informally speaking

THE FORMALDEHYDE NEWSLETTER FROM PERSTORP FORMOX autumn/winter 2004

This CAP sets the standard!

Perstorp Formox is constantly searching for ways to boost plant output. This has led to one major improvement after the other over the years. And it follows a pattern: from theory to pilot runs, to full-scale testing in our own plants, to proof of performance, and finally to becoming our new standard. The latest such success? CAP technology with high inlet!

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Reading the signals

You may have read that HCHO has been reclassified by the IARC (an advisory body to the WHO) as a carcinogen rather than a probable carcinogen. Though we in the industry viewed this with concern, it didn't seem to create that much publicity. Why? It seems that formaldehyde already had such a poisonous reputation that everybody assumed that it was carcinogenic – even lethal. So perhaps by pointing out that the only cancer attributable to formaldehyde is a very rare form (accounting for less than a quarter of a percent of cases in North America), the IARC has done us a favor. And since these data were collected several decades ago, when exposure levels were much higher than today, the relevance of the findings can be questioned. After all, at least one epidemiological study suggests that workers in the formaldehyde industry are healthier than workers in other industries!

What the IARC has issued is a hazard classification for HCHO itself, but it does not take into account the exposure levels, and it is the *dose* (not the substance) that actually determines carcinogenity. (If this were not the case, no one would escape, since formaldehyde occurs naturally in most living things – including our own bodies.)

But we cannot ignore the reclassification, because of the signals such a reclassification might send to people who are not motivated to look beyond it. In some quarters, there is a kind of Murphy's Law: any scientific finding that can be misunderstood will be misunderstood. And even misinterpretations can have real effects.

We all need to be prepared to fight fears with facts. In the last issue of ***informally speaking***, you could read about the FCI in North America. In this issue we are pleased to present Cefic. Both organizations are to be praised for their efforts to influence the authorities and others to stick to the facts, to keep the discussions – and the legislation – well rooted in science.

Mikael Ekblad
General Manager
Perstorp Formox

Need more capacity? Go CAP!

Increasing the methanol inlet concentration is the easy part; you also need to be able to remove the heat and control the temperature, and this is where CAP comes in. CAP allows the heat of reaction to be distributed along the length of the reactor tube, boosting the efficiency of the available heat transfer area. This in turn allows increasing the methanol inlet to as much as 10 vol%, which gives a capacity increase of nearly 20% (compared to an inlet of 8.5 vol%).

CAP (which stands for Catalyst Activity Profile) is a further development of the mixed layer concept; catalysts of different activities are combined to match the activity distribution – and therefore heat release – to the plant's capabilities. CAP was first introduced as a concept at the seminar hosted by Perstorp Formox in Helsingborg in May 2003, as duly reported in the spring/summer 2003 issue of ***informally speaking***. Here's an update on our performance experience.

Crystal clear

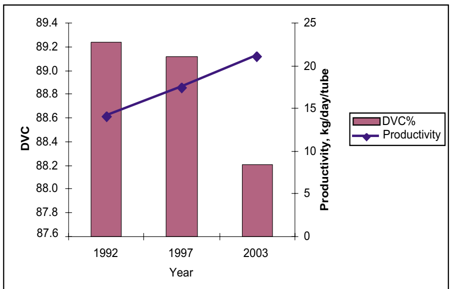
When Perstorp Formox first went public with the CAP concept in May 2003, we'd already been successfully operating our own plant #5 at high inlet using CAP loading plans for a couple of loads. Since then, we've started using CAP in our other plants as well. The benefits are now crystal clear: increased production capacity at negligible investment cost, improved plant performance and lower DVC (see box "Per's experience").

Many of our customers have been quick to take advantage of these benefits. In fact, more than 40% of all catalyst loads sold this year have been for High Inlet operation, and most of the feedback is very positive. Small wonder, since CAP enables increased productivity at no or low investment cost, combined with maintained or better plant performance.

Raising the bar again

Based on the proof of overwhelmingly favorable results, Perstorp Formox is pleased to announce that our new plant range (see page 4) will adopt CAP/high inlet operation, thus once again raising the bar for what formaldehyde producers can – and should – expect.

Looking at the effects of developments in recent years (see graph), the improvements are dramatic. Not only have we seen a big drop in direct variable costs (DVC), but this has been accompanied by rising productivity. Taken together, you have something worth cheering about on your bottom line!



Limitations?

Since Perstorp Formox plants are designed to be upgraded (see box), you may be able to incorporate this development at minimal cost. Here are the criteria:

- You need additional capacity.
- Your plant has long enough tubes and the cooling medium covers sufficient length.
- Your plant has a high enough airflow.
- Your plant uses heat transfer oil as the cooling medium.

Other plants may also be able to benefit from CAP technology, although it may not be possible to find a loading profile that works all the way up to 10% inlet, and maybe not during the entire catalyst lifetime.

To find out if you can benefit from this development, contact your Perstorp Formox representative. But don't forget to check that the rest of your plant can also handle the additional capacity.

FACTS about CAP technology & high inlet

- Enables operating at 10% inlet throughout the catalyst lifetime.
- Short start-up period (about a week) to reach 10 vol% inlet.
- Yield is maintained or even slightly improved.
- Specific steam production is increased.
- Specific power consumption is reduced.
- Catalyst lifetime is somewhat shorter, but is more than compensated by the other benefits.

Per's experience

Per Grönberg is the plant manager for our own HCHO plants in Sweden, and as such has the longest first-hand experience with full-scale operation using CAP technology of anyone in the world. Let's see what he has to say about it….

Does this CAP thing really work?

"Fantastic! I can't think of a better word. In just one year, we've increased capacity by 10% and cut the cost of producing formalin by 1.5% per year – all without major investments or rebuilding work. We have a yield over 93% of theoretical and downstream users of our formalin have expressed their delight about the quality – the low content of methanol, formic acid and ash. So it's a plant manager's dream come true!"

Where did the idea come from?

"Our marketing, process and R&D people are open to feedback from each other, and from us here in production. And of course from our customers worldwide. And we have the capability not only to see where we and our customers want to go, but to take it to pilot and full-scale stages, all the while developing the catalysts to match the process changes. It's a pretty good way of working."

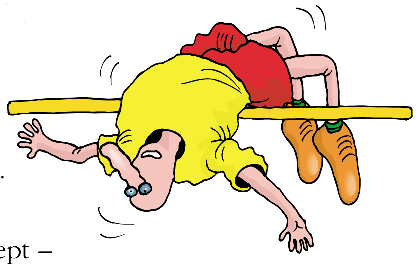
Where will it all end?

"Your guess is as good as mine! We're making gains in energy balance, we're fine-tuning a new range of catalysts for optimum fit for operation with CAP, and there are all kinds of projects underway. We in fact reached an all-time-high in our formalin production in March, and broke the record again in August, but I'm sure there's a lot more to come. Look at it this way: These latest developments have amounted to the equivalent of half a new plant. Think of the savings in investment costs!"

Don't you want to sell more plants?

"Hey, I'm in production. I just want more formalin. But I'm sure there are lots of formalin producers who wouldn't mind a plant that gives them so much more!"

