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PRESENTATION OF A MODULAR SYSTEM FOR DRYING SEWAGE SLUDGE FROM SEAGOING VESSELS

Attila KÁRI-HORVÁTH,[1] Zsolt LANTOS,[2] Gábor KRISTÓF[3]

[1] *Hungarian University of Agricultural Sciences and Life Sciences, Technical Institute, Department of Materials Science and Mechanical Processes. Gödöllő, Hungary, kari-horvath.attila@uni-mate.hu*

[2] *Gyémánt-Pirazol Ltd. Debrecen, Hungary, zsolt.lantos@gyemantpirazol.hu*

[3] *Gyémánt-Pirazol Ltd. Debrecen, Hungary, gabor.kristof@gyemantpirazol.hu*

Abstract

Nowadays, people who take a cruise don't realize that they are putting both the environment and human health at risk significantly more than if they had chosen to travel by any other means. The large quantities of fuel burned during the voyage pollute the atmosphere and thus endanger health, and the (hazardous) waste and sewage of all kinds that are generated on board every day cannot be left on board. A ship carrying about 3000 passengers produces on average about 80 m^3 of waste water per day! Newer ships are often capable of carrying a minimum of 8,000 passengers, so the amount of waste water they produce is obviously higher. Just look at these huge floating cities of 10-12 stories. The amount of waste generated on board, being far greater, must be managed in an environmentally friendly way in accordance with ever stricter standards. These factors justify that companies in the industry are constantly working to develop new technologies and solutions, not only with the building of new ships, but also the modernization of older ones.

Keywords: *sewage sludge, waste recovery, MARPOL Convention, modular system.*

1. Waste management options

Waste hierarchy is a priority order established by the European Union giving the options for managing waste, from the most favourable to the least favourable. The waste hierarchy system helps to establish a priority order between waste management activities, based on which – with certain exceptions – the best solution is prevention. However, if this is not possible in certain circumstances, then reuse and recycling should be applied to as much waste as possible, and only as a last resort should waste be incinerated or landfilled **[1]**.

It focuses first on prevention and reuse, giving products a “second chance”. This is followed by recycling and composting, and waste incineration, which can generate electricity. Landfilling is the most harmful solution for the environment and our health, but it is also the cheapest **[2]**. Recovery therefore means the use of waste in a way that results in the exchange of raw materials and resources. In this way, waste becomes a marketable, economically advantageous secondary raw material or energy carrier that has a positive social perception and thus contributes significantly to achieving environmental protection goals. There are two main types of recovery, material recovery and energy recovery. The recovery, recycling and regeneration of components should be considered, among other things, as recovery in their material. In international practice, components suitable for energy production are called RDF (Refuse-Derived Fuel) or SRF (Solid Recovered Fuels), i.e. fuel derived from waste or alternative fuel.

2. The MARPOL Convention

The **MARPOL 1973/1978 Convention** *(International Convention for the Prevention of Pollution from Ships)* aims to protect the marine environment and prevent pollution from ships. The convention, which is mandatory for all seagoing ships of over 500 GT engaged in international trade, addresses the following potential hazards and sources of pollution. From our point of view, the provisions of Annex IV are the most important, so we will elaborate on this.

Annex I: Oil pollution prevention regulations
Annex II: Regulations for the prevention of pollution caused by toxic substances in bulk liquid form
Annex III: Requirements for the prevention of pollution caused by packaged dangerous goods transported by sea
Annex IV: Regulations for the prevention of pollution by sewage from ships
Annex V: Regulations for the prevention of pollution caused by household and other wastes generated on board ships
Annex VI: Regulations for the prevention of air pollution from ships

2.1. Annex IV.

Wastewater:

a) drainage and other waste from any type of toilet, urinal and toilet cistern;
b) drainage from medical premises (pharmacy, patient bay, etc.) through washbasins, washbasins and tumuli located in such premises;
c) discharge from places containing live animals; or
d) other wastewater, if mixed with the above-mentioned sewers.

Application

The provisions of this Annex shall apply to:

a) i. new ships of 200 gross tonnage or more;
 ii. new ships of less than 200 gross tonnage and certified to carry more than 10 persons;
 iii. new ships which do not have a measured gross tonnage and are certified to carry more than 10 persons;
b) i. existing ships of 200 gross tonnage and above, 10 years after the entry into force of this Annex;
 ii. new ships of less than 200 gross tonnage and certified to carry more than 10 persons;
 iii. new ships which do not have a measured gross tonnage and are certified to carry more than 10 persons.

