JM

Purification solutions

For the gas processing industry

Johnson Matthey
Inspiring science, enhancing life

Proven processes for hydrocarbon purification

PURASPEC™ technology uses a fixed bed containing a mixed metal oxide in engineered granules to remove traces of contaminants from hydrocarbon gases and liquids. In particular, the processes are designed to remove mercury, arsenic and a range of sulphur compounds – most frequently hydrogen sulphide (H_2S) and carbonyl sulphide (COS). They are widely used for sweetening to meet pipeline specifications and polishing to meet individual customer feedstock requirements.

Our processes deliver a wide range of operating benefits:

- **Low capital cost:** fixed-bed processes are simple and require only low capital outlay. It is possible to phase installation and match expenditure to the development of a project.
- **Impurity removal to very low levels:**
    - **Sulphur:** Treated streams can be as low as ppbv for H_2S from natural, associated gas, shale gas and copper strip 1A quality for propane/LPG. If required, total removal can be achieved.
    - **Mercury:** These are typically <10ng Nm^3 for mercury from natural and associated gas and <1ppb wt from NGLs, LPGs and hydrocarbon condensates.
- **High capacity: PURASPEC** absorbents are the industry choice for longest bed life and toughest duties. High capacity leads to less change-outs and longer lifespans, minimising the cost of mercury and sulphur removal over time.
- **Effective low temperature operation: PURASPEC** processes operate at temperatures from 0-200°C (32-400°F) for sulphur removal and 0-95°C (32-200°F) for mercury applications.
- **High operating flexibility: PURASPEC** processes are flexible and accommodate changes in throughput. The technology is truly 'fit-and-forget'.
- **Easy operation:** For dry or saturated gas and in high or low CO_2 - containing gases. End of life discharge is free flowing under gravity.
- **Easy retrofitting:** For existing onshore and offshore installations.
- **No feedstock losses:** Only the impurities are reacted and absorbed.
- **Environmentally friendly:** There are no vents, flares, noises or problematic effluents and the plant has a minimal footprint. Used absorbents can be reprocessed and disposed of in an environmentally sound manner. Energy use and CO_2 emissions during operation are effectively zero.
- **Low pressure drop design:** Our radial flow reactors offers a low pressure drop solution for larger flows.

You can depend upon **PURASPEC** performance to provide effective removal of sulphur compounds and mercury. This has already been proven for nearly 30 years, with hundreds of installations world-wide including both onshore and offshore installations.

PURASPEC Hydrogen sulphide (H_2S) removal

PURASPEC H_2S removal technology is ideally suited for polishing and is targeted at applications where the sulphur removal capacity required is no greater than 500kg/day H_2S.

It can also be used in conjunction with other bulk sulphur removal technologies, allowing installation of the most cost effective solution.

Applications include:

- Sales and fuel gas
- Reboiler vent gas
- Carbon dioxide
- Tank vapours
- Amine off-gas

PURASPEC H_2S removal processes operate effectively in the temperature range of 0-200°C (32-400°F), pressures from atmospheric up to 120bar (1750psi) and flow rates exceeding 2.0million Nm^3/hr (1.8Bscfd).

