SAVONIA

The Application Market of Shock Wave Generator in the Energy Field in Finland

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Bachelor's Thesis

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SAVONIA UNIVERSITY OF APPLIED SCIENCES **THESIS**
Abstract

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Abstract

The objective of this thesis was to discover material handling problems appearing in heat and power plants in Finland and based on this study to find out the potential application for SPE "ISTA" shock wave generators.

As a target market for the research Finnish bioenergy field was chosen. In theoretical part the information concerning biofuels and bioenergy in Finland is available overviews. Also literature about material handling process on power plants is analysed.

The shock wave generator "ISTA" is introduced in this thesis. The properties and applications, advantages and disadvantages of technology are described.

The practical approach of the objective was done by qualitative methods. Data was collected through interviews of professionals with strong experience in the field or research

As a result of this thesis possible applications for shock wave generators in Finnish energy field are described. SPE "ISTA" has innovative technology for solving material handling issues and has practical benefits comparing to competitors. After SPE "ISTA" overcomes challenges of entering international market, it can probably succeed in the Finnish market due to advantages of its products.

Keywords
Shock wave generator, air-cannon, biofuel, bioenergy, arching, ratholing, material handling

SAVONIA-AMMATTIKORKEAKOULU **OPINNÄYTETYÖ**
Tiivistelmä

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Tiivistelmä

Opinnäytetyön tavoitteena oli selvittää materiaalinkäsittelyssä ilmeneviä ongelmia lämmön ja sähkön tuotannossa Suomessa ja tämän tutkimuksen perusteella selvittää SPE " ISTA " -paineilmatykin markkinointimahdollisuuksia.

Markkinaselvityksen kohteeksi valittiin Suomen bioenergia-ala. Teoreettisessa osassa käsiteltiin Suomen bioenergiaa ja biopolttoaineita. Työssä kuvattiin kiinteiden aineiden materiaalinkäsittelyyn liittyviä ongelmia siiloissa.

Työssä esitellään paineilmatykki "ISTA", jota käytetään holvausongelmien estämiseksi. Opinnäytetyössä selostetaan laitteen ominaisuudet ja sovellukset, edut ja haasteet.

Työn tavoitteet on saavutettu laadullisen tutkimusmenetelmien kautta. Aineisto kerättiin haastattelemalla ammattilaisia, joilla on vahva kokemus tekniseltä alalla.

Työn tuloksena kuvattiin paineilmatykkien mahdolliset sovellukset Suomen energia-alalla. Todettiin, että SPE "ISTA":lla on innovatiivinen teknologiaratkaisu materiaalinkäsittelyongelmiin. Laitteella on käytännön hyödyt kilpailijoihin verrattuna. Jos SPE "ISTA" ratkaisee tietyt haasteet, se voi päästä kansainvälisille markkinoille. Laite voi todennäköisesti menestyä Suomen markkinoilla.

Avainsanat
paine-ilma, materiaalikäsittely, biopolttoaineet, bioenergia, siilot

CONTENTS

1 INTRODUCTION

SPE "ISTA" pneumatics is a company operating in technical field. The company was established in 1991 by the former staff of the applied-research laboratory at the Polytechnic University in St. Petersburg. Staff group consists of the best professionals in the field of the company's activity. Close cooperation with the leading scientists produces unique potential for solving intricate technical problems. (Ista-pneumatics)

The company actively introduces technological innovations, electronic facilities, and novelties in quality. SPE "ISTA" has numerous projects in Russia and Estonia. It can be claimed to be one of the market leaders in the field, despite its small size. The prospective plan of SPE "ISTA" is to develop international relationships and enter the international market. To pursuit this objective SPE "ISTA" has collaborated with a Finnish company Savonlinnan Yrityspalvelut Oy, which offers its expertise to businesses, entrepreneurs and future entrepreneurs in terms of information, guidance and support for development. Savonlinnan Yrityspalvelut OY focuses on regional business development and investment projects and its priority areas are technology, woodworking and tourism. (Savonlinnan yrityspalvelut)

SPE "ISTA" suggests solutions for loose material handling issues in different industries. Although applications in energy sector are quite new for the company, it introduces variety of possibilities for increasing SPE "ISTA" market share in Finland.

1.1 Aims

The main objective of the present thesis was to make a potential market research for SPE "ISTA"'s production, to discover possible applications mainly in energy field and to determinate interest of Finnish companies and power plants in using "Ista-3" air cannons for preventing material hanging and arcing.

The research also concentrates on description of material handling challenges in heat and power production processes such as fuel storage, fuel feeding, ash collecting and others.

1.2 Scope

SPE "ISTA" has patented products air-cannons "ISTA-3" and "ISTA-4" with a registered trademark. Air-cannon is a pneumatic equipment whose implemented task is to provide a comprehensive service to solve hanging and arching problems of loose materials in industrial bunkers. The spectre of application of SPE "ISTA"'s products is wide-ranged. Air-cannons can be used in food processing, construction, energy, chemical, pulp and paper, mining, metallurgy and many other industries where hanging and arching of loose materials in industrial silos can appear.

Due to a broad range of applications of "ISTA" production it would be impossible to make proper research covering all fields within one thesis. Therefore the scope of this thesis is limited with research in energy field in Finland. Finnish power plants use loose material, such as wooden chips, pellets and peat as primary or secondary fuel, so hanging and arching can possibly appear in silos, bunkers, fuel feeding and other processes.

1.3 Research methods

The main questions of this thesis research were

- *What are problematic issues in material handling processes in Finnish energy industry?*
- *Is production of SPE "ISTA" suitable for the determination of these issues?*
- *Are there some other possible solutions for the shock wave generator in Finnish energy sector (cleaning of economizers etc.)?*

In order to answer these questions and to achieve thesis objective, qualitative research methods were used. Narrative analysis and expert interviews were chosen as primary research methods. Theoretical part consists of overviews of specialized literature, publications and internet articles. The practical part of thesis includes data collected through interviews and interview analysis.

For interviews there was created a questionnaire (Appendix 1) in order to determinate existing handling problems of solid materials, describe typical solution for them and figure out possible application of SPE "ISTA"'s products.

2 FUEL HANDLING ISSUES

This chapter gives an overview of information about bioenergy in Finland and biofuels used in power plants. It also describes fuel handling process and problems that can occur during it. Besides in some cases fuel feeding problems for charcoal are discussed in the thesis.

