COMPARISON BETWEEN RUSSIAN AND EUROPEAN MECHANICAL STANDARDS FOR REACTOR PRESSURE VESSELS

Valeriia Kiseleva

Bachelor Degree thesis

Materials Processing Technology programme, Engineering

2020

DEGREE THESIS	
Arcada University of Applied Sciences	
Degree Programme:	Materials Processing Technology
Identification number:	20199
Author:	Valeriia Kiseleva
Title:	Mechanical standard comparison between Russian and European standards for Reactor Pressure Vessel
Supervisor (Arcada):	Silas Gebrehiwot
Commissioned by:	Anne Vilkman

Abstract:

In this thesis work it is conducted a comparative analysis for Russian standards for reactor steel mentioned in Russian regulations for design of the Nuclear Power Plant. For comparative analysis there is considered the most essential differences, for which detailed explanation is required. However, all minor differences or the same statements are provided in attachments. The key aspects for comparative analysis are methods of tests and approaches. After comparative analysis there is provided a conclusion, if the Russian regulations can be applied in Europe.

This thesis work focused on identification of European standards for Russian standards regarding Reactor Pressure Vessel mentioned in the Russian regulations. This thesis work contains the process of identification of the European standards to Russian standards based on the content of the standards.

An additional, there is provided the detailed information of standards selection process. There are chosen the standards used for comparative analysis. Most of the standards chosen for comparative analysis related to the mechanical properties of material. The results of this thesis work will be used in the case company for evaluating the acceptability of usage of Russian standards.

Keywords:	Russian standards, European standards, Russian regulations, mechanical standards, reactor pressure vessel, reactor steel, comparative analysis
Number of pages:	28
Language:	English
Date of acceptance:	17.09.2020

CONTENTS

Figures

List of abbriviations

ASME	American Society of Mechanical Engineers
EN	European
LUT	Lappeenranta-Lahti University of Technology
NP	Russian standards and rules
NPP	Nuclear Power Plant
PED	Pressure Equipment Directive
PNAE	Russian rules and standards in Nuclear Power field
RPV	Reactor Pressure Vessel
RU	Russian
SFS	Finnish Standards Association
STUK	The Radiation and Nuclear Safety Authority
TU	Technical conditions
UAS	University of applied siences
USSR	Union of Soviet Socialist Republics
VVER	Water-water power reactor
YVL	Regulatory Guides on nuclear safety

1 INTRODUCTION

1.1 Background

One of the most important advantage of the nuclear industry is its inexhaustible supply. Once oil, coal, natural gas and other minerals can dry out, what is going to happen? Energy is one of aspect why this world exists, because we use it at home, on our work and studying on daily basis. Especially, in this case nuclear power is like a perpetual motion machine.

The advantage of nuclear energy is that it requires significantly smaller amounts of fuel and building spot per megawatt of generated energy than traditional plants. For this reason, the Finnish government has decided to construct a new nuclear power plant in Pyhäjoki with collaboration of Russian experts in this sphere. However, Russian Federation, Europe and Finland use different requirements and standards during whole designing process. In order to avoid misunderstanding and keep its safety huge number of experts have to compare all standards, differences and come up with mutual solution.

Standards are the documents, which include requirements, guidelines, specifications or characteristics, which will be used consistently in order to ensure that products, process and services are fit for their purposes. (ISO, 2020)

The need for electricity in Finland is growing, and it is important to focus on creating efficient and environmentally friendly solution. The aim of this thesis is to study new cases and to help to the case company to succeed the project.

1.2 Objectives

This thesis project has four aims, which are related to Russian and European standards comparison for design of Nuclear Power Plant. All countries have a large number of the standards and it is not possible compare all of them. For this reason, the work for this thesis project was limited by these aims:

1. Identification EN standards for Russian standards (GOST) related to reactor pressure vessels listed in the Russian regulations (PNAE), which have the same content and topics;
2. To identify Russian standards (GOST) related to the reactor steel, which are listed in the Russian regulations (PNAE);
3. To compare Russian standards (GOST) related to the reactor steel, which are listed in Russian regulations (PNAE) with EN standards. The aim is to recognize the differences between Russian (GOST) and European (EN) standards for reactor steel;
4. To conclude if Russian regulations regarding the reactor steel can be applied for design in European projects.

