FlareMaster™ and The World Bank Zero Routine Flaring By 2030 Initiative

In reply to the world bank zero routine flaring by 2030 (ZRF) initiative and the global gas flaring reduction partnership (GGFR).
www.worldbank.org/en/programs/zero-routine-flaring-by-2030
www.worldbank.org/en/programs/gasflaringreduction

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Abstract. The Global Gas Flaring Reduction Partnership GGFR has been working to reduce carbon emissions from flaring against a backdrop of renewed realisation of global dependence on the oil and gas industry. In order for this to be effective there must be a coordinated drive to make the industry as clean as possible and limit all unnecessary carbon emissions where achievable. One such area of hydrocarbon waste is the routine flaring of hydrocarbon gases during oil and gas production. The World Bank has generated an important initiative to address this issue, called Zero Routine Flaring by 2030 Initiative. (RZF). However, whilst changes are made to the physical infrastructure of the flare systems to make them more efficient, and changes are made in the management of flare systems to reduce unnecessary flaring, it is equally essential to measure the flare emissions to effectively and accurately monitor the implementation of these changes towards achieving the RZF goal. This paper highlights that there are serious challenges in measuring near to zero flow rates for a flare, and also presents innovative solutions to those challenges.

Introduction

Whilst humanity increasingly wakes up to the environmental concerns over the impact of our global carbon emissions, governments still realise the essential need for heating and energy supplies for our existence. Only through good governance, regulation, and green initiatives can our sources of energy be constructively diversified away from carbon into renewable sources, and our carbon emissions reduced without significantly impacting our essential industry infrastructure and damaging the welfare of the elderly and vulnerable. Recent events that have impacted the world's oil and gas supply infrastructure have forced governments to reconsider their energy independence from foreign states, as the costs and risks associated with losing their own independent oil and gas reserves has become only too evident.

The initiatives and incentives to reduce carbon emissions have now therefore become even more important if any progress is to be made against such a backdrop of a renewed realisation of global dependence on the oil and gas industry. Therefore, there must be a coordinated drive to make the industry as clean as possible and limit all unnecessary carbon emissions where achievable.

One such area of hydrocarbon waste is the routine flaring of hydrocarbon gases during oil and gas production. The World Bank has generated an important initiative to address this issue, called Zero Routine Flaring by 2030 Initiative. (RZF). However, whilst changes are made to the physical infrastructure of the flare systems to make them more efficient, and changes are made in the management of flare systems to reduce unnecessary flaring, it is equally essential to measure the flare emissions to effectively and accurately monitor the implementation of these changes towards achieving the RZF goal. And this highlights major issues with the measurement, since there are serious challenges in measuring near to zero flow rates for a flare.

FlareMaster™ and The World Bank Zero Routine Flaring By 2030 Initiative

Whilst the world's governments and the oil and gas industry look into ways to reduce routine flaring to meet the zero flaring target, as an instrumentation company we understand the measuring aspect of this problem, because there are considerable issues to overcome in realising this goal of RZF.

ABLE Instruments have been a specialist in difficult measurement applications, especially flow, for many years, with bespoke products developed for multiphase flow and flare metering applications. Flare measurement is particularly difficult, because the gas pressure in the flare line is barely at or just above atmospheric during normal operations, and this limits the technologies that can accurately measure flare flow rates.

As a direct culmination of years of flare data analysis, we increasingly realised that there are serious limitations with the current ultrasonic flare meters on the market. Despite ultrasonic flare meters being the de facto standard, and considered to be the only real available method for meeting the fiscal accuracy required for mass flow carbon emissions, there are major limitations that affect all the flare meters on the market. There are temporary conditions such as wet gas, or transducer fowling by liquids, and sludge and carbon deposits on the faces of the transducers, that affect all ultrasonic meters. However, the biggest limitation of all available models is the upper flow velocity limit. Very high flow velocities such as seen during emergency blow-downs often exceed the upper velocity limit of the ultrasonic flow meter, where velocities can reach hundreds of metres per second. At these flow rates, all current meters are unable to provide a fiscal measurement that meets the requirement to quantify these emissions. Whilst flare meter manufacturers state theoretical upper limits of 100 or 120 m/sec, this only applies to very small pipe sizes under perfect conditions. The actual performance on a real-life flare meter application is likely to be severely compromised over 80 m/sec. Another limitation is high CO2% in the flare gas, causing the flare measurement to be compromised or fail due to the absorption of ultrasound. Another issue is wet gas. Gas with liquid condensate mists can impede the ultrasound signals and reduce the accuracy of the flare measurement. Again some flare lines see extreme temperature events, and even if the transducers can survive these events, the measurement is most often lost or the accuracy is significantly affected by the process event.

ABLE have therefore developed a technological solution to these problems by using a secondary measurement that is immune to these issues, that extends the upper flow velocity range of the meter into many hundreds of metres per second to effectively measure even the most extreme blow down velocities, and ensures the continued operation of the measurement during conditions that impair the ultrasonic measurement, such as high CO2, wet gas, high and low temperatures and any condition that causes the ultrasonic measurement to be impaired or fail completely.

However, aside from the big issue of measuring blowdown velocities and process conditions that typically lead to mismeasurement, all the flare meters on the market are also significantly compromised at very low flow rates which has a direct impact on the zero routine flaring initiative, and this paper highlights the priority of solving this issue as an essential part of tackling the effect of excess flare emissions on climate change. This is because as an instrumentation company, ABLE realise you cannot achieve ZRF without measuring the flare flow rates at very near to zero flow.

