

The First Industrial Experience with the Haldor Topsøe Exchange Reformer

Various options are available for a capacity increase in the front-end of an ammonia complex. Out of these, convective gas heated reforming stands out as an attractive option from both a technical as well as a cost effective perspective. The Haldor Topsøe Exchange Reformer (HTER) technology is a proven revamp option where a capacity increase of 20 - 25 % can easily be achieved, while the methane leakage is retained at a low level.

The HTER technology has now been in successful commercial operation since early 2003. A full size industrial unit has been revamped with an HTER installed downstream of an Autothermal Reformer (ATR), this has resulted in a 33% increase in reforming capacity. The revamped capacity is approximately equivalent to the front-end production for a 1100 to 1200 MTPD ammonia plant. Further to the capacity increase, an improved gas composition is obtained by careful selection of the operating parameters and the flow split between the HTER and the ATR.

This paper describes the experience gained during the implementation of the HTER into the Sasol Synfuels Plant in Secunda, South Africa. The technical challenges such as metal dusting and revamping inside a large, compact and complex running plant, and the successful results are described.

The paper also describes how this technology is adopted in an ammonia plant and what benefits can be offered to the ammonia industry.

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Introduction

Sasol Synfuels successfully operates a very large facility in Secunda, South Africa, for conversion of coal to liquid fuels and other refined hydrocarbon products. One of the important process steps on the way to the final products is the reforming section in which a methane rich gas is converted to syngas on the basis of autothermal reforming using Haldor Topsøe burner technology. Sasol operates 16 parallel autothermal

reformers (ATRs) each with a capacity equivalent to a syngas production for a 900 to 1025 MTPD ammonia plant.

Sasol Synfuels are actively pursuing opportunities for reforming capacity increase, in particular, opportunities that allows capacity increase without an increase in oxygen consumption. This can be achieved with the Haldor Topsøe Exchange Reformer (HTER) technology, where the sensibleheat from the ATR effluent is effectively utilised for

steam reforming rather than raising less valuable steam. In this way, a significant capacity increase can be achieved and at the same time the carbon and hydrogen efficiencies of the process are improved and, as a third and very important benefit, the hydrogen/CO/CO₂ ratio of the syngas can be controlled to match the stoichiometry of the downstream processes much better.

Sasol and Haldor Topsøe A/S have set up a project in 1999 to integrate the Haldor Topsøe Heat Exchange Reforming technology in the Secunda facility. In order to save time and money, a decision was made to proceed straight to a commercial scale demonstration in which one HTER should be installed directly in one of the existing ATR lines rather than starting building a pilot unit and afterwards a side-stream Process Demonstration Unit.

Sasol provided the capital for the project and carried the production risk of integrating the new reforming unit into the existing methane reforming operations at Sasol Synfuels. The revamped unit was started up early 2003 and an extensive full scale 22-month long demonstration run was performed at Sasol's expense to prove the viability of the concept. The ATR/HTER pair has been in operation since the initial start-up and lives up to the expectations.

The HTER technology is not only suited for syngas preparation for Coal to Liquids or Gas to Liquids facilities, with minor adaptations it is equally suited to boost the capacity of a methanol or an ammonia producing facility. This option will be discussed further at the end of this paper.

Flow Scheme

Figure 1 is a sketch of the reformer section of the Sasol Synfuels plant prior to the revamp.

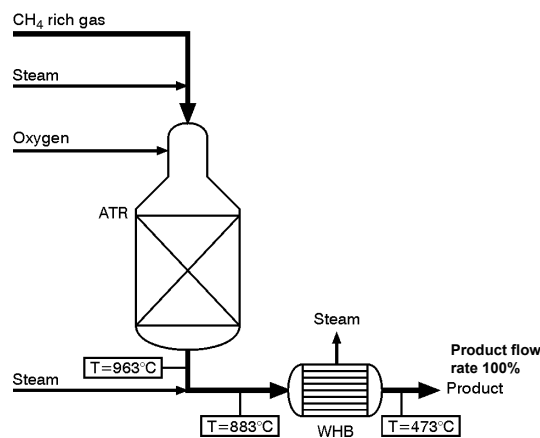


Figure 1: Layout of reforming section prior to revamp

The layout is quite conventional with the high level heat of syngas being cooled in a steam generating waste heat boiler placed downstream the oxygen fired ATR. One of the limitations to the process in the Sasol plant is the waste heat boiler inlet temperature as well as the duty. Both are stressed to or beyond the original design capacity and in order to protect the boiler, steam is used to quench the gas before the entrance to the boiler. This is obviously not optimal from an energy perspective.