For the first aim requires to read and analyse all standards content. In order to select all standards related to the reactor pressure vessel it is considered types of the steel used for reactor steel and for welding. Russian and European standards have different content and information. For this reason, in some cases for Russian standards can be found several corresponding European standards. However, some standards can have exactly the same content, it can make easier process of identification of European standards. For the second aim, in order to identify the standards related to reactor steel, it is used the type of the steel used for the reactor. All Russian standards regarding the reactor steel are selected. In additional, Russian technical specifications are used as supporting material. Russian technical specifications contain the numbers of the Russian standards used for the reactor steel. The third aim connected with second one. Comparative analysis is conducted for all Russian standards related to the reactor steel. Each position and statement of the Russian standards are compared with European one. All differences are divided for categories and some differences are considered detailly. The fourth aim is to make conclusion based on comparative analysis. The conclusion contains information about applicability of the Russian regulations in Europe.

Based on these aims it is possible to formulate two research questions:

- What are the differences between Russian and European standards related to the reactor steel?
- Can the Russian regulations related to the reactor steel be applied for the design

of Nuclear Power Plant in Europe?

Russian Federation has a big list of regulations for Nuclear Power Plant design. For this reason, the work for this thesis project was limited. These regulations were chosen based on the company needs. This is the list of the Russian regulations, which will be used for project:

- Regulations for strength analysis of equipment and pipelines of atomic power plants (PNAE G-7-002-86);
- Regulations for design and safe operation of the atomic power plant equipment and pipelines (PNAE G-7-008-89);
- Equipment and pipelines of nuclear power plants, welding and weld surfacing guidelines (PNAE G-7-009-89);
- Equipment and pipelines of nuclear power plants, weld seams and claddings (PNAE G-7-010-89);
- Unified method of testing of basic materials (semi-finished items) welded joints, surfacing of equipment and pipe-lines of nuclear power plants (NPP) (PNAE G-7-015-89);
- Unified method of testing of basic materials (semi-finished items), welded joints and weld seams of equipment and pipe-lines of the nuclear power plants (NPP) (PNAE G-7-030-91);
- Unified method of testing of basic materials (semi-finished items), welded joints and deposits of equipment and pipe-lines of atomic power plants (PNAE G-7-017-89);
- Unified procedures of testing of basic materials (half-finished products), welds and overlays of Nuclear Power unit equipment and pipe-lines (PNAE G-7-016-89/PNAE G-7-016-89);
- Unified inspection procedures for basic materials (semi-finished products), welded joints and weld deposition of equipment and piping of Nuclear Power Plants (NPP) (PNAE G-7-031-91);
- Unified procedures of testing of basic materials (semi-finished items), welded joints and surfacing of equipment and pipe-lines of nuclear power plants (NPP) (PNAE G-7-014-89);

- Certification rules for welding of equipment and piping of Nuclear Power Installations (PNAE G-7-003-87).

In addition, American standards (ASME) are used in controversial situations. For example, when Russian and European standards have a significant difference. It should help to manage controversial situations, because it is an advantage to consider the experience of another country.

Nuclear plant design and construction is complex procedure, which involves a lot of suppliers from different countries and as a result there is variability of standards for each stage of the project. In this thesis work will be used methodology based on comparative analysis of Russian national standards in Reactor Pressure Vessel design and EN standards in this area. As well it is considered the further evaluation of applicability for Nuclear Power Plant design in Finland in compliancy report format.

2 LITERATURE REVIEW

2.1 Reactor Pressure Vessel

The reactor pressure vessel is the pressure vessel containing the reactor core and other key reactor internals. Most of commercial power reactors are light water reactors (PWRs and BWRs), which are cooled and moderated by high-pressure liquid water (e.g. 16 MPa in case of PWRs) and therefore the reactor vessel must withstand high pressures. It is a cylindrical vessel with a hemispherical bottom head and a flanged and gasketed upper head. The bottom head is welded to the cylindrical shell while the top head is bolted to the cylindrical shell via the flanges. The top head is removable to allow for the refueling of the reactor during planned outages. (Gidropress, 2020)

The scheme of the Nuclear reactor is introduced on the picture below (Figure 1).In case-type power reactors water power reactor (VVER) in as a neutron moderator and coolant ordinary water is used (heterogeneous reactor). The reactor core is located in one building, where a steady flow of water passes through the primary circuit. The nuclear reactor and its circuit are used as heat sinks. In the primary circuit water pressure is 16,2 MPa at 328,9 degrees (C). Nuclear reactor and its circuits can be considered as a steam generator. The heat from the primary circuit is transferred to the second circuit through the pipe walls. This heat turns the second circuit water to steam. The steam pressure is usually 6 MPa when it arrives to the turbine. Primary circuit, reactor completely isolated from the second, which reduces radioactive emissions into the atmosphere. Circulating pumps ensure steady flow of water to the nuclear reactor and its circuits.(the circulation pumps are powered by turbines). The water in the reactor loop is under high pressure, so despite its high temperature (328.9 degrees at the outlet, 298.2 degrees at the inlet of the reactor) it does not boil. (ROSATOM Overseas, 2020)

