"Conventional Heavy Oil Vent Quantification Standards"

Issued: November 2004

Endorsed by Project Participants Representing:

Canadian Natural Resources Ltd.
Exxonmobil Canada Ltd.
Husky Energy
Nexen Inc.

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Vent Quantification Standards
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Contents

General Purpose and Validation of this Standard

Motivation - Provincial regulators require that gas production from all hydrocarbon-producing wells be reported to allow proper management of gas resources. Solution gas volumes associated with oil production are generally reported as a Gas to Oil Ratio (GOR), based on periodic well tests, with the GOR assumed to be relatively constant between tests, and gas volumes are then estimated, or measured and prorated, based on the measured oil production. For low rate heavy oil wells under primary or secondary production the volumes of gas produced and GOR's are not very large in comparison to other types of production, but historically have shown a tendency to fluctuate wildly from test to test. The GOR fluctuations have resulted in a great degree of uncertainty in the reported GOR's, and have also shown a great deal of inconsistency between companies with operations in the same pools, for which solution GOR's should be similar. With increasing pressure to conserve vent gas and minimize greenhouse gas (GHG) emissions, there is a growing need to better understand the vent gas variability and ensure that GOR's reported are representative of the actual volumes being produced. A solid understanding of vent volumes will help to prioritize vent reduction efforts and also to ensure that the most sustainable methods are used to mitigate the vents through balancing environmental, economic and local needs of all stakeholders.

Standard Development Process - This standard was developed through a Joint Industry Project initiated in October, 2002 by Nexen, Inc. and funded by major conventional heavy oil producers: Nexen, CNRL (incl. input from Petrovera), Husky, ExxonMobil. It was developed to address the inconsistencies in vent gas testing and estimating practices between the various heavy oil producers in Alberta and Saskatchewan. The work was conducted by New Paradigm Engineering Ltd, through collection of data from participants and evaluation of the various testing and estimation methods used by producers. It was determined that much of the variation in solution GOR's being reported are mainly due to inconsistent testing and estimating methods between heavy oil producers, as well as variations in gas production behaviour from these wells over the well's producing life.

<u>Disclaimer</u>

This standard is intended as a guide for producer field operations and technical personnel to improve consistency in estimating conventional (non-thermal) heavy oil solution gas volumes that are produced, used as fuel or vented on the well leases. Provincial and other regulations and guides, as revised from time to time, take priority over this document. While the study participants represent major players in conventional heavy oil production, this standard has not been formally adopted by CAPP or any other industry association.

Contact for More Information or to suggest enhancements to these standards:

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1.1 – Regulations and Assessment Standard for Alberta

Objective:

To highlight current Alberta regulations related to conventional heavy oil well vent gas production volume estimation and emissions assessment.

Applicability:

Applicable to all heavy oil producing wells in Alberta where solution gas is not currently required to be conserved or continuously measured for royalty, equity or engineering purposes. Testing is required to:

- Meet provincial regulations
- Ensure that non-solution gas (associated gas) resources are not being lost
- Allow improved decision making for vent mitigation actions
- Allow improved corporate reporting of greenhouse gas emissions

What are the Requirements:

- **Basis** - This standard is based on AEUB Interim Directive ID 91-3 Heavy Oil/Oil Sands Operations with Clarifications
- **Use** - Applies only to vents determined to be Class III in which royalty, equity and engineering concerns do not exist
- **Measurement Accuracy:**
    - +/- 20% for <500m3/d
    - +/- 10% for 500 – 16,500 m3/d
    - +/- 5% for >16,500 m3/d
- **Test Frequency:**
    - Monthly 24 hour test for new wells until GOR's stabilize
    - Annual 24 hour test minimum where gas rate is less than 500m3/d
    - Semi-annually for gas rates between 500 and 1000 m3/d
    - Monthly for gas rates between 1000 and 2000 m3/d
- **Reporting of Vent Volumes:**
    - Monthly Reporting through Petroleum Registry
    - Minimum Report Volume = 100 m3/month
    - Reporting Accuracy = +/- 100 m3/month
- **Other Resources/Information:**
    - AEUB Website – www.eub.gov.ab.ca
    - Latest version of AEUB Guide 60 for Flaring and Venting
    - AEUB Field Offices:
        - Bonnyville; Phone 780-826-5352; Fax 780-826-2366
        - Wainwright; Phone 780-842-7570; Fax: 780-842-7536

Suggested Processes:

- **Database** - Maintain a database of all wells that contains all production information so that compliance can be easily checked and deviations from compliance flagged for action.

- **Data base contents:**
    - Oil Rates – daily volumes
    - Water Rates – daily volumes
    - Vent Gas Rates – daily volumes estimated
    - Fuel Use – daily volumes measured or estimated
    - Gas Exported – daily volumes (should be measured for custody transfer and royalty payments.)
    - Vent Gas Tests – Dates and results of all successful 24-hour tests and reasons for rejection of unsuccessful test.
    - Comments on well vent behaviour
- Include data analysis to flag wells/sites deviating from regulatory minimums or where 24-hour vent gas volumes are not felt to be representative.

1.2 – Regulations and Assessment Standard for Saskatchewan

Objective:

To highlight current Saskatchewan regulations related to conventional heavy oil well vent gas production, volume estimation, and emissions assessment.

Applicability:

Applicable to all heavy oil producing wells in Saskatchewan where solution gas is not currently required to be conserved or continuously measured. Testing is required to:

- Meet provincial regulations
- Ensure that non-solution gas (associated gas) resources are not being lost
- Allow improved decision making for vent mitigation actions
- Allow improved corporate reporting of greenhouse gas emissions

What are the Requirements:

- **Basis** - This standard is based on Minister's Order MRO 827/04 issued September 13, 2004 effective October 1st, 2003.
    - "a minimum test duration of 24 hours to determine the gas rate from the tubing/production casing annulus"
    - 24 hour gas rate plus estimates of gas vented at the tank and gas used for fuel on the lease are to be used to calculate a GOR for reporting
    - A test must take place within 6 months of first production
- **Test Frequency:**
    - Annually < 850 m3/d
    - Semi-Annual 850-3500 m3/d
    - Continuously over 3500 m3/d
- **Measurement Accuracy:**
    - As accurate as possible
- **Excessive Gas Venting** - Within 90 days of a test showing: a) a gas rate greater than 3,500 m3/d and GOR greater than 177 m3/m3, or b) a GOR over 3,500 m3/m3. The operator must either:
    - Shut-in the well

