Министерство образования и науки Российской Федерации
Федеральное государственное автономное образовательное учреждение
высшего образования
**«НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ»**

Институт Физико-технический
Направление подготовки 14.04.02 Ядерные физика и технологии
Кафедра Физико-энергетические установки

МАГИСТЕРСКАЯ ДИССЕРТАЦИЯ

Тема работы
Нейтронно-физические характеристики водо-водяных энергетических реакторов

УДК 621.039.577.001.5

Студент

Группа	**ФИО**	**Подпись**	**Дата**
0АМ3Б	СТЕЛЛА НТИВААХ		

Руководитель

Должность	**ФИО**	**Ученая степень, звание**	**Подпись**	**Дата**
Доцент	Наймушин А.Г	к.ф.-м.н.		

КОНСУЛЬТАНТЫ:

По разделу «*Финансовый менеджмент, ресурсоэффективность и ресурсосбережение*»

Должность	**ФИО**	**Ученая степень, звание**	**Подпись**	**Дата**
Доцент	Рагимов. Т. Р.	к.ф.н.		

По разделу «*Социальная ответственность*»

Должность	**ФИО**	**Ученая степень, звание**	**Подпись**	**Дата**
Ст. Преподаватель каф. ПФ ФТИ	Веригир Д.А.			

ДОПУСТИТЬ К ЗАЩИТЕ:

Зав. Кафедрой	**ФИО**	**Ученая степень, звание**	**Подпись**	**Дата**
ФЭУ	Долматов О.Ю.	к.ф.-м.н., доцент		

Томск – 2017 г.

Министерство образования и науки Россиской Федерации
Федеральное государственное автономное образовательное учреждение
высшего образования
**«НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ»**

Институт Физико-технический
Направление подготовки 14.04.02 Ядерные физика и технологии
Кафедра Физико-энергетические установки

УТВЕРЖДАЮ:
Зав. Кафедрой ФЭУ
________ ________ О.Ю. Долматов
(Подпись) (Дата) (Ф.И.О.)

ЗАДАНИЕ
на выполнение выпускной квалификационной работы

В форме:

Магистерской диссертации

(бакалаврской работы, дипломного проекта/работы, магистерской диссертации)

Студенту:

Группа	ФИО
0АМ5И	СТЕЛЛА НТИВААХ

Тема работы:

ОПТИМИЗАЦИЯ РАСЧЕТА КИНЕТИКИ НУКЛИДОВ В ТВС ИССЛЕДОВАТЕЛЬСКОГО ЯДЕРНОГО РЕАКТОРА	
Утверждена приказом проректора-директора (директора) (дата, номер)	

Срок сдачи студентом выполненной работы:	

ТЕХНИЧЕСКОЕ ЗАДАНИЕ:

Исходные данные к работе *(наименование объекта исследования или проектирования; производительность или нагрузка; режим работы (непрерывный, периодический, циклический и т. д.); вид сырья или материал изделия; требования к продукту, изделию или процессу; особые требования к особенностям функционирования (эксплуатации) объекта или изделия в плане безопасности эксплуатации, влияния на окружающую среду, энергозатратам; экономический анализ и т. д.).*	1. Оптимизация нейтронно-физических свойств активной зоны ВВЭР-1000. 2. Обогащение топлива в диапазоне 1-100%. 3. Использование ТВСА и альтернативный ТВС-2 для реактора ВВЭР-1000. 4. Номинальная тепловая мощность реактора - 2700 МВт. 5. Определение отравления реактора на разных уровнях мощности. 6. Использование WIMS-ANL с 69 библиотекой оцененных ядерных данных ENDF-VII.
Перечень подлежащих исследованию, проектированию и разработке вопросов *(аналитический обзор по литературным источникам с целью выяснения достижений мировой науки техники в рассматриваемой области; постановка задачи исследования, проектирования, конструирования; содержание процедуры исследования, проектирования, конструирования; обсуждение результатов выполненной работы; наименование дополнительных разделов, подлежащих разработке; заключение по работе).*	1. Определение влияния обогащения топлива на запас реактивности активной зоны. 2. Определение оптимальных размеров элементарной ячейки ядерного реактора; 3. Определение эффектов реактивности активной зоны при различных изменениях параметров реактора; 4. Определение отравления активной зоны реактора при различных уровнях мощности; 5. Определение энергетический вклад изотопов в общее энерговыделение активной зоны;

Консультанты по разделам выпускной квалификационной работы	
Раздел	**Консультант**
Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	Рагимов. Т. Р.
Социальная ответственность	Веригир Д.А.
Названия разделов, которые должны быть написаны на иностранном языке:	
Теоретическая часть	
Практическая часть	
Результаты	
Финансовый менеджмент, ресурсоэффективность и ресурсосбережение	
Социальная ответственость	

Дата выдачи задания на выполнение выпускной квалификационной работы по линейному графику	

Задание выдал руководитель:

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент	Наймушин А.Г	к.ф.-м.н.		

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0АМ5И	СТЕЛЛА НТИВААХ		

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«ФИНАНСОВЫЙ МЕНЕДЖМЕНТ, РЕСУРСОЭФФЕКТИВНОСТЬ И РЕСУРСОСБЕРЕЖЕНИЕ»

Студенту:

Группа	ФИО
0АМ5И	СТЕЛЛА НТИВААХ

Институт	ФТИ	Кафедра	ФЭУ
Уровень образования	Магистратура	Направление/специальность	Ядерные физика и технологии

Исходные данные к разделу «Финансовый менеджмент, ресурсоэффективность и ресурсосбережение»:	
1. *Стоимость ресурсов научного исследования (НИ): материально-технических, энергетических, финансовых, информационных и человеческих*	*- Стоимость ресурсов научного исследования (НИ): материально-технических, , финансовых, информационных и человеческих*
2. *Нормы и нормативы расходования ресурсов*	*- Нормы и нормативы расходования ресурсов*
3. *Используемая система налогообложения, ставки налогов, отчислений, дисконтирования и кредитования*	*- Используемая система налогообложения, ставки налогов, отчислений, дисконтирования и кредитования*
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. *Оценка коммерческого и инновационного потенциала НТИ*	…
2. *Разработка устава научно-технического проекта*	…
3. *Планирование процесса управления НТИ: структура и график проведения, бюджет, риски и организация закупок*	*- Планирование процесса управления НТИ: структура и график проведения, бюджет и организация закупок*
4. *Определение ресурсной, финансовой, экономической эффективности*	…
Перечень графического материала *(с точным указанием обязательных чертежей):*	
1. *«Портрет» потребителя результатов НТИ* 2. *Сегментирование рынка* 3. *Оценка конкурентоспособности технических решений* 4. *Диаграмма FAST* 5. *Матрица SWOT* 6. *График проведения и бюджет НТИ* 7. *Оценка ресурсной, финансовой и экономической эффективности НТИ* 8. *Потенциальные риски*	