Setting new standards



From theory to practice, once a new idea is tested and proven to give real value, it is usually incorporated into Perstorp Formox's standard plant designs. Some examples of major changes in recent years:

1992 The standard plant operates at atmospheric pressure and 8.5 vol% in inlet.

1997 The standard plant is now pressurized at 0.3 bar g.

2004 The new standard – introducing the CAP technology and High Inlet concept – increases the methanol inlet to 10.0 vol%

As part of our Technical Data series, Perstorp Formox is producing a guide to the upgrades available for Perstorp Formox Plants. This will be published early in 2005, so if you'd like a copy, please contact your local representative.

Methylal available?

Do you have ready access to methylal (dimethoxymethane) or mixtures of methanol and methylal, e.g. as by-products from other production? Some of our customers do and have been using this feedstock with Perstorp Formox catalyst for many years – confirming our own findings that methylal can be substituted for methanol – provided that some changes are made in the normal operating procedures and that all risk factors are taken into account.

Our studies showed that in the upper part of the tube, methylal was hydrolyzed to methanol and formaldehyde (step 1). Then the usual partial oxidation of methanol to formaldehyde (step 2) followed. Due to the endothermic nature of step 1 and the relatively low methanol concentration in the upper part of the tube, the HTF temperature had to be increased by 4 – 7 °C to maintain the conversion and yield after switching from feeding methanol to methylal.

The reaction zone was typically broadened and the maximum hot-spot temperature decreased. After switching back to feeding methanol, the original conditions were restored. No unusual observations were made when characterizing the spent material.

Since methylal is a strong solvent (one application is as a paint stripper!), attention should be paid to the risk of damaging gaskets and other components coming into direct contact with the liquid. There can also be other limitations that could make methylal unsuitable at your plant, and these must be carefully reviewed. Formaldehyde production with methylal is not for everyone!

So to cut a long story short, methylal can be used in the production of formaldehyde with our catalyst. If you are considering using methylal as a complete or partial substitute for methanol, contact your Perstorp Formox catalyst representative during your planning stage for detailed recommendations on the right loading plan and changes in operating procedures. During operation with methylal, we will as usual be prepared to review your operating data and, if appropriate, propose measures to optimize yield and catalyst lifetime.

Step 1

$$CH_3O{-}CH_2{-}OCH_3 + H_20 \rightarrow 2\,CH_3OH + HCHO \qquad \Delta H = -71\ kJ / mole$$

Methylal

Step 2

$$CH_3OH + {}^{1}/{}_{2}\,O_2 \rightarrow HCHO + H_20 \qquad \Delta H = 157\ kJ / mole$$

State-of-the-art for 2005

One of the strengths of the Perstorp Formox process is that it produces high-concentration formaldehyde solutions with a consistent concentration and hence a fixed composition (see also page 6). This is why the Perstorp Formox process is the choice when formaldehyde quality is an issue. The latest plant designs retain consistency but take flexibility and performance to new levels.

For almost two years now (as duly reported in ***informally speaking***), we have been testing a new "flexible" approach to the design and operation of our formaldehyde process. What's new is that the plant can be operated in many different ways – you can select the methanol inlet rate, the airflow and even the pressure of operation to suit your particular requirements. Moreover, the plant is designed for relatively easy future expansion by the addition of other equipment.

CAP technology (see page 2) is a key element in the new design, made possible by the wide range of catalyst types Perstorp Formox manufactures. CAP adds to the producer's flexibility, since catalyst loads can be optimized to meet particular process objectives such as: low methanol content, best yield, highest production rate.

Designed for control

To utilize CAP effectively, temperature control is crucial. In the Perstorp Formox design, excellent control is achieved by using a large number of small-diameter catalyst tubes immersed in boiling heat transfer oil. The new reactor design features the same three reactor sizes used previously, but these now have longer tubes.

The combination of a high surface area per unit volume of catalyst and high vaporization heat transfer coefficients means that the system can handle very high methanol feed rates. CAP also allows operation with a much more aggressive feed ramp. Full capacity can be achieved fast – and maintained over the working life of the catalyst.

3 sizes

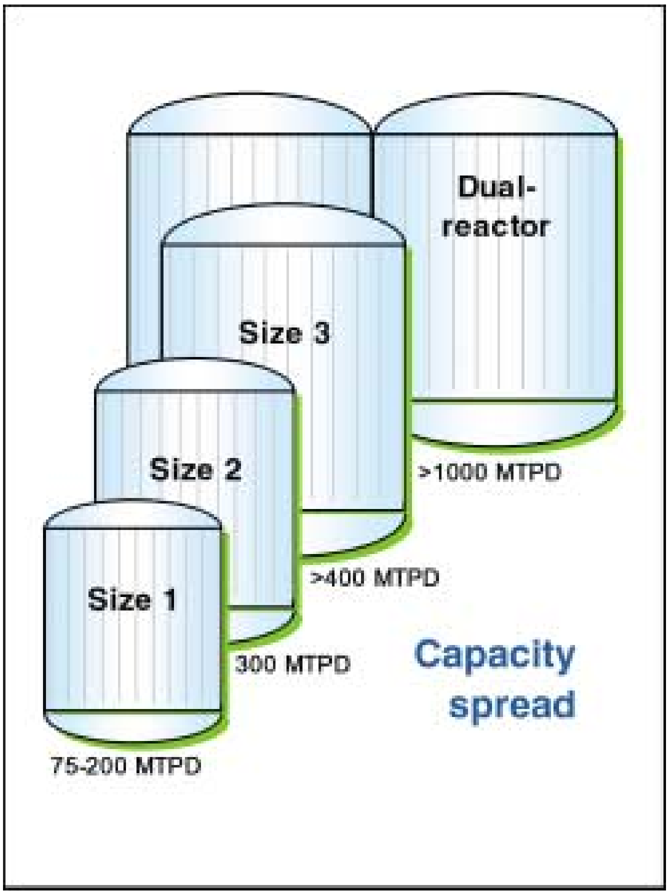
The latest standard range consists of three sizes. The smallest reactor (Size 1) covers the range from 75 to almost 200 MTPD; Size 2 takes the capacity up to nearly 300 MTPD and Size 3 takes us over 400 MTPD.

The layout also permits the addition of a pre-reactor – which can extend the range still further. This dual reactor design uses an identically sized but lightly loaded pre-converter ahead of the main reactor. Methanol is fed to both, so you can feed more methanol per unit of process gas than is possible in the single-reactor design.

The largest reactor is also available as a twin-stream design – with a capability in excess of 1000 MTPD. This design is probably the ultimate in flexibility; if initially installed with only one reactor line, operating capacity can be expanded in stages from 300 MTPD all the way up to over 1000 MTPD!

The new design thus incorporates full flexibility of capacity by allowing you not only to change the intensity of operation, but to add a dual reactor to the line – or both.

Designed for flexibility



Proven performance

CAP technology has already been tested extensively in full-scale operation, and "tank-to-tank" yields (i.e. including losses) are in excess of 93% of theory – a major advantage given rising MeOH prices. Steam production levels are also increased. Virtually the only drawback is that the harder the plant is run, the higher the catalyst consumption – at least with the current range of catalysts. (A new range is under test and is showing great promise!)

