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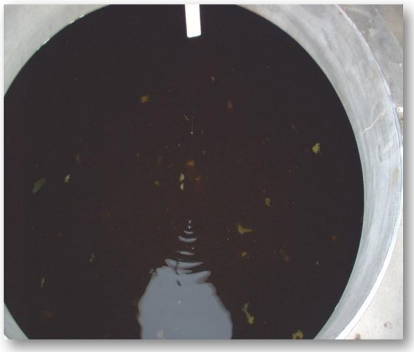

Figure 1: Contaminated Tote

Maximum Contamination Limits (Particles/ 100ml)	NAS Class 8 Specifications	NAS Class 6 Specifications
5 to 15 µm	64,000	16,000
15 to 25 µm	11,400	2,850
25 to 50 µm	2,025	506
50 to 100 µm	360	90
Over 100 µm	64	16

Figure 2: Comparison of NAS 6 and NAS 8 Particle Loadings

Subsea Chemical Cleanliness Specifications

Operators and chemical vendors responsible for chemical delivery to subsea developments are aware that the use of chemicals with unacceptable solids loadings can result in the plugging of injection lines, subsea metering systems, subsea connectors, and downhole injection locations. However, there is relatively little agreement across the industry regarding the exact chemical cleanliness specifications that need to be applied.

This article compares the common approaches to specifying chemical cleanliness and subsequently presents high-level guidance that can be used to select appropriate quality control criteria for those chemicals deployed through long-distance umbilicals to subsea and sub-surface injection locations.

Requirements for Solids Control

The requirements for effective solids control for subsea-deployed chemicals are a result of the tight tolerances and high pressure drops associated with long tie-back subsea chemical delivery systems. This means that a relatively small increase in pressure drop can prevent the use of an umbilical or that a very small amount of accumulated solids can plug chemical rate-control valves, poppets and connectors, check valves, or injection points.

The high cost of supplying subsea infrastructure commonly means that systems are operated with minimal redundancy and limited ability to reconfigure systems to overcome the loss of umbilical tubes or injection points. Hence, it becomes critical to effectively control product quality to ensure that these problems do not arise.

Supply-Side Solids Control

Acceptable levels of solids loadings are generally specified during chemical manufacture. Chemical suppliers will generally only contractually commit to specified solids loadings in their chemicals at the point of manufacture, rather than the point of delivery. However, rigorous tank cleaning programs are generally employed by the major suppliers to ensure that product contamination is controlled to low levels.

Filters are generally used during chemical transfer from tote tanks to permanent storage. The filters must be sized to remove gross product contamination, as shown in Figure 1, but does not appreciably impact the ability of chemicals to meet common cleanliness specifications for subsea delivery. If these filters are sized too small, then gravity drain may not be sufficient and pumping may be required. It is also common for 25-40 micron filters to be placed upstream of chemical injection pumps and for 3-15 micron filters to be placed downstream to provide direct protection against the fouling of umbilicals and subsea distribution systems as a result of solids build-up. Some operators size large filters downstream of pumps to gather larger particles.

Common Solids Control Standards

There are three standards that are typically considered in the industry as a means of qualifying the cleanliness of production chemicals. These are the National Aerospace Standard (NAS) 1638, the Society of Automotive Engineers (SAE) Aerospace Standard AS4059, and the International Standards Organization (ISO) 4406. All of these represent the solids loading profile of a fluid as a simplified rating or class.

The first standard to gain acceptance for chemical cleanliness assessments for subsea-deployed chemicals was NAS 1638. Although it may seen incongruous that an aerospace standard became a common measure of production chemical solids loadings, the adoption of the standard was originally made for hydraulic control systems where the hydraulic fluid industry were used for supplying product to NAS 6 grade for aircraft control systems.

Contamination Classification According to NAS 1638-01/1964

NAS-Class	Number of Particles/100 ml 2 - 5 µm	5 - 15 µm	15 - 25 µm	25 -50 µm	50 - 100 µm	> 100 µm	Amount of Contamination (ACFTD) [mg/l]
00	625	125	22	4	1	0	—
0	1,250	250	44	8	2	0	0.01
1	2,500	500	88	16	3	1	—
2	5,000	1,000	178	32	6	1	—
3	10,000	2,000	356	63	11	2	—
4	20,000	4,000	712	126	22	4	0.1
5	40,000	8,000	1,425	253	45	8	—
6	80,000	16,000	2,850	506	90	16	0.2
7	160,000	32,000	5,700	1,012	180	32	0.5
8	320,000	64,000	11,400	2,025	360	64	1
9	640,000	128,000	22,800	4,050	720	128	3
10	1,280,000	256,000	45,600	8,100	1,440	256	5

