A formaldehyde magazine from JM Formox

Informally Speaking

Autumn 2015

Methanol update

Formaldehyde Europe

The development of the Formox process - Part 1

Upgrades

Preparing for new opportunities

Dear reader,

Once again, the global economical landscape is changing. China's slowing economy is a wet blanket on the global chemical industry, the strong US dollar is shifting the playing field, and the sanctions against Russia are affecting western companies doing business with Russian counterparts. On the positive side, the agreement between the US, EU and Iran regarding Iran's nuclear program is paving the way for sanctions to be lifted early next year, and the global chemical industry is already preparing for the opportunities that this will create. Against this backdrop, the outlook for the formaldehyde market is generally positive, and new capacity is coming on stream in the US and in Eastern Europe in the near future to meet the growth in demand.

Since the last issue of Informally Speaking, we have held two customer conferences; one in Moscow, Russia at the end of 2014, and the other in Helsingborg, Sweden in May of this year. Both were a great success with a high number of attendees, interesting presentations and training, and many productive meetings and discussions.

In this issue, I would especially like to draw your attention to the article by Dr. Phil Hope of Formacare on the changing classification of formaldehyde, as well as the special feature on how the Formox process has been developed since its introduction in the 1950s.

Also, please note the upcoming conferences we will be holding in Brazil (September) and China (October). Be sure to join us there in order to get the latest market and technical news from the world of formaldehyde!

Mårten Olausson
Market Director
Petrochemicals

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Contributing writer:	Charles Hodgdon
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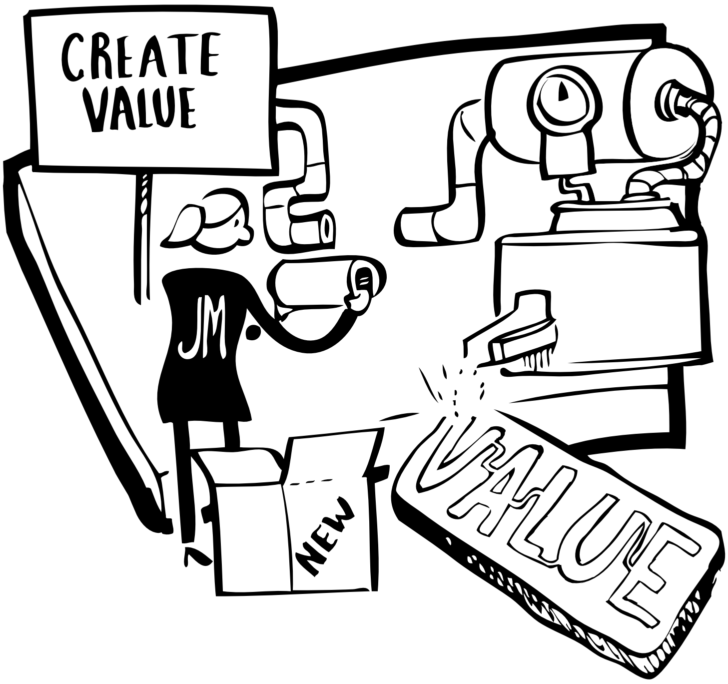
In previous issues of Informally Speaking we have described the importance of customer focus and innovation through collaboration. This time we speak with David Prest, Managing Director of the Process Technologies Chemicals Business, and newly appointed Market Director for Petrochemicals, Mårten Olausson, who is now combining the responsibility for formaldehyde with catalysts and technology for the petrochemicals market.

Combining strengths

to create value for you



Following the acquisition of Formox by Johnson Matthey in 2013, we are now taking a further step in the integration of the Formox business into the Process Technologies Division through the creation of a new business unit, Chemicals. Here, Formox is joining forces with the licensing business formerly known as JM Davy, as well as with the global catalyst business serving the petrochemical and renewables markets.

- This is a natural progression which combines the strengths of the individual businesses, says Mårten Olausson, newly appointed Market Director for Petrochemicals. It reinforces our offer to the market, taking advantage our broader capability in process licensing & technology, and catalysts.

Why has this new business unit been created?

- We are combining our strengths in catalysts and process technology through market-focused teams that will align commercial and technical activities, says David Prest, Managing Director at Chemicals. The business will increasingly develop integrated technologies for our target market of the chemical process industries, with a focus primarily on the petrochemical and bio-renewable sectors. We continue to recognize formaldehyde as a key component of our growing business.

What are the benefits for our customers?

- Through collaboration within JM, we have already accelerated improvements in the formaldehyde process technology. When we collaborate together within our different market areas, we will achieve new opportunities to help our customers grow their businesses with continuous improvements and operational effectiveness, David continues.
- Our customer focus is being reinforced. Our customer support organization will have a similar structure, and most customers will have the same contacts as before, but the new business has a broader geographic presence. By combining our strengths in the new Chemicals businesses, we look forward to enhancing our offer in the areas of technical support, product development, technology development and supply chain, Mårten adds.

BY

Anna Rundblad,
Communications Manager,
JM Formox AB

Formaldehyde Europe 2015

World leading formaldehyde conference

- Formaldehyde for the future
- Upcoming legislation
- Latest developments
- Networking
- Training and much more...

There was quite a buzz in the city of Helsingborg when JM Formox's annual conference took place during some intensive and educational days this spring. During May 6 – 8, some 80 delegates, mostly customers from all over the world, but also JM Formox representatives, gathered together to get the latest news on subjects like:

- Methanol – the new global challenge
- Consequences of formaldehyde reclassification in Europe
- R&D specialists are challenging the limits
- Energy utilization & productivity

The first day was dedicated to presentations from both JM Formox managers and from outside expertise like Wolfgang Seuser from Methanol Market Services Asia (MMSA). With his 35 years of experience from the global chemical industry, Mr. Seuser held an in-depth presentation of the methanol market and also talked about how methanol is growing as a chemical and is positioned for growth as an energy option. Elaine McColgan, Global Regulatory Affairs Manager from Johnson Matthey Process Technologies, talked about key chemical regulations in the EU and beyond. Her main topic was the REACH-system (Registration, Evaluation, Authorization and restriction of Chemicals), a set of regulations that aims to improve the protection of human health and the environment and is applied in all 28 member states of the European Union.

Classifications, energy utilization and future R&D projects

Phil Hope, Secretary General of Formacare, the formaldehyde sector group of the European Chemical Industry Council (Cefic), discussed the immediate impact of the recent classification of formaldehyde as CMR 1B in the CLP regulation, which will become mandatory in Europe on 1 January 2016. In the energy utilization block, our suppliers from Siemens in Germany showed us the advantages with predesigned turbo blowers and steam turbines. Of course, there were also presentations on how JM Formox has developed over the last two years, market updates, and an overview by our R&D specialists of the different ongoing and future development projects for increased productivity, regarding both plants and catalysts. The benefits of using the JM Formox CAP 3.0 concept, which enables operations at higher production rates and provides a longer catalyst lifetime, was also highlighted this first day.

Training in focus

The second and third days of the conference took place in the village of Perstorp, close to our head office. On the agenda was education and training for our catalyst customers in topics like optimization of plant/catalyst operation, incidents, troubleshooting, cases from reality etc. The classroom exercises were mixed with more hands-on activities such as GC-measurements, cleaning tubes, gas warning device, etc., performed in different areas of the plant. At the end of the day there was also a visit to the JM Formox R&D center, with Robert Häggblad, Manager R&D Catalysts, as our guide.

Views of the conference

JM Formox's first plant customer, **Foresa**, who celebrated their 50th anniversary last year, was attending the conference and was interested in having a closer look at the possibilities of upgrades. -We have been customers for a very long time and we think it is a good experience to visit the conference to get tips and ideas on, for instance, upgrades to increase our capacity, says Begoña Ferro, Production Manager at Foresa in Spain.
–I find this conference interesting; it is nice to meet and share information with other people in the same business and get new ideas.

What would you like to hear more about?
- I would like to get a more tailor made training and plant visit just for our needs. It would be interesting to see how the shifts are organized; for new operators it is a good idea to participate in these training days and also for those who have been working as operators for some time.

Oxiquim has been a customer of JM Formox for many years. Their first Formox plant was built at the site in Viña del Mar. It was one of the first licensed plants and begun already in 1966 with one reactor. JM Formox has just completed a plant audit on their plant to identify potential upgrades and/or improvement areas.

Why did you do a plant audit?
-It's a chance for us to investigate what possibilities we have to increase our production with a small investment. We see it as an advantage that it is JM Formox conducting the audit because of their knowledge and updated information in this field, says Günther Füllgraff.

