Methanol Casale's Presence in Russia: 13 years of Successes in the Methanol Industry

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For presentation at the
METHANOL CONFERENCE 2007
Shokino, Tula region, RUSSIA
April 25-27, 2007

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1) Introduction

Methanol Casale began its activities in Russia in 1994 with the revamping of the two reactors operated by Methafrax in Gubakha, Perm region.

Since then, the Casale presence in the Russian methanol market has become very important and today, with the only two grass-root high capacity methanol plants erected in Russia in the last 15 years, Casale is the market leader in this field.

Casale is, of course, present in many other countries, but its presence in the Russian market is very special, thanks to its deeply knowledge of this reality and the fruitful collaboration with local companies (both End-Users and Engineering firms).

At the beginning of the new century, Casale has introduced a completely new design for reactors, based on the heat removal from the catalyst mass by means of plate exchangers. This new design has been applied for the first time in a methanol synthesis converter in 2002.

At the end of last year, two different Casale isothermal converters have been put on stream, featuring innovative characteristics.

These features are:

- Direct steam generation
- Axial-radial flow in the catalyst beds.

2) The New Methanol Plants in Russia

Casale has designed and successfully put the second methanol plant in Togliatti in operation in December 2006, with a capacity of 1’590 MTD that, together with the first line, in operation since January 2000, will allow the company to reach a production of 1’000’000 MTY.

The process scheme of the two plants is very similar, and only few modifications were carried out to increase the capacity from 1'350 to 1'590 MTD, both using a steam reformer, CO_2 addition in the make-up gas and the same Casale Horizontal methanol converter.

For both the plants, the Methanol Casale scope of supply was the following:

- License;
- Basic and detail engineering (excluding civil and structural);
- Supply of proprietary and special equipment;
- Construction supervision;
- Commissioning, start-up and test-run assistance.

It should be underlined, that, thanks to the unique experience gained during the construction of the first plant, where already several pieces of equipment manufactured in Russia were employed, and to the full collaboration of the plant staff, it was decided to further reduce the amount of equipment purchased outside Russia, maximizing the use of resources available inside TOAZ and in Russia, with strong reduction in costs, delivery and transportation time.

With this in mind, for the second plant, the only equipment supplied from Western Europe was:

Reforming section:

- Combustion air heating system (fans, exchanger and burners);
- Reformer tubes bottom manifolds and risers only.

Methanol loop:

- Methanol converter and its internals;
- Loop air-cooler.

Distillation section:

- Refining columns air-cooler;
- Topping and Refining columns trays;
- Small plates exchangers.

Machinery:

- Syngas and CO_2 compressors, their turbines and steam condensers;
- Pumps.

All the other equipment, including the reformer catalytic tubes, the HP methanol loop equipment (gas-gas and water cooler heat exchangers, HP separator) and both the distillation columns have been manufactured in Russia, and mainly by TOAZ, according to Casale specifications and under Casale quality control.

The following table summarizes the splitting of supply of main pieces of equipment:

Supplied by MCSA and manufactured in Western Europe	40
Supplied by TOAZ and manufactured in Russia	60
Available at site, designed for a GIAP ammonia plant	4

The results is a very efficient plant, thanks to application of Casale technologies combined with a lower capital investment cost, and therefore, with a shorter-than-normal payback.

Thanks to the excellent collaboration between Casale and a local engineering company and to the adoption of Russian standards, the project was quickly approved by the local authorities. Nevertheless, the design and plant performances have not been jeopardized by these choices.

Piping manufactured in Russia according to GOST should have been employed without any problem even in connection with equipment directly supply from abroad.

The result is a new methanol plant, with performances comparable to other new plants outside Russia.

3) The New Design approach for methanol plants: the IMC reactors

Methanol Casale is a well-established designer of high efficiency reactors that is its core business. In the Methanol Industry it is mostly known for its ARC design for synthesis converters, which has been widely adopted through revamping or new installations in steam reforming plants during the '90s.

At the beginning of the new century, Casale has introduced a completely new design for reactors, based on the heat removal from the catalyst mass by means of plate exchangers, the so-called IMC (Casale Isothermal, plate-cooled Methanol Converter design).