2.1 Bioenergy and biofuels in Finland

Bioenergy is the conversion of biomass resources such as agricultural and forest residues, organic municipal waste and energy crops into useful energy carriers including heat, electricity and transport fuels. (Introduction to Bioenergy)

Bioenergy is renewable and therefore is promising alternative to fossil fuels. Renewable energy is becoming a worldwide priority as it is aimed to reduce greenhouse effect and air emission. Bio-energy solutions are based on a local fuel supply. Finland is the land of forests. Wood has been used as energy source for thousands of years to warm houses and to cook food, and still nowadays it is the largest biomass energy resource.

Biofuels are mostly used in combined heat and power plants and district heating plants. Bio-boilers can usually operate on a wide variety of biofuels. Most of them are designed to combust also highly wet fuels, such us wood chips, wood residues, bark and sawdust. (Teir, 2003) The most popular biofuel in Finland are wooden chips and pellets.

The wooden chips are solid biofuel, mechanically chipped wood, which is used in heating plants and power plants. Different types of boilers require very different quality of wood chips. For small heating systems more suitable are 1-3 cm long, uniformed and dry wooden chips. Large scale plants can use forest chips, sawmill chips, cutter chips, and mixtures of them as well as combination with other solid fuels. It is important to get the chips moisture content as low as possible.

The pellets are cylindrical extrudates, which are usually made of sawdust or flakes. In Finland, no chemical additives are used for manufacturing the pellets, but wood materials (lignin, etc.). The pellet diameter is 5 to 15 mm and length 10-30 mm. (Puuperäiset polttoaineet)

Biofuels have wide variation in properties. Different types of biofuels vary especially by moisture and particle size distribution. Moisture contained in biofuel affects boiler combustion temperature and efficiency. But it also can influence fuel handling process.

2.2 Fuel handling process

The principle of material handling process at biomass heating plants is usually similar to heating plants that run on other solid fuels. The fuel is delivered to the plant and stored normally in onsite large-volume storages. The scrappers discharge fuel from storage and deliver it to conveyors and other automated devices, which transport fuel from storage to fuel feeding tank. This tank separates the rapid flow of fuel and helps to control feed rate into the combustion chamber (M.Maker, 2004). Most systems also have crushers between storage bin and fuel feeding tank.

The typical fuel handling process in power stations is shown in the Figure 1.

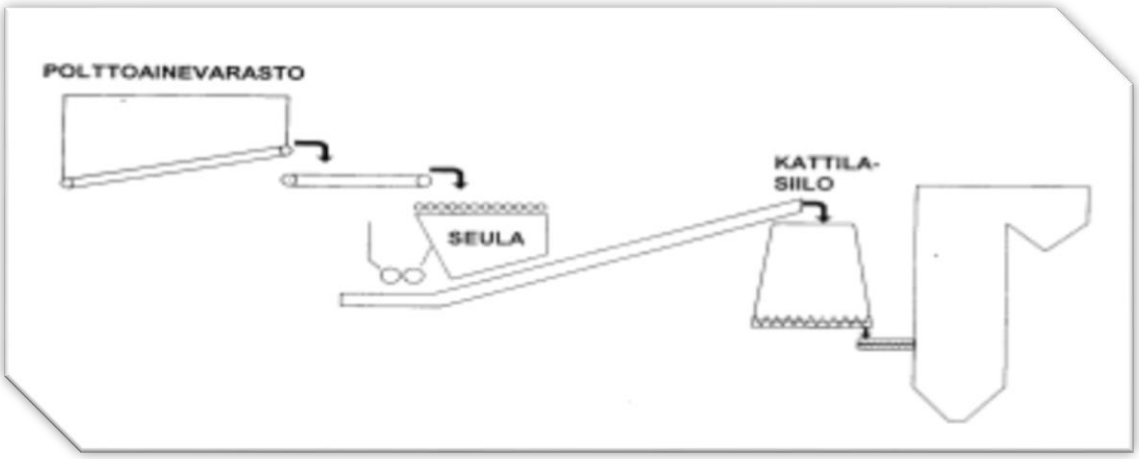

Figure 1 An example of fuel handling at 1-30 MW scale heating plant (SavonVoima Oyj:n Bioenergiaohjelma, 2001)

2.3 Fuel handling challenges

The most important task of fuel feeding is to supply the system with uninterrupted flow of fuel. This is especially significant for direct-fired systems. Smooth and systematic flow of fuel to the boiler affects the steadiness of combustion, reduces emissions caused by burning as well as reduces the use of secondary fuel, which affects the total consumption and has financial impact.

However, due to fuel characteristics some problems can occur in fuel handling process. The ultimate problems of biofuel handling are caused by large particle size, oversized pieces and long stick-like pieces. Fuel hanging and arching as well as feeding interruption are typical problems concerned with biofuels. Especially it is resided in weather conditions in Finland, where temperature below 0 degrees can stay for 4—5 months. Due to high moisture level biofuel gets freezed and iced during wintertime. As a result ratholing effect in silos and conveyors and arching problems are more likely to appear, which can lead to interruptions affecting power plant is normal operation. These problems can even result in the running the power plant down which cause will also financial losses and affect company's profit. (Kertola, 2009) (SavonVoima Oyj:n Bioenergiaohjelma, 2001)

Regardless of silos' construction problems in discharging silos can appear. There are several reasons of no-flow conditions:

- arching or bridging — material forms a stable arch (bridge) across the outlet of a bin
- ratholing or hanging —material forms a stable open channel within the bin resulting in unbalanced flow
- flooding or flushing — solid fuel behaves like a fluid and flows uncontrollably through an outlet or feeder
- flow rate limitation — an insufficient flow rate, typically caused by counter-flowing air slowing the gravity discharge of a fine powder
- particle segregation — separation of particles by size, shape, density, etc. (Maynard E. , 2013)

