SGS UPSTREAM SERVICES ADDS UP

SGS OIL, GAS AND CHEMICALS SERVICES

SAMPLING IN GAS WELLS: CHALLENGES & CONCEPTUAL SOLUTIONS

SMS®

WHEN YOU NEED TO BE SURE

SGS

SAND SERVICES – MEETING AGENDA

- Challenges
- Operator Issues
- Basic Sand Sampling
- Sand Services
  - Side-stream Sandbox
  - Setting Up of Sandbox
- Oil Wells Sand Sampling
- Gas Wells Sand Sampling
- Gas Well Sand Profiling
- Onsite & Offsite Analysis
  - PSD via LPSA / JM Canty
  - QEMSCAN / XRD/XRF
- SMS Oilfield – Acoustic Sand Sensor
- Sample Report
- Other Sand Services
  - In-Situ Sand Injection
  - Sand Screen Retention Testing
  - Wall Thickness Measurement (SMS)

CHALLENGES

- Sand is found in vessels, but standard sampling practices for gas wells are not able to capture sand?
- Acoustic Systems not always showing sand production or estimated production doesn't match up with what is found in facilities…
- What can we do?...

OPERATOR ISSUES

- Unable to find competent personnel or service providers
- Level of risk too high to attempt (gas leak/gas volume)
- Sampling representativeness questionable
- Lack of vessels (facilities) in the process system to capture solids or sand at full bore level or at individual well level

BASIC SAND SAMPLING CONCEPTS

Sampling is a method for obtaining representative samples of solids from a well or process stream. If taken regularly samples can also be used to estimate the quantity of solids produced over time. It can then be analysed to determine composition and grain size. However, to be effective it is essential that suitable sampling locations, equipment, procedures and analysis are utilised. Difficulties with sampling which is it is only representative of that moment in time, therefore without real time monitoring it is very difficult to understand if the sample is representative.

- Ideal sampling locations should be along a horizontal section of pipe from a 6 o'clock sampling point.
- Sand samples taken from a turbulent flow are more representative thus sand sample points located downstream to a turbulent point such as valves, reducers, elbow/bend will imply likely representative samples. For Gas Wells this is even more challenging and often a probe will need to be inserted for isokinetic sampling.
- Take multiple samples to obtain more accurate representation.
- Volumes or weight of sand or solids collected must be recorded.
- Well details, sampling time, sampling location must be labelled on the sample bottle.
- Conduct PSD analysis to determine if sample sizes are larger than downhole screen size as this indicates downhole sand control failure.
- PSD analysis on sand samples is also used to determine accurate erosion rates and sand drop out (deposition calculations).

APPLICATION – CLIENT A

Well: XX-1

Filter ID	Filter Size (µm)	Date	Start Time	End Time	Choke Size (%)	Tracer Liquid Production Rate, Q_ℓ (bbl/d)	Sand Weight (g)	Sand Rate (kg/d)	Remarks
1	5	10-05-18	17:15	17:45	24%	255.59	0.1260	0.8533	1st run
2	5	10-05-18	18:15	20:15	24%		0.0729	0.1277	2nd run
1	10	11-05-18	15:00	17:00	24%		0.4130	0.7297	1st run
2	10	11-05-18	17:35	19:35	24%		0.1349	0.2394	2nd run
6	5	13-05-18	13:40	15:40	29%	N/A	0.1364	N/A	Highest Rate

*Sand Rates are computed using the liquid flowrates from tracer exercise.

Well: XX-2

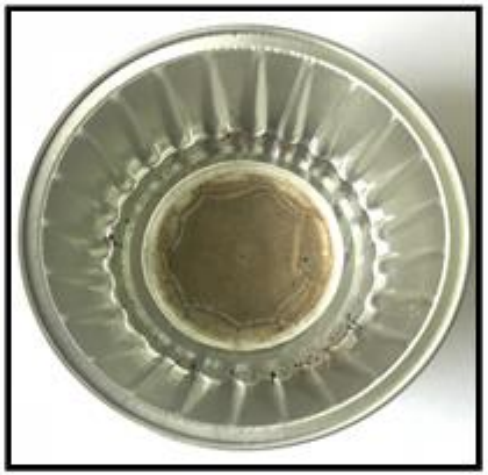
Filter ID	Filter Size (µm)	Date	Start Time	End Time	Choke Size (%)	Tracer Liquid Production Rate, Q_ℓ (bbl/d)	Sand Weight (g)	Sand Rate (kg/d)	Remarks
5	5	13-05-18	08:45	10:45	44%	N/A	0.5122	N/A	Highest Rate

Well: XX-3

Filter ID	Filter Size (µm)	Date	Start Time	End Time	Choke Size (%)	Tracer Liquid Production Rate, Q_ℓ (bbl/d)	Sand Weight (g)	Sand Rate (kg/d)	Remarks
3	5	12-05-18	10:05	11:05	26%	213.66	0.0194	0.1648	1st run
4	5	12-05-18	11:25	12:25	26%		0.0187	0.2117	2nd run
3	10	12-05-18	12:55	13:55	26%		0.0295	0.1822	1st run
7	5	13-05-18	18:50	20:50	42%	N/A	0.1393	N/A	Highest Rate

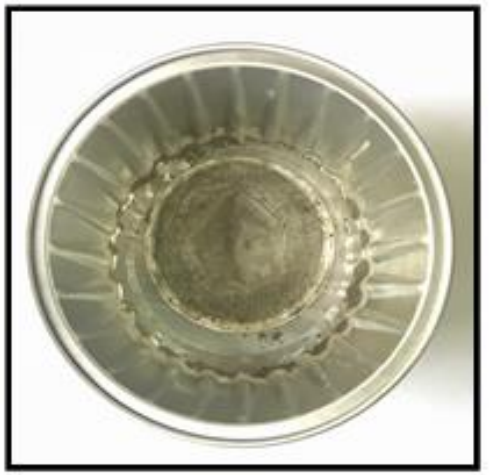
*Sand Rates are computed using the liquid flowrates from tracer exercise.