This new design was applied for the first time in Russia, in the Nevinnominsk plant where the methanol synthesis was revamped in 2002, and since then it has run successfully for 4 and half years.

Very recently the plants have been shut-down for catalyst replacement. The advantages of the ICM design were even underlined during the shut-down: the catalyst download was very fast (all the catalyst went through the drop out pipes once again demonstrating the efficiency of the design that allows a unique heat removal).

Other 2 converters similar to the first one, have been put in operation in 2005 in Novomoskovsk, allowing the plant to reach the production of 1'000 MTD.

Last year, two different Casale isothermal converters have been put on stream, featuring innovative characteristics.
These features are the direct steam generation and the axial-radial flow in the catalyst beds.

The use of cooling plates in synthesis converters has been already illustrated in the past for an axial, gas-cooled converter. The new designs presented in this paper are still based on the use of cooling plates and are:

- The first steam-raising plate-cooled converter;
- The first axial-radial, gas-cooled converter.

These two designs are new not only for CASALE, but for the whole methanol industry and disclose very interesting areas of development.

3.1) The Steam Raising Plate Cooled Converter

At present there are already several steam raising converters of various configurations in service, having nevertheless one common feature: they are tube-cooled, meaning that the cooling surface is made with tubes.

This fact represents a restriction to the overall design, leading to limitations in the highest capacity that can be reached, and, in general, to a rather involved construction.

Cooling Plate

The plate-cooled converters, on the other hand, make use of cooling plates immersed in the catalyst mass for heat removal. The boiling water is flowing inside the plates, from the bottom to the top, and is then collected in a manifold and exits the converter through a nozzle on the shell.

There is no tubesheet, therefore there is no constraint in the converter size, and the construction is light, consisting of a normal pressure vessel containing the catalyst bed and the plates

The plates are dimpled, obtained in an automatic production process, having a very high quality consistency, where the manual input is minimal.

The plates are surrounded by the catalyst mass where the process gas is flowing. The process gas flow can be axial or axial-radial.

The advantage of the plate-cooled steam-raising design is to overcome the traditional limitations, allowing much higher production rates in a single converter, to introduce a new concept in reliability and catalyst handling, and to allow a better temperature control in the catalyst mass, increasing the operating life of the catalyst charge.

This design has been applied for the first time in the Metafrax plant in Gubakha, Russia, in a revamping aimed at capacity increase. The details of the project are presented in chapter 3.

In this plant the plate cooled converter is installed on the fresh make-up gas as a once-through unit, producing about 850 MTD of methanol and 30 to 40 t/h, (SOR and EOR respectively), of 32 bar saturated steam.

It is a completely new converter and the performances obtained are excellent.

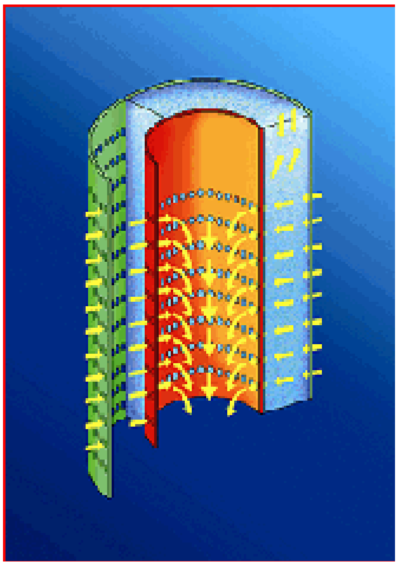
3.2) Axial-radial gas cooled converter

Other than the water-cooled converter, there are only a few gas-cooled converters in modern methanol plants, and they are all axial. Again the limitation of these designs is the use of tubes to cool the catalyst mass, preventing from the use of an axial-radial, or radial, flow in the beds.

The axial flow is in itself an important design drawback, as it limits the maximum capacity that can be reached. This factor is important for revamping as well as for new plants.