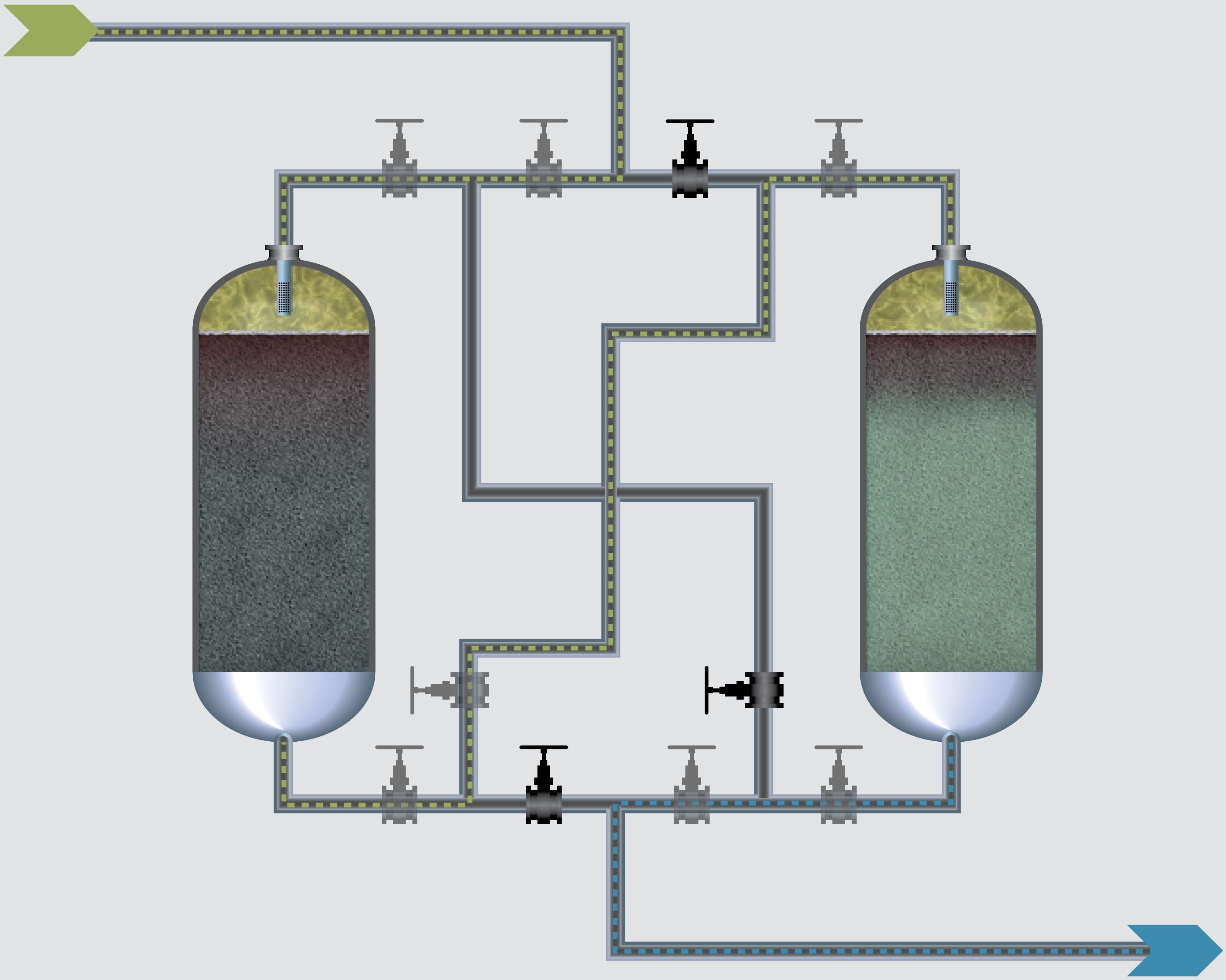

Figure 1: Typical lead-lag process flow diagram

How it works

PURASPEC is a market leading product for H_2S removal from hydrocarbon streams. It is a well-proven and robust product for complete removal of H_2S via an irreversible chemical reaction.

Once the H_2S has reacted with the metal oxide present in the absorbent, it is chemically bound into the material and cannot escape.

Even when the absorbent is fully saturated, it will not desorb H_2S or sulphur, making it safe to handle spent material.

The spent material is shipped to a smelting plant that can remove the sulphur before the metals are extracted and recycled into industrial applications. These smelting plants are designed to handle both mercury and sulphur, allowing a complete audit of the entire recycling route.

Vessels can be single, parallel, lead-lag or in a series configuration. A typical lead-lag process flow diagram is shown in Figure 1.

PURASPEC Mercury removal

Many hydrocarbons contain mercury. In the case of natural gas and natural gas liquids, it is likely to be present as elemental mercury. The concentration of mercury in natural gas varies widely depending on the geographical location and on the geology of the well formation. Mercury levels can vary in some fields from less than 0.01µg/Nm^3 to more than 5000µg/Nm^3.

The main concerns associated with mercury are:

- Corrosion of process equipment
- Emissions to the environment
- Exposure of workers to high levels of mercury during maintenance operations
- Difficulty in disposal of mercury contaminated equipment
- Potential liabilities resulting from mercury contaminated product streams

PURASPEC technology offers fixed bed solutions for mercury removal. Our granules, containing an active mixed metal sulphide finely dispersed through an inert support, are engineered to provide effective removal of mercury from hydrocarbon gases and liquid to meet customer feedstock requirements.

PURASPEC mercury guards operate effectively in temperatures ranging from 0°C - 95°C (32°F - 200°F), pressures from atmospheric up to 200bar (2900psi) and flow rates exceeding 2.0million Nm^3/hr (1.8Bscfd).

