

Project No.	EF/2013/12	**Price to NMO**	
Project Title	Traceability of the national flow measurement standards	**Co-funding target**	
Project Lead		**Stage Start Date**	October 2015
Project Team		**Stage End Date**	September 2016
		Est Final Stage End Date	
Sector	Energy, Environmental sustainability, Advanced Manufacturing & Services	**Activity**	Energy, environmental, petrochemical, utilities, chemical, pharmaceutical, food & drink, transport, aerospace, nuclear
Project Champion		**Contractor**	

Summary

The national flow measurement standards are a suite of facilities that provide UK industry, researchers, regulators and government with a world-leading metrological capability that underpins trade and innovation in the flow measurement arena. Traceability of the measurements undertaken on the facilities is essential for ensuring user confidence in the data produced and for enabling the UK to meet legal obligations. Traceability of the national flow measurement standards requires two activities: firstly, the thorough and regular calibration of the instruments associated with each facility, and secondly, the intercomparison of facilities of a similar type using an appropriate test artefact.

The Need

Energy security and the mitigation of climate change will be major global challenges over the next 50 years; accurate flow measurement will underpin the R&D and innovation necessary to bring about the political commitments to provide sustainable energy supplies and reductions in harmful emissions. As well as providing the national standards against which industrial flow measurement is referenced, the National Flow Measurement Facility supports innovation through its availability for independent R&D, evaluation and test of new and developing products and services relating to flow measurement.

From a UK perspective, the provision of facilities that are able to support the challenges associated with Carbon Capture and Storage (CCS), emissions measurement and security of energy supply is vital. Oil production will see innovation in terms of production of higher viscosity crude oils, production at higher static pressures and increasingly complex fluid combinations such as oil, gas, water and sand. In the longer term, the development of a hydrogen economy will provide significant flow measurement challenges. These are but a few of the important areas underpinned by the national flow measurement standards.

All of these areas require accurate, dependable and unbiased measurements, which are covered by rigorous traceability.

The Solution

Traceability is the chain of measurement quality. Through calibration, assessment, investigation and management, the structure of traceability offers confidence and fitness for purpose. This is essential for any scientific work. It may not be ‘exciting’ part of engineering development, but, make no mistake, no other practical project can use ‘tools’ that have not had a traceable foundation.

Traceability of the national flow measurement standards requires two main activities: firstly, the thorough and regular calibration of the instruments associated with each facility, and secondly, the intercomparison of facilities using an appropriate test artefact.

NEL systems have been developed over many years to present a robust but flexible level of traceability to underpin such internal and external activities. This approach is not stagnant. The traceability systems must be maintained and developed in order to support emerging measurement challenges and meet financial efficiencies.

Project Description (including summary of technical work)

Flow measurement requires a mixture of quantities: time, frequency, mass, temperature, pressure, fluid properties (e.g. density, viscosity, compressibility) and many more. The project offers mechanisms to support the measurement and traceability of these quantities and their associated equipment:

Instrument calibrations - Fully traceable measurements on each facility. Regular calibration of all instruments (now amounting to hundreds of items) used for primary and secondary measurements on the flow facilities is undertaken against reference standards, which, in turn, are calibrated to the appropriate levels of accuracy by UKAS accredited laboratories through to national standards. The traceability chain.

Facility quality assurance and assessment –Includes evidenced-based uncertainty budgets, which have a friendly user interface. Periodic review of instrument calibration histories to identify problems and inform the review of the measurement and its uncertainty.

The QA procedures - are audited through ISO 9001 quality procedures and ISO 17025 (UKAS) to confirm the stated primary uncertainties for each national flow standard and review the proper procedures within the daily use of the

facilities.
Intercomparisons - Maintaining confidence in the UK national standards by confirming their BIPM Calibration and Measurement Capabilities (CMCs). Comparing results with other NMIs through carefully designed exchange exercises. Traceability is not as static as it may appear. New endeavours (e.g. CCS or erosive flow) frequently require adapting measurement techniques, which, in turn, can push calibration envelopes and extend traceability sources.

Impact and Benefits

Traceability, by definition, maintains measurement capability. UK industry benefits through confidence in the national flow measurement standards and by the elimination of barriers to trade. The benefits and impact of the facilities are of a long-term and strategic nature. Full traceability of the related measurements is a key part of realising the strategic role of the facilities.
Good performance in intercomparison exercises reinforces international recognition of the facilities that comprise the UK national flow-measurement standards and thus maintains their world-class status. The MRA initiative means that calibrations carried out in the UK are recognized anywhere in the world, allowing UK flowmeter manufacturers to address wider international markets without the added expense of re-calibrating their products against local standards. UK consumers will benefit from improved fairness of trade resulting from links to UKAS and Trading Standards. Closer to home, all projects using the national flow facilities can be assured of measurement confidence and fitness for purpose. Such projects can relate to the NMS Engineering & Flow Metrology Programme, commercial endeavours, or other areas.