3. Thermal drying

Drying is basically the phenomenon of removing liquid from a solid by evaporation. Mechanical methods of separating liquid and solid are not considered drying. The principles and phenomena of drying processes are generally independent of the type of energy used. A significant part of the energy consumption during drying is for the evaporation of liquid water (2258 kJ/kg at 101.3 kPa). The solid may contain water in different forms, such as free moisture or bound form, which directly affects the drying rate [3].

The dewatering option is called thermal drying when an external supplemental energy source allows the waste to be heated. Thermal drying requires the input of significant amounts of thermal energy to the wet solids to evaporate the water and to heat the solids and remaining water. Gravity convection or forced air convection drying ovens can provide greater uniformity, temperature control, and rapid drying capability. Oven drying can result in an efficient dehydration process and short drying times, with maximum temperatures of 250–350 °C. [4]

The dewatering option is called thermal drying when an external auxiliary energy source allows the waste to be heated. The drying process is usually used to evaporate the water from the residual solids in the wastewater. In addition to the dryer, the drying system usually consists of material handling and storage equipment, heat generation and transfer equipment, air handling and distribution equipment, emission control equipment, and auxiliary systems. These equipment systems can take many forms. In direct heat dryers, hot air/gas flows through a vessel and comes into direct contact with wet solid particles. The contact between the hot air and the cold wet concentrate allows the transfer of thermal energy, which causes the temperature of the wet material being dried to increase and the water to evaporate. The hot air/gas can be produced by almost any heat source, but is most often produced by a gas or oil-fired furnace. Examples of direct drying equipment include rotary drum dryers (Figure 1). [5, 6, 7]

In this type of system, the heat is supplied through a fuel-burning furnace that is fed directly into the dryer drum. The dried material is separated from the hot exhaust gas, screened and processed, and then either returned to the dryer or to storage silos. The exhaust air/gas is cooled and a portion is returned to the dryer. The remaining air/gas is treated in air pollution control equipment and then discharged to the atmosphere. The recirculation of the dryer exhaust gas serves three important functions. First, it increases the overall thermal efficiency of the drying system, second, it minimizes the volume of exhaust gas

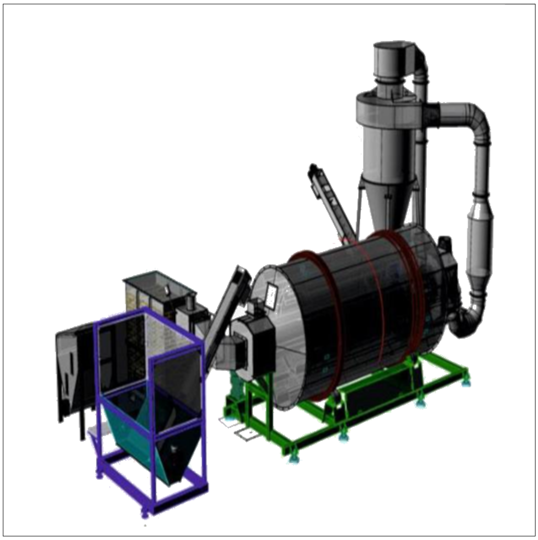

Fig. 1. *Schematic diagram of a rotary drum dryer* [8]

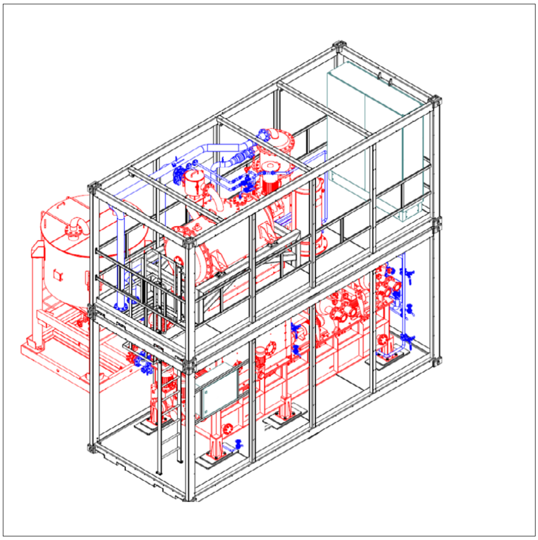

Fig. 2. *Schematic diagram of the frame structure.*

that requires air pollution control, and third, it provides a safety role by limiting the oxygen concentration in the system, which reduces the risk of explosions. Air pollution control processes for tumble dryers typically consist of additional particulate removal followed by regenerative thermal oxidation to eliminate odors and volatile organic compounds. [5, 9, 10]