ABLE FlareMaster™

After years of research, ABLE designed a new product solution called FlareMaster™, which uses a bolt on secondary sensing method to address the measurement of blow down velocities. This secondary measurement is cross calibrated to the ultrasonic measurement to give the same level of uncertainty, whilst at the same time being immune to the same issues that impair the performance or cause the failure of the core ultrasonic technology. This provides an effective means to reliably measure mass flow of hydrocarbons when conventional flare meters are unable to function, are compromised by contaminants, or when the flow range is exceeded. In some environments such as very high H2S processing plants, where transducer extraction may only be performed during a full plant shutdown, any process fowling may lead to the complete loss of the fiscal measurement. The FlareMaster™ design concept utilises the cross calibrated secondary measurement to perform real-time repair of the mass flow rate whenever it becomes erratic.

Utilising this secondary measurement principle effectively provides full redundancy, and achieves a unique metering method that can meet the fiscal requirement, including for all blowdown velocities, where all flare meters on the market will fail.

The World Bank Zero Routine Flaring By 2030 Initiative

In 2015 the World Bank initiated a worldwide initiative for cooperation towards a goal of zero routine flaring (ZRF) in the production of oil and gas. They looked to the governments and oil companies around the world to engage with them in meeting a commitment to reduce routine flaring to zero by 2030, and have been looking for solutions to achieve this goal.

ABLE Instruments realised that you cannot drive the flare emissions down to towards zero without the tools to measure flow at ultra-low flow velocities, down to the smallest fractions of a metre per second gas flow velocity. As explained above, ultrasonic flow meters have a very good turn down ratio, good performance down at low flows, and 45 degree cross-pipe installations measure this gas velocity at atmospheric pressures non-intrusively. Therefore, ultrasonic flare meters are currently the De Facto worldwide standard for flare measurement.

Yet the need for a production flare, is for emergency pressure release. Even when flaring is significantly reduced to the barest minimum waste, a flare purge gas is still required to keep positive flow in order to ensure the safe burning of any gas released during emergencies. The gas used for purging is a carbon neutral gas such as nitrogen. However, there are known limitations with flare measurement near to zero flow as outlined below, making this critical ultra-low flow measurement really challenging.

Overall Electronic And Digital Limitations Of Measurement

All flow meters experience a much greater uncertainty at near to zero flow, where any measurement error is a greater percentage of the true flow. Thus even minimal electronic and digital signal processing errors have a larger impact at near to zero flow, forcing manufacturers to limit their accuracy statements to flows above zero.

