

NEFTEMER
a versatile and cost effective multiphase meter
by

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Neftemer - overview

- Objective of paper
 - To bring metering community up to date with Neftemer story
 - A different approach to multiphase metering
 - Different applications
 - › Heavy oil, relatively low producers
- Outline of Neftemer development
- Field test results
- Laboratory test results
- Conclusions

Western approach

- Multiphase metering development
 - Began in late 1970s /early 1980s
 - Aim was low cost meter per well
 - Expectation of dramatic savings
 - › In field development costs, from simpler equipment
 - › In operational costs, from improved information
- Expectation partly realised
 - Multiphase meters better than test separators
 - About 1600 meters installed in West
 - › Many as replacement for test separator
 - Still expensive to buy and install

Neftemer – late 70s to 1990

- Request from Russian oil companies
 - Solutions for measuring “unseparated” flow
 - Land wells, lowish production, heavy oil
- V. Kratirov at Space Institute in St Petersburg
 - γ -ray meter for steam/water flows in nuclear reactor
 - Based on interpreting fast fluctuations in density
 - Could be adapted for oil industry
- Field research in Belorussia
 - Data from wells gathered over several years
 - How best to deploy detectors

Neftemer – late 70s to 1990

- Additional expertise required
 - V. Kratirov originally not flow expert
 - Involved Russian flow experts as consultants
 - Involved experts in statistical data processing
- Practical methods for gathering field data
 - Separator tank on weigh bridge (gas not important)
 - Oil and water from interface measurements
 - Mass units the automatic choice
- Development of fluid model and algorithms
 - Calculate phase flowrates and integrate to get totals
 - Compare with totals from test tank, adjust parameters

Neftemer – late 70s to 1990

- ‘PULSAR’ meter designed 1988
 - Approval required from State Authorities
 - Covered comparison method, performance criteria, supervising tests and preparing report
- Commercial prototypes
 - 10 ordered in 1989 for testing in three oil companies in Belorussia, Russia and Kazakhstan
- Tests showed
 - There was a major need to measure lower liquid production rates
 - It was essential to be able to measure watercut

Neftemer – 1991 - 98

- 1991 Complex Resource set up
 - To develop improved meter, in line with test findings
- Intrusion of “real world” issues
 - Collapse of former Soviet Union
 - › Research funding suspended
 - Collapse of Soviet manufacturing industry
 - › Firm which manufactured ‘PULSAR’ out of business
 - V. Kratirov had effectively to start again
 - Major financial crisis (1998 rouble crisis)
 - Collapse of oil price
- All in all, a difficult period

‘Neftemer’ appears

- In 1995 new prototype appears targeting
 - thermally stimulated, high watercut, heavy oil wells
 - › Flowrates 5 – 300 tonnes/day (about 30 – 1800 bbl/day)
- Tests 1995/96 at Langepas
 - Contract for yet more advanced version
 - › Tested 1997 in commercial operation
 - › Signal processing improved (5% accuracy for 70% of points)
 - › Certification for meter achieved
- Tests 1998 at Langepas
- Shortcomings of earlier versions removed
 - › Acceptable as flow rate indicator
 - › Submitted to State Register of Measuring Equipment

Neftemer – 1998 to present

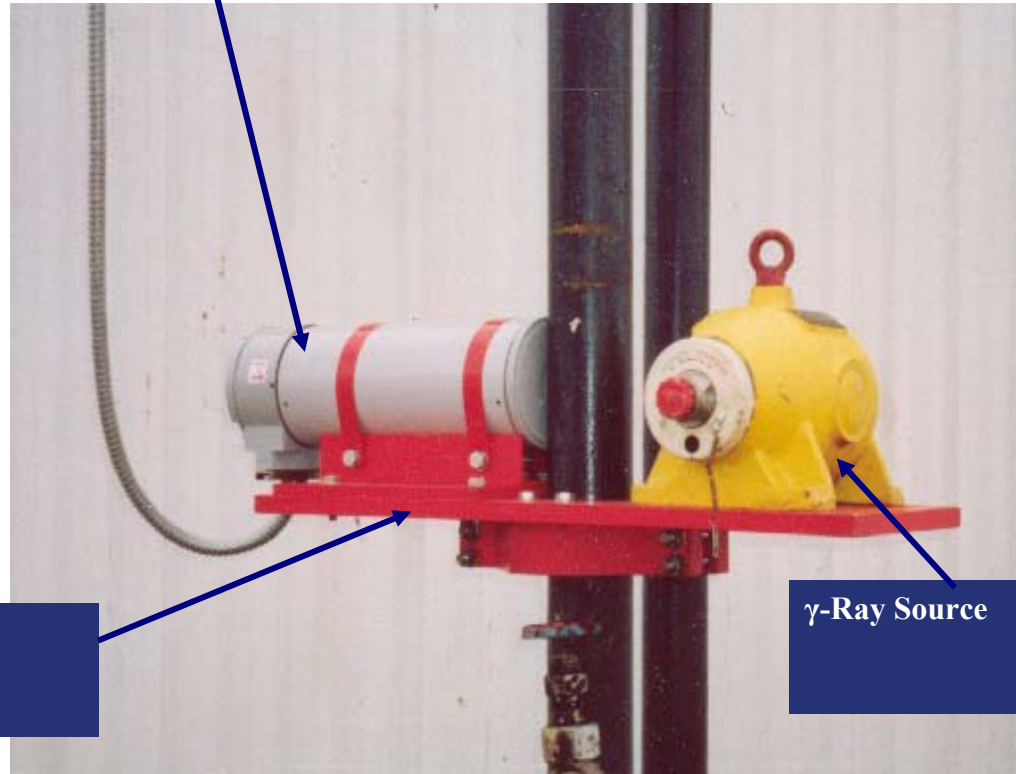
- Operational tests 2001
 - Komi Republic
- Large scale installation
 - By end 2005, 50 wells operating with Neftemers
 - Heavy oil, thermally stimulated
 - Installed as multiple assemblies
 - During 2006, further 150 wells operating
- Benefits other than metering
 - Detecting faults, need for well wash, detecting leaks
- 2006 test at gathering station