SAMPLES COLLECTED



Filter ID-1 5µm (1st run)

Filter ID-2 5µm (2nd run)



Filter ID-1 10µm (1st run)

Filter ID-2 10µm (2nd run)

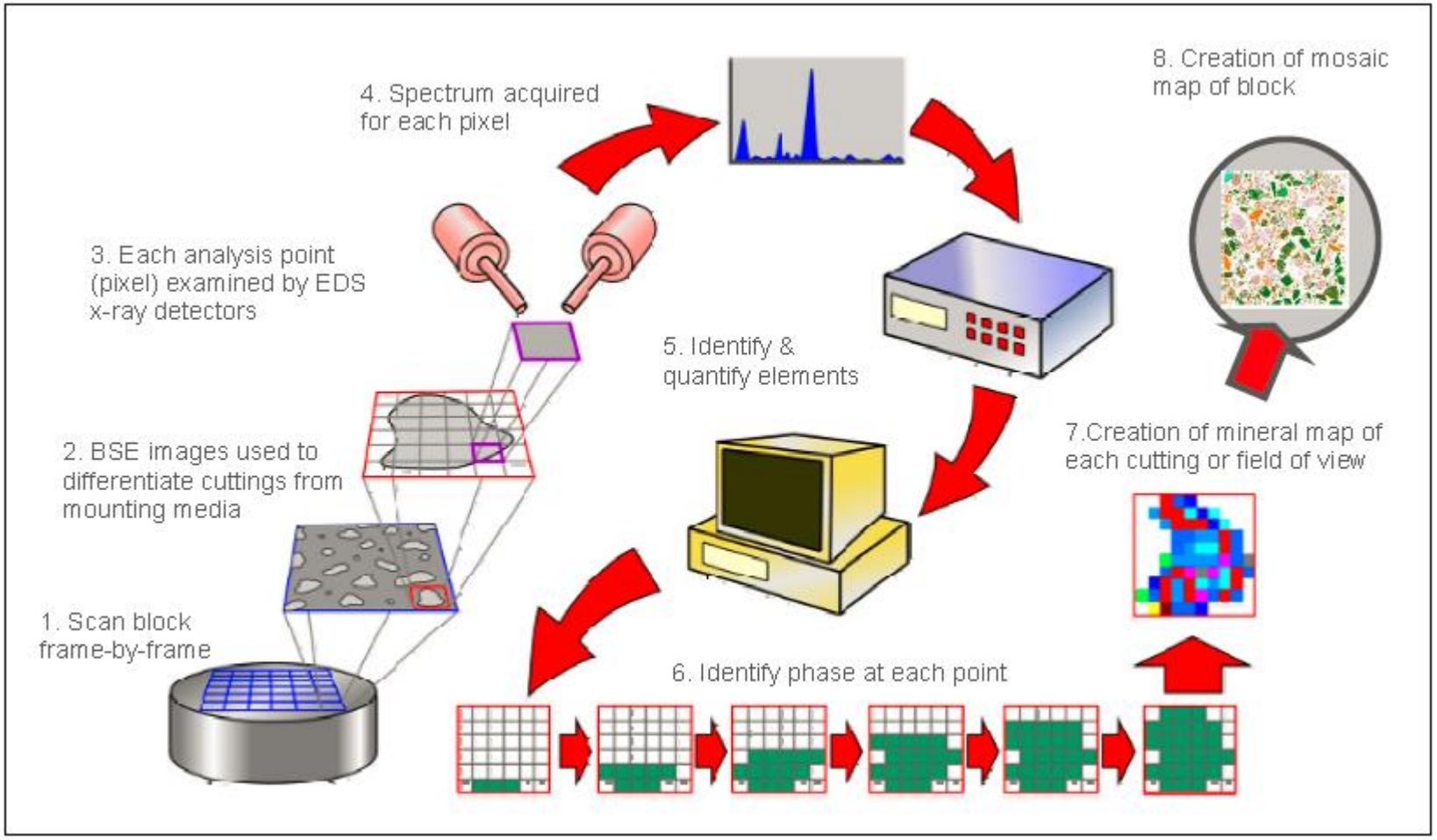
Filter ID-6 5µm (Highest Rate)

< 1g samples in every run, unable to perform XRD / XRF to determine the composition where it requires a minimum of 50g.

ARQS – WHAT IT IS?

- ADVANCED RESERVOIR QUALITY SERVICES
- The analytical methodology used scans the electron beam over the sample at a pre-determined stepping interval;
- At each step a mineralogical determination is made based on the resultant BSE and X-ray signals. This results in a mineralogical “image” of each particle with a resolution equal to the beam stepping interval.
- For this study, measurements were set up to optimize both textural and modal mineralogical information and so the samples were analyzed at a beam stepping interval (resolution) of 10 microns.
- Using the QEMSCAN image analysis software (iDiscover), all of the individual Field Image frames were stitched together to form mineralogical images of the samples.

