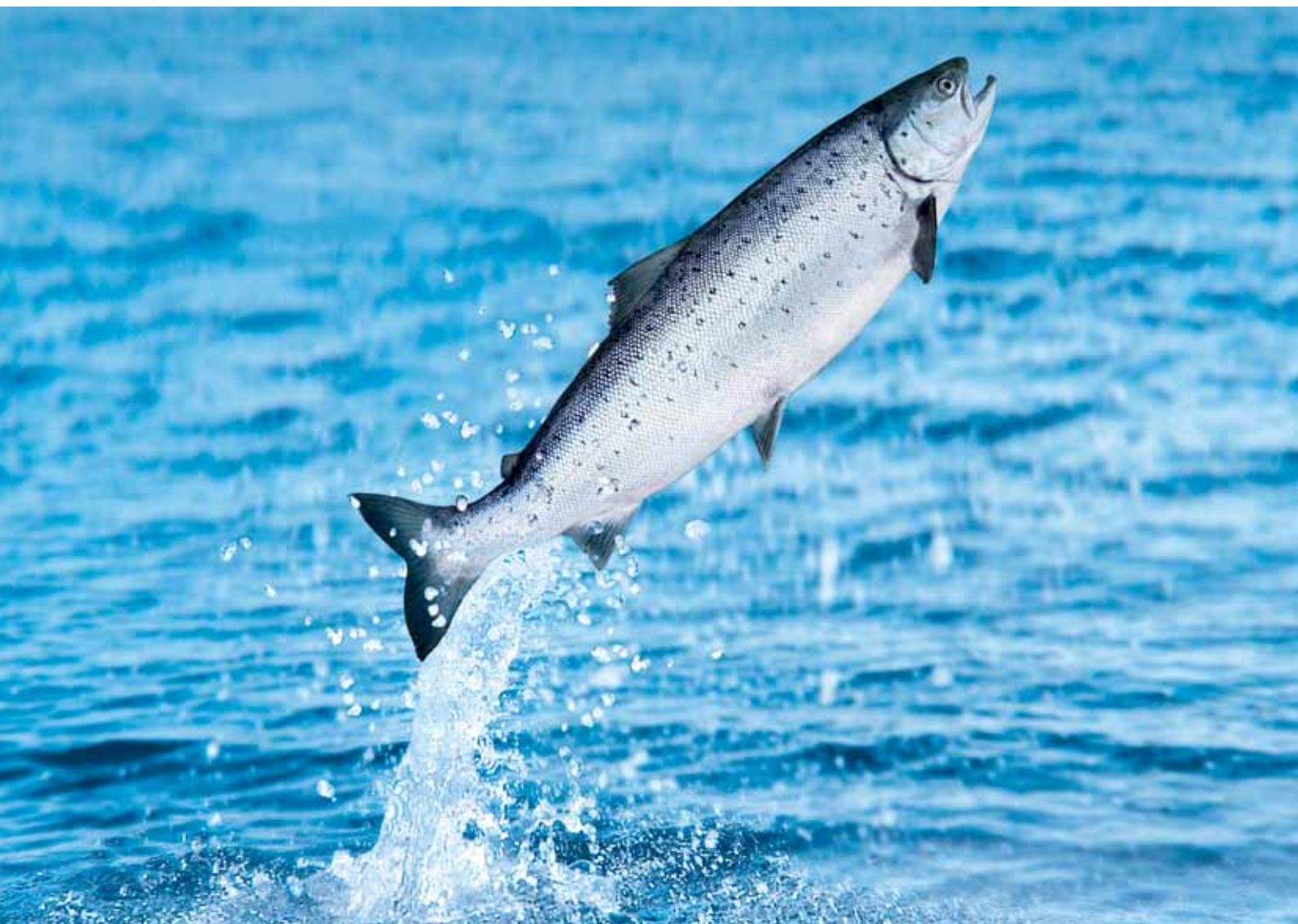


Making our world more productive



Taking Oxygenation to a New Level

Innovative Aquaculture Solutions



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Who we are

Linde is a leading industrial gases and engineering company. The company employs approximately 80,000 people globally and serves customers in more than 100 countries worldwide. Linde delivers innovative and sustainable solutions to customers in the manufacturing industry, as well as the food, process and oil industries. We also provide specialty gases for laboratories, and medical gases for hospitals. Linde creates long-term value for all stakeholders. We are making our world more productive by providing products, technologies and services that help customers improve their economic and environmental performance in a connected world.