Дата выдачи задания для раздела по линейному графику	

Задание выдал консультант:

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Доцент	Рагимов. Т. Р.	к.ф.н		

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0АМ5И	СТЕЛЛА НТИВААХ		

ЗАДАНИЕ ДЛЯ РАЗДЕЛА
«СОЦИАЛЬНАЯ ОТВЕТСТВЕННОСТЬ»

Студенту:

Группа	ФИО
0АМ5И	СТЕЛЛА НТИВААХ

Институт	**ФТИ**	**Кафедра**	**ФЭУ**
Уровень образования	Магистратура	**Направление/специальность**	Ядерные физика и технологии

Исходные данные к разделу «Социальная ответственность»:	
1. *Описание рабочего места (рабочей зоны, технологического процесса, механического оборудования) на предмет возникновения:* – *вредных проявлений факторов производственной среды (метеоусловия, вредные вещества, освещение, шумы, вибрации, электромагнитные поля, ионизирующие излучения)* – *опасных проявлений факторов производственной среды (механической природы, термического характера, электрической, пожарной и взрывной природы)* – *негативного воздействия на окружающую природную среду (атмосферу, гидросферу, литосферу)* – *чрезвычайных ситуаций (техногенного, стихийного, экологического и социального характера)*	1. Описание рабочего места инженера, выполняющего расчеты на ПК, на предмет возникновения: – вредных факторов производственной среды: повышенный уровень электромагнитных излучений, ионизирующее излучение; – опасных факторов производственной среды: вероятность возникновения пожара, вероятность поражения электрическим током.
2. *Знакомство и отбор законодательных и нормативных документов по теме*	2. Ознакомление с законодательной и нормативной документацией.
Перечень вопросов, подлежащих исследованию, проектированию и разработке:	
1. *Анализ выявленных вредных факторов проектируемой производственной среды в следующей последовательности:* – *физико-химическая природа вредности, её связь с разрабатываемой темой;* – *действие фактора на организм человека;* – *приведение допустимых норм с необходимой размерностью (со ссылкой на соответствующий нормативно-технический документ);* – *предлагаемые средства защиты (сначала коллективной защиты, затем – индивидуальные защитные средства)*	1. Анализ выявленных вредных факторов: – повышенный уровень электромагнитных излучений, ионизирующее излучение; – средства защиты.
2. *Анализ выявленных опасных факторов проектируемой произведённой среды в следующей последовательности* – *механические опасности (источники, средства защиты;* – *термические опасности (источники, средства защиты);* – *электробезопасность (в т.ч. статическое электричество, молниезащита – источники, средства защиты);* – *пожаровзрывобезопасность (причины, профилактические мероприятия, первичные средства пожаротушения)*	2. Анализ выявленных опасных факторов: – электробезопасность (в т.ч. статическое электричество, средства защиты); – пожаровзрывобезопасность (причины, профилактические мероприятия, первичные средства пожаротушения)
3. *Охрана окружающей среды:* – *защита селитебной зоны*	

– *анализ воздействия объекта на атмосферу (выбросы);* – *анализ воздействия объекта на гидросферу (сбросы);* – *анализ воздействия объекта на литосферу (отходы);* – *разработать решения по обеспечению экологической безопасности со ссылками на НТД по охране окружающей среды.*	
4. *Защита в чрезвычайных ситуациях:* – *перечень возможных ЧС на объекте;* – *выбор наиболее типичной ЧС;* – *разработка превентивных мер по предупреждению ЧС;* – *разработка мер по повышению устойчивости объекта к данной ЧС;* – *разработка действий в результате возникшей ЧС и мер по ликвидации её последствий*	
5. *Правовые и организационные вопросы обеспечения безопасности:* – *специальные (характерные для проектируемой рабочей зоны) правовые нормы трудового законодательства;* – *организационные мероприятия при компоновке рабочей зоны*	
Перечень графического материала:	
При необходимости представить эскизные графические материалы к расчётному заданию (обязательно для специалистов и магистров)	Нет

Дата выдачи задания для раздела по линейному графику	

Задание выдал консультант:

Должность	ФИО	Ученая степень, звание	Подпись	Дата
Ст. Преподаватель каф. ПФ ФТИ	Веригир Д.А.	к.ф.-м.н.		

Задание принял к исполнению студент:

Группа	ФИО	Подпись	Дата
0АМ5И	СТЕЛЛА НТИВААХ		

Результаты обучения

Код результата	**Результат обучения** (выпускник должен быть готов)
Профессиональные компетенции	
Р1	Применять глубокие математические, естественнонаучные, социально-экономические и профессиональные знания для теоретических и экспериментальных исследований в области использования ядерной науки и техники
Р2	Способность определять, формулировать и решать междисциплинарные инженерные задачи в ядерной области с использованием профессиональных знаний и современных методов исследования
Р3	Уметь планировать и проводить аналитические, имитационные и экспериментальные исследования в сложных и неопределённых условиях с использованием современных технологий, а также критически оценивать полученные результаты
Р4	Использовать основные и специальные подходы, навыки и методы для идентификации, анализа и решения технических проблем в ядерной науке и технике
Р5	Готовность к эксплуатации современного физического оборудования и приборов, к освоению технологических процессов в ходе подготовки производства новых материалов, приборов, установок и систем
Р6	Способность разрабатывать многовариантные схемы для достижения поставленных производственных целей, с эффективным использованием имеющихся технических средств
Общекультурные компетенции	
Р7	Способность использовать творческий подход для разработки новых идей и методов проектирования объектов ядерного комплекса, а также модернизировать и совершенствовать применяемые технологии ядерного производства
Общепрофессиональные компетенции	
Р8	Самостоятельно учиться и непрерывно повышать квалификацию в течение всего периода профессиональной деятельности.
Р9	Активно владеть иностранным языком на уровне, позволяющем работать в иноязычной среде, разрабатывать документацию, презентовать результаты профессиональной деятельности.
Р10	Демонстрировать независимое мышление, эффективно функционировать в командно-ориентированных задачах и обладать высоким уровнем производительности в профессиональной (отраслевой), этической и социальной средах, а также руководить командой, формировать задания, распределять обязанности и нести ответственность за результаты работы

Summary

The masters' dissertation consist of (95) pages; 30 figures; 19 tables; 36 references and 5 appendixes.