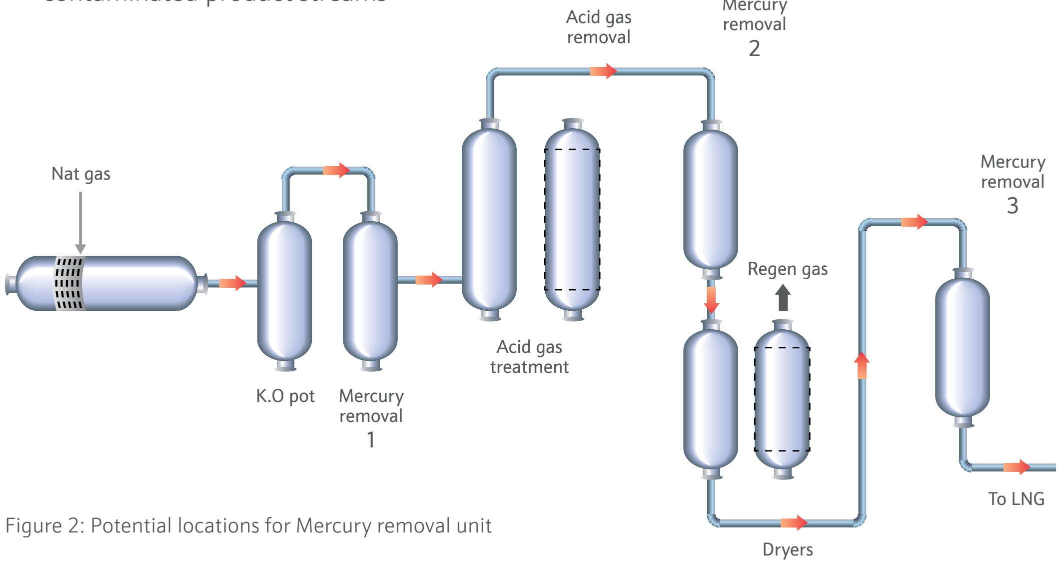

Figure 2: Potential locations for Mercury removal unit

How it works

Johnson Matthey's **PURASPEC** material relies on the high reactivity of mercury with the specially manufactured metal sulphides.

$Hg + M_xS_y = M_xS_a + HgS$

The reactive metal is finely dispersed through a highly porous inorganic support. The absorbent can be supplied in its pre-sulphided active state, or it can be sulphided in situ by reaction with H_2S from the hydrocarbon to be treated. Once the mercury has reacted with the metal sulphide present in the absorbent, it is chemically bound to the material and cannot escape.

Even when the absorbent is fully saturated, it will not desorb mercury, making it safe to handle spent material.

The spent mercury absorbent can be recycled through metal smelters. This is made possible by the use of a combination of metals with an inorganic support that is compatible with smelting processes. The spent material is collected in airtight UN approved metal drums and shipped to the smelter. These plants are designed to handle both mercury and sulphur, allowing a complete audit of the entire recycling route.

Benefits of PURASPEC absorbents

- Granules are engineered to give a high capacity for mercury, resulting in smaller vessels with minimal footprints and longer lifes.
- Mercury is chemically captured within the absorbent.
- **PURASPEC** processes are flexible and accommodate changes in throughput. The technology is truly 'fit-and-forget'.
- Recycling of the spent material uses a fully auditable recycling route.

Location of the mercury removal unit

The location of the mercury removal unit (MRU) is critical for ensuring that the mercury coming into the plant is removed as far upstream as possible.

There are many potential locations for an MRU, as illustrated in Figure 2. The three locations are:

1. Before the acid gas removal
2. Before the molecular sieve driers
3. After the molecular sieve driers

Undoubtedly the easiest duty is after the molecular sieve driers (3) as the gas is cleanest here. However, having a MRU in this location means mercury will have contaminated all of the upstream equipment and mercury will be released to atmosphere.

Locating the MRU in positions (1) and (2) present their own challenges. Treatment of the raw gas before the acid gas removal (1) is undoubtedly the preferred location to avoid emissions of mercury to the atmosphere and contamination of plant equipment. This location will ensure any NGLs produced are free from mercury. However, this location is more of a challenge for the mercury removal absorbent.

Adding value to your plant

Reactor design

Traditionally mercury removal reactors have used axial flow designs. This is mainly because they are cheaper, simpler and a well proven technology.

Axial beds

Axial beds allow for a simple design but constraints can arise when designing fixed bed reactors for large flow rates, resulting in high bed pressure drops.