In the heat exchanger-steam generator, the coolant circulating in the first circuit, gives off heat to the water of the second circuit. The generated steam is led to the turbines, where part of its energy is released for rotating the turbine. Afterwards, the steam is led to condenser. Capacitor, cooled by the water of the circulation circuit, provides collection and condensation of exhaust steam. Condensate, having passed the system of heaters, is fed back to the heat exchanger. In the case of a boiling reactor, the core is located in a high-strength, thick-walled steel tank. The reactor consists of a housing with a cover and gaskets. elements; baskets in which fuel assemblies with fuel elements; heat shield; system organs management; thermal and biological protection. The reactor vessel is one of the critical structural elements and must ensure absolute reliability and complete tightness both under normal operating conditions and in case of possible emergency situations. The casing is completely filled with high pressure water. The cover is sealed in the housing using a nickel or copper gasket, which fastened with nuts or studs screwed into the housing. In the reactor vessel, thermal screens surrounding is considered as the core. They are made of stainless steel in the form of coaxial cylinders that form annular gaps. The coolant passing through the gaps cools the housing reactor and reflects neutrons. Water is supplied to the reactor from below under pressure. The top of the reactor is a closed steel lid that seals its body and is biosecure. Overheating of the fuel in case of dehydration is prevented by core mounted system, which allows aqueous solution of boric acid to be filled to the active zone. This prevention shuts down the reactor fission chain reaction completely. (ROSATOM Overseas, 2020)

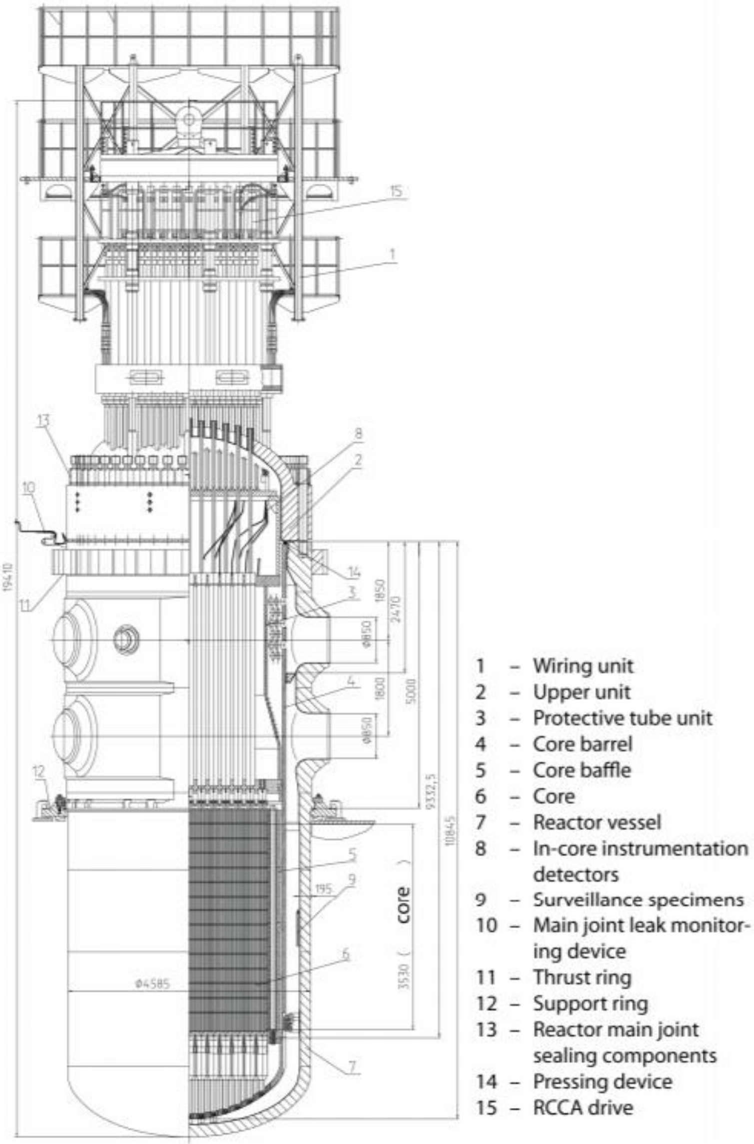

Figure 1.Scheme and parts of Reactor Pressure Vessel VVER-1200 (Status report 108 - VVER-1200 (V-491) (VVER-1200 (V-491)) from Gidropress (Anon.2011)