Contamination Classification According to SAE AS 4059: D

ISO 4402 Calibration	>1 µm	>5 µm	>15 µm	>25 µm	>50 µm	>100 µm
ISO 11171 Calibration	>4 µm(c)	>6 µm(c)	>14 µm(c)	>21 µm(c)	>38 µm(c)	>70 µm(c)
SAE Code	A	B	C	D	E	F
000	195	76	14	3	1	0
00	390	152	27	5	1	0
0	780	304	54	10	2	0
1	1,560	609	109	20	4	1
2	3,120	1,220	217	39	7	1
3	6,250	2,430	432	76	13	2
4	12,500	4,860	864	152	26	4
5	25,000	9,730	1,730	306	53	8
6	50,000	19,500	3,460	612	106	16
7	100,000	38,900	6,920	1,220	212	32
8	200,000	77,900	13,900	2,450	424	64
9	400,000	156,000	27,700	4,900	848	128
10	800,000	311,000	55,400	9,800	1,700	256
11	1,600,000	623,000	111,000	19,600	3,390	512
12	3,200,000	1,250,000	222,000	39,200	6,780	1,020

Contamination Classification According to ISO 4066:1999

ISO-Class	Number of Particles/1 ml more than	up to and up including	ISO-Class	Number of Particles/1 ml more than	up to and up including
0	0.00	0.01	15	160	320
1	0.01	0.02	16	320	640
2	0.02	0.04	17	640	1,300
3	0.04	0.08	18	1,300	2,500
4	0.08	0.16	19	2,500	5,000
5	0.16	0.32	20	5,000	10,000
6	0.32	0.64	21	10,000	20,000
7	0.64	1.3	22	20,000	40,000
8	1.30	2.5	23	40,000	80,000
9	2.50	5	24	80,000	160,000
10	5	10	25	160,000	320,000
11	10	20	26	320,000	640,000
12	20	40	27	640,000	1,300,000
13	40	80	28	1,300,000	2,500,000
14	80	160			

Figure 3: Cleanliness Standard Comparison (NAS/SAE/ISO)

Reference

1) Schroeder Industries. *Appendix*. Retrieved from http://www.schroederindustries.com/

NAS 6 is the most commonly used chemical cleanliness standard, where some Operators have subsequently relaxed the NAS 6 limit for production chemical application in umbilical systems down to NAS 8. At a pragmatic level, this generally works to prevent plugging of chemical delivery systems, while also resulting in the need to remove approximately one quarter of the solids specified for a NAS 6 rating (see Figure 2). However, each system should be reviewed in detail prior to selecting the NAS cleanliness levels.

In recent years, there has been a slow industry move towards using the SAE AS4059 distributions as an alternative to NAS 1638. This is due to the requirement contained within the SAE standard for the use of National Institute of Standards & Testing (NIST) calibrated particle detectors as well as the use of standard test procedures. These are not requirements that are detailed in the NAS standard and so leave the derivation and interpretation of test results associated with the NAS criteria as being open to greater uncertainty when chemicals are analyzed at different locations or at different times.

The ISO 4406 standard applies similar levels of rigor to the analysis, quality control and reporting of results as the SAE standard, and predominantly sees application in those areas of the world where the US-derived NAS and SAE standards have not previously been commonly applied.

However, as an observation, it is noted that the SAE standard is favored where the NAS standard has previously been used because its contamination classes represent an extension of the those used in the NAS standard. AS4059 reports smaller particles than NAS 1638, but otherwise enables a direct comparison to the older standard that is lacking with ISO 4406 (see Figure 3). As such, it is expected that use of this standard will continue to gain ground against the older NAS standard as more Operators require the use of standard calibration and analysis procedures for solids measurements.

Recommendations

The extremely low tolerance of many subsea chemical metering valves to solids deposition means that there exists a risk to chemical injection availability in the long-term. As a result, GATE commonly recommends the following for a generic injection system arrangement:

- Chemicals that arrive on to the facility should be checked for the required cleanliness levels on-site prior to offloading on to the facility system. Filtration on the facility should not be considered as the significant manner of attaining the required cleanliness levels. Chemical cleanliness starts from the chemical manufacturing facility, clean and effective tank cleaning and manufacturing processes, robust chemical system preservation, maintenance and commissioning practices as well as clean operating processes.
- All subsea and sub-surface injection production chemicals supplied via umbilicals to be subject to topsides filtration on delivery (micron requirements depend on gravity feed or pumping), filtration upstream of charge pumps (40-60 microns depending on the chemical and topsides configuration), 40-60 micron filtration upstream of injection pumps (if charge pumps are not installed) and 3-15 micron filtration downstream of injection pumps.
- NAS 6 cleanliness requirements (or equivalent) to be applied for subsea and downhole chemicals where point to point, topsides metering, or subsea metering valves are used to distribute products from a common header to multiple injection points.

Conclusions

GATE experience suggests that the design of the injection system and its inherent fouling tendency should be used to determine cleanliness requirements in a more rigorous way than arbitrarily selecting one specification or another. It should also be remembered that maintaining chemical cleanliness also requires the use of appropriate commissioning procedures, operating strategies, chemical handling and inventory management, staff training, and working in partnership with chemical suppliers.

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