Support for Programme Challenge, Roadmaps, Government Strategies

This project is fundamental to presenting facilities on which all R&D projects carried out by NEL, on behalf of NMO, are dependant. In this sense, the project supports all aspects of the draft new programme roadmaps covering single phase, multiphase and non-contained flow respectively.

Synergies with other projects / programmes

All flow metrology experimental research and development projects undertaken within the Engineering and Flow Programme is dependent on these facilities which in turn are dependent on this project. This is not to be understated. Without efficient traceability, then proper scientific investigations are undermined at every level.

Risks

As this is a traceability project, a fundamental objective is to minimise risk through regular calibration of key devices and instrumentation. Standard methods & experience already promote a relatively low risk. (Every other facilities-based project should identify an increase in their risk if support for traceability is reduced.)

Knowledge Transfer and Exploitation

The KT aspects of traceability are presented in a separate proposal ("Flow Metrology KT"). Intercomparisons between independent facilities prove and possibly improve measurement uncertainty. At the international level, to fulfil UK obligations on fair trade, it is vital to support the international Mutual Recognition Arrangement initiative (MRA) run by the international weights and measures metrology Bureau (BIPM). Achieving mutual recognition requires facility intercomparisons between National Measurement Institutes (NMIs); mutual recognition reduces barriers to trade. Intercomparison exercises are dissemination activities at the core of which are two-way knowledge transfer. By actively participating at an international level in intercomparison exercises through the MRA initiative, the Programme is given the widest possible exposure. This includes publication through the BIPM website with direct links from the website.

Co-funding and Collaborators

The facilities are co-funded on an on-going basis by NEL through the provision of the building that houses them and through the costs of power and other associated running costs.

In terms of collaboration, NEL has many on-going partnerships with companies providing specific services that directly support the national flow measurement standards. These range from health & safety related topics, such as water quality testing, and advice and support on pressure systems, through to suppliers of major items of specialist plant. NEL also contributes to international intercomparison exercises which may be organised by other NMIs and funded through their support networks.

Deliverables

1	**Start: 01/10/15**	**End: 01/09/16**	
Instrument calibrations			
2	**Start: 01/10/15**	**End: 01/09/16**	
Facility quality assurance			
3	**Start: 01/10/15**	**End: 01/06/16**	
Intercomparisons			

Project No.	EF/2013/13	**Price to NMO**	
Project Title	Maintenance of the national flow measurement standards	**Co-funding target**	
Project Lead		**Stage Start Date**	October 2015
Project Team		**Stage End Date**	September 2016
		Est Final Stage End Date	
Sector	Energy, Environmental sustainability, Advanced Manufacturing & Services	**Activity**	Energy, environmental, petrochemical, utilities, chemical, pharmaceutical, food & drink, general process, transport, aerospace, nuclear
Project Champion		**Contractor**	

Summary

The national flow measurement standards are a suite of facilities that provide UK industry, researchers, regulators and government with a world-leading metrological capability that underpins trade and innovation in the flow measurement arena. The objective of this project is to maintain this facility in the appropriate operational state with regard to capability, reliability, availability and health & safety.

The Need

Measurement associated with environmental impact is fundamental to the drive to reduce emissions of all forms of waste. The global energy challenge, and associated issues of climate change, is the number one issue for the world over the next 50 years; accurate flow measurement will underpin the research, development and innovation necessary to bring about the political commitments to provide sustainable energy supplies and reductions in harmful emissions.

From a UK perspective, the provision of facilities that are able to support the challenges associated with Carbon Capture and Storage (CCS), emissions measurement and security of energy supply is an imperative. Oil production will see innovation in terms of production of higher viscosity crude oils, production at higher static pressures and increasingly complex fluid combinations such as oil, gas, water and sand. In the longer term, the gradual development of a hydrogen economy will provide significant flow measurement challenges. While less topical, there are major issues associated with acceptable levels of pollution in water, and again flow measurement is at the heart of quantifying discharge pollutants, and improving upon targets. These are but a few of the important areas underpinned by the national flow measurement standards.

The Solution

The national flow measurement standards are a suite of facilities that provide UK industry, researchers, regulators and government with a world-leading metrological capability that underpins trade and innovation in the flow measurement arena.