Increasing vessel diameters can usually reduce bed pressure drop but other problems arise:

- Vessel manufacturers have fabrication limits
- Larger diameter vessels require thicker walls
- Thick walls result in heavier vessels
- Escalation of transportation and fabrication costs
- Increasing bed diameter reduces bed length, which may have a negative effect on the distribution of flow.

Restrictions are also placed on bed dimensions during the design to prevent maldistribution.

Radial beds

Johnson Matthey has developed alternative radial bed designs for applications where axial flow designs have not been able to provide the ideal solution. Radial flow reactors have a much lower pressure drop and are less susceptible to fouling whilst the vessels have more complex interiors, the vessel diameter is reduced minimising the impact of large flow rates (Figure 3).

The pressure drop savings possible with these designs are shown in Figure 4, where the comparison has been made for a light natural gas at 25°C (77°F) and 60bara (870psia).

Advantages of radial design

- Pressure drop at least five times lower than an axial design
- The extra flow resultant from a lower pressure drop can produce:
- ~ US$1.1M revenue/day (US$400M/year) or
- ~ £680,000 revenue/day (£250M/year)

The above assumes:

- Gas spot price = US$4/MMBTU
- Currency conversion US$1 = £0.62

Table 1: Process conditions

Flowrate	1.4 BSCFD
Pressure	112 Bara
Temperature	15 °C
Impurity	Mercury - 5 μg/Sm^3
Specification	<0.01 μg/Sm^3

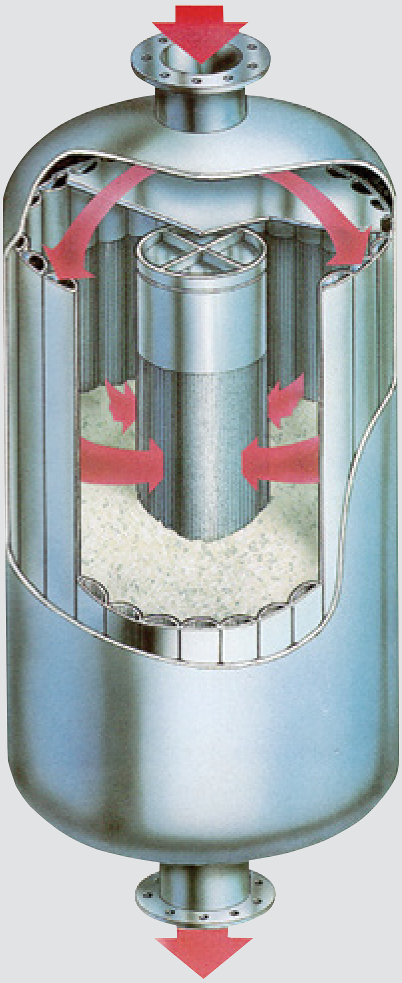

Figure 3: Typical radial bed

Reactor modelling

Computational fluid dynamics (CFD) plays an important role in the design of purification systems, from details of the vessel such as inlet distributors and outlet collectors through to optimisation of the catalyst bed and support materials.

With the help of CFD Johnson Matthey (JM) has been able to work with and help customers diagnose and eliminate problems in existing systems.

Typical CFD applications include distributor redesign to reduce gas velocities at the bed surface and minimise the risk of catalyst movement, and pressure drop and flow distribution studies to eliminate bypassing and optimise catalyst utilisation. Depending on the application the modelling work may include effects such as reaction and heat transfer, and require the use of proprietary data and correlations for JM products. Project timescales vary from a single day to several weeks, depending on the complexity of the geometry and necessary level of detail in the model.

