Next generation SRU control with ABC+

Gerton Molenaar and **Aernout Henning** of Jacobs Nederland B.V. discuss the superior SRU performance achieved with the new Jacobs Advanced Burner Control+ (ABC+) and report on the first full year of commercial operating experience at the Suncor Simonette Gas Plant in northern Alberta, Canada.

The operation of sulphur recovery units (SRUs) is faced with many challenges with respect to environmental compliance on the one hand and continuously changing acid gas feed streams on the other. Reliable and efficient sulphur recovery is not only very essential, it's even critical for many operating companies. Not complying with the regulatory emission limits and efficiency requirements can, apart from safety concerns and bad publicity, result in significant fines and ultimately in loss of production.

Nowadays, many SRUs, if not all, must be able to process acid gas feed stocks that vary in both composition and flow rate due to fluctuating upstream operating conditions. Especially in refinery applications it is common to process acid gas from multiple sources as well as sour water stripper gas containing NH_3. In gas plants the raw gas composition entering the plant regularly varies as well due to the many different gas wells that feed into the main pipelines.

The performance of SRUs is very sensitive to proper air-to-acid gas ratio control. Changing acid gas flow rates and/or composition, and incidents such as hydrocarbon carry-over, cause frequent upsets in SRUs. As a consequence, reduced performance, SO_2 emission violations and unscheduled downtime occur on a regular basis. Generally speaking, this is true for any SRU based on modified Claus technology, such as sub-dewpoint processes (i.e. MCRC™/CBA); direct oxidation processes (i.e. SUPERCLAUS®) and SCOT type processes.

To improve the SRU's response to feed gas variations Jacobs Comprimo® Sulfur Solutions (Jacobs CSS) has recently implemented its newly developed Advanced Burner Control+ (ABC+) at Suncor's Simonette Gas Plant's SRU in northern Alberta, Canada. This control system uses an acid gas feed analyser and dynamic algorithms to control the combustion air flow to the reaction furnace.

How does ABC+ work?

Looking at the big picture, ABC+ is designed to maximise sulphur recovery efficiency (SRE) by continuously adjusting the combustion air flow to feed gas changes. The maximum SRE can only be achieved when the proper amount of air is