TYPICAL PERFORMANCE FIGURES

Intensity of Operation	→	Low	Medium	High
MeOH consumption	MT/MT 37%	0.424	0.424	0.424
Yield	% of theoretical	93	93	93
IBL power	kWh/MT 37%	73 (35*)	65 (27*)	73 (35*)
Catalyst consumption	MT 37%/kg	22	20	18
Steam produced	kg/kg, normal (max)	0.49 (0.75)	0.52 (0.78)	0.53 (0.79)

* Low-power operation using steam to drive an optional turbine

Go for gold

The higher productivity of the new design – not to mention all the flexibility – comes at a price very little more than the current design. There is even flexibility in the way the design is offered: as an Equipment Package, a Process Engineering Package or a Detailed Engineering Package. And for the full Equipment Package we're cooperating with equipment producers worldwide in an effort to make our prices even more competitive.

Our calculations show that this latest version of the Perstorp Formox process is *less* expensive than the modern versions of the silver process – and even close to the very simple silver processes still seen in some parts of the world.

In addition, the latest Perstorp Formox process has clear advantages over all silver processes:

- lower production costs
- expansion possibilities (you may not need another plant)
- a consistent and reliable product at high concentration and with low methanol content
- access to high-quality UFC
- better yield – crucial since methanol prices are more likely to trend up rather than down
- simpler to operate and requires less skilled operators
- long-term technical support – silver processes have little or no support.

With this kind of "golden" performance, why would anyone settle for silver?

China news

Left and above: At the recent Chinese Formaldehyde Producers Association seminar in Guangzhou, Zhao Dayang (far right) of our office in Beijing released some details of the new version of the Perstorp Formox formaldehyde process.
Right: Zhao at the beautiful Pearl River.
Below: Perstorp Formox was pleased to have the opportunity to take good care of some important customers.

The importance of fixed composition

by Bob Crichton

"Why should I use the Perstorp Formox Process?" I'm often asked this question and there are many possible answers. One very important but often neglected reason is that the Perstorp Formox Process produces high-strength formaldehyde solutions with a consistent concentration and a fixed composition. This is why the Perstorp Formox Process is the process of choice when formaldehyde quality is an issue – such as when producing chemical intermediates or high quality binder resins for the board industry.

Not that simple

Why is composition important? Because the end product of each type of formaldehyde process is not the same! This is because the end product is not simply formaldehyde (HCHO) but something much more complex. In solution formaldehyde exists as a hemiformal with the general formula:

$$HO\text{-}(CH_2O)_n\text{-}H$$

Formaldehyde solutions are thus actually a complex mixture of soluble oligomers of formaldehyde in equilibrium:

$$HCHO + H_2O \longleftrightarrow HOCH_2OH$$
$$HCHO + HOCH_2OH \longleftrightarrow HO\ (CH_2O)_2H$$
$$HCHO + HO\ (CH_2O)_{n-1}H \longleftrightarrow HO\ (CH_2O)_nH$$

From simple theory to complex reality

Formaldehyde
HCHO

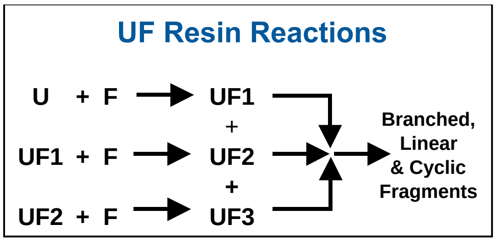
Formaldehyde solutions
$HO\text{-}(CH_2O)_n\text{-}H_2$

In the general formula, the value of "n" varies according to conditions and the way in which the solution is made. For the aqueous solution known as "formalin", the value of "n" can be as high as 10 (the average is between 2 and 8). But the concentration of each component is different in formaldehyde of different strengths.

As concentration increases, there is a downward trend in glycol (n=1) and dimer (n=2), but a rising trend in higher oligomers (n= 3 to 10). As dissociation is a slow process, what you make is what you get. As a consequence, concentrating 44% formaldehyde to 55%, as is done in some processes, will give a higher concentration of the species present at 44% – but it will be different from a product actually produced at 55%.

Crucial consistency

The ability of the Perstorp Formox process to produce a consistent product in high quality is much appreciated in the chemical industry, where the Perstorp Formox process is the preferred choice. Since chemical producers generally have to install their plants in potentially hazardous environments, the high safety and environmental standards of this process are also highly appreciated. This much is clear. But why should the Perstorp Formox process also be favored in the board industry?



Apart from lower operating costs, the key driver is consistency – an important issue where low-fume resins are concerned. The basic difference between low-fume resins and other resins is in the amount of urea added at the end of the batch – typically to give a final molar ratio (F:U) in the range 1.09:1 to 1.15:1.

Reducing formaldehyde in this way certainly reduces emissions, but low-molar-ratio resins are less tolerant than higher-ratio resins, both in manufacture and in application. Small variations in the resin-making process can have major effects on the board-making plant. And unfortunately, in resin-making process variations are a fact of life.

The problem is that there are many possible reaction paths (see diagram), i.e. many different chemical species can be formed. And even if the resin has the same *physical* characteristics from batch to batch, the *chemical* composition can be very different. This in turn means variable performance in the board plant, leading to a high reject rate.

What about UFC?

Different resin makers approach the problem in different ways. Some react urea and formaldehyde under specially controlled conditions. Others rely on UFC*, which potentially eliminates formaldehyde quality issues in the early stages of the reaction and provides a more consistent starting material for the key resin reaction steps. But the UFC itself must also be consistently produced to a fixed quality and molecular weight distribution – and this means UFC produced continuously in an oxide process such as the one offered by Perstorp Formox.

But whatever the technique, consistency can only be achieved by using consistent raw materials and taking them through a consistent and reproducible reaction path. And this will almost certainly require an automated reaction process and a computerized batch procedure.

If you need assistance in this regard, Perstorp Formox is able to help, both with resin technology and with plant and equipment. Perstorp Formox has in fact supplied integrated resin and formaldehyde plants to some of the largest board producers in the world.

** As UFC is more stable than formaldehyde, it can be transported over long distances. For this reason UFC comes into its own when the intention is to sell UFC for others to convert to resins.*

What a week!

At the request of our clients, Perstorp Formox held a Formaldehyde Process Training Course in Sweden in late September. For the better part of a week, more than 20 participants from 11 countries and 4 continents gathered for a packed program that everyone seemed to find both informative and enjoyable.

Recurring needs

The reasons for attending a course like this vary from client to client. The most common reasons are when a formaldehyde producer has new personnel who may need to be brought up to speed on plant operation. Then there are those who want a refresher course, or to catch up on recent developments.

Perstorp Formox's special training courses are usually initiated like this: Once several clients have expressed interest in attending such a course, we may mention the idea to a few more. When a "critical mass" has been achieved, we announce the course right here in ***informally speaking***, and send out invitations. Registration is on a first-come-first-served basis.

