Development and Installation of the ABLE CTM Ultrasonic Cargo Transfer Metering System on the BP Amoco Schiehallion FPSO

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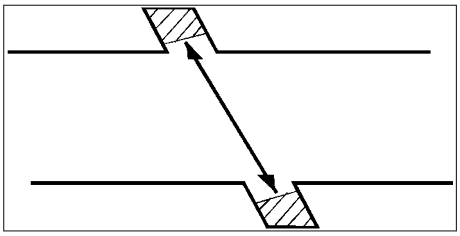
1. Introduction

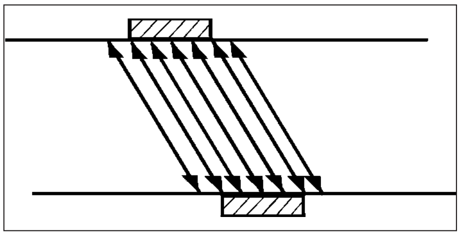
Late in 1993 whilst exploring the deep waters to the west of the Shetland Isles the semi-submersible drilling rig, the Ocean Alliance, discovered the Schiehallion oilfield. The Schiehallion field is located beneath 400M of some of the most hostile sea in the UK Continental Shelf. Field reserves were estimated at 425 million barrels and it was anticipated that as many as 29 subsea wells in 4 producing clusters could be required for recovery. It was decided that use of the emerging FPSO technology would be most suited to the task and the world's then largest new build FPSO vessel Schiehallion was commissioned.

2. Why the CTM System for Offload?

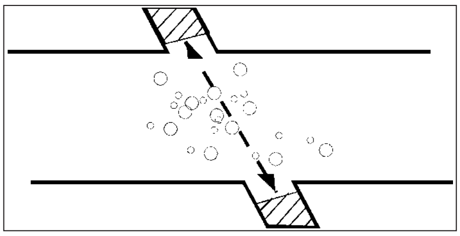
Discussion between BP Amoco and the DTI, revealed ABLE's pioneering work with the North Sea Operator Kerr McGee Oil (UK) Plc on the Gryphon A. A clamp-on ultrasonic system had been specifically developed to address the unique nuances of FPSO offloading, a system which operated dependably despite the non-stable flow conditions experienced through backwash and tank stripping conditions. A system that delivered significant CAPEX and OPEX advantages.



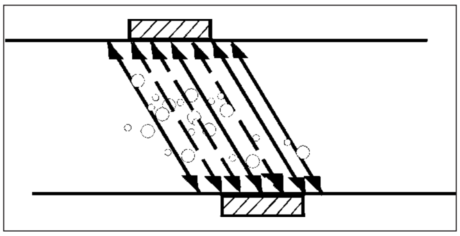
Wetted transducer – pencil beam of ultrasound



Clamp-On DERF transducer – «shover» of ultrasound



Wetted transducer – signal easily destroyed by aeration



Clamp-On DERF transducer – only a small proportion of signal is removed by aeration

Figure 1 - The advantages of the clamp-on system developed for FPSO offloading

On the Gryphon A a single **CTM***flowstation*™ had been placed on the export line, before the existing metering point, where its performance had been verified against the DTI accepted calibrated turbine flowmeter skid. Over a period of several months data had been acquired which showed deviations from the reference volume export values to be well within the limits acceptable by the DTI for stand alone offshore loaders. It is worth noting that the Gryphon, like the Schiehallion, was not a strict custody transfer point and as such the normal requirement for 0.25% accuracy was relaxed in favour of 1%.

The live tests on Gryphon A had resulted in a submission being made to the DTI for moth balling of the conventional metering skid, on the basis of the significant operational and cost benefits of the clamp-on **CTM***system*™. Extracts from the findings of Kerr McGee showed that:-

- Tanker export times reduced from 24 to 18 hours for a typical 66000 tonne export.
- Benefits of faster export of cargo proven during poor weather conditions where slower metering would have resulted in the need for export to have been interrupted and the shuttle tanker to have returned to complete loading.
- Cost savings, taking maintenance and re-calibration of conventional skid in to account as well as reduced transport charges in the region of £200,000 p.a.

BP Amoco having satisfied themselves of the benefits a clamp-on system with no moving or wetted parts could provide with regards to minimum maintenance, manning and intervention, proceeded with purchase.

3. BP Amoco's Commitment to the CTM*system*™

The initial scope of supply was for a master and slave flowstation configuration which utilised an off the shelf comparator / flow computer. Essentially this meant one flow station would take the role of primary measurement - master meter, with measurements from the second or slave meter, being used to determine any undefined shift in the readings of the master meter.

Extensive system testing at the Danfoss calibration facility in Stonehouse, Gloucestershire was witnessed by a core of flow experts who were to become central to the initial development of the **CTM***system*™ (see appendices 1 through 3).

Bill Strang BP Amoco - Schiehallion E & I Project Engineer
Vincent Withers BP Amoco - Metering Specialist
Lewis Philp DTI - Head of Gas and Oil Measuring Branch
Brian Bowers Brown & Root - Lead Instrument Engineer

Whilst testing and calibration proved highly successful it also revealed a number of system limitations which ABLE, BP Amoco and the DTI discussed in depth with a view to improving performance. The master / slave system configuration meant the points of incidence between the flow stations were not identical, therefore the decision as to which station was providing the better performance could not be made with certainty. Furthermore BP Amoco could see the value of individual path interrogation, as it would allow not only the optimisation of the flow measurement, but also allow information relating to the condition of the process to be obtained.