Fig 1: **Claus conversion efficiency**

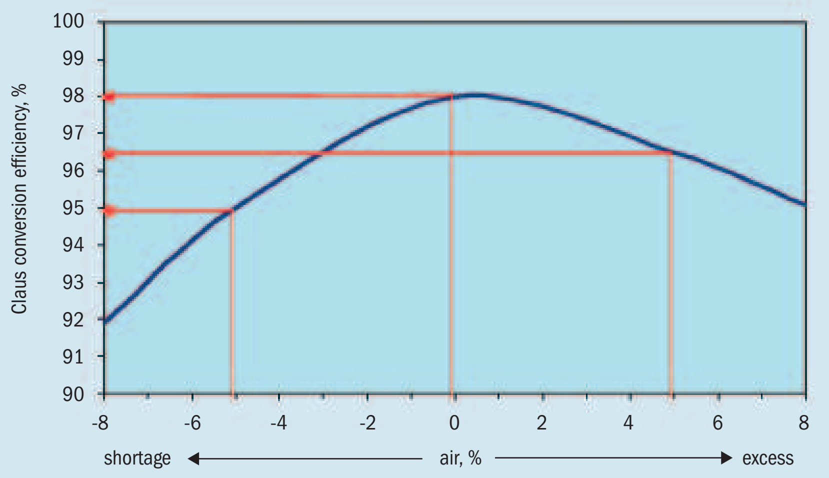
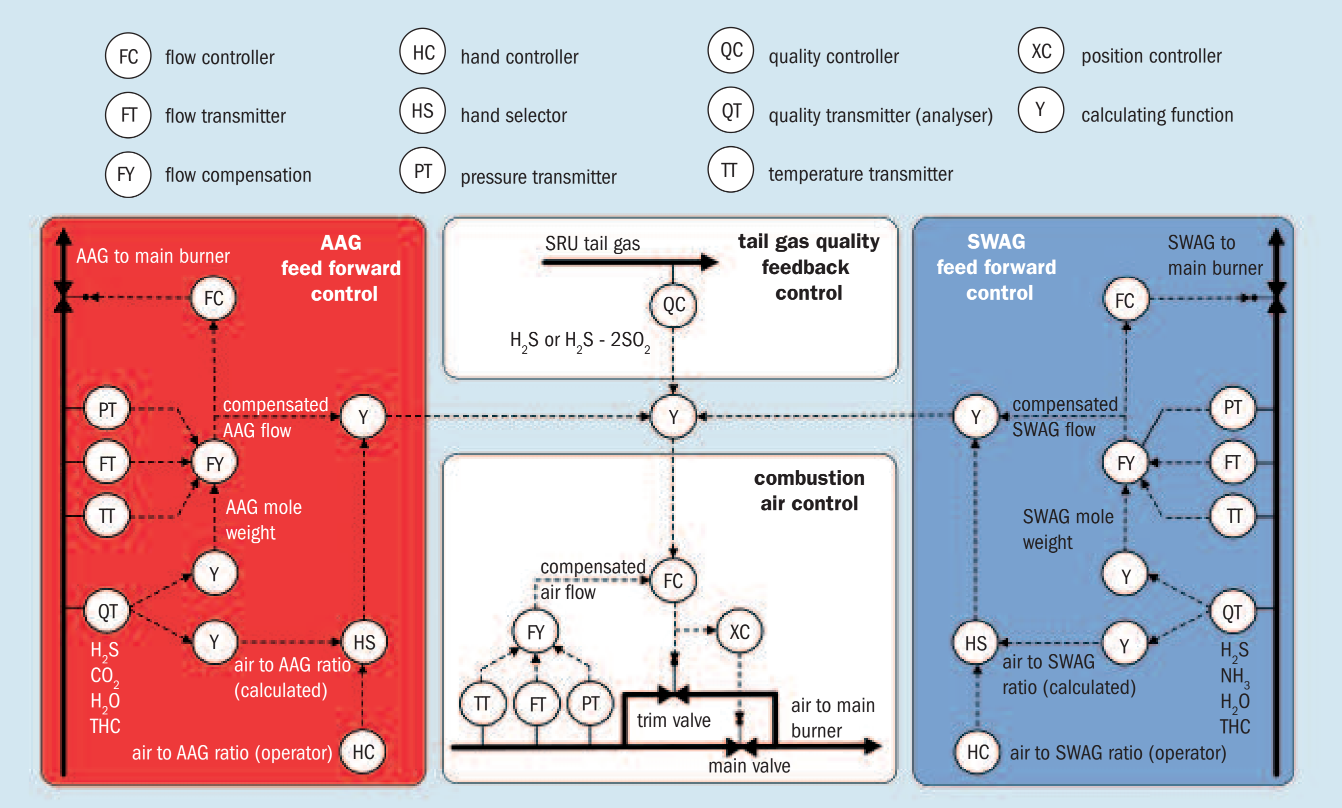


Table 1: **Cause and effect matrix**

% feed gas change caused by	% effect on feed gas flow rate	% effect on air-to-feed gas ratio	% effect on feed gas air demand
Flow rate, +1	+1.00	0	+1.00
Pressure, +1	+0.22	0	+0.22
Temperature, +1	-0.09	0	-0.09
Molecular weight, +1	+0.50	-4.37	-3.90

Fig 2: **Overview of Advanced Burner Control+ (ABC+)**



supplied. Figure 1 shows the sensitivity of the Claus conversion efficiency to the air supply. In order to stay in the top of the conversion curve, the error in combustion air supply should be ≤0.5%, which is a very tight requirement.

Changes in feed gas flow, like Amine Acid Gas (AAG) and Sour Water Stripper Acid Gas (SWAG), can be caused by changes in flow rate, pressure, temperature and molecular weight. The effects on feed gas flow rate, air-to-feed gas ratio and feed gas air demand in Table 1 indicate the significance of these changes. Note that the feed gas flow rate is multiplied by the air-to-feed gas ratio to determine the feed gas air demand.