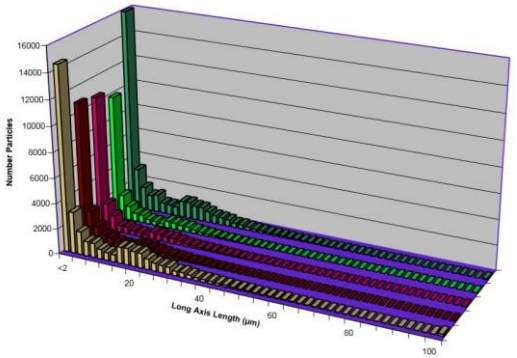
ARQS – ANALYSIS PROCESS MAP

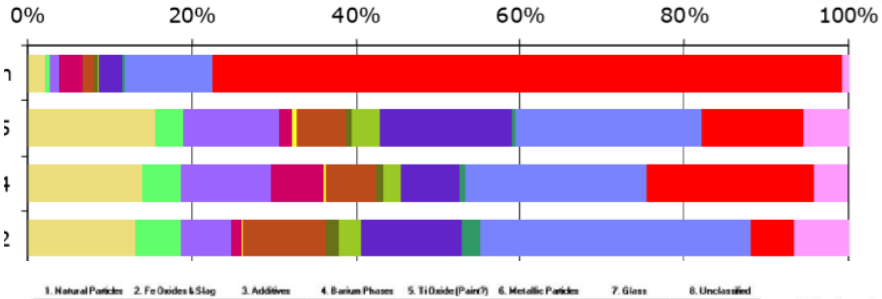


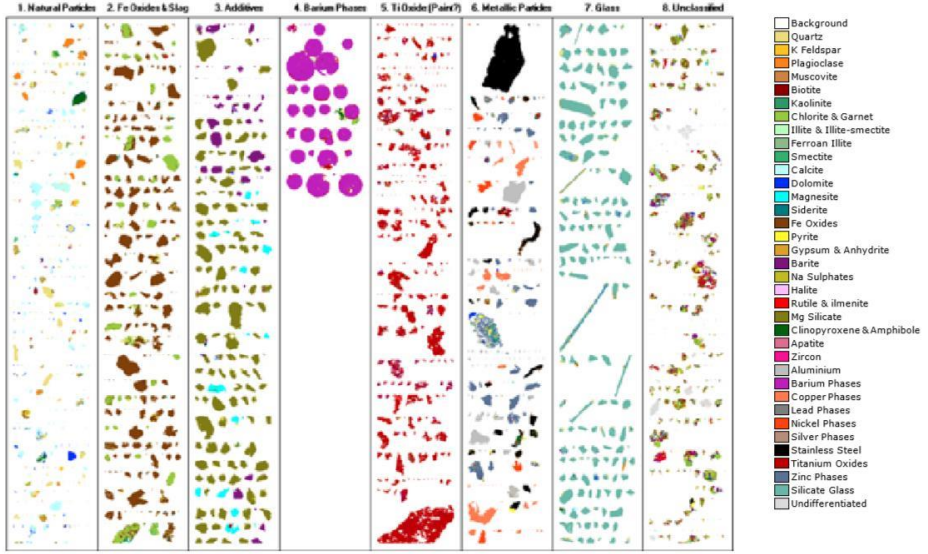
OFFSITE CHARACTERIZATION

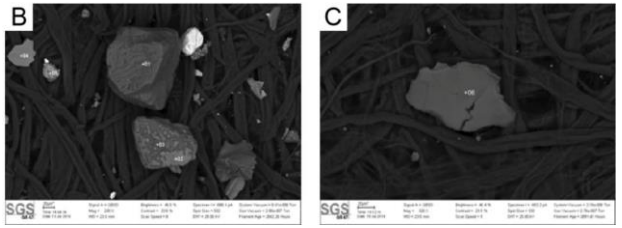
QEMSCAN

- QEMSCAN can provide quantitative bulk mineralogy, mineral size, calculated grain density, and dependant on sample quality, particle size distribution data.
- QEMSCAN combines Scanning Electron Microscopy with EDS-Xray detection combined with specialist analysis software to allow consistent and statistically sound measurement of mineralogy, type and texture.
- Aids in determing the makeup of the sand and any clay effects that may be causing screen issues.