Neftemer outside Russia

- First contacts outside Russia about 1996
 - Paper presented at 1997 “Norflow” seminar
 - Interest shown, but R&D budgets had been cut
- Consortium to market Neftemer met in 2003
 - Tests to be done at Cranfield University
- Testing began 2005
- Approval work proceeding
 - International electrical safety certification
 - Approval for radioactive source holder
- Target market
 - Heavy oil wells similar to those in Russia

Neftemer construction

Detector



Clamp Mounting

γ -Ray Source

Neftemer installations



Single meter on beam-pump well

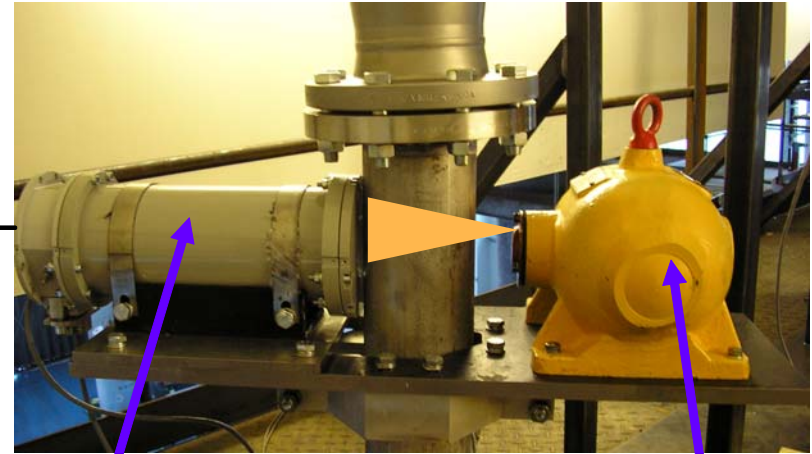
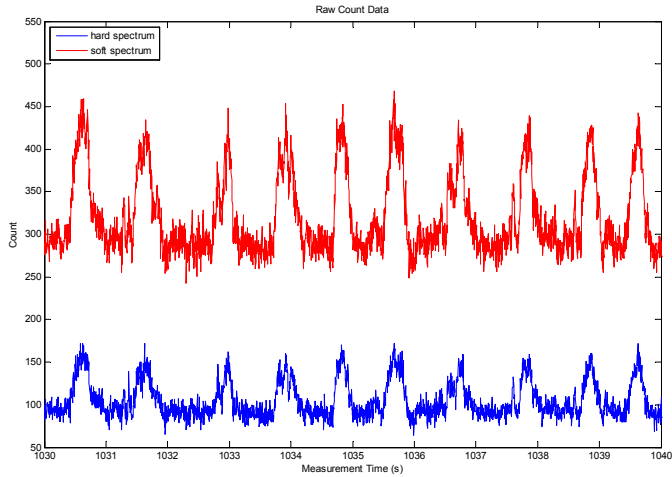