Key words: PWR; VVER-1000; WIMS-ANL; lattice cell; fuel assembly; neutronic characteristics; reactivity; effective multiplication factor; reactivity temperature and power coefficient; Xenon poisoning.

The purpose of this study is the optimization of neutronic characteristics of the VVER-1000 reactor core.

Calculations and simulations in this study, were performed using the nuclear reactor lattice cell calculation code, WIMS-ANL and its 69 library package for investigating temperature and power effect on the VVE-1000 reactor core reactivity for different enriched uranium in two medium.

The results of this work are means of optimizing the reactivity coefficient and ideally ways of reducing the insertion of negative reactivity of VVER-1000 reactor core in the absence of control rods and burnable poisons.

Basic design, technological, technical and operational characteristics: the design and characteristics are based on the heterogeneous vessel type VVER-1000 reactor which uses light water as both coolant and moderator. Fuel assembly is of the hexagonal structure and is 163 in quantity with 312 fuel elements. Reactor was operating with unit capacity of 35,18MW/ tU.

Level of implantation: fully working on this thesis during 4^{th} semester.

Cost-effectiveness/value of the work: high feasibility, does not require much cost.

Applied areas: this research can be well applied in areas, such as nuclear physics and engineering field. The result of the study present some tables and graphs that provides useful information for nuclear engineers in reactor core design.

Future plans: apply to optimize neutronic properties' in the presences control and protection systems and prolong the operational time of the reactor.

CONTENT

NOMENCLATURE

VVER	water-water energetic reactor
PWR	pressurized water reactors
LWR	light water reactors
k_{eff}	effective multiplication coefficient
FA	fuel assembly
Zr	Zirconium alloy
Nb	Niobium
MWt	megawatts per tonnes
UO_2	uranium dioxide fuel
GWd	gigawatts per day
ρ	reactivity
RTC	reactivity temperature coefficient
RTE	reactivity temperature effect
M/C	moderator/coolant
RPC	reactivity power coefficient
RPE	reactivity power effect
U-5	uranium 235
U-8	uranium 238

Introduction

The neutron physical characteristics of a nuclear power reactor has great effect on the reactors stability and is some cases predict the design operational systems of the reactor. These characteristics are those associated with the interaction of neutrons with the material component of the structure. Therefore, precise knowledge of this dependence for each reactor is absolutely necessary. Modelling of the kinetics and thermal hydraulic of the whole reactor are too complicated and it's advisable to handle it partially, simulations are therefore recommended.

Series of analysis have been performed on temperature, power and poisons effect on the reactor core reactivity design using different programs and modes.

Topic: this dissertation commences the neutron physical parameters which contribute to the variation of the core reactivity. Particularly, the effect of power and temperature coefficient on the core reactivity for different enriched UO_2 fuel in two media. In addition, studies were also made on the effect fission product poisons has on the core reactivity. Almost all fission product in some ways can be considered as reactor poisons since they can capture neutron to certain extend thereby reducing the effective multiplication factor. This products are slowly formed as the fuel consumes and the impact is a major contribution to the decreasing fuel reactivity as a function of time and the neutron flux. Therefore understanding their buildup sequence and analyzing it contribution to reactivity in the reactor core is very important. . Moreover it also introduces practically the energy released by isotopes in the core. By understanding this, the plant could be operated safety, prolonged the life time of reactor and reduced the nuclear wastes [14]. Furthermore, calculations were made based on the mathematical equations dependently on the multiplication factor, and analysis were made visually with graphs and data tables

In this dissertation, the WIMS-ANL codes which use transport theory to calculate the neutron flux as a function of energy and spatial location in a one dimensional unit cell were used in simulating the core. This codes were largely obtained due to the effort of L.S. Leopando from the Philippine Nuclear Research

Institute. The first version of this code, the WIMS-D4 was originally developed in 1980 and obtained by Oak Ridge National Laboratory, (RSICC) in 1992. There are many versions of the WIMS in use but the most recent is the WIMS-ANL which is the revised version of the WIMS-D4M [2]. This version has improved error checking, output control, can accommodate cross section libraries greater than 69energy groups (172 energy groups) and suitable for reactor physics calculations. The results values of the simulation received are acceptable and shows relatively the design values of the VVER-1000 reactor core.

Purpose of this work: optimizing the neutronic parameters for VVER-1000 reactor core using WIMS-ANLS code.

Objective of work:

– Convey the calculated research on the neutron physical characteristic associated with the VVER-1000 reactor core.

– Find the effect reactivity temperature and power coefficient has on the reactor core reactivity by optimizing fuels of different enrichment.

– Investigate the influence of xenon poisoning on the reactor core as well.

– Determine the energy contribution of isotopes with the maximum energy contribution.

To study the effect these parameters have on the VVER-1000 reactor core operations using the WIMS-ANL lattice cell calculation code.

During fission reaction, the temperature of the fuel in the fuel assembly as well as the temperature of the coolant (as the heat is transferred from the fuel to the moderator/coolant) in the reactor core increases rapidly as the reactor power is increased. This temperature, pressure and power variations alters the neutron flux hence core reactivity changes. Therefore, by studying the effect temperature and power has on the core reactivity, it can easily be evaluated and calculated the effect of neutronic properties on the reactor core.

Chapter 1

1.1 Literature Review

1.1.1 Reactor type.VVER-1000

Reactor VVER-1000 also known as the WWER-1000 is the Water-water energetic reactor (in Russian: Водо-Водяной энергетический реактор) is a pressurized light-water reactor originally developed by Soviet Union and now Russia by OKB Gidropress. It is generation III type and was constructed after 1975 but launched in May 1980. It is a four looped system housed in a container typed structure. It is a heterogeneous, vessel type reactor, which uses light water for both coolant and moderator. Fission reaction is caused by collision between thermal neutrons and a parent nuclei.