Radial vs. axial
Vessel volume = 50m^3

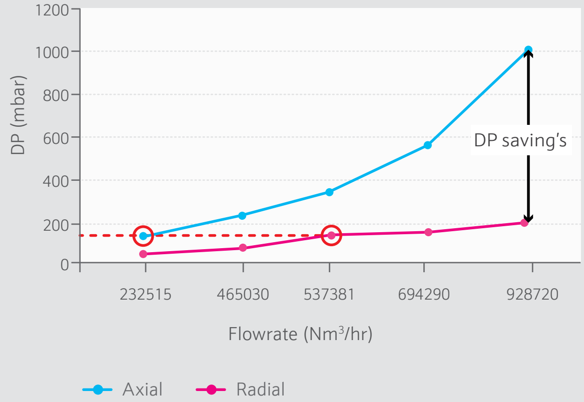

Figure 4: Possible pressure drop savings

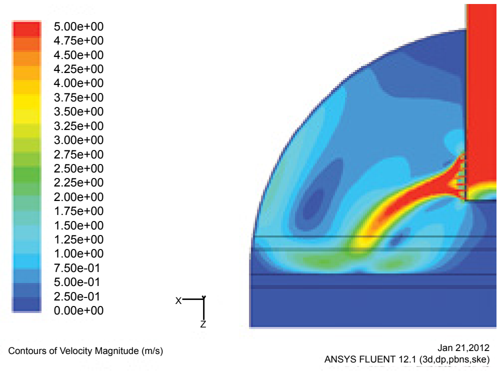

Figure 5: CFD output

Effective sulphur and mercury removal from a dense phase natural gas

Situation

The UK North Sea's Central Area Transmission System (CATS) terminal at Seal Sands on Teesside receives gas that has high levels of natural gas liquids. It is relatively sweet but contains small amounts of H_2S and mercury that must be removed.

Conventionally raw gas would be split into different hydrocarbon fractions with each being processed separately. However, as this would require a large number of reactors, a more cost-effective solution would be to treat the gas as received under high pressure in dense phase. The risk with this is that any phase separation of gas and liquid hydrocarbons could lead to flooding and channelling in a fixed bed system.

Johnson Matthey's solution

Because of uncertainties regarding the behaviour of the raw dense phase gas at 120bar (1750psi) and 4°C (40°F), Johnson Matthey installed a small side-stream reactor with provision for heating/cooling of the gas and operation at reduced pressure. This demonstrated that even when condensation was taking place, there was complete removal of H_2S.

Running the side-stream reactor also confirmed that some of the absorbents proposed for H_2S removal were also effective for mercury removal.

The side-stream demonstrated that **PURASPEC** technology was a practical way to purify dense phase gas, with the additional attraction of providing a safe and environmentally acceptable process requiring minimum operator attention.

Successful operation

The plant was completed on time and within budget with production commencing in October 1997. An identical unit was successfully commissioned in October 1998. Operation continues to be reliable and trouble-free, proving that **PURASPEC** absorbents offer a reliable, low pressure drop method for H_2S and mercury removal from dense phase natural gas. Johnson Matthey also manages the change-outs and re-processing of the absorbent for BP CATS via its **PURACARE™** cradle to grave offering.

Desulphurisation of CO_2

Situation

The vent stream from the acid gas removal unit (AGRU) on a gas plant in Argentina is purified before joining an existing low pressure CO_2 pipeline with beverage grade specifications.

A competitor's iron-based absorbent was being used to remove approximately 100ppmv of H_2S. However, the system had difficulty in achieving beverage grade specification and the media had to be changed-out every three months due to high pressure drop.

Johnson Matthey's solution

Johnson Matthey reviewed the design and with the help of some CFD modelling, the proposed solution was to replace the two beds of iron-based absorbent by a single, slightly shorter, bed of **PURASPEC** 2075. The new bed was retrofitted into an existing vessel without any vessel alterations. Only a small amount of capital expenditure was required to substitute the second separator for a shell and tube superheater.

The expected life of the **PURASPEC** 2075 is three years compared to the three month life of the iron-based absorbent.

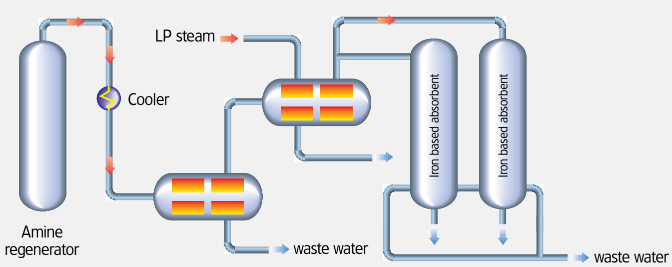

Figure 6: Existing iron based design

Customer benefits

The customer saw two significant benefits from installing the **PURASPEC** catalyst solution. Installation of the new beds reduced the pressure drop over the bed, allowing the plant to export approximately double the amount of CO_2, significantly increasing this income revenue stream.

Since installing **PURASPEC** 2075 the plant has experienced two years of steady operation, gaining approximately four months of additional operation compared to using the iron-based absorbent (when the plant would have been unavailable due to change-outs). The original bed of **PURASPEC** 2075 continues to operate well with spare capacity.