Prototype in field installation



Multiple meters (up to ten) surrounding a single multi-window source

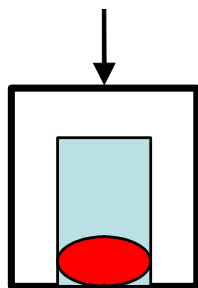
Neftemer operation



Detector

Gamma Source

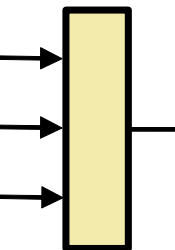
*Advanced
Signal
Processing*



Gas Flow Rate

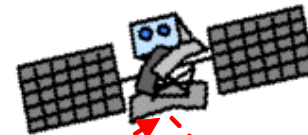
Oil Flow Rate

Water Flow Rate



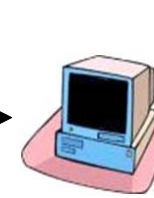
*Secure Data
Connection*

*Satellite
Link*

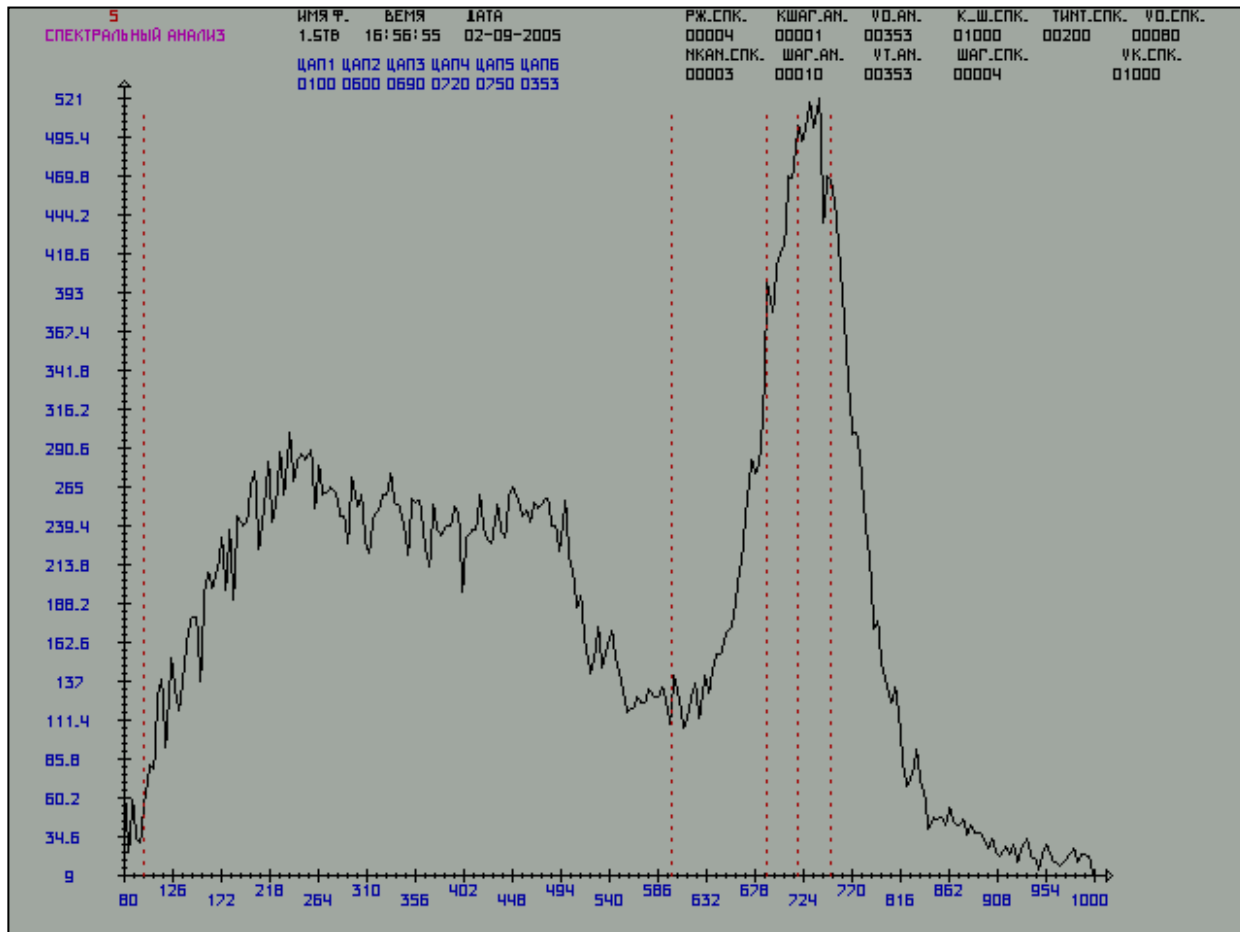


Local Display

Remote Display



Detected Spectrum



How it works - Basics

- Calculation cycle runs every 2 seconds
 - Effectively flow is divided into 2-second sections
 - › liquid mass flowrate
 - › gas volume flowrate
 - › (mass) watercut of liquid
 - Integrate to get totals for liquid, oil, water, gas
- Neftemer depends on density fluctuations
 - In practice for much of the time there aren't any
 - › Hold last good calculated values, update when data allows
- Gas bubbles give liquid and gas velocities
 - Bubble sizes can be inferred from amplitude and width of density fluctuations

How it works - Velocities

- Bubbles below critical size are entrained in liquid
 - Give liquid velocity
- Average velocity of all bubbles
 - Gives gas velocity
- From R&D programme, spectral patterns found
 - For both liquid and gas
 - Frequency of appearance strongly related to velocity
- High scan rate of 250 Hz
 - Allows velocities to be calculated over wide range