Something for everyone

The curriculum comprises both theory and practice, starting with a general process review, plant and catalyst operation, a study of various system functions, trouble-shooting, and all the way to storage and handling. Depending on the participant's prior knowledge and experience levels, there can be an awful lot of information to absorb. (Perhaps we should set up a classroom in the absorber tower?!) And the response at this year's session was overwhelmingly favorable. In addition to top marks on the course evaluations, some even wrote afterwards to express their appreciation.

No play? No way!

There's more to the course than the classroom. There are lots of opportunities for informal discussions, networking and just plain fun: dinner on the boat to Denmark, go-carting and other activities were also on the program.

Next?

Will there be another opportunity to attend a course like this in the future? "Certainly!" says **Marie Grönborg**, head of Technical Support, which includes operator training programs. "Some training needs we handle on a customer-by-customer basis, either in Sweden or at the customer's site. We'll also be holding an extra course in connection with our next seminar in Helsingborg in May 2006. And of course we always provide training in connection with a new plant. But as soon as our customers express an interest in a special week like this one, we'll start looking into it!"

The portal of knowledge? Perhaps not, but the consensus among the participants was that they had felt they learned a lot!

The beautiful "classroom" at Stensmölla (left-hand column below), complete with crystal chandeliers. The building is the former residence of the founding family of the Perstorp Group. The week also included a plant tour and time for networking during the breaks and evening activities.

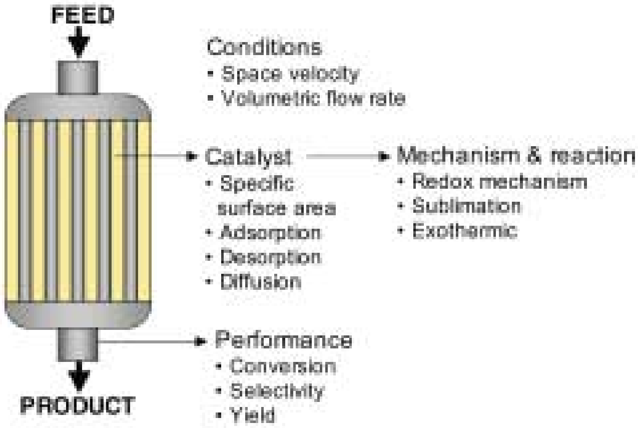
In technical terms...

Our "Catalyst School" continues with some useful definitions from Professor Arne Andersson

Discussions of the performance of formaldehyde processes and catalysts involve a lot of special terminology. I'm guessing that some of the readers of ***informally speaking*** are not clear about all of the vocabulary we use, and I hope you'll find some definitions useful.

Here's a selection of technical terms you're likely to encounter. The figure below gives an indication of how they're related to our process and catalysts. If you'd like us to explain other terms or subjects in future issues, please send us your suggestions!

Arne



Volumetric / mass flow rate

The *volumetric flow rate* is the flow of gas per unit of time (m^3/h) at a defined pressure and temperature. Since the volumetric flow rate varies along the reactor due to pressure and temperature changes, and since the reactions give rise to mole changes, it could be better to use the *mass flow rate* (kg/h). The mass flow rate is the same all along the reactor, as long as there is no accumulation to account for (which there seldom is in the Perstorp Formox process under continuous operating conditions).

Space velocity (SV)

The total volumetric flow rate at the inlet of the reactor, usually recalculated to standard conditions (0°C and atmospheric pressure), divided by the total bulk volume of the catalyst, not including the inert material (h^{-1}). For example, if the volumetric flow rate per tube is 2.5 m^3/h and the catalyst load is 1 m in a 21 mm tube, then the space velocity is 7218 h^{-1}. In packed-bed reactors, the catalyst mass may be used instead of the catalyst volume in the formula. In that case, we talk about the *weight hourly space velocity (WHSV),* expressed as $m^3/(h \cdot kg$ catalyst).

Specific surface area

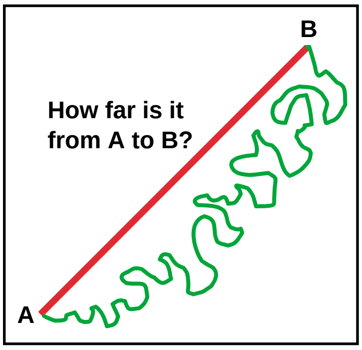
This is the surface area expressed as the per-unit mass of the catalyst (m^2/g), i.e. how much surface area you get per gram of catalyst, including both the external (visible) surface and the surfaces inside the pores of the catalyst ring. The specific surface area is very important in formaldehyde production (catalysis on solids), since it is a measure of the maximum surface area available for catalysis when multiplied by the total mass of catalyst in the reactor. For methanol oxidation, a specific surface area in the range 4-8 m^2/g is preferred.

Adsorption

The binding of a species (substance) in the fluid phase to the catalyst surface. In catalysis, adsorption usually involves *chemisorption* (i.e. strong adsorption), which means that bonds are formed between the reactant molecule and the catalyst surface. Chemisorption is usually a dissociative process, causing the reactant molecule to split up into two or more species binding to the surface. For example, methanol (CH_3OH) is adsorbed in the form of a methoxy (CH_3O–) species and the hydrogen atom binds to a surface oxygen, forming a hydroxy (–OH) species. Without going into any details, molecules with double and triple bonds or a lone pair of electrons can also adsorb strongly without dissociating. Weak adsorption, also known as *physisorption*, involves electrostatic interaction without bond-breaking. Physisorption is usually not of importance for the catalytic mechanisms. Its main importance in heterogeneous catalysis is for the determination of the specific surface area of the catalyst.

Absorption

The dissolution of a molecule in the bulk of a liquid, e.g. in our process formaldehyde is absorbed (= dissolved) in water. Thus, *absorption* is a bulk phenomenon, while *adsorption* is a surface process. So the words have similar spellings, but the meanings are quite different!



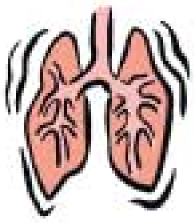
A road (green) from A to B can be much, much longer than the flight path (red) if you count all of the twists and curves. In the same way, a porous catalyst surface comprises much more total surface than the outer dimensions of the pellet.

Desorption

The reverse of the *adsorption* process, i.e. when a species leaves the catalyst surface and moves into the bulk of the fluid phase. For instance, in the last step of selective oxidation of methanol, formaldehyde is desorbed from the catalyst surface. Desorption is actually the opposite of both adsorption and *absorption*, e.g. when a formalin solution is heated, formaldehyde desorbs.