    - Apply for concurrent production status
    - Provide a plan to address the high gas production.
- **Other Resources/Information:**
    - Saskatchewan Industry and Resources Website – www.ir.gov.sk.ca
    - SIR Field Offices:
        - Lloydminster; Phone 306-825-6434; Fax 306-825-6433
        - Kindersley; Phone 306-463-5400; Fax: 306-463-5405

Suggested Processes:

- Maintain a database of all wells that contains all production information so that compliance can be easily checked and deviations from compliance flagged for action.
- Data base contents:
    - Oil Rates – daily volumes
    - Water Rates – daily volumes
    - Vent Gas Rates – daily volumes estimated
    - Fuel Use – daily volumes measured or estimated
    - Gas Exported – daily volumes (should be measured for custody transfer and royalty payments.)
    - Vent Gas Tests – Dates and results of all successful 24-hour tests and reasons for rejection of unsuccessful test.
    - Comments on well vent behaviour
- Include data analysis to flag wells/sites deviating from regulatory minimums or where 24-hour vent gas volumes are not felt to be representative.

2.1 – Criteria for a Successful Test

Objective:

To define the type of 24-hour test result that would be suitable for obtaining a realistic GOR that is likely to be representative of solution gas production until the next test.

Applicability:

Applicable to wells that:

- Are in steady state operating mode
- Have annulus gas production stabilized at a flowrate in excess of 100 m3/d.

Responsibility:

- Operators or third party contractors conducting annulus vent gas measurements to obtain a successful test result.
- Field technical personnel monitoring testing to ensure tests used for reporting and GOR determinations are acceptable.

What are the Requirements:

- **Test Duration** - Minimum 24 hours on test unless an alternate method is approved by the provincial regulator. In all cases the actual test duration MUST be reported to the regulator not just the adjusted 24hr rate.
- **Excessive Venting Limit** - Well should be venting at a total (annulus vent + fuel + tank vent) solution gas GOR lower than 150 m3/m3. If vent rate is higher than 150 m3/d, additional testing is required. (See Standard 2.2)
- **Successful Test** - The profile of the vent gas rate should match behaviour designated as Type A (see example profile below).
    - Readings taken at 15-20 minute intervals
    - 95% of the data points within +/- 5% of the average rate

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Type A – Example average flow rate 694 m3/d. Max=720 m3/d; Min=684 m3/d.

1) Observed in 60% of random tests.
2) Higher percentage of continuous tests.
3) Smooth gas flow.
4) Minimum variation during the test.
5) May have low amplitude cycles; or occasional spikes.
6) Should give consistent test results relatively independent of the test duration.

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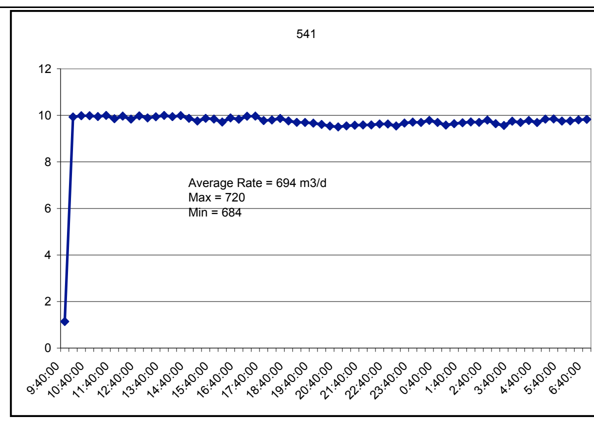

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- **Totalizer Meters** - If the measurement system used for a test is a totalizer meter,gas rates should be measured over 4 consecutive test periods (of 15-20 minutes each) in the first two hours of the test. The tests rates of each of the four test periods should fall with in +/- 5% of the average rate measured over the full 24-hour test period.
- **Failed Test** - If a 24-hour test indicates an average produced gas volume of more than 100 m3/d AND if a Type A gas flow profile cannot be achieved which meets the above, then criteria alternate testing methods are required. (see standard 2.2)
- Test documentation and testing procedure suggestions:
    - Actual duration of the test (hours)
    - Record the stream which was being measured and where else the gas could exit from the well during the test
    - Casing pressures during test
    - If possible, record of flow pattern to determine type (If not Type A see Standard 2.2)
    - Meter type, size and configuration (See Standards 5.1-5.3)
    - What type of equipment the vent gas is providing fuel to. (e.g. engine and size, tank burner(s) and size)
    - If vent gas is normally mixed with an external fuel source, the use of vent gas for fuel should be discontinued for the duration of the test.
    - If only vent gas is being used on a site (all other sources turned off) then this should be noted.
    - Any problems or unusual events during test
    - Pump rpm and size
- **Short Tests** - If a test is not being used for regulatory or corporate reporting, shorter tests of 60-90 minutes length should be acceptable for uses such as spot monitoring for pump operation, or 15-30 minute tests to determine fuel usage as long as conditions are stable and pressures are not affected by testing. Should only be done on wells whose last test successfully met the Type A criteria.

Suggested Processes:

- **Test Record Sheets** – Should be provided to provide a checklist of potential problems, standard well lease configurations used in the area and additional information to be collected on the site to allow the total produced gas rate to be determined.
- **Equipment** - Personnel being requested to carry-out testing should ideally be provided with metering equipment which provides both a visible trace of the data and captures the data digitally for analysis, record keeping and verification.
- **Pre-test Information** – Personnel conducting tests should have a checklist to ensure that the following conditions are met for each well before testing begins:
    - Well has been in stable operation with for at least 2-3 days.
    - Well has not had any other adjustments made to it in the past 2-3 days.
    - Well operators are made aware that testing is underway and to avoid making any adjustments to the well during the test period.
    - If casing gas is being used for fuel that the burner operation is steady. If burner operation is not steady a chart recorder might be used to measure fuel pressure at the burner to assist in estimation of fuel used.

2.2 – Assessing Non-type A Wells

Objective:

To provide guidance on actions to take if the gas rate test on a well does not meet the criteria described in Standard 2.1.

Applicability:

Apply to wells which:

- Are not in steady state operating mode for Cold Heavy Oil Production (CHOP)
- Are new wells
- Do not show Type A behaviour

Responsibility:

Field Technical Staff, Operators or 3rd Party Testers responsible for obtaining reliable well gas test data.