Linde's international Innovation Centre for Aquaculture and Water Treatment is located in Ålesund, Norway. This is where the products and solutions offered to fish farming and aquaculture, nationally and internationally, are developed and enhanced.



Linde's Innovation Centre for Aquaculture and Water Treatment in Ålesund, Norway

Linde and Aquaculture

The global demand for fish products has doubled over the last 50 years. Today, more than 50% of the world's seafood comes from land or offshore-based fish farms. These fish farms cultivate fresh water or marine species in controlled environments. These facilities face the challenge of maintaining optimum fish farming conditions: appropriate nutrition, prevention of diseases, and maintaining a stable and healthy aquatic environment. The most important factor to ensure healthy fish is a constant supply of fresh, clean water. Controlling the oxygen concentration in the water is, therefore, of vital importance to the fish farm.

Maintaining the right oxygen level in the water improves feed utilization, shortens the growth period, and reduces fish mortality. Appropriate use of oxygen will significantly enhance the fish farm's financial viability and provide additional production stability. With the SOLVOX® product line, Linde offers the right solution to meet these specific needs. SOLVOX comprises a variety of oxygen dissolution and distribution products and solutions.



The Best Technology Comes from Linde's New Innovation Centre for Aquaculture and Water Treatment

Linde is the leader in oxygenation technology for fish farming. We have worked with fish farmers since the early days of this industry. Our extensive experience and ongoing research and development allow us to deliver the latest technology and know-how to our customers. Fish farms are growing larger and more complex, and the trend is for more farming to take place onshore, or in closed systems. The Innovation Centre for Aquaculture and Water Treatment is Linde's basis for developing gas technology for the aquaculture of the future. Advanced oxygenation solutions from Linde will be key to the development of the sustainable aquaculture. With SOLVOX® oxygenation solutions, Linde provides a wide range of products to ensure an optimum tank environment. The products and solutions are designed for high energy efficiency, good oxygen utilization, operational reliability and optimum hydrodynamic conditions inside the tank.

The center is designed to conduct trials with sea water, fresh water and brackish water. The same applies to testing involving the recirculation, flow-through or heating of water. Any water quality that a fish farmer might normally encounter in a fish hatchery or fish farm can be simulated here.

Linde's Innovation Centre for Aquaculture and Water Treatment is also used for training activities. Our customers can view demonstrations and presentations of our products and solutions. Our own employees from Norway and abroad attend courses on a regular basis. Linde's service technicians receive product updates, ensuring that service agreements with our customers are performed correctly and professionally. There is also close cooperation with Linde's training department, whose program includes gas safety courses for our customers at hatcheries and fish farms.



Technical hall at Innovation Centre in Ålesund

SOLVOX® venturi

The SOLVOX® series offers a wide range of oxygenation systems for the aquaculture industry, comprising equipment for optimized dissolution of oxygen in water, distribution of oxygenated water to the fish, and dose adjustment applications for smooth and reliable operation. Equipment can be designed and dimensioned for all types of aquaculture facilities.



SOLVOX® venturi product series

SOLVOX venturi: Low-pressure oxygen dissolver for salt water and brackish water

SOLVOX venturi is a patented, flexible dissolving unit, usually integrated into the pipe installation, that oxygenates the entire water supply to the tank. In larger tanks, more than one SOLVOX venturi unit can be installed in order to achieve optimum distribution of the dissolved oxygen. SOLVOX venturi is easy to install and combines high oxygenation efficiency with low energy requirements. The unique structure of SOLVOX venturi removes nitrogen from the water while adding oxygen at the same time. This is important, as fish are vulnerable to nitrogen supersaturation. It is recommended that an installation using SOLVOX venturi be supplemented with a SOLVOX streamline device (see following page).



SOLVOX® venturi installation

Available sizes SOLVOX® venturi

Product ^{1,2}	Nominal water flow [l/min]	Oxygenation capacity* [kg/h]	Length [mm]	Pipe diameter [mm]
SOLVOX venturi 4	65	0.14	200	40
SOLVOX venturi 6	100	0.23	250	50
SOLVOX venturi 9	150	0.36	300	63
SOLVOX venturi 15	250	0.55	250	63
SOLVOX venturi 24	400	0.94	360	90
SOLVOX venturi 33	550	1.30	310	90
SOLVOX venturi 45	750	1.72	400	110
SOLVOX venturi 54	900	2.09	350	110
SOLVOX venturi 150	2,500	6.62	500	160
SOLVOX venturi 175	3,000	7.2	700	200
SOLVOX venturi 250	4,000	9.54	800	250
SOLVOX venturi 400	7,000	16.2	875	280
SOLVOX venturi 700	12,000	23.3	1000	350
SOLVOX venturi 1100	18,000	36.0	1100	400
SOLVOX venturi 1800	30,000	60.0	2000	630

*At an available water pressure of > 0.2 bar. customer-specific installation capacity will vary; ¹ for all venturi 4 to 54 - fixed flange; ² for venturi 150 to 1800 - loose flange.