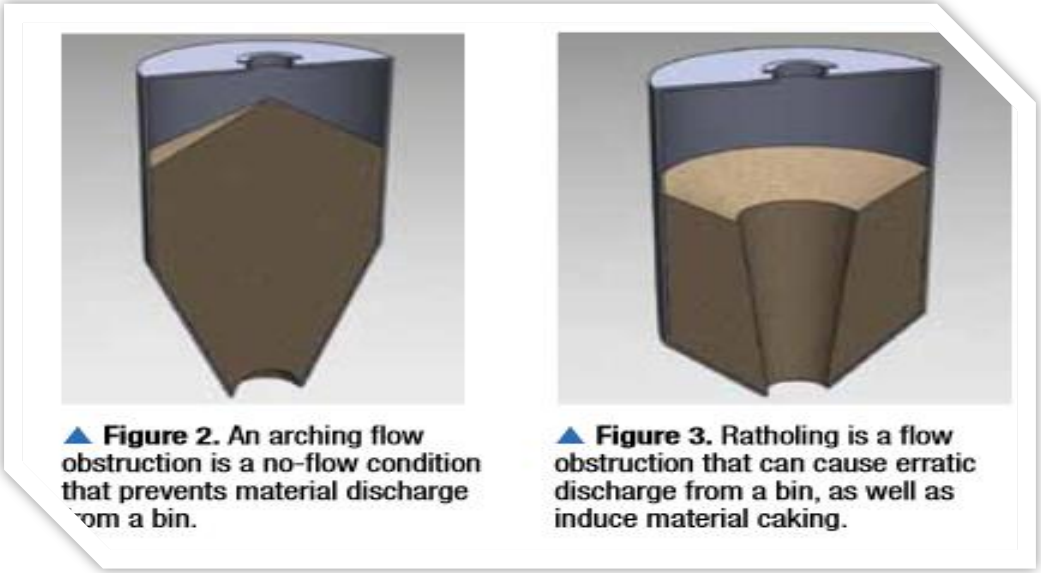

Figure 2 Ratholing and Arching Effect (Maynard E. , 2013)

For solid biofuel the most typical fuel handling problems occur due to either arching or ratholing. The arcing issues are caused by internal friction between material and silo and as well because of the property of material to hang together. The hanged material is accumulated in the upper part of silo and as a result the gap in the lower part is formed that prevents material from flowing out of the silo. (Maynard E. P., 2004)

The ratholing is common for cohesive materials, such as wood chips, limestone, fly ash etc. The ratholing effect occurs when there is material flow in the channel located above the silo outlet. Material stagnates to the silo's walls. Depending on cohesive strength material may or may not slide down. When particles of material are packing together, they form a stable rathole in the silo. (Khambekar J., 2013)

The consequences of ratholing and arching are not only fuel feeding interruption. In addition to that, when arches and ratholed material suddenly collapse, it provides sudden dynamic forces. As a result walls, floors, feeders and other surrounding equipment can be damaged. More than that, undesirable oxidation of stagnant material can occur (Khambekar J., 2013)

To ensure smooth and trouble-free handling of material handling in silos and conveyors variety of auxiliary equipment and accessories are available. For example, among the solutions are rotary valves, discharging equipment, rotary feeders, silos geometry modernization, low friction coatings, preheating etc.

Fuel preheating in wintertime prevents fuel freezing and removes undesirable extra moisture from fuels.

Modernization of bunkers' geometry is a quite complex process. It must be done on planning stage, otherwise it will be difficult to retrofit it on site. A typical bin for handling solid materials is presented on figure 3.

The solid material handling process includes an inlet feed conveyor, a storage bin or silo and outlet feeder that controls solids discharge. Most commonly silo has narrowing down geometry. To make bunker efficiently dischargeable the proper diameter and height of bunker, the angle of hopper, should be calculated. These characteristics depend on properties, volume, flow pattern etc. of solid material. (Maynard E. , 2013)

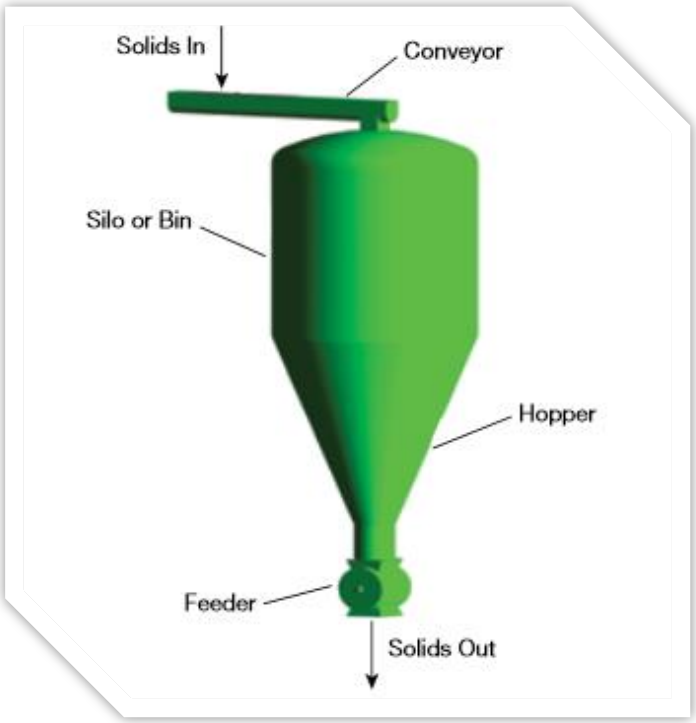

Figure 3 A typical solids handling operation. (Maynard E. , 2013)

Also better fuel quality plays significant role in preventing hanging and arching issues. Fuel with higher quality is more homogenous and doesn't get crumbled so fast. The flow of fuel material is more even and smooth, so there are less problematic conditions in handling it.

In some cases there are two parallel fuel feeding lines. Each of them should be able to provide needed amount of fuel for boiler to ensure continuous flow of fuel in case the others become corrupted. (Kertola, 2009) (SavonVoima Oyj:n Bioenergiaohjelma, 2001)

3 PRODUCT DESCRIPTION

SPE “ISTA” offers its solution for arcing and ratholing problems in the form of air cannons. This method is quite known, but “ISTA” offers innovative technology. This chapter describes the product for which market analysis was made.