The pressurized water type reactors are widely developed in Russia. The low cost of the coolant-moderator used in them and the relative operational safety, despite the need to use enriched in these reactors' uranium. The VVER-1000 reactor is the second generation of high-power light-water reactors. The electric power of the power units is 1000 MW. Nuclear reactors of this type are installed on Kola, Kalinin, Balaklava NPPs (Russia), Zaporizhzhya, Rivne, Khmelnitsky, South Ukrainian NPPs (Ukraine), also at NPPs in Bulgaria, Czech Republic, Finland. (ROSATOM Overseas, 2020)

2.2 Definition of standards

Indeed, standardization ensures the safety of services, products, work for our lives, property and the environment, the compatibility and interchangeability of products. Moreover, standards are responsible for the quality of services, consistent with the level of development of the field of activity, and it also helps to save resources.

Standardization is a framework of agreements to which all relevant parties in an industry or organization must adhere to ensure that all processes associated with the creation of a good or performance of a service are performed within set guidelines. This ensures that the end product has consistent quality and that any conclusions made are comparable with all other equivalent items in the same class. (Grant, 2019)

The aims of standardization:

- improving the safety of life and health citizens property;
- to protect individuals and legal entities, state and municipal property, safety of life and health animals and plants;
- competitiveness;
- quality of products (works, services);
- unity of measurements;
- saving and rational use of resources;
- interchangeability of technical means;
- technical and informational compatibility;
- assistance in compliance with technical regulations;
- stimulation of scientific and technological progress.

Standardization is a key factor in supporting state socio-economic policy, contributes to the development of fair competition, innovation, lowering technical barriers to trade, improving the safety of life, health and property of citizens, ensures the protection of consumer interests, the environment and the saving of all types of resources. (ISO, 2020)

2.3 Russian national regulations (PNAE)

Russian regulations for nuclear power plant PNAE establish the basic requirements for the design, construction, manufacture, installation, operation and repair of equipment and pipelines, nuclear power plants for industrial heat supply and installations with research or experimental reactors.

The rules are created on:

- the basis of the current rules for the design and safe operation of equipment of nuclear power plants;
- experimental and research nuclear reactors and installations;
- taking into account the accumulated domestic and foreign experience in the creation and operation of nuclear power plants;
- as well as proposals and comments from interested ministries, departments, organizations and enterprises.

Changes to these Rules are made in accordance with the regulation of the USSR Gosatomenergonadzor on the procedure for developing regulatory and technical documentation in the field of nuclear energy. The rules are binding on all ministries, departments, organizations and enterprises designing, constructing, manufacturing, installing, operating nuclear power plants controlled by the USSR Gosatomnadzor.
(Gosatomenergonadzor of the USSR, 1990)

The list of the standards is used for this thesis work in objective part (Chapter 1.2) of this project. These rules are applied to vessels:

- functioning under pressure (including hydrostatic pressure) and in vacuum (including reactor vessels, their safety casings and shells, steam generators and heat exchanges);
- pump cases and accessories and system's pipelines of NPP with water-moderated water-cooled and graphite-moderated water-cooled reactors;
- fast breeder reactors with liquid metal coolant and installations with research and pilot reactors of the mentioned types (hereinafter vessels, pump cases and fittings

are named as equipment and all mentioned NP are named as nuclear power installations). (Gosatomenergonadzor of the USSR, 1990)

2.4 American national standards (ASME)

ASME helps the global engineering community develop solutions to real world challenges. Founded in 1880 as the American Society of Mechanical Engineers, ASME is a not-for-profit professional organization that enables collaboration, knowledge sharing and skill development across all engineering disciplines, while promoting the vital role of the engineer in society. ASME codes and standards, publications, conferences, continuing education and professional development programs provide a foundation for advancing technical knowledge and a safer world. (The American Society of Mechanical Engineers, 2020)

The American society of mechanical engineers specialized technical literature (books, magazines), holds more than 30 international conferences and organizes about 200 professional courses annually. ASME has released some 600 standards, which are recognized and used in more than 113 countries. Today, ASME is the world's largest organization for the publication and dissemination of engineering and technological standards. The most famous standards of the Society of Mechanical Engineers are the standards for boilers and pressure vessels - ASME BPVC. These standards are updated every two years.