This particular VVER-1000 reactor is designed for the production of thermal energy with an installed thermal capacity of 2700 MWt and a rated electrical capacity of 1000MW. The core of the reactor is made up of 163 fuel assemblies, identical in design, of hexagonal shape on a hexagonal grid with a constant pitch of about 200-240mm whilst some PWR are made of square fuel assemblies on a square grid with 193 FAs. The FAs of VVER-1000 consist of 312 fuel elements but with variable fuel enrichment [24].

1.1.1 Structure of fuel assembly type

The reactor core is occupied by fuel assembly design for both base TVSA and alternative TVS-2. The TVSA fuel assembly (FA) is considered as a base version of fuel assembly (FA) design and as an alternative version is TVS-2. Both versions of FA are interchangeable and are of reference character.

The core of the reactor includes 163 fuel assemblies; which are identical in design and 312 fuel elements. Each FAs comprises of the following components, top nozzle, bundle of fuel rods, bottom rod, guiding channels and spacing grid as shown in *Fig 1.1* and *Fig 1.2* [1]. The fuel rods are cylindrical and cladded with Zr with 1% Nb.

Each rod contains fuel pellets with inner and outer diameter of 0,6cm and 0,78cm respectively. Additionally the fuel pellet are also cladded with material of 0,772cm inner diameter and an outer diameter of 0,910cm.

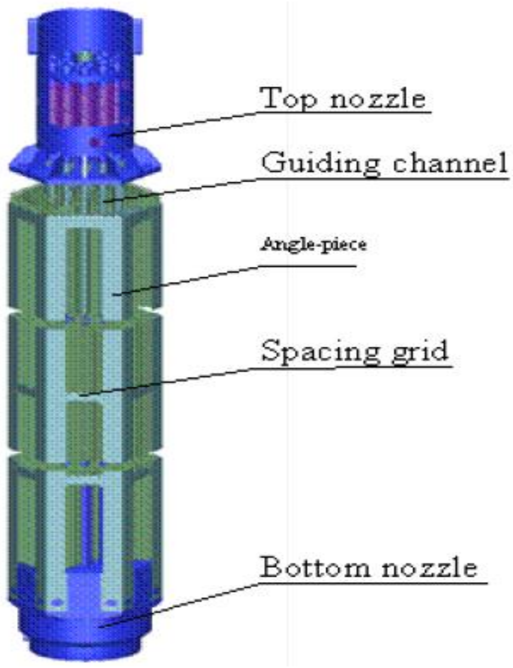


Fig.1– TVSA general view

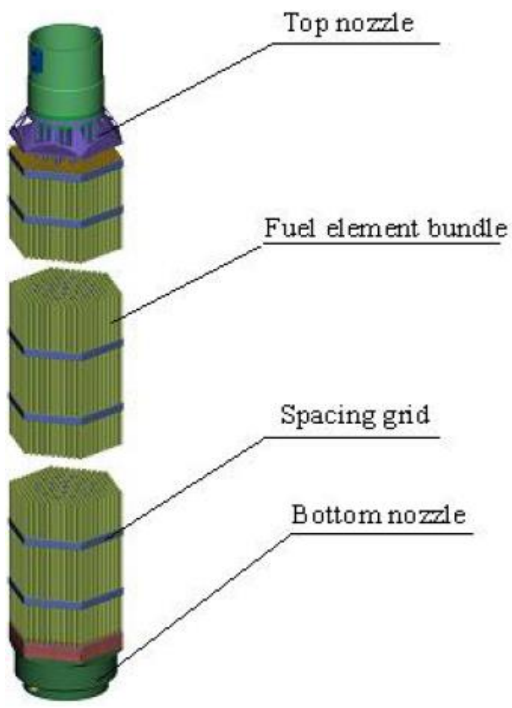


Fig.2 – TVS-2 general view

During reactor operations, fuel rods are fully immersed in water at a nominal pressure of 15MPa preventing the water from boiling at a normal (220˚C to cover 300˚C) operating temperature. Fuel is low enrich (varying between 2,4 % to 4 %) UO_2.

Since boiling on the pallet surface is prohibited the temperature of cladding depends on the type of fuel used. The inserted fuel assemblies contains 312 fuel elements, 18 guide tubes, central tube and one instrumentation tube, all arranged in a triangular lattice with a pitch of 1,275. The hexagonal lattice pitch of the assembly cell is 23,6 cm.

The structure and configuration of the fuel assembly in the core are kept unchanged but rather refueled at the end of its fuel cycle. Water is mostly used as reflector. The huge size of the FAs contribute to the increase of multiplication factor and the short migration length.

The reactor VVER-1000 are required for large scale power generation and are mostly enhanced by increasing the size or length of fuel assembly or advancing the fuel (UO_2) without changing the volume of the core. After modernization, power of the reactor can only be increased by 2-5% of nominal reactor power. Period of refueling of FAs ranges from 12 – 18 months. The main characteristics of this prototype reactor are listed in the table 1.1 below.

Table 1.1 – Main parameters of the VVER-1000 reactor

Main parameter, unit		**Values**
Nominal thermal capacity, MW		2700
Rated Electrical capacity, MW		1000
Fuel assembly quantity		163
Cladding material(Alloy)		Zr + 1%Nb
Fuel mass in the rod(kg)		1,575
Fuel rod effective height (cm)		353
Fuel material		UO_2
Density of fuel, g/cm^3		10,5
Fuel temperature, K		500
Fuel pallet diameter, cm		
	inner	0,78
	outer	0,06
Cladding diameter, cm		0,915
Moderator-coolant		H2O
	Pressure, MPa	14
	Temperature, C	300
Fuel assembly form		Hexagonal
Lattice, cm		1,35
Type of Lattice		triangle

1.1.2 Configuration of the core and FAs of VVER-1000

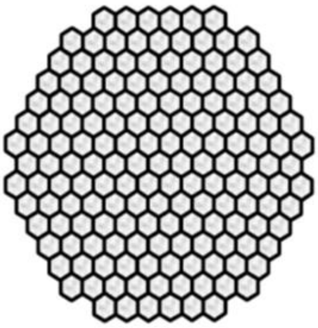


Fig 1.3 – Core (163 FAs)

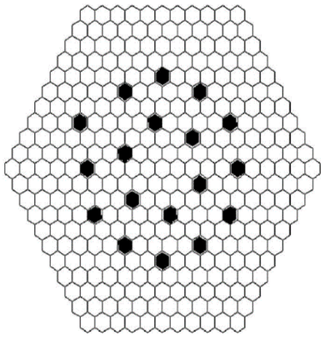


Fig 1.4 – FAs (312 FE)

In modern VVER-1000 with uranium enrichment 3-5% at 2-3 years of campaign with partial overload has burnup ranging from 40-50 GWd/KgU and it is even more in intense fuel elements as compared to the burnup of PWR reactors which ranges from 45 to 50 GWd/KgU. Average burnup of unloaded fuel in PWRs is 52,8 GWd/KgU.