Project Description (including summary of technical work)

Maintenance activities

Ensuring the availability of fully operational national standard facilities through the execution of planned preventive maintenance schedules. This covers: (a) weighbridges, diverters, reference meters and those isolation valves that have a crucial metrological function: (b) fluid handling equipment within the flow loops such as compressors, pumps, chillers, filters, valves, tanks and pipework; and (c) fluid inventory management.

Strategic development

Improved functionality of the facilities. On-going small scale improvements and innovations to enhance the facilities and process service conditions. It is envisaged that some facilities and control cabins could be moved to allow more effective sharing of equipment and buildings. The fluid conditioning systems will be reviewed to establish the most energy efficient means of temperature control and improve overall stability. Improvements to signal conditioning systems are proposed to keep up with advances in meter technology in particular with respect to digital communication techniques.

Health , safety and environment

Ensuring legal and regulatory compliance with regard to the health, safety and environmental performance of the facilities through risk assessment, robust control measures and continual improvement, thorough and working examinations of high pressure systems and regular inspections of lifting equipment. Also employing appropriate monitoring and management of waste streams and meeting set environmental objectives and targets.

Impact and Benefits

The benefits and impact of the facilities are of a long-term and strategic nature, and are perhaps best illustrated by two recent examples:

I. As world oil reserves are now split approximately into 70% high-viscosity and 30% (low-viscosity) conventional light oils. Exploitation of these viscous deposits is growing rapidly due to an increasing demand for security of energy supply. As such, there exists a growing requirement for accurate flow measurement of heavy crude oils and other viscous products. Unfortunately, the performance of conventional flowmeters when applied to viscous fluids remains relatively poorly known. However due to the continued development of the National standards in heavy oil flow measurement at NEL these technical challenges and innovations are being identified. These include the higher viscous friction of the fluid being metered, the increased pressure losses incurred across internal bends and restrictions, the possibility of extreme or varying velocity profiles, and the increased susceptibility of viscous liquids to entrain secondary components such as solids or gas.

II. The wet gas and multiphase flow national standards have continued to support the development and deployment of multiphase metering technology for over two decades. The availability of these technologies has been a vital factor in the decision to develop deep-water marginal-fields, without which the UK oil & gas industry would be nowhere near as strong as it is today.

The impact of both has had an enormous financial and political impact on the UK, and the facilities are now being used to tackle the major flow related challenges of today in exactly the same way.

Within the programme of work outlined in this document are projects to enhance the existing facilities to provide the necessary platform for innovative research and development, and the production of measurement standards for new applications. A key aim with the maintenance and development of the flow measurement standards is to ensure that they evolve effectively to tackle the ever changing needs of industry.

Support for Programme Challenge, Roadmaps, Government Strategies

The project is fundamental to the provision of facilities on which all R&D projects carried out by NEL on behalf of NMO are dependant. In this sense, the project supports all aspects of the draft new programme roadmaps covering single phase, multiphase and non-contained flows.

Synergies with other projects / programmes

All experimental research and development projects included in the current round of proposals, as well as those already running, are dependent on these facilities.

Risks

As this is a maintenance project, a fundamental objective is to minimise risk through regular maintenance and an ongoing programme of upgrade to the facilities.

Knowledge Transfer and Exploitation

Knowledge transfer is the subject of a separate proposal

Co-funding and Collaborators

The facilities are co-funded on an on-going basis by NEL through the provision of the building that houses them, and through the costs of power and other associated running costs.

In terms of collaboration, NEL has many on-going partnerships with companies providing specific services that directly support the national flow measurement standards. These range from health & safety related topics, such as water quality testing, and advice and support on pressure systems, through to suppliers of major items of specialist plant.

Inter-comparison exercises organised by NEL are usually performed in partnership with other NMIs, and at their expense.

Deliverables

1	**Start: 01/10/15**	**End: 30/09/16**	
Maintenance Activities			
2	**Start: 01/10/15**	**End: 30/09/16**	
Strategic Development			
3	**Start: 01/10/15**	**End: 30/09/16**	
Health & Safety			

Project No.	EF/2013/14	**Price to NMO**	
Project Title	National Gear Metrology Laboratory	**Co-funding target**	
Project Lead		**Stage Start Date**	October 2015
Project Team		**Stage End Date**	September 2016
		Est Final Stage End Date	September 2016
Sector	Dimensional	**Activity**	Core Funding
Project Champion		**Contractor**	

Summary

This project will provide the necessary core funding to ensure that independent experts and facilities are available to support the needs of UK gear manufactures and gear users. The UK National Gear Metrology Laboratory (NGML) provides gear measurement, gear calibration and gear measuring machine service to industry. NGML is part of an independent consultancy, Design Unit at Newcastle University, with an international reputation for expertise in gear transmissions.