The activities of the Society of Mechanical Engineers cover many industrial sectors:

- nuclear - standards for cranes;
- design drawings - standards for dimensions and tolerances, letter and symbolic designations, drawings with several sections and illustrations, drawings of forgings, springs;
- equipment - standards for screw threads, valves, flanges, gaskets;
- hydraulics - standards for the characteristics of horizontal end and centrifugal, linear vertical pumps with end suction without seals;
- oil industry - standards for pressure vessels, pipe threads, valves, flanges, fittings, serviceability;

- plumbing systems - standards for sewage systems, water metering systems, gutter roofing systems;
- safety - safety standards for elevator equipment, escalators, forklifts, conveyors, etc.

2.5 European standards and SFS

The Finnish Standards Association SFS is the central standardization organization that controls and co-ordinates national standardization work in Finland. SFS members include professional, commercial and industrial organizations as well as the state of Finland. SFS develops, approves and publishes national SFS standards. It also sells standards and communicates information about the standards and standardization to the public. In addition, SFS operates the national Enquiry Point. SFS is a member of the International Organization for Standardization (ISO) and the European Committee for Standardization (CEN). The majority of SFS standards are based on international or European standards. SFS prepares standards together with its 11 affiliates called ‘standards writing bodies’. Founded in 1924, the central organization of SFS currently employs some 50 people. (Finnish Standard Association, 2020)

The development of the standard begins with the establishment of its needs and relevance, after which the idea is discussed by experts and a draft of the future standard is created. The next stage is voting, along with the opinions of respondents. The decision to recognize the standard is made on a consensual basis. Otherwise, the draft is returned for revision to the technical committee and is being edited before a new vote. Commission meetings are most often held online. It takes 3 years for an idea to acquire the status of an established specification.

According the ISO the principles of developing standards for ISO include:

- compliance with market needs;
- globalization of opinion;
- the participation of experts from various fields of application of the developed standards;
- general voting system adopted.

ISO is considered to be one of the first associations that is vested with deliberative right in the UN Council. Community-created specifications are used in 164 countries. All members of the International Organization for Standardization are divided into 3 groups:

- countries with national standardization bodies. Their representatives participate in the voting and adoption of specifications;
- countries where there are no standards organizations. They receive all relevant information about the specifications, but do not participate in their establishment;
- observer countries - they can only track changes in standardization with a minimum membership fee, as they are countries with underdeveloped economies.

2.6 Regulatory Guides on nuclear safety (YVL)

According to the views on the Finnish nuclear regulatory guides (Wahlström, 2011) the most practical applications, the YVL-guides (regulatory guides on nuclear safety) form the actual regulatory system. A total of 68 YVL-guides are in force. The guides are grouped under the following subdivisions:

- General Guides, YVL 1.0 ... YVL 1.16,
- Systems, YVL 2.1 ... YVL 2.8,
- Pressure Vessels, YVL 3.0 ... YVL 3.9,
- Buildings and Structures, YVL 4.1 ... YVL 4.3,
- Other Structures and Components, YVL 5.1 ... YVL 5.8,
- Nuclear Materials, YVL 6.1 ... YVL 6.21,
- Radiation Protection, YVL 7.1 ... YVL 7.18,
- Radioactive Waste Management, YVL 8.1 ... YVL 8.4.

The YVL-guides are, as the name actually indicates, not legally binding but advising rules for the license holder. The regulatory system allows deviations from the requirements of the YVL-guides, if the license holder presents an acceptable solution by which the safety level given in the YVL-guides is attained. This possibility puts some demands on the content of the YVL-guides. In addition to giving one acceptable procedure or solution, a practical guide should also clearly state the safety target, against which alternative solutions can be judged. (Wahlström, 2011)

The YVL-guides as such apply to new nuclear facilities. Upon revision of an old guide when a new guide is issued, the license holder sends to the radiation and nuclear safety authority (STUK) a statement, how the requirements of the new guide are to be applied on the installation. STUK makes then a separate decision of the application to these installations. It should also be pointed out, that the publication of a YVL guide does not necessarily alter any decisions by STUK made prior the publication. STUK also issues another set of guides, the ST-guides. The ST-guides mainly apply to non-energy applications of nuclear or radiation technologies. These guides were only mentioned very briefly during this survey. The nuclear law and decrees give STUK the mandate to set and supervise the safety requirements of the nuclear installations. In Finland this is done through the regulatory system and not in individual plant licensing conditions. In addition, STUK can issue letters to the license holder, if a plant inspection or some other cause reveals findings that require corrective actions. Letters may also list new requirements or other actions that the license holder must conduct within a specified time. (Wahlström, 2011)

For this thesis work are used YVL_E.3 (pressure vessels and piping of a nuclear facility), YVL_E.8 (valves of nuclear facility) and YVL_E.9 (pumps of nuclear facility), they are related to Mechanical standards for Reactor Pressure Vessel. These YVL guides help to navigate, the references of these guides help to keep shorter the information searching time. The reading of the YVL guides can help to understand the EN standards and YVL guide contains the list of references with EN standards, which can be used for comparison.