As an example of how to read Table 1, if the feed gas pressure increases by 1%, the feed gas flow rate would increase by 0.22%, provided flow compensation is applied to pressure fluctuations within the control scheme. There would be no effect on the air-to-acid gas ratio, as the feed gas composition stays the same and thus the feed gas air demand would also increase by 0.22%. From Table 1 it becomes clear that commonly applied feed gas flow compensation (on pressure and temperature) only takes the smallest effects in feed gas air demand into account. In fact, the biggest contributor to feed gas air demand is the combined effect of a molecular weight change to both feed gas flow rate as well as air-to-feed gas ratio; a 1% increase in molecular weight would lead to 3.9% less feed gas air demand. Without molecular weight compensation within the control scheme this would lead to a significant loss in Claus conversion; it would drop more than 1% as a result of 3.90% excess air according to Fig. 1. Also, the combustion air composition may vary with the relative humidity of ambient air, influencing the oxygen content. However, these changes are normally rather slow processes but they can be compensated as well.

Now that the relative impact of changing feed gas variables on the feed gas air demand is known, the functionality of ABC+ will be explained. ABC+ consists of three components (see Fig. 2):

- AAG/SWAG feed forward control;
- tail gas quality feedback control;
- combustion air control.

The AAG/SWAG feed forward control is accomplished by measuring the flow rate and compensating for pressure and temperature fluctuations, just like most other feed gas applications for SRUs. ABC+ takes this one step further by also compensating the feed gas flow for molecular weight fluctuations using a dedicated feed gas com-

Fig 3: **ABC+ control with fluctuating feed gas composition**

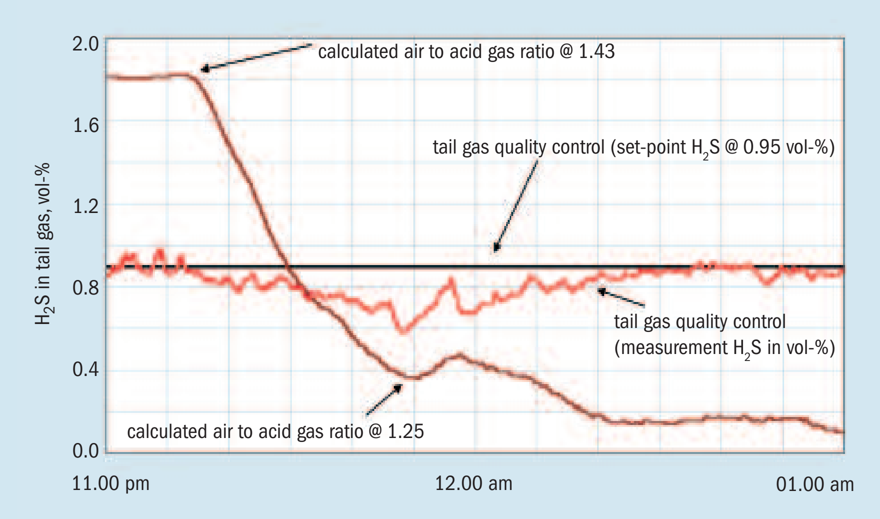
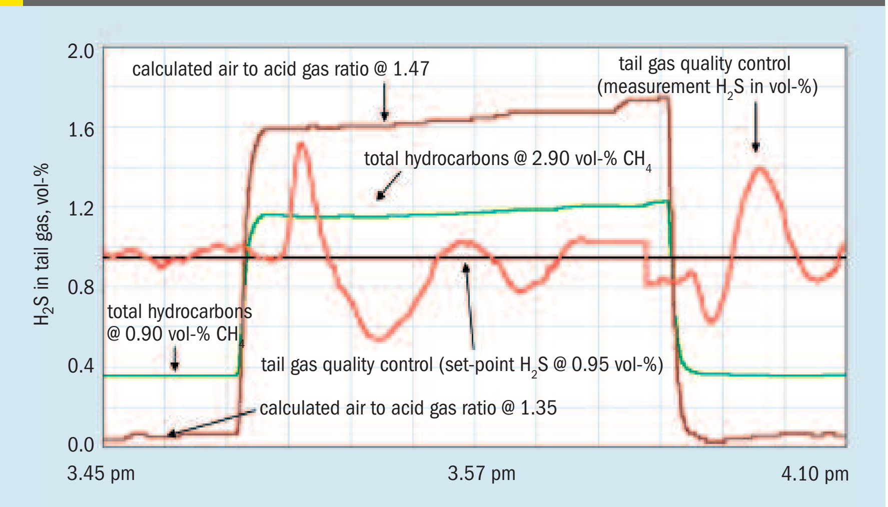