Direct drying systems vary considerably in the type of equipment used to process wet and dried biosolids. Even the rotary drum systems shown in Figure 1 vary considerably in the general layout and equipment used. Another type of direct dryer, which is increasingly used in the United States and Europe, is the belt dryer. This is usually a lower temperature system than the rotary drum system. The heat supply is usually a fuel-burning furnace, but unlike the rotary drum system, the system exchanges heat with a heat transfer fluid, hot water, or flue gas in an air heat exchanger, rather than the furnace being directly immersed in the drying chamber. [7]

4. The principle of modular design

In the current international competitive shipbuilding market, success is based on offering both competitive prices and short delivery times. This has led to a focus on cost reduction in terms of steel structure, machinery and manufacturing process optimization. However, as the opportunities for further development of steel structure manufacturing and assembly techniques are diminishing, the shipbuilding industry has explored other options to reduce lead times and costs. Recently, modularization has become an incslireasingly popular method for reducing manufacturing costs.[11]

Modularity is an approach that divides a system into smaller parts, called modules, that can be independently created and assembled to create a final product. Modular manufacturing is widely used in the automotive, aerospace, and other industries, with proven time and cost savings. [11] The characteristics of modular manufacturing, such as the use of assembly lines, high levels of prefabrication, and outsourcing, allow for significant improvements in quality while reducing costs and production lead times. In our case, modularity means that the equipment we designed and built fits into 2 containers (Figure 2). The lower unit, Frame I, is an extended-height 20' HC container (H:6060 × SZ:2440 × M:2900 mm), while the upper unit, Frame II, is a 20' HC container with increased height (H:6060 × SZ:2440 × M:2600 mm). The unit is the same size as a standard height 20'DC (L:6060 × W:2440 × H:2600mm) sea container. The units can be lifted using corner elements designed and manufactured to the same design as the factory.

5. Implementation process of the drying equipment

Our equipment is a drying device composed of several parts, which has a Pre-dryer part and a Main Dryer part. The former's task is to preheat and pre-dry the material to be treated by applying it in a thin layer (~80% moisture content). The latter's task is to dry the material to the desired <=20% moisture content. Pre-drying takes place in thin layers applied to the surface of heated cylindrical drums with a combined feeding and crushing, with a total pre-drying surface of approx. 5.7 m2. Main drying takes place in the heated frame with two parallel shafts, heated double-walled individual leaf augers, with a total main dryer heated surface of approx. 25 m2. The capacity of the device is 800 - 1000 kg/h, and its maximum energy requirement is 110 kW/h. According to previous shipboard experience, by treating this (so-called) “sticky phase” in such a way that, thanks to the structural design, it continuously shears the clumping material and shreds it while transporting it.

The frame elements are transported separately, with the necessary mechanical and electrical disassembly and assembly work. In the vertical direction, the upper frame is loaded with its entire weight on the lower one, no other fastening connections (e.g. screw connections) have been created. This is sufficient when installed on land, but additional fastening elements may be required when placed on a ship. Sidewall and roof frame elements with sandwich panel inserts have been manufactured for both frame components, which can be assembled with screw connections and are equipped with their own small lifting lugs to facilitate their movement.

The sandwich panel inserts ensure the preservation of the structure during transport. The upper frame container can be completely paneled during operation, if the internal operating temperature allows this. In the case of the lower container, the long side panels (at least on one side) and the distant short side panels should be removed during operation. In the case of outdoor placement (if necessary), rain shield plates according to the picture below have been designed for the frame structures on one of the long sides. A frame element with a passenger door has been used on the shorter side of the lower container according to **Figure 3**. Access to the frame structure is ensured even with panels installed through this. The upper Frame Structure II. unit can be accessed using the access ladder placed inside the door.

We planned to test the pre-dryer first, so the production of the related components began in parallel with the container frame structures. These were: the silo, the tank with a unique mixer, the shredder-feeder, the filling-preparer, the pre-drying drum, the knife material separator and the oil tanks. In the meantime, the control and the design of the weak and strong current systems were carried out. The tests of the pre-drying unit were carried out while the electrical and control system was already in operation (**Figure 4**).

