



*A fine specimen: The cod is a favorite among seafood lovers.*

Linde-technology for fish farming

## Elixir of life for Codfish & Co.

Fish is appearing more and more frequently on menus throughout the world. To protect the oceans from greater overfishing, the number of farming facilities is increasing. But for salmon and cod to thrive in those fish farms, they need to have plenty of oxygen. Linde develops technologies for intensive fish farming.

All the world eats fish. People are eating seafood in great quantities, and consumption has been rising for many years. Fishing operations and farms are running in high gear: While there were around 100 million tonnes of fish caught and bred in 1990, by 2002 this figure had already increased to more than 130 million tonnes. And there is no end to fish consumption in sight. According to estimates by the United Nations' Food and Agriculture Organization (FAO), demand will rise nearly 40 percent to 180 million tonnes by the year 2030. In China especially the appetite for fish is growing at a tremendous rate.

In order to keep pace with market demand, a good one fourth of all of the fish that end up in the cooking pot today already comes from farming facilities, which, especially in the case of freshwater fish, are known as aquacultures. The salt-water variety is also called mariculture. Nearly all of the usual table fish, such as salmon, perch, cod, turbot, sturgeon, halibut, catfish, and even shrimp, mussels and seaweed, are now increasingly being grown in intensive farming facilities. These fish farms have certain advantages over industrial fishing: When fishing boats cast their enormous nets over the seabed, for example, they destroy flora and fauna along the way, decimating the diversity of species in the oceans. Furthermore, the nets can trap other ocean-dwellers that have absolutely no business being there, such as whales, dolphins and seabirds. Such problems do not arise when fish are raised under controlled conditions in enclosed breeding tanks. What is more, some fishing grounds in the oceans have been essentially fished clean in the past 50 years. For example, cod stocks in the North Sea have nearly collapsed altogether.

In order for the fish farm residents to thrive as they should, they need to have sufficient oxygen in the water for respiration at all times. They require at least 80 percent oxygen saturation in the water for optimal growth. To achieve this, the concentration of the life-sustaining gas must be constantly monitored and kept above the critical threshold. Insufficient oxygen levels cause poor digestion in the fish, so that they require more food. The risk of illness also increases. The most important issue for the aquacultures is thus supplying oxygen to the water. The farmers do not simply use air for this, but rather add the gas in its pure form. "The partial pressure of pure oxygen is five times higher than that of oxygen in air. As a result, it dissolves more easily in water," explains Heiko Zacher, Manager of Market Development Food at Linde Gas. Linde offers complete systems to supply entire fish farms. "We not only produce oxygen, we develop the technology for adding oxygen to the water and we supply the software for optimizing the breeding conditions."

### Differences between fresh and salt water

The technology that is used for oxygenation depends on such factors as whether salt- or freshwater fish are being raised, explains Ove Gjelstenli, Customer Segment manager aquaculture at Linde Gas: Significantly less energy is required to add oxygen to salt water than fresh. This is because the gas bubbles do not combine in salt water and thus remain small. As a result, the oxygen has plenty of time to dissolve in the water. In fresh water on the other hand, small gas bubbles rapidly combine into larger ones and rise quickly to the surface. The core oxygenator is well established in the market for dissolving of oxygen in water.



*High demand: According to estimates by the FAO the world's appetite for fish may increase to about 180 million tonnes per year.*



*European frontrunner: The large fish farms of Norway primarily raise salmon.*

Water and oxygen are introduced together under pressure in a conical tank made of fiberglass or steel. The intensive mixing in the cone brings about the desired oxygenation. This technology has been available for some time. "But a new development has enabled us to raise the efficiency by 50 percent," explains Karsten Glomset, Product Development Manager at AGA Gas, Norway.

The company is selling this new technology under the name ReOx. The system – consisting of the cone oxygenator and ReOx – is available in a range of sizes, which can oxygenate from 500 to 2,000 liters of water per minute, depending on the need. With the added oxygen, the number of fish per tank can be increased considerably: If the breeder raises the oxygen saturation in the farm from 90 to 100 percent, for example, fish production can increase by one third. But because the water in the enrichment systems is highly oversaturated with oxygen,

it is enough to enrich about 10 to 30 percent of the incoming water with oxygen in order to achieve the desired 100 percent oxygen saturation. After oxygen enrichment, the water flows into the tank via a special instrument known as the Oxy-Stream. This instrument can be customized as far as dimension and capacity to fit the specific fish tank. Its specially shaped outlet nozzles create a circular flow in the tank. In this way, the oxygenated water is distributed quickly throughout the fishtank for a homogeneous mixture.