Swirl Profile Distortions From Pipe Bends And Directional Changes

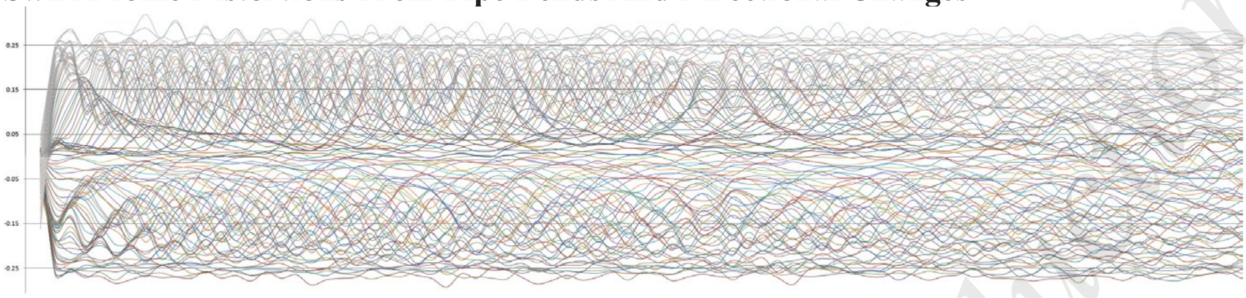

Fig.1 *CFD generated complex gas swirls*

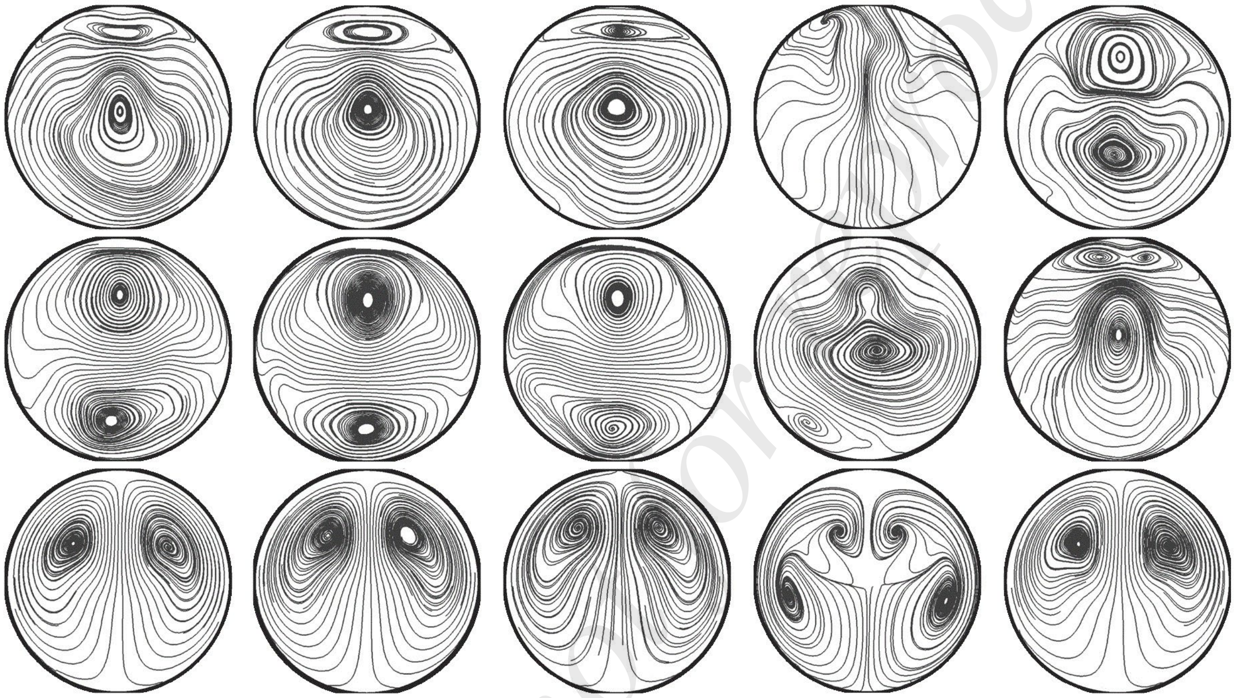

Fig.2 *Examples of gas swirl CFD generated images*

Whilst ultrasonic flare meters can perform well in the laboratory, or at a specialist calibration flow rig, this is in no way comparable to real world applications. Real world applications have profile distortions from bends in the upstream and downstream pipe runs, and all flow restrictions cause swirl and distort the flow shape at the measuring point, causing mismeasurement. There are well documented technical articles on the subject of gas swirl and profile errors even with recommended straight runs of pipe, and these affect all flare meters on the market. When major oil and gas companies have reviewed their flare meter installs with CFD modelling, they have sometimes seen in excess of 15% error despite using a spool calibrated on a traceable flow rig installed with straight pipe runs in accordance with the manufacturer's instructions. But this known phenomena is even worse at ultra-low flows, where the effect of gas swirls and profile distortion is most unpredictable and where fluctuating forward and back pressures induce flow profiles with exponential uncertainty for ultrasound chords at near zero flow. The profile at low flow is so unstable that it is directly affected by the wind speed and direction, where the back pressure fluctuates at the flare header. This problem affects both diagonal 45 degree cross pipe, and bias 90 insert transducers, but the issue is worse with bias 90 transducers in swirling gas conditions in ultra-low flow.

Moisture And Dewpoint Changes At Ultra-Low Flow Rates

Fig.3 Image of condensates on pipe wall inner surface

Fig.4 Image of condensation on ultrasonic transducer probe face

Again, in real world applications the atmospheric conditions have a direct effect on the operation of the flare measurement. At higher flow rates the whole flare system is relatively stable, with the process pressure and temperature being maintained as a semi-constant by the process throughout the flare pipework. However, at ultra-low flows there is no system stability, and external variations in temperature, humidity and atmospheric pressure have a direct effect on the conditions in the flare line. These ultra-low flow conditions are therefore more susceptible to passing though the dew point threshold, where moisture will condense on the pipe surfaces and on the face of any measurement transducers with changes in atmospheric conditions. This will cause the meter to regularly mismeasure and even fail completely for periods of time.

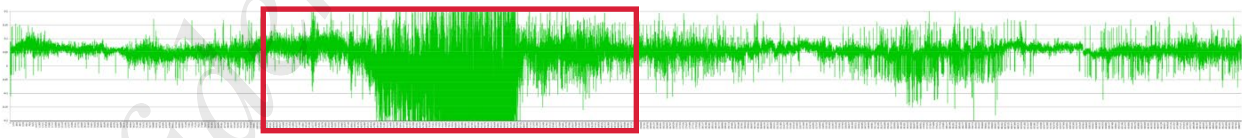

Fig.5 Example 1 of ultra-low flow over five days at gas storage facility at 0.05 m/sec

The above example is from five days of flare data from a gas storage facility, where the gas flow is virtually zero, at 0.05 metres per second. This is at the actual minimum of the flare meter range.

The signal is already compromised due to the electronic limitations and the exponential uncertainty of the meter at near to zero flow. However, this is a very good example of a meter performing extraordinarily well at the very limits of its capabilities. However, when the weather changes, due to the low flow rate, the pipe conditions change in line with the atmospheric variations, and the moisture in the gas stream condenses on the pipe wall and the transducer probes due to passing through the dew point. The condensate droplets on the probe faces interfere with the ultrasound signals and the measurement is seriously compromised for several hours.