Fig 4: **ABC+ response to THC upset**



position analyser. The feed gas composition measurements are also used to calculate the air-to-feed gas ratio. The feed gas analyser, part of the ABC+ hardware which will be discussed further below, can be set up for AAG applications to measure H_2S, CO_2, H_2O and total hydrocarbons or THC (indicated as CH_4). This analyser can also be set up for SWAG applications to measure H_2S, NH_3, H_2O and THC. On-line calculations convert the components concentrations into specific air-to-feed gas ratios on the basis of SRU specific chemical reactions and process design. This revolutionary development changes the air-to-feed gas ratio dynamically to precisely deliver the proper air volume for each feed gas supplied to the main burner. This results in very accurate feed forward control and improves the SRU control robustness.

Tail gas quality feedback control is used to correct the combined feed forward air demands. Any air demand deviation that occurs due to typical measurement errors like inaccuracy, dynamic and static errors or even failed measurements is compensated by this feedback control to calculate the total air flow set-point. Effective means are implemented in this controller to cope with typical SRU non-linearity, like feed gas load dependent residence time. Due to the fact that the tail gas measurement is located at the back of the SRU, it may take up to several minutes before the effects can be seen of improper air flow to the main burner. In addition, feedback control can only be tuned very slowly, in order not to initiate instabilities or process oscillations. In ABC+ tail gas quality feedback control only air fine-tunes the total air demand, where traditionally this controller has always been the most important controller in SRU combustion air control.