Diffusion

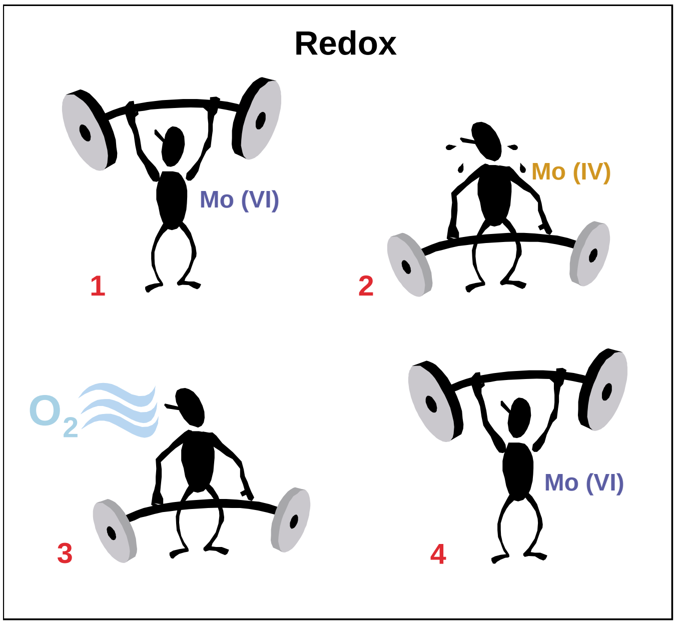
The gradual and spontaneous mixing of species, caused by random thermal motion. Unless there are other forces to prevent it from happening, molecules of a given species within a single phase will diffuse from regions of higher concentrations to regions of lower concentrations. That is why methanol diffuses from the external surface of the catalyst (where the methanol concentration is high) into the pores of the catalyst (where the methanol concentration is lower). Formaldehyde is produced in the pores and here its concentration is higher than at the pore opening, causing diffusion of formaldehyde from the interior to the exterior part of the catalyst ring. In this way, it would be possible to view the pores of a catalyst as “lungs”, breathing in methanol and breathing out formaldehyde!



Redox mechanism

A mechanism by which the reactant is adsorbed at the catalyst surface, where it reacts with O^{2-} surface species of the oxide to form products and a partially **red**uced catalyst. In a separate subsequent step, the reduced catalyst is re**ox**idized by reacting with gaseous oxygen to restore the catalyst to its initial state. This type of mechanism is also known as the *Mars-van Krevelen mechanism.* A simple scheme for methanol oxidation to formaldehyde is as follows:

CH_3OH + Mo(IV) + O=Mo(VI) → CH_3O–Mo(V) + HO–Mo(V) →
CH_2O + H_2O + 2Mo(IV)
Mo(IV) + $0.5O_2$ → O=Mo(VI)



Here we can see that an Mo(VI) species is reduced to form an Mo(IV) species, which then is reoxidized by gaseous oxygen to the initial Mo(VI) state. Most mechanisms in hydrocarbon oxidation to produce aldehydes, anhydrides and acids on metal oxide catalysts are redox mechanisms.

Sublimation

The process in which a species transforms from the solid state directly to the gaseous state, without ever becoming a liquid. Under certain conditions, for example, snow or ice may turn directly into water vapor without first becoming water. (The reverse process – changing directly from a gas into a solid – is called *condensation*, but that term is more commonly used for changes from the gaseous to the liquid state.) In methanol oxidation, sublimation of Mo species is a major reason for the ageing of the iron molybdate catalyst.

Exothermic reaction

A reaction that generates heat. The opposite is an endothermic reaction, which requires a heat supply. Methanol oxidation to formaldehyde and the major side-reaction to CO are both exothermic reactions, which is why we have to cool the reactor.

Conversion

The percentage of the reactant that is converted into products in the reactor. The conversion is usually defined in terms of the limiting reactant, i.e. the theoretical conversion limit is 100%. For a flow reactor we simply use the molar flow rates of methanol at the inlet (F_0 kmol/h) and the outlet (F kmol/h) to calculate the methanol consumption rate in the reactor (F_0 - F kmol/h) and thus the percentage of methanol conversion = $100 \cdot (F_0 - F)/F_0$.

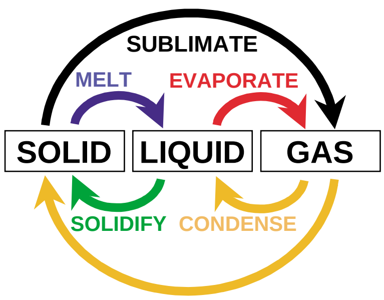
Selectivity

The amount of methanol that has reacted to formaldehyde divided by the total amount of reacted methanol (i.e. not only reacted to HCHO but also to CO, DME etc). Using this definition, the sum of the selectivities to all products will be equal to 100%. Thus, the selectivity (%) to formaldehyde = $100 \cdot F_{FA}/(F_0 - F)$ where F_{FA} is the molar flow rate of formaldehyde at the outlet. For F_0 and F, see the definition of *conversion*. As 2 molecules of methanol are consumed per molecule of DME formed, the selectivity to DME = $100 \cdot 2F_{DME}/(F_0 - F)$ where F_{DME} is the molar flow of DME at the outlet of the reactor. Perstorp Formox uses this definition of selectivity, but other definitions of selectivity can be found in the literature, so some recalculation may therefore be required when comparing values from different sources.

Yield

The portion of the methanol feed that has been transformed to the specific product. According to this definition, the yield of formaldehyde = $100 \cdot F_{FA}/F_0$, which is obtained by simply multiplying the conversion by the selectivity. If both are given as percentages, then we need to divide by 100. Thus, the sum of all yields will be equal to the conversion value and can never exceed 100%.

NOTE! Not everyone in the catalysis business uses this definition! In some cases the yield is defined as a mass flow ratio (mass flow of produced product/mass flow of reactant), in which case the theoretical limit for the yield is not necessarily 100%. For instance, one mole of phthalic anhydride (148 g) can theoretically be produced from one mole of *o*-xylene (106 g). The highest possible yield when defined as the mass ratio is thus 139.6%, while the corresponding yield calculated as a molar ratio is 100%! So when comparing yield figures, it is essential to compare definitions as well!



A new line
can make all the difference…

Perstorp Formox has a new line for processing spent catalyst. It's designed for improved quality, greater environmental responsibility and faster turn-around times. Here's the story – and a guided tour.

The first test runs started in early 2004, and following a series of adjustments and modifications, the new line began running at full capacity in August. What's so new about it?

Quality first

Spent material entering the old line was dependent on visual inspection – and subjective judgment – to determine whether the material needed to be centrifuged prior to screening (the process of separating the ceramic inert rings from the spent catalyst). This bottleneck has been eliminated. Everything is centrifuged, then screened. The separation is thorough and fast.

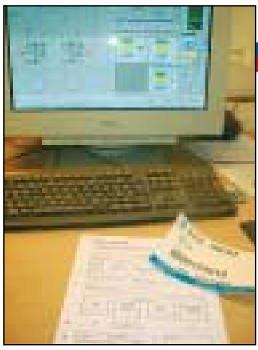
The washing of the ceramic rings is also much more efficient and effective (and it's done for a modest fee), which means enhanced quality and better performance in the customer's plant the next time around.

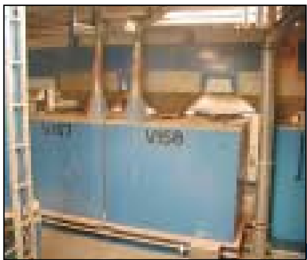
Hazard elimination

Environmental considerations have always been a compelling reason for returning spent catalyst. Perstorp Formox is committed to minimizing the environmental impact of everything we supply, from plants to catalysts.