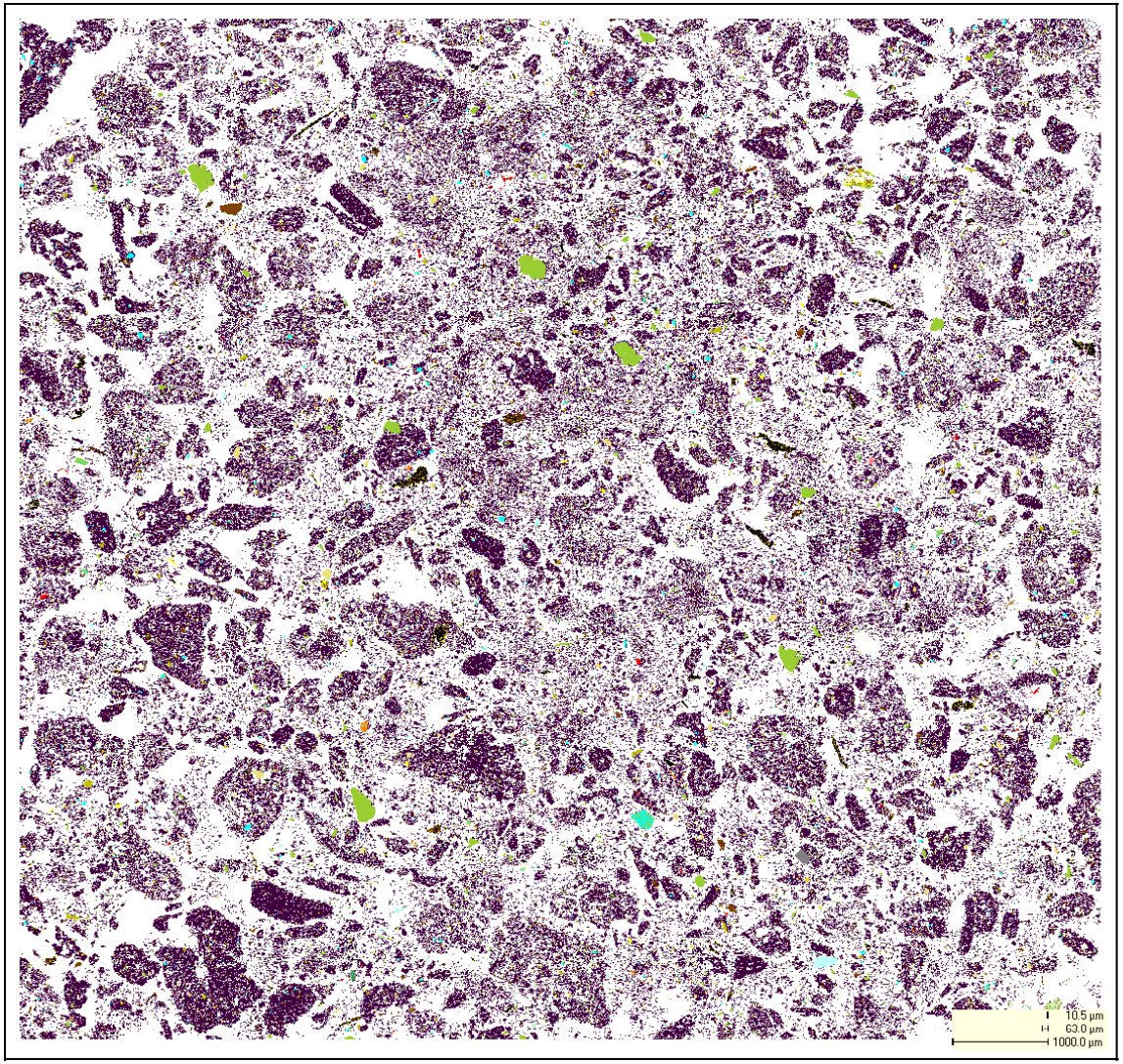


ARQS – SAMPLE PREPARATION

Samples collected at wells

Samples after cleaning and amalgamation

QEMSCAN MINERAL IMAGES: WELL XX-1



Colour	Mineral	Area %
	Quartz	1.8
	K Feldspar	0.1
	Plagioclase	0.3
	Muscovite	0.1
	Biotite	0.1
	Kaolinite	0.2
	Chlorite	3.6
	Illite & Illite-smectite	0.7
	Calcite	0.3
	Dolomite	0.9
	Fe Oxides & Siderite	1.9
	Fe Sulphides	1.5
	Cu Sulphides	0.6
	Zn & Pb Sulphides	0.2
	Barite	85.8
	Anhydrite	0.1
	Rutile & Ti Silicates	0.2
	Apatite	0.0
	Zircon	0.0
	Tungsten Carbide	0.5
	Stainless Steel	1.2
	Undifferentiated	0.0

Well:	A1
Reservoir:	Carbonate Gas Well
Sample Type:	Filtered Solids
Lab ID:	MI8387-JUL18:01
Notes:	Five filters combined

Mineralogical image of a cross section through the sample block showing the shape and mineral composition of the particles.

Major Minerals:
Barite

Minor Minerals:
Quartz, Chlorite, Fe Oxides & Siderite, Fe Sulphides, Stainless Steel

Minor Minerals:
Plagioclase, Muscovite, Kaolinite, Illite & Illite-smectite, Calcite, Dolomite, Cu Sulphides, Zn & Pb Sulphides, Anhydrite, Rutile & Ti Silicates, Tungsten Carbide

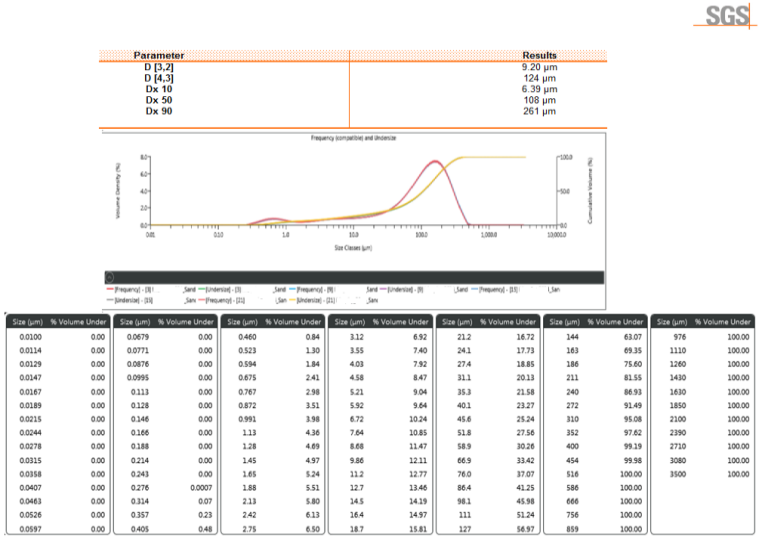
APPLICATION CLIENT - B

No.	Sampling Date	Well	Choke Size (%)	Pipeline			Average Sand Rate, Qs (kgd)
				Press. (psi)	Qg (MMscf/d)	Qc (bbl/d)	
1	9-Nov-18	1	60%	150.0	3.20	503.30	0.032
2	9-Nov-18	2	N/A	200.0	N/A	5.29	24.214
3	10-Nov-18	3	100%	150.0	1.21	851.57	0.012
4	10-Nov-18	4	50%	230.0	11.69	1131.95	0.117
5	10-Nov-18	5	100%	150.0	0.72	301.72	0.007
6	11-Nov-18	6	Well shut in				
7	11-Nov-18	7	100%	200.0	1.20	125.80	0.012
8	12-Nov-18	8	Well shut in				
9	12-Nov-18	9	80%	450.0	17.94	805.10	0.179
10	13-Nov-18	10	100%	400.0	16.95	367.20	0.170
11	13-Nov-18	11	100%	350.0	1.09	355.20	0.011
12	13-Nov-18	12	100%	300.0	0.85	332.80	0.009
13	14-Nov-18	13	90%	150.0	1.40	401.79	0.014
14	14-Nov-18	14	50%	150.0	3.86	677.62	0.039

OFFSITE CHARACTERIZATION

PSD via LPSA

- The Mastersizer 3000 is the latest generation of the world's most widespread particle sizing instrument, used by many thousands of companies and research institutes across a wide range of industries.
- Measuring over the nanometer to millimeter particle size ranges, it packs exceptional performance into the smallest of footprints, bringing operator-independent measurements that every user can rely on.
- ability to measure over a maximum size range of 0.01 - 3500 microns using a single lens range
- Wide dynamic range - from submicron to the millimeter size range
- Rapid measurements - results generated in less than a minute
- Repeatability - large numbers of particles are sampled in each measurement.