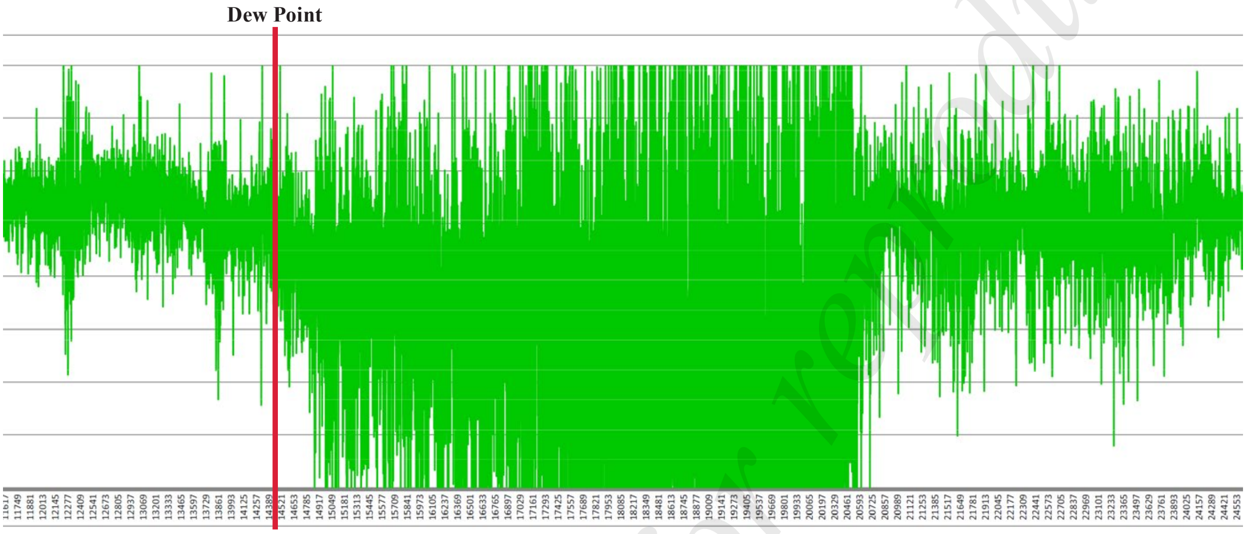

Fig.6 *Example 1 extract where ultrasonic measurement is lost during dew point changes*

This situation repeats over several days during a weather front, and each time the conditions pass through the dew point the signals are compromised and the measurement is temporarily lost.

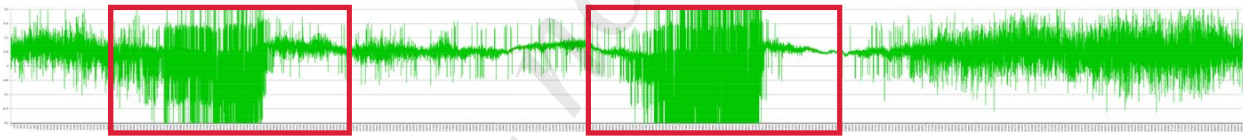

Fig.7 *Example 2 of ultra-low flow over next five days at gas storage facility at 0.05 m/sec*

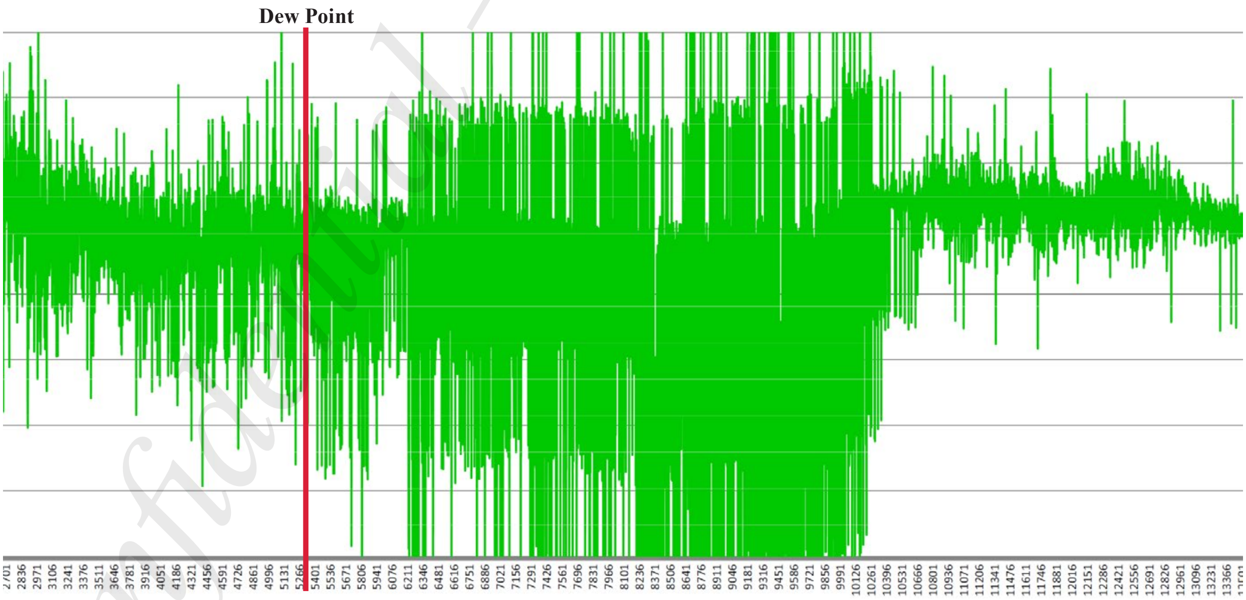

Fig.8 *Example 2 extract a: ultrasonic measurement is lost during dewpoint changes*

