



LP^{OXO}™ 2-Propyl Heptanol

2-Propyl Heptanol (2-PH) is the precursor to Di-propylheptyl-phthalate (DPHP): a similar component to Di-ethylhexyl-phthalate (DEHP) and Di-octyl-phthalate (DOP) which is made from 2-Ethyl Hexanol (2-EH).

Since the 1990's, the use of higher carbon chain plasticisers has increased in Europe and North America with legislation driving the trend of moving away from the use of DEHP/DOP in PVC. With the growing middle class in Asia, this is driving global consumption of plasticiser alcohols. In the past, there has been restricted availability of higher carbon chain plasticisers in Asia, which has in turn resulted in continued high usage of DEHP/DOP. However, this trend is now changing. This has resulted in 2-PH having the highest growth rate in the higher carbon global alcohol market since 2006.

In anticipation of growing demand for higher alcohols and building on the learning of the successful propylene to 2-EH technology, in the 1990's, Johnson Matthey (JM) and a predecessor of Dow Global Technologies, LLC (DGTL) jointly developed a low-pressure process for producing mixed C5 aldehydes and 2-PH, using LP OxoSM Technology with NORMAXTM Catalyst. DGTL is an affiliate of Univation Technologies, LLC. The majority of the world's 2-PH is made from the LP OxoSM Process: JM and DGTL have granted

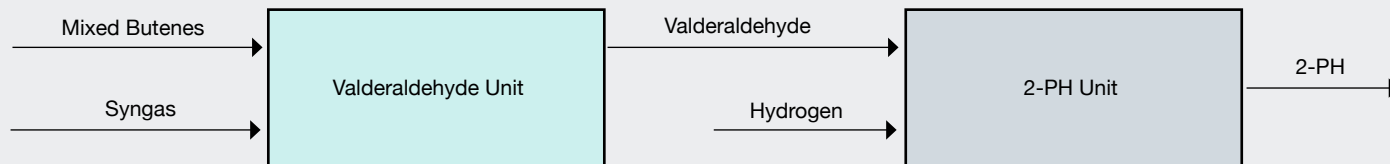
licenses for production of more than 500 kTPA mixed C5 aldehydes for conversion to 2-PH of which more than 400 kTPA is in operation.

The LP OxoSM Process is the DGTL/JM rhodium based low pressure hydroformylation process which is primarily used to convert propylene and synthesis gas to butyraldehydes which are then reacted to form 2-EH and/or butanols. For the production of 2-PH, the LP OxoSM Process converts C4 olefins with syngas to produce mixed C5 aldehydes which are further reacted by aldolisation and hydrogenation to produce excellent quality 2-PH (Figure 1).

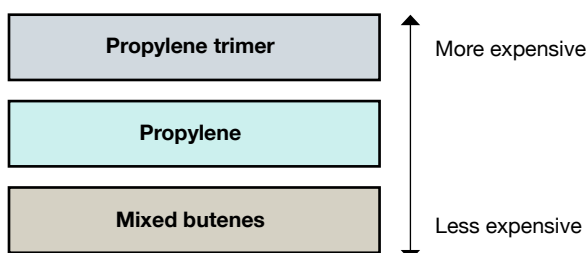
2-PH LP OxoSM Technology uses a simple flowsheet, ensuring excellent plant reliability and a high onstream factor. The active NORMAXTM Catalyst and hydrogenation catalysts provide high feedstock efficiency and low utility usage, and ensure a consistently excellent quality 2-PH product.

Compared to the conventional high-pressure technologies used to make higher oxo alcohols, the LP OxoSM Process represents a paradigm shift in plant design and operation, with enhanced safety from operating at substantially lower pressures and temperatures: less than 30 bar and 170°C, compared to more than 250 bar and 200°C for the high pressure alternatives.

Figure 1



The LP Oxo Process with NORMAX Catalyst offers a key advantage in 2-PH production by enabling the use of mixed butene feedstocks—helping reduce one of the most significant cost drivers: olefin feed. The use of mixed butene represents a major OPEX advantage in comparison to other plasticiser alcohols, as mixed butenes are essentially fuel value. For example, isodecanol (IDA) uses propylene trimer as feed; and 2-EH uses propylene as feed, and typically the olefin feedstock price is:



1-Butene streams may also be used as feed to LP Oxo 2-PH plants, however, polymer grade 1-butene is used typically as a co-monomer in the production of polyethylene (PE) and is generally more expensive than mixed butenes.

Mixed butenes are available from steam crackers and refineries, but they are typically limited in availability as they are often used in upgrading motor fuels. Methanol-to-olefins (MTO) plants, Fischer-Tropsch (FT) plants, and ethylene oligomerisation, offer new viable sources of mixed butenes (Figure 2).

As well as providing a cost improvement, phthalate esters prepared from 2-PH for flexible PVC applications also offers many other advantages relative to lower molecular weight phthalate esters, such as DEHP / DOP:

- More environmentally friendly than lower molecular weight phthalate esters, such as DEHP/DOP;
- Reduced toxicity and health risks, to humans and aquatic life, compared to DOP/DEHP;
- Low volatility in vinyl for automotive products;
- Long-term property retention;
- Excellent outdoor performance properties.

The major end-use markets include construction and automotive production. Additionally, there are emerging uses of 2-PH such as surfactants, acrylate esters and lube additives, as well as possibly nitrates and other higher value specialities in the future.

We predict that there will be a continued shift to higher oxo alcohols in all international markets. In markets where there is currently overcapacity for DEHP / DOP, existing 2-EH producers with access to mixed butenes could consider producing 2-PH for DPHP, to reduce their feedstock costs.

For existing LP OxoSM Licensees who currently produce 2-EH, it is possible to make relatively minor modifications to their plant to make 2-PH. These modifications could enable campaign production of 2-PH or 2-EH, so that producers can maximise their profitability as market requirements change.

Figure 2