Parameter	Results
D [3,2]	9.20 µm
D [4,3]	124 µm
Dx 10	6.39 µm
Dx 50	108 µm
Dx 90	261 µm

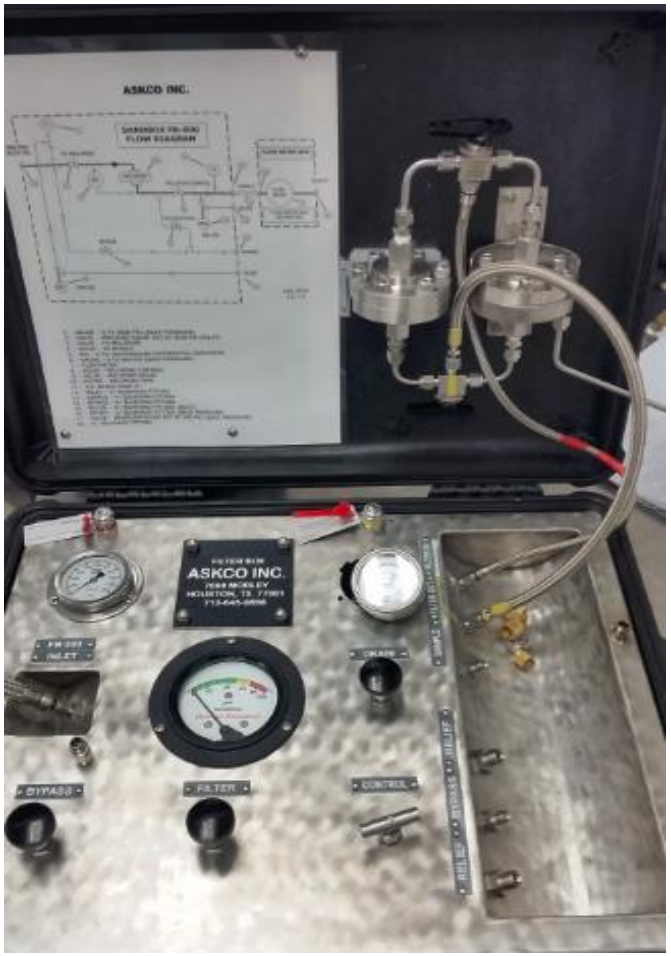
Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0679	0.00	0.460	0.84	3.12	6.92	21.2	16.72	144	63.07	976	100.00
0.0114	0.00	0.0771	0.00	0.523	1.30	3.55	7.40	24.1	17.73	163	69.35	1110	100.00
0.0129	0.00	0.0876	0.00	0.594	1.84	4.03	7.92	27.4	18.85	186	75.60	1260	100.00
0.0147	0.00	0.0995	0.00	0.675	2.41	4.58	8.47	31.1	20.13	211	81.55	1430	100.00
0.0167	0.00	0.113	0.00	0.767	2.98	5.21	9.04	35.3	21.58	240	86.93	1630	100.00
0.0189	0.00	0.128	0.00	0.872	3.51	5.92	9.64	40.1	23.27	272	91.49	1850	100.00
0.0215	0.00	0.146	0.00	0.991	3.98	6.72	10.24	45.6	25.24	310	95.08	2100	100.00
0.0244	0.00	0.166	0.00	1.13	4.36	7.64	10.85	51.8	27.56	352	97.62	2390	100.00
0.0278	0.00	0.188	0.00	1.28	4.69	8.68	11.47	58.9	30.26	400	99.19	2710	100.00
0.0315	0.00	0.214	0.00	1.45	4.97	9.86	12.11	66.9	33.42	454	99.98	3080	100.00
0.0358	0.00	0.243	0.00	1.65	5.24	11.2	12.77	76.0	37.07	516	100.00	3500	100.00
0.0407	0.00	0.276	0.0007	1.88	5.51	12.7	13.46	86.4	41.25	586	100.00		
0.0463	0.00	0.314	0.07	2.13	5.80	14.5	14.19	98.1	45.98	666	100.00		
0.0526	0.00	0.357	0.23	2.42	6.13	16.4	14.97	111	51.24	756	100.00		
0.0597	0.00	0.405	0.48	2.75	6.50	18.7	15.81	127	56.97	859	100.00		

SAND SERVICES

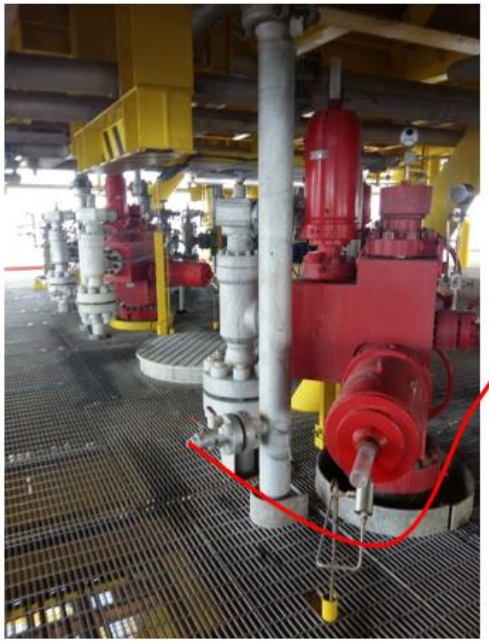
- **SGS Side Stream Sandbox**
- The SGS SandBox FB-300 system is a Proportion-to-Flow pressurized Millipore style filtration device – primarily for oil wells.
- It allows a representative sample of produced sand to be captured at pressure from a liquid sample point. It also incorporates a geared flow meter to allow sample volume calculation so sand rate per volume of live oil can be calculated.
- The unit is rated up to 5000 PSI inlet pressure with an 800 psi Sample Back Pressure and incorporates a primary bypass system allowing a continuous representative sample to be captured.
- All SandBox Integrity is protected by pressure relief valves. The unit is purely mechanical so no Ex-hazards are present and it can be used in all Zoned Areas.
- Acoustic systems for approximation purposes.

  - Used along with ported Genie Probe for representative sampling.