Why are you participating in this conference?
-It's good to meet the JM Formox staff face to face and to build relations with people in this business. We get a lot of information from these days, both from the topics presented but also when networking with the other participants. At the visit to the R&D center it was interesting to see the analysis capacity you have, says Marcelo Esteban

What would you like to hear more about?
-It would be nice to also get an update on the Global (not only the European) methanol market. More details of maintenance and best practices, maybe presented by some customer, Gustavo Birke says.

Gustavo Birke, Günther Füllgraff and Marcelo Esteban from Oxiquim at the training day.

UPCOMING CONFERENCES

If you have missed one of our conferences and would like to know more about any of the topics, please contact us or sign up for one of our upcoming conferences.

- **Formaldehyde South America** (in English), September 29 – 30, 2015 in Guaruja outside São Paulo in Brazil.
- **Formaldehyde China** (in Chinese), October 19 – 21, 2015 in Hangzhou, China.

BY

Anna Rundblad,
Communications Manager,
JM Formox AB

Formaldehyde Russia 2014

During December 4 – 5, some 20 delegates from 10 different customers joined our seminar "Formaldehyde Russia 2014" that took place outside Moscow. Day one started off with general presentations and continued in the afternoon with a one and a half day training course which was ended day two with a test (which all passed!). The delegates represented several different plant sites and many good discussions were heard.

BY

Yuriy Babkin,
Regional Sales Manager,
JM Formox AB

Formacare represents the key European producers of formaldehyde, aminoplast glues and resins.

Consequences of formaldehyde reclassification in Europe

The European Union has reclassified formaldehyde from a “suspected” to a “presumed” human carcinogen. While this may not seem like a large change, it is sufficient to trigger action under a number of legislations, including the REACH Regulation, the over-arching European regulation for chemicals safety. Formaldehyde is currently undergoing Substance Evaluation in REACH, a process that could result in wide-ranging consequences for the industry. This article briefly outlines industry’s continuing engagement with the legislative process.

The European Union recently reclassified formaldehyde as carcinogen category 1B, under the CLP Regulation[1]. In effect, formaldehyde has changed from human carcinogen category 2 (suspected) to category 1B (presumed). The classification applies only to nasopharyngeal cancer, very rare in Europe.

The new classification came into force in June 2014, but with a transition period until 1 January 2016 during which it may be applied on a voluntary basis. After this date, the new classification becomes mandatory, making any substance containing more than 0.1% by weight of free formaldehyde subject to a new labelling regime. The new classification must also be reflected in the substance’s Safety Data Sheet (SDS).

The classification also triggers action in a number of other EU legislations, for example Occupational Health and Safety legislation, and legislation covering biocidal products and cosmetics. But most importantly it triggers scrutiny under the EU’s REACH Regulation[2].

Risks are adequately addressed

Formaldehyde is currently undergoing Substance Evaluation under REACH. The purpose is to ensure that any risks are adequately addressed, and if necessary to recommend additional measures. This can comprise specific local restrictions, but could even go so far as to constitute an eventual phasing out of the substance from the market.

Two Member States have taken the lead in the process. France is evaluating risks to workers from process emissions, and has recently decided to begin a formal Risk Management Options analysis. The Netherlands is evaluating risks to consumers from the presence of formaldehyde in indoor air, and has requested additional information from industry. Formacare is working closely with the industry’s REACH consortium, and with downstream industry, to provide the requested information. The timing is not yet clear; but recommendations could come next year at the earliest.

Industry has already addressed the management of risk. During 2012 and 2013, independent experts TNO Triskelion and RPA Limited carried out a comprehensive Risk Management Options study, with full access to the industry. Their study, commissioned by Formacare, found safe use today in the workplace and for consumers. However, taking into account the pending reclassification to category 1B, they recommended Europe-wide measures by introducing a mandatory occupational exposure limit, to protect workers, and a mandatory emissions standard for wood-based panels, to ensure that consumers remain fully protected.

Under the REACH Regulation, it is clearly industry’s responsibility to maintain

safe operations and products, following reclassification. Formacare continues to work closely with European and National legislators, to understand and address any concerns as they arise. There will be challenges, but with the support of formaldehyde producers and users, we will meet them openly and positively.

BY

Phil Hope,
Secretary General,
Formacare

1 Classification, Labelling and Packaging of Substances and Mixtures (EC 1272/2008)
2 Registration, Evaluation, Authorisation and Restriction of Chemicals (EC 1907/2006)

Formaldehyde expected to grow beyond GDP globally

The Global formaldehyde market outlook 2015 is the view of JM Formox and assesses growth for the next years. The key data is based on our analysis of internal and external market sources, including macro economical indicators such as GDP sources from IMF and EU-statistical information. The objective is to give a brief outlook of how we view the global FA market, without making any representation as to the accuracy or completeness of this information.

Global formaldehyde growth is projected to exceed 4% annually and demand is expected to grow from 46 to 58 million tons by the end of 2020 (fig. 1).

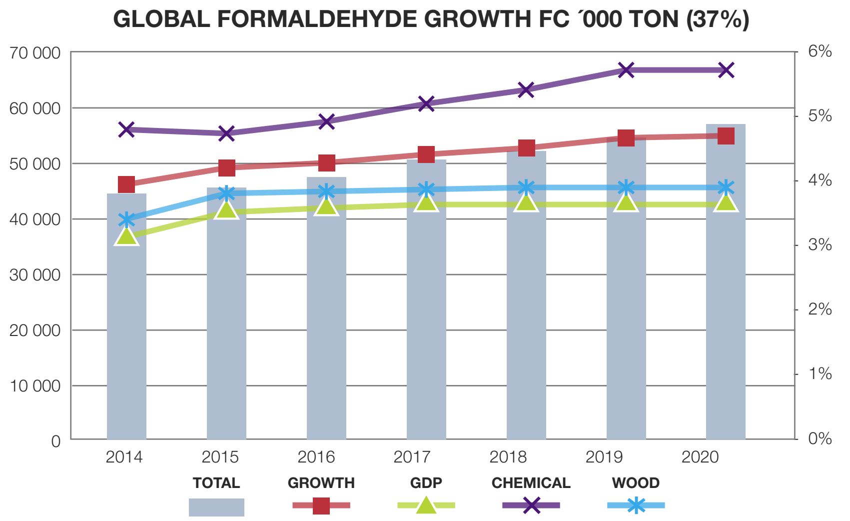


***Fig 1**. Estimated formaldehyde demand (37%), forecasted global GDP (%), total growth formaldehyde (%) and growth by market segment (%).*

Wood segment still biggest

The largest market segment is wood (board and panels industry), totaling approximately 25 million tons (37%) and representing 55% of the global formaldehyde demand. UF resins dominate with 75% of this segment, which also includes Melamine resins for lamination products and coatings (flooring and panels), as well as Phenol resins offering excellent moisture-resistant properties. MDI is also still used for wood to a small extent.

Growth of most wood resins correlates well with GDP, but with significant regional deviations. Global GDP is projected to be 3.5% in 2015, but the regional split is large. While GDP in Europe will range from 1.2% to 1.5%, the outlook in Asia Pacific looks solid, although the downturn in China's real estate sector will certainly have an impact and China will be down to between 6.2 and 6.5%. Low global oil/gas prices are boosting the global economy, but there are also negative factors such as less growth in oil-exporting countries. The U.S. is among the few markets recovering, showing a raise in projected growth from 2.4% to 3.3%. South America is down 1.3% compared to 2014.

Thus the wood segment is expected to grow and the global formaldehyde (37%) demand within the segment will rise from 25 million tons to more than 30 million by the end of 2020. Substitutes for formaldehyde resins in the wood segment do exist, but are still only marginally used.

Growing demand in Chemicals segment

In the chemicals segment, formaldehyde demand is expected to show stronger growth than GDP, and global annual growth above 5% is projected for the period. Formaldehyde is used as an intermediate chemical in large and growing numbers of applications. One example is the production of various engineering plastics increasingly used to replace their metal counterparts in various applications within the automotive industry, electronics, appliances, aircraft, etc. Another area experiencing expansive growth is BDO and the production of fibers for weather resistant sportswear (spandex) and more.

Global formaldehyde growth will be significantly impacted by demand in China, the coal-to-chemicals industry and the Chinese economy, as well as by industrial developments and further advanced technology for producing formaldehyde.

In summary, the formaldehyde industry faces challenges, particularly in the wood segment where tougher and stricter regulation/legislation is a factor. But there are also great opportunities for growth. The drivers and indicators for formaldehyde are positive, and we don't see any real available substitutes for formaldehyde during the next five years, particularly not for chemical intermediates.