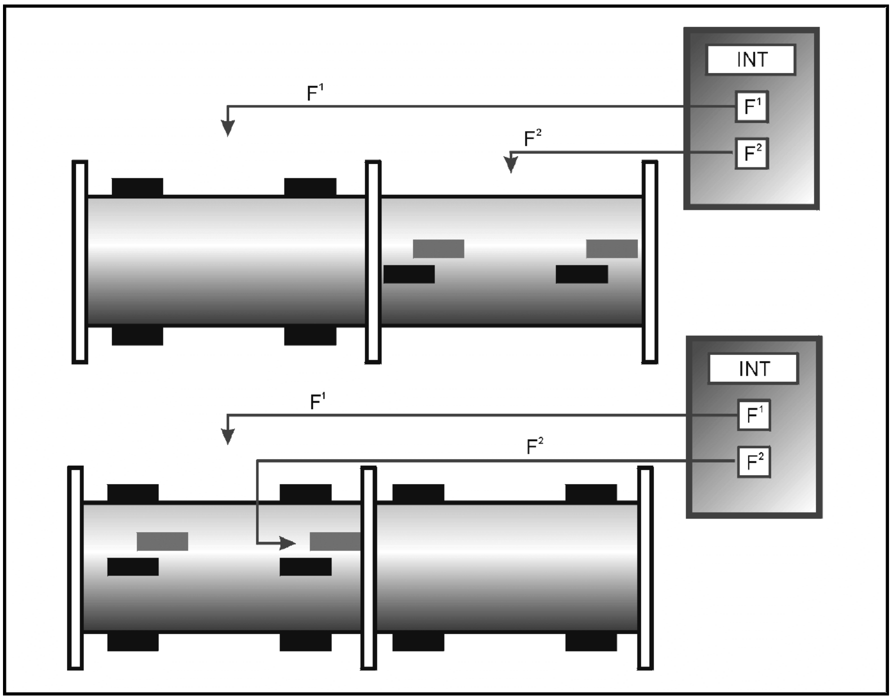


Figure 2 - Original system design is shown in the upper portion, lower diagram shows the current configuration of Schiehallion's Offload Metering System

4. System Development

This resulted in a redesign of the existing Schiehallion CTM cargo offload metering system and the deployment of a single spool system with both flowstations measuring at the same cross sectional point, therefore allowing a true comparison of individual transducer signal conditions to be achieved. To maximise the advantage gained by improved transducer location, extensive product development of the process interrogation system was required. It was recognised that a lot of diagnostic data was available and a facility to combine this in a simple Operator Confidence figure was proposed. This resulted in the development of OpCon, a unique feature allowing access to process detail and incorporating a degree of automated diagnostic capability. OpCon constantly verifies multiple parameters received by each transducer, whilst simultaneously providing a real time register of parameters including temperature, pressure, aeration and sonic velocity.

5. Commissioning of the CTM*system*™

Successful commissioning of the **CTM***system*™ highlighted a number of issues. In the calibration laboratory the **CTM***system*™ had performed exceptionally, however it soon became clear that process conditions varied enormously for differing installations and that the Schiehallion offload process bears no resemblance to the «clean» and stable conditions associated with a calibration rig or indeed an export terminal.

Operational experience indicated that during an offload there are numerous events, which can have a detrimental effect on achievable metering accuracy including: -

1) Weather Windows - The onset of bad weather is always a possibility, particularly when it is considered that an offload can take up to 18 hours to complete. During extreme conditions it is not unknown for a tanker to have to re-engage five times.
2) Tank Stripping - Completely draining the cargo tanks aboard the FPSO.
3) Backwashing - To ensure all the available oil is removed from a cargo tank, high pressure oil is sprayed on to the walls and ceiling washing off valuable congealed oil (often referred to as «clingage»)
4) Start Up Procedure - Priming of pipes and pumps.
5) Offload End Procedure - Long slow decline in pressure induces aeration.

The periods at either end of an offload provide unique challenges for accurate metering. High aeration levels and low pressure are characteristic plus an increase in entrained solids make metering difficult. The ability of an offload metering system to perform at all under these circumstances is vital as during these periods, of up to an hour, acceptable offload figures are won or lost. These problems are amplified when poor weather conditions re quire a tanker to disengage and then reengage to resume offload.

Similar problems during tank stripping and backwashing procedures occur, as excess air, sediment and congealed solids are drawn into the export line. Once again these conditions are not ideal for metering.

Discussions between ABLE and BP Amoco concluded that no matter how intrinsically accurate an offload metering system, the only process for achieving acceptable live offload results was to increase metering up time. As a result BP Amoco redefined offload procedures to incorporate suggestions from ABLE including priming of pumps and pipes where possible.

6. The Development of OpCon

The movement of the oil from the storage facility on the Schiehallion via pipeline to the Shuttle tanker Loch Rannoch periodically suffered from problems such as gas outbreak, tank stripping and slugging. Without OpCon little information would have been available about the condition of the process during an offload. A metering skid would have «masked» potential problems since turbines would continue to spin regardless of whether metering gas or crude, whilst a wetted transducer ultrasonic system would have been unlikely to continue operation due to signal failure through breaks in the narrow ultrasonic beam caused by gas breakout. Information available through OpCon was logged via the **CTM***gatherer*™, this allowed operators to rerun individual offloads and build an accurate profile of the offload procedure. Using this information, thresholds within OpCon could be adjusted to maximise metering up time.

The introduction of OpCon effectively freed the Schiehallion cargo offload metering system from depending upon a Master / Slave relationship, where only one flowstation supplies the recorded data. BP Amoco's drive for improved offloads resulted in OpCon intelligence giving «weight» to the return signals from the flow paths of favourable measurement signals. As an extension of this philosophy OpCon was actually designed to disregard data from any flow path producing outside acceptable thresholds.

The ability of OpCon to allow greater functionality plus the DTI's requirement for guaranteed availability under all offload conditions culminated in the development of a purpose built central brain, the MCVS. The MCVS was developed since conventional flow computers are not designed to interface at the path level of ultrasonic flowmeters. At best a flow computer can manipulate the outputs from ultrasonic meters, however even this requires special programming. The MCVS incorporates two autonomous flow stations, which can be used independently or simultaneously via use of the MCVS depending upon process conditions. The MCVS can mix and match up to eight measurement paths across the two spools if necessary, depending on process and hardware diagnostic OpCon thresholds.

7. CTM*system*™ Control Methodology

In order to comply with the ever-changing demands of each individual offload BP Amoco implemented several changes in the recording of offload data. BP Amoco required that the **CTM***system*™ be flexible enough to accommodate both start / stop metering and also continuous batch metering. Ultimately this ensured compatibility with whichever offload regime was required. The development of a continuous batch measurement process provides total accountability and ensures that no cargo is lost. The period between batch runs also allows the **CTM***system*™ to run a complete routine of self-checks, from auto zeroing through to cabling integrity.

8. Conclusion

Successful system enhancement was achieved by a combination of operational experience and fuller knowledge of the process conditions gained by the implementation of an intelligent metering system (see appendices 4 through 7).

9. Subsequent Systems and the Future

The first full redundancy system governed by a dual MCVS was purchased by Enterprise Oil late in 1997, with successful commissioning taking place in the spring of 1999. This system provides the ultimate in security, as should the operation of either MCVS be found to be inadequate or be producing unusual results, the second fully functional MCVS system will automatically be brought on line without the loss of any data.

