DRIVING PIPELINE DECOMMISSIONING BEST PRACTICE THROUGH EXPERIENTIAL LEARNING

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Abstract

A combination of complex economic conditions and diminishing production in mature fields continues to drive growth in the oil and gas decommissioning market. Whilst industry attention tends to focus on well plug and abandonment (P&A) or topside removal and dismantling, subsea infrastructure presents its own challenges. When a pipeline system reaches the end of its operational life, multiple options might exist for cleaning and decommissioning. Pipeline configuration, condition, contents, and available disposal routes will all have a bearing on the chosen methodology. A 5-year decommissioning programme of more than 2000 km of multiple subsea infield and export flowlines of varying diameter has offered a unique opportunity to utilise experiential learning to apply best practices to pipeline end of life.

Introduction

In 2015, Halliburton was tasked with decommissioning a large subsea pipeline network made up of gas and methanol pipelines from three distinct fields. The pipelines contained significant inventory and other materials, including hydrocarbon gas, condensate, water, methanol, sludge, and naturally occurring radioactive material (NORM) contaminated debris. The vast majority of the gas pipelines had not been pigged since being precommissioned. Others had not been pigged for decades and some lines had stuck spheres left over from their operational life. A number of the methanol pipelines had been down rated and some lines had issues with sludge blockage.

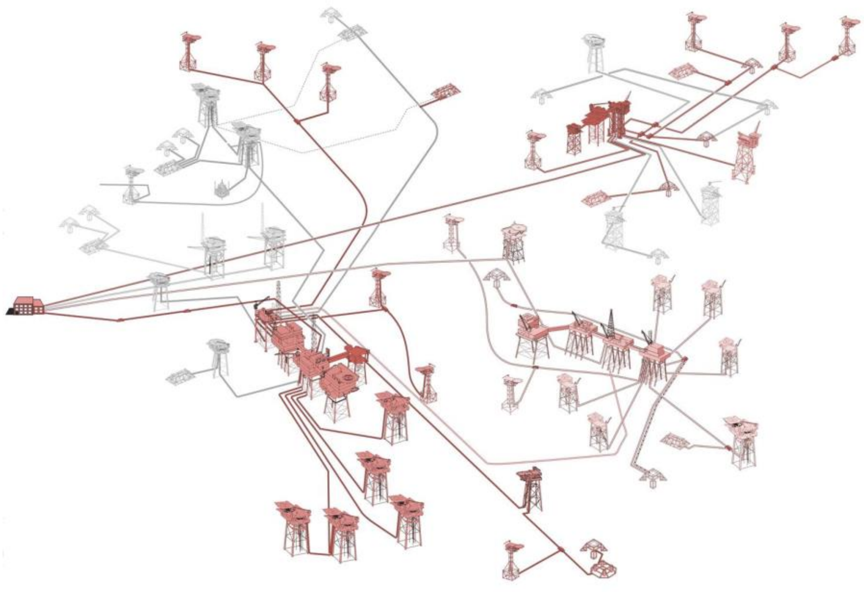

Figure 1: Three-field layout southern North Sea (SNS) >2000 km of subsea pipeline infrastructure

The main objective of the project was to remove hydrocarbons from the gas lines and leave them flooded with seawater with an oil in water (OIW) content of less than 30 mg/litre; this would allow subsequent cutting of the pipeline risers at seabed level, which would further allow the safe removal of the jacket and topsides infrastructure. The pipelines would be left open-ended on the seabed to decay with minimal effect on the marine environment. Cleaning of the gas pipelines would be performed with a bespoke design of multiple-pig, chemical cleaning trains propelled with raw seawater. Methanol lines would be flushed with filtered seawater to displace the methanol that was recovered.

Displaced condensate, water, methanol, sludge, and NORM contaminated debris was injected down nominated disposal wells (depleted gas wells) to minimise the need for waste handling and transportation.

The decommissioning campaign was conducted as three distinct projects (one for each field), over a 5-year duration. In total, Haliburton decommissioned 89 pipelines from 35 worksites, with a total length of more than 2000 km.