Reactivity margin for VVER-1000 reactors is approximately equal to 0,25 Δk/k. The loss of reactivity due to Xe^{135} poisoning in the reactor core is equivalent to % but reactivity worth, also known as Xenon load which is proportional to the Xenon concentration varies with the steady power of the reactor for LWR [26].

Time required for xenon to achieve it maximum equilibrium concentration is between 30-40hr, with specific yield of (γ) ≈ 0,03 % directly from fission and a total fission yield of (γ) ≈ 6,6%. For most thermal reactors the value of optimum lattice lies between 0,5 to 0,6R. [21]

The experimental values obtained for reactivity coefficient of PWRs reactors are summarized in the table 1.2 below. [10]. According to the estimation, coefficients in PWRs are mostly negative

Table 1.2 – Reactivity coefficients of PWRs [10]

Parameter	Value
Moderator temperature coefficient	$(+\mathbf{0,8} \sim -\mathbf{9,4}) \cdot \mathbf{10^4}(\boldsymbol{\Delta k/k})/^{\mathbf{0}}\boldsymbol{C}$
Fuel temperature coefficient	$(-\mathbf{2,1} \sim -\mathbf{5,2}) \cdot \mathbf{10^5}(\boldsymbol{\Delta k/k})/^{\mathbf{0}}\boldsymbol{C}$
Void coefficient	$(+\mathbf{0.7} \sim \mathbf{3.1}) \cdot \mathbf{10^3}(\boldsymbol{\Delta k/k})/$%Void fraction
Pressure coefficient	$(+\mathbf{8.0} \sim \mathbf{0.5}) \cdot \mathbf{10^5}(\boldsymbol{\Delta k/k})/(\boldsymbol{kg/cm2})$
Moderator density coefficient	$(+\mathbf{0.51} \sim \mathbf{0})\ (\boldsymbol{\Delta k/k})/(\boldsymbol{g/cm^3})$

Because LWRs use the low-enrichment fuel containing a lot of U^{238}, the reactivity decreases when the resonance absorption of U^{238} increases. Thus, the reactivity coefficient becomes a negative value. The Doppler reactivity coefficient of LWRs is in a range of $5 \cdot 10^5$ to $1 \cdot 10^5$(Δk/k)/˚K.

1.2 WIMS-ANL code

The WIMS-ANL (Winfrith Improved Multigroup Scheme) are codes extensively used for power and lattice physics analysis. This developed program was initially aimed at using the transport theory to calculate the neutron flux as a function of energy spatial location in one dimensional cell. The program uses its own 69 group constant library and the ENDF/BV library prepared for various materials, power and temperatures bases on the ENDF format. [2]

There are two main transport option known as DSN (discrete ordinates) and PERSUS (collision probability). Transport solutions are performed using any specified intermediate group structure up to the number of library groups. The main transport is mostly preceded by one or two STECTROX flux spectra calculation(s) for few spatial regions in the few region library group structure after which calculation of spectra for a spatial region in the full number of energy groups of its library are performed using the spectra to condense the basic cross sections into few groups. [2]

After completion of the main transport solutions, the intermediate group cross sections are collapsed to the broad group structure (≤ 20 groups) and may be written in the microscopic or macroscopic ISOTXS format for use in subsequent transport or diffusion theory codes. The microscopic ISOTXS cross-sections contain the full P_o and P_1 scattering matrices for transport calculations, but their primary use will be in Multigroup diffusion theory analyses [2]. The cross sections are also burnup and spatially dependent. The cross section and energy group of the 69 library groups are shown in Appendix B.

Main purposes of this code developing algorithms for the WIMS code, creating main data and prelude data to calculate spectra for few spatial region and rated regions in homogeneous medium, creating libraries for theses program. WIMS code and its 69 group libraries are found to be one of the adequate predictor of cell reactivity, burnup process and flux spectrum cell modelling. The input data model includes prelude data (the two transport solutions i.e. PERSUS & DSN) and main data (geometry, composition, cell characteristics, burnup and reaction rate edit)

1.2.1 The general scheme of WIMS-ANL simulation method

To perform neutron calculation in the core of the reactor, simulation of the reactor is required. In this research work, the cell calculation which stimulates the fuel assembly in the reactor core was performed and the output was used in the core calculation which apparently determines the neutronic parameters of the reactor. Firstly, the simulation of the fuel assembly, the WIMS-ANL codes were used. It is necessary to remember that the occurring process in the simulation corresponds to the actual physical process. A neutron will be absorbed by a nuclei to sustain the fission chain reaction by dividing itself and releasing energy. These happens at the end of the simulation, the particle that appear in simulation is known as the neutron flux (neutron clusters). Internally, the WIMS code also generates region-averaged cross sections in an intermediate group structure that can utilize maximum number of fine groups in the library. Presently, fine-group libraries with 69 and 172 groups are used in the ANL RERTR Program [2].

The WIMS-ANL codes uses the transport theory to calculate the neutron flux as a function of energy and positions in the cell. It begins by performing spectra calculations for few regions in the full number of energy groups of its 69 library and uses these spectra to condense the basic cross section into few groups. The obtained flux values are then expanded by using the formal spectra calculations in order for the reaction rate at reach point to be calculated in each library structure. Different geometries such as (the elementary ones are homogenous, annulus, rod clusters in cylindrical geometry and finite cylinders in r-z geometry) are evaluated. In addition to the primary cell calculations, the program is used to carryout burnup calculations using time steps intervals or power value.