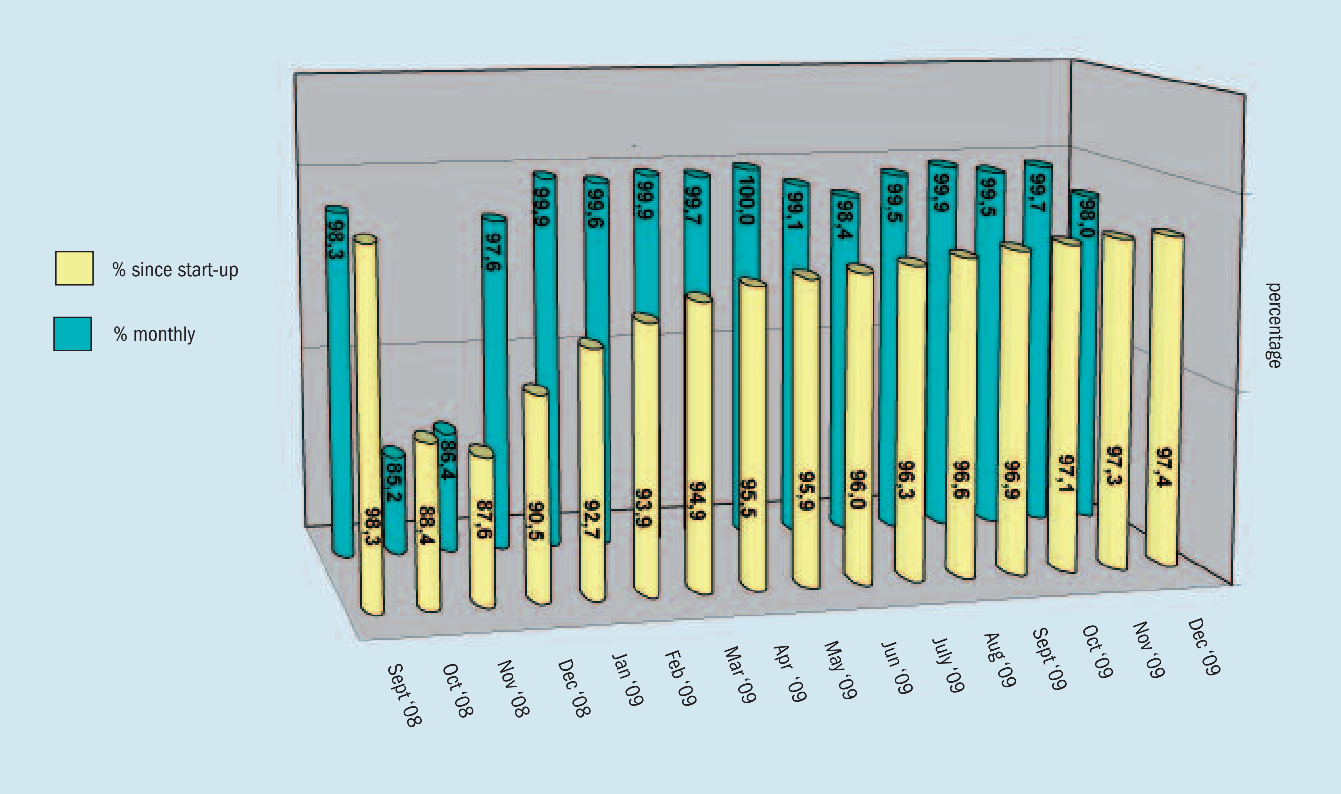
The total air flow set-point, being the total feed gas air demand compensated for tail gas quality deviations, is the parameter that drives the air control. Accurate and fast air flow control is ensured by combining specific trim and main air valve characteristics in a smart way. Driven by the total air flow set-point the total air flow controller (FC) acts on the trim valve, which by default is controlled at half of its air flow capacity. As such, the trim valve is always optimally positioned to cope with positive or negative changes in total air flow set-point. However, since the capacity of the trim valve is limited the trim valve position controller (XC) ensures that the trim valve always stays within its operating window by manipulating the main air valve if required. Various calculating functions take care of typical SRU non-linearity, like load dependent control valve capacities. An overview of the control functionality of ABC+ is shown in Fig. 2.

Over the last decades the world has seen many efforts to integrate feed gas analysers into SRU combustion air control. Due to its application in highly concentrated acid gas like AAG/SWAG providing reliable on-line measurements has proven to be a very difficult task. Due to the potential effect of a combustion air control failure most companies are very reluctant to integrate on-line analysers. Instead they decide to use its measurements for indication purposes only. And when time passes and the reliability of the feed gas analyser system deteriorates, maintenance tends to invest less effort in maintaining 'just an indicating function only'.

Integrating feed gas analysers within the air control system requires a well thought-out control design in combination with high demands on the ABC+ hardware in terms of quality, reliability, availability, accuracy and reproducibility, to mention only a few success factors. The ABC+ hardware, as discussed, consists of a feed gas analyser, a sample conditioning system, interconnecting sample gas tubing, a sample probe and, if required, an analyser walk-in cabinet. Currently only ABB's Multiwave PIR3502 infrared photometer meets the qualifications for the analyser part. It is expected that in 2010 alternative analysers may be offered for the ABC+ hardware concept.

Apart from strict ABC+ hardware requirements, installing a feed gas analyser requires critical design considerations such as analyser location and speed of analyser signal response. Depending on the feed

Fig 5: **ABC+ on-line time**



gas header design the analyser location is preferably as far as possible upstream of the SRU. However, the gas analysed needs to represent the feed gas that enters the SRU main burner. Once the optimum analyser location is determined, the time lag caused by sample gas transport and analysing within the ABC+ hardware must be limited to the absolute minimum. Also in the DCS there may be challenges, such as handling high SRU turndown in combination with big feed gas piping volume. This may require actually delaying the measurements from the feed gas analyser depending on the SRU load.