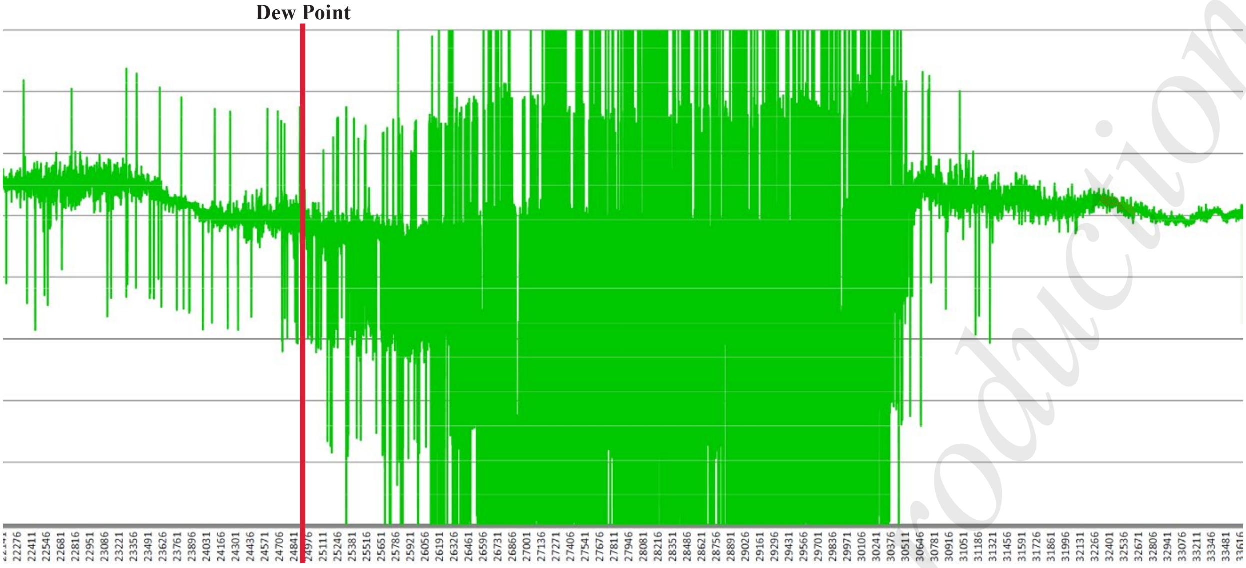

Fig.9 *Example 2 extract b: ultrasonic measurement is lost during dewpoint changes*

The appendix includes graphs of 50 days of ultra-low flow where the temperature conditions pass through the dew point, causing condensation that compromises the flare measurement.

Gas Stratification At Ultra-Low Flow Rates

Hydrocarbon flare gas compositions include gases of very different densities. Other gases like nitrogen have twice the density of methane, which is the most dominant flare gas component. At standard conditions methane has a density of 0.688 kg/m3 whilst nitrogen has nearly twice the density at 1.165 kg/m3, with other components like ethane having virtually twice, and propane having much more than 2.5 times the density of methane. The potential for phase separation of different density gases has therefore been the subject of several studies, where at very low pressures and near to zero flow rate the gases can separate into stratified layers.

When nitrogen is added to purge the flare at near to zero flow and atmospheric pressure conditions in a flare line, there is the potential for gas stratification to occur as the different density gases of methane and nitrogen start to separate. Any stratified flow patterns arising, compromise ultrasonic flare gas flow measurement by distorting the Time-Of-Flight directional computation by refraction, generating measurement errors.

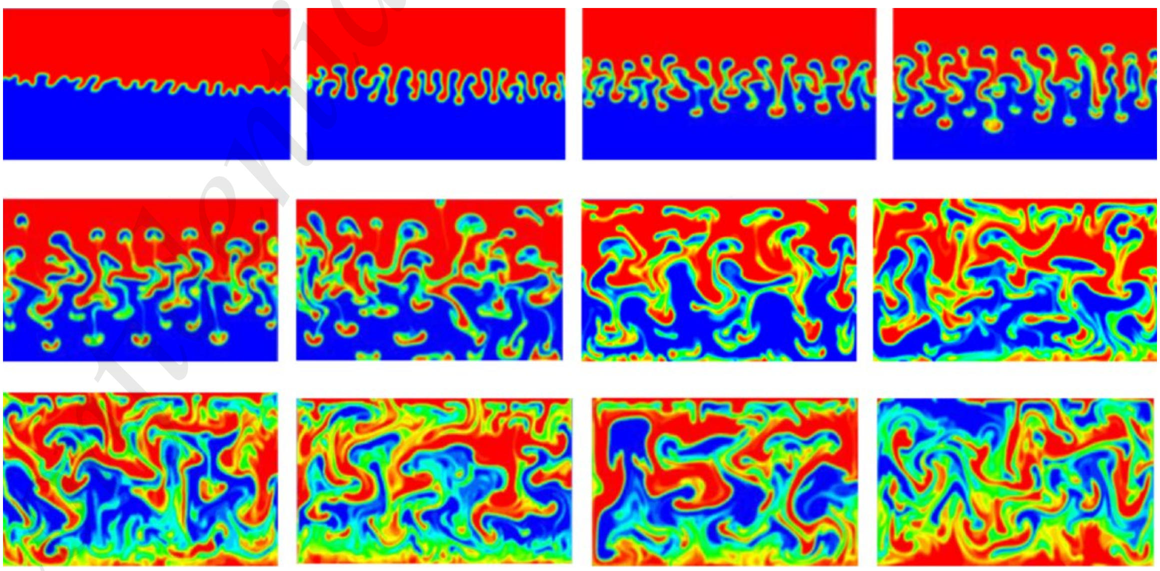

Fig.10 *CFD study of hydrocarbon gas phase separation at near to zero flows*

It is the combination of the above ultra-low flow measurement limitations that can significantly hamper efforts to successfully measure flare reduction toward near to zero flaring (ZRF).

The FlareMaster™ Solution

ABLE have developed a secondary measurement principle that enhances the main flare meter operation and provides redundancy of measurement. The technology and method can be applied to any manufacturers' flare meter. Early research proved this secondary method was unaffected by the conditions that limit the ultrasonic transducers, being immune to liquid, sludge and oil contamination.

Most importantly this secondary method does not have an upper flow velocity limit. There is also growing evidence that the FlareMaster™ secondary method is immune to the effects of swirl. Using an adaption of ABLE's patented dual technology software to intelligently combine two measurement methods by cross calibration, provides a unique metering method that can truly meet the fiscal requirement; Including for high blowdown velocities into several hundreds of metres per second, where all commercially available flare meters are unable to measure.

This same FlareMaster™ secondary measurement with cross-calibration has also been adapted to solve flow measurement uncertainty at ultra-low flow rates, even below the minimum stated by flare manufacturers. This means that FlareMaster™ can play a major role toward achieving the goal of zero routine flaring by providing a means to measure ultra-low flow rates.