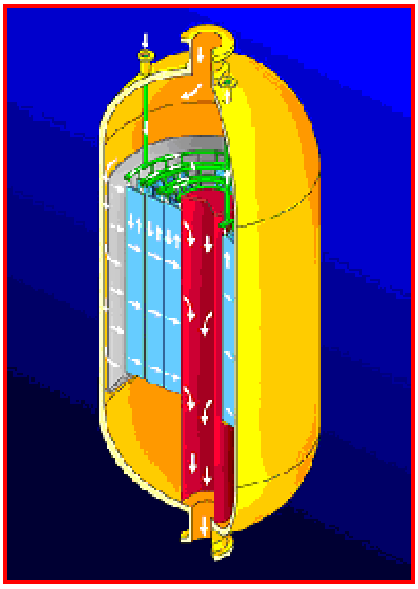
In the revamping of existing converters, when it is desired to increase the plant capacity, and to switch from a quench-cooled design to IMC, in order to increase the efficiency, the axial flow can create a pressure drop in the converter that is not acceptable. The use of axial-radial flow, already very common in ammonia plants, can solve this problem, greatly reducing the pressure drop of a converter.

For new plants the issue is about the maximum capacity that can be reached, without having to go to multiple parallel converter units, with reasonable pressure vessel diameters. It is clear that an axial-radial design leads to a much slimmer vessel for the same catalyst volume, allowing to reach capacities above 7'000 MTD in a single vessel converter.



Axial-Radial Flow Catalyst Bed

The first axial-radial gas cooled converter is now on stream in the AMPCO plant in Equatorial Guinea. This design can be obtained easily with the use of plates as cooling surface area, The flow of cooling gas inside the plates can have the same direction of the gas in the catalyst, that is in a horizontal direction, co-current or counter-current (see figure).



Axial-Radial Plate Cooled Converter

This arrangement allows for an optimal temperature profile in the catalyst bed, which further increases the converter performances.

The AMPCO converter has been revamped with the ‘in-situ’ technology, i.e. re-utilizing the pressure vessel in which new internals are installed during a turnaround. Also this revamping has been done within a capacity increase projects, detailed in chapter 4.

The converter was originally a four-bed three-quenches design, and, without modifying the pressure vessel, it has been revamped to a new configuration featuring two axial-radial beds, each one gas cooled with plates.

4) METAFRAX Revamping Project

METAFRAX is a Russian company owning a methanol plant in Gubakha, Russia. It is a natural gas based plant. This plant was originally designed according to the ICI process in the early eighties, with a nominal capacity of 2’500 MTD. It was revamped to a capacity of 2’700 MTD in 1994 by installing the Casale ARC internals.
Metafrax then, in 2001, decided to further increase its capacity to 3’050 MTD.

In order to obtain the higher production the main bottlenecks were:

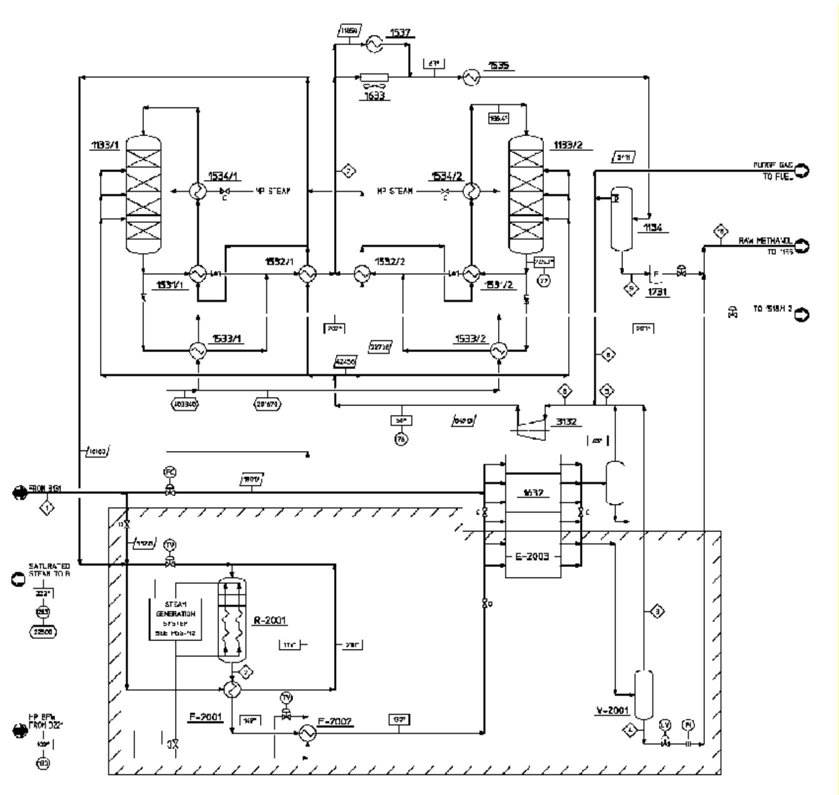
- The reforming section;
- The syngas compressor and turbine;
- The synthesis loop;
- The steam balance;
- The distillation section.