Moreover, the program reads the basic macroscopic cross section from its library tape. It then calculates the macro cross sections for each material, with automatically calculated resonance shielding the preliminary spectrum is evaluated using the collision probability methods. In this work, fuel assemblies with different enrichments has been modelled using the WDSN (transport calculations are performed in one dimension) and the main transport option for finding the problem K_{eff} (homogenous) in the finite geometric medium. In modeling it is recommended to convert the hexagonal structure of the fuel assembly (having a triangular lattice pitch) to circular fuel assembly model since WIMS code can only perform cell calculation in circular model. In converting the hexagonal structure to the circular model the volume remains unchanged. The *fig 1.5* and *fig 1.6* below shows the hexagonal model and the circular model used for cell computation respectively.

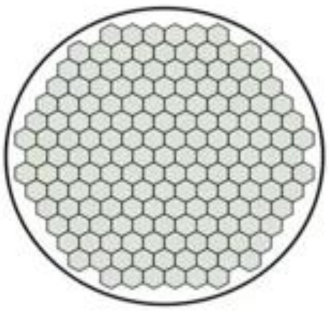


Figure1.5–Hexagonal model

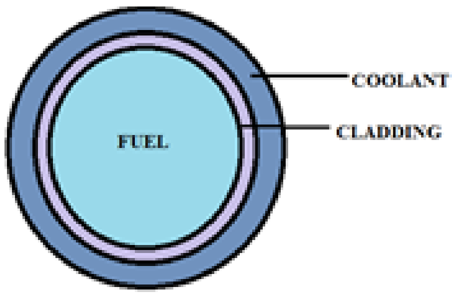


Figure 1.5–circular model for a unit cell

The WIMS code requires the following information;

– the material of each part of the cell,

– the geometry of the fuel assembly,

– burnup parameters,

– buckling value of the call,

– temperature and power used and other information depending on the method used for the calculation. At the end of the simulation, the values obtained for effective multiplication factor in each medium were used in evaluating the optimum sizes for the four regions of the lattice cell and were further used for optimizing the neutronic parameter associated with the dynamics of the reactor.

1.2.2 Simulating the VVER-1000 reactor core using WIMS-ANL codes

Analysis was performed on the neutronic characteristics associated with the reactor VVER-1000 design using the WIMS-ANL code. In simulating, two main inputs were used i.e. the main input data and the prelude input data.

The prelude input option comprises of method of solution, which contains the SEQUENCE card which defined the main transport routine used in the lattice calculation, and the CELL card was used in the selecting the cell type which in this case was a single homogenous cell [1], 2) accuracy of solution which contains the NGROUP card which set the number of main transport group that was used. Note the larger the number of group selected usually results in a more accurate flux and cell reactivity calculation and the NMESH card was set to calculate the number of mesh points in the main transportation calculations.

Description of the core geometry (NREGION) and compositions (NMATERIAL) were also defined in the prelude data. The NREGION card was used to set the number of zones in the given lattice whilst the material card defined the number of material component and lastly the NREACT card was used in some cases [1] for the finite medium.

The secondary input option for a one dimensional geometry the ANNULUS card was used to define the unit cell and the NMATERIAL card in specified the density/composition, temperature and spectrum type of the material in the set lattice, other input used in the main data were the POWERC (calculation of fuel depletion over a time step) card, reaction rate card and the ISOTXS (for writing micro and macro cross section in the output data file), the BEGINC card which ends the main data input and the PRTOPT card set at 1 to edit result in the full output [1]

4 Financial management, resource efficiency and resource conservation.

4.1 Financial Management.

Currently, the prospects for scientific research are determined not only by the scale of the discovery, which is difficult to estimate at the first stages of the life cycle of a high-tech and resource-efficient product, but rather as a commercial value of development. Evaluation of the commercial value (potential) of development is a prerequisite in the search for sources of funding for scientific research and commercialization of its results. This is important as developers needs represent the state and prospects of ongoing research. It must be understood that the commercial attractiveness of scientific research is determined not only by exceeding technical parameters over previous developments, but also how quickly the developer will be able to find answers to such questions as whether the product will be in demand by the market, what will be its price, to satisfy the consumer, what is the budget of the scientific project, etc. Thus, the purpose of the section "Financial Management, Resource Efficiency and Resource Saving" is to determine the prospects and success of a research project, to develop a mechanism for managing and supporting specific project solutions at the implementation stage [17].

The section of financial management in this dissertation includes two sections, the first section is an evaluation of cost competitiveness of operating PWR (VVER-1000) nuclear power plant with low enriched uranium fuel to other power plant, its resource efficiency and consolidated energy investment. The second includes a budgetary report of the scientific project. The cost evaluation where performed for PWR plants with low enriched fuels and SWOT analysis were performed.

4.1.1 Definition of Financial management by scholars.

Scholars in the field of financial management have different definitions for the term as stated below;.

Financial Management deals with procurement of funds and their effective utilization in the business "by S.C. Kuchal says.

Financial management "as an application of general managerial principles to the area of financial decision-making by Howard and Upton:

Financial management is also "the operational activity of a business that is responsible for obtaining and effectively utilizing the funds necessary for efficient operations by Joshep and Massie. Therefore considering the definition made by these scholars we can conclude that:

Financial Management is simply concerned with the effective funds management in the nuclear industry.

Industrial Resource efficiency is often defined in supply chain terms, highlighting a firm's material, natural resource and energy efficiencies, and the generation and impact of waste. In some cases, only the resource efficiency of non-energy carrying materials is considered. In this case, the term 'material productivity' is used instead of the resource efficiency

4.1.2 Cost structure of operating a PWR Nuclear power plant.

PWR nuclear power plant especially the Russian VVER-1000 is one of the most efficient, economic and play an important role in providing secure, low-carbon electricity supplies in many countries**.** Organisation for Economic Co-operation and Development (OECD) studies comparing the costs of electricity generation from different sources indicate that nuclear power is competitive on a levelised cost per kWh basis (particularly when the costs of carbon-dioxide emissions are taken into account). Volatility in fossil fuel prices has also increased the attractiveness of nuclear in more stable generating costs. Despite the numerous advantages of nuclear power plants, NPPs are more capital-intensive than other large-scale power generation plants, because they are more complex and take longer to construct. Once in operation, the higher capital costs are offset by lower and more stable fuel costs, but the need to finance high up-front construction costs presents a challenge to those wishing to invest in new nuclear capacity, particularly in areas with competitive electricity markets. An approximate breakdown of levelised electricity generating costs for nuclear, coal and natural gas fired generating plants is shown in table A below [22].

