

## PERP Program – Maleic Anhydride - New Report Alert

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Nexant's *ChemSystems* Process Evaluation/Research Planning (PERP) program has published a new report, ***Maleic Anhydride (03/04-7)***. To view the table of contents or order this report, please click on the link below:

[http://www.nexant.com/products/csreports/index.asp?body=http://www.chemsystems.com/reports/show\\_cat.cfm?catID=2](http://www.nexant.com/products/csreports/index.asp?body=http://www.chemsystems.com/reports/show_cat.cfm?catID=2)

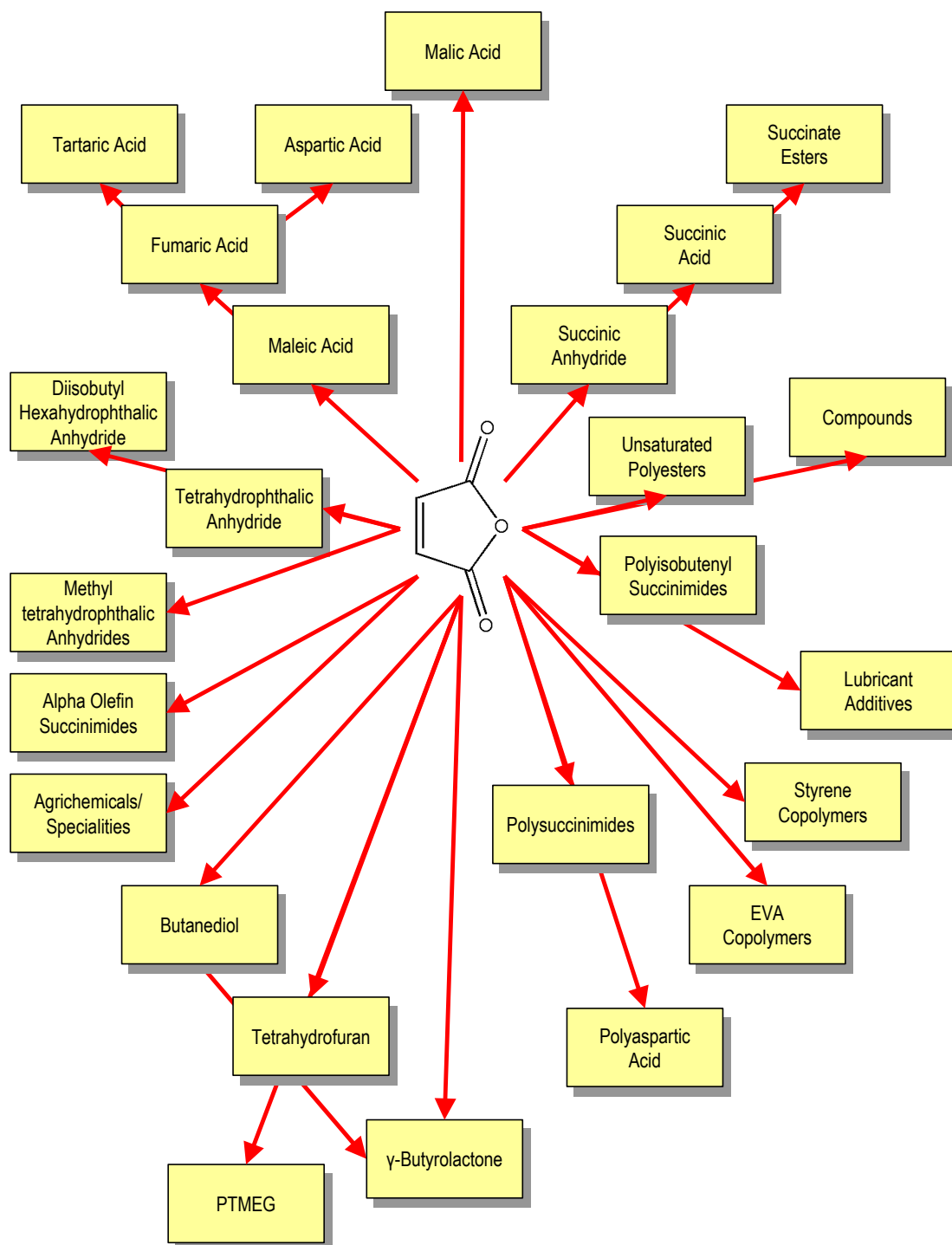
### Uses

Maleic anhydride (MAN) is a versatile molecule that lends itself to many applications requiring multifunctionality. With three active sites (two carboxyl groups and one double bond), it is an excellent joining and cross-linking agent. The broad range of derivatives is shown in Figure 1.