The flow computers are now in their second generation and use a digital encoded signal technique (DERF), removing any uncertainty regarding transmit / receive ultrasonic signal detection times. New High Precision Transducers have evolved which provide the greatest possible signal amplitude and have no sonic signal distortion. This combination of new flow computers and transducers is providing greater accuracy and superior stability, which ultimately extends metering «up time» during adverse conditions (see appendices 8 through 10).

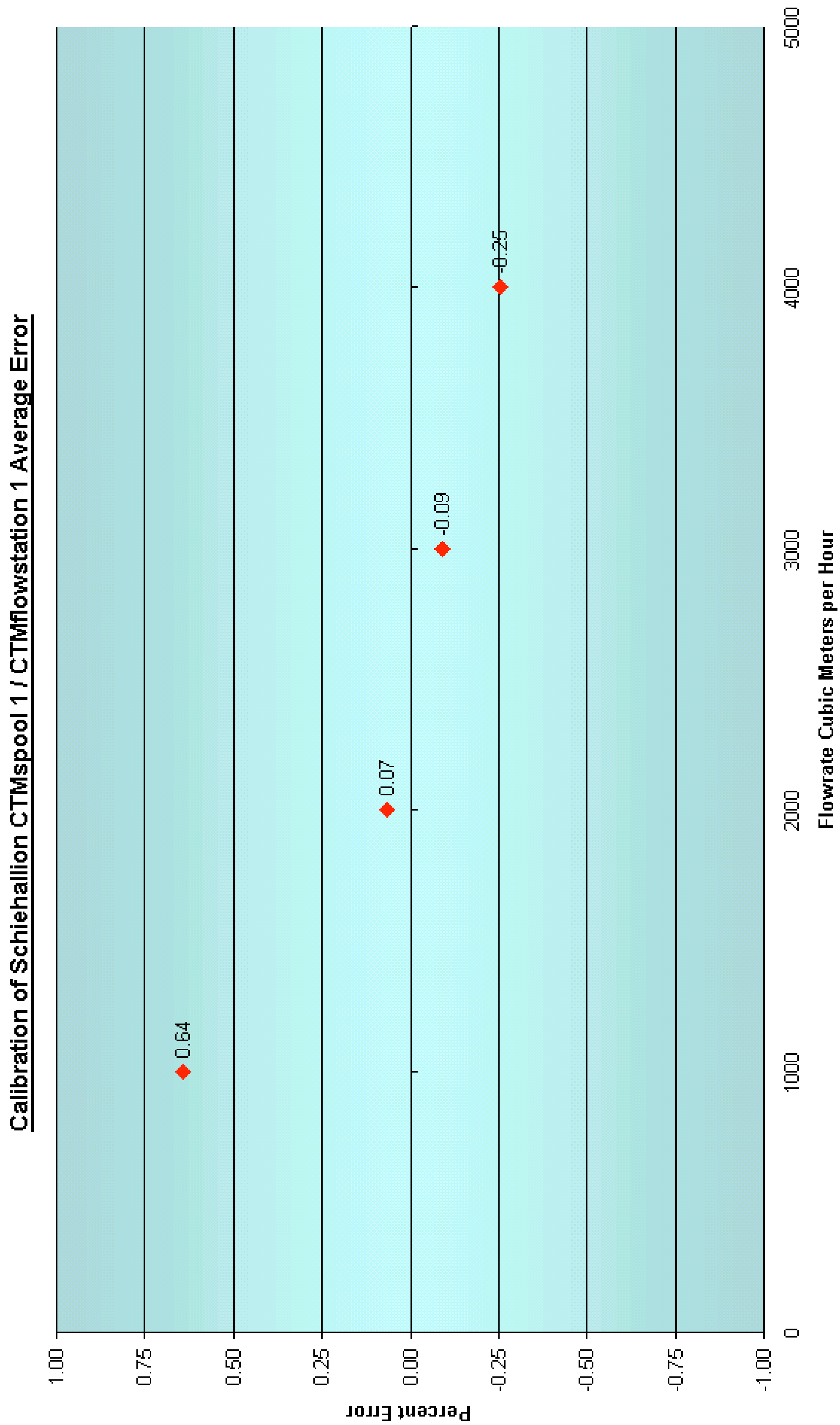
The MCVS is being developed to interrogate up to sixteen different paths simultaneously. This we see as a natural extension of our capability to solve the most difficult flow applications that we are likely to encounter.

Continued development of software and hardware has pushed the **CTM***system*™ further toward the definitive goal of providing similar cost and operational advantages for a fully fiscally approved custody transfer system.