SOLVOX® streamline

SOLVOX® streamline is a flow distributor with integral water-flow indicator for improved oxygen distribution and optimum hydrodynamic conditions in the tank.

SOLVOX streamline ensures that oxygenated water is homogeneously distributed throughout the fish tank's water volume. It is designed to achieve an optimal circulation speed in the fish tank, depending on the fish species and fish size.

SOLVOX streamline is used in combination with oxygenation equipment such as SOLVOX venturi. This combination of equipment guarantees that the required environmental conditions in terms of hydrodynamic performance and oxygen concentration can be set individually for each fish tank. SOLVOX streamline is a customized product that can be adapted for required water flow rates ranging from 50 l/min to 20,000 l/min.

For larger water flows, two or more inlets per tank are recommended, ensuring greater operating flexibility.

An important feature is the water-flow indicator, which helps the fish farmer to control the water flow into each tank. Available water resources can thus be optimally utilized.

SOLVOX® streamline

Type	Average water flow [l/min]	Coupling / external diameter [mm]
SOLVOX streamline 4	65	40/90
SOLVOX streamline 6	100	50/110
SOLVOX streamline 9	150	63/125
SOLVOX streamline 15	250	75/140
SOLVOX streamline 24	400	90/160
SOLVOX streamline 33	550	110/180
SOLVOX streamline 45	750	125/200
SOLVOX streamline 54	900	140/225
SOLVOX streamline 150	2500	225/315
SOLVOX streamline 175	3000	225/315
SOLVOX streamline 250	4000	280/400
SOLVOX streamline 400	7000	355/500
SOLVOX streamline 1100	18000	560/710

SOLVOX streamline is delivered without the mounting flange



SOLVOX® streamline with flow indicator

SOLVOX® Oxystream

SOLVOX® Oxystream is a low-pressure oxygenation system for seawater, brackish water and freshwater tanks. The system is a patented all-in-one product that both oxygenates the water and creates flow in the tank. The product is equipped with an integrated water flow indicator that provides an overview of the water consumption in each tank.

Even mounted in the largest tanks, due to its design and patented technology, SOLVOX Oxystream allows the easy adjustment of water circulation in the tank by rotating the external pipe.

The microbubbles produced in SOLVOX Oxystream are active in both the inflow pipe and the tank. This reduces nitrogen levels and the total gas pressure in the water, which reduces or even removes the need for external degassing of the water source.

A SOLVOX Oxystream system can be installed easily by connecting the product to the tank pipe and fitting the unit to the base of the tank. This also makes the product suitable for simple retrofitting in existing tanks. It is designed for stable operation and minimal maintenance, reducing operating cost. If very large water bodies are operated or

high variations occur in the water flow, each tank can be equipped with an additional dissolver unit.

SOLVOX Oxystream is fully effective from a salinity of approximately 15 ppm, and normally only requires a pressure of between 0.05 and 0.2 bar to oxygenate, strip the nitrogen, and create optimal hydrodynamic conditions inside the tank, adapted to the facility's production. The low-pressure requirement leads to external pumps or extra energy for oxygenation and degassing of the water normally not being required. In freshwater installations, SOLVOX Oxystream is normally used for supplementary oxygenation of the water, in combination with SOLVOX cone.

SOLVOX Oxystream can be adapted to most tank sizes available on the market today, and covers water flows from 100 l/min to 25,000 l/min per intake.

For optimum operation and oxygenation, Linde recommends that an installation using SOLVOX Oxystream is supplemented with a SOLVOX gas dosing cabinet. This gas dosing cabinet can be easily connected to the facility's existing control system for automatic oxygen dosing.



SOLVOX® Oxystream



Close-up of SOLVOX® Oxystream

SOLVOX® dosing cabinet

SOLVOX® dosing cabinet

Fish grow best when the level of oxygen in the tank is kept constant. However, oxygen consumption varies depending on biomass, feeding regime, temperature, etc. The dose of oxygen required in order to maintain the optimal oxygen level in each individual tank will vary.