3.1 Product overview

The air-cannon “ISTA-3” and shockwave impact system “ISTA-4” are designed to generate the air shock waves for the purpose of collapsing arches and eliminate hanged materials in industrial bunkers, removing plaque material on the heating surfaces of boilers and heat exchangers (including economizers), work surfaces of cyclone devices, filters, electrostatic precipitators and other objects by converting compressed air energy into the energy of the shock. (Ista-pneumatics)

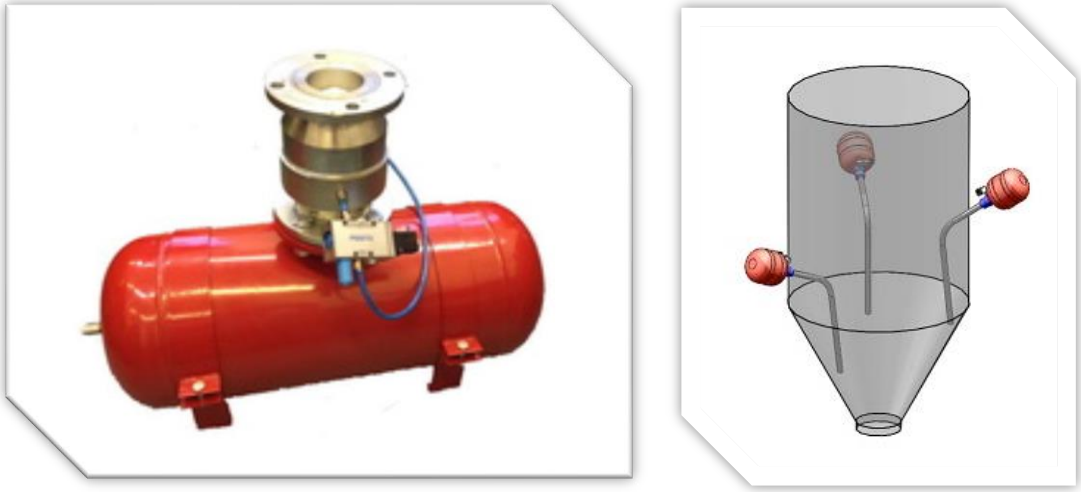

Figure 4 Air-cannon "Ista-3"

The air-cannons are fed by compressed air from an autonomous compressor or from the plant’s pneumatic circuit and can be controlled by electronic control unit.

The main unit of the device is a direct-admission air valve with diameter of 40 mm and actuation time of 0.5 msec. The performance of the valve ensures higher efficiency of the “ISTA-3” air gun as compared to all the known counterparts, because the action of a pulse jet is accompanied in it by the effect of a powerful air knock wave.

The performance characteristics of “ISTA-3” are following.

- Working gas pressure, MPa 0.5 – 0.8
- Volume of the high-pressure chamber, liters 5- 100.0
- Time of opening of the valve gate, sec 0.001
- Time of closing of the valve gate, sec 0.003
- Total mass, kg 4.6
- Guaranteed number of actuations, at least 10^6 (Ustroistvo Pnevmoimpulsnoe "Ista-3". Technical description and operating manual)

To ensure proper operation air-cannons should be installed in certain parts of bunkers and in certain quantity. These values are calculated for each case individually depending on properties of material, size of bunker and other features. (Yurkin, 2014)

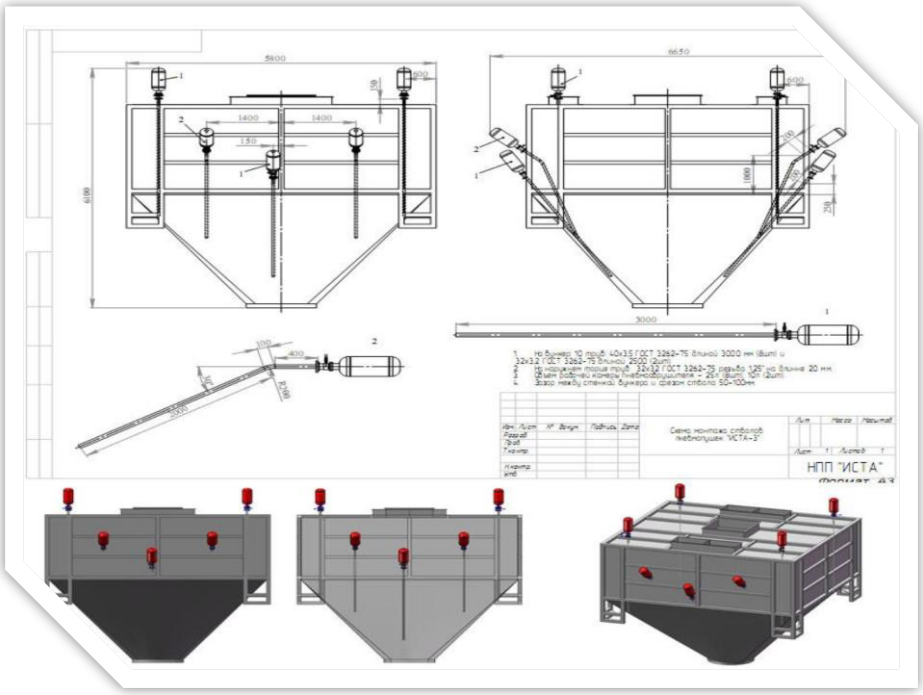

Figure 5 Air-cannon installation on bunker

The air-cannon “ISTA-3” is certified for use in any industry including potentially explosive environment (GOST certificate); which is important especially for energy field plants.

3.2 Comparison with competitive products

The hanging and arching issues were solved on the global market with devices similar to Ista's products starting from late 1980s. For more than twenty years there have been several dozen of large and medium-size companies that specialize in air-cannon services.

For example there are Standard Industrie (Gemany), VSR GmbH (Germany), Pulsonics Inc (USA), Mass Flow BV, PNEUPLANT. Among other important companies as Pneumat Systems'Inc. (USA), Monitor technologies' LLC (USA), VIBCO'Inc. (USA), ProWell Technologies, Ltd (Israel), MM Fabricators ltd. (India). VSR Industrietekhnik (Germany) and PNEUPLANT (Finland) are representatives of the Finnish market players.

There is no doubt that with the development foreign companies can appear more widely on the Finnish market, which will lead to more intensive competition and market growth. Benefits of SPE ISTA are 20 years of experience in this market and high performance of produced equipment, which has conceptual differences.

All companies have approximately the same standard series of air-cannons with receiver capacity from 5 to 500 litres. It is important to note, that the air-cannon "ISTA-3" due to the unique valve has heightened efficiency, so the problem is solved by installing a smaller air-cannon (the maximum capacity of the largest receiver of air-cannon "ISTA" is 100 litres).

Figure 6 Ista-3 with reservoir capacity 8l

The master node of any air-cannon is a pneumatic valve that must be opened as soon as possible after received signal. The smaller valve opening time is, the greater part of the energy is converted into a compressed air pulse. All “ISTA” air-cannons have valve opening time only 2ms. Valves in competitive air-cannons open starting from 6-10 ms or more.

The second relevant difference is small valve closing time - no more than 3ms. Valves competitors use valves which close very slowly, which can be ineffective in some applications.

