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Innovative containerised Shaft Ventilation Systems for Projects in Belarus and the UK

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CFT GmbH Compact Filter Technic has designed, built and installed containerised shaft ventilation systems for potash mines in Belarus and the UK. This article describes the new equipment and explains how the innovative design has proved successful.

Mining • Shaft sinking • Ventilation • Efficiency • Belarus • UK

In 2018 and 2019 the Gladbeck-based German company CFT GmbH Compact Filter Technic supplied custom-designed and built ventilation systems for shaft sinking projects at two potash mines that are currently being constructed and/or developed. These are the Nezhinsky mine in Belarus, which is owned by the Russian mining company IOOO Slavkaliy, and the Woodsmith Mine in north-east England, which is operated by Sirius Minerals Plc.

The ventilation equipment destined for the Belarus operation was supplied to the project contractors Redpath Deilmann GmbH of Dortmund, Germany (former Deilmann-Haniel GmbH), while the system intended for the UK project was delivered to DMC Mining Services (UK) Ltd of Scarborough. Both companies have been contracted to carry out the shaft sinking work. A new generation of mechanised sinking machine is to be employed in both countries.

Containerised ventilation equipment is being installed above ground to provide an adequate supply of fresh air during the sinking phase. This equipment will ensure that both the sinking machines and the in-shaft workforce are able to operate in the best-possible climatic conditions. The ventilation systems will therefore make a fundamental contribution to workplace health, and safety and environmental protection while at the same time promoting the efficiency and durability of the shaft sinking machines.

Shaft Sinking in Belarus

Redpath Deilmann was awarded the contract to sink the new shaft in July 2017. The project, which is to be carried out in the Belarus potash mining region some 200 km south of the country's capital Minsk, involves the construction of two 750 m-deep shafts using the freeze sinking method.

Both shafts are to be sunk to a diameter of 8 m and will be constructed in parallel using two Herrenknecht type-SBR (Shaft Boring Roadheader) machines whose bottom section is fitted with a telescopic roadheader boom that can rotate through 360 °.

The material extracted by the cutting drum is collected across the entire width of the shaft floor by a pneumatic mucking system that delivers it via a 30 m-long intake line to a suction tank, the latter operating on the cyclone principle to separate the debris from the air stream. The rock is then transferred to a kibble for transport to the surface. The dust fraction in the intake air that cannot be separated out in the cyclone is also extracted through a CFT type-CSBR dry deduster and reduced to a residual dust content of ≤ 0.05 mg/m³. The filter system is mounted on-board the SBR and operates at negative pressure. The vacuum required for this debris suction unit – also part of the 'pneumatic conveying' system – is produced by three rotary blowers attached to the clean gas zone, each with a drive rating of 315 kW.

The Belarus project marks a second outing for this new type of sinking installation (**Fig. 1**), the method having already been used in 2012 for the sinking of two potash shafts at the BHP Billiton owned Jansen mine in Canada [1]. When it becomes fully operational it is expected that the new mine in Belarus will be capable of producing around 1.2 million t of potassium chloride a year [2].

Ventilation System Requirements

The first exploratory talks between Redpath Deilmann and CFT took place in July 2017. These initially set out the requirements for the ventilation system and other framework conditions relating to the subsequent operation of the installation. After calculating the airflow requirements and air duct routings the technical discussions focused on the temperature conditioning of the

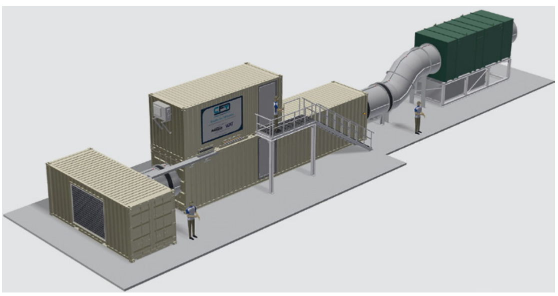

Fig. 1: CFT shaft ventilation system for Belarus
(from left to right heater battery container, fan container with attached E-house container and air cooler)
Source of the figures: CFT GmbH Compact Filter Technic unless otherwise specified