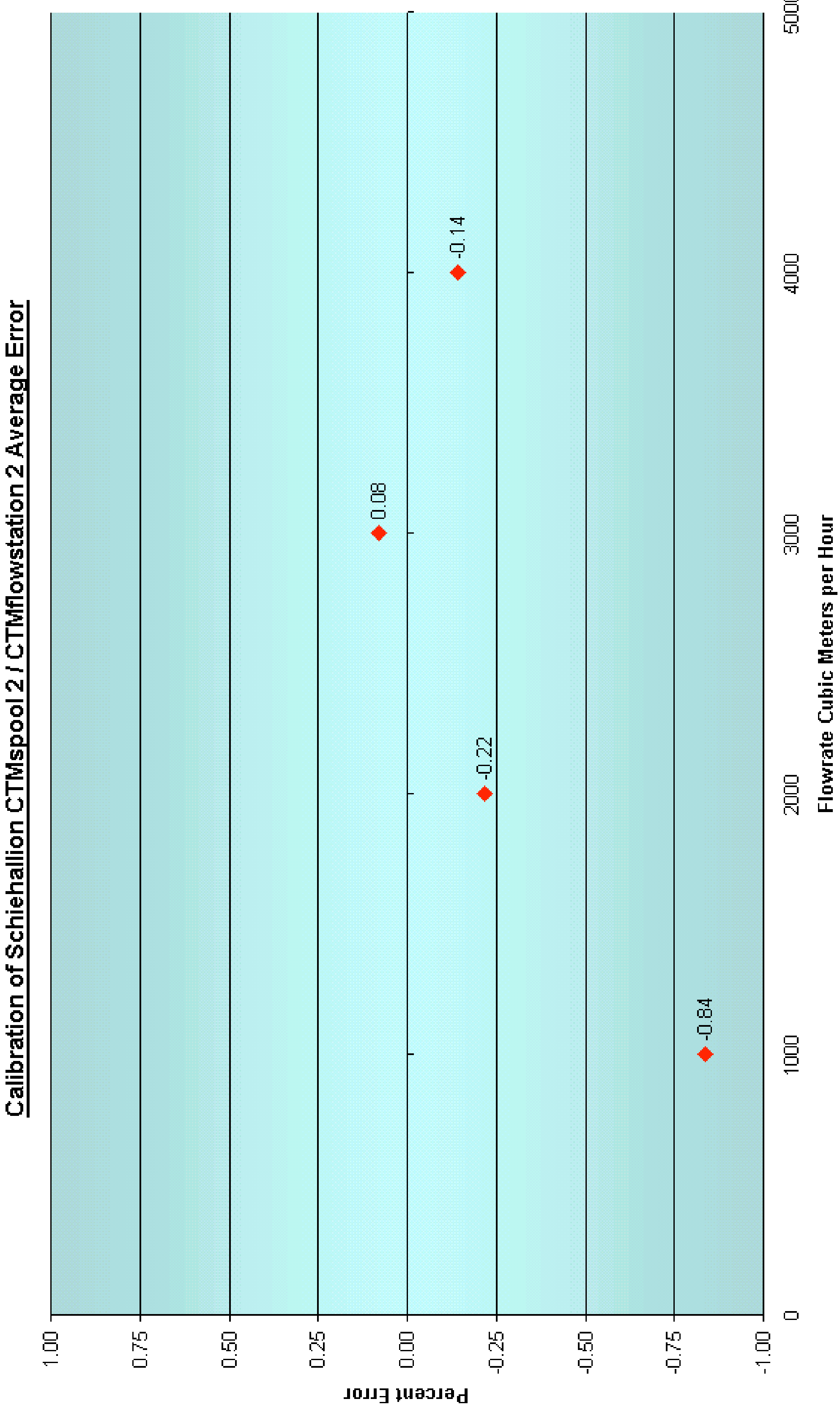
10. Glossary of Terms

CTM - Cargo Transfer Metering
DERF - Digitally Encoded Resonant Frequency
DTI - Department Of Trade and Industry
FPSO - Floating Production, Storage and Offloading
MCVS - Master Control & Verification System
OpCon - Operational Confidence

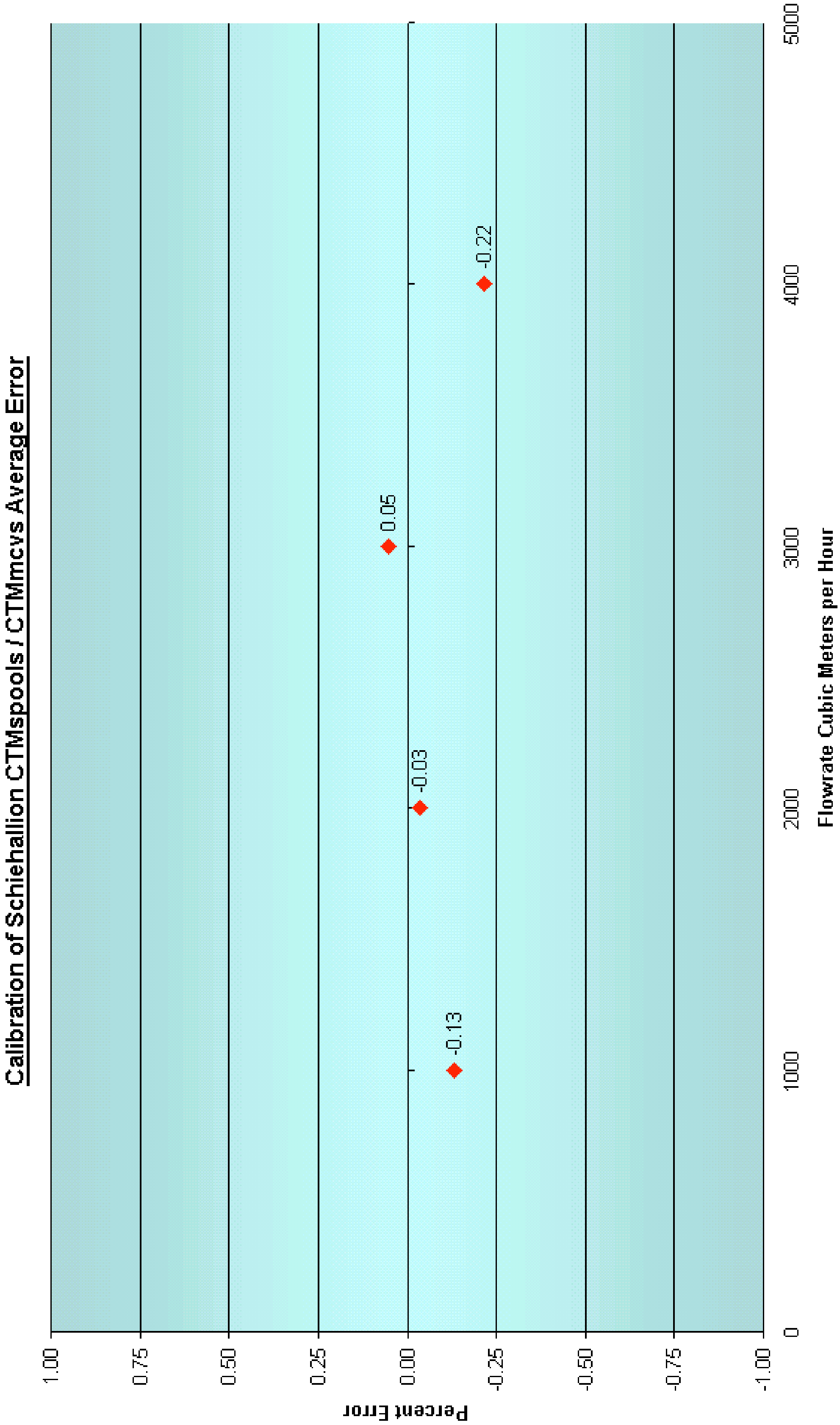
11. Appendix 1 - CTMflowstation(tm) 1 Calibration Average