Field results Suncor Simonette

The Suncor Simonette Gas Plant in Alberta Canada is an example of a challenging SRU control application. The plant processes gas from over 65 wells using four main pipe lines, including one as long as 110 km. In the various raw feed gas streams the H_2S content ranges from 2 vol-% to 16 vol-%, which means the acid gas composition from the MDEA sweetening units to the SRU varies significantly. Sometimes the H_2S composition in the acid gas to the SRU changes as much as 15 vol-% within several minutes. In 2008 the existing ABC system was upgraded by Jacobs CSS to ABC+ in order to improve the control of their SRU (2+1 SUPERCLAUS® configuration). Extreme feed gas composition changes resulted in frequent upsets in the SRU, decline in SRE, SO_2 emission excursions and other unwanted consequences.

Since its installation, more than one year of operational data has been gathered and analysed to evaluate the performance of ABC+. The performance is shown in terms of control trends, ABC+ on-line time and by its effects on SRE. In addition, some interesting operational facts will be described.

ABC+ control with fluctuating feed gas composition

Suncor Simonette's ABC+ went on-line on September 15th 2008 and during the first week of start-up tests were carried out by purposely creating changes in the acid gas feed composition. These changes in H_2S, CO_2 and THC content were obtained by shutting down or introducing variant raw gases to the plant. Even with a significant change in air-to-acid gas ratio from 1.43 to 1.25 in only 35 minutes Fig. 3 clearly demonstrates that the H_2S content in the tail gas is maintained closely to the desired set-point of 0.95 vol-% (see Fig. 3).

ABC+ response to THC upset

In Fig.4 the THC content in the acid gas feed was increased from 0.9 vol-% to 2.9 vol-% within 10 seconds by introducing natural gas to the upstream amine regenerator. As a result, the calculated air-to-acid gas ratio immediately showed a significant increase in air demand. After an initial modest H_2S concentration spike at the tail gas analyser, the response of ABC+ was very satisfactory as within several minutes the H_2S concentration returned to its set-point (see Fig 4.). Also at the reverse upset, where THC was decreased again, an identical response was observed.

Conventional control systems are not able to respond to these changes adequately and timely. In fact, tests as in Figs 3 and 4 would cause major upsets causing acid gas flaring and emission violations.

During the ABC+ start-up dedicated timers and reporting functionality were added to the plant PLC in order to monitor the ABC+ performance. An important parameter for this is the ABC+ on-line time. It is defined as the percentage of operation time during which the ABC+ hardware is available for control and activated by the operator (on the air-to-acid gas ratio selector, see Fig. 2). An overview of the ABC+ on-line time is given in Fig. 5.

Figure 5 shows that the ABC+ on-line time has usually been higher than 99%, without creating nuisance trips or plant upsets due to analyser failure. As of early 2010, the ABC+ on-line time since start-up is 97.4%, while the monthly score varied between 85% and 100%. The average ABC+ on-line time over 2009 is 99.4%. This means that on average ABC+ was not available only one hour each week of operation, which is an impressive score.

The robustness of ABC+ was also demonstrated by the fact that the SRU functioned properly for several days without tail gas control due to a failed tail gas analyser. Suncor Simonette operators were able to run the SRU only on the feed forward analyser, while keeping the SRE at an acceptable level. This is quite a change compared to the pre-ABC+ era, where they were forced to run the SRU almost blindly with limited success. This again confirms that within ABC+, feedback control using the tail gas quality is only required for fine-tuning.

Suncor Simonette further reports that '*…the analyser requires very little maintenance thus far; a zero-check is usually only executed quarterly unless there is a specific problem. Apart from some minor failures, the sample conditioning system performs very well also requiring very little maintenance. An example for that may be that since start-up cleaning of the analyser lenses was not necessary and drift of the analyser measurement has not been experienced. The installed ABC+ alarms and safety system do work well and do not result in nuisance alarms…*' (reference Suncor Simonette plant personnel).