Starting at the top of Figure 1 and moving clockwise, a description of major maleic anhydride chemistries and derivatives now follows:

- The catalytic hydration of maleic anhydride yields malic acid – an important acidulant in the food and personal care industry.
- The catalytic hydrogenation of maleic anhydride yields succinic anhydride which can be hydrolyzed to the acid. Esters of succinic acid are used in the agrichemicals industry.
- The reaction of maleic anhydride with phthalic anhydride with propylene glycol yields a commodity unsaturated polyester resin which is usually dissolved in styrene for use in reinforced compounds, artificial marble, etc.
- The Diels Alder addition of maleic anhydride with polyisobutylenes yields succinimides which form key components in lubricant additives when reacted with polyamines, etc.
- Maleic anhydride copolymers with styrene, ethylene vinyl acetate, etc, serve a number of niche market segments for adhesives, coatings, anti-fouling agents, etc.
- Polysuccinimides and polyaspartic acid are newer developments targeted at detergent and anti-corrosion applications.
- Butanediol and derivatives represent the outlet for unrefined maleic anhydride supporting downstream industries such as engineering polymers, spandex fibers, solvents and specialties.

**Figure 1 Maleic Anhydride Derivative Tree**



- Maleic anhydride finds extensive use in agrichemical intermediates for pesticides and herbicides.
- Maleic anhydride can be reacted with alpha olefins to provide intermediates for a whole host of applications from lubricants through to personal care products.
- The reactions with diolefins such as butadiene and isoprene yield specialty anhydrides used for curing agents in epoxy resins serving primarily electrical/electronic markets.
- The hydration and isomerization of maleic anhydride yields maleic and fumaric acids which find widespread uses in fine chemicals, resins, acidulants, etc.

Extensive discussion is provided in the report for major end uses such as unsaturated polyester resins; fumaric, malic, maleic, and succinic acids; specialty adducts; lubrication oil additives; agricultural chemicals; and styrene and other copolymers. Miscellaneous other end uses are mentioned briefly.

## Technology

There are various process options available for the production of maleic anhydride that must be considered by potential producers for choosing the process configuration optimum for any particular local situation. Process options include:

- Feedstock (benzene, *n*-butane)
- Reactor (fixed-bed, fluid-bed)
- Energy integration (co-product, power, etc.)
- Recovery (aqueous, solvent)
- Purification approach
- Feed recycle or one-through

It is fair to say that in the final analysis the reactor is still the heart of the maleic anhydride process and will continue to focus the mind of chemists and engineers alike in improving conversion, selectivity and throughput.

The report generically discusses the influences of the various options on the maleic anhydride process. Specific process descriptions are provided for the processes offered by major licensors Huntsman, Lonza/ABB Lummus, and Scientific Design.

Process information also is provided for selected maleic anhydride derivatives:

- Unsaturated polyester resins
- Polyisobutenyl succinamides
- Fumaric acid
- Polyaspartic acid
- Butanediol

## Economics

Cost of production estimates are provided for the generic process configurations shown in Table 1.

**Table 1 Summary of Maleic Anhydride Production Cases**  
(USGC, Average 2004)

Reactor	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fluid	Fluid	Fluid	Fluid
Recovery	Solvent	Solvent	Solvent	Aqueous	Aqueous	Aqueous	Solvent	Solvent	Solvent	Solvent
Feedstock	<i>n</i> -Butane	<i>n</i> -Butane	<i>n</i> -Butane	<i>n</i> -Butane	<i>n</i> -Butane	Benzene	<i>n</i> -Butane	<i>n</i> -Butane	<i>n</i> -Butane	<i>n</i> -Butane
Scale, tons per year	120	80	40	80	40	40	80	40	80	80
Commercial	Yes	U.Cons'n*	Yes	Yes	Yes	Yes	Yes**	Yes	No	No
Comment									Improved Catalyst	Oxygen Enrichment

\* Two reactor fixed bed/solvent recovery under construction for GACIC at Al Jubail

\*\* BP operates a fluid bed maleic unit at Lima, OH, to manufacture butanediol in its GEMINOX™ unit

The extraordinarily high cost of benzene in 2004 had a major impact on maleic anhydride production costs, and many benzene-fed units were forced to shut down. Aqueous recovery processes can provide a larger co-product steam credit than solvent systems. This emphasizes the site-specific needs of maleic anhydride technology with respect to energy integration. Fixed costs form only a modest proportion of production cash costs in the 18 – 25 percent range. So while scale is important, energy integration has a much greater impact on production costs.