BY

Lars-Olle Andersson,
Business Manager,
JM Formox AB

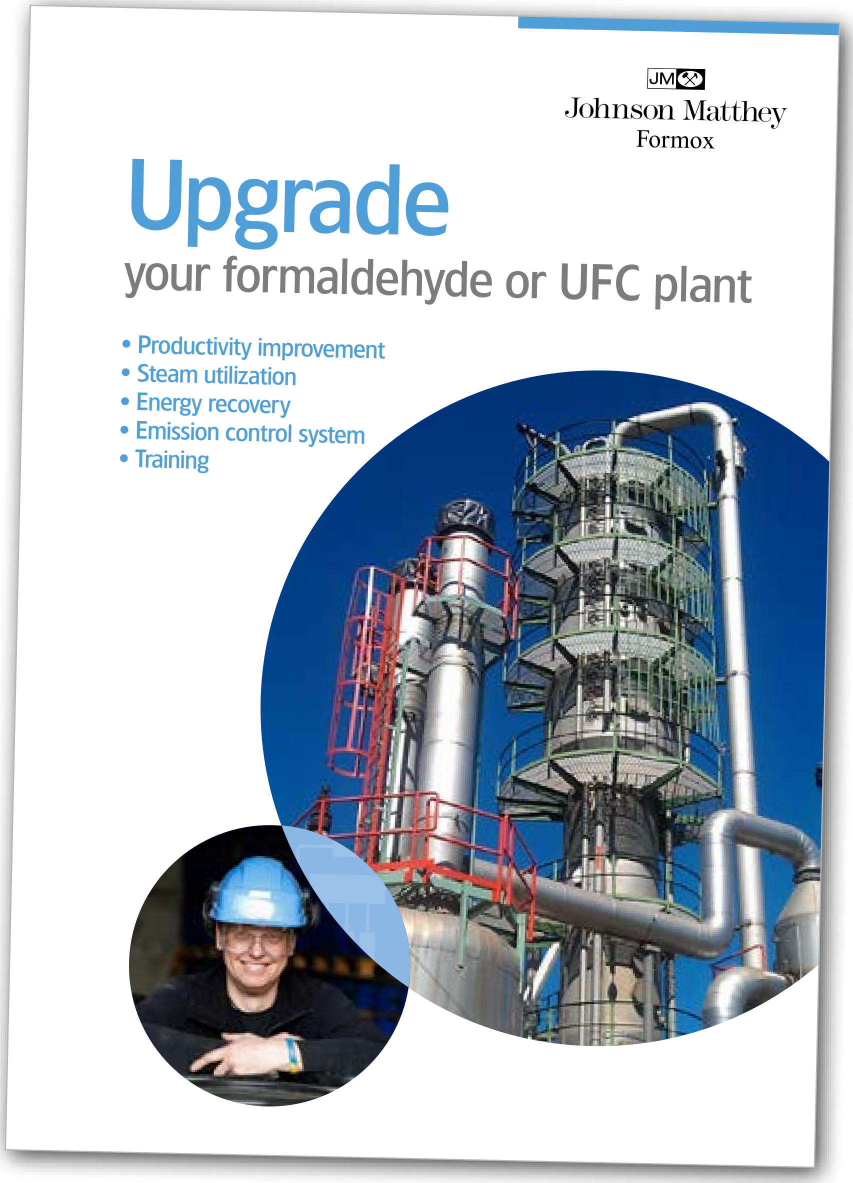
Upgrades

– why and what?

At the Formaldehyde conference in Helsingborg in May we presented a few basic concepts for the types of revamps we can offer and I am happy that a large number of customers have showed great interest in these. The reasons why a plant needs to be upgraded are as many as there are plants, but in general we see five main areas:

- Higher productivity – more MTPD
- Higher energy efficiency (increased steam production or use of the steam)
- Improved emission control – new legislation
- Product quality - Demand for UFC production
- Replacement of outdated equipment

We are, obviously, offering upgrades to all JM Formox plants, but also to other oxide plants. The starting point for every project is the filling out of an RFQ form by the customer. We typically then have to compile a feasibility study in order to map the possibilities in that specific plant, and to find out what equipment needs to be upgraded and/or added in order to reach the requested demand. After the feasibility study is completed we make a detailed offer based on what the customer sees as the best solution for their needs, which hopefully will result in a project to improve the customer's plant. If you have any demand for an upgrade, please contact your sales representative or me directly.



BY

Andreas Magnusson,
Global Product Manager
Plants, JM Formox AB

MMSA – Methanol Market Services Asia - located in Singapore with offices in Shanghai, Frankfurt and Seattle specializes in global methanol, acetic acid, and formaldehyde market and technical analysis, tracking the demand for all major derivatives of these strategically important and versatile petrochemicals.

Global overview of methanol market

Over the past few years, global methanol demand growth has been less dependent upon its traditional driver, growth of macroeconomic activity. Rather, methanol demand has risen on the back of its competitiveness in innovative applications which replace increasingly high cost refined crude products, especially gasoline, naphtha, LPG, and diesel. Therefore, despite continued deceleration of the Chinese economy, methanol demand growth was healthy, again driven by demand growth in Asia.

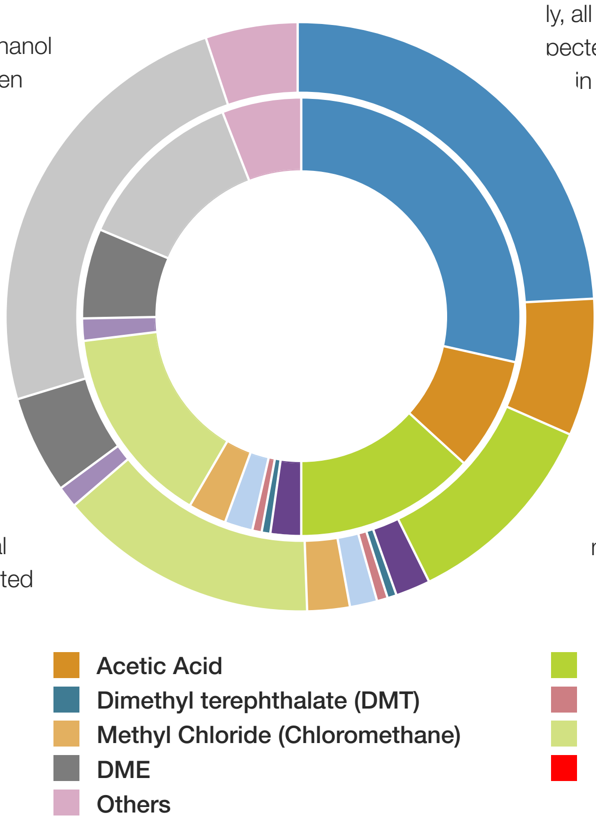
Demand

Over the past five years, methanol demand growth rates have been uniquely higher than most "base" petrochemicals, which include ethylene, propylene, benzene, and paraxylene. Methanol demand growth continues to be driven by cost-effective substitution of refined products in energy applications, particularly in China.

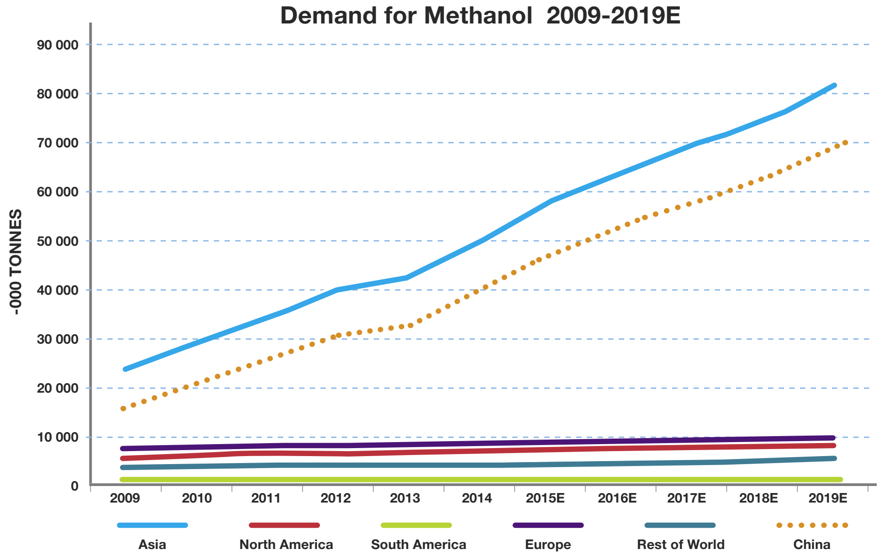
The strongest growth of methanol demand in the forecast will come from the Methanol-to-Olefins (MTO) application, driven by a number of commercial projects now underway. It is expected that this application will consume just over 26.0 million metric tons of methanol in 2019. Major change in the methanol demand landscape will also come from the balance of the "alternative" fuel uses including gasoline blending, direct combustion cooking and heating, biodiesel, dimethyl ether, and power generation.