What are the Requirements:

- **Failed Tests** - 24-hour test results from wells not showing Type A behaviour, described in Standard 2.1, cannot be reliably used to obtain a gas rate suitable for use in GOR calculations and estimation of future gas production.
- **Non-Standard Tests** - For these wells alternative test methods are recommended based on the well type and described in Standards 3.1 to 3.4.
- **Backpressure Effects** - Often the volumes measured may be highly sensitive to backpressure and may change radically just by making changes required to put the well annulus on test.
- **Well Behaviour Types** - These wells are characterized into four Types based on produced gas flow profiles over a 24-hour test as follows:

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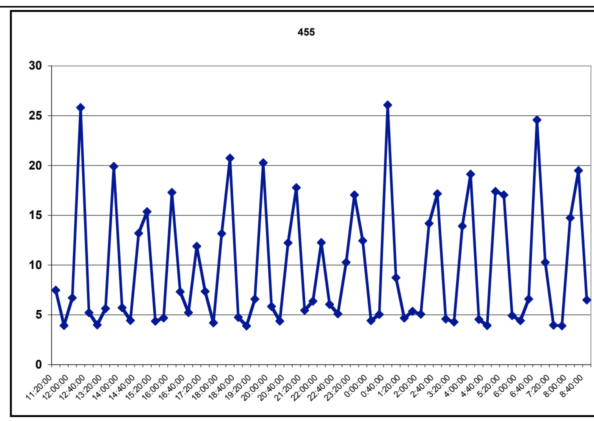
<td>Type B – Example average flow rate 708 m3/d. Max=1944 m3/d; Min=288 m3/d
• Cyclic gas flow, with regular cycles of relatively consistent periods of 1-2 hours between peaks and amplitudes of consistent size.
• Key test is average of first half of the test should be close to the average of the second half of the test, otherwise it is a Type D or F
• These profiles may be due to either inflow instability and/or pump off conditions in the well. The concern is that more gas may be emitted from the tank vents while this behaviour is occurring.</td>
<td>
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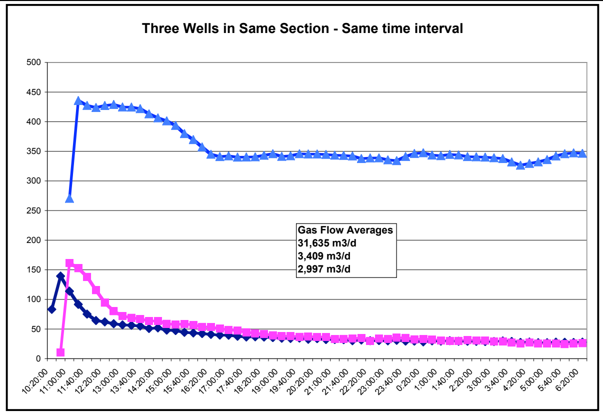
Type C – Examples are three wells at a single pad with rates recorded at the same time.

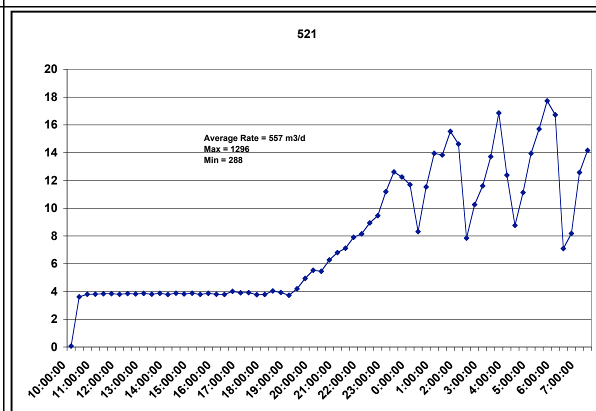
- Well 1 – Average rate 25,635 m3/d; Max=31,680; Min=23,400
- Well 2 – Average rate 3,409 m3/d; Max=11,664; Min=1,728
- Well 3 – Average rate 2,997 m3/d; Max=10,080; Min=1,944
- "Concurrent" production is likely occurring.
- The wells are normally venting into the suction of a compressor system but are diverted to atmosphere for rate testing. This causes a step change in backpressure resulting in an increase in flow before it stabilizes at a new rate.
- Well #1 seems to show effects of higher venting from the other two wells due to the reduction in backpressure and gradual pressure drawdown.

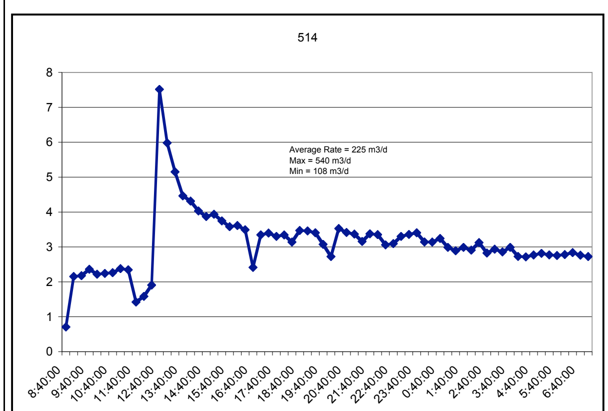


- Our interpretation is that all three wells, and maybe some others are producing gas from a shared gas cap in the area. Once stabilized they look like Type A but will likely have higher than expected GOR's and are unlikely to give consistent tests.

Type D – Generally D wells can look like A, B or C but have transitions in behaviour and gas rates during the 24-hour test.

- Example #1 Average Rate 557 m3/d; Max=1296; Min=288.
- Well transitions from Type A at a low rate to Type B at a higher average rate.
- Change initiated around 6pm so speculated that this may be an increase in pump rpm initiated by operator late in the day.
- Other examples (not shown) seem to go the reverse and transition from B (high rate) to A (lower rate) or B with lower amplitude cycles and lower average gas rate.
- Example #2 Average Rate 225 m3/d; Max=540; Min=108
- Well transitions from Type A at a lower rate to Type A at a 50% higher rate with a sharp spike similar to Type C behaviour.
- Speculation is that some of these might be attributable to operation changes such as a change in pump speed or changes in annulus valves, others may be due to well loading while testing was underway.