For large bunkers totally new technology was developed and patented as shock wave system “ISTA-4”. It’s a system with one receiver for several numbers of guns (unlike ISTA- 3 has individual receiver for each valve). System like that can be implemented only with the valves, which have a very short time closing, otherwise through different guns impact different amount of compressed air. (Yurkin, 2014)

3.3 Air-cannon applications

Since 2002 SPE "ISTA" has won six international tenders. Three of them were opened to such participants as Standard Industrie VSR Industrietechnik GmbH. The company has successfully executed contracts for equipment slate silos with its systems in power plants in Estonia.

In twenty years is set over seven thousand air-cannons "ISTA-3" for more than 700 Russian and foreign companies to the tune of $ 3 000 000,00. Air-cannons have been assembled in various industries that deal with loose material in silos, bins and bunkers. Mostly, air-cannons are installed in food industry, especially baking factories. Energy industry makes 21% of “ISTA”’s market.

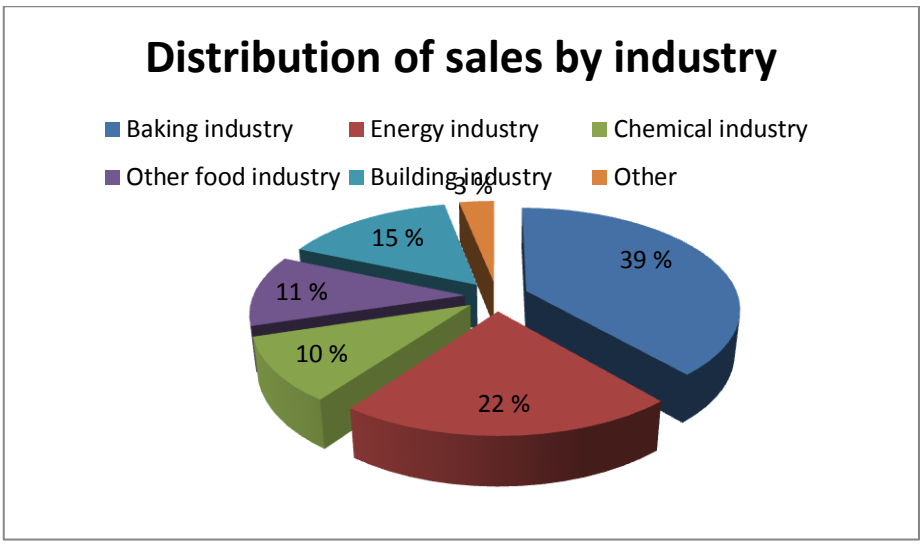

Figure 7 Distribution of sales by industry

In 2003 SPE “ISTA” started cooperation with the large chemical enterprise JSC “Akron ". A radically new technology “ISTA-4” was developed to solve the apatite hanging problem in a 6000-ton-concrete bunker. Air-cannon system "ISTA- 4” has a conjoint collector for thirty air-cannons. Within a year, pneumatic pilot system “ISTA- 4" was mounted and, 1,300 tons of raw materials from the "eternal storage" was collapsed. (Yurkin, 2014)

In Russia systems “ISTA-3” are mounted at more than a hundred enterprises of food industry, at numerous enterprises of building systems and many enterprises of other industries. A full list or references can be found on official web page of SPE “ISTA”

In 2002 - 2014, export of air cannons "ISTA-3™" to foreign countries was about 30% of total turnover. The largest foreign customers are Estonian shale electric stations – AS Narva Elekrijaamad, AS Ahtme Soojus, AS Kohtla-Jarve Soojus (Ista-pneumatics)

3.4 Air-cannon’s references in energy field

In 2000, SPE “ISTA” equipped with air-cannons a silo with crushed coal on power plant Nizhnesaldinskaya GRES. Installed air-cannons worked successfully until plant changed fuel type. In 2002, five air-cannons were dismantled and reinstalled on the bunker on the Talc plant, where they are successfully solving the problem of hang in two bunkers with talc. (Yurkin, 2014)

In 2002 a Baltic power plant in Estonia was supplied with air-cannons. Estonian power plant is the closest to St. Petersburg power plant working on solid fuel. The power plant with capacity of 90 MW runs on stale coil. This type of fuel is prone to hanging and arcs forming when stored in silos. T eliminate coil hanging are used methods such as vibrating systems, various coatings, breaking of solid fuel by compressed air from interplant pneumatic circuit didn't give positive result. The problem was solved by installing air-cannons "ISTA-3" with auxiliary equipment. The Baltic power plant was equipped with 16 air-cannons. The air-impact knocking system operates in an automatic mode. When a switch on the fuel transporter evaluates absence of fuel, a signal from the terminal automatically actuates the air-impact knocking system until the transporter is loaded again. After mounting of the air-cannons no emergence situation due to fuel feeding interruption was detected. (Siirde A. E., 2006)

4 DEFINITION OF POTENTIAL MARKET

This chapter describes potential market for air-cannon applications.

As the main objective of air impact system is prevention of hanging and arching of loose material, potential objects for air-cannon application can be power stations that work on solid fuel, such as coil, peat and biomass.

Finland is one of the world leaders in utilization of wood-based fuels and peats. There are over 400 medium and large scaled bio power and heat plants. If small scaled power plants are added here, it makes potential market quite large. The total use of woodchips in heat and power plants is nowadays at a level of about 5,4 billion solid-m3/a, that is about13,5 billion loose-m3/a (11 TWh/a). (Härkönen, 2010)

According to figures below biofuel makes about 20 % of all types of fuel used in district heating and related power production. Other solid fuels as peat and coal make additional 31 %.

Fuel	**2012**	**2011**
Natural gas	27,4 %	31,4 %
Coal	14,5 %	23,3 %
Peat	15,6 %	17,6 %
Forest biofuel	14,2 %	11,8 %
Industrial wood residue	7,4 %	7,1 %
Other biofuel	1,5 %	1,0 %
Mixed fuel	1,9 %	1,7 %
Secondary heat from industry	1,3 %	1,8 %
Heavy fuel oil	3,3 %	2,9 %
Light fuel oil	0,3 %	0,3 %
Other	2,40 %	1,1 %
Total	100,0 %	100,0 %

Figure 8 District heating and related power production. The relative proportions of fuels used. (Kaukolämpötilasto 2012, 2013)

As shown in figure 9, about 30 % of electricity in Finland is produced using solid fuels, peat, coal and biofuels. That is half of total domestically generated electricity.