Whilst testing the FlareMaster™ software in preparation for new deployments in the UK at onshore gas storage applications, months of recorded data highlighted the issues with moisture build up on the probes causing prolonged periods of loss of measurement. These periods occurred during atmospheric changes. This issue is expected to affect every flare metering application where the environmental agencies are working to reduce flaring towards zero, since external temperature and pressure changes have a greater effect on the flare line internal environment at near to zero flow.

The data analysis proved that the ABLE FlareMaster™ dual redundancy method can work very effectively in this ultra-low flow measuring range, giving stability of measurement into the smallest fractions of a metre per second velocity, and is capable of restoring a valid measurement in real world flare applications even down in the region of 0.02 metres per second which is well below the flare meter's normal measurement range capability.

The associated set of graphs give trend examples of FlareMaster™ resolving ultra-low flow, where the green trend line is the raw flow velocity and the red trend is the FlareMaster™ repaired flow. These graphs taken from a gas storage facility raw data, show that the target process flow rate is just 0.05 metres per second. At stated before, this is literally just at the minimum flow rate of the specified range of the meter, and there are repeated periods where the meter is unable to measure at this very low flow rate due to contamination of the probes from condensates. This is because at such low flow rates the flare is less stable, and more affected by changes in external conditions of pressure and temperature as the weather changes.

The trend in figure 11 is from a site control room printed graph of the flare meter raw mass flow, trended against the FlareMaster™ repaired flow. The flow velocity is in the region of 0.10 and 0.20 metres per second, giving a mass flow in the region of 180 kg/hr. The trend captures a period when the flare meter (green trend line) is unstable due to prevailing conditions affecting the low velocity flow application. The FlareMaster™ is repairing this flow rate (blue trend line) in real time. The raw flare reading fluctuates by up to +/- 650% of the true flow value, yet even so to the human eye the correct value is still discernible in small snapshots. However, the nature of the flow error during erratic fluctuations is so large that no form of digital smoothing can resolve a flow value that is suitable for fiscal reporting.

Raw meter mass flow variation	*-990 kg/hr to +1350 kg/hr*
Raw meter velocity variation	*-8.25 m/sec to +11.25 m/sec*

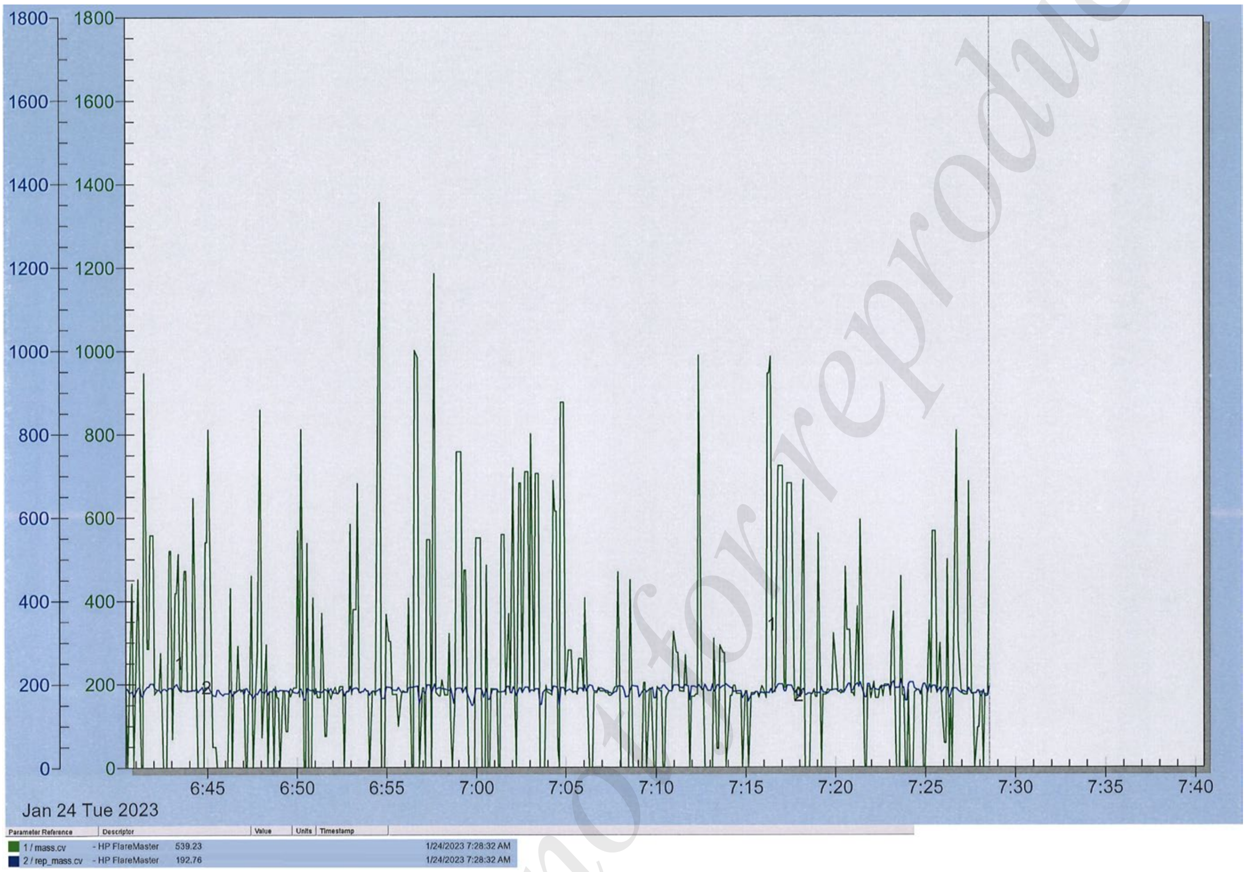

Fig.11 *FlareMaster™ repairing mass flow measurement in real time during meter instability*

The FlareMaster™ resolves the flow through a truly independent flow measurement method that is cross calibrated to the main flow ultrasonic measurement, and it is this secondary method that fully resolves the true mass flow in real time, during any periods of instability of the main meter.