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Type F – Example average rate 1,253 m3/d; Max=6,264; Min=0

- Show other gas rate features that indicate gas rate averages may not be representative of "normal" gas flow.
- Example well is from the same pad as the examples for Type C wells.
- These may indicate wells where there is gas phase communication between wells and a slight change in backpressure or operation of one well may cause changes in the gas production from near-by wells. In this case overall GOR for an area may be constant but individual wells may produce more solution gas than others so high GOR may not indicate concurrent production.

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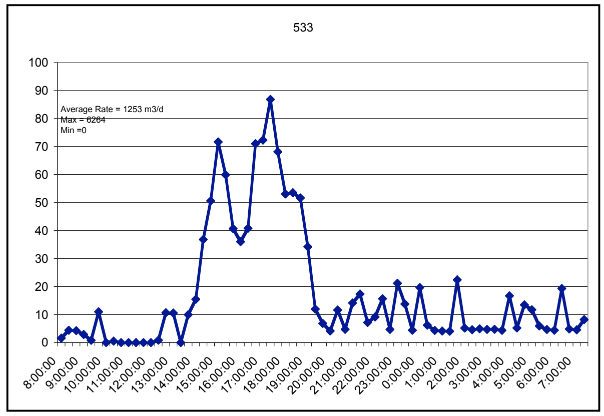

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Suggested Processes:

- **Tester Training** - All personnel testing wells should be familiar with these types of vent gas profiles and should be required to assess the profile Type when they report test data.
- **Pressure Plot** - It was suggested that producing pressure should be plotted (recorded and monitored) to ensure variability is minimized to obtain a good test.

3.1 – Testing Type B Wells

Objective:

To provide guidance for re-testing wells that show Type B gas flow behaviour.

Applicability:

- Wells showing cyclic flow behaviour not attributed to beam pump operation
- Assumption (pending additional field trial results) is that this behaviour represents either:
  - Well Pump Off and that more gas than normal is being drawn through the downhole pump so would exit from the tank vent.
  - Tank Fuel Use where burner cycling is causing changes in gas being vented.

Responsibility:

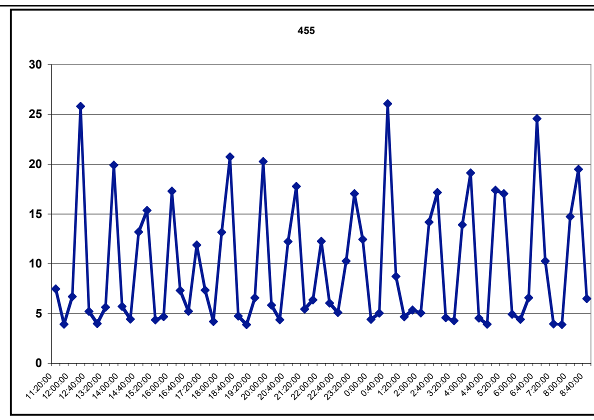
Operations staff to attempt to change profile to allow a successful test, or to carry out additional testing to ensure all the gas is being accounted for.

What are the Requirements:

- **Profile** - Type B wells have a profile as shown below:

Type B – Example average flow rate 708 m3/d. Max=1944 m3/d; Min=288 m3/d

- Cyclic gas flow, with regular cycles of relatively consistent periods of 1-2 hours between peaks and amplitudes of consistent size.
- Key test is average of first half of the test should be close to the average of the second half of the test, otherwise it is a Type D or F
- These profiles may be due to either inflow instability and/or pump off conditions in the well. Concern is that more gas may be emitted from the tank vents while this behaviour is occurring.



- **Cause of Type B Behaviour** - Due to evidence that wells can change between Type B and Type A behaviour over a 24-hour test by increasing production rate, the assumption is that Type B profiles can be converted to Type A by reducing pump speed.
- **Retesting Options** - Suggested options for retesting are to either:
  - **Reduce Pump Speed** - Have operator gradually reduce pump speeds until Type B behaviour disappears or is reduced to where deviation from average is within +/- 5% of the average during a 24-hour test. Allow well production to stabilize for at least 72 hours. Retest well to determine GOR.
  - **Tank Burner** - If tank burner operation appears to be the cause of the cycling, either measure tank burner operating time during the test or switch to an alternate fuel source for the duration of the test.
  - **Other** - If tank burner operation does not appear to be the cause of the

cycling measure tank vents during the test (see Standard 4.3)

Suggested Processes:

- **Plotting Profiles** - To assess gas profiles digital well rate information must be plotted consistently with the rate axis crossing at zero. Otherwise some A wells will show fluctuations.
- **Sampling Intervals** - Time intervals during test must be consistent throughout the test with 15-20 minutes between intervals.
- **Other Potential Causes of Variation** - Ensure that variation is not due to other causes due to equipment, fluids in the measured stream or tank burner cycling. As the exact cause of these behaviours is unknown all potential sources of cyclic behaviour of any equipment connected to the vent gas system or well operation should be reviewed.

3.2 – Testing Type C Wells

Objective:

To provide guidance for re-testing wells that show Type C or high GOR Type A gas flow behaviour.

Applicability:

Applicable to:

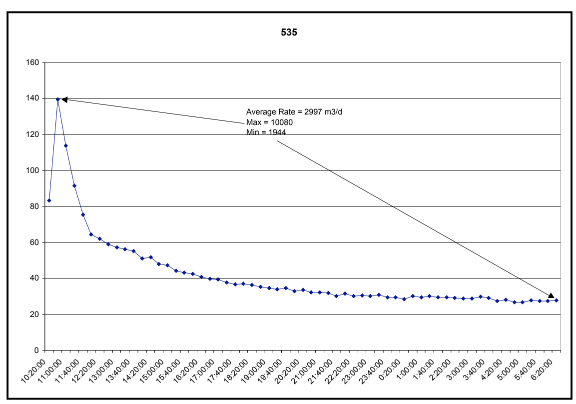
- Wells showing Type C exponential flow behaviour as a result of a sudden change in back pressure.
- Wells showing Type A profiles with GOR's over 150 m3/m3

Responsibility:

Technical staff responsible for area measurement and area management responsible for regulatory compliance.