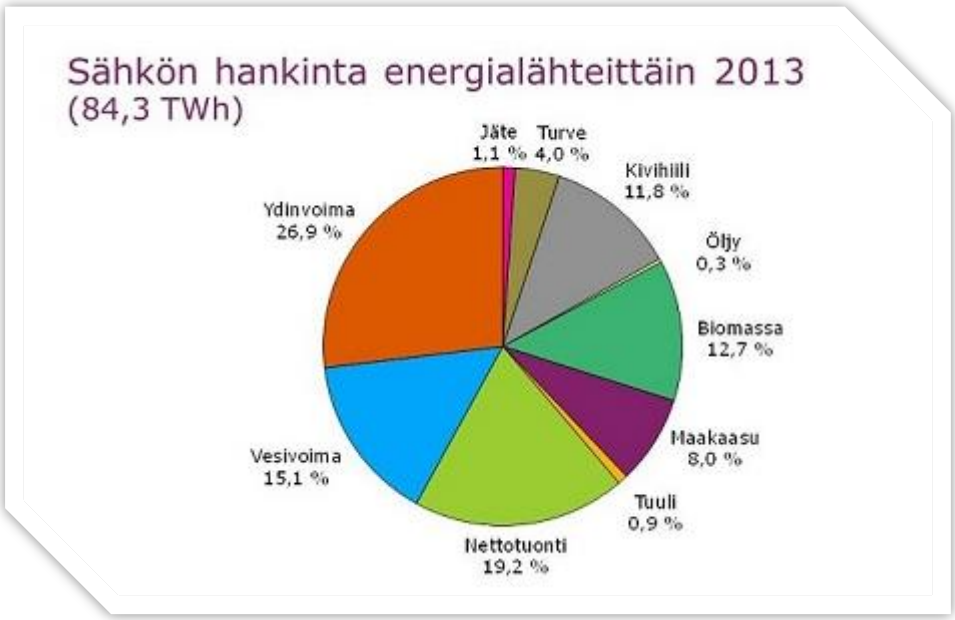

Figure 9 Electricity procurement by types of fuel (Sähkötuotanto, 2013)

The number of power and heating plants is increasing all the time. In the figure below it is shown how widely industry has developed in 8 years. The availability, environmental friendliness, good combustion properties and simplicity of handling make biofuel more and more popular material.

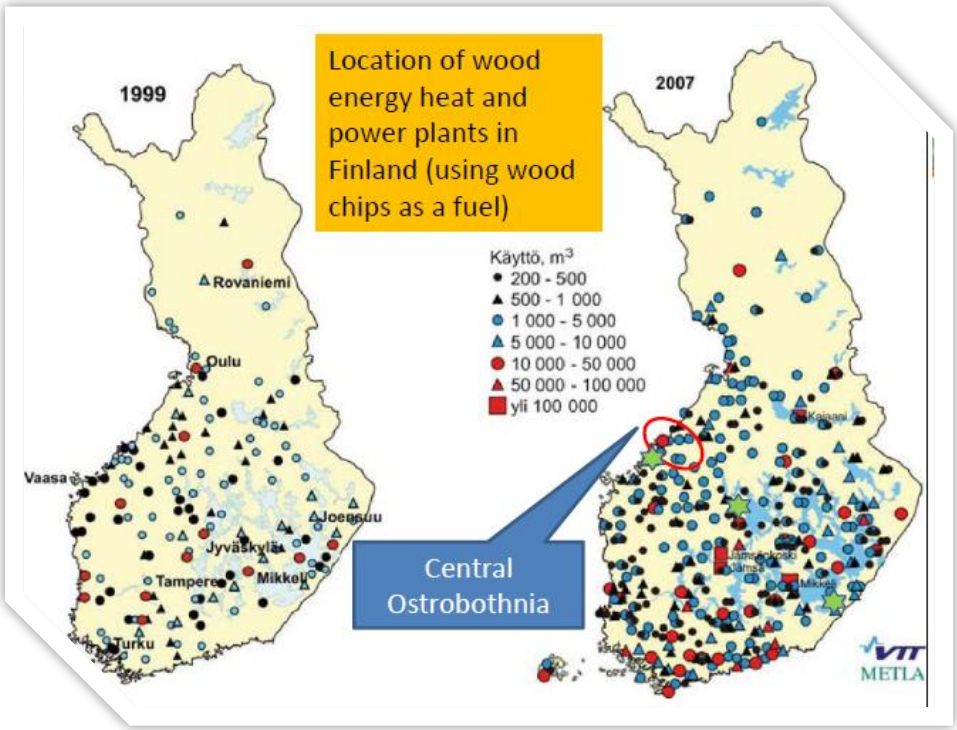

Figure 10 Location of wood energy heat and power plants in Finland (http://www.forestpower.net/data/liitteet/859=martti_biomass_conversion_in_finland.pdf)

From figure 10 it can be noticed that potential objects for air-cannon “ISTA” applications are concentrated in southern and middle parts of Finland. The heat and power plant are located near the border with Russian Federation. That is good in terms of logistic costs and delivery times.

Is was found out from the interviews power and heating plant working with woodchips experience challenges related to hanging and arching effect. SPE “ISTA”’s production is quite flexible; it can be designed and implemented in various scaled bunkers. If there are issues in certain cases, they are probably to appear more widely. It can be concluded that bioenergy field in Finland is suitable site for expanding on international market.

5 POTENTIAL APPLICATIONS

In this chapter analysis of interview is made and potential applications for air-cannons are determinated. Besides, benefits and challenges of air-cannons are described.
The information in this chapter is based on the answers of interviewed experts.

5.1 Interview questionnaire

To make primary analysis we developed a list of questions in order to figure out current situation on market and potential interest of companies to purchase Ista's products. In this case qualitative analysis is more effective, because numbers are not so important. But the level of competency and experience in engineering field plays bigger role.

The questions for interviews were based on spin selling strategy, to achieve better contact with potential customers. Customer oriented approach was supposed to add value to interviews. The questions were created to discover existing problems, to determine effect of them and to find out the level of interest in implementation of new technology.

For interviews different types of experts were contacted in order to describe issue from various angles. Among them there were bio-energy producers and equipment suppliers in Finland, who are considered to be highly experienced engineers. In total 8 professionals were contacted (Appendix 2)

5.2 Existing challenges in material handling

Purpose of this part was discovering problem. We tried to collate material handling issues described in theory to realities analysis. Interviews helped to figure out whether there are problematic situations in practice. The analysis contributed understanding of current situation, general difficulties and dissatisfaction of customers.