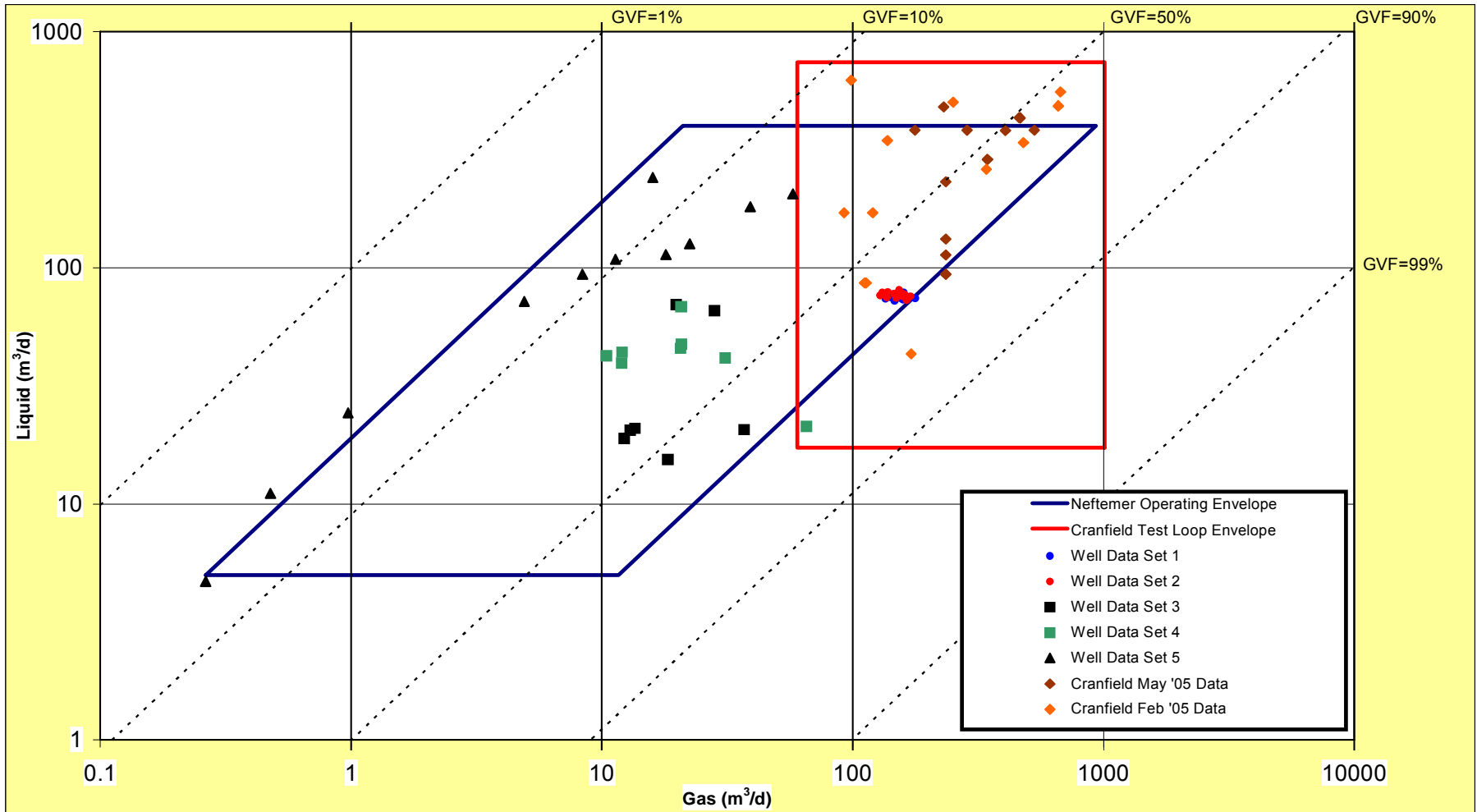
How it works – Phase fractions

- Single phase γ -absorptions
 - Input to system during calibration
- Phase fractions determined using
 - First, overall γ -density
 - Second, standard dual-energy equations
 - › Absorptions at two pre-defined energy levels in detected spectrum
 - Third, overall shape of detected spectrum
 - › Shape related to oil, water and gas fractions
- Phase fractions and liquid and gas velocities
 - Combined with area gives phase flowrates

How it works – In practice

- **Basis of method**
 - Sophisticated mathematical analysis
 - Sophisticated statistical signal processing
 - Yields accurate measurements
- **In practice**
 - Simplifications
 - › To allow Neftemer to operate in real time
 - Tuning
 - › Required for a new application

Operating envelope



Field testing

- Earlier field tests (1995/96, 1998, 2001)
 - Show improvements and moves to heavy oil
 - Discussed in paper
- July 2006 tests
 - Comparative testing on heavy oil wells not possible
 - Separator on weighbridge designed but not ordered
 - Discrepancies between
 - › Neftemer indications and operator expectations
 - Great interest in “demonstration” test
 - › At gathering station with good oil and water metering
 - › Using light oil (density 820 kg/m^3)