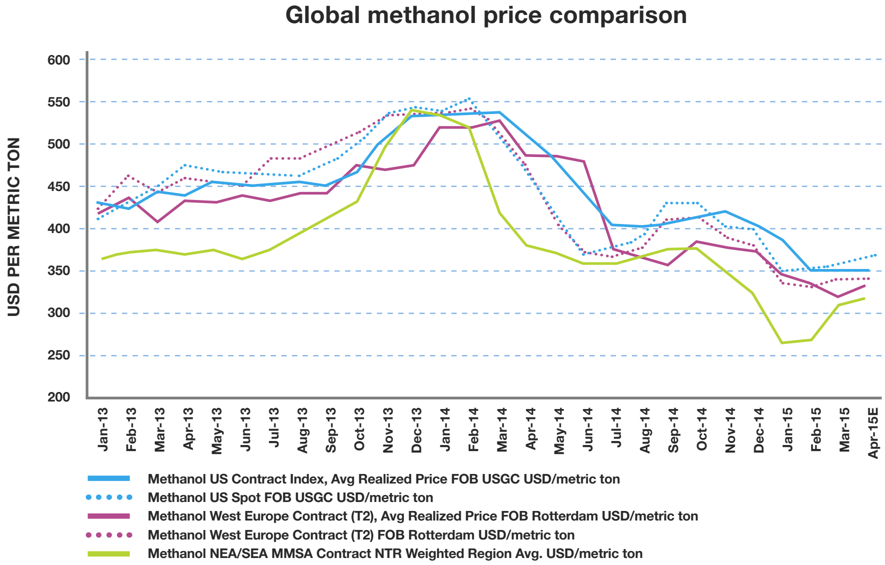
The chart below depicts the distribution of global methanol demand at the beginning and end of the forecast. It shows that energy use of methanol will shrink the percent of demand for in the three largest traditional uses (formaldehyde, acetic acid, and MTBE) by 2019. Alternative uses will claim almost 20 percent of the overall demand market by the end of the study forecast, while MTO demand will comprise about 25 percent of the global methanol market.

From this chart, it can be surmised that the relatively slow growth in use of methanol for traditional applications (particularly formaldehyde and acetic acid) contrasts with the swift MTO growth. The growing demand from Asia, in particular China, is largely energy related. Generally, all traditional methanol sectors are expected to grow with global economies in the next five year period. Within Asia, China remains the largest engine of demand growth. By itself, China is a larger methanol consumer than any other region in the world. The chart on the next page shows demand for methanol by region and indicates China demand for comparison. The other regions' methanol demand growth pales by comparison, meaning the world will continue to rely on Asia for incremental methanol demand growth.



Within Asia, China remains the largest engine of demand growth. By itself, China is a larger methanol consumer than any other region in the world. The chart to the right shows demand for methanol by region and indicates China demand for comparison. The other regions' methanol demand growth pales by comparison, meaning the world will continue to rely on Asia for incremental methanol demand growth.





Global supply

Investment in methanol production capacity in China is expected to takes the global lead. The next largest region for methanol production capacity growth is anticipated to be North America, advantaged by low cost natural gas. Relocation of methanol capacity to the United States, along with US greenfield investment are anticipated. Methanol projects in many other locales, including Azerbaijan, Algeria, and Russia are being considered, although MMSA has only included projects it deems realistic. Longer term, additions to methanol production capacity will issue from those locales which can most competitively support growing demand for methanol in Asia.

Methanol Global Pricing

Methanol price finding processes are different in the regions. Whereas in the US market a monthly contract price system is established, Europe contract price is determined in the benchmark area of Rotterdam based on FOB T2 valid for three months. Leverage for the single regional values is provided by the import development in China, thus driven in particular by non-integrated MTO producers. As long as these facilities are competitive with naphtha based olefins global methanol supply demand balance is stable. Ups and downs in oil pricing and the following affecting naphtha are providing an impact on import volumes resulting subsequently in availability of methanol on the globe. Lower import volume may provide the driver for lowering pricing in other regions.

Methanol Europe

Methanol consumption is relatively mature, although growth in Eastern European countries has been evident. For the European market, formaldehyde will continue to play a large role in methanol fortunes in the region.

Europe consumption is highly dependent on imports supplied from the Caribbean producer, Africa, Middle East and Russia. Local production is established in Norway and Germany covering almost 25% of the demand.

Environmental protection issues in particular plans to reduce CO2 emissions are likely supportive developing methanol demand for energy applications. In particular the shipping industry driven by new regulations regarding the sulphur content in bunker fuel have a certain eye on methanol a replacement option.

Other plans include methanol as an energy carrier using CO2 as a feedstock. Furthermore overcapacity of wind and solar based electricity can feed electrolysis units producing hydrogen and oxygen which could combined with emitted CO2 to produce methanol used as a battery for electricity.

BY

Wolfgang Seuser,
MMSA – Methanol Market Services Asia

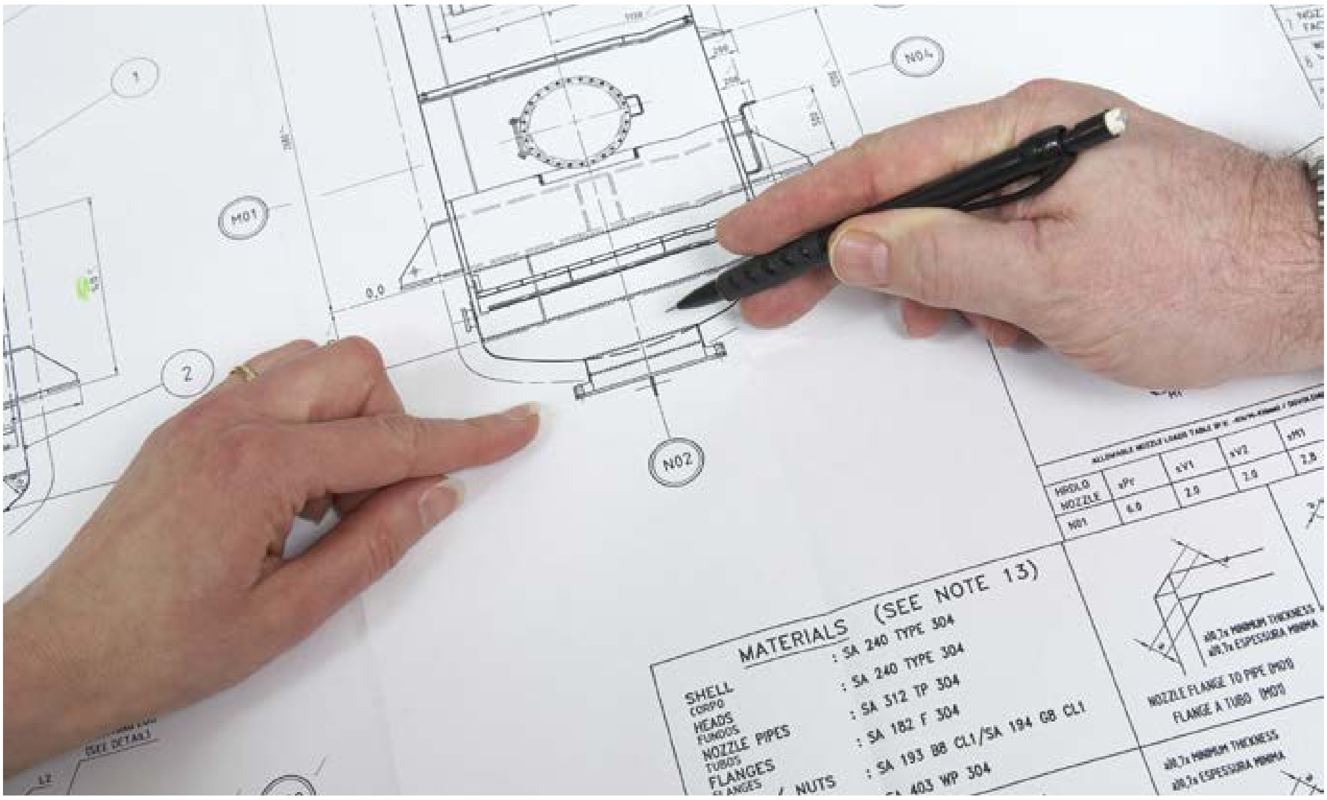
Large capacity plants

The formaldehyde plants have traditionally been kept small compared to many other types of chemical plants. The underlying reason for this is the problem with transporting concentrated formaldehyde, which has made it necessary to produce it close to the downstream consumer. This is very different to transportable chemicals like methanol, etc., where economy of scale always drives the market to build the largest plant technically possible.