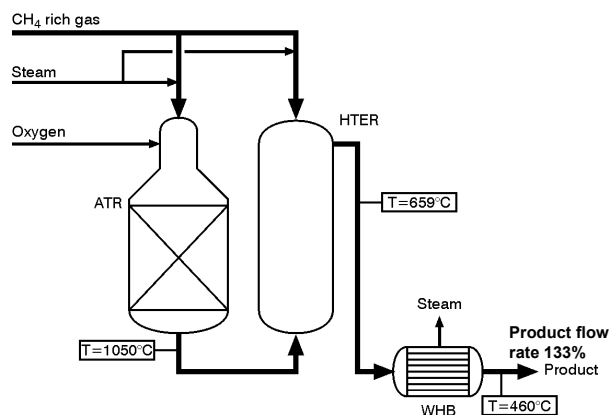


Figure 2: Layout of reforming section revamped with an HTER in parallel with the ATR

A more efficient process would be feed-effluent heat exchange at high temperatures reducing the oxygen required inside the reformer or, more attractively, increasing the total syngas product flow by driving additional endothermic reforming reaction with the high level heat. This process concept is depicted in Figure 2, where the HTER taking care of the additional reforming is installed in parallel with the ATR. This revamp scheme was chosen for the Sasol Synfuels project. The most important changes to the process are:

- The syngas production capacity of the combined unit is increased by 33% compared to the stand-alone ATR
- The oxygen consumption per produced syngas flow unit is decreased by 20%
- The quench steam is eliminated
- The Ribblett ratio of the gas (a ratio conveniently expressing the syngas quality in relation to the downstream high temperature Fischer-Tropsch reaction) is significantly improved
- The steam production is lowered by 45% and thereby the steam export is eliminated

Challenges

With the implementation of a project of this nature in a large and complex facility, a number of technical challenges exist and these should be addressed properly.

When the syngas is cooled slowly, as is the case in a syngas feed-effluent exchange reformer, metal dusting is a well-known concern. Only few materials are suited for these conditions, and based on Haldor Topsøe's experience and laboratory tests, the prime material candidates were initially identi-

fied. A testing method developed by Sasol Technology allowed long-time exposure of these material candidates to conditions simulating the expected conditions and temperature ranges for the HTER in existing equipment at the Sasol Synfuels Gas Reforming plant. In this way, the risk of metal dusting could be evaluated and the best possible material selected prior to the final design of the HTER.

Materials being resistant to metal dusting are generally high cost materials and, consequently, it is important to make optimal use of the surfaces that are subjected to a metal dusting potential. The HTER is made with a unique double tube arrangement resulting in two parallel catalyst beds where all internal surfaces provide heat transfer area. This design ensures at the same time a very compact piece of equipment. More details on the reformer concept can be found in [1].

Another significant practical challenge is the tie-in to the existing reforming plant, in particular the connection between the ATR and the existing waste heat boiler. The Sasol Synfuels plant was already prior to the revamp very compact in layout and addition of new equipment in between the ATR and the WHB would look almost impossible as can be seen from Figure 3. Nevertheless, a solution was found placing the HTER on the opposite side of the ATR, and routing the product gas from the HTER on the back side and underneath the HTER and the ATR back to the existing Waste Heat Boiler. Figure 4 shows the layout of the revamped unit.