“Demonstration” test

- At gathering station
 - Crude oil from three fields separated and metered
 - › Oil using Smiths PD meters
 - › Water using Halliburton turbine meters
 - › Gas not metered accurately
- Single Neftemers installed
 - On vertical sections of 3-phase pipelines from fields
 - › One 325 mm pipe, two 219 mm pipes
 - › 325 mm pipe conveyed >99% of total production
- Set up equipment, then seal for one month
 - Independent comparison of daily production totals
 - Data shown is from 11-day preliminary period of test

Results of 2006 test

Date	Error (only for 325 mm pipeline)				Error (all 3 pipelines)			
	Relative error mass liquid, %	Relative error mass water, %	Relative error mass oil, %		Relative error mass liquid, %	Relative error mass water, %	Relative error mass oil, %	Abs. error Mass Watercut %
06/07/06	-0.6	-3.2	5.5		0.1	-2.2	5.6	-1.6
07/07/06	-1.9	-4.7	5.4		-1.2	-3.7	5.5	-1.9
08/07/06	-0.1	-2.3	6.1		0.7	-1.4	6.3	-1.5
09/07/06	-1.7	-1.8	-1.4		-0.9	-0.8	-1.3	0.1
10/07/06	0.5	1.3	-1.4		1.3	2.3	-1.2	0.7
11/07/06	1.3	3.7	-5.0		2.0	4.7	-4.8	1.9
12/07/06	-1.8	-1.5	-2.6		-1.0	-0.5	-2.5	0.4
14/07/06	-0.3	2.0	-5.9		0.5	3.0	-5.7	1.8
15/07/06	1.0	5.2	-9.1		1.7	6.1	-9.0	3.1
16/07/06	-2.2	-4.4	3.6		-1.5	-3.4	3.7	-1.5
17/07/06	-1.1	-3.7	5.9		-0.4	-2.8	6.1	-1.8
Average	-0.63	-0.84	0.10		0.11	0.12	0.25	-0.02
2 x Std. Dev.	2.43	6.76	10.90		2.44	6.79	10.90	3.49

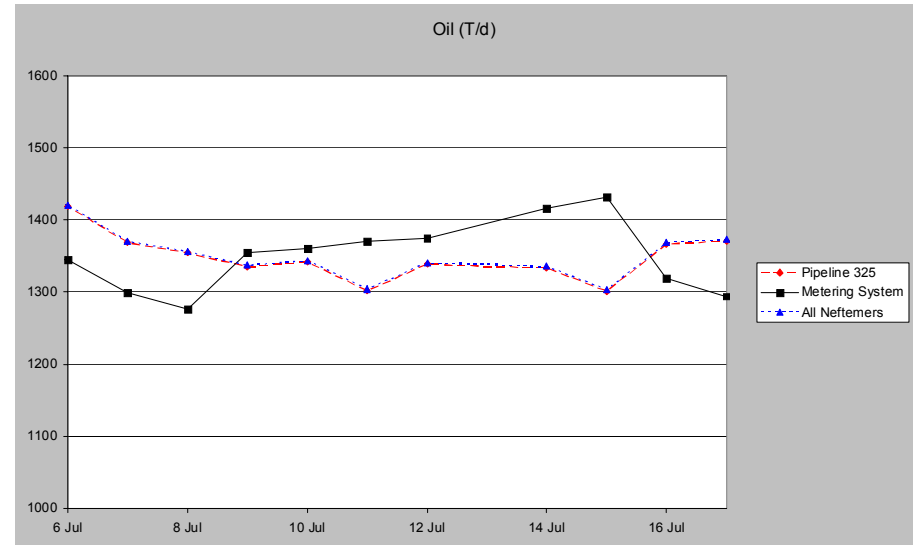
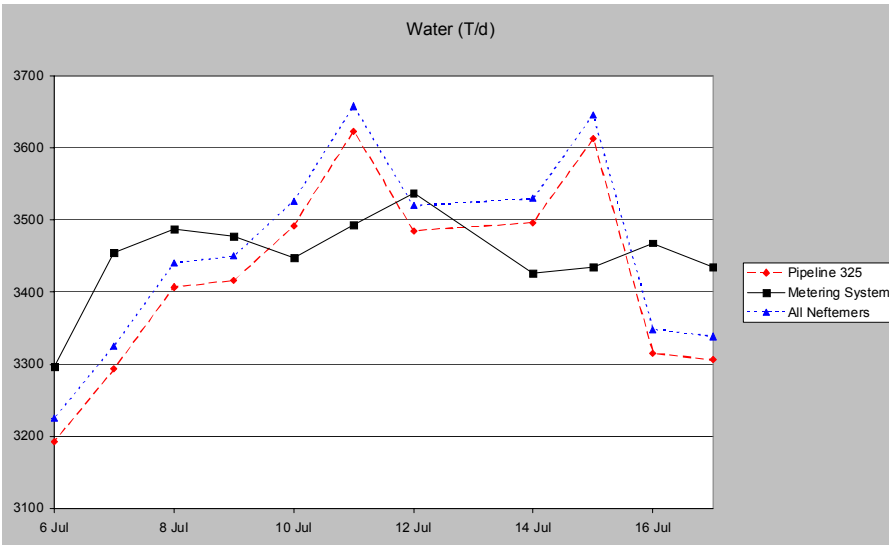
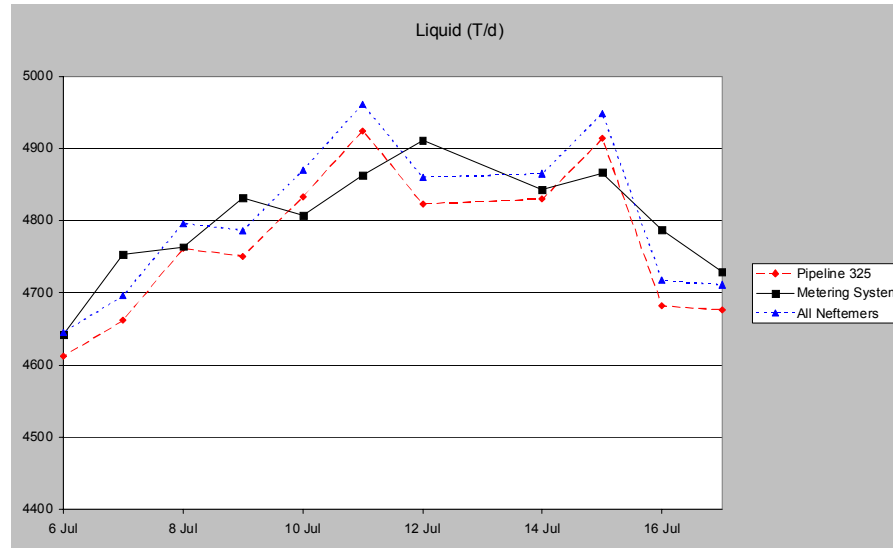
Observations on test - 1