Toward the end of the second project, decommissioning plans for the final field infrastructure were underway. During pre-engineering, it was realized that this field would require a different approach because of the inclusion of multiple dead legs, unpiggable tees, and other unique considerations, such as difficulty with subsea sampling, to confirm branch pipelines were clean. Experience gained from a project historical track record, where no pig interface between contents and flushing medium were used, showed that significant overflushes, on the order of multiple-line volumes, were required to achieve the desired OIW content.

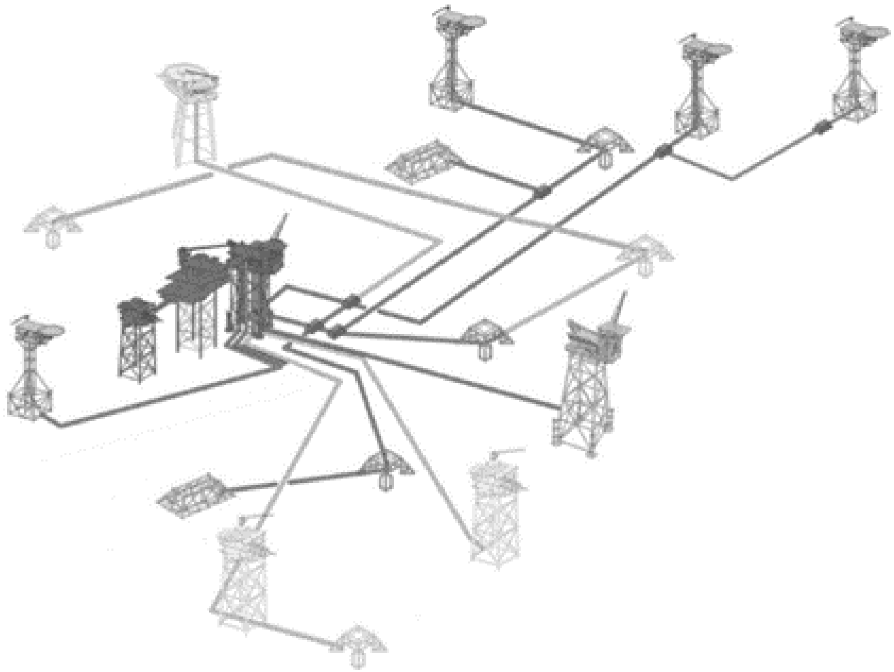

Figure 2: Close-up view of the third field subsea pipeline infrastructure

From experience obtained during the two previous field projects (and other previous decommissioning projects), it was clear that to be able to achieve efficient pipeline cleaning results, whilst minimizing overflush durations, a cleaning train consisting of multiple pigs separating chemical batches was essential. Without the use of chemical slugs, significantly extended flushing durations would be expected, leading to increased costs for the operator because of multiple decommissioning scopes ongoing in the field requiring the hire of a diving support vessel, accommodation/work rig, and a P&A drill rig. The complexity of multiple subcontractors and operators working on the same or adjacent assets made adhering to schedules essential.

Figure 3: Examples of debris displaced by cleaning trains

Because of the system constraints, a revised cleaning train consisting of the same combination of cleaning chemicals was designed. A custom gel was used, instead of foam or gel pigs, to separate the chemicals and provide an interface between the hydrocarbon content of the pipelines and the flushing medium.

To help ensure the revised cleaning train would be effective, a trial run was conducted on a section of pipeline between two satellite platforms. Access to both ends of the trial pipeline was essential because it allowed monitoring of the returns to establish at what point during the overflush the OIW content was reduced to an acceptable level.

The trial run provided excellent results that were comparable to using the solid pig methodology. An overflush of 1.4 times the line volume was sufficient to achieve three samples below the 30-mg/litre OIW target and produced results with a final reading of 1.5 mg/litre.

The data received from the trial run meant the design philosophy for the third field could be finalised with a high degree of certainty that reaching the desired targets within the challenging subsea pipeline architecture could be achieved.