What are the Requirements:

- Profile - Type C wells have a profile as shown below after a step change downwards in back pressure.
- Continuous Measurement Required - If a well has a significant decline or increase in rate over a period of 1-6 hours after a step change in backpressure then it is likely producing gas from a large, pressurized, gas filled region in the reservoir so is potentially co-production of a gas cap. The well should be on continuous measurement at normal operating conditions as the gas being produced or vented will likely vary significantly and be



independent of oil rate. GOR is not useful for estimating gas rates produced in Type C wells.

- **Test vs. Regulatory Cut-offs** - Even if the average vent rate is less than regulatory cut-offs during a test, higher rates might be occurring when the well is off test.
- **High GOR "Type A" Profile Test Procedure** - If a well, on initial testing has a type A profile (see Section 2.1) but a GOR greater than 150 m3/m3 it should be tested to determine if it is a stabilized Type C. Suggested procedure for testing:
    - Install measurement and recording equipment on the vent to atmosphere so that a flow profile can be generated.
    - While recording, cause a 100 kPa or higher step change in casing annulus backpressure up or down and allow well to stabilize over 6-24 hours.
    - While still recording flowrates, reverse the step change to return to normal operating backpressure.
    - If these changes cause Type C gas flow response then the well should be reviewed by Reservoir Engineers to assess the possibility that the well is co-producing gas cap gas.
    - Well should put on continuous measurement to allow assessment of performance and potential gas sources and appropriate reports made to regulatory bodies.

Suggested Processes:

- **Retesting** - Wells with GOR's from 24-hour tests that are above 150 m3/m3 should be retested as soon as possible to confirm the test is valid.
- **Test Measurement Kits** - Due to the potential for recording error it is recommended that kits provided for 24-hour well testing only contain a limited number of orifice plate options to minimize risk of recording error. For vents to atmosphere orifice sizes of 0.25, 0.5 and 0.625 would provide a reasonable range of orifices for normally expected flows and less likely to result in recording errors. (e.g. easy to confuse 0.25 with 0.75 on a handwritten report).

3.3 – Testing Type D Wells

Objective:

To provide guidance for re-testing wells that show Type D gas flow behaviour.

Applicability:

Applicable to:

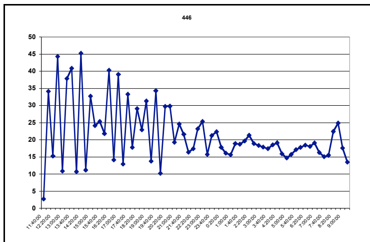
- Wells venting over 100m3/d that show a step change in behaviour during a 24-hour well test.

Responsibility:

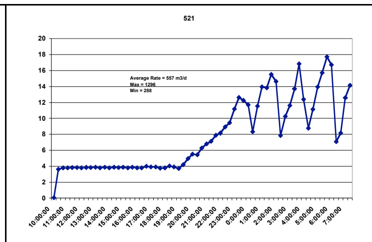
For technical staff responsible for overall well testing quality and operators to improve probability of a successful test.

What are the Requirements:

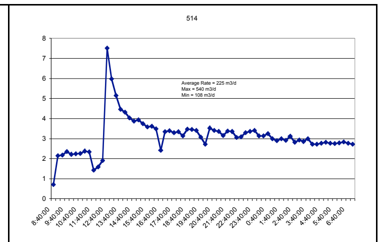
- **Profile** - Type D tests are any tests that show a sudden step change, or transition, in gas flow behaviour, between two types of behaviour, during a 24-hour test. Gas flow is continuous, however, such a change makes it impossible to ensure that the average gas rate represents a normal stable gas flow that could be used to generate a reliable GOR. Examples are shown below:



#446 Avg 1550 m3/d



#521 Avg 557 m3/d



#514 Avg 225 m3/d

- **Cause of Behaviour** - Change is assumed to indicate that an operational adjustment of some type occurred, or was made, while the well was on test. Changes affecting testing might include:
  - Change in pump speed or pump shutdown
  - Change in annulus backpressure due to valve adjustments or compressor operation or shutdown
  - Well loading
  - Chemical addition to well annulus
  - Changes in lease fuel demand
  - Operational changes at nearby wells if they are in pressure communication with the well under test
- **Retest Required** - If Type D behaviour is observed well should be retested for a period of 72 hours, while operators maintain consistent well operation.

Suggested Processes:

- **Well Under Test Signs** - Large, highly visible signs should be placed on a lease when a well is under test to alert operators to avoid making changes while testing is underway.
  - This would avoid unnecessary cost of retesting or wasted time responding to regulators concerns about tests.

3.4 – Testing Type F Wells

Objective:

To provide guidance for re-testing wells that show Type F gas flow behaviour.

Applicability:

Applicable to:

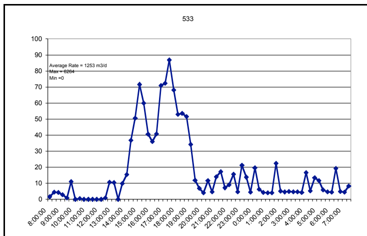
- Wells venting over 100 m3/d that show highly variable flows which do not match patterns exhibited by Type A, B, C or D wells.

Responsibility:

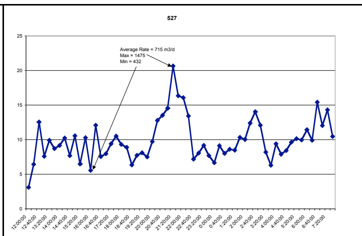
For technical staff responsible for overall well testing quality and reservoir engineers assessing well behaviour and potential of concurrent gas production in an area.