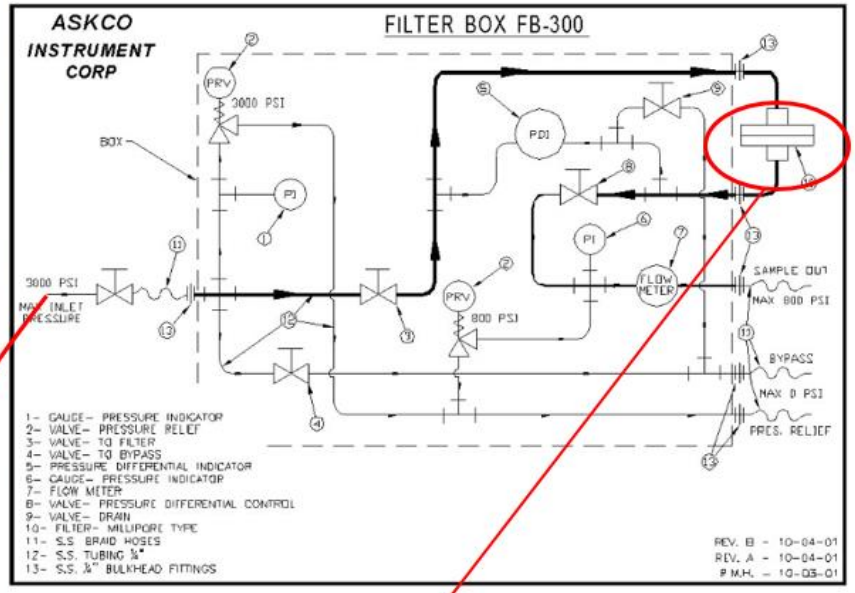
- IDEALLY USED ALONGSIDE ACOUSTIC SAND METERING SYSTEMS FOR A FULL DIAGNOSTIC SERVICE



SETTING UP OF SANDBOX



Sampling point



Remove the filter, weigh the sand

Bring the sand to onshore lab for LPSA analysis

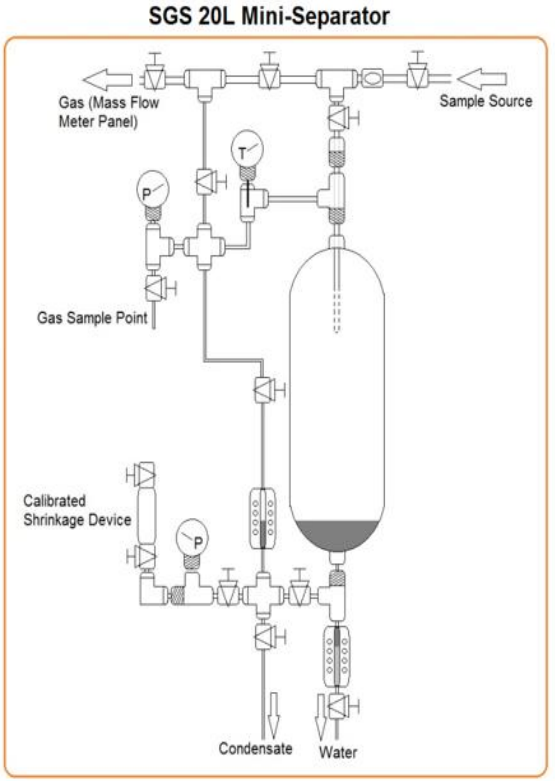
SAND SERVICES

- **SGS Side Stream Sandbox – gas work**
- The Sandbox was modified for gas use by SGS and has been used on multiple projects by combining with a mass flow meter as opposed to a turbine meter.
- What was found however was that without utilizing a sampling probe, it was a challenge to capture any large scale amount of sand. (1 grams or more).
- Example Filter below contained 0.04g of sand. This is insufficient for standard lab analysis for PSD (LPSA) but is sufficient for QEMSCAN derived PSD.
- SGS decided to evaluate other potential sampling methods for gas wells…