12. Appendix 2 - CTMflowstation(tm) 2 Calibration Average



13. Appendix 3 - CTMmcvs(tm) Calibration Average

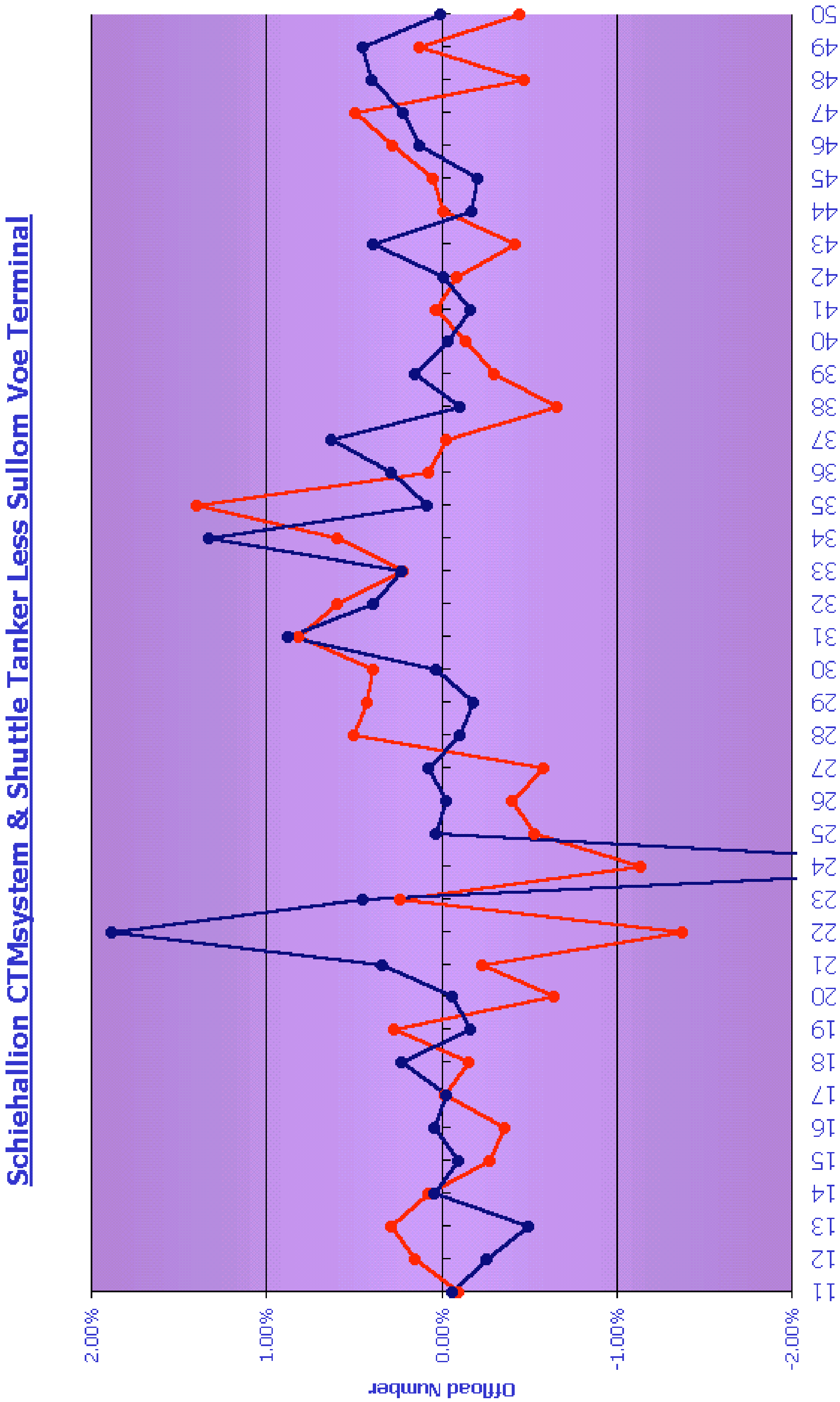


14. Appendix 4 - Accuracy Data for Offloads 11 through 50

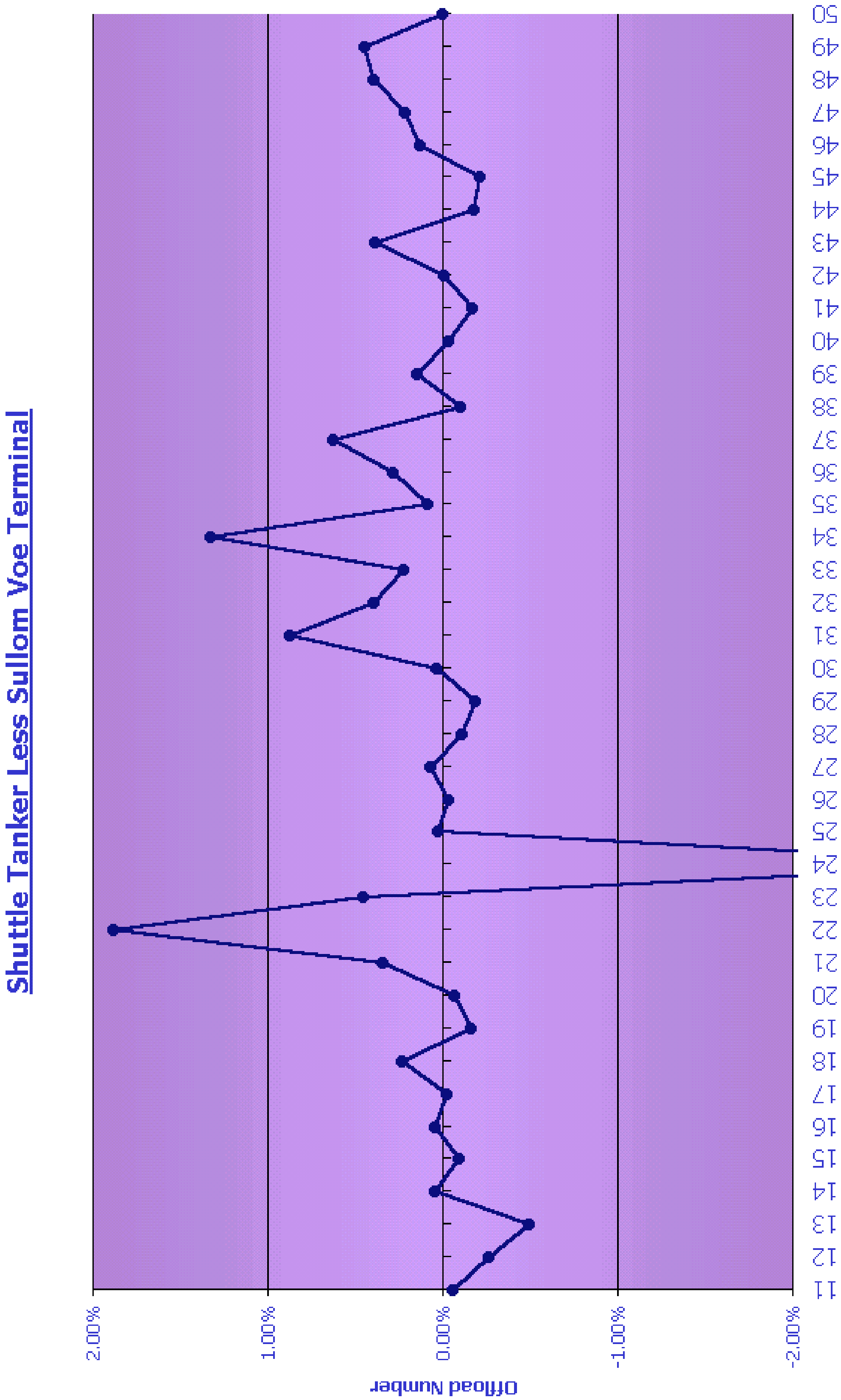
Offload	FPSO Less SVT	Shuttle Less SVT	Shuttle Less FPSO
11	-0.10%	-0.06%	0.03%
12	0.15%	-0.26%	-0.41%
13	0.29%	-0.50%	-0.78%
14	0.07%	0.04%	-0.03%
15	-0.27%	-0.10%	0.18%
16	-0.36%	0.04%	0.41%
17	-0.02%	-0.03%	-0.01%
18	-0.16%	0.23%	0.39%
19	0.27%	-0.17%	-0.44%
20	-0.64%	-0.06%	0.58%
21	-0.24%	0.34%	0.58%
22	-1.38%	1.88%	3.31%
23	0.23%	0.45%	0.22%
24	-1.14%	-3.36%	-2.24%
25	-0.53%	0.03%	0.56%
26	-0.41%	-0.03%	0.37%
27	-0.58%	0.07%	0.66%
28	0.50%	-0.11%	-0.60%
29	0.42%	-0.19%	-0.61%
30	0.38%	0.03%	-0.35%
31	0.82%	0.87%	0.06%