Table A. Approximate cost structure []

	Nuclear	Coal	Natural Gas
Investment costs	50	35	14
Operating and maintenance costs	30	20	9
Fuel cost		45	77

4.1.3 Fuel cost

Nuclear plants require fissile fuel for energy generations. Generally, the fuel used is uranium, although there are other materials that can be used as fuel eg thorium and MOX fuel. In 2005, prices on the world market for uranium averaged US$20/lb (US$44.09/kg). Fuel costs account for about 28% of a nuclear plant's operating expenses. As of 2013, half the cost of reactor fuel was taken up by enrichment and fabrication, so that the cost of the uranium concentrate raw material was 14 percent of operating costs. Therefore doubling the price of uranium would add about 10% to the cost of electricity produced in existing nuclear plants, and about half that much to the cost of electricity in future power plants. The cost of raw uranium contributes about $0.0015/kWh to the cost of nuclear electricity. As of 2008, mining activity was growing rapidly, especially from smaller companies, but putting a uranium deposit into production takes 10 years or more

4.1.4 Fuel enrichment cost

Enrichment is also a fundamental parameter that relates financial cost of the system to its reactivity. Higher enrichment relates to larger costs and a more reactive system. Optimal enrichment for this system varies depending on concentration and moderation. A lower enrichment price means that more enrichment will be used as opposed to uranium in creating the required enriched uranium and this will be reflected in the selection of lower tails assays at the plants. There is an optimum for the buyer for every mix of uranium and enrichment prices, and uranium demand will now be notably lower. Hence there is an important impact on uranium prices which themselves should be pushed down by lower enrichment prices. Uranium prices at $20 per pound are partly a reflection of its benefit as compared to other source of fuel.

4.1.5 Cost of Energy productions.

Figure 4.1 is an example of energy production costs taken from a 2008 study by the Finnish Lappeenranta University of Technology, and compares the economic competitiveness of various power plant alternatives (nuclear, CCGT, coal-fired, peat-fired, wood-fired and wind). The calculations were carried out by using the annuity method with a real interest rate of 5 % per annum and a fixed price level as of January 2008. With an annual base load utilization time of 8000 hours (corresponding to a load factor of 91,3 %) the production costs for nuclear electricity would was 35,0 €/MWh, for gas based electricity 59,2 €/MWh and for coal based electricity 64,4 €/MWh, when using a price of 23 €/tonCO2. Without emissions trading the production cost of gas electricity is 51,2 €/MWh and 45,7 €/MWh for coal electricity, while nuclear remains the same (35,0 €/MWh). Therefore, at least under Finnish conditions, nuclear is with and without carbon prices the most competitive base-load supplier in terms of production costs. Regarding renewables, independent of the issue of much smaller load factors, wind has higher production costs than nuclear, mainly due to twice as high capital costs:

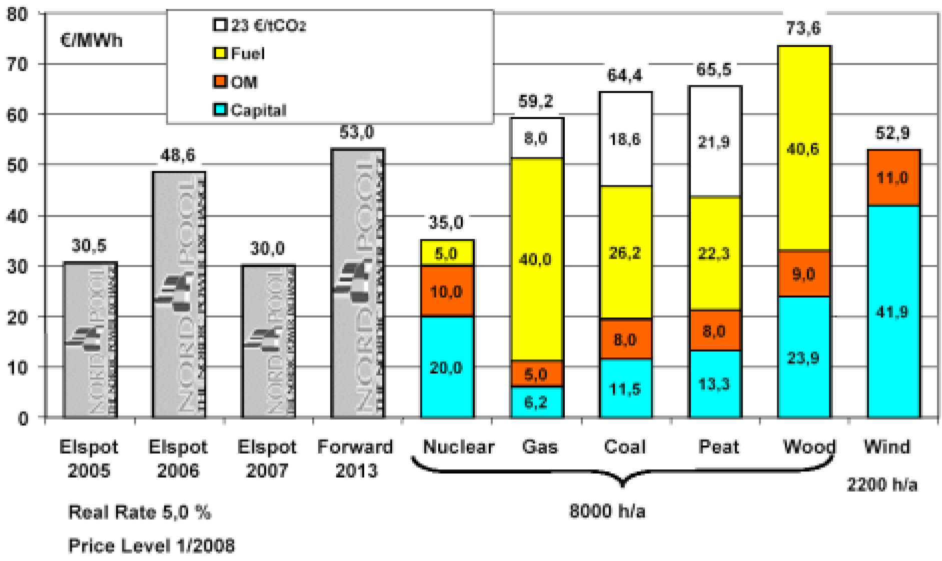


Figure 4.1–illustrate the energy production cost at 23€/tonCO_2[].

The relatively low cost values obtained here for capital intensive technologies (nuclear, wind) are to be related to the relatively low value of 5% (real) for capital cost, assumed by Lappeenrata University as pure interest rate, while many utilities will rather use values of 8% to10

4.1.6 Resource Efficiency

According to the United Nations Environment Programme (UNEP), resource efficiency is about ensuring that natural resources are produced, processed, and consumed in a more sustainable way, reducing the environmental impact from the consumption and production of products over their full life cycles. By producing more wellbeing with less material consumption, therefore resource efficiency enhances the means to meet human needs while respecting the ecological carrying capacity of the Earth (UNEP, 2012).