Fig. 2: Shaft Boring Road Header (SBR) by Herrenknecht AG
Source: Herrenknecht AG

fresh air being delivered through the shaft ducting to the SBR (**Fig. 2**). The detailed discussions on air temperature centred on three key factors:

- **Protecting the freeze wall from thawing**
  As the first 160 m of shaft are to be sunk using the ground freezing method the freeze zone can potentially suffer a partial thaw due to the significant levels of waste heat generated inside the shaft. In spite of the machine cooling systems in place it can be assumed that during the sinking phase the technology installed on the shaft boring machine will cause 800 kW or so of waste heat to be introduced into the airflow rising up through the shaft. In summer the outside air temperatures in Belarus can reach daytime maximums of 30 °C with 70 % relative humidity. As it is drawn in by the fans this air will be warmed up even further due to compression and its temperature will then be raised even more as it is passed through the shaft ducting to the SBR. This subsequent warming process can be attributed to the waste heat from the boring machine that flows up through the shaft and warms up the shaft ducting. In order to prevent this heat having a negative impact on the freeze wall and to create temperature conditions under which the in-shaft technology can operate trouble-free it is necessary to set up a surface cooling system for the fresh air. The aim here is to ensure that the fresh air entering the shaft is as cool as possible so that when it adsorbs heat in the shaft it will only be warmed up to a mixed temperature that will not result in a thawing of the freeze zone.
- **Air drying to prevent condensate formation**
  Air drying was another objective connected with the air cooling process. Because of temperatures falling below the dew point at the frozen shaft inner wall condensate would immediately be formed on the surfaces of the walls if the air being introduced were not pre-cooled and dried. It was also important to avoid fog formation – and in extreme cases even rain forming – in the shaft. In this particular case the use of an air cooling system automatically results in an air drying process as the temperatures at the coils inside the air cooler are already below the dew point and the condensate is removed from the air by means of droplet eliminators before it can flow on towards the shaft and SBR.
- **Increasing the fresh-air temperature in winter**
  The temperature levels present during the winter months also had to be taken into account. According to the climate tables temperatures of as low as −10 °C at 100 % relative humidity can be expected during the winter period. Especially at the beginning of the project, when the sinking is fairly shallow in depth and the shaft ducting still has a short reach, the air being fed to the shaft floor could be at too low a temperature during the coldest time of the year. The ventilation plant was therefore modified to include an electric heater battery for warming up the air.

As well as choosing the most efficient ventilation technology it was also important to get the layout of the overall installation just right. CFT proposed an innovative solution in which the ventilation equipment would be housed in shipping containers. This involved modifying standard ISO containers in such a way that component parts such as fans, heater batteries, air coolers and electrical control systems could all be fitted inside. The advantages of the container system lie in better noise protection, higher equipment mobility thanks to the modular design concept and shorter assembly times on site. This brings another significant benefit in that it saves on the need for a fan housing to provide all-weather protection for the different system components. Containerised components can be set up outdoors and already come with their own built-in weather protection for the system components and control equipment.

Design and Development of the Ventilation System

Two German firms – Korfmann Lufttechnik of Witten and WAT Wärme-Austausch-Technik, based in Hamminkeln – were called in to help with the configuration and selection of the system components (**Table 1**).

After establishing the pipework routings and the levels of resistance offered by the various assemblies along the integrated circuit the design team was able to get to grips with calculating and selecting the fan units (**Fig. 3**). The calculation showed that the fan system, which was based on SIA standard 196 [3], had to deliver 28.0 m^3/s in order to achieve a required volume flow of 25.9 m^3/s at the shaft floor. The total pressure loss for all the ventilation equipment, including ancillaries and surface components, was calculated at 7,400 Pa.

To meet this specification it was decided to opt for two Korfmann, contra-rotating axial fans type GAL 14-900/900 mounted in series (**Fig. 4**). The fan installation has an impeller diameter of 1.40 m and an electrical power rating of 90 kW per fan stage, resulting in a total electrical output of 360 kW. The fans, which are sensor monitored, are mounted on vibration dampers to isolate them from the installation as a whole. Using a completely sound-insulated 40 ft ISO container ensures a high level of sound protection. In order to facilitate short downtimes for maintenance purposes the container sides are provided with service hatches for rapid fan changeovers.