32	0.60%	0.39%	-0.20%
33	0.22%	0.22%	0.00%
34	0.59%	1.32%	0.73%
35	1.39%	0.08%	-1.29%
36	0.07%	0.29%	0.21%
37	-0.03%	0.63%	0.66%
38	-0.66%	-0.11%	0.56%
39	-0.30%	0.15%	0.45%
40	-0.14%	-0.04%	0.11%
41	0.03%	-0.17%	-0.20%
42	-0.09%	-0.01%	0.07%
43	-0.43%	0.39%	0.82%
44	-0.01%	-0.18%	-0.16%
45	0.05%	-0.21%	-0.26%
46	0.28%	0.13%	-0.15%
47	0.49%	0.21%	-0.27%
48	-0.48%	0.39%	0.87%
49	0.13%	0.45%	0.32%
50	-0.45%	0.00%	0.45%
Average Offloads 11 to 50	-0.04%	0.08%	0.11%
Standard Deviation Offloads 11 to 50	0.51%	0.70%	0.79%

Offload 22	(magenta)	Poor start to offload	OpCon 67%
Offload 24	(yellow)	Shutdown in middle of Offload	OpCon 84%
Offload 35	(red)	Slow pumping for 15 hours	OpCon 62%

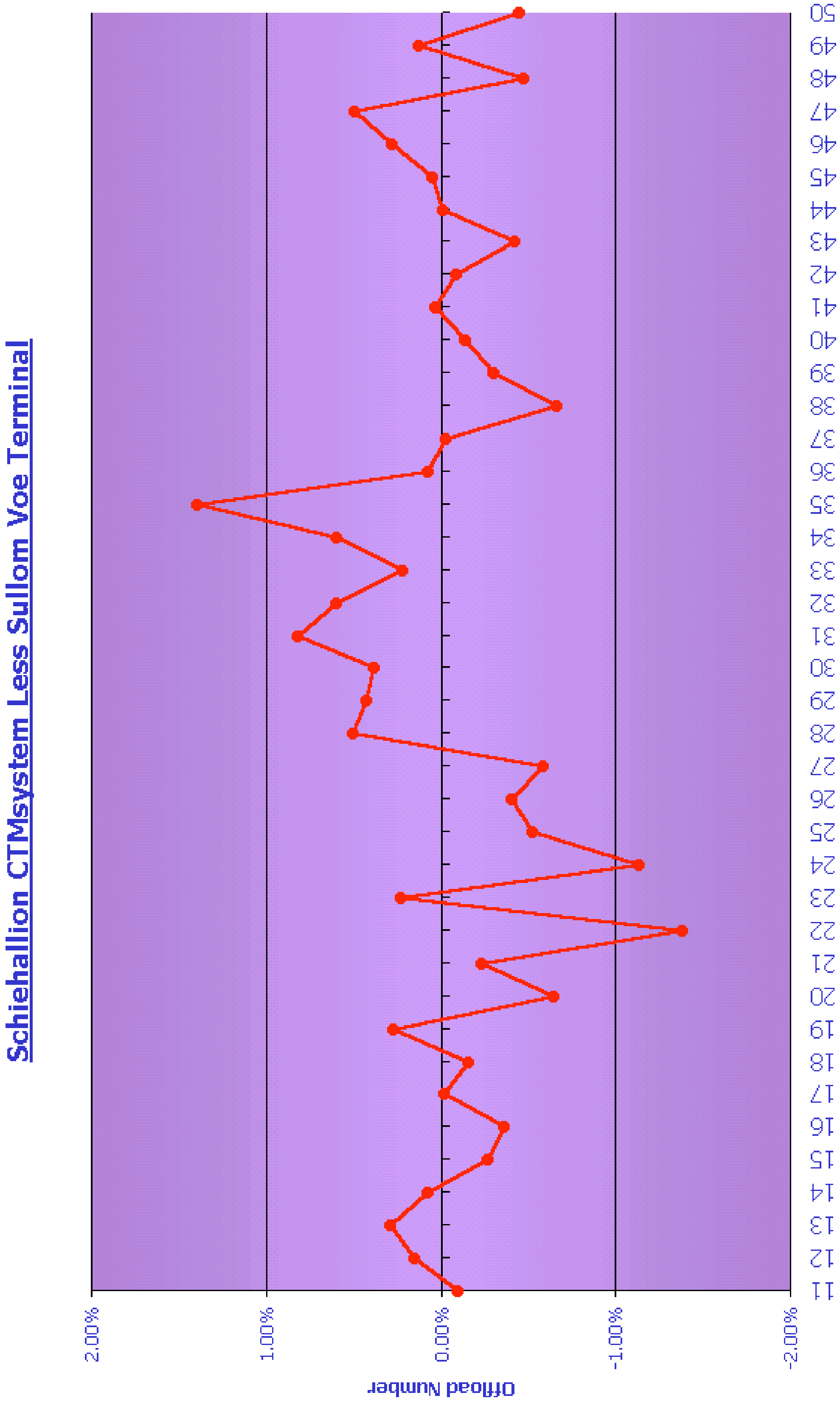
15. Appendix 5 - CTMsystem(tm) & Shuttle Tanker Offloads