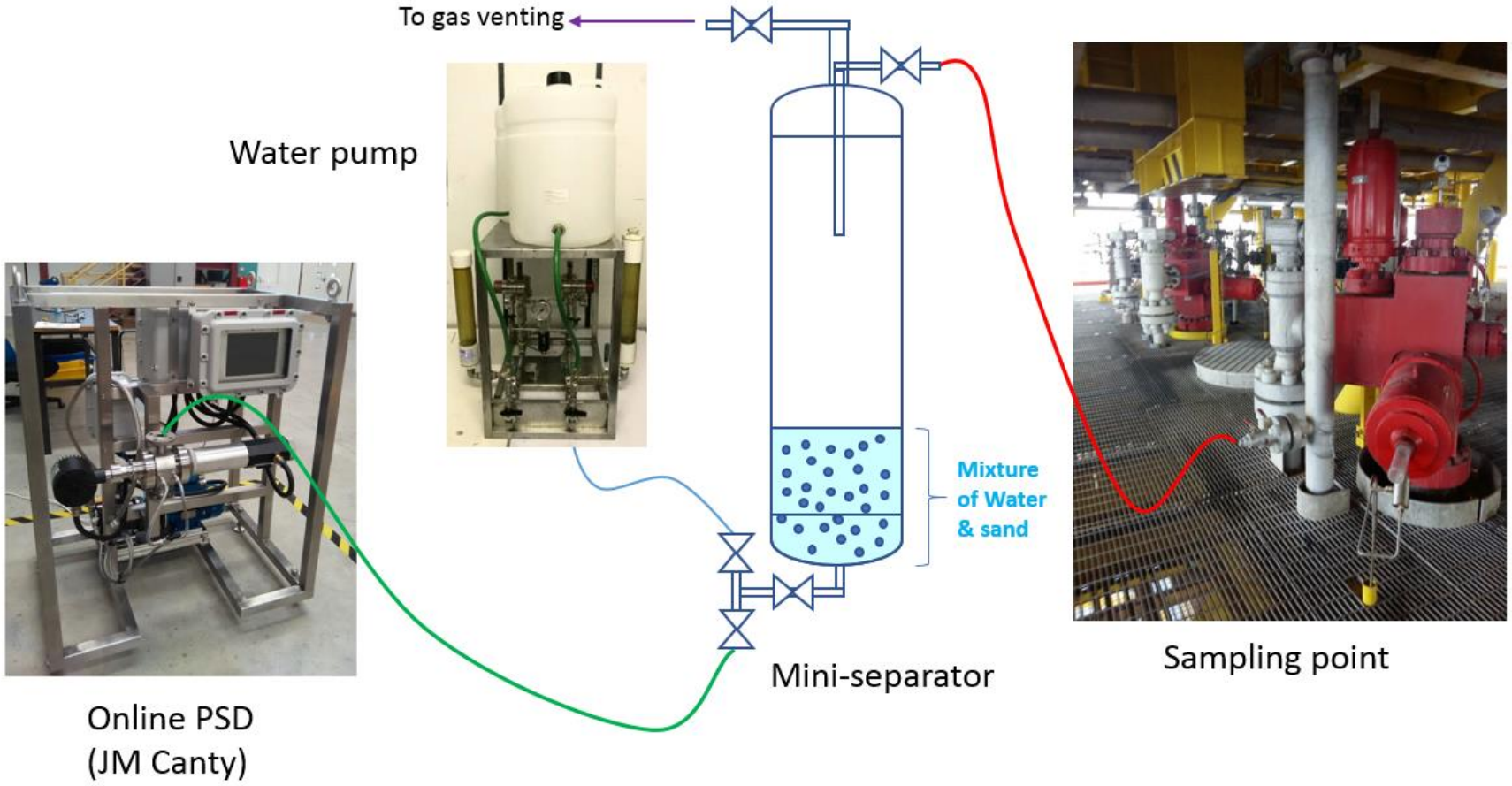
GAS WELLS – SAND SAMPLING AND PROFILING VIA WATER FILTRATION AND GENIE PROBE

SGS Side Stream 20L Mini Separator Sampling System

- An alternate conceptual methodology for side stream sampling of sand from gaseous wells involved scrubbing the sand out via slowing the velocity of the particles through a side stream mini separator filled with pre-filtered water.
- Side stream 3 phase mini separator with dual or single sight glasses for level monitoring and visual sand monitoring.
- Extended dipstick to bubble gas through pre-filtered water.
- Used in conjunction with mass flow metering system for gas volume measurement and acoustic sand monitoring system.
- Profiling Possible by repeating at multiple choke sizes.

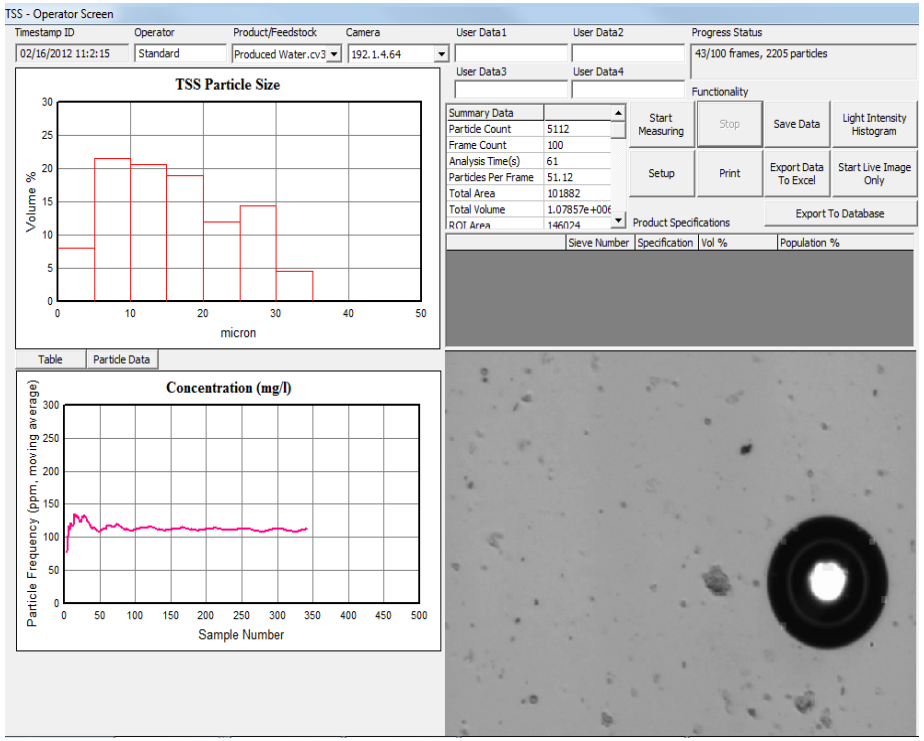


SETTING UP OF MINI-SEP BASED SIDE-STREAM SAND SYSTEM WITH REALTIME PSD FOR GAS WELLS.



GAS WELLS – SAND PROFILING VIA WATER FILTRATION & JM CANTY

SGS also offer the ability to measure PSD of Sand onsite . This is done via online JM Canty system, or offline using traditional LPSA. For online, realtime PSD results, SGS utilize the JM Canty Online analyzer . JM Canty is vision based technique works on the basic principle of presenting the fluid between a high intensity light source, and microscopic camera. The captured images are then sent to software for analysis, where the suspended particulate (sand, water, oil, gas bubbles etc.) is measured under a number of different parameters to provide size, shape and concentration data. *SGS is currently evaluating JM Canty vs LPSA for PSD work.*