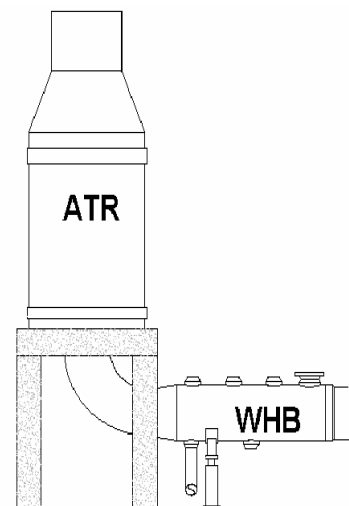


Figure 3: Original mechanical layout of ATR and WHB

This may not at first sight seem the most practical routing of the refractory lined transfer lines, but with this design no existing equipment had to be moved and in addition, it was possible to prefabricate and pre-install all major equipment while the plant was still kept on-line. Only for the installation of the last pieces of transfer line was it necessary to shut-down the ATR. It was moreover noted that all installation work was carried out while the parallel reformer lines situated in close proximity to the line being revamped were kept on-stream. This was possible because all tie-ins that would affect the entire factory had been prepared at a previous maintenance turn-around and thus, production losses were kept at a minimum.

In the Sasol Synfuels reforming plant, the ATRs are heated up from cold condition with an external heater under atmospheric pressure. This is an additional complication when an HTER is added at the downstream side. A special start-up system has to be devised in which the product gas is bypassing the HTER until suitable process conditions are es-

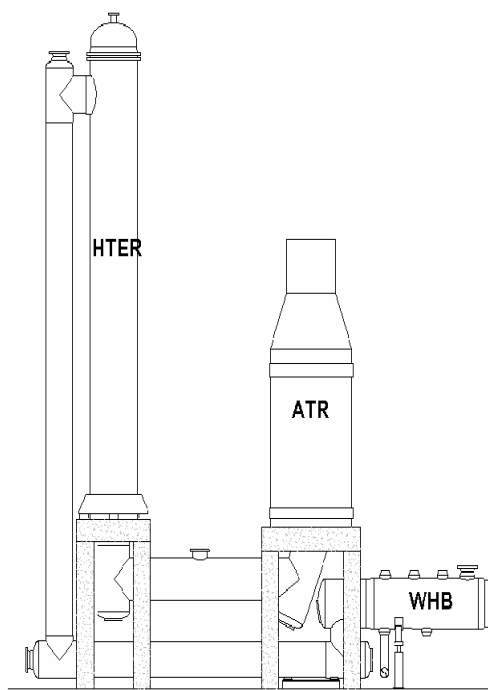


Figure 4: Routing of syngas from ATR to HTER and on to the WHB after revamp

tablished in the ATR. When the correct conditions are confirmed, the HTER is gradually put into service as the by-pass is closed.

Industrial Experience

The revamped unit was ready for operation and started up in January 2003. Only 4 years had passed since the first basic ideas were exchanged about the project. During this period of time, the project went through pre-feasibility and feasibility studies including material screenings, etc., basic and detailed engineering as well as construction and commissioning. This remarkable achievement was possible only through a committed effort from the involved parties, Sasol Synfuels, Sasol Technology and Haldor Topsøe.

Figure 5 shows a picture of the HTER internal being lifted after arrival to the site.



Figure 5: HTER internals being installed

Since the initial start-up, there have been no unforeseen stops that were related to the HTER, and the HTER has been in continuous operation with the exception of planned shut-downs and the period of by-pass operation mentioned below. This has led to a high availability factor (97%).

During the test-run, it was shown that the predicted capacity increase and conversion of the revamped unit was reached – in fact, there was some additional capacity in the unit compared to the expected figures of a 33% capacity increase. Likewise, the pressure drops have been found to be stable and well within the anticipated values.

Since this new equipment was built into the plant as a full scale industrial unit with no prior pilot scale or side stream operating experience, the operators were anxious to learn how the reformer pair behaved under industrial conditions with

whatever up-stream and down-stream fluctuations that could be anticipated. It was found that the ATR/HTER pair was easily operable, however, slightly more sensitive to fast cut-back of the feed or the oxygen than the stand-alone ATRs.

As a risk-mitigating arrangement it was important for the plant owner that the revamped reforming unit could easily be converted back to the original operating mode. This requirement was taken into consideration during the design phase, and it involves removal of the HTER internals from the pressure shell and operation of the unit without the cooling effect of the HTER - the so-called by-pass mode. The bypass mode was demonstrated during a 2 month period in which the ATR was operated at the full (original) load. One of the concerns was whether the higher outlet temperatures would be a problem for the complicated

transfer line configuration, but no adverse effects of the bypass operation were identified.