Our new reprocessing line takes this approach an incremental step further. All wastewater is treated in a state-of-the-art treatment plant and re-used. We are bound by strict limit values, so only the minutest trace quantities of molybdenum are emitted. Iron is recovered for re-use in the iron industry. Broken ceramic rings are rendered non-hazardous before going to landfill – and we're working on ways to re-use them too.

On arrival, the spent catalyst is tagged with a batch number and registered in the system that will track it all the way. Note how well packed the arriving catalyst is – a big help to speed things up, and safer to handle.





The spent material is then emptied into a large vessel, from where it is transported up to two receptacles (top) for the respective screening lines.

The upper fraction of inerts is separated from the broken particles and dust.

Dust and broken pieces are collected in another vessel, weighed 500 kg at a time…

All water used to clean and process spent catalyst goes to this state-of-the-art wastewater treatment plant at our site in Sweden.

Under control

Each shipment from a customer is tagged on arrival, and the batch number is retained throughout the process. And only one batch at a time is processed, to assure that each customer will get back his own ceramic rings, and not someone else's.

The opportunity to recover spent molybdenum for use in the production of fresh catalyst helps to enable Perstorp Formox to offer inexpensive washing of the ceramics, and to keep catalyst prices under control even now, when molybdenum prices have been increasing dramatically.

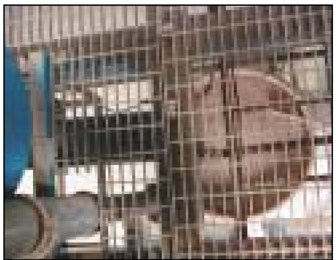
"The new line is also helping to eliminate a severe reprocessing bottleneck that has unfortunately been delaying the return of ceramic rings," says **Eva Lindgren**, head of catalyst production. "We've had a huge backlog, but now we're hopeful that we'll get caught up by next autumn."

You can help

Turn-around times can be shortened, and quality and safety can be improved if a few simple guidelines for returning spent catalyst are followed:

- Load the spent catalyst into water-tight big-bags or drums.
- Mark the packaging clearly.
- Drums should be placed on pallets in such a way that they will not fall off (e.g. wrapped in plastic, see first picture below).

But above all: Send it back! It's your best assurance of stable prices and environmentally sound handling.



The inerts are screened again (overhead view) …

… and transferred to a big-bag.

The used inerts are then washed in batches…

…then screened again and dried.

Finally, the used, thoroughly cleaned inerts are collected and packed in 50 kg drums, ready to roll again!

…and released into a tank where the fluid removes dust particles.

The broken pieces are collected in a separate container.

Photos by Daniel Larsson

Iron (the "cakes" below) and molybdenum are recovered, broken inerts are safely disposed of, and all fluid goes to the treatment plant (see top of page).

Global Compact

– business ethics for a better world

At the World Economic Forum in 1999, UN Secretary General Kofi Annan challenged business leaders to adopt the Global Compact, a code of ethics for international business and other organizations. Since then, hundreds of companies, international trade unions and other groups have joined the Global Compact. One of the companies that has joined in 2004 is the Perstorp Group.

What it is – and isn't

The Global Compact provides a framework for joint action to promote responsible citizenship for businesses. It represents a serious effort to come to terms with injustice and unethical behavior, with the ultimate goal of contributing to a more sustainable and comprehensive global economy. This entirely voluntary initiative has two objectives:

1. to integrate the Ten Principles (see box) into business practices worldwide;
2. to act as a catalyst (how appropriate for formaldehyde producers!) for measures to support the targets of the UN.

Membership thus gives companies an opportunity to be part of the solution, not part of the problem. The Global compact does not seek to be a regulatory body, nor does it attempt to be a "policeman" and monitor a company's actions. Rather, it relies on responsibility, openness and the enlightened self-interest of its member companies.

What it covers

The 10 principles (see box) of the Global Compact cover four general areas: human rights, working conditions, the environment and anti-corruption. Companies are encouraged to strive to support and implement these principles. The principles may seem self-evident (they certainly should be!), and there are few who could deny that the world would be a better place if they were universally practiced.

It starts at home

It would be naïve to think the world will change if a company joins the Global Compact. It would be worse than naïve to think the world can change if no one does. At Perstorp Formox, we intend to do our part. We hope that our customers, suppliers and competitors will do likewise. Visit www.unglobalcompact.org to find out more.

The 10 principles of the Global Compact

1. Support and respect the protection of internationally proclaimed human rights.
2. Do not be complicit in human rights abuses.
3. Uphold the freedom of association and the effective recognition of the right to collective bargaining.
4. Eliminate all forms of forced and compulsory labor.
5. Abolish child labor.
6. Eliminate discrimination in respect of employment and occupation.
7. Support a precautionary approach to environmental challenges.
8. Undertake initiatives to promote greater environmental responsibility.
9. Encourage the development and diffusion of environmentally friendly technologies.
10. Work against all forms of corruption, including extortion and bribery.

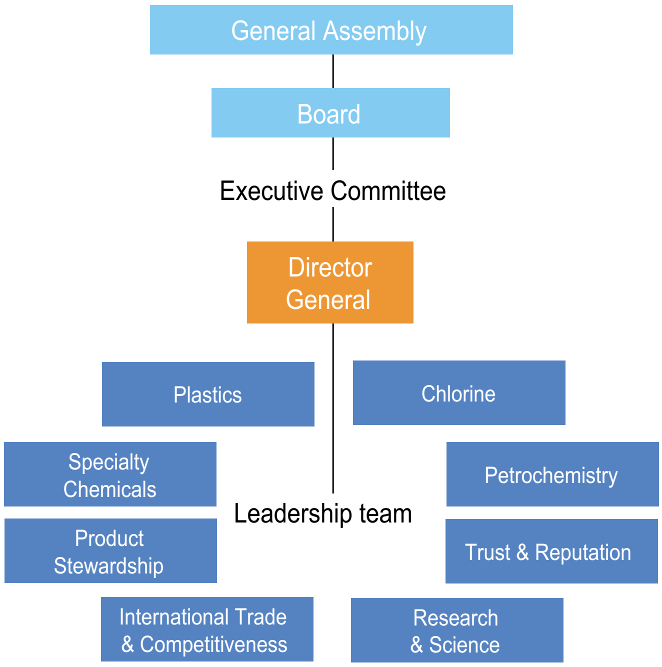
Photo: Lars-Erik Johansson

A Perstorp Group subsidiary in India, Perstorp Aegis Chemicals, sponsors an SOS Children's Village in the town of Pune – one small step in line with the efforts of the Global Compact to abolish child labor.

Meet CEFIC

– the European Chemical Industry Council

The European chemical industry is indisputably a key pillar of the European economy. The number of jobs this sector represents, the indirect support it entails for numerous other industrial sectors, and the sheer volume of sales and exports give it a vital role in Europe's success. In view of the challenges faced by European chemical companies, it is useful – to put it mildly – to have a pan-European organization that represents the interests of the chemical industry. An organization like CEFIC.