A control system with automatic mode is able to run the installation to a preset volume flow so as to ensure an efficient and user-friendly operating routine. This is achieved by automatic frequency adjustment of the motor speed. The control system is housed in a separate 20 ft E-house container (**Fig. 1**).

In order to determine the required cooling capacity WAT carried out an advance climate calculation of the shaft temperatures to be expected during the sinking phase. This was based not only on the specified design temperature and air humidity levels during the summer months but also on the additional heat input of the fans to the fresh-air volume flow and the waste heat being discharged by the shaft boring machine with its impact on the shaft ducting. In order to deal directly with the thermal input of the fans the air cooler was positioned behind them and operated in pressurised mode.

A temperature of 4 °C was specified as an efficient cooling limit and this was set as the target temperature behind the air cooler. Based on the results of the calculations it was decided to use a coiled tube cooler with a cooling output of 2,200 kW. During the cooling cycle, at temperatures of 30 °C with 70 % relative humidity, the system produces about 1,500 litres of condensate an hour and this water is separated from the air stream by means of a droplet eliminator. A distinctive feature of WAT coiled tube coolers is their low pressure losses and large heat exchanger surface. The cold water needed to operate the air cooler is provided from the client's own freeze plant.

In order to maintain constant temperatures in the shaft for both summer and winter operations a target heater-battery temperature of +2 °C was chosen for the new layout. With the additional input of heat from the fans the temperatures at the exit from the shaft ventilation system can therefore be regulated on an identical basis irrespective of the time of year.

The electric heater battery has an output of 520 kW, this being divided into eight battery stages. One of the eight battery stages is thyristor controlled while the other seven stages are switched on by an electric contactor. The advantage of this system configuration is that it allows the target temperature in the heating regime to be precisely controlled to within half a degree Celsius. The switchgear panels controlling the heating battery are centrally housed within the E-house container.

Table 1: Summary technical data for the shaft ventilation plant in Belarus, 1 system per shaft

General	type	shaft ventilation plant
	design	containerised
	supply voltage	400 V
	length	approx. 30.0 m
	width	approx. 6.0 m
	height	approx. 5.2 m
	overall weight	approx. 50 t
	operation mode	24 h/d, automatic operation acc. to preset volume flow
Fan module	type	2 contra-rotating GAL 14-900/900 axial fans
	operation mode	blowing
	volume flow	28.0 m^3/s
	pressure	7,400 Pa
	impeller diameter	1,400 mm
	electric output	4 x 90 kW = 360 kW
Air cooler	type	coiled tube cooler RWK 2.200
	cooling performance	2,200 kW
Air heating	type	electric heater battery
	electric heating output	520 kW

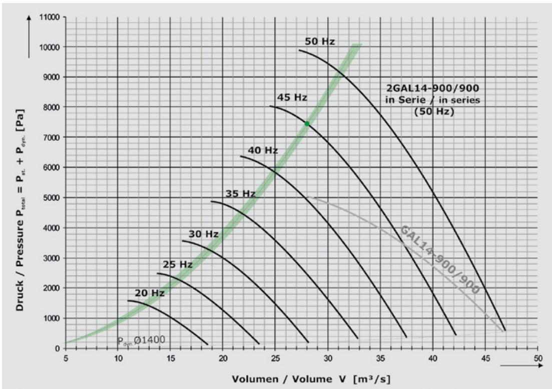

Fig. 3: Performance characteristics for axial fan with 2 GAL 14-900/900 units

Fig. 4: Fan station with 2 GAL 14-900/900 units

Assembly of the Ventilation Equipment at the Factory and Installation at the Mine Site

The entire ventilation system was assembled at the CFT factory in the autumn of 2018 (**Figs. 5 + 6**). The total weight of the installation was about 50 t, with the heaviest module – the fan container – weighing in at 16.5 t. The ventilation systems for shaft numbers 1 and 2 were assembled one by one and were then put through an extensive series of function tests and checks.