Linde's oxygen dosing cabinet is designed for precisely this purpose. Designed with a strong focus on gas safety, only approved components are used. The cabinet includes an integrated emergency oxygen function; in the event of a power outage, the emergency solenoid valves will open automatically. The oxygen flow rates for each state are pre-set via dosing valves.

SOLVOX dosing cabinet for cones

SOLVOX dosing cabinet for cones is used for dosing gas to pressure dissolvers and it can communicate with most control systems. Linde dosing cabinets are designed to maintain an even oxygen level in the pressure dissolver, with the emphasis placed on simple, flexible installation and maximum safety.

All cabinets are delivered CE marked and adapted to the specific installation's oxygen needs.



SOLVOX® dosing cabinet for the operation of two SOLVOX cone units



SOLVOX® dosing cabinet with outlets for three SOLVOX cones ensuring operational and emergency oxygen supplies for a SOLVOX Oxystream installation

SOLVOX® cone

SOLVOX® cone is an oxygenation unit specifically designed to increase the oxygen content of fresh water. Thanks to continuous product improvement, efficiency approaches 100% during standard operation. SOLVOX cone is the most efficient freshwater oxygen dissolver currently available on the market.

The cone is easy to operate, with water and gas introduced through the top of the cone, pressurized and mixed with oxygen bubbles.

As the cone widens, water velocity is reduced. Small gas bubbles that are not yet fully dissolved rise in the cone against the downward water flow, so only water free of gas bubbles leaves the cone at the bottom. It is important that there is sufficient pressure in the downstream pipe network to ensure that the oxygen remains dissolved up to the tank.

Since SOLVOX cone is normally operated at elevated pressure, the concentration of dissolved oxygen may be significantly above normal saturation levels. Thanks to their high reliability, efficiency and simple installation, these cones are used widely in aquaculture. SOLVOX cone units are made from glass-reinforced plastic (GRP) and are delivered with CE marking.

A standard SOLVOX cone installation generally includes a SOLVOX cone booster nozzle (see page 12).

Technical data

	SOLVOX cone 60	SOLVOX cone 110
Water flow	60 m ³ /h	110 m ³ /h
Total height	2440 mm	2710 mm
Volume	610 liters	1167 liters
Diameter footprint	1140 mm	1350 mm
Weight (empty)	170 kg	210 kg
Weight (water-filled)	ca. 750 kg	ca. 1350 kg
Inlet coupling	DN 100	DN 150
Outlet coupling	DN 100	DN 150
Maximum working pressure	3.8 bar [g]	3.0 bar [g]

Capacity

SOLVOX cone 60 with cone booster 60* at max. working pressure 3.8 bar [g]

Water temp. °C	5	10	15	20	25	30
kg O ₂ /h	10.8	10.0	9.3	8.7	8.2	7.7

SOLVOX cone 110 with cone booster 110* at max. working pressure 3.0 bar [g]