2.7 Previous researches of Mechanical standards comparation

It is important to consider the previous researches regarding standards comparison. It can give some fresh ideas and thoughts. For this reason in this thesis work two different works regarding nuclear field are considered.

2.7.1 Comparison of EN and ASME welding and its allied processes standards

In the Lappeenranta University of Technology was done research for comparison of EN and ASME welding and its allied processes standards by Juho Syrjänen in 2016. The thesis was made in cooperation with Wärtsilä and Sandvik. The main purpose of the thesis is to clarify the best suitable American standards for European standards used in Wärtsilä's investigation checklist and to make wide and easily readable tables for Wärtsilä and their subcontractors. One of the most important issues is to make clear if the compared American standards are demanding enough for Wärtsilä's needs. The research is done by comparing EN standards mentioned in Wärtsilä's investigation checklist to corresponding American standards (ASME). The research shows that there is visible lack of requirements in American standards compared to European ones. Some areas of American standards are more demanding than European standards but in larger scale EN standards are much wider and more demanding than American standards. Because of these reasons, usage of European standards should be recommended for Wärtsilä's subcontractors to ensure the quality and reliability of production. (Syrjänen, 2016)

In the thesis work from LUT university it is possible to see all differences between EN and ASME standards for welding and its allied processes. The research was made very clear and detailed. It will contribute for this thesis (Mechanical standard comparison between Russian and European standards for Reactor Pressure Vessel) in process of comparation, when ASME standards are used in unclear situations. Moreover, the thesis work from LUT university can be a good example for initial data preparation.

2.7.2 Comparison of ASME and European specifications for mechanical testing of steels for pressure equipment

A study was conducted under the ASME Standards Technology to compare ASME and European specifications for mechanical testing of steels for pressure equipment. The study has concluded that there are no technical differences between the two systems, the ASTM/ASME requirements and the EN requirements for material testing. The systems are slightly different, but, when used in conjunction with their respective construction codes, the European Pressure Equipment Directive (PED) and the ASME Boiler & Pressure Vessel Codes, they assure the production of safe pressure equipment. There are three significant differences worthy of separate note. These are the EN requirement for elevated temperature proof testing, the EN requirement for a minimum absorbed energy impact test value for all pressure equipment materials, and the ASME requirement for lateral expansion values for some materials and some equipment to be reported from impact tests, in addition to the absorbed energy. (Upitis & Gold, 2005)

This previous research of comparison of ASME and European specifications for mechanical testing of steels for pressure equipment will be a supporting material for this thesis. This research will be helpful for all PNAE mechanical standards (listed above in the objectives part), when are used ASME standards in unclear situations. In this previous research everything was divided in the parts: test parameter, name of EN standard, name of ASME standard, area of differences and net effect. The similar structure will be used in this thesis work, because it helps to order all information.

DISCUSSION

In order to design nuclear power plant, it is required to follow different standards and regulations. If Nuclear Power Plant is constructed in Finland, it means that the Plant supplier has to consider European standards. However, sometimes the equipment and components are supplied from another countries. It means that this equipment meets standards of another country. In this case, the question appears: are the supplier’s country standards corresponded to the Buyer’s country standards? For this reason, it is essential to consider the standards and requirements for equipment and components. The main idea is to identify contradictions and to define applicability for construction of Nuclear Power Plant. Technical knowledge allows to determine it, stricter requirements can provide better quality of supplied equipment and components.

In this thesis work it is considered European and Russian standards for the reactor steel. Identification of contradictions in this thesis work is complicated by incorrect translation of Russian standards in some cases. For this reason, the opportunity to read the Russian standards in original language is an advantage. Moreover, it is noticed that European and Russian standards have a different structure. After conduction of comparative analysis, it is as well complicated the work. It is possible to see the advantages of application of Russian standards and regulations for the reactor steel in Europe.

CONCLUSION

Increasing of the safety level is a key aim of the most industry. In order to achieve a certain level of safety, it is necessary to increase the quality of the equipment and components. For this reason, during the construction and design of Nuclear Power Plant all companies have to follow some standards and regulations. However, each country follows to standards of its country. In case if some equipment and components are supplied from another country, the standards have to be checked for any contradictions and differences. If the company does not do this process, it can lead to the catastrophic consequences. Moreover, checking standards in timely manner saves company´s budget. If some component is not made according to standard, new funds will be spent to produce a new component.