JM Formox has covered the formaldehyde market with three standard size reactors introduced in the early 90s. Necessary increases in formaldehyde production due to the development of downstream processes over time have been covered through capacity improvements within the standard reactor range. This strategy has been very successful, giving an 80% increase in production capacity for reactors of the same size, without a corresponding rise in plant costs.

There has, however, been a trend over the years of fewer small and more large reactors sold. The reasons for this is consolidation in the downstream markets, new greenfield plants in China and a move to the raw materials in the Middle East and shale gas in the USA. It is also expected that fuel substitution to products based on methanol/formaldehyde will have a large impact on demand. This trend can also be seen in other chemicals where there is a will to move away from oil based raw materials, and towards lighter hydrocarbons like methanol. A typical example is MEG production in China.

There are two ways to increase capacity



– build a larger reactor or increase the load on the present design. JM Formox has the capacity to develop both. There are different site conditions that will fit the two different solutions.

Larger reactor

A larger reactor has the advantage of being able to use present catalyst systems without modification. The same high performance is expected also in the larger reactor. The design of the rest of the equipment is also fairly straightforward. There will also be a reduction in cost per ton based on economy of scale. The main problem is the larger size of the equipment. Transporting a larger reactor by road to some sites can be difficult.

Higher reactor load

Higher load means higher methanol feed to the present reactor and more formaldehyde production per tube. The oxygen feed also needs to be increased without increasing the gas velocity in the reactor tubes. The method for doing this is to increase system pressure. We are already operating the present plants at 0.5 bar overpressure. To increase the pressure more would result in higher power consumption per ton if Roots blowers were used for the fresh air. This will under many circumstances make the production uneconomical. The development of the JM Formox turbocharger concept has made it possible to increase the pressure without any increase in power consumption. The application of the turbocharger now makes it possible to feed more methanol to the standard reactor by means of a higher system pressure.

The main advantages of this solution are low plant investment costs, small footprint and economical production. The difficult part is the high capacity catalyst system that is being developed, as well as the increased load on the other plant systems for tasks such as reactor cooling and methanol evaporation.

JM Formox is working on both concepts to meet the demands from the industry both today and in the future. It is also expected that some of the solutions will benefit the present plants.

BY

Ola Erlandsson
Senior Process Specialist,
JM Formox AB

Part 1 (of 2)

How a fourfold productivity increase has been obtained

- A survey of the developments of the Formox^{TM} process from the 1950s to present time

The first plant in Perstorp for the production of formalin was built in 1907. At that time methanol and air were reacted over a copper wire catalyst to produce formaldehyde, which was then absorbed in water to produce formalin. In the 1930s, the plant was rebuilt with new reactors, and silver was introduced as the catalyst in the form of either nets or granules. Although Adkins and Peterson in 1931 [1] reported that methanol was selectively oxidized to formaldehyde over an oxide catalyst with molybdenum and iron, it was not until the 1950s that the molybdate catalyst gained commercial importance. Production in Perstorp using the new process with an iron molybdate catalyst began in 1959. Presently, global production of formaldehyde is divided roughly equally between the oxide and the silver-catalyzed technologies. The two technologies differ in that the silver process operates at methanol-rich conditions, whereas the oxide process (Formox^{TM} process) is run under methanol-lean conditions. A benefit of the latter process is that it gives a higher formaldehyde yield (~93% as opposed to <90% for the silver process). The silver process, however, gives a somewhat lower investment cost due to the higher methanol content in the feed.

Typical performance data for a number of selective hydrocarbon oxidations and oxidative dehydrogenations are presented in Table 1. Compared with other selective oxidations, the data shows that the $MoO_3/Fe_2(MoO_4)3$ system in methanol oxidation presents outstanding selectivity (92–95%), which is achieved at high conversion (>99%). Selectivity is an important parameter because the cost of methanol is about 94% of the production cost, whereas power and catalyst costs are about 4% and 2% respectively.

Considering the good performance of the ferric molybdate catalyst, finding a more selective composition is no simple task; a position demonstrated also by the fact that the chemical composition of the catalyst is essentially the same today as when first reported in 1931. Yet in spite of this, a considerable (near fourfold) increase in productivity has been achieved. In this volume of Informally Speaking, a first part of this survey will summarize the factors that have made such a substantial increase possible. In the next volume, some catalyst development work related to the volatilization of molybdenum species from the catalyst, which occurs under process conditions and is a major cause of catalyst deactivation will be described.

Process development

The process developments that have been made since the late 1950s are summarized in Table 2. The corresponding pro-

Table 1. A comparison of the performances of a selection of selective gas phase (amm)oxidations on metal oxide catalysts

Process	Catalyst	Temperature (°C)	Conversion(%)	Selectivity(%)
Methanol to formaldehyde	Fe-Mo-O	250 – 380	> 99	92 - 95
o-Xylene to phthalic anhydride	$V-O/TiO_2$	350 - 450	99.9	80 - 82
Propene to acrolein	Bi-Mo-O	300 - 400	< 98	83 - 90
Propene to acrylonitrile	Bi-Mo-O	420 - 450	98	80 - 83
Ethene to ethylene oxide	Ag/Al_2O_3	200 - 300	7 - 15	80 - 90
Butane to maleic anhydride	V-P-O	350 - 420	75 - 85	65 - 73
Propane to propene	V-O/MCF	550	41	68
Propane to acrylic acid	Mo-V-Nb-Te-O	350 - 400	80	50 - 60
Propane to acrylonitrile	Mo-V-Nb-Te-O	420	86	72

At his farewell presentation at JM Formox, Arne Andersson explained how the productivity has been almost fourfolded in the Formox™ process since the 1950s to present time.

ductivity increase is displayed in Fig. 1, and Fig. 2 shows the related steam production and power consumption. In the 1950s the reactor was loaded uniformly with uncalcined catalyst granules (crushed filter cake). These were activated in the reactor to form $Fe_2(MoO_4)_3$ and MoO_3 by successively increasing the methanol concentration from 4 up to 6.5 vol% over 3 to 4 weeks to avoid collapse of the granules. The feedstock was air and methanol only, without any recirculation being used, giving a formaldehyde yield of 89%.

The use of pre-calcined catalyst granules began in the early 1970s, allowing more rapid start-up of the multi-tubular reactor. Moreover, recirculation of O2-deficient gas from the absorber back to the reactor was introduced, which allowed increase of the methanol inlet concentration up to 7.5 vol% with 10–11 vol% oxygen in the gas, and still within the safe operation window. The modifications performed resulted in higher yield (~92%), an increase in productivity from 7.3 to 8.5 kg 37% formaldehyde solution per reactor tube and day (Fig. 1), and increased steam production from 330 to 395 kg/ton coupled with decreased power consumption from 95 to 81 kWh/ton (Fig. 2). The oxygen-to-methanol ratio could be decreased without negative consequences. Oxygen-to-methanol ratios for the different reactions of interest are given in Table 3. For the desired reaction, that to formaldehyde, the required ratio is only 0.5. In spite of this fact, a higher ratio can be used without any negative influence on the selectivity to formaldehyde, showing that the active Fe-Mo-oxide surface creates site isolation, where the number of active oxygen species in the vicinity of the adsorption site (active ensemble) is structurally limited. According to the site isolation concept introduced by Callahan and Grasselli [2], in an oxide catalyst that is active and selective for partial oxidation, site isolation should be created by the catalyst structure rather than by limitation of the partial pressure of oxygen. Moreover, the metal-oxygen binding energy should admit both fast reduction and fast reoxidation of the catalyst. In contrast to the oxide process, site isolation in the silver process is created by limitation of the oxygen pressure. Here, an oxygen-to-methanol ratio of about 0.2 is required for the silver surface to be active and selective for combined dehydrogenation and oxidative dehydrogenation to produce formaldehyde. The lower selectivity (< 90%) of the silver process compared with the oxide process is due to the oxygen species being rather statistically distributed over the silver surface, whereas distribution on the oxide surface is more well-defined and controlled by the lattice of anions and cations.