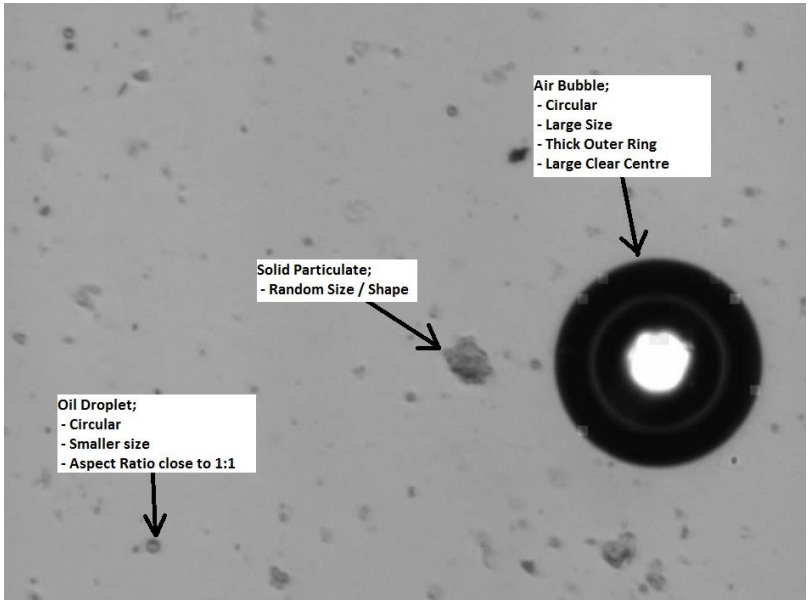
Graphical outputs of particle size distribution and concentration

JM Canty Online Analyzer

Onsite Analysis – Particle Size Distribution

The retrieved images are analysed by the control PC running the Software

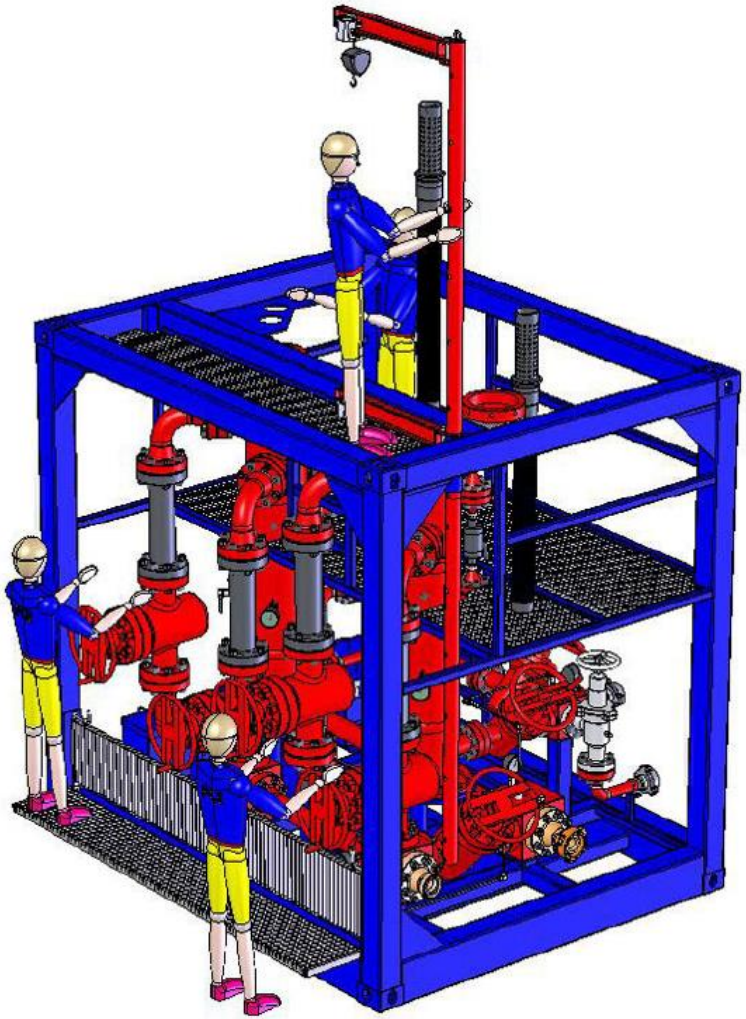
- Each particle is analysed under a number of different parameters (major axis, minor axis, area, perimeter, circularity, aspect ratio….)
- Oil droplets have a circularity value and an aspect ratio close 1
- Solid particulate is randomly shaped
- Air bubbles tend to be larger and have a clear centre
- Software filters (size / shape) can be applied so only particles with the characteristics of oil, solids, or air bubbles are individually analysed



Key features :

- 1600 x 1200 Pixel Array configurable to 0.35µm per Pixel Resolution
- 1/100,000s Shutter Speed
- Particle / Droplet Size to 0.7µm
- Simple RJ45 Network Connection to Control PC

DUAL POT SAND FILTER



DUAL POT SAND FILTER

Process & Operating data	
Service	H2S service per NACE MR01-75
Dry gas flow capacity(1)	58 MM scf/day
Liquid flow capacity(1)	9400 bbl/day (@ 400 microns)
	5000 bbl/day (@ 200 microns)
Filtration cut-out	200 microns (100µ to 400µ available)
Max differential pressure	1350 psi (2030 psi screen burst pressure)
Vessel capacity (total)	65 litres

1- Under intermittent operation, 10k psi working pressure, 60°F temp., gas sg 0.7 and oil sg 0.85. Consult FCE for flow capacity at anticipated flow conditions.

Design Data	
Design pressure	10000 psi
Design temperature	-29°C to + 121°C (-20°F to +250°F)
Codes of construction	API-6A / ASME VIII guidance / ANSI B31-3

CLOSING THOUGHTS

Sand Sampling in Gas Wells

- Sand Sampling in gas wells poses a difficult challenge without full bore devices.
- It may be possible via a side stream filtration system as discussed – this has yet to be performed.
- It may also be possible to measure PSD at site in near realtime from gas wells. This has abilities to perform profiling of PSD at different production rates. *(Benefits screen evaluation etc).*
- Side Stream Sampling will take time with gas wells – potentially a full 12 hours of sampling may be required to scrub out sufficient sand for measurement.
- Sample Point Suitability is critical
- Gas Sampling should always be done in conjunction with an acoustic metering system to aid in indication of events.
- Acoustic Metering Systems on Gas wells need accurate flow rate data of all phases to work well. Often these wells can be wet gas wells and production data is provided by a WGM. *It is imperitive that the WGM providing this data is calibrated and validated (eg Upto date verification via Tracer, uptodate PVT Flash table)*

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WHEN YOU NEED TO BE SURE