Fig. 5: Assembly of the ventilation system for number 2 shaft at the factory

Fig. 6: Service hatch (shown open) for fan container with axial fans behind

Fig. 7: Commissioning of ventilation system for number 2 shaft at the mine in Belarus

The entire installation was then broken down again into its individual transport modules and shipped out on schedule in November 2018. The work of assembling the plant on site, including the first commissioning run, was completed in a week thanks to the modular design of the installation (**Fig. 7**). Both units were connected to the on-site process control system in order to ensure constant access to the ventilation system's data and status modes. Following the commissioning phase training sessions were held at the mine for the future plant operators. The project was successfully completed in December 2018 with the final assembly and commissioning of the ventilation plant for shaft number 1.

Shaft Sinking in the UK

In October 2018 CFT was awarded a further contract to design and build containerised ventilation systems for shaft sinking operations. The project partner in this case was DMC Mining Services (UK) Ltd., a company that has been commissioned to sink four shafts for developing the Woodsmith Mine in the North York Moors National Park.

The two main shafts for the new polyhalite mine, which when completed will be 1,600 m in depth, are also to be sunk using Herrenknecht SBR shaft boring machines. In order to meet the National Park's strict rules and planning permission the mineral raised via the two main shafts will eventually be carried from the National Park by a series of conveyors running within a 37 km-long transport tunnel linking the mine site to Teesside on the north-east coast of England. Here the product will undergo further processing before being shipped out by sea. Constructing the mineral transport tunnel will require two additional shafts of 250 to 350 m depth that will be sunk using conventional technology. When it becomes fully operational the mine is expected to produce up to 20 mill. t of polyhalite a year [4].

Authorisation for the development of the new mine within the North York Moors National Park was subject to stringent environmental mitigation conditions. One of the key requirements included an adherence to sound pressure levels of between 42 and 55 dBA at various points within a limited radius of the mine.

Engineering Design and Build of the Ventilation Systems

The detail planning work needed for the ventilation system commenced in October 2018. It was decided that each of the four shafts would be provided with an intake fan station designed to blow fresh air into the shaft and an exhaust fan station to draw air out of the shaft (**Figs. 8 + 9**). With this system the fresh air is always delivered to the bottom shaft zone while the waste air is exhausted from the head of the shaft column.

The ventilation systems for the two main shafts are technically identical (**Table 2**). The fresh-air supply, which has a stipulated volume flow of 29.2 m^3/s at a pressure of 8,700 Pa, is delivered by two Korfmann contra-rotating axial fans type GAL 14-900/900 along with an additional AL 14-900 axial unit connected in series. The air intake station has a total electric output of 450 kW and is housed in a completely sound-insulated 40 ft ISO container. For further soundproofing on the air intake side an additional 10 ft ISO container is fitted to the fan container that is specifically designed as an acoustic baffle silcencer. The fans are monitored by sensors and are also mounted on vibration damping mats that isolate them from the rest of the installation.

The shafts for the UK project are not being constructed using the freeze sinking method that is required in Belarus. Nevertheless, air cooling is still of particular importance on two grounds: firstly, for occupational health reasons measures have to be put in place to ensure that the temperatures in and around the workplaces on the shaft boring machine do not exceed certain threshold values. Secondly, the technology installed in the shaft should not cause disruptions resulting from excessively high ambient air temperatures. In this connection the client has prescribed a cooling capacity of 2,000 kW per shaft and the use of finned-tube heat exchangers for air cooling purposes. Finned-tube heat exchangers consist of a series of pipes surrounded with fins to enlarge the heat exchanger surface, resulting in a very compact design. As it flows through the heat exchanger the air is cooled down on contact with the cold finned tubes. The temperature of the finned tubes is determined by the temperature of the water flowing through the tubes of the heat the exchanger. The WAT design provides for two heat exchangers per shaft each with a capacity of 1,000 kW. Each air cooler is installed in its own 20 ft ISO container and the fresh air flowing through is cooled to a target temperature of 4 °C at the exit point from the shaft ventilation system. The technical design of the heat exchangers allows them to reach their full performance at an inlet temperature of 1 °C at the water-side entry point to the air cooler.