Better, not more

The European chemical industry is among the most highly regulated in the world, and this industry is committed to working with the authorities to support legislation that satisfies all aspects of sustainability: environmental, social and economic. Cefic therefore believes that legislators must adopt a practical, science-based approach that will lead to *better* laws, not necessarily *more* laws. For this reason, Cefic is an avid supporter of the worldwide Responsible Care program, launched in 1985, and with national programs running in most European countries. Cefic feels that Responsible Care should strive to offer real benefits to the industry, while at the same time enhancing the reputation of the chemical industry.

In Cefic's view, the European chemical industry is doing its part in protecting the environment and promoting the health and safety of Europeans.

"In return, we ask for policies and legislation that recognize our social and economic contribution," says Cefic President Eggert Voscherau, "and that will enable the chemical sector to keep contributing to Europe's prosperity."

Broad coverage

Cefic is a major organization (see chart) with a full-time staff of 140 people, working with over 4,000 people across the European chemical industry – the largest chemical industry in the world, representing some 29,000 companies. (One of its board members is Inge Pettersson of the Perstorp Group.)

Cefic covers nearly every sector (120 and counting) of the chemical industry, from life sciences to formaldehyde, and every aspect of the industry's interfaces with society and legislative bodies. By the way, "Cefic" originally stood for *Conseil Européen des Fédérations de l'Industrie Chimique*, and the acronym has remained.

What about formaldehyde?

Since the readers of ***informally speaking*** are by definition particularly interested in the formaldehyde-related sector of the chemical industry, the key question is what Cefic is doing to represent our interests.

"One of the things we do is nominate experts who serve as observers at IARC [the International Agency for Research on Cancer] meetings," says Annemarie Ojanperä, a Cefic communications manager. "The recent reclassification of formaldehyde by the IARC is a recommendation, but one we take seriously. So far, it has not affected any EU decisions, but rumor has it that the EU will be re-evaluating the status of formaldehyde in 2005. Our job is to maintain regular contact with the experts, and to see that the information is maintained on the scientific level."

Cefic's Formaldehyde Sector Group has also launched a study on proposed HCHO exposure limits, which will be conducted by the University of Heidelberg and its Institute and Out-Patient Clinic for Occupational and Social Medicine.

More information

For more information about Cefic, we suggest visiting www.cefic.org. Information specifically relating to formaldehyde is to be found at

www.formaldehyde-europe.org.

This site offers good factual information about formaldehyde in the light of the IARC reclassification – information that formaldehyde producers may find useful in responding to inquiries from the press or public about possibly over-inflated attitudes towards formaldehyde.

You may even want to mark that site as a favorite for quick access to updates.

Measuring your performance

by Magnus Hernelind

For many years we measured the performance of our formaldehyde plants in Sweden with an on-line gas chromatograph (GC). Those of you who've already tried on-line GC measurements may know how troublesome that can be – especially measurements in the reactor outlet, since para easily is formed on cold surfaces and methanol/water may condense before reaching the GC. The para is not only difficult to remove, it may also cause inaccurate readings, since it can absorb methanol. We overcame many of these problems by using a portable GC – as many of you know because our technical support teams also use them for troubleshooting, The portable GC overcomes many of the in-line problems but the calibration procedure can still be tricky. The gas bottles required for the carrier gas (He) have to be refilled every now and then, and they cannot be transported by air. Moreover, the portable GC is still only way to measure performance on a multiple-line plant. But we still needed another method for simple monitoring of overall performance. We've found one: IR.

Why not?

In the final inspection of Perstorp Formox's ECS catalyst – where activity is determined by the temperature when CO is combusted to CO_2 – one of the tools we use is an infrared (IR) gas analyzer. So we thought why not try borrowing one of these units to measure CO and CO_2 in the process gas from the recycle blowers in one of our formaldehyde plants? It worked very well; so well that after a few weeks we permanently installed a new unit in our plant #5.

Learning how

The principle behind IR gas analysis is the ability of different gases to absorb infrared energy. A given amount of light is passed through measuring and reference chambers, then into a detector chamber, where the difference in the amount of light absorbed is measured. This determines the CO concentration.

Although the IR gas analyzer can be connected anywhere in the formaldehyde process, a good sampling point is after the recycle blowers, since there the HCHO content is the lowest – as is the risk of para formation in the instruments. Even so, we found that the HCHO concentration at this position is high enough to cause problems, in the form of damage to the IR gas analyzer after a couple of months in operation.

So we installed a gas washer bottle between the sampling point and the instrument to absorb all traces of formaldehyde. Then we found that IR gas analyzers don't work well with humid gases, so we had to remove the water before analysis (the amount of removed water has to be taken into account when calculating the correct CO concentration). At our plant in Sweden, we used a gas cooler to lower the temperature to 5°C (dew point) before the analyzer, which turned out to be good enough. And we've learned that it's a good idea to refresh the water in the gas washer bottle every two weeks.

IR vs GC	IR gas analyzer*	In-line GC	Portable GC
Investment cost	€ 6,000-11,000	€ 38,000-56,000	€ 22,000-33,000
Response time	Seconds	10 minutes	~1 minute
Operation & calibration	Quick & easy	Tricky & time-consuming	Fairly easy after training
Measured components	CO (CO_2) only	CO, DME, MeOH etc	CO, DME, MeOH etc
Suitable applications	Overall system yield only	Individual reactor yield	Individual reactor yield

* including gas cooler

Benefits & drawbacks

With a normal gas flow, e.g. 0.5 liters per minute, measurements take just a few seconds. And it's possible to connect the signal to the DCS so that the CO and CO_2 concentrations can be monitored on-line from the control room. (The CO_2 concentration can be good for determining when to recatalyze, since it generally increases rapidly at the end of the catalyst run.)

The IR gas analyzer is easy to calibrate, and the procedure takes a mere 2-5 minutes just once a week. Another advantage is that the investment cost for an IR instrument is much lower (see box) than for a GC.

But there are some drawbacks. The IR gas analyzer only measures CO and CO_2. To get the full picture, you also need to know the DME and MeOH losses and this requires a GC measurement. Another disadvantage is that if you have several reactors and all are connected to the same absorber, you can only measure the average performance of both reactors. If you need to know each individually, you again need the GC measurement.

What's best? Your call!

So what method is best for your needs? That's something you'll have to decide for yourself, based on the conditions at your plant. But Perstorp Formox will be happy to provide advice, so you can make an informed choice.

Gas chromatograph

IR gas analyzer

Methanol market update

The following article was kindly contributed by Simon Maddren, Methanex

Simon

2004 has been a good year for low-cost methanol producers with global pricing sustained at levels well above US$ 200 for a second year. Methanol pricing has typically been very cyclical in the past, and sustained periods of high or low pricing are pretty unusual. High methanol pricing is normally bad news for consumers, particularly in the formaldehyde sector, but a strong global economy has underpinned demand for chemicals and wood-based products and thus mitigated the impact on all of our downstream markets.