CASALE was awarded a contract first to debottleneck the synthesis loop, and then for the reforming, while the other section were dealt with directly by METAFRAX.

The reformer revamping consisted of replacement of the rotary combustion air preheater with a new fixed plate type, the replacement of the mixed feed coils, now fully finned, the replacement of the boiler feed water heat exchangers, and the addition of a purge fuel gas preheater.

The synthesis loop was revamped by adding a new once-through synthesis section on the make-up gas.

This new section consists of the new, plate-cooled steam raising converter, followed by a gas-gas heat exchanger preheating the gas entering the converter, an air condenser and separator, as illustrated in the flow sheet.



New Synloop Configuration

The existing synthesis loop was modified by replacing the HP separator with a new one, while the rest was left unchanged. This solution has been selected to avoid the need for revamping the two converters working in parallel as well as the downstream equipment, also in parallel.
A further advantage of the new synthesis section is the production of MP steam that is used as process steam in the reformer, and sent to the new mixed feed heater coil.

The revamping works have been carried out in two stages in 2005/06, the plant is now successfully on stream and the test run has been completed.

The main operating data are illustrated in table 1 below:

Plant capacity	MTD	3065
Nat. Gas Consumption	Gcal/MT	7.84
IMC Conv. MeOH Prod.	MTD	845
IMC Conv. Steam Prod.	T/h	32

5**) The AMPCO Revamping Project**

Atlantic Methanol Production Company L.L.C. (AMPCO) owns a methanol plant in Equatorial Guinea, Africa.

The methanol plant was designed by different Licensors for various parts (for instance F.W. for the primary reformer and MHI for the methanol converter). It has a design production capacity of 2’500 MTD, while the capacity before revamping was about 2’900 MTD.
It is a natural gas based plant, i.e. using natural gas for feed and for fuel.

AMPCO desired to increase the plant capacity up to 3’200 MTD in a first step, and to 3400 MTD in a second step.

METHANOL CASALE was awarded a contract to increase the capacity of the reforming section and of the synthesis converter.

The main plant characteristic and problems resulting from the existing plant operation and constraints can be summarized as follows:

- The heat flux on primary reformer was close to the maximum.
  To overcome this restriction it was decided to install a new pre-reforming section, to be supplied by METHANOL CASALE.

- The methanol loop circulator was close to its maximum performance and the synthesis converter also was at its maximum capacity.
  To overcome the synloop limitation the synthesis converter had to be revamped with new IMC internals from METHANOL CASALE.

The project had a tight schedule, overall of 14 months, and included modifications in several parts of the plant, including Steam reformer, Compressor and turbine, Methanol synthesis.