The HTER has been shut-down at a number of predetermined occasions for inspection. The main purpose of these inspections has been to verify the mechanical integrity given the high material temperatures experienced in this piece of equipment and to examine for signs of corrosion, viz. metal dusting. It has been concluded from these inspections that the HTER is performing well and the projected life-time of the HTER internal has been confirmed. As an additional benefit, these inspections have served to confirm the maintainability of the HTER, and they have given valuable experience in shutting down and restarting the ATR/HTER pair.

In the future, the ATR/HTER line at Sasol Synfuels is anticipated to follow the normal maintenance schedule of the factory and the line will thus only be stopped when dictated by a predefined maintenance activity or a catalyst skim/replacement on the ATR, i.e. a continuous run-length of up to 2 years.

Three years of operating experience with the unit revamped to comprise an ATR/HTER pair has proven the viability of this concept. The operational benefit that was anticipated has been fulfilled, and Sasol and Haldor Topsøe are jointly in the process of studying how future capacity expansions can be made with this promising technology.

Use of HTER Technology in Ammonia Plants

In the above case, the HTER is placed downstream of an ATR, but the HTER is equally well suited to be located after a secondary reformer or even after a stand-alone tubular reformer. The technology is thus interesting in many business areas such as hydrogen production, methanol production, GTL/CTL and ammonia production. In this section, we shall be looking specifically into the HTER option for ammonia plants – both as a

revamp option or as an alternative to the classical layout for a grass-root plant.

Figure 6 is a sketch of a traditional ammonia plant front-end (reforming only) with a tubular primary reformer and an air fired secondary reformer followed by a Waste Heat Boiler (WHB). This unit can be revamped with an HTER in parallel to the primary reformer as is shown in Figure 7.

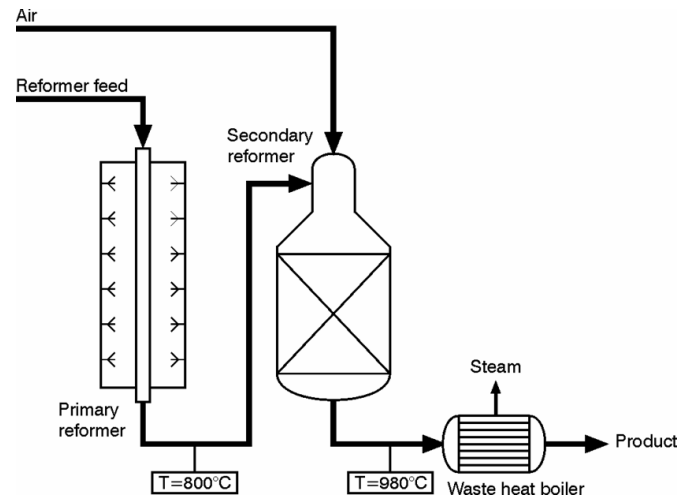


Figure 6: A traditional ammonia plant front-end

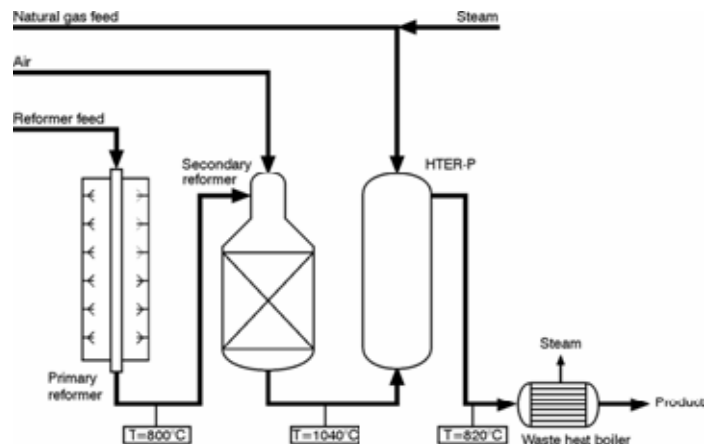


Figure 7: Ammonia plant front-end including an HTER-p

The parallel option can be executed in two ways: either the effluent from the secondary reformer (or ATR) is mixed with the reformed gas coming out of the HTER catalyst bed before cooling of the combined product gas takes place, or the two streams are cooled separately and mixed at the

exit. Both ways have their advantages, and the selection of option depends on the circumstances. For the revamp case at Sasol Synfuels, the first option was chosen. In other cases where a low CH₄ leakage is crucial such as in syngas production for ammonia, the second option is the most attractive.