Arching and hanging issues can appear in every process, which involve solid material storage or transportation. The reason for these issues is properties of handled material.

For example interviewees mentioned that in Northern Savo regional power plants there are arching issues in fuel feeding process. The problems appear with solid biofuel in feeding chute in heating boiler system.

Besides when flowing from storage bins to tanks and from fuel feeding tank to burner, wooden chips mixed with peat sometimes stuck and form arches.

Figure 11 Savonlinna power plant (http://www.pohjolanvoima.fi/filebank/165-4065-Savonlinnan_voimalaitos.pdf)

The problem prevails particularly in winter time, when biofuel is stored outside and is subjected to freezing. To prevent freezing heating systems are installed.

Arcing and hanging issues are related in larger scale to wooden chips, pellets, biofuel, ash, cements.

For pellets it's typical that after long storage time they begin to crumble. The crumb absorbs the moisture easier. Wet crumb tends to stick to walls and to cohere. For this case some coating is used to make surface more slippery.

Ash when getting wet also can get stacked in pipes and channels and especially fly ash scrubbers might be also potential market for air cannon systems in Finland.

In flue gas channels sometimes scaling effect appears. The particles of fuels after combustion become light and can go through filters. On their way they scale to walls. The channel becomes smaller and the flow rate increases resulting higher dust emission. Usually this issue is solved by washing flue gas channels with water during maintenance breaks, or bigger flue gas fans are used.

Understanding the scale of consequences of problems can motivate potential customer for changes in case outcomes of problems are serious.

If design, operation and maintenance actions are not prepared to hanging and arching problems, it can lead to emergency shutoff of process. The staff of company will have to examine the reasons and manually solve hanging of material.

As a consequence there can be interruption of process. If fuel feeding is not even, it can cause extra emissions and complications. However, normally there are several silos with fuel. If one silo does not work, another must function. Of course it cannot solve the problem 100 %, but as temporary solution it works.

When the feeding chute is blocked, the fuel supply is interrupted and the boiler is powered down. Fuel material is changeable. If it is uniform and same quality all the time, the risk of ratholing and arching effect is minimized. But rare power plants are working on homogenous fuel.

Normally arching and hanging problems are handled during planned maintenance periods. Problematic points normally have portals, which help cleaning.

As a result of process interruption there are production losses with financial consequences, allocation of resources.

5.3 Typical solution for material handling issues

The interviewed experts adduced that the most typical solution for preventing ratholing and arching effects is changing geometry of bunkers. However, it is quite an expensive solution that requires time and is not always effective. Normally recognition of arching effect happens when silos and bunkers have already been installed and processes are launched. In this situation silos can be changed only during maintenance break. Meanwhile time arching issues are disturbing processes.

Other solution is mechanical vibrators. It is suitable only for certain type of bunkers. They are typically massive, mechanically demanding, expensive and not easy to install. Post-installation is difficult as well.

Pneumatic systems similar to Ista's production are also used for solving material handling issues, but they differ in valve actuation time. Besides simple pneumatic air injection has been tested in some cases for the material feeding problems. The difference in technology of Ista's shock wave generator described in chapter 3.2 gives certain benefits compared to competitors.

For preventing freezing of wood chips in winter time heating systems are installed in fuel storages. Another solution is coatings, which make surface smoother, although don't solve the core of the problem, the flow behaviour.

Also very important aspect in preventing material handling processes is proper material selection. The higher quality of fuel is, the fewer problems in handling appear.

5.4 Benefits and challenges of air cannons

This part helps to formulate benefits of Ista's technology and products in problematic issues and to understand if there are benefits in new shock wave generator and air cannon technology from detached point of expert view. Analysing of interviews helped to discover possible weaknesses and strengths of a product.

The interviewed experts mentioned following benefits:

- Usage of compressed air. In explosive environment the electric device cannot be used, so air impact system can be helpful.
- Easy to install.
- Post-installation possible
- Comparatively low cost
- Simplicity of usage
- Doesn't require much space
- Vibrators can make material stuck even more, while air-cannons give impulses and unstuck material.

Challenges:

- Air impact to the process can lead to some problematic issues. In closed bunkers there shouldn't be any additional air, so it would be necessary to install filters if using air-cannons.
- Certification for EU is obligatory.
- According to experts who work with biofuel effectiveness for wet wood chips are not evident. Especially in moisture condition wood chips have very special structure. The particles get through each other and make arcs, which are difficult to break. SPE "ISTA" doesn't have references so far. It would be more convincing if there were an experiment done on tanks with chips.

- Some interviewees questioned the financial benefit of installing air-cannons compared to electric vibrators and other solutions.
- Vibrator influences surfaces, but air-cannon influences material.

5.5 Potential applications for Ista products

The aim of this part is to describe possible targets of implementing Ista technology and t figure out potential interest in changes and objective in using new solutions for existing problems.

5.5.1 Energy field

Shock wave air cannons are suitable for solving arching and hanging issues in Energy field. There are two possible lines in marketing. Post-installation to existing problematic objects can be offered to power plants, pulp mills, lime kilns etc. Supply of air-cannons as additional options to bunkers and other equipment can be offered to workshop.

Figure 12 The tank in workshop. Possible application for Ista-aircannon

“ISTA” is making at the moment research for application on economizers. But according to interviews at modern plants in economizers nowadays pure water is used, so there is no stagnation on the surfaces. But in cases where industrial water is used soiling can appear.

Economizers are normally used to increase the energy efficiency of boiler. They recycle energy produced in main circle and if they are soiled the efficiency decreases. The sooting depends also on fuel quality. The higher quality is the less soot blowing is needed. Besides, experts mentioned that biofuel causes fewer problems in economizers, than for example charcoal.

Figure 13 Economizer
(http://www.saacke.de/images/land/products/components/econonmiser.jpg)

5.5.2 Lime kilns and other possible applications

Besides energy field in interview some other interesting application for ISTA air cannons came up.

In lime kilns, where coal is used for heating there are also issues with fuel feeding. The coal flows from fuel storage to the burner through crusher. The crusher hopper is a weak point in fuel feeding process. After being crushed coal from mass, which tends to form archs. The optimal flow of crushed coal can be achieved by right calculated feeding chute angle. But sometimes problematic effects still appear.