Everything was designed so that after the pre-drying tests, the dryer could be “slid” into place by lifting the individual components. The installation of the pre-drying tests and the necessary units was ensured by making a “mold” of the main dryer that held the elements designed for the main dryer. The production of the main dryer took place in parallel with the pre-drying tests, where several difficulties had to be addressed:

– Since both screws were designed to be heated from the inside, the deformation caused by welding had to be minimized during the production of the screw blades.
– Due to the unidirectional rotation of the two pulleys, we faced additional alignment challenges
– On the first try, both pulleys were made according to the drawing, but we found that they did not "turn in each other", so one of the pulleys had to be re-manufactured to match the other, made according to the drawing.
– The co-rotation of the gears that turn the pulleys had to be fine-tuned along with their control, which was only possible after many attempts.

Fig. 3. *.The frame element of the pedestrian door.*

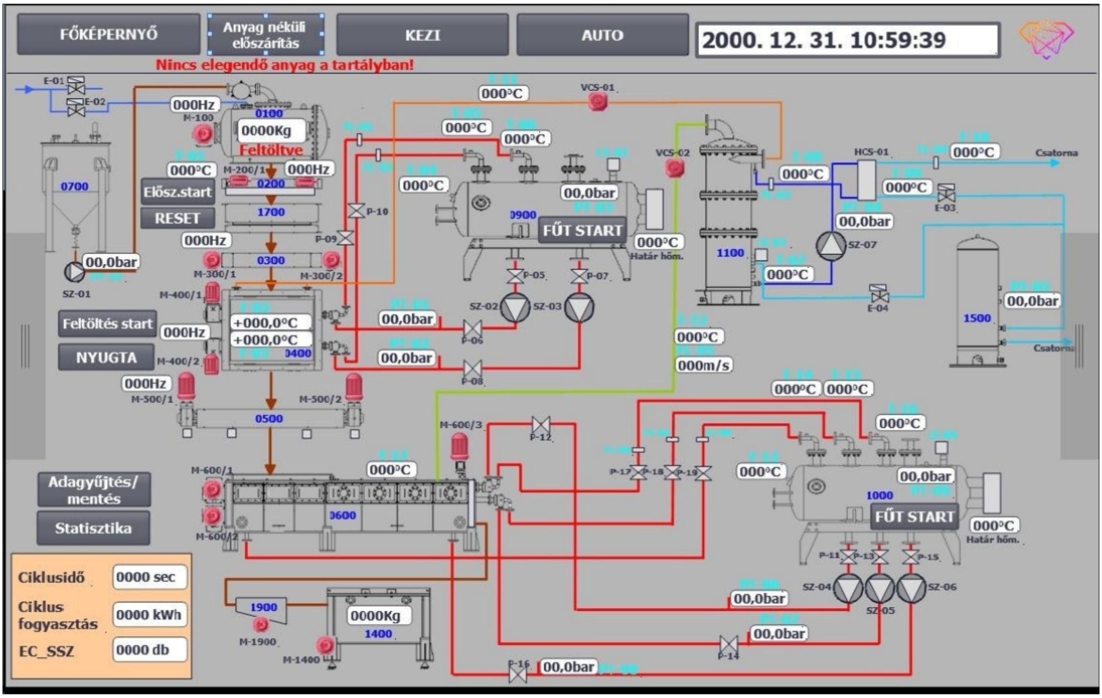

Fig. 4. *Schematic diagram of the control system (detail).*

After solving these problems, the production was followed by the mechanical assembly phase, which was implemented as an installation in the frame structure unit, in order to ensure optimal space utilization. In the meantime, the testing of the equipment continued, the commissioning, the licensing process was started, and the documentation for obtaining utility model protection was prepared. Test protocols (notes/records) were prepared for the testing steps, in which the function tests to be performed and tested, as well as mechanical, mechanical and electrical operation tests were precisely defined. The tests ended with good results, the equipment was installed, and its operation has been flawless ever since. The assembled equipment is shown in **Figure 5.**

6. Conclusions

The drying process is usually used to evaporate water from the residual solids in the wastewater. In addition to the dryer, the drying system usually consists of material handling and storage equipment, heat generation and transfer equipment, air handling and distribution equipment, emission reduction equipment and auxiliary systems. These equipment systems can take many forms, one of which is the drying equipment designed and manufactured by us, which operates on the Oasis of the Seas ship. Our equipment is a drying equipment composed of several parts, which has a so-called Pre-dryer part and a so-called Main dryer part. The task of the former is to preheat and pre-dry the material to be treated by applying it in a thin layer (~ 80% moisture content). The task of the latter is to dry the material to the desired ~ 20% moisture content.

Fig. 5. *The assembled equipment*

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