In this case the cold water circuit is a closed system. After passing through the air cooler the water flowing out of the heat exchangers on the water side has an exit temperature of about 12 °C and is then delivered by a pair of pumps to two Carrier 30XBP air-cooled chillers. The air-cooled chillers each of 1,000 kW cooling capacity cool the water back down to the 1 °C that is required for the air cooling process before the pumps return the water to the finned-tube heat exchangers.

As well as providing a fresh air supply the ventilation system is also designed for the extraction of waste air from the shafts. The specified extraction volume of 46.2 m³/s is obtained by means of an AL 16-1100 axial fan with an impeller diameter of 1.60 m and a motor output of 110 kW. For effective soundproofing the installation is enclosed in a sound-insulated 40 ft ISO container with an additional baffle silencer.

All the equipment needed to control the shaft ventilation system, the latter comprising the intake station, air cooling system and exhaust station, is enclosed with-

Fig. 8: Assembly of the ventilation system for the service shaft at the factory
(from left to right: exhaust-air container, 2 air-cooled chillers, intake-air container with attached E-house container and 2 stacked cooler containers)

Fig. 9: Assembly at the factory viewed from a different angle
(in foreground 2 cooler containers each with a 1,000 kW finned-tube air cooler)

Table 2: Summary technical data for shaft ventilation systems in the UK, 1 system per main shaft

General	type	shaft sinking ventilation system
	design	containerised
	supply voltage	11,000 V
	length	ca. 35.1 m
	width	ca. 13.3 m
	height	ca. 5.5 m
	overall weight	ca. 86.0 t
	operation mode	24 h/d
Fan module Intake station	type	2 contra-rotating axial fans + 1 axial fan
	operation mode	blowing
	volume flow	29.2 m³/s
	pressure	8,700 Pa
	impeller diameter	1,400 mm
	electric output	5 x 90 kW = 450 kW
Air cooler	type	finned-tube heat exchange
	cooling performance	2,000 kW
Fan module Exhauster station	type	axial fan
	operation mode	exhausting
	volume flow	46.2 m³/s
	pressure	1,250 Pa
	impeller diameter	1,600 mm
	electric output	110 kW

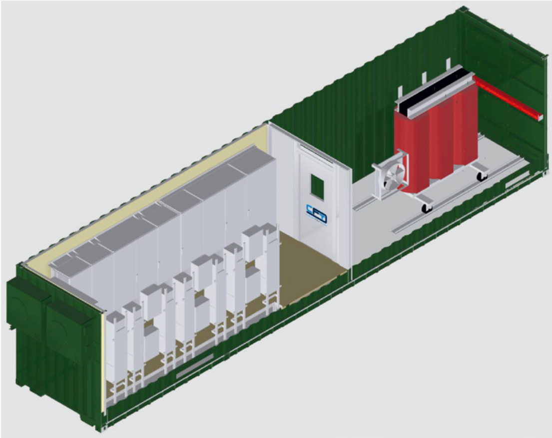

Fig. 10: Interior view of E-house container (left control room with switch cabinets and right transformer room)

in a specially modified 40 ft ISO container (**Fig. 10**). As the client's power supply was set at a predetermined voltage of 11 kV an electric transformer also had to be included as part of the system. The detailed engineering therefore provides for the control container to be divided into a control room with external access, where all the switch cabinets and frequency inverters needed to control the system are located, and a separate compartment accessible from the control room, where the transformer system with its nominal rating of 2,200 kVA is housed.

The final assembly of the ventilation systems was carried out between April and August 2019, commencing with the assembly of the MTS shaft ventilation systems at the CFT factory. This project phase was accompanied throughout by intensive works testing.

Benefits of containerised Enclosures for Shaft Sinking Operations

Mobile containers have proved to be a cost-effective solution for shaft sinking projects and their flexibility and reusability can open up new application options (see also the video [5]). If the equipment has to be redeployed to another operating site their capacity for rapid dismantling and subsequent re-assembly make for a frictionless process that helps maintain adherence to specified time schedules. Containers are also easy to transport and can readily be placed in interim storage. Not having to provide individual enclosures for the different components makes the system even more efficient, while containerisation also meets the highest demands when it comes to acoustic insulation.

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