- Low average errors in daily production totals
 - Liquid 0.11%, water 0.12%, oil 0.25%
 - › Indicates daily variation was mostly random
- Average errors for pipe 325 (e.g. liquid -0.63%)
 - Reflect introduction of systematic error
 - › Smaller pipelines transporting mostly water
 - › Neftemer could see small changes in multiphase flow
- Variation in daily production over test <6%
 - Can consider test as 11 repeats
 - › 2 x standard deviation gives indication of uncertainties
 - › Slijkerman et al. 1995 call for 5-10% liquid, 2% watercut
 - › Results indicate 2.4% liquid and 3.5% watercut

Observations on test - 2

- Reconsider variation in liquid production
 - Indicated uncertainty 2.4%, less than variation of 6%
 - › Expect Neftemer to track this variation, and it does
- Variation in water and oil production
 - Indicated uncertainties slightly less than variation
 - › Water : 6.8% uncertainty, 7.3% variation
 - › Oil : 10.9% uncertainty, 12.2% variation
 - Do not expect to see clear tracking
- Neftemers on smaller pipelines
 - Measuring very low flowrates
 - › Plots indicate that they give reasonable data
 - › Key to this is the high scan rate of the detector

Comparison of daily totals



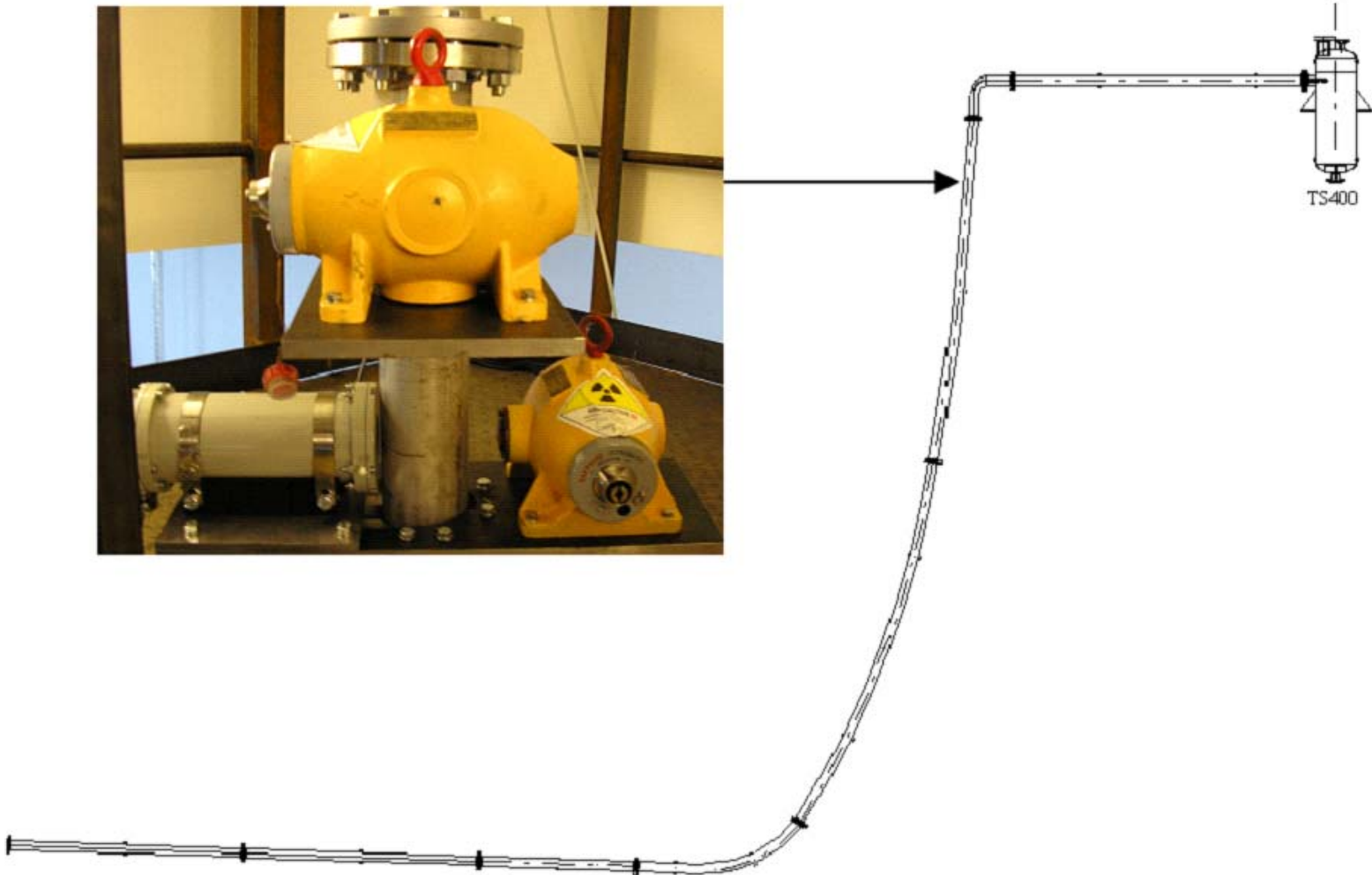
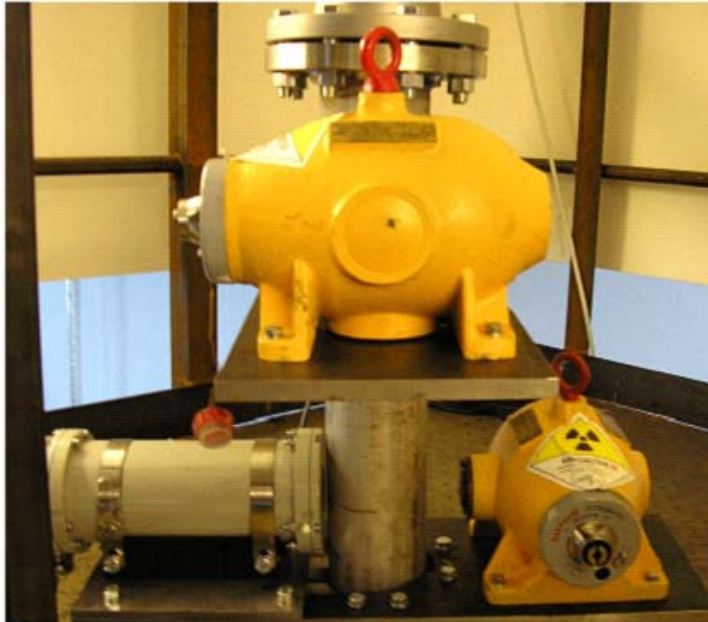
Laboratory testing

- Using Cranfield University multiphase facility
- Test programme based on Multiflow 2 JIP
 - To give direct comparison with other meters
 - Subset of test points
- Significant differences from field conditions
 - Stainless steel versus carbon steel pipe
 - Light lubricating oil versus heavy oil
- Target was to get agreement with test facility
 - $\pm 10\%$ relative for gas and liquid
 - Follow trend for watercut