In the 1980s, emission control systems (ECS) became common, leading to increased steam production (555 kg/ton) but no increase in productivity. The replacement in 1986 of the granular catalyst with a Raschig ring-shaped catalyst allowed the gas flow rate to be increased. As a consequence of the improved flow characteristics and the pressure drop being reduced, productivity increased to 10.5 kg per tube and day. The yield to formaldehyde grew higher (~92.5%) as the mass and heat transfer effects were reduced. The influence of diffusion limitations is demonstrated in Fig. 3, which shows that the selectivity to CO decreases with increasing macropore volume. The macropores serve as transportation pores in the catalyst pellet where the active surface is mainly that of mesopores. Alternatives to ring-shaped catalyst are e.g. pellets with two or three holes, as well as wheel-shaped catalyst. However, it is important to account for the deactivation process, which involves volatilization of molybdenum from the catalyst pellet, giving increased porosity

Table 2. Summary of process developments in methanol oxidation to formaldehyde over the $MoO_3/Fe_2(MoO_4)_3$ catalyst system

Year	Development
1959	Dried granules of catalyst were used, and the feed consisted of 6.5 vol% methanol in air
1972	Gas recirculation, 7.5 vol% methanol, pre-calcined granules
1984	ECS
1986	Pre-calcined catalyst rings, lower pressure drop and higher gas velocity
1988	Pre-vaporizer
1992	Mixed catalyst layer, 8.5 vol% methanol, higher gas velocity
1998	Pressurization to 0.3 bar g
2003	Refinement of the catalyst activity profile (CAP 1), 10 vol% methanol
2007	Pressurization to 0.5 bar g
2009	CAP 2.0, higher yield, lower pressure drop, less aging
2011	CAP 2.0T, turbocharger, reduced power consumption
2012	CAP 3.0, 11 vol% methanol gives slightly lower yield compared to 10 vol%, but higher productivity due to the higher inlet concentration

From left: *Robert Häggblad, Manager R&D Catalysts, Arne Andersson, Catalyst Specialist, Ola Erlandsson, Senior Process Specialist and Johan Holmberg, Catalyst Specialist, all at JM Formox.*

and brittleness to the pellet. In this regard, wall thickness is a crucial parameter.

Dilution of the first part of the catalyst (1992) with inert rings (mixed layer) gave better temperature control and faster start-up. It also allowed increase of both the methanol concentration (8.5 vol%) and the gas velocity, and consequently productivity increased to as high as 14 kg per tube and day. Instead of using a mixed layer, the question arises as to whether or not it is possible to use a low surface area catalyst. Use of a low surface area $MoO_3/Fe_2(MoO_4)_3$ catalyst prepared by calcination is not an alternative as this type of catalyst is less stable. Previously, we have reported that the active surface of the molybdate catalyst is a 5–10 nm thick amorphous layer with a Mo/Fe atomic ratio of about 2.1 [3]. In the low surface area catalyst more of the excess Mo is present in the form of crystalline MoO_3, which is known to volatilize much more rapidly than the excess Mo in the amorphous molybdate structure [4].

A further development was pressurization of the plants (0.3 bar g), which was introduced in 1998. The predicted decrease in yield was avoided through adjustment of the loading plan, which resulted in a nearly unchanged yield of 93% and a rise in productivity to 17.4 kg per tube and day.

More recently, refined catalyst activity profiles (CAP) consisting of several catalyst layers have been introduced by JM Formox to the market (see Table 2), allowing the reaction rate and the temperature to be properly distributed along the length of the reactor tube. The development work at JM Formox aims at increased productivity with greater flexibility, lower pressure drop, longer catalyst lifetime and preserved or higher yields. Here, loading plan design is an essential step in creating a suitable catalyst activity profile in the reactor tube, it being an issue of matching process conditions and gas flow in different reactor coordinates with the type of catalyst and the degree of dilution. Generally, there are two important aspects to consider, namely the initial performance and the performance development, i.e. the aging of the catalyst. The type of catalyst and the loading plan have a great impact on both aspects. Unfortunately, the process conditions often limit the choice of catalyst and the type of loading plan. The challenge is to obtain sufficient conversion of methanol without also converting the already formed formaldehyde further to CO. CAP 1, which was introduced in 2003, made it possible to operate plants with a methanol concentration at the inlet of up to 10 vol% at 0.3 bar g. For the first time, productivity per tube and day exceeded 20 kg (Fig. 1). In 2007, further pressurization up to 0.5 bar g was introduced, giving higher productivity (24 kg/tube and day) and somewhat higher power consumption.

Following CAP 1 (~93% yield), the CAP 2.0 and 2.0T loading plans were introduced in 2009 and 2011 respectively, giving even higher yield (93–94%) and lower pressure drop in combination with slightly less catalyst aging. The most recent development, KH-CAP 3.0 INI CAT, allows operation with 11 vol% methanol at the inlet. Optionally, CAP 3.0 can be used for lower methanol inlet concentration, giving longer lifetime. In 2011, the option of pressurization above 0.5 bar g using a turbocharger was introduced. One benefit of using a turbocharger is that pressurization is achieved without increasing power consumption. Operating a plant at 1 bar g with 11 vol% methanol at the inlet would increase productivity to more than 30 kg per tube and day.

As Fig. 1 shows, the process developments that have been undertaken since the 1950s have resulted in an almost fourfold increase of the specific productivity, from 7.3 up to 29 kg 37% formaldehyde per reactor tube and day.

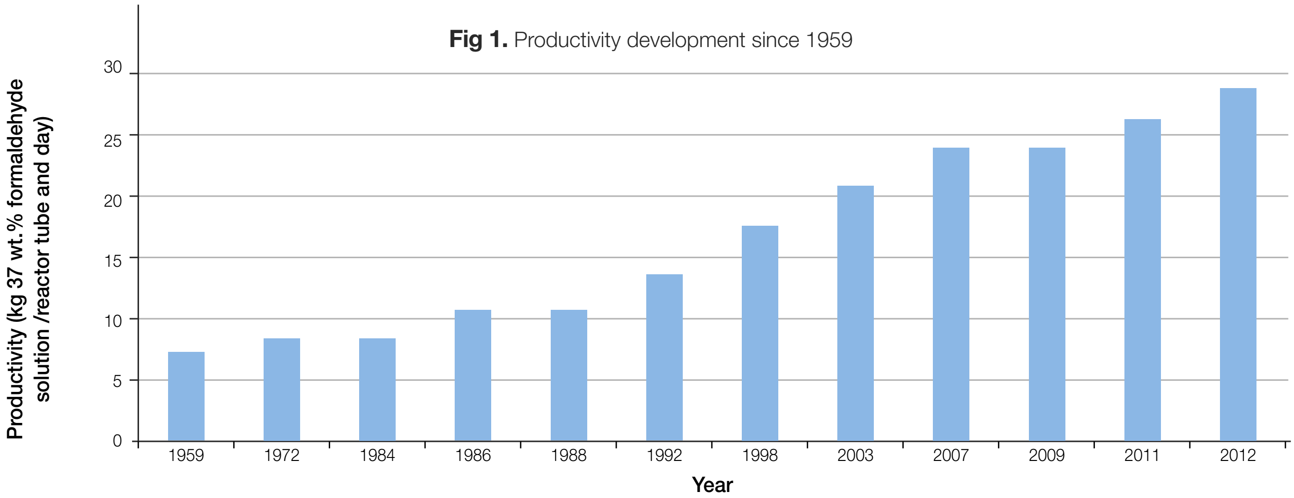


Fig 1. Productivity development since 1959

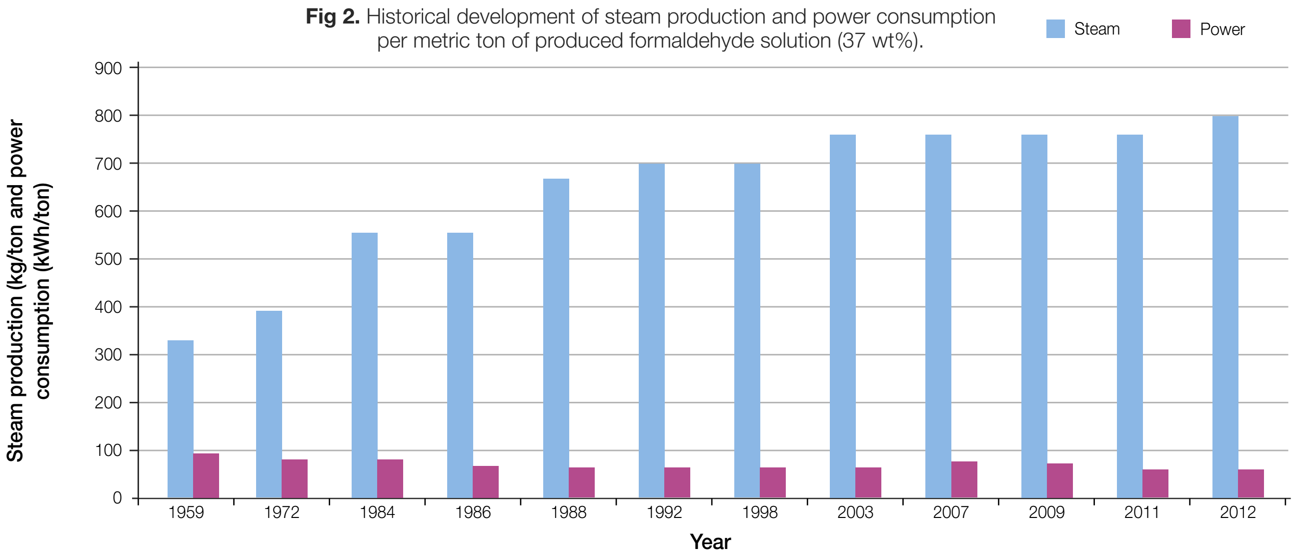


Fig 2. Historical development of steam production and power consumption per metric ton of produced formaldehyde solution (37 wt%).