This current phase of high pricing arises from two factors. Firstly, the substantial increase in energy costs that we've seen this year has driven up the marginal cost of making methanol. Although the industry is now supplied substantially from plants in low-cost, stranded gas locations like the Middle East, Chile and the Caribbean, for the time being we are still reliant on methanol produced in the United States and Europe. Competition for gas in these locations is currently very strong and has led to a large run-up in gas pricing. Gas prices in the US passed US$ 8 / GJ recently and this means a US methanol producer would be facing costs of over US$ 300 / MT right now. Without this US production, the industry would go short and therefore the cost of producing these marginal tons determines the methanol price.

Secondly, demand has been growing strongly over the last couple of years, driven substantially in Asia-Pacific by a booming Chinese economy. Recovering US and Japanese economies are also supporting demand.

Supply has been unable to keep pace with this new demand, and at a time when the industry has required higher capacity utilisation rates, we've seen substantial planned and unplanned outages in each of the regional markets. With a move to larger scale plants over the last few years, any unplanned outages from these facilities tend to have a significant impact on the market. These lower operating rates have drawn down global inventory and created further upward pressure on methanol pricing.

We commenced operation of our new 1.7M MT joint-venture Atlas plant on Trinidad [see photo] in June this year. This is now the largest plant in the world and marks the first in a wave of large-scale low-cost capacity scheduled to come on stream. Looking forward a year or so, our fourth plant in Chile (840K MT) is scheduled for start-up in Q1 2005. MHTL is adding a 1.7M MT plant on Trinidad next year, while a Saudi/Japanese consortium is currently commissioning a 1M MT plant in Saudi Arabia. Finally, a 1.7M MT plant in Iran is reportedly scheduled for start-up in early 2006. As this capacity comes on, we would expect to see the higher-cost North American and European plants come under pressure and begin to rationalise. This further shift from high- to low-cost capacity should prompt a return to methanol prices closer to re-investment economics of around US$ 150.

Finally, it's worth adding that China continues to support its own demand growth by adding methanol capacity. However, it remains to be seen how sustainable this will be at lower methanol prices, given current high feedstock costs in China. It is our expectation that China will play an increasingly influential role in methanol pricing beyond the next year or two.

Photo courtesy of Methanex

This huge Methanex facility in Trinidad went on stream this year. Nicknamed "Atlas", the new plant has a capacity of 1.7M tons, and is a joint-venture with BP.

Projects & start-ups

The full slate of projects is certainly keeping us out of mischief! Here's an update:

New projects

- A new project for a client in France has been launched. The plant is scheduled for start-up by the end of 2005.
- A plant with Perstorp Formox technology will be built for a client in the Middle East.

Ongoing projects

- The second of three FFS3UFC plants we are building for **Metafrax** in Russia is running on schedule…
- …as is the third. All three are located in Gubakha.
- The project for another client in Russia is ongoing.
- The new FFS3 plant for **Yantai Wanhua Polyurethane in China** is proceeding as planned.
- The FFS3 plant for **Yuntianhua** is also running on schedule.
- The plant for another client in China is expected to go on stream within the next few months.

Revamps

- The plant for a Chinese client went back on stream in June after pressurization.
- The two plants we were upgrading for a European client are ready, but one of these will now be further upgraded (to dual reactor).
- Pressurization of the **Oxiquim** plant in Concepción, Chile, is underway, and will be restarted in January.

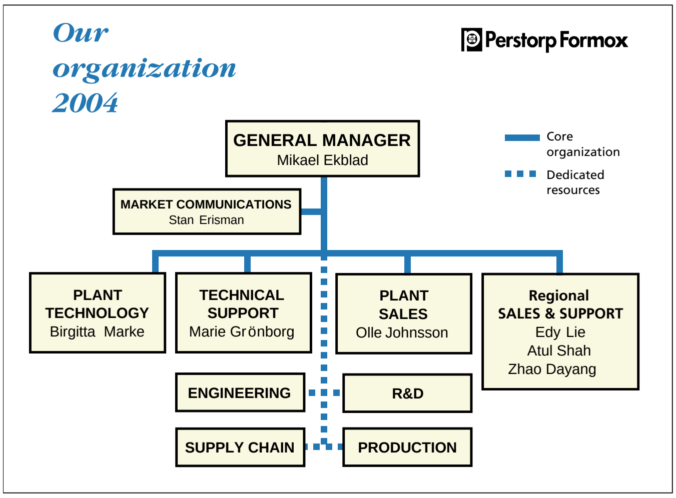
Faces & Places

In the last issue, when we covered the transition from Claes to Mikael, the question asked was: Are there any other changes? The answer, as you can see from the chart, is very little. The new Perstorp Formox organization emphasizes closer cooperation among Plant Technology, Technical Support and Sales. At the same time we have full access to dedicated engineering, R&D, production and supply chain resources, i.e. resources within the Perstorp Group that are dedicated to serving Perstorp Formox and our customers, but who are organizationally part of larger units in order to achieve economies of scale. (This has always been the case with the team of engineers from Perstorp Engineering who help us at customer sites in connection with the construction of new plants.)

One change, however, is that in the environmental area we shall focus only on developing PPt-47 for the ECS units of our customers' plants. Work with other VOC catalysts is being transferred to a separate consultancy and trading company being started by **Gunnar Blomkvist** and **Olivier Bommenel**. We wish them the very best of luck with this new venture!

Season's Greetings!

Everyone at Perstorp Formox would like to wish all of our customers, suppliers and other readers of ***informally speaking*** a wonderful holiday season and a great new year! Instead of cards, it is our custom to donate the money to Save the Children (www.savethechildren.org).



Test yourself!

- What are the effects of alcohols and ethers on the catalyst? [Effects of contaminants]
- Do you know what formula to use to calculate the MeOH losses during filling and emptying? [Estimation of formaldehyde losses in storage tanks]
- There are a couple of simple rules for preventing paraformaldehyde formation. Do you know them? [Formation of paraformaldehyde]
- Do you know how to use a GC to determine HTF oil in your formaldehyde? [GC determination of HTF oil in formaldehyde solutions]

You won't find the answers here, but you will find them among the technical documents [see titles above] on the Perstorp Formox Customer Center on

www.formaldehyde.com

If you haven't signed up, it's high time!

Next seminars

We're in the midst of our "seminar break", but are pleased to be able to announce the time and place for:

- **Formaldehyde Americas 2005**
  The place: Vancouver, B.C., Canada
  The time: October 11-12, 2005.
  Further information will be forthcoming on our website (www.formaldehyde.com) and, of course, in the next issue of ***informally speaking***. But since the time and place are set, you might want to make your calendar now!

Our other forthcoming seminars:

- **Formaldehyde Europe 2006**
  To be held in Helsingborg and Perstorp (Sweden) in **May 2006**.
- **Formaldehyde Asia 2007**
  Some time during the early part of 2007. The exact time and place have not yet been decided.

informally speaking

aims to provide **information** about **form**aldehyde in an **informal** forum and is published twice annually by Perstorp 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.
Additional copies are available from:
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Publisher: Mikael Ekblad

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Layout: Gösta Mårtensson
Printer: Perstorps Tryckeri