What are the Requirements:

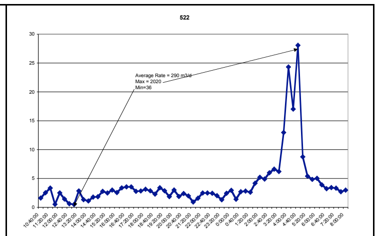
- **Profile** - Type F tests are any tests that show a sudden change in gas flow behaviour during a 24-hour test making it impossible to ensure that the average gas rate represents a normal stable gas flow that could be used to generate a reliable GOR. Unlike Type D wells the changes in flow a brief gas surges or reductions in flow for 1-6 hours rather than a transition from one type of stable flow profile to another. Examples are shown below:



#533 Avg 1253 m3/d



#527 Avg 715 m3/d



#542 Avg 290 m3/d

- **Cause of Behaviour** - Unstable behaviour is assumed to indicate that gas and/or oil inflow into the well is being affected by factors that may or may not be controllable. Behaviour changes of this type may be due to:
  - Deterioration of PCP condition, as similar results have been observed in continuously measured wells prior a pump failure and went away after pump replacement.
  - "Trapped" or periodic gas flow into a well from behind the well casing.
  - Metering system problems such as ice build-up prior to freeze-off, problems with inappropriate orifice size or problems with electronic data recording.
  - Gas or oil flow changes in the reservoir due to formation of wormholes or flow communication between wells that might cause periodic gas flows.
  - Short-term changes in flow behaviour triggered by a slight backpressure change when well is put on test.
  - Changes in nearby wells, such as a pump being taken down for repairs or an engine shutdown for maintenance.
- **Retesting** - If Type F behaviour is observed in wells averaging between 100-2000 m3/d well should be retested for a period of 72 hours. Prior to retesting:
  - Pump condition should be reviewed to determine if the poor test might have been due to pump deterioration. If so redo test after the next pump change.
  - Check metering equipment, procedure and ensure retest is unlikely to be affected by liquids production or freezing.
- **High Vent Rates** - If a Type F well tests over 2000 m3/d then it should be considered

for continuous measurement.

Suggested Processes:

- **Test GOR vs. Pool Normal** – If the GOR obtained from a 72-hour test is similar to the pool average GOR then the cause is likely a near well effect, such as gas trapping behind the casing. The longer tests should generate a reasonable average. If stable gas flow is desirable to be able to utilize the vent gas for fuel consideration could be given to adding some perforations higher in the well to reduce gas trapping potential and stabilize the flow.
- **Non-Reproducible Test Results** – Because of Type F flow behaviour it may not be possible to obtain reproducible tests from these wells. The intent of the longer, 72-hour test, is to obtain a more representative average but continuous measurement may be a better option. It is assumed that the number of wells showing Type F behaviour will be low, and that any variation of this type that is not caused by pump deterioration or metering problems will be due to changes in reservoir behaviour in older producing wells where oil rates are low and the impact of an error in GOR would be reduced. If a particular operating area has a tendency to have larger numbers of Type F wells then other options such as continuous testing, more frequent testing, or grouped well testing should be considered to improve reproducibility of testing.
- **Follow-up** - Internal studies could be conducted to determine if there is any correlation between frequency of Type F tests vs. pump run time. Gas flow may provide an indication of pump condition and pump efficiency and allow prediction of pump failure.
- **Grouped Well Testing** - In pools where there are wells showing Type C or Type F behaviour or interwell pressure communication, consideration might be given to testing groups of wells at the same time. The gas volumes measured for the group, and the GOR determined for the group, would be more likely to be representative of the normal GOR for the area than individual well tests.
- **Minimum Disturbance** - Conducting well tests with minimum disturbance of the well annulus pressure is desirable to avoid causing a short-term instability in gas flow.

4.1 – Direction of Testing

Objective:

To outline a standard process and procedures for planning, initiating, directing reporting, and responding to testing of heavy oil vent streams.

Applicability:

Applicable to all non-thermal heavy oil producing wells in Alberta and Saskatchewan.

Responsibility:

Area personnel responsible for planning testing of heavy oil wells in a particular operating area.

What are the Requirements:

- **Documentation of Process** - A process for ensuring that required testing is undertaken when needed, and that the results are clearly documented as required by regulations and for reliable estimation of gas volumes produced, used for fuel, vented or flared. Process should include:
  - Statement of corporate policy clearly stating that all regulatory requirements are to be met, and that volumes reported should be representative of actual volumes produced, used or vented
  - Responsibilities for individuals, clearly laid out for all steps in the measurement and reporting process for each operating area, including but not limited to:
    - Selection of metering equipment to be used, design of the meter run and procedures/instructions for it's use for each type of lease piping configuration in the area.
    - Initiating and coordinating testing activity
    - Actually carrying out the testing at each well
    - Estimating non-measured streams such as fuel use and tank vents
    - Assessing unsuccessful test results and directing follow-up actions
    - Calculation of a representative GOR
    - Reporting test results for internal, external and regulatory purposes
    - Follow-up actions with regulators if a regulatory trigger is reached based on GOR, volume or economic assessment indicators
- **Application of the Standard** - The requirements for this standard only apply to meeting Regulatory needs, although the test results can be used for other purposes.
- **Non-Regulatory Testing** - If a test being conducted for business or operational needs (i.e. not a 24-hour test) indicates a gas flow rate, which would trigger regulatory action, then the well should be retested as soon as possible utilizing regulatory test standards.

Suggested Processes:

- **Maintenance of Standard Procedures** - Each company and operating area should generate and maintain standard procedures for non-regulatory testing to meet various business and operational objectives. Regulatory testing should be used as part of the process to validate less rigourous testing conducted to meet other needs.

- **Test Data Management** - A computerized well test tracking system should be developed to help flag when tests are due, and to track past testing results. Ideally this system should be integrated with production reporting of oil, water, gas disposition, outside fuel use, and other factors that might affect test planning.

4.2 – Adjustments for Fuel Use

Objective:

To ensure that methods of estimating produced gas used for lease fuel produce reasonable estimates.

Applicability:

Applicable to all sites where vent gas is used for fuel on the leases (for tank, engine fuel or both) and not continuously measured.

Responsibility:

Field technical staff and personnel carrying out field testing.

What are the Requirements:

- **Quality of Estimations** - The accuracy and consistency of estimation of the volume of produced gas will decline as the number and type of non-measured stream(s) involved in the calculation increases. For regulatory testing to determine well GORs the following streams should be acceptable for measurement:
    - Total casing gas from a single well is the preferred stream so that estimates for fuel use will not impact produced gas volume or GOR calculations.
    - Measuring an individual well's vent to atmosphere is acceptable for test purposes only if:
        - The site vent gas fuel demand is stable with any tank burners in continuous operation at a consistent and representative firing rate during the test
        - The production casing gas is being used as fuel in tank heater(s) and/or an artificial lift drive engine dedicated to producing the well under test, and
        - The fuel system using vent gas is not open to other fuel sources during the test.
- **Estimation of Fuel Gas Streams** - Even if the total produced gas stream is measured, fuel use estimates are still required for determining vented and consumed volumes. In order to obtain a GOR value suitable for calculating total gas volumes produced, vented and consumed between tests, fuel use estimates must be based on defendable estimating methods and realistically linked to fluid production levels and operating practices for each well. Acceptable methods for determining produced gas used for fuel are:
    - Direct measurement