The first aim of this thesis work was to identify European standards for Russian standards related to reactor pressure vessel listed in the Russian regulations. All the Russian standards were written down from the Russian regulations PNAEs. The next step was to find the names of all standards, because PNAEs documents contain only the numbers of the Russian standards without any details. Based on the content and scope of the standards, it was chosen only standards related to the reactor pressure vessel. For all standards related to the reactor pressure vessel were identified European standards as well based on the content and scope of the standards. In some cases, one Russian standard could have several corresponding European standards. As well the work was complicated, because of limited access to European standards.

The second aim was to identify Russian standards related to the reactor steel, which are listed in PNAEs. In order to identify the standards related to the reactor steel, it was used Russian technical specifications, because they contain the information regarding the types of steel are used in design of the reactor for Nuclear Power Plant. In these specifications are mentioned the Russian standards responsible for the quality and the testing of the reactor steel. For the future comparison it was chosen the standards mentioned in Russian regulations and Technical Specifications at the same time.

The third aim was to conduct the comparative analysis of the Russian standards related to the reactor steel listed in Russian regulations with European standards. The aim was to recognize a difference between Russian and European standards for the reactor steel. Each position/rule/statement in each standard was compared and divided for different categories: “the same statement”, “the minor difference”, “Russian standard is stricter”, “European standard is stricter” and “significant difference”. For this reason, in “significant difference” cases American standards were considered in order to identify, which standard has advantage in some special case. The most important differences were pointed out, which require detailed explanation. Other differences as well marked in Appendix part. During whole work American standards were considered twice. In both cases, based on information extracted from American standards, the significant differences were attributed to European standards. American standards use the similar methods and methodology. During the work, it was not identified any critical differences or contradictions. In the most of the cases it was found minor differences or stricter requirements/recommendation. During the work there were identified: 57 the same statements, 22 minor differences, 22 cases when RU standards are stricter and 10 cases when EN standards are stricter. It is possible to conclude, that Russian standards can be applied in the Europe, but under control of experts in the Nuclear field and clarification of some unclear moments regarding strictness of the standards.

The last aim was to conduct a short analysis based on comparative analysis of the Russian and European standards, if the Russian Regulations regarding the reactor steel can be applied in Europe. In order to clarify this moment, it was made a table contained all the number of differences and stricter requirements regarding the Russian regulations PNAEs. It was identified that only PNAE G-7-002-86 and PNAE G-7-010-89 contain the Russian standards regarding the reactor steel. It is possible to conclude that PNAE G-7-002-86 can be used in Europe, because this Regulation contains the standards with a big number of the exactly the same requirements and a big number of the stricter requirements. This Regulation has a significant advantage, because stricter requirements for the equipment and components can allow to receive the products with a high quality. However, PNAE G-7-010-89 has a bigger number of the minor differences. It is possible to conclude that this Regulation can be applied, but with strict control of the experts in the Nuclear field.

In the end of this thesis work it could be given some recommendations for action in relation to the problem investigated. Based on the findings of the research, what specific solutions are possible and what measures should be implemented:

- It is important to consider other standards regarding to reactor pressure vessel, such as welding and etc.;
- it would be a good advantage if the future research regarding the standard comparison will be conducted by the experts, who could read the Russian standards in original language. It was already mentioned that in some cases the translated standards have incorrect translation, this problem can confuse the reader;
- in process of design of Nuclear Power Plant, it would be better to pay more attention for differences of PNAE G-7-010-89 regarding to the reactor steel.

REFERENCES

Finnish Standard Association, 2020. *SFS.* [Online]
Available at: https://www.sfs.fi/en/sfs_in_brief
[Accessed April 2020].

Gidropress, 2020. *Nuclear Power.* [Online]
Available at: https://www.nuclear-power.net/nuclear-power-plant/nuclear-reactor/reactor-pressure-vessel/
[Accessed March 2020].

Gosatomenergonadzor of the USSR, 1990. *Rules for Arrangement and Safe Operation of Equipment and Piping of Nuclear Power.* [Online]
Available at: http://en.gosnadzor.ru/framework/nuclear/PNAE%20G-7-008-89.pdf
[Accessed May 2020].

Grant, M., 2019. *Investopedia.* [Online]
Available at: https://www.investopedia.com/terms/s/standardization.asp
[Accessed 14 May 2019].

Head of 8th Directorate of GosAtomNadzor of Russia, 2003. *Technical Specification TU 08 93-013-00212179-2003.*.