The Need

Users of gear products require increased power density, reduced costs and reduced noise from their gears. Reducing material use and wastage, minimising power consumption during manufacturing and the increasing demand for improved operational efficiency of plant and equipment can only be achieved with support from precise and effective gear metrology.

The Solution

Improvements in manufacturing capability and competitiveness demand the highest standards of gear measurement in the manufacturing environment. This can only be achieved if the independent facilities and expertise available in the NGML are state of the art and that this expertise is transferred to manufactures and users though a combination of commercially available services and range of knowledge transfer activities. NGML work with the British Gear Association, UK Wind Turbine Users Group and Eurotrans (European Transmission Association) to transfer expertise to gear manufacturers.

Project Description (including summary of technical work)

How will the project be carried out? Include delivery mechanisms and a summary of the technical work. The project will:

- Establish and develop traceability to PTB, NPL and Y12 for gear parameters.
- Manage inter-laboratory comparisons with UKAS accredited gear calibration laboratories.
- Reduce measurement uncertainty of helix and profile parameters though more appropriate traceability.
- Support the work to participate in an international key comparison.
- Improve the calibration of Klingelnberg P65 gear measuring instrument.
- Provide expertise and participate in ISO TC60 WG2 and BSI MCE/005/2 standard development working groups

Impact and Benefits

Gears play vital roles in transport, defence, aerospace, power generation, agriculture, industrial process equipment, machine tools, food-processing, printing and tool and gauge manufacturing industries. They improve the overall operational efficiency of a transmission and reduce manufacturing costs and environmental impact. They are sophisticated products and require highest standards of design, manufacturing and measurement capability. UK manufacturers supply £1.5Billion gears/annum.

UK industry benefits directly from improvements in measurement capability through UKAS accredited calibration, measurement work and on-site instrument verification work and also consultancy and training services. These activities improve shop-floor measurement capability, thus improving manufacturing accuracy, reduce costs and improve the competitiveness of UK industry. With relatively high costs in the UK, the development of the high accuracy, low to medium volume products and 'added value' operations that demand high skill levels and state of art measuring and manufacturing equipment will increase in the future.

Many fields including defence, power generation (both conventional and wind and tidal/wave), oil industry and nuclear support industries require traceable measurement to ensure the UK can compete and comply with the relevant standards in increasingly competitive markets.

The project will provide a cost effective and internationally competitive gear measurement, gear calibration and on site gear measuring machine calibration service available for gear users and manufacturers.

Support for Programme Challenge, Roadmaps, Government Strategies

The project is core funding but contributes to roadmap objectives of

- improving the effectiveness of gear measurement by using measurement data to predict stress, reliability and reducing noise.
- quantifying probe system performance

Energy Generation and supply: gear failures in onshore and offshore power generation and have expensive consequences. Many existing gearboxes are out of warranty and thus provide an ideal opportunity for UK manufacturers to supply replacement transmissions and improve the reliability of the power supply. Furthermore we need expertise in the UK to support wind turbine operators to ensure the correct quality assurance processes are applied to gearboxes that are supplied. The work in this project underpins these requirements.

Synergies with other projects / programmes

Not applicable, this is core funding to maintain and develop calibration facilities.

Risks

The risks are minimal:

- Measuring instrument failure- mitigated by the availability of a second less accurate measuring machine
- Loss of key staff- mitigated by training staff from other disciplines within Design Unit.
- Newcastle University close the Design Unit- mitigated by the fact Design Unit is a commercially viable operation.
- Collaborative projects are cancelled- mitigated by the range of opportunities that are available from Design Unit
- commercial projects.

Knowledge Transfer and Exploitation

The expertise and facilities is transferred by:

- Training and seminars provided in collaboration with KT partners.
- The provision of independent expertise to directly support industry through commercial consultancy.
- Provide traceability and technical expertise to support UKAS.
- Provision of independent measurement and calibration services to industry.
- Provide support for research and undergraduate teaching related to gears.

Co-funding and Collaborators

There is no co-funding associated with this project. The development of the measurement interface to gear analysis and stress analysis programs requires us to work in collaboration with commercial and collaborative research work undertaken by the Design Unit.

Deliverables

1	**Start: 01/10/15**	**End: 30/09/16**	

Maintain and develop the gear measurement and calibration capability of the National Gear Metrology Laboratory.