UK Onshore Production

UK Offshore FPSO

UK Offshore FPSO

Fig.1............. Computer Generated Complex Gas Swirls Math simulation using Q-basic modelling .....August 2021
by T.Skelding ABLE Instruments

Fig.2 .... Swirl switching in turbulent flow through 90° pipe bends ....August 2015
PHYSICS OF FLUIDS 27, 085112 (2015) By C. Carlsson, E. Alenius and L. Fuchs
Division of Fluid Mechanics, Department of Energy Sciences, Lund University, 221 00 Lund, Sweden
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Fig.3 .... Internet Image published under Creative Commons Licence ....Commercial/non-commercial use

Fig.4 .... ABLE Instruments illustration, UK gas storage site, condensation on transducers ....July 2017

Fig.5- Fig.9:.. ABLE Instruments illustration, UK gas storage site, flow velocity trends...............................Oct 2018
Ultra-low flow, setpoint 0.05 metres per second flow velocity, usm meter.
Figures 5 and 7 graphs represents 120 hours @ 8.5 seconds data logging
Figures 6, 7 and 8 zoomed detail of measurement errors during changing atmospheric conditions

Fig.10............ Rollover of Liquid Natural Gas in a Storage Tank: A Numerical Simulation ....2016 -2018
By Yinbin LU1 and Chenwei LIANG of School of Mechanical Engineering,
Xi'an Shiyou University, Xi'an, China
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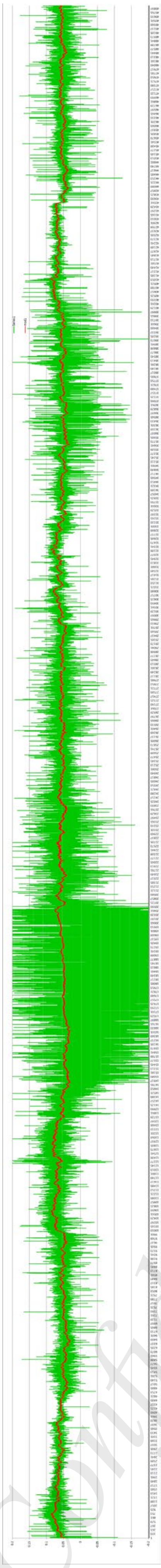
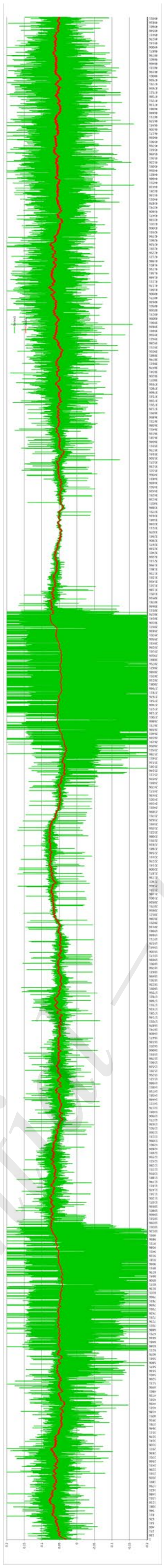
Appendix

The following appendix contains graphs of fifty days of flare data from a gas storage facility where the flow setpoint is 0.05 m/sec with a mass flow rate of barely 30 to 40 kg/hr. Each graph represents five days / 120 hours of trending with 8.5 second data log intervals, with approximately 50,000 datapoints for the five days on each graph.

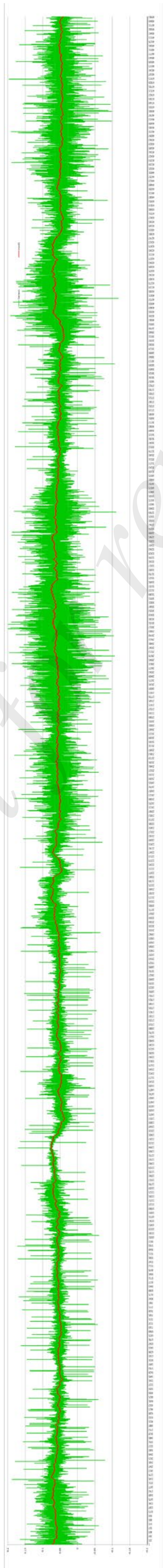
In each graph the green trend line is the raw flow meter, and the red trend line is the FlareMaster™ repaired flow value. The FlareMaster™ repaired flow rate is generated in real time. Where the flow is at the very limits of the flare meters capabilities, and on occasions becomes completely unstable, it's clearly evident from the data it just would not be possible to resolve the flow using digital smoothing or averaging techniques. Whereas the FlareMaster™ method truly resolves the flow from a measurement principle that is immune to the conditions that upset the ultrasound measurement and cause it to fail.