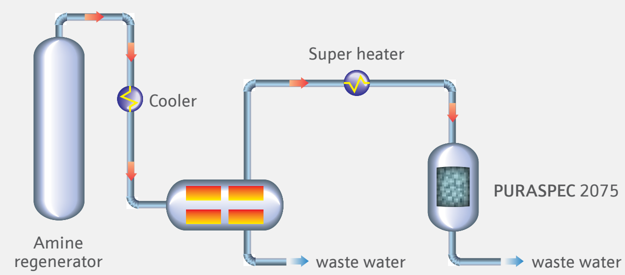

Figure 7: **PURASPEC** design

Replacement of sulphur impregnated carbon with PURASPEC absorbents

Situation

A world scale gas plant in the Middle East processes 1,420MMSCFD of associated gas producing ethane, C_3+ NGLs and fuel/sales gas.

The mercury removal units (MRUs) are installed at the ethane recovery plant, which includes two cryogenic turbo expander trains to recover 95% of the ethane from the residue gas of the NGL recovery plant. The plant operates three identical parallel reactors for the removal of mercury (Hg) from the gas.

The original design for the plant consisted of three sulphur impregnated carbon beds which were designed to remove the Hg down to less than 10ng/Nm^3.

After a few months in operation the end user noticed that Hg was slipping from their MRUs and they became concerned as to the long term impact on their plant assets.

This was a major concern as the high Hg slippage from their MRUs could lead to the catastrophic failure of their aluminium brazed heat exchangers in the cryogenic section of their plant.

Johnson Matthey's solution

After a thorough investigation and evaluation of all potential technologies the customer decided to replace all of the carbon beds with **PURASPEC** absorbents, which has a high mercury removal capacity.

Figure 8 shows the exit analysis from the three **PURASPEC** beds.

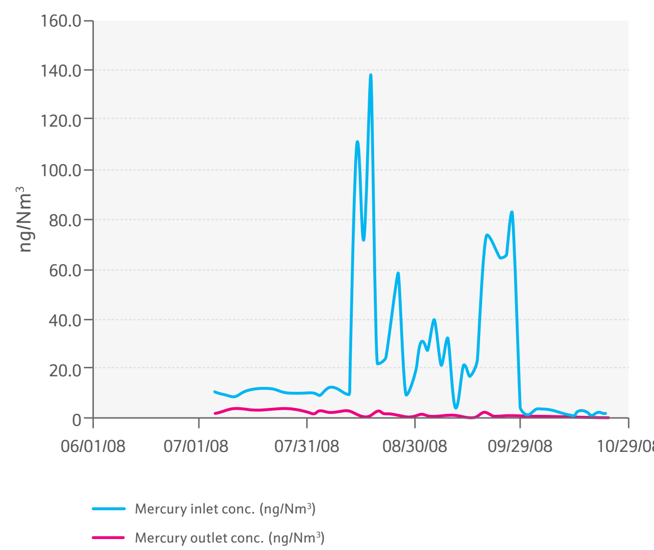

Figure 8: Mercury inlet and outlet after bed replacement

The analysis data showed that the **PURASPEC** beds successfully removed the mercury down to the exit specification of less than 10ng/Nm^3. The results also showed that the mercury content in the common outlet of each bed was averaging at 10ng/Nm^3.

Customer success

The end user successfully resolved the high mercury content in the feed gas by replacing the activated carbon with **PURASPEC** mercury removal absorbents. In operation **PURASPEC** absorbents have shown superior mercury removal capacity compared to the activated carbon and this was confirmed by monitoring the mercury in the outlet. The end user continues to operate with peace of mind that their downstream operations are protected from mercury.

Case study 4

PURASPEC mercury removal absorbent outperforms competition

Background

A refinery in South East Asia requested the design of a mercury removal unit (MRU) from Johnson Matthey for treatment of a light straight run (LSR) naphtha.

The inlet mercury concentration of the naphtha was 500ppb wt with an exit specification of <5ppb wt. Johnson Matthey designed an MRU using **PURASPEC** absorbent, and the bed was commissioned.

The MRU operated in line with expectations to meet the required specification of <5ppb wt mercury, including withstanding numerous upsets which resulted in excessive free water and particulate ingress on to the absorbent bed. Results are shown in Figure 9.