Cranfield multiphase facility

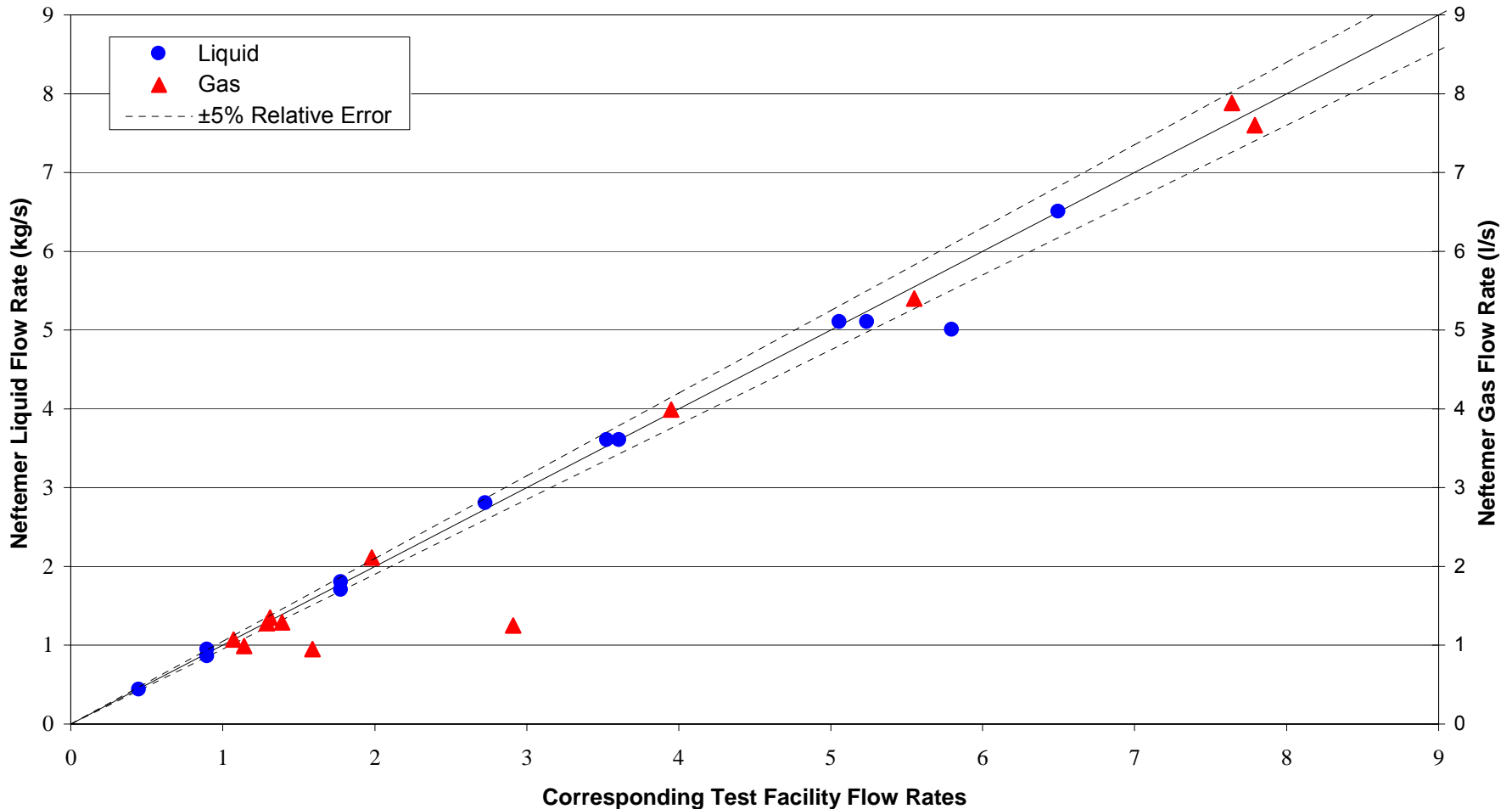


Test setup at Cranfield



Liquid and gas comparisons

Neftemer Phase Flow Rates vs. Test Facility Reference Flow Rates



Results

- February 2005 tests gave encouraging results
 - Liquid and gas met target
 - Watercut showed large spread of errors
- Further tests done in May 2005
 - To date have not been able to make sense of these
 - › Partly due to intense activity in Russia
 - › Partly due to difficulties in reprocessing data
 - Operation of test loop checked
 - The two Neftemers were tracking each other
- Warning for application of Neftemer
 - Initially choose similar applications to Russia

Test loop / meter interaction

- Warning on meter/test loop interaction
 - Much still to be understood
- Basis of Neftemer design
 - Measures slowly changing flow of producing wells
 - › For abrupt changes in production
 - › Time needed to build up statistics on new flow condition
 - › Then get accurate measurements
- Comparison with test loop time consuming
 - At least 30 minutes per test point
 - Some test loops cannot provide stable conditions
 - › For long periods
 - › At high flowrates

Conclusions

- Neftemer development extends over 25 years
 - Non-intrusive measurement principle can work
 - › Lower production, artificially lifted, land based wells
 - › Wide range of crude oils, especially heavy, high watercut
- Field calibration method practical
 - Based on separator on weighbridge
 - Should be considered for Western applications
- Challenge to thinking behind use of test loops
 - Need to combine field and laboratory methods
- Warning when tackling new applications
 - Non-intrusive Neftemer can assess applications
 - › Prior to deciding on permanent installation

Conclusions

- Perception that multiphase metering is a mature technology
 - 0.2% market penetration suggests not
 - › about 2000 meters for 1 million wells worldwide
 - We consider impact is just beginning to be felt
 - Diverse range of meters and equipment required
 - Neftemer is a cost-effective and versatile addition to that range