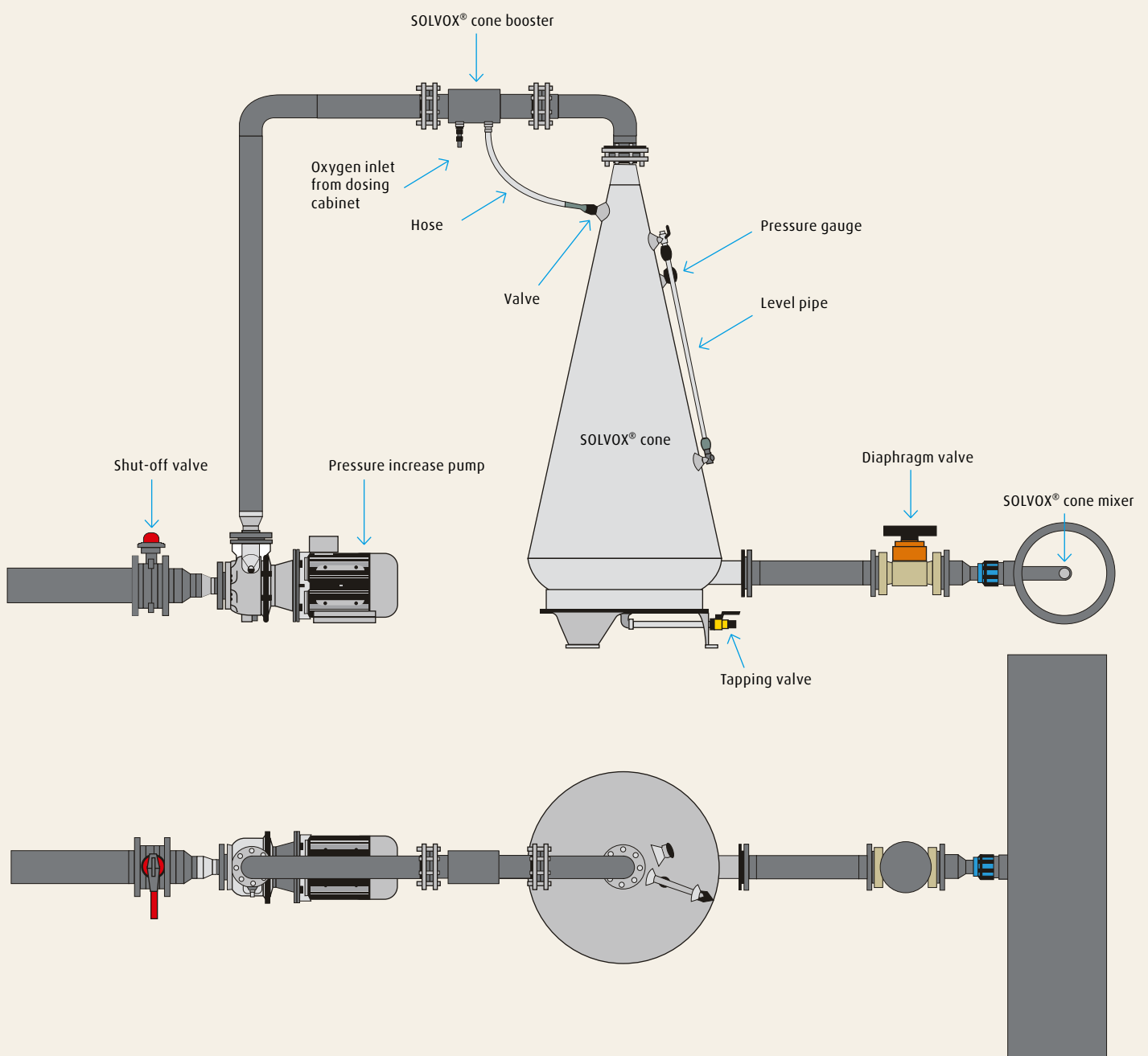
Water temp. °C	5	10	15	20	25	30
kg O ₂ /h	15.8	14.7	13.6	12.8	12.0	11.3

*Oxygenation capacity in kg/h in fresh water at nominal water flow.



A complete SOLVOX® cone installation consists of:

- SOLVOX cone booster installed on the inlet pipe
- SOLVOX cone
- SOLVOX cone mixer return to main water flow
- Valve and hose mounted on the cone
- Pressure increase pump
- Inlet fitting
- Level pipe



SOLVOX® cone installation, seen from the side and from above

SOLVOX® cone booster – for Increased SOLVOX cone Oxygenation Capacity

SOLVOX® cone booster

SOLVOX® cone booster is an additional system to boost the oxygenation capacity and efficiency of SOLVOX cone cones, allowing up to 50% higher oxygen dosing capacity. SOLVOX cone booster uses a venturi nozzle system to recirculate undissolved oxygen that collects at the top of the cone.

The system can be quickly installed with minimal downtime. SOLVOX cone booster is flanged directly onto the cone's water feed pipe. This allows an increase in the water flow to the cone of up to 25%, which then provides a further 25% increase in oxygen capacity.



SOLVOX® cone booster

SOLVOX cone mixer

SOLVOX cone mixer is a specially-adapted nozzle unit used in combination with SOLVOX cone installations. SOLVOX cone mixer is used when pressurized, highly oxygenated water from SOLVOX cone is returned to a water flow at a lower pressure.

SOLVOX cone mixer makes it possible to mix water with a high oxygen concentration into a main water flow, without degassing and reducing efficiency. The unit is designed and specifically adapted for each project and installation.

SOLVOX cone mixer can be installed individually for each tank or in the facility's main water supply, providing basic oxygenation.

SOLVOX cone mixer is generally used as part of a complete freshwater oxygenation solution.