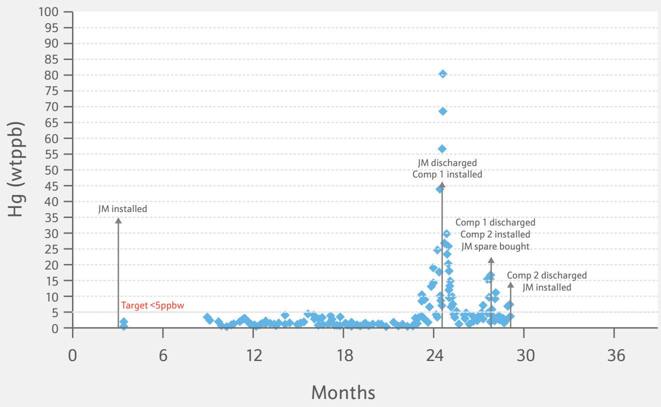

Figure 9: Mercury - LSR naphtha

Situation

After two years of successful bed operation, the **PURASPEC** approached the end of its expected bed life. The customer decided to try a cheaper alternative competitor product in order to compare its performance against **PURASPEC**. The competitor claimed equivalent performance to **PURASPEC** and it was duly installed.

The competitor product failed to consistently maintain <5ppb wt mercury specification and as a result was discharged within four months of operation. At this point, the customer decided to buy an emergency charge of absorbent from another competitor, whilst also purchasing a spare charge of **PURASPEC** mercury removal absorbent..

The second competitor charge again failed to consistently meet the LSR mercury specification and within two months needed to be discharged.

Replacement success

After the failure of two competitors within six months of operation, the **PURASPEC** absorbent material was loaded and the bed has consistently achieved the LSR mercury exit spec of <5ppb wt.

This experience has been very costly to the customer who has now initiated a long term supply contract with Johnson Matthey.

Radial beds in wet gas application

Situation

An oil and gas operator treating gas offshore in the Gulf of Thailand approached Johnson Matthey to provide a mercury removal system for a gas at its water/hydrocarbon dew point.

Johnson Matthey designed two radial flow vessels operating in a lead-lag configuration. This was chosen by the client because of the company's reputation for product quality and excellence of service. The **PURASPEC** mercury guard beds were installed on a wet gas duty directly downstream of the inlet separator and a filter coalescer.

Commissioning assistance

Upon commissioning, the on-line mercury analysers recorded mercury slip from the beds. Johnson Matthey was called to assist with investigations. After a thorough interogation of online data and field instrumentation and through working with plant engineers, Johnson Matthey was confident that the parameters were well within design conditions for **PURASPEC** absorbents. We recommended that the client work with a recognised mercury measurement specialist to investigate the performance issues.

Successful operation

The third party mercury analysis demonstrated that the on-line mercury analysers were not operating as required. It also showed that the **PURASPEC** absorbent beds were achieving an outlet mercury level well within the design specification, on a very challenging duty directly downstream of the slug catchers.

Computational fluid dynamics (CFD) modelling capabilities

Situation

A gas plant in North America operates **PURASPEC** absorbents beds for the co-removal of sulphur and mercury. The beds were designed to process 420mmscfd of natural gas and successfully operated without any process issues. Due to operational requirements, the operating flow rate increased outside of the design rate. The plant consequently noted an increase in bed pressure drop along with an increased change-out frequency of the downstream dust filter.

Johnson Matthey's investigation

Johnson Matthey was called to help with investigations into the cause of the high bed pressure drop. Utilising in–house CFD capabilities, we were able to model the flow patterns and velocities at the inlet distributor and the top of the bed, as illustrated in Figure 10.

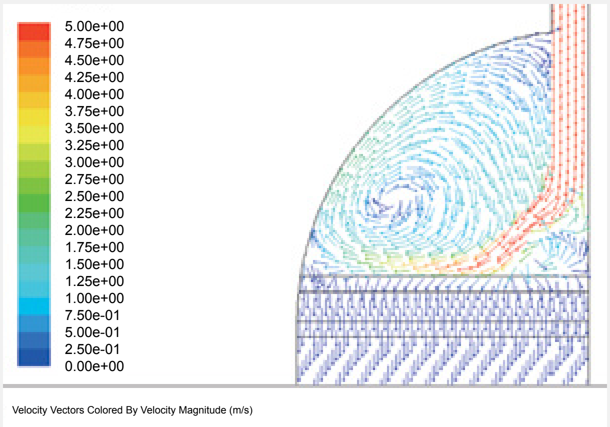

Figure 10: Flow direction

CFD modelling identified that the potential cause of the high bed pressure drop was due to the design of the distributor. When operating outside of the design flow rate, poor gas distribution was occurring at the top of the bed causing extremely high localised velocities. This had the potential to cause movement/milling of the **PURASPEC** absorbent.

Through use of CFD we were able to offer the following solutions:

a. Skimming the bed to leave greater clearance between the inlet distributor and the top of the bed. (The operator was given advice with respect to the skim required).

b. Replace the distriutor to a JM design to improve distribution of flow, (Figure 11).