- Fuel use by difference (Total produced minus total vented)
- Empirical data from fuel use measurement vs. fluid production
- Calculation based on volumes and process conditions
- Calculation based on manufacturers calculations with load

Suggested Processes:

- **Development of Fuel Use Factors** - Shorter spot tests to develop empirical fuel use relationships for tanks and engine drives vs. fluid production in a given area and well configuration, are likely going to be the easiest and lowest cost method to use. Factors can be adjusted if more data is gathered or conditions change. Assumes consistent operating practices between wells.
- **Fixed Rates Based on Equipment (Not Recommended)** – Some producers have in the past used a fixed fuel gas volume per equipment unit of a given type on the lease. This practice should not be used as it tends to over-estimate GOR if the vented stream is normally measured or under-estimate gas vented if the total vent gas stream is normally measured.

4.3 – Adjustments for Tank Vents

Objective:

To provide direction for estimating gas volumes which might be emitted from lease tank vents.

Applicability:

Applicable to:

- Tanks that do not have vapour recovery systems to collect tank vapours
- Tanks receiving production from a single producing well

Responsibility:

Area technical staff.

What are the Requirements:

- **Tank Vents Normally Not Measured** - In most cases gases from tank vents are not routinely measured and are often not of major interest to regulators unless odours are emitted.
  - For most of the well's producing life tank vent volumes are likely low (less than 5% of total flow), cause few, if any odour problems and the major concern is estimating greenhouse gas emissions.
  - An exception is believed to be the early phase of Cold Heavy Oil Production with Sand (CHOPS), which lasts from 1-6 months from production start. In this case it is believed that most of the solution gas will be produced with the oil in the form of a stable foam which requires tank heating to breakdown.

- **Inclusion of Tank Emission Estimates** - Tank emissions should be included in GOR calculations. Pending further testing and tank vent measurement the following methods should be used to estimate tank vent volumes, based on the phase of well production:
    - **Early Phase** – Assume total gas produced from tank vent and casing annulus will be equal to the average GOR of wells in the same pool that show Type A gas flow profiles and have GOR's less than 150 m3/m3.
    - **Established Type A Gas Flow** – Once tests indicate that the annulus is venting at a consistent GOR, based on at least 2 tests, 2 months apart with GOR's within +/- 15% of each other, the tank vent should be assumed to be 5% of the casing annulus gas flow.
    - **Type C Gas Flow Behaviour** – It is unlikely that large volumes of gas can pass through the bottom-hole pump so assume the GOR of the oil entering the tank is 5 m3/m3 of oil.
    - **New Early Phase Wells in New Pools** - In the case of isolated wells or wells in new pools where there is no established GOR, an average GOR from wells in similar nearby pools should be used until a consistent GOR can be established.

Suggested Processes:

- **Pool GOR's** - All areas should calculate a running average GOR for each pool they operate.
- **Tank Vent Measurement Options** - Tank vents could be directly measured by various means, even though this is not recommended on a routine basis due to hazards associated with accessing tank roof vents. To minimize impacts of water vapour in the stream tank vent gas rates should be measured while the tank heater is off. Some potential methods are listed below:
    - **Rotating Vane Anemometers:** Portable hand held units with a rotating vane (impeller blades) that are commonly used in ventillation applications. They measure average true air speed over the sample area and many can calculate volumetric flow rates with a user inputted cross sectional area of the vent. Accurate and direct volumetric flow rate measurement can be achieved by connecting the rotating vane to a flow hood that fits over the vent and directs all the gas flow through the rotating vane.
    - **Rotameters:** Consist of a float, which moves up or down in a vertical, slightly tapered, tube and are a popular flow meter for gas and liquids over wide pressure and flow ranges. They require no straight runs of pipe before or after the point of installation and can read over a tenfold range of flow. One producer has made up a kit with various sizes of plastic fittings that can be connected to a variety of small volume vents that can be connected down to rotameters of different flow ranges until they get a suitable reading.
    - **Gas Meters:** Another approach an instrumentation service company uses incorporates a positive displacement gas meter connected to the vent (similar to a residential gas meter), with a bypass hose line and valve that must be opened when the tank is loaded on to a truck to prevent a vacuum in the tank as the meters only allow flow one way. Some piping and connections are required to ensure that the meter is oriented horizontally.

- **Bag Orifice:** Developed for measuring vents that overcomes the problems normally associated with trying to measure low flow rates and difficult geometries is to use a bag placed over the end of the vent with a known orifice size and a manometer to measure the pressure drop across the orifice allowing the flow rate to be calculated. Based on experimentally derived coefficients for this method the equation $q = 4.25 \times D^2 \times \text{sqrt}(h/\rho)$ can be used where q is gas flow in cu.ft./min, D is in., h is in. of water and ρ is lb./cu.ft. (Measuring Flow through Vents, Chemical Engineering Shortcut Book, Jonathan R. Smith). The bag size should be large compared to the orifice diameter, to prevent tearing or flapping. The orifice should be sized so that a differential pressure reading of 1 – 4 in. is obtained – lower is hard to measure and higher will tend to blow the bag off. If a rough estimate of flow is known the hole diameter, in., necessary to give a pressure of 2.5 in. of water is approximated by $D = .21 \times \text{sqrt}(q)$. The manometer probe should project slightly through the bag wall so that the axes of the vent pipe, the bag orifice and the probe end are all perpendicular. The orifice diameter should be measured during operation.
- **Velocity traverse using standard stack/duct sampling procedures:** Performed using either thermal air velocity meters (thermal anemometers) for low velocity flows (down to .01 m/s), or a manometer and a pitot tube for moderate to high velocities (above 5 m/s recommended). These two instruments measure the air velocity at one point, so several measurements must be taken to determine an average air velocity, otherwise known as a velocity traverse. There are standard accepted methods for doing this published by regulatory bodies and standards organizations – explanations are often available from the instrument manufacturers. Once the average air velocity is determined it is multiplied by the cross sectional area and in some cases a correction factor (if known for better accuracy) to determine a volumetric flow rate.

4.4 – Calculation of GOR

Objective:

To ensure that GOR's calculated from gas flow tests and oil production volumes are representative of actual GOR's.