The pressure air devise, analogue to ISTA air cannon is at the moment used for solving arching issue. But current solution has some disadvantages. It is quite noisy, which makes working environment uncomfortable. Also valve of installed air cannon has high

opening time, so receiver is discharged slowly. Air impact in this case is not effective as impulse is weak. As a conclusion in addition to bio boilers also the energy industry using fossil charcoal might be potential customer segment for the shockwave generator and effective air cannon systems in Finland and at least one potential application has been characterized in this study. The number of lime kilns in Finland is about 15 and material ringing problems in limekilns are also interesting application for the effective air cannon systems.

Figure 14 Coal feeding chute. Nordkalk Oy.

Other possible target in lime kilns could be silo, from which limestone is discharged.

Figure 15 Air-cannon in limestone discharge silo.

After being burned limestone is delivered to the silo. The silo is typically cylindrical with geometry of tapering down part. This part is the most critical point in silos of similar geometry. The limestone sticks to the silo's walls and forms ratholes. The consequence of this condition is that limestone is not discharged to the tracks completely and so called "eternal" storage appears, because the hanged limestone can never be used, until it collapses. Slow wave air cannons cannot be used in this situation, because the silo contains a lot of dust, and the valve becomes rapidly soiled and cannot function. Also limestone silos are normally large scaled and would need large amount of air cannons to be effective. In this case ISTA-4 system could be applicable.

6 CONCLUSION

The market analysis detected that a large number of Finnish heat and power plants work in biofuels. Due to the fact that such biofuels as wooden chips and pellets have tendency to cause arching and ratholing effects, they can be an object of ISTA technology application. Interviewees also confirmed that there could be an interest in using ISTA production in Finland, because material handling problems occur and new ones will probably appear in future. Therefore if problems exist, the demand for finding solutions should appear.

The results of analysis of the experts' interviews discovered the potential applications for shock wave generators in Finnish industries. The majority of interviewed engineers expressed interest in using equipment in fuel storages, bunkers, bins and fuel feeding chutes. Moreover, they mentioned the possibility to apply the technology in fly ash silos and scrubbers, flue gas channels. In order to expand the market share air-cannons "ISTA" can be used not only in bioenergy field, but also in lime kilns and industries working with fossil charcoal.

Finnish companies could be ready for collaboration in case SPE "ISTA" would overcome main challenges of entering the market. The biggest stumbling stone for coming to international market is EU certification. The production has recognition of GOST certificate in Russia, but there are different requirements for certification in Europe Union. Without proper certificates equipment cannot be delivered and applied in the area of European Union.

The fact that there are no references of using technology in bioenergy field can slow down the process of getting new customers. Next step could be a pilot project on some wood chip silo. Also within this thesis research some interesting pilot project options in lime kiln and charcoal feeding applications were discussed with the potential air cannon customers. As marketing activities it could be suggested visits directly to enterprises of potential customers with presentations of technology and products.

After SPE "ISTA" overcomes challenges, it can probably succeed in the Finnish market due to benefits of its products. Thus equipment is simple to operate and maintain. It is also easy to install and post-installation is possible. Shock wave generators use compressed air. That makes possible installation in explosive environment, where electric devices cannot be used.

This thesis concentrated on the cases and interviews with specialists in bioenergy field. So the exact numbers for the shock wave generators and air cannon systems markets are not easy to calculate within this study. However the number of bioboilers, limekilns and other possible market segments for the technology evaluated in the thesis are quite big.

The interviewed specialists were familiar with the air cannon technology and depicted that material handling problems almost in every interviewed case. As a conclusion it can be noted that the pilot projects and the search for the delivery partner or own marketing representative for Ista Pneumatics could be the next business step in Finland.

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Appendix 1

QUESTIONNAIRE

Are there arching and hanging problems in fuel feeding systems, heat exchangers and other processes? For what kind of materials these issues are most common?

How critical are these problems? What are the consequences of them?

What are the common solutions for hanging and arching issues?

Doyou find the use and applications of air cannons in the field of energy production possible?

What could be benefits and challenges of air cannons compared to other solutions of hanging and arching issues?

Appendix 2

LIST OF INTERVIEWEES

For overall overview of energy market in Finland.

Jussi Heinimö, Miktech

Power plant experts:

Mika Laine, power plant director, Järvi-Suomen Voima Oy, Savonlinnan CHP-voimalaitos

Esko Hilttunen, Savon Voima, Pieksämäen voimalaitoksen käytön esimies.

Yrjö Hilttunen, Mikkeli UAS

Engineering and construction experts

Jukka Raninen, Valmet

Seppo Rasimus Saimatec Oy,

Jari Kapanen, Andritz Oy

Risto Saavalainen, Nordkalk Oy

Appendix 3

ISTA-PNEUMATIC REFERENCES OF AIR-CANNON “ISTA-3” APPLICATIONS

Food industry: JSC "Karavai", JSC "Nevskaya Melnitsa" (St.Petersburg), JSC "Rot-Front", JSC "AGRO-3", MPZ "KAMPOMOS", JSC "Agroprominzhiniring" (Moscow), UK "Sibirsky Bereg" (Novosibirsk), JSC "SUN Interbrew", JSC "Tekhnik" (Kiev).

Enterprises of building system including: JSC "Metrobeton", JSC "Keramika", JSC "Skanmix", JSC "Objedineniye 45", JSC "Petromix", JSC "Kraski TEKS", FGUP "211 KZhBI", JSC "House-Building Industrial Complex No.5" (St.Petersburg), JSC "345 Mechanical Plant", JSC "198 KZhBI", JSC "CENTER" (Moscow), JSC "Samara Gypsum Industrial Complex", JSC "Kvant" (Nizhni Novgorod), JSC "Volgograd Gypsum Industrial Complex", JSC "Iskitimtcement" (Novosibirsk), JSC "Salavatsteklo".

Enterprises of other industries including: JSC "B.P.Konstantinov Kirovo-Chepetsky Chemical Industrial Complex", JSC "Caustic", JSC "Kuibyshevazot", JSC "Phosphorite" (JSC "EVROKhIM"), Severstal Group, JSC "Arkhangelsk Pulp and Paper Mill", JSC “Solombala Pulp and Paper Mill", JSC "ERA-HENKEL", JSC "SUAL", JSC "ROSTERMINALUGOL", JSC "Baltic Bulker Terminal", JSC Russian Railways, branch "Novosibirsk Switch Plant".


SAVONIA