In parallel, the specific steam production has more than doubled, from 330 to nearly 800 kg/ton of 37 wt% formaldehyde solution, while power consumption has been reduced from 95 to about 60 kWh/ton solution (see Fig. 2). Using a turbocharger further reduces the power consumption down to about 45 kWh/ton solution. Besides the temperature difference between the inlet and outlet gas flow of the ECS reactor, a comparison of the developments summarized in Table 2 with the data in Fig. 2 shows that a main factor affecting the specific steam production is the methanol concentration in the feed to the reactor. The main causes for the decrease in the specific power consumption are the increase of the methanol content in the feed gas, the reduction of the pressure drop, and the use of a turbocharger. Additional energy savings can be obtained by integrating a steam turbine to drive the recirculation blowers and generate electricity.

An extended version of this article will be presented within short in the scientific journal Topics in Catalysis

BY

Arne Andersson
Catalyst Specialist
JM Formox AB

References

[1] H. Adkins, W. R. Peterson, Journal of the American Chemical Society 53 (1931) 1512-1520.
[2] J. L. Callahan, R. K. Grasselli, AIChE Journal 9 (1963) 755-760.
[3] E. Söderhjelm, M. P. House, N. Cruise, J. Holmberg, M. Bowker, J.-O. Bovin, A. Andersson, Topics in Catalysis 50 (2008) 145-155.
[4] A. Andersson, M. Hernelind, O. Augustsson Catalysis Today 112 (2006) 40-44.

Turbocharger in China

The turbocharger was introduced to the Chinese market several years ago. The first two turbocharged plants in China were built at the same time in 2013, and started up at end of 2014. The customer is very happy with the savings in electric power. Now more and more existing and potential customers understand and realize that a turbocharger is an effective energy saving technology, especially after the successful start up of the reference plants in China. For virtually all new prospects and revamp projects, we are seeing interest for the turbocharger, especially in the region where the price of electric power is higher.

BY

By Huamin Zhang I 张华民,
Sales Manager Plants,
JM Formox, China

We have moved to new offices:

Singapore

Eddy Lee, Regional Sales Manager in Singapore says: - I can see 3 countries from here: Singapore, Malaysia and Indonesia and that always reminds me of that our customers are close at heart.

Johnson Matthey Formox
3 Temasek Avenue
Centennial Tower Level 21
Singapore 039190

Phone +65 6549 7170
Fax +65 6549 7001
Email: formox@matthey.com

Russia

Since December 2014, Yuriy Babkin our Regional Sales Manager in Russia, has moved to a new office on the 27th floor at Moscow International Business Center.

Johnson Matthey Formox
Presnenskaya Enbankment 10, block C, 27th floor
RU-123317 Moscow
Russian Federation

Phone +7 495 921 2100
Fax +7 495 921 2113
Email: formox@matthey.com

Engineering review meeting with

Xinjiang Xinye

The company Xinjiang Xinye Group adhere to the concept of circular economy to develop the coal and electricity integrated industry, and make full use of the coal, limestone, salt and other valuable natural resources of the Chinese province Xinjiang.

A delegation from their company had an engineering review meeting with JM Formox in Perstorp, Sweden, during May 26 - 27.

Why are you choosing a JM Formox formaldehyde plant?
-There are several reasons for that, JM Formox has the best technology, there are many reference plants in China and we have developed a good commercial communication whith each other, Mr Fan Lijun, Chariman & President at Xinjiang Xinye Energy Chemical Co. LTD, says.

When is your formaldehyde plant ready and what is the downstream product?
-In the second half of 2016 the plant will be ready and we are producing BDO for the polyester and spandex industry. Our impression of JM Formox so far is very good, it is easy to cooperate and we plan to continue our cooperation together, Mr Wang Xiaoqiang, Instrument Engineer & Commercial Manager at Sedin Engineering CO. LTD, says.

Is this your first visit in Sweden?
-Yes, my impression is that you have a good environment, a lot of green nature, good air and not so many people, Mr Wang Xiaoqiang says.

BY

Anna Rundblad,
Communications Manager,
JM Formox AB

Wanhua Chemical Group in Yantai, China:

Plant II signing ceremony

JM Formox and Wanhua Chemical, China, signed a new FT3 formaldehyde plant with turbocharger on June 4, 2015. The capacity is 836 MTPD and the downstream is mainly for MDI. It's the 7th project that JM Formox has in cooperation with Wanhua.

The names and titles from left to right are: from Wanhua Chemical - Yuqin Lu (Process engineer), Xiaoling Cheng (FA Plant manager), Deyong Yin (Purchasing Manager), Yunshuan Shen (Utilities Plants Manager), Boxue Liu (Vice President), from JM Formox - Lars-Olle Andersson (Business Manager), Charlene Holmström (Legal Counsel), Fredrik Rietz (Global Market Manager – Plants), Eric Li (Senior Sales Manager) and Huamin Zhang (Sales Manager).

Watch your CO!

The biggest contributor to the operating cost of any formaldehyde plant is by far the methanol. Buying the methanol at the lowest possible price, without sacrificing the raw material quality of course, and then using as little as possible to produce your formaldehyde, will give you low operating cost and a great advantage over competitors not doing their homework as well as you do.

The yield is the key

Low methanol consumption can be achieved by minimizing the losses in the reactions taking place in the reactor. Unfortunately, the partial oxidation of methanol to formaldehyde in the reactor tubes by means of the catalyst is not the only reaction taking place. A good yield in the formaldehyde reactor is between 92.5 and 93.5 percent, which means that besides the main reaction – the formation of formaldehyde – there are other side reactions that also take place. Taking a look at the most significant losses we can see that CO loss is normally the largest loss we have to deal with. Fortunately, it is possible in most cases to do something about an unnecessarily high CO loss.

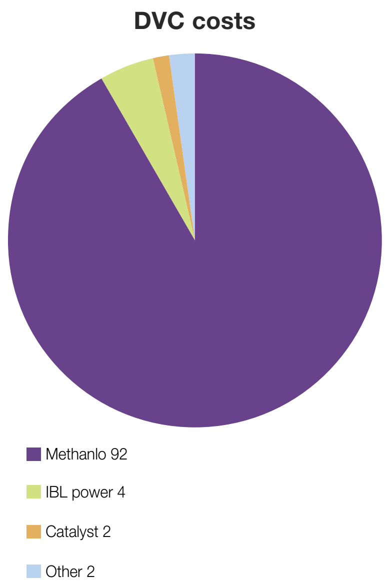
How do I measure?

To be able to do something about high CO loss we must first, however, be able to establish what the loss really is. Here we are fortunate in that there are some very good instruments available that are also quite affordable. JM Formox's present range of formaldehyde plants includes an in-line IR instrument suitable for CO analysis of the process gas. The CO analyzer is integrated with the paramagnetic oxygen analyzer and can thus analyze the same gas as the oxygen analyzer. The sample point is after the recycle blowers, but before the methanol vaporizer and the methanol feed point. An integrated gas cooler removes most of the water in the sample stream, which is preferable for instrument longetivety.