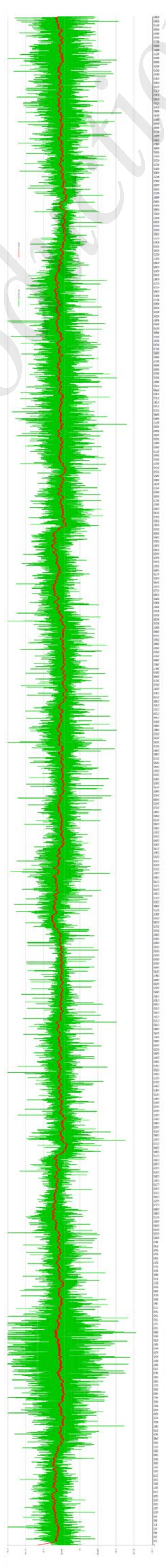
Day 1-5



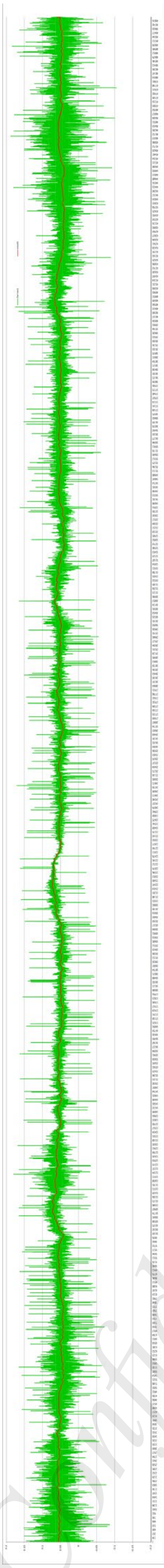
Day 6-10



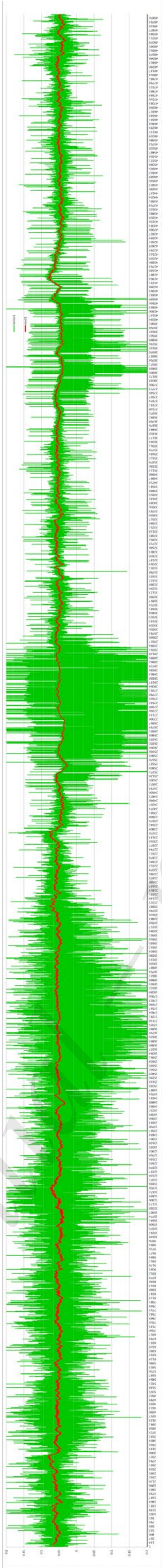
Day 11-15



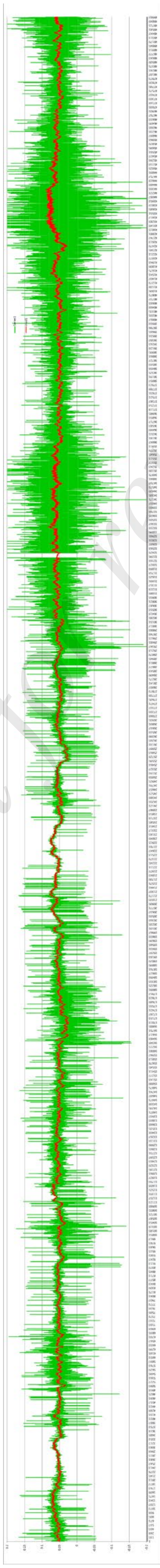
Day 16-20



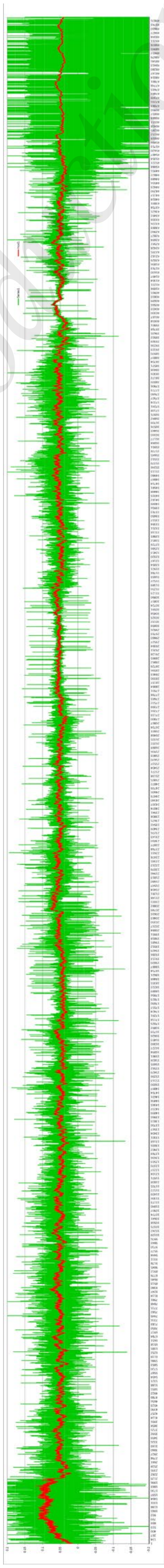
Day 21-25



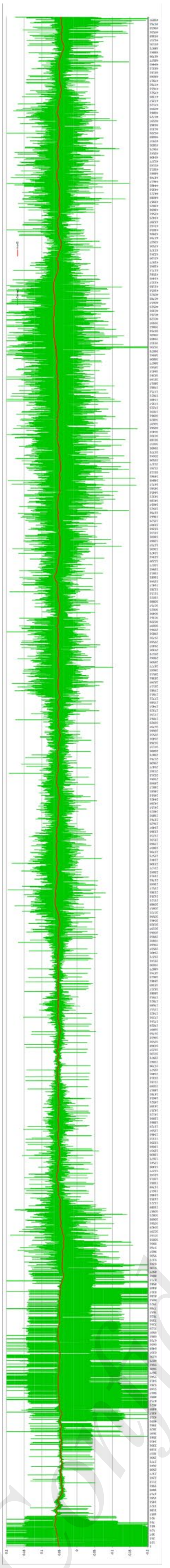
Day 26-30



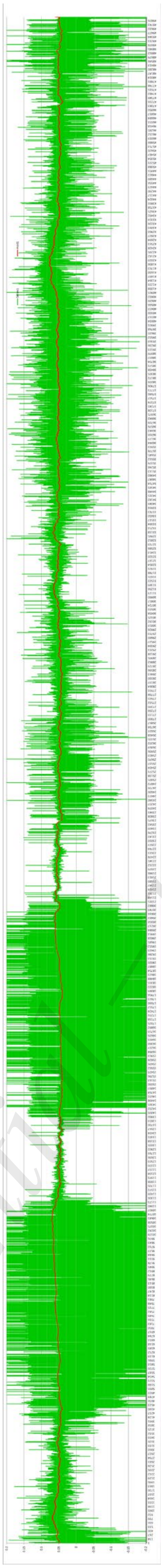
Day 31-35



Day 36-40



Day 41-45



Day 46-50