The HTER design can be made to accommodate both the above options and otherwise be optimised to suit the process requirements in the best possible way. The main features of the HTER will in all cases be the same as those demonstrated industrially at the Sasol Synfuels Gas Reforming Plant. The HTER suited for an ammonia plant will be made up of a number of double tubes that are

furnished with a bayonet return tube. The heat transfer is laid out in such a way that only a very limited surface area will be subjected to metal dusting conditions, and consequently, the use of special resistant materials can be minimised.

To illustrate a revamp situation for an ammonia plant, a comparison between a base case and the revamp case is made in the below table. As can be seen, a 25% increase in reforming capacity and equivalent ammonia production can be achieved by introduction of the HTER. It is noted that this capacity increase could equally well be translated into an unchanged capacity and a correspondingly smaller load on the primary reformer.

	Base Case	HTER Revamp Case	Change
Dry product flow, kNm³/hr	280	351	+25%
Equivalent NH₃ production, MTPD	2225	2800	+25%
CH₄ leakage	0.44	0.38	
Steam production in syngas WHB	100%	90%	

Table 1: Key figures for the base case and the same ammonia plant revamped with an HTER.

The steam production in the syngas WHB is lowered by 10% only, but it should be emphasised that the total steam production in the plant (including the ammonia loop) is essentially unchanged. This means that it will not be necessary to upgrade the steam system in the plant, which will save both time and investment cost for the revamp. It can also be noted that the methane slip is kept around the original level in order to keep the inert level in the loop unchanged.

The above case clearly demonstrates that the HTER technology is attractive as a revamp option for an ammonia plant. The HTER is, however, also an attractive solution for a new grass root plant. As such, the benefit of introducing an HTER can either be harvested in terms of a significant capacity increase if an existing plant is revamped, or as an

option to minimise the size of the primary reformer in a new plant and thereby save capital cost and improve operability of the plant. An additional benefit for a new ammonia plant is that the steam production and the steam consumption is partially balanced, i.e. virtually no steam import/export. This would be of particular interest for a stand-alone ammonia plant.

In the revamp option, the mechanical layout needs special consideration based on the actual available space in the plant. Often it is possible to locate the HTER next to the secondary reformer and re-route the exit transfer line to the bottom of the HTER. The combined exit gas from the HTER is led back to the existing WHB, preferably without moving any equipment in the front-end. It should be noted that there is no need for any special start-up sys-

tem, because the HTER is easily heated up and put on-stream together with the primary and secondary reformer.

Conclusion

Haldor Topsøe's first industrial reference with an HTER has been in successful operation at the Sasol Synfuels plant in Secunda, South Africa, for more than 3 years. The HTER, which is a full scale plant, has been operating on a commercial basis for the entire period.

As an integrated part of the project implementation, the first part of the operating period was designated a demonstration period, where the viability of this new technology was evaluated. It was concluded that the benefit in terms of capacity increase, lower specific oxygen consumption and gas quality has been achieved.

This promising technology is attractive not only in a synthetic fuels plant. As the example in this paper has demonstrated, significant increases in ammonia production can be achieved if an ammonia plant with a traditional front-end layout is revamped with the HTER technology. Likewise, it has been shown that a new plant can be designed with a smaller and less costly primary reformer when an HTER is installed from the beginning.

References

- [1] Loock, S., Ernst, W.S, Thomsen, S.G, Jensen, M.F.: "Improving carbon efficiency in an auto-thermal methane reforming plant with Gas Heated Heat Exchange Reforming technology", presented at the 7th World Congress of Chemical Engineers, Scotland 2005.
- [2] Damand, F.A., Boe, M., Erikstrup, N.H.B., Marcher, J., Nielsen, H.C.L.T., Kelling, D.: "Loading of Catalysts in Steam Reformers Using the SpiraLoad™ Method", AIChE Ammonia Safety Symposium, Orlando, 2003.