Where there were practical issues related to sampling of the flushing medium (e.g., where branch pipelines merged with other pipelines), it was agreed that an overflush of 1.6 times the line volume (based on the volume required to clean the trial pipeline) would be pumped.

It was agreed with the operator that multiple techniques would be deployed to clean the pipeline systems in the third field. These techniques included solid pigs, custom gel alternatives, and unsampled overflushes. The agreed decommissioning philosophy was used as a baseline to create a budget for the overall decommissioning programme. This allowed funding to be agreed to by the multiple partners/stakeholders and allocated to the project.

Results

The average flushing volume for the final field was 1.132 times the line volume. This yielded an average result of 11.57-mg/litre OIW across all gas/condensate pipelines. The actual volume pumped varied from pipeline to pipeline because the flushing completion was determined by achieving three acceptable samples taken at 15- to 30-minute intervals and the results analysed on site. It is estimated that this approach saved the client approximately $3.5 million[(1)] in equipment and personnel costs because of reduced pumping time.

Where it was impractical to perform sampling during the flushing operations, Halliburton calculated the required volume to be flushed, including contingency, to help ensure the required OIW limits were met.

During the previous projects, flushing of the methanol pipelines used a conservative approach of a three-line volume flush. Latterly, based on results achieved, the methanol pipelines (and some umbilical lines) were flushed with 1.05 to 1.2 times the line volume to displace the methanol. For major, larger-diameter methanol service pipelines, a debris pickup gel was used as an interface between the methanol and the flushing medium to remove entrained solids and minimise the overflush volume to +5%. For shorter and smaller-bore pipelines and umbilicals (where overflush volume was less of an issue), a +20% overflush was used. This change in methodology was confirmed as adequate via sampling during the early stages of the campaign. Note sampling was not a regulatory requirement.

[1] Conservative figure based on savings associated with equipment and personnel hire for reduced duration in comparison to "standard" three-line volume flush, e.g., time X (equipment cost + personnel cost). No account taken of additional savings to operator associated with vessel hire, rig hire, rig movement, schedule optimization, etc.

Figure 4: Debris removed from 4-in., 118.7-km methanol pipeline

Figure 5: Supply vessel-based flushing spread complete with flushing 2-in. high-pressure (HP) hose deployed to satellite platform