Similar oxygenation systems exist for salt water. AdOx, a new highly efficient technology which does not require a cone oxygenator, has been available since August 2005. It can be operated at a pressure of only 0.2 bar – just one fifth higher than atmospheric pressure. "These systems thus require very little energy compared to oxygenation systems for fresh water," explains Zacher. AdOx is used for small fish tanks; the alternative

for larger tanks, which is also patented, is called Oxy Process. As with ReOx, the enrichment device used with AdOx and Oxy Process is located outside the fish tank. This makes it easy to monitor its functional capability. Equally important for successful fish breeding: the systems must also be equipped to handle emergencies. “If the power fails, for example, the oxygen concentration in the fish tanks must not fall too far,” explains Karsten Glomset. Automatic emergency systems are installed for this purpose: non-electrical solenoid valves open and ensure that the oxygen feed is maintained in the tanks until the electricity is restored.

#### Temperature and water quality are crucial

The fish in such breeding farms must also be specially protected from diseases, which would spread very quickly in the tanks. For that reason, ozone is often added to the water circulation to reduce pathogens in fish farms. Besides the oxygen content, temperature is another important factor that must be constantly monitored. If the fish pools become too warm, the water loses its capacity to dissolve gases. Tiny gas bubbles form, as in a glass of mineral water, but these bubbles are filled with nitrogen.

Nitrogen dissolves easily in water and is released with heat. The nitrogen gas beads must be removed as quickly as possible, otherwise they can cause what is known as gas bubble disease. This condition in fish can cause embolisms in the circulatory system or blindness. The problem can be prevented by the addition of pure oxygen.

Up to now, fish farming has been practiced mostly in so-called open systems, in which water flows into the breeding facility from open waters and back. But the trend is more toward closed systems. “In that case, 90 percent of the water remains in recirculation,” explains Heiko Zacher. Such systems – because they are almost completely closed off – are more environmentally friendly than open systems. With support from Linde, a French fish farming operation set up the first facility in Europe with closed water circulation in 1992. In order to ensure safety in such closed facilities, carefully controlled water treatment is a requirement. Carbon dioxide and ammonia accumulate in the water of fish farms due to respiration and excretion. With nearly closed water circulation, these substances must be removed. This is done either by means of aeration (in the case of carbon dioxide) or through biological filtration (in the case of ammonia).

*Oxygen-rich: To maximize yield in aquacultures, the oxygen concentration must be kept constant. Linde engineers have developed several different technologies for this.*





*Fast processing: The growing demand for shrimp and other seafood requires an efficient production chain.*

### Mussels from the wind farm

Seafood no longer has to be bred in fjords and seas. The most curious location for aquaculture was studied by Dr. Bela Buck of the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany. The researcher suggests in his dissertation that mussels and a variety of algae known as "sugar kelp" should be farmed among the towers of the wind power plants which are planned in the middle of the German Bay.

The institute awarded him the Study Prize for his research. In the open sea, aquaculture must endure much harsher conditions than in a protected bay or in a pond. But the settlement frames arranged in a ring around the wind power plants are able to withstand the strong current and the waves. One advantage of this farming method is that some of the harmful parasites that often afflict mussels have never once appeared in the tested areas in the open sea.

The country with the highest fish farming production in the world is China. There, traditional techniques still dominate the market. Aquatic plants and algae are grown using liquid manure from hog farming in order to give the carp being bred plenty to eat. Thirty million tonnes of fish are produced each year using these methods. That is more than double the amount produced by the rest of the world combined. Only a small and vanishing fraction of global fish production takes place in Germany. While traditional pond farming is losing relevance more and more, industrial fish farming operations with closed circulation systems are growing in importance.

### Linde fish farming research in Norway

Norway is leading the way in Europe. The large salmon farms in the fjords make themselves known to consumers each year at Christmastime when Norwegian salmon fills the supermarket shelves. Every year some 500,000 tonnes of fish are produced in this Scandinavian country. With many years of experience on which to draw, Norwegian fish farming is a highly developed industry. Linde has thus focused its efforts in this area: Several hundred Linde systems are already in operation. The fish farming experts at Linde work mainly with the large, global companies in the industry. For the past two years, Linde has been operating a development center for fish farming technology in Ålesund on the Norwegian coast. "There – in cooperation with partners from research and industry – we are working to develop new

technologies, for example to optimize the operation of fish farming facilities," says Zacher. It is possible to vary the temperature and salt levels within the system to simulate conditions in the Mediterranean, for example.

The Mediterranean region is already a major market for fish farming, particularly in Spain, France, Italy, Greece and Turkey. In the future, South America and Asia could also develop into interesting markets. According to a study by the International Food Policy Research Institute, consumption will increase in developing countries as well, from 62.7 million tonnes in 1997 to 98.6 million tonnes in 2020. So that customers all over the world can also take advantage of modern fish farming systems, the research and development center in Ålesund gives seminars. The connection with customers is crucial, stresses Zacher: "It is essential to speak the fish farmers' language. Because in the end it is their needs to which our systems must adapt."

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### Links for further reading:

[www.linde-gas.com](http://www.linde-gas.com)

[www.ttzsh.de](http://www.ttzsh.de)

[www.fona.de](http://www.fona.de)

[europa.eu.int/comm/fisheries](http://europa.eu.int/comm/fisheries)