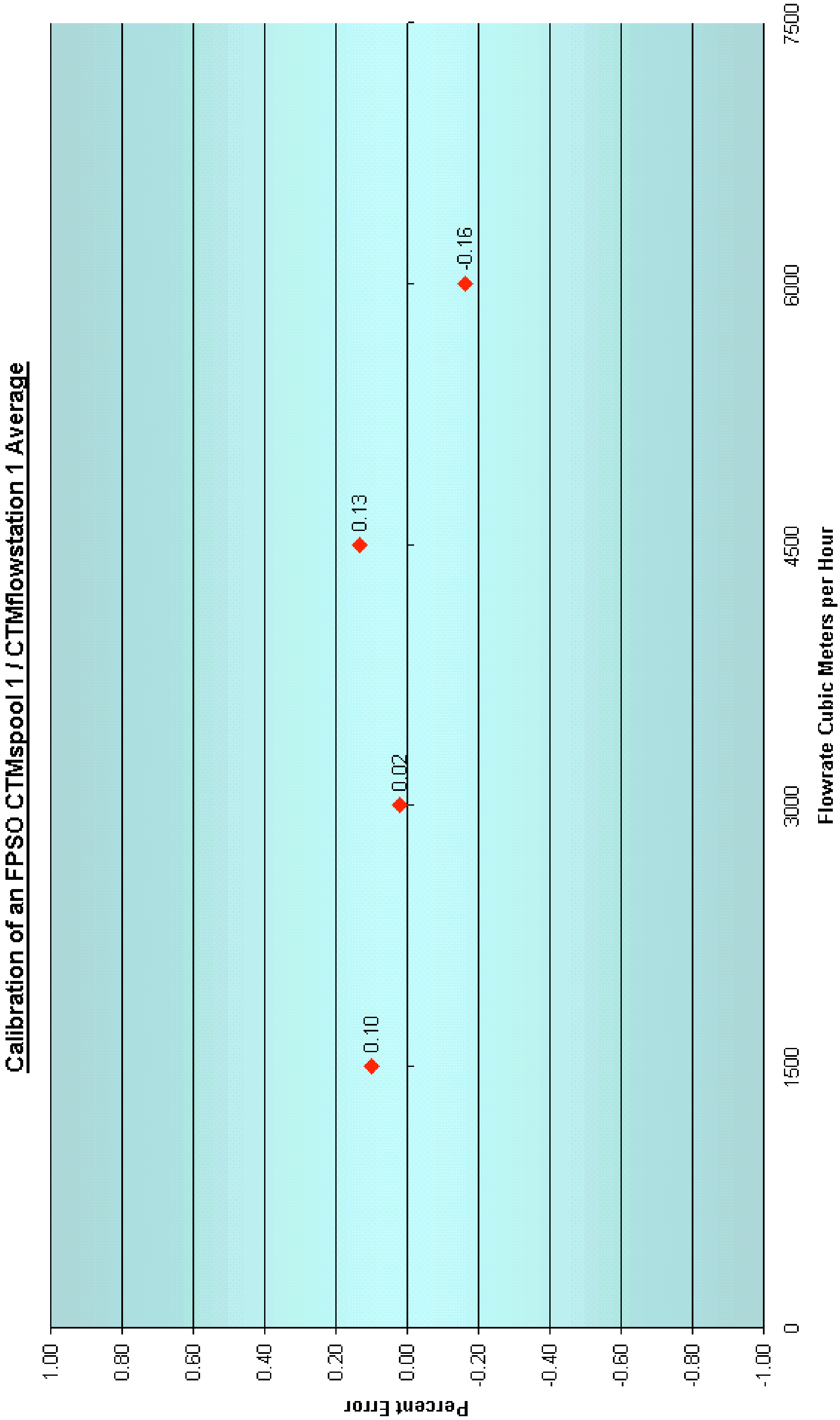
16. Appendix 6 - Shuttle Tanker Offloads