No.	Size in.	Length km	OIW mg/litre	No.	Size in.	Length km	Year
1	12 Gas	3.7	7.7	49	3 MeOH	3.7	2015
2	12 Gas	5.1	16.4	50	2 MeOH	5.1	2015
3	12 Gas	5.6	22.9	51	2 MeOH	5.6	2016
4	12 Gas	4.1	14	52	2 MeOH	4.1	2016
5	12 Gas	3.9	6	53	2 MeOH	3.9	2016
6	12 Gas	12	9.1	-	-	-	2016
7	16 Gas	0.15	By calc	54	3 MeOH	0.15	2016
8	16 Gas	13.4	10	55	3 MeOH	13.4	2016
9	12 Gas	5	4.3	56	3 MeOH	5	2017
10	16 Gas	13.5	20.4	57	3 MeOH	13.5	2017
11	10 Gas	3.8	9.9	-	-	-	2017
12	16 Gas	26.9	12.2	58	3 MeOH	26.9	2016
13	**24 Gas Export**	**10.9**	**14.2**	59	3 MeOH	10.9	2017
14	**28 Gas Export**	**138**	**18.5**	60	3 MeOH	138	2017
15	12 Gas	4.5	By calc	61	3 MeOH	4.5	2017
16	8 Gas	0.05	By calc	-	-	-	2017
17	12 Gas	14	1.55	62	3 MeOH	14	2017
18	18 Gas	20	6.8	63	3 MeOH	20	2017
19	16 Gas	11	8.39	64	3 MeOH	11	2016
20	12 Gas	0.2	By calc	65	3 MeOH	0.2	2018
21	12 Gas	20.3	26.5	66	3 MeOH	20.3	2018
22	12 Gas	42	11.3	-	-	-	2017
23	8 Gas	0.05	By calc	-	-	-	2017
24	10 Gas	17.8	11.8	-	-	-	2018
25	14 Gas	4.5	6.9	67	3 MeOH	4.5	2018
26	10 Gas	22.3	16.4	68	2 MeOH	22.3	2018
27	20 Gas	16.8	10.6	69	3 MeOH	16.8	2018
28	10 Gas	7.5	20.2	70	3 MeOH	7.5	2018
29	10 Gas	4.3	3.5	71	3 MeOH	4.3	2018
30	10 Gas	10.6	22.6	72	3 MeOH	10.6	2018
31	18 Gas	16.1	2.5	73	3 MeOH	16.1	2018
32	12 Gas	22	4.6	74	3 MeOH	22	2018
33	12 Gas	16	4.1	75	3 MeOH	16	2018
34	10 Gas	13.5	0.8	76	3 MeOH	13.5	2018
35	14 Gas	43	16.6	77	3 MeOH	43	2018
36	10 Gas	3.7	By calc	78	3 MeOH	3.7	2018
37	**26 Gas Export**	**188**	**8.8**	**79**	**4 MeOH**	**188**	**2019**
38	**36 Gas Export**	**118.7**	**14.9**	**80**	**4 MeOH**	**118.7**	**2019**
39	18 Gas	28	6	81	3 MeOH	28	2019
40	16 Gas	30	25.6	82	3 MeOH	30	2019
41	6 Gas	15.5	By calc	-	-	-	2019
42	10 Gas	11	12.5	83	3 MeOH	11	2019
43	10 Gas	0.05	By calc	-	-	-	2019
-	-	-	-	84	3 MeOH	10.4	2019
44	8/10 Gas	27.9	By calc	-	-	-	2019
-	-	-	-	85	3 MeOH	8.5	2019
-	-	-	-	86	3 MeOH	5.5	2019
45	10/12 Gas	26.6	8	-	-	-	2019
46	10/12 Gas	14.2	By calc	87	3 MeOH	14.2	2019
-	-	-	-	-	-	-	2019
47	12 Gas	13	By calc	-	-	-	2019
-	-	-	-	88	3 MeOH	12.5	2019
48	10 Gas	17.1	By calc	-	-	-	2019
-	-	-	-	89	3 MeOH	17	2019

Table 1: Pipelines flushed during the decommissioning programme and OIW results

Figure 6: 36-in., 118.7-km Gas export pipeline onshore flushing station

Conclusion

A total volume of 38 240-m^3 (240,539-bbl) fluids and NORM debris was disposed of downhole, which based on fluid volume alone, resulted in an estimated savings of around $13.8 million[(2)] for the asset owners, not taking into account any additional disposal costs associated with NORM contaminated material. In addition, this approach was more environmentally acceptable, as opposed to processing returns onshore or filtering and treating offshore with subsequent overboarding of the waste fluids to the marine environment.

Although the use of a custom gel to separate the cleaning chemicals was effective, it is recommended that if the line is piggable, suitable pigging facilities are available, or access to fit temporary traps is available, the solid pig approach be used because it requires less chemical consumables, less of an overflush, and is correspondingly less costly. Should a pipeline system not allow the use of solid or gel pigs, a custom gel can be used effectively to separate the cleaning chemicals and achieve an excellent result.

Where the cleaning train has to traverse barred tees, or installation of gel pig launching canisters is difficult, a custom gel can be used to separate the chemical cleaning slugs and provide the desired result consistently.

Where topsides OIW sampling is not possible and subsea sampling would be technically difficult and costly, a contingency overflush can be calculated — based on previous experience — to achieve the desired OIW content.

Figure 7: 36-in., 118.7-km Gas export pipeline offshore pig receipt

[2] Figure based on recent costs associated with onshore disposal of received fluids from a similar project, including transportation, treatment, disposal, and associated tank cleaning.