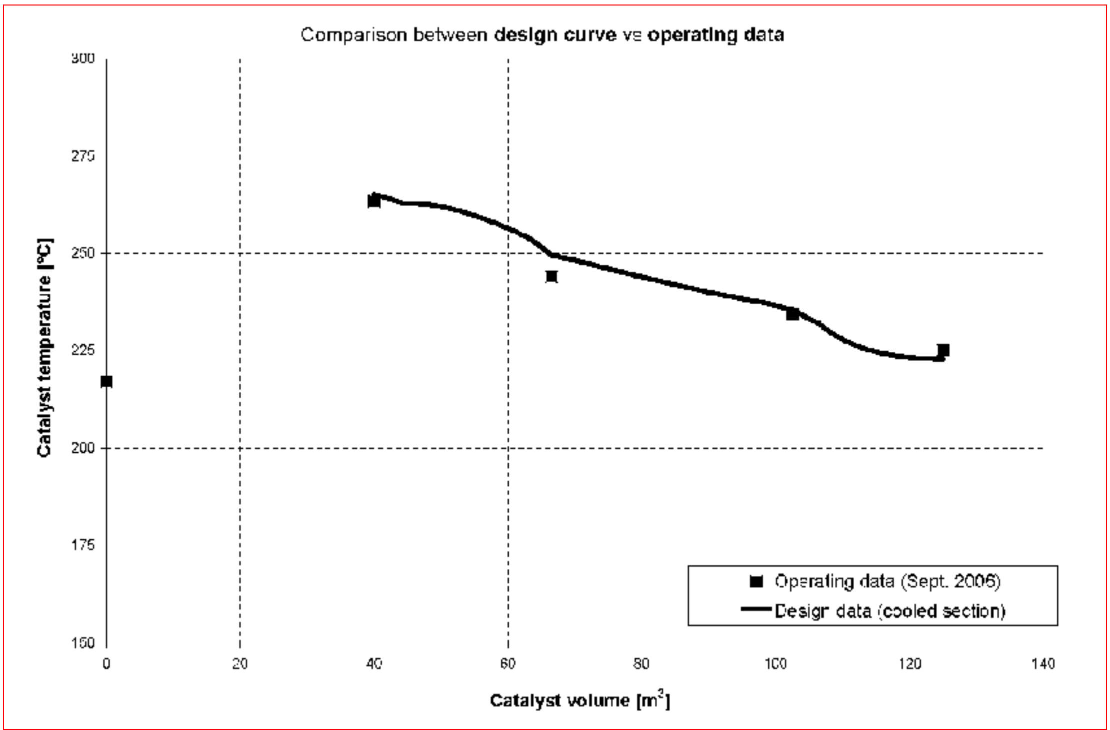
Methanol Synthesis

In order to revamp the synthesis loop it was necessary to increase the performance of the existing converter. It was, therefore, decided to install the new Casale plate-cooled internals (IMC).
This design,offers a higher conversion per pass, higher carbon efficiency, and, being axial-radial, a lower pressure drop.
The catalyst volume loaded in the new internals is about 140 m^3.

The new design is based on the use of plates immersed in the axial-radial catalyst bed to remove the reaction heat while it is formed.

The use of plates for cooling, allows the design of a pseudo isothermal converter increasing the conversion per pass and, improving the loop carbon efficiency up to 98 %.

Temperature Profile in the Casale IMC



As indicated in the figure above, the temperature profile achieved in the catalyst bed is downward, following the line of maximum reaction rate, so obtaining the highest possible conversion per pass from a given catalyst volume.

Thanks to the new internals, it is possible to achieve the higher capacity without alteration to the circulating compressor and without major modifications to the synloop.

The main operating parameters are presented in the table below:

Plant Capacity	MTD	>3'000
Conv. Outlet P.	Psig	1'400
Converter DP	Psi	32

At present, since the capacity is limited by the syngas compressor, that will be modified in the near future, the pre-reforming section has been pre-commissioned, but is not in operation.

5) Conclusions

The two projects illustrated have been successful, as they have dramatically improved the performances of the two existing plants where they have been implemented. They are even more so as they include two new designs of CASALE methanol converters.

These two new designs set very important milestones for the methanol industry, as they make new instruments available to improve the efficiency and production capacities of existing plants, and set new references for converters in new plants, as their combination allows the design of very efficient methanol converters with production capacities in a single vessel exceeding by far any previous design. In fact a new, gas-based, plant with a capacity of 7'000 MTD has been already designed with a single vessel converter, featuring the direct steam generation in one part and the axial-radial, gas-cooled bed in the other.

Furthermore, the experience gained by Casale is unique and can be applied in other similar projects in order to cut down the cost of equipment in the TOAZ new methanol plant. It has already been done not only in Russia, but also in other countries, like China, where Casale has a very strong position thanks to its special approach consisting in maximizing the use of local resources for common benefits and success.

Lugano, April 2007
Code:Paper/conf/met/meetings/shokino paper