ISO, 2020. *International Organization for Standardization.* [Online]
Available at: https://www.iso.org/standards.html
[Accessed April 2020].

International Organization for Standardization 2011, *ISO 6892-2:2011 Metallic materials — Tensile Testing-Part 2: Method of test at elevated temperature*

International Organization for Standardization 2016, *ISO-148 Metallic materials - Charpy pendulum impact test*

International Organization for Standardization 2016, *SFS-EN ISO-7438 Metallic materials-bend test*

International Organization for Standardization 2013, *ISO 4967 Steel — Determination of content of non-metallic inclusions — Micrographic method using standard diagrams*

International Organization for Standardization 2017, *SFS-EN ISO 377 Steel and steel products-Location and preparation of samples and test pieces for mechanical testing*

International Organization for Standardization 2019, *SFS-EN ISO 6892-1 Metallic Materials-Tensile Testing-Part 1: Method of test at room temperature*

International Organization for Standardization 1997, *ISO 11652 Steel and iron - Determination of cobalt content - Flame atomic absorption spectrometric method*

International Organization for Standardization 1986, *ISO 9556 Steel and iron – Determination of total carbon content – Infrared absorption method after combustion in an induction furnace*

International Organization for Standardization 2016, *ISO 4939 Steel — Determination of nickel — Dimethylglyoxime spectrophotometric method*

International Organization for Standardization 2004, *ISO 13899-1 Steel — Determination of Mo, Nb and W contents in alloyed steel — Inductively coupled plasma atomic emission spectrometric method — Part 1: Determination of Mo content*

International Organization for Standardization 1983, *ISO 7627-5 Hard metals — Chemical analysis by flame atomic absorption spectrometry — Part 5: Determination of cobalt, iron, manganese, molybdenum, nickel, titanium and vanadium in contents from 0,5 to 2 % (m/m)*

ROSATOM Overseas, 2020. *The VVER today.* [Online]
Available at:
https://www.rosatom.ru/upload/iblock/0be/0be1220af25741375138ecd1afb18743.pdf
[Accessed July 2020].

State committee for product quality control and standards of the USSR 1984, *GOST 9651 84-Metals. Methods of tension tests at elevated temperatures*

State committee for product quality control and standards of the USSR 1978, *GOST 9454-78 Method of impact bending test at low, indoor and high temperatures*

State committee for product quality control and standards of the Moscow 2003, *GOST 14019-2003 Metals. Methods of bend tests*

State committee for product quality control and standards of the USSR 1970, *GOST 1778-70 Steel. Methods of micrographic examination for determination of non-metallic inclusions*

State committee for product quality control and standards of the USSR 1984, *GOST 1497-84 Tension test*

State committee for product quality control and standards of the USSR 1978, *GOST 12353-78 Alloyed and high-alloyed steels. Methods of cobalt determination*

State committee for product quality control and standards of the Moscow 2003, *GOST 12344-2003 Alloyed and high-alloyed steels. Methods for determination of carbon*

State committee for product quality control and standards of the USSR 1981, *GOST 12352-81 Alloyed and high-alloyed steels. Methods of cobalt determination*

State committee for product quality control and standards of the USSR 1986, *GOST 12354-81 Steels alloyed and high-alloyed. Methods for the determination of molybdenum*

Syrjänen, J., 2016. *Comparison of En and ASME welding and its allied processes standards.* [Online]
Available at:
https://lutpub.lut.fi/bitstream/handle/10024/124418/Kandidaatinty%C3%B6_ENASME_JuhoSyrj%C3%A4nen.pdf?sequence=3&isAllowed=y
[Accessed Aprila 2020].

The American Society of Mechanical Engineers, 2020. *ASME setting the standard.* [Online]

Available at: https://www.asme.org/about-asme/asme-strategy
[Accessed 30 June 2020].

The American Society of Mechanical Engineers 2015, *E290-14 Standard test methods for bend testing of material for ductility*

The American Society of Mechanical Engineers 2011, *E1018 Standard test methods for determination of carbon, sulfur, nitrogen, and oxygen in steel, iron, nickel, and cobalt alloys by various combustion and fusion techniques*

Upitis, E. & Gold, M., 2005. *Comparison of ASME specifications and EN standards for Mechanical testing of steel for pressure equipment.* [Online]
Available at: http://www-eng.lbl.gov/~shuman/NEXT/MATERIALS&COMPONENTS/Pressure_vessels/US_vs_EU_material_strengths.pdf
[Accessed April 2020].

Wahlström, B., 2011. *STUK.* [Online]
Available at: https://bewas.fi/YVLreport_010619.pdf
[Accessed 30 June 2020].