Another indicator for successful ABC+ operation is the observed increase in average SRE of about 0.2%. The resulting reduction in SO_2 emissions is equivalent to a significant reduction of more than 15% of the daily SO_2 emissions. Furthermore, the SO_2 emission violations were considerably reduced from 27 violations in 2007 to only three violations since the start-up of ABC+ in September 2008. Similarly, the number of flaring events and the amount of sulphur flared decreased drastically. After the turnaround mid 2009 the operators managed to start up the SRU without a single emission violation for the first time in Suncor Simonette history.

Apart from improved performance and reduced emissions, ABC+ enabled Suncor to operate their SRU much closer to its design capacity when, normally, an extra margin was required to manually deal with sudden plant upsets. Suncor reported *'…an increase in capacity of about 10% which directly increased revenues…'* (reference Suncor Simonette plant personnel). Finally, Suncor Simonette operators' experience and feedback are an important measure of success. Suncor indicated that *'…operators have embraced ABC+ and the system has paid enormous dividends…'* (reference Suncor Simonette plant personnel). Suncor also credits ABC+ for providing a safer working environment with reduced risk of catalyst and equipment damage. On March 17, 2009 Suncor formally recognised Suncor Simonette and its innovative ABC+ implementation by awarding this project the President's Operational Excellence Award in the category Environmental Excellence.

Does your SRU benefit from ABC+?

The actual benefits of ABC+ are different for each individual SRU. Nevertheless, it is evident that ABC+ is beneficial to each Claus-based sulphur recovery process, as proper air-to-feed gas control is the key. In the following section some challenging SRU operations are briefly discussed.

Do SO_2 emission violations occur in your plant?

SO_2 emission violations are generally caused by improper air-to-feed gas ratio control. ABC+ automatically calculates and controls the air-to-feed gas ratio based on the measured feed gas composition. As a result, stable SRU operation is maintained at all times and emission violations are prevented.

Do you experience SRU upsets due to hydrocarbon carry-over?

ABC+ prevents the vast majority of these upsets as the hydrocarbon content in the feed gas is detected timely and the required combustion air flow is adjusted accordingly. Besides preventing a plant upset, increased emissions and equipment/catalyst damage are also avoided.

Do you experience increased SO_2 emissions during start-up?

Usually the acid gas composition is not known during the introduction of feed gas into the SRU (start-up). The used air-to-feed gas ratio is relatively high in order to avoid high levels of H_2S in the tail gas. As a consequence increased SO_2 emissions are very common during start-up and it can take several hours before the unit is in stable operation and emissions are reduced. ABC+ can prevent these increased emissions as the feed gas composition, and therefore the required air-to-feed gas ratio is known before the feed gas is introduced. In this way start-up is a lot safer, quicker and easier compared to start-up with a conventional control system.

In addition ABC+ also provides the following benefits:

- reduced acid gas flaring;
- increased on-line time and plant capacity with increased revenues as a result;
- reduced OPEX due to increase of catalyst life and less risk of equipment damage;
- improved safety as plant upsets are prevented;
- real time SRE and CO_2 emissions data available in DCS;
- enables Operations to troubleshoot and optimise upstream sweetening and sour water stripper units;
- less operator attention required for combustion air control, as ABC+ works fully automatically.

In conclusion, ABC+ provides a safer, efficient, cleaner and cheaper way to recover sulphur. Altogether, ABC+ has many advantages for operations, for the regulators, and ultimately, we all benefit from a safer and cleaner environment.

Future plans

Based on the benefits and the success of ABC+ at Suncor Simonette Gas Plant, Jacobs CSS has added ABC+ to its portfolio. For this purpose a strategic partnership has been developed enabling fit-for-purpose ABC+ solutions for any Jacobs CSS client. This will be based on a generic and improved ABC+ hardware concept that can be applied in AAG or SWAG feed systems, or alike, and designed to meet the hardware requirements indicated earlier. With this concept Jacobs CSS can provide added value to new and existing SRU air control systems worldwide. ■

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