Implementing either solution reduces the localised velocities at the top of the bed.

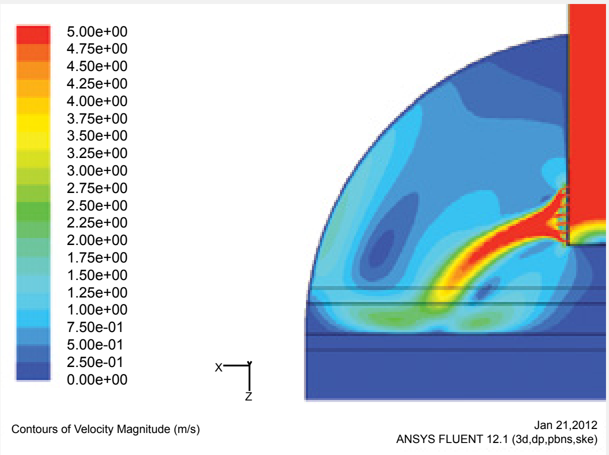

Figure 11: Flow rate pattern

Implementation of a solution

During a turnaround, disturbance at the top of the bed was observed as predicted by the CFD; the integrity of the material suggested milling had occurred. Due to time constraints the operator completed a bed skim to alleviate immediate problems.

Successful operation resumes

On restart, bed pressure drop and downstream filter change-outs returned to expected levels, indicating milling was no longer occurring. Plans are in place to replace the inlet distributor at the next turnaround to further improve flow distribution and allow for further flexibility for plant uprates.

PURACARE
guaranteed peace of mind

Performance guaranteed

There is no such thing as a standard **PURASPEC** process. The choice of absorbent, catalyst and the design of the reactor vessel will vary according to the type of feedstock, the level of contaminants, pressure and temperature conditions and the pipeline or end use purity specification. Our experienced engineers will ensure optimum design for your conditions.

Your problems solved

Tell us your problem and Johnson Matthey will draw upon its wide experience to devise and implement an individual solution. Our engineers will select from the family of **PURASPEC** processes or, where necessary, develop a variation to meet your needs precisely, regardless of the size of the application.

The scope of any **PURASPEC** technology package can also be tailored to your individual needs.

Johnson Matthey can offer the end user a full engineering capability, supplying the full **PURASPEC** technology package, complete with detailed engineering, piping and instrumentation specifications. However, our flexible approach also enables us to work with engineering companies - large or small - or a customer's own design team to deliver the package you require. At its simplest a **PURASPEC** package can be the supply of the requisite absorbents/catalysts together with operating instructions.

PURACARE is a unique service designed to take care of all aspects of operation, maintenance and absorbent/catalyst disposal for our customers in the gas processing industry; from cradle to grave. Under the expert direction of the Johnson Matthey team, this hands-on service enables customers to save time and manpower, and also to comply with all current and anticipated environmental legislation.

The complete service package

As with the **PURASPEC** package, we will tailor the scope of **PURACARE** to meet your specific requirements anywhere in the world and it can cover the complete operating cycle.

- **Design considerations**
  We will provide advice to ensure that change-out considerations are addressed at the design stage. This includes consideration of access to vessel and sufficient laydown for media and change out equipment

- **Delivery and loading**
  We will manage the delivery of the agreed quantities and grades of materials to your plant, followed by loading using the most appropriate technique for the type of reactor vessel and site conditions. Our experienced on-site consultants will be at hand to provide advice and assistance during the loading. We will take responsibility for quality and reliability in every detail, review of method statements to road haulage and fork-lift handling on site.

- **Optimum operation**
  We will advise you on how to make the most cost-effective use of our process in your plant. Our experienced and dedicated team will monitor and support your operation to ensure optimised performance to maximise bed lives. Towards the end of life we will provide recommendations on the timing for absorbent replacement.

- **Material discharge**
  Prior to discharge, the discharge procedures will be evaluated with contractors. Operating instructions to handle the discharged material will be provided along with onsite support during change-out. We will provide trained people and suitable equipment to facilitate the clean and safe discharge of the used absorbents and catalysts, and transport them from site.

- **Environmental disposal**
  In today's climate of environmental concern our policy is to ensure the environmentally sound disposal of all our spent products. These often contain high concentrations of metals which makes recovery by smelting worthwhile. We audit smelting companies to ensure that they operate within their home nation's environmental standards and frequently our customers also visit to ensure full compliance with corporate standards. We manage the whole process from unloading through transportation to the issue of a "certificate of destruction", the final step in the life of a charge of absorbent.

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