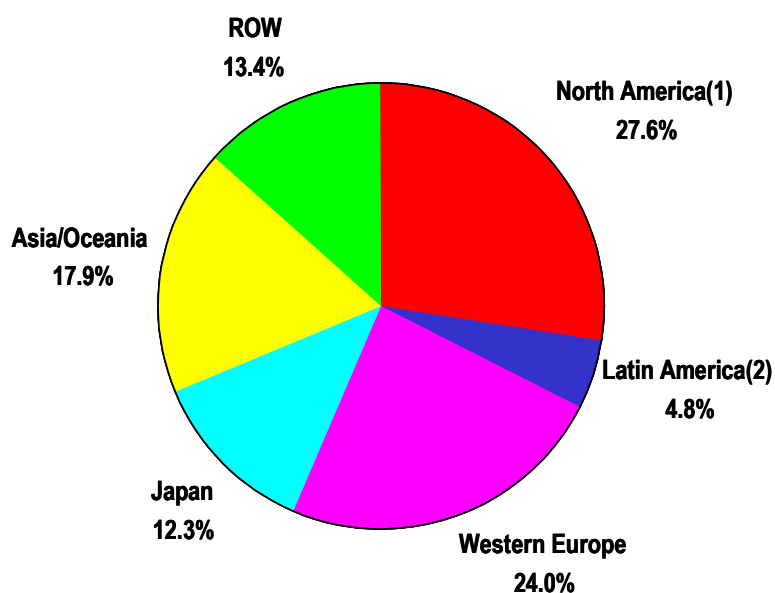
Production cost estimates are also included for unsaturated polyester resins, fumaric acid, polyaspartic acid, and polyisobutylene succinic anhydride.

## Commercial Analysis

The report presents global maleic anhydride demand by end use and by region for the period 1998-2015. Maleic anhydride demand by region in 2004 is shown in Figure 2, while Figure 3 presents the details of the North American (U.S. and Canada) maleic anhydride market by end use in 2004. The global supply/demand balance is also estimated for the same period. Corollary information is provided for North America, Western Europe, and Japan.

Unsaturated polyester resins are by far the largest segment of global maleic anhydride demand, and they are expected to remain so throughout the forecast period. Developed economies are showing demand growth in line with average GDP. However, demand growth could prove stronger given that the functionality of the maleic anhydride molecule is constantly leading to new products. If new businesses based on polysuccinimides and polyaspartic acid can be developed rapidly, then there may be even stronger demand for maleic anhydride in developed economies. End-use markets like polyester resins, succinimides, copolymers, agrichemicals, malic and fumaric acids are developing strongly in Asia, especially China, encouraging new investment.

**Figure 2 Global Maleic Anhydride Demand by Region, 2004**



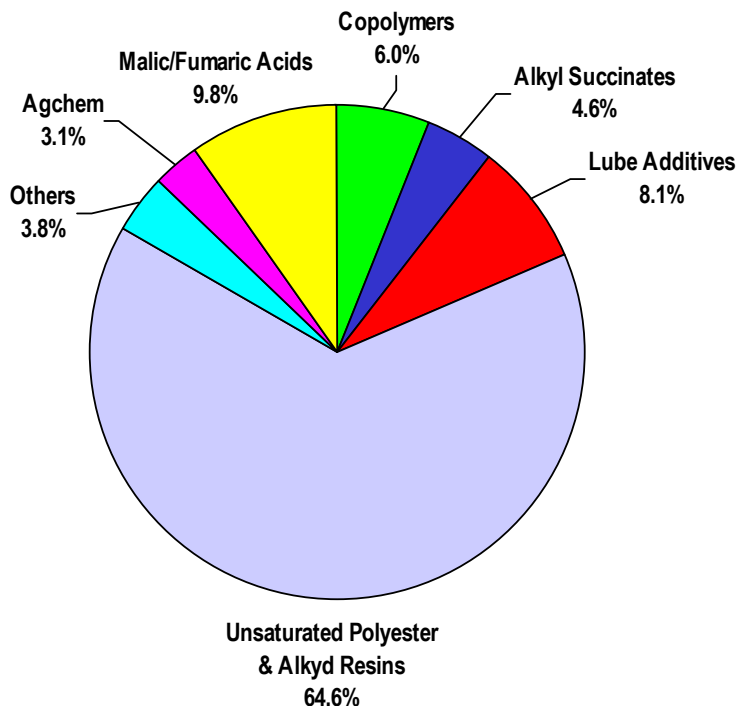
**Total Refined MA Demand = 1.03 Million Tonnes**

(1) United States and Canada only

(2) Including Mexico

(3) Does not include unrefined MA for butanediol manufacture

**Figure 3 North American Maleic Anhydride Demand by End Use, 2004**



**Total Refined<sup>(1)</sup> MA Demand = 285 Thousand Tonnes**

<sup>(1)</sup> Does not include unrefined MA for butanediol manufacture

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