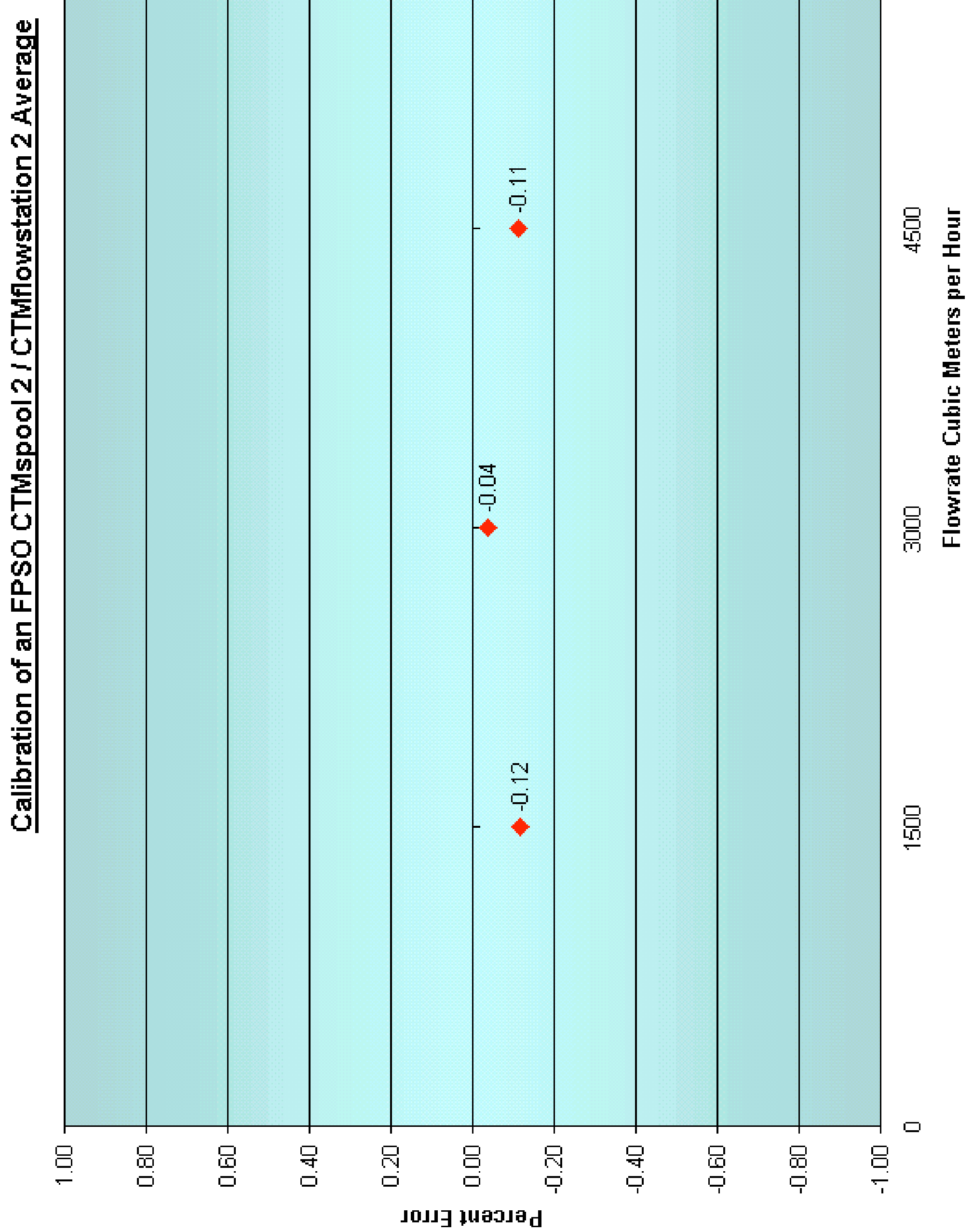
17. Appendix 7 - CTMsystem(tm) Offloads



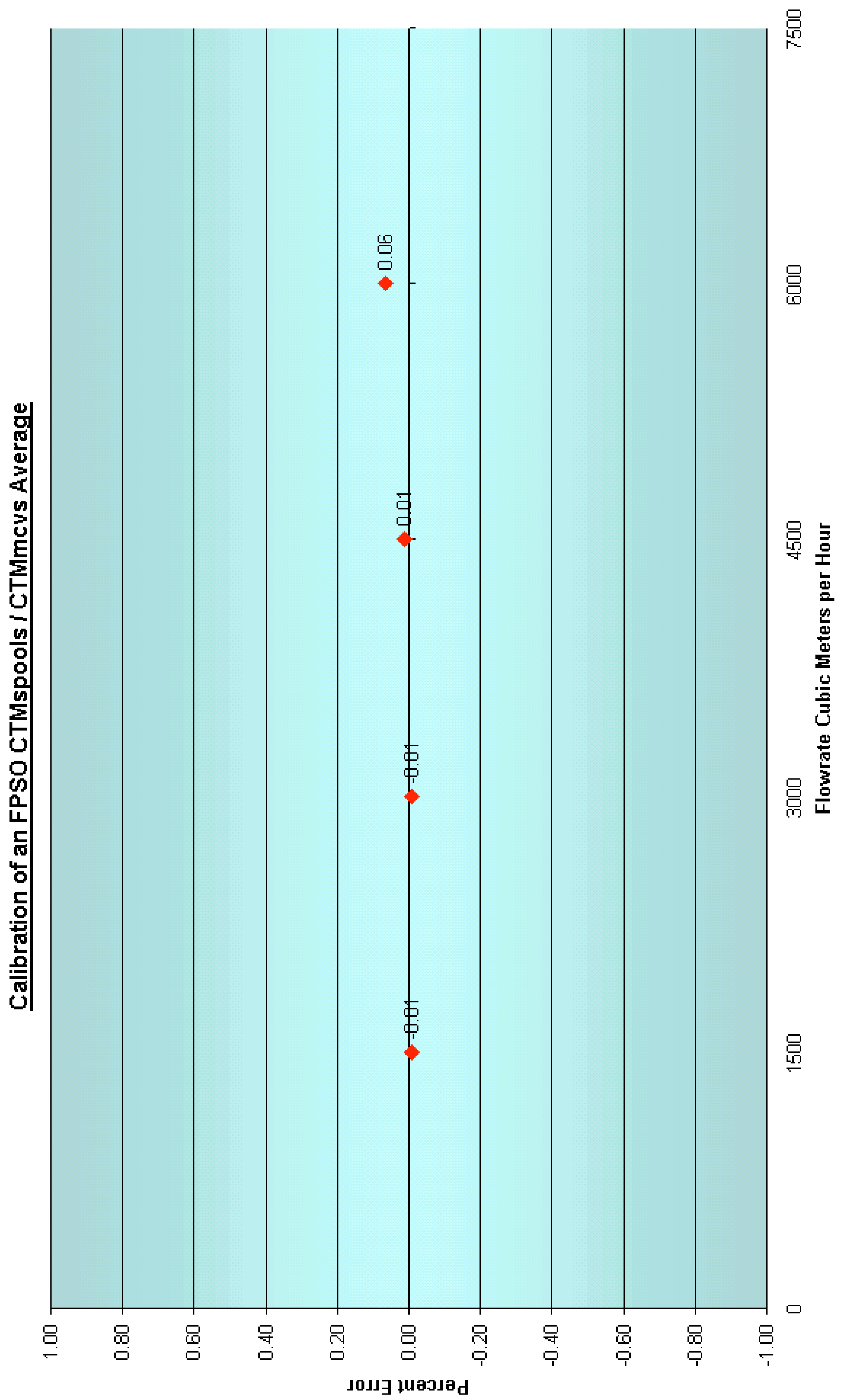
18. Appendix 8 - CTMflowstation(tm) 2 Calibration Average



19. Appendix 9 - CTMflowstation(tm) 2 Calibration Average.



20. Appendix 10 - CTMmcvs(tm) Calibration Average



References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.