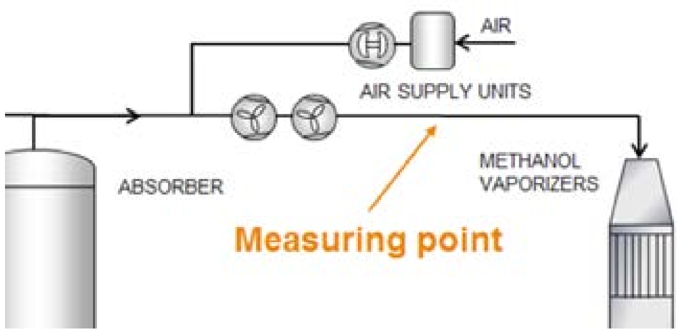
If your plant does not have an in-line analyser you can retrofit it with a separate CO analyser, but another interesting alternative would be to buy a portable instrument. This costs less and also gives you the flexibility to measure at different points throughout the plant; e.g. in the stack to check the status of the incinerator system. And if you have more than one plant, you only need one instrument. When using a portable instrument, we recommend measuring at the same point as described for the in-line instrument.

The portable CO instrument pictured here is the one we have experience with. It is working with a chemical cell and measures both CO and O_2. It requires calibration once or twice per year, but apart from that it is very robust and reliable. Contact your Formox representative if you are interested and would like more information.

Of course you can also use a GC to obtain your CO values, but a GC is much more expensive to buy and to operate and therefore more for those who need to make a complete gas analysis.



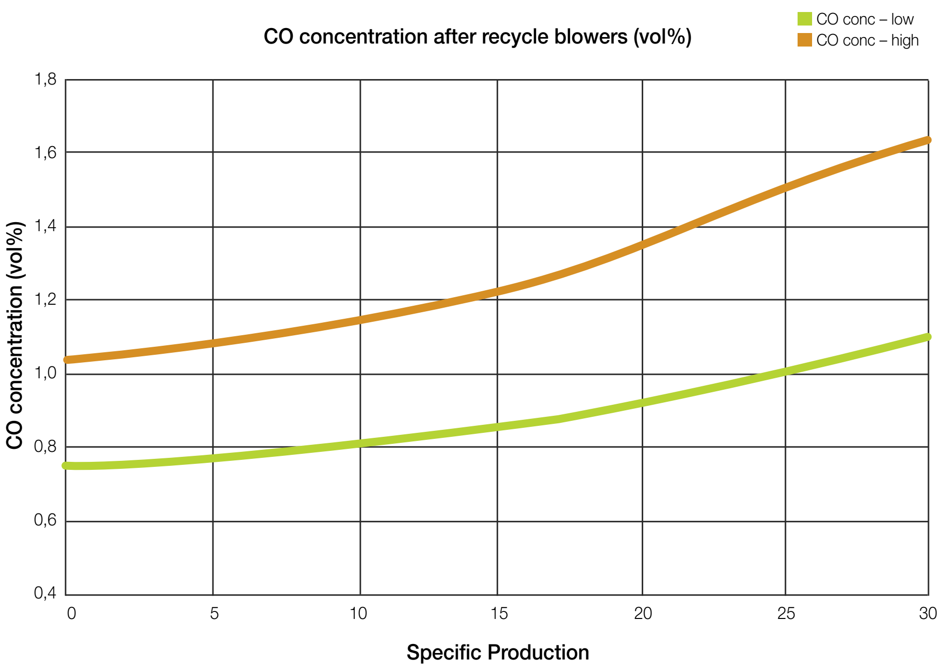
methanol →	formaldehyde	HCHO	Yield	92-94%
methanol →	dimethylether	DME	Loss	1-2.5%
methanol →	carbon monoxide CO		Loss	3-6%
methanol ⋯→	methanol	MeOH	Loss	1-3%



Why measure the CO?
Pros and cons:

+ Easy in single line plants
+ Quick result
+ Relatively low cost
+ Good indicator on performance
+ Good in UFC plants where MeOH in product is difficult to measure

- Best done on dry gas
- Measuring CO concentration alone does not give the yield
- Gives the total CO concentration in a multi-reactor plant



What is the reading telling me?

So, now that you have the possibility to measure the CO concentration, how can you use it to improve plant performance and economy? In the chart below you can see the kind of values we expect to see in a well-functioning plant. There are of course differences in how the curve looks over the catalyst's lifetime depending on factors such as the pace you run your plant at and the kind of loading plan you are using. But values within the high and low boarders are considered OK.

It's important to remember that the measured CO concentration is affected by the oxygen concentration used in the plant, as well as whether or not the value is obtained with dry gas. The ranges in the diagram are valid for plants running at 11 vol% oxygen and with analysis made on dry gas. If you compare values from different plants, this needs to be taken into consideration.

Plant adjustment

By using mainly the HTF temperature, the gas flow and the methanol inlet, it is possible, in most cases, to optimize performance and get the CO loss under control. Thanks to the fast and easy CO measurement, the result from a change in the process is almost instant.

BY

Lars Andersson,
Regional Manager Technical Support, JM Formox AB

Norsechem Sabah's 35th anniversary

Eddy Lee and Fredrik Rietz had the pleasure of attending at our customer Norsechem Sabah's 35th anniversary celebration in Sabah on 7th of March 2015 in Borneo.

Celebrating the anniversary with cake! At the left Norsechem Sabah's General Manager Ms Chang Ah Mee joined by company colleagues and chairman YB Charles O Pang Su Pin.

Datuk Dr Foong (the pioneer director and shareholder of the company was first to bring the Formox process into Asia in the seventies in West Malaysia), Eddy Lee, Regional Sales Manager JM Formox, Fredrik Rietz, Global Sales Manager Plants JM Formox and Ms Chong Yoke Seng, Company Secretary and Group Manager at Norsechem Sabah.

Projects & start-ups

New Projects

- An agreement for an FT3 plant to east Europe has been signed.
- A client in South America has signed an agreement for supply of an FS3 plant.
- An agreement for an FT3 plant to China has been signed.

Ongoing projects

- The project for supply of a new FS3 plant to east Europe is in the engineering phase.
- The project with two FS3 UFC plants is in the engineering phase.
- The FS1 plant for Masnova Quimica, S.A. de C.V., a Masisa Company, in Durango, Mexico, is approaching shipping.
- The FS3 plant for Xinjiang Xinye Energy Chemical Co., Ltd, located in China, is due for shipping.
- The FT2 plant for a client in the Middle East is in the installation phase.
- The project with two FT3 plants is in the installation phase.
- The project for BASF PETRONAS Chemicals Sdn Bhd, Malaysia, is in the installation phase.
- The project for a FS2 plant in US is in the installation phase.
- Works on two FT3 plants to be located in China is proceeding with installation.
- The project for an FT3 plant for Xinjiang Markor Chemical Industry Co., Ltd. in Korla, China, is in the construction phase. This will be their third JM Formox plant in Korla.

Start-ups

- For Xinjiang Tianzchi Chengye Chemical Industrial Co., Ltd (part of Xinjiang Tianye Group) two FT3 plants have successfully been started in October and March. The plants are located in Shihezi City, China.
- One FS1 UFC plant to a client in the Middle East went on stream in March.
- The project for CHONGQING CHANGFENG CHEMICAL INDUSTRY Co., Ltd, Chongqing, China, went on stream in January.

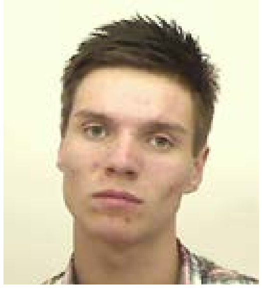
BY

Jonas Lindborg,
Chief of Projects,
JM Formox AB

New...

Charlene Holmström,
Legal Counsel

Alejandro Pérez Navarro,
Regional Technical
Support Manager



André Nyberg,
Process Operator

Tommy Rydén,
Automation Specialist

Ingrid Paulsson,
Financial Assistant

Amin Mehdipoor,
Regional Sales Manager

Sarah Axelsson,
R & D Engineer

Katarina Andersson,
Sales Assistant

Filip Vrgoc,
Process Engineer

...& left

Hillevi Arvidsson, R&D Engineer

Mikael Edmundsson, Process Engineer

Pengwei Dong, Project Engineer

Andreas Blomqvist, Mechanical Engineer

We are very glad to have had you as our colleagues and wish you the best of luck in your coming challenges.

A formaldehyde magazine from JM Formox

The newsletter Informally Speaking aims to provide information about formaldehyde in an informal forum and is published twice annually by JM Formox for its customers and contacts in the formaldehyde business. The information included herein is part of our customer service and in no way entails or implies any undertakings, legal responsibilities or liabilities.

Johnson Matthey Formox

Johnson Matthey Formox AB
SE-284 80 Perstorp, Sweden. Phone: +46 435 380 40
e-mail: formox@matthey.com www.formox.com