Applicability:

Applicable to wells:

- Where gas flow is not continuously measured
- Where produced fluids are trucked and volumes calculated from truck tickets and tank gauging.

Responsibility:

Area technical staff analyzing field data for regulatory reporting.

What are the Requirements:

- **Oil Rates** – Oil rates used for GOR calculations must be:
  - Representative of average fluid production during the period of the gas test.
  - Accurate to at least one decimal point. i.e. 10.2 or 2.1 m3/d. (This is especially needed at low oil rates as most wells will be below 10 m3/d and a difference of 1 m3/d in oil rate can significantly change the calculated GOR on low rate wells.)
- **Determining Average Oil Rate** - Average oil rates should be calculated based on one of the following methods:
  - Tank gauging during the gas flow test if tank gauge is calibrated in 0.1 m3 increments.
  - Tank level indication using a diaphragm type indicator with output to the nearest 0.1 m3.
  - Average oil production volumes as calculated from tank gauges calibrated to the nearest 1 m3 and truck ticket volumes for a period of 10 days of stable oil production that includes the 24 hour gas test on the well.
- **Water Cut** - The water cut used for production accounting in the same period as the gas test, should be used to adjust tank fluid volumes to allow GOR calculation.
- **Consistent Application** - Once a method of calculating GOR is established, the same process should be implemented for all similar producing wells.

Suggested Processes:

- **Suggest Oil Rate** – Consistently using the 10 days of production prior to a gas flow test is likely to provide the best results as the oil rate selected would not be biased by the gas rate indication or any potential well operating adjustments which might be triggered by the gas test.

5.1 – Metering System – Orifice Meter

Objective:

To define minimum requirements for orifice metering equipment and flow calculations.

Applicability:

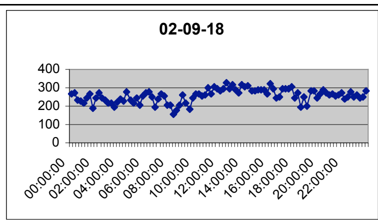
Applicable to operations where orifice meters are the preferred method of produced gas measurement.

Responsibility:

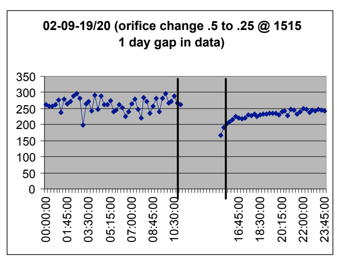
Technical staff selecting metering equipment and calculating gas flowrates from test results.

What are the Requirements:

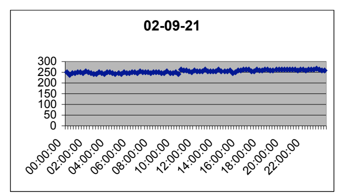
- **Minimal Disruption to Flow** - System should be designed to minimize gas flow disruption or annulus backpressure during installation of metering equipment for a test while still allowing sufficient differential for an accurate test.
- **Minimum Differential Pressure** - Differential pressures across the orifice should be at least 5 kPa. Example below shows the impact of a change of orifice for the same well being continuously measured over 4 consecutive days. At differentials less than 1 kPa temperature effects on equipment and changes in atmospheric pressure during the 24-hour test can negatively impact the accuracy of the readings.



Well at a flowrate of between 200-300 m3/d. 0.5” orifice. Differential pressure recorded <1 kPa.



Orifice change from 0.5”on the left to 0.25” on the right.



Well flowrate 250 m3/d. 0.25” orifice. Differential pressure recorded 7-10 kPa.

- **Downstream Static Pressure** - At low pressure differentials, during measurement of vent streams at near atmospheric conditions, changes in atmospheric pressure with elevation or daily variation can become significant. E.g. if static atmospheric pressure is assumed to be 14.7 psia (100 kPa) actual atmospheric pressure may be 13.4 psia (91 kPa) at 800 m above sea level which would cause a 10% increase in gas volume if this is not adjusted for.

Suggested Processes:

- **Trace Readout** - To allow personnel doing testing to monitor well Type and identify bad tests a local chart or display of the test is preferred. To allow analysis of results by technical staff a digital output is preferred. Therefore equipment selected should allow for both a visual display of the flow profile during testing and a digital record.
- **Orifice Selection** - To avoid confusion with orifice size it is recommended that only

three orifice plates be provided in heavy oil produced gas test kits. Orifices of 0.25", 0.5" and 0.625" should provide an acceptable range for almost all non-Type C wells and avoids potential confusion on plate size (e.g. 0.25 and 0.75 could be confused).

- **Accommodating Tests** - Ideally valves and fittings should be installed so that meter run can be set up on a bypass loop around a manual block valve.

5.2 – Metering System – Diaphragm Meter

Objective:

To define minimum requirements for diaphragm metering equipment and flow calculations.

Applicability:

Applicable to operations where diaphragm meters are the preferred method of produced gas measurement.

Responsibility:

Technical staff selecting metering equipment and calculating gas flowrates from test results.

What are the Requirements:

- **Digital Data** - To allow determination of gas flow characteristics or flow type, the diaphragm meter must collect data digitally rather than just totalized data.
- **Manual Profile Generation** - A totalizing meter is not acceptable unless personnel undertaking the test also record volumes produced over a series of four fixed (15-20 minute) intervals at the start of the test and the rates calculated for each of these intervals should agree with the other three intervals and the overall mean rate obtained over the 24-hour test period.

Suggested Processes:

- **Equipment Options** - Diaphragm meters should be purchased with digital data collection.

5.3 – Metering System – Rotary Meter

Objective:

To define minimum requirements for rotary metering equipment and flow calculations.

Applicability:

Applicable to operations where rotary meters are the preferred method of produced gas measurement.

Responsibility:

Technical staff selecting metering equipment and calculating gas flowrates from test results.

What are the Requirements:

- **Digital Data** - To allow determination of gas flow characteristics or flow type, the rotary meter must collect data digitally rather than just totalized data.
- **Manual Profile Generation** - A totalizing meter is not acceptable unless personnel undertaking the test also record volumes produced over a series of four fixed (15-20 minute) intervals at the start of the test and the rates calculated for each of these intervals should agree with the other three intervals and the overall mean rate obtained over the 24-hour test period.

Suggested Processes:

- Equipment Selection - Rotary meters should be purchased with digital data collection.