SOLVOX® cone mixer

SOLVOX® aquaculture hose for Additional Oxygen without an External Power Supply

SOLVOX® aquaculture hose is fixed on a support or rack which is placed at the bottom of a tank. No outside power source is required to operate SOLVOX aquaculture hose, making it suitable as an emergency oxygenation system. When no additional oxygen is required, the pores close tightly, leaving the hose ready for operation at any time.

The hose is highly UV-resistant, and will therefore not become brittle due to sunlight exposure. Flexible and easy to work with, it provides a cost-effective, easily installed solution.

Specifications:

Length per coil	60 meters
Outer and internal diameter	13/20 mm
Normal working pressure	1.5–3.0 bar
capacity kg/h m hose	0.05–0.5 kg/h/m

*Depending on operating pressure and water depth



SOLVOX® aquaculture hose

SOLVOX ceramic diffuser

Ceramic diffusers are used to stabilize oxygen levels directly in the fish tank. In addition, the diffusers can be used for emergency oxygenation. SOLVOX ceramic diffusers produce gas in the form of microbubbles that start dissolving at low pressure and can also help produce an aeration/stripping effect for unwanted gases.

Designed with ultra-fine ceramic pores, the diffuser provides an even and stable oxygen supply across its entire surface. The efficiency of ceramic diffusers varies with water depth, salinity and gas pressure/amount. SOLVOX ceramic diffuser is simple to install and operate. Efficiency is maintained by undertaking standard recommended maintenance.

Specifications:

Dimensions [L x W]	670x80 mm
Surface area [L x W]	610x63 mm
Weight	2.0 kg
Max. working pressure	3.0 bar
Dosing capacity	ca 1 kg O ₂ /h



SOLVOX® ceramic diffuser

SOLVOX® dropin

Today's seawater fish farming requires increasing levels of oxygenation. This applies during various forms of delousing (using lice shields/skirts), but also in holding pens and other enclosed/partially enclosed forms of production. Here, oxygen levels are often reduced due to the unavailability of sufficient new water – with a resulting decline in the fishes' appetite, growth and wellbeing.

Today's solutions, utilizing diffusion hoses, are often cumbersome and require many operators to deploy. They are also prone to leaks or blockage and often require that the oxygen supply is turned on even before the hoses are deployed in cages.

With SOLVOX® dropin, Linde has developed an entirely new product specifically designed to oxygenate large volumes of water in enclosed or partially enclosed ocean production facilities.

Technical data for SOLVOX® dropin

Energy consumption	2.2 kW/h
Capacity	max. 50 kg O ₂ /h
Measurement	135 cm x diameter 20 cm
Weight	40 kg

In size and design, SOLVOX dropin is reminiscent of a gas cylinder. It consists of an electric pump plus a patented oxygen dissolver and distribution nozzles. Water is sucked into the lower part of the unit and the oxygenated water is dispersed through four nozzles at the top of the unit.

With the aid of the oxygen dissolver, oxygen is added to the water in the form of small bubbles, known as microbubbles. These bubbles have a large surface area in relation to their volume and therefore a low speed of ascent. This leads to bubbles remaining in the water longer, optimizing oxygenation even at low pressures and depths. Water is dispersed into the surrounding water through the distribution nozzles, where the oxygen continues to dissolve and the oxygen saturation in the body of water increases.

SOLVOX dropin is designed for ease of operation and handling as well as increased efficiency. It is therefore designed to be as light and compact as possible, weighing only around 40 kg. When in use, the device is hung vertically from a buoy to the desired depth.

SOLVOX dropin is connected to a multicable that provides power, oxygen and sensor signals to the device. An oxygen sensor registers oxygen saturation in the pen and a control system starts the pump as required, dosing oxygen to the desired pre-set saturation level.



If no oxygen is required, the device will not consume any energy or oxygen. Automated monitoring and operation are important in situations such as feeding in cages equipped with lice shields, where oxygen values within the pen can vary greatly. SOLVOX® dropin can then adjust the oxygen dose in order to maintain the optimal oxygen levels in the cage.



SOLVOX® dropin in operation

Getting ahead through innovation

Our innovative concepts ensure that we play a pioneering role in the global market. As a leading technology company, our task is to constantly raise the bar. Traditionally driven by entrepreneurship, we are focused on developing new, high-quality products and innovative processes.

Linde offers more. We create value, clear competitive advantages and greater profitability. Each concept is tailored specifically to meeting our customers' requirements – offering standardized as well as customized solutions. This applies to all industries and all companies regardless of their size.

Linde – Making our world more productive

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