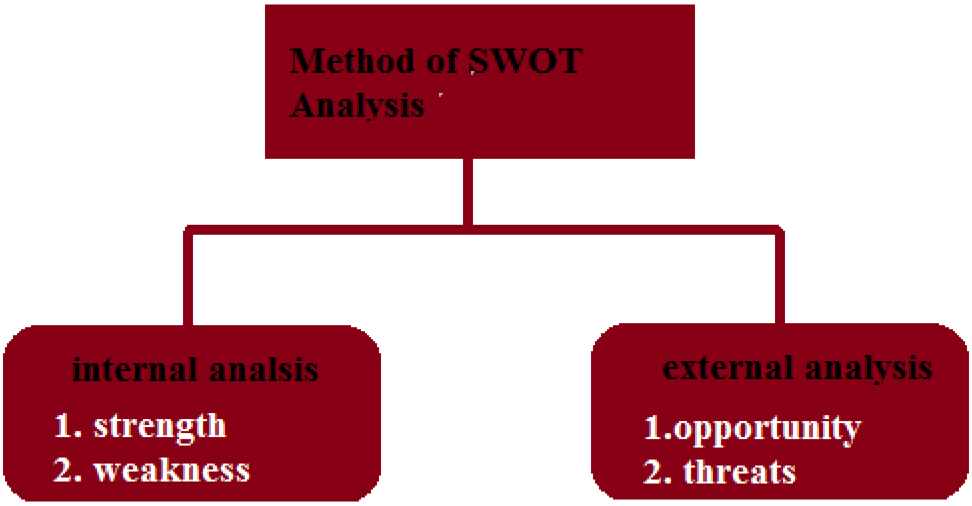
According to the World Nuclear Association, "the world's present measured resources of uranium (5.7 Mt) in the cost category less than three times present spot prices and used only in conventional reactors, are enough to last for about 90 years. This represents a higher level of assured resources than is normal for most minerals.

Further exploration and higher prices will certainly, on the basis of present geological knowledge, yield further resources as present ones are used up." The amount of uranium present in all currently known conventional reserves alone (excluding the huge quantities of currently-uneconomical uranium present in "unconventional" reserves such as phosphate/phosphorite deposits, seawater, and other sources) is enough to last over 200 years at current consumption rates. Fuel efficiency in conventional reactors has increased over time.

Additionally, since 2000, 12–15% of world uranium requirements have been met by the dilution of highly enriched weapons-grade uranium from the decommissioning of nuclear weapons and related military stockpiles with depleted uranium, natural uranium, or partially-enriched uranium sources to produce low-enriched uranium for use in commercial power reactors. Similar efforts have been utilizing weapons-grade plutonium to produce mixed oxide (MOX) fuel, which is also produced from reprocessing used fuel. Other components of used fuel are currently less commonly utilized, but have a substantial capacity for reuse, especially so in next-generation fast neutron reactors. Over 35 European reactors are licensed to use MOX fuel, as well as Russian and American nuclear plants. Reprocessing of used fuel increases utilization by approximately 30%, while the widespread use of fast breeder reactors would allow for an increase of "50-fold or more" in utilization.

4.1.7 SWOT Analysis

The SWOT analysis is a compact method to show the results obtained by this study in a strategic way. The Strengths and Weaknesses of the PWRs (VVER-1000) nuclear power plant in the Russian scenario are reported to internal factors evaluation. Indeed the Opportunities and the Threats are reported from external factors evaluation. A collected strengths of considerable importance for the competitiveness and profitability of an investment. As for the weaknesses there is the negative effect of economies of scale and the direct consequence of this factor: the lack of competitiveness PWRs as compared to other power plants. These opportunities are very relevant and although they cannot be quantified and valued, provide a strategic advantage that adds competitiveness to a possible deployment of the. PWR reactors**.**



Strength

"Strength" are understood here as internal factor which positively impact the relative competitiveness of nuclear in the future. The following list of opportunities has been identified:

– Nuclear power generation is much less sensitive to fuel price increase than fossil fuels.

– Uranium security of supply is based on resources coming in a major part from politically stable countries. In addition, due to its high energy density, nuclear fuel may be easily stored in small volumes

– Nuclear power plants do not emit CO_2, and the use of nuclear power across its lifecycle results in only very small amounts of greenhouse gas emissions.

– Social benefits of nuclear power include direct employment and positive impacts of stable and predictable cost of electricity on the economy.

– Production factors (long-term power supply)

– Satisfy demand of consumers since its used as baseload power production

Weakness

"Weakness" are understood here as internal factor which positively impact the relative competitiveness of nuclear in the future. The following list of opportunities has been identified

– Uranium resources are limited as compared to unlimited availabilities of renewable energy resources.

– Uranium mining & mill tailings need long-term stewardship.

– A huge plant is needed for enrichment to occur.. In addition to this effect, the centrifuge requires for the spinning of uranium must be of an extreme special metal.

– The low utilization ratio of nuclear fuel is a major problem in the process of nuclear power development.

– Nuclear power is capital intensive; therefore variations in construction costs have significant impact.

– Sufficient Human Resources are critical to use of nuclear energy

– Proliferation concerns are a specific problematic characteristic of the nuclear fuel cycle.

– Waste disposal is also a major problem.

Opportunities

Opportunities" are understood here as external factor which positively impact the relative competitiveness of nuclear in the future. The following list of opportunities has been identified.

– High fossil fuel prices;

– Need of new power generation capacity due to increased electricity demand and necessary replacement of old carbon-emitting power plants;

– Lower energy generating cost as compared to wind, solar and so on.

– New generations of nuclear reactors with packages for better uranium resource utilization and waste minimization.

– Energy supply stability as compared to wind power, solar, hydro which have a characteristics of intermittency, randomness or shortage.

Threats

“Threat” here are understood as the external factors that could threaten or negatively impact the relative competitiveness of nuclear in the future. The following are list of threats that has been identified:

– Nuclear security/terrorist threats to the nuclear infrastructure and materials

– Risk of accident during plants’ operation, and corresponding risk perception following bad accident management.

– Changes in nuclear accident liabilities

– Uncertainties in the construction cost i.e. increase in construction and raw material cost.

– Implementation programs for waste management are very slows

– Scarcity of water of water in some areas of plants operation.

– The global energy competitive markets design in the near future.

4.2 PROJECT

4.2.1 Works

List of stages, works and distribution of performers

Main stages	No. of work	Work content	Position Performer
Development of technical specifications	1	Selection of research topics	Supervisor 1
Choice of direction Research	2	Study of scientific literatures	Engineer
	3	practice	engineer
	4	Searching for material and studying in library	engineer
	5	Data processing	Engineer
Theoretical and experimental studies	6	Comparison of experimental results with theoretical studies	Engineer Supervisor1
	7	Split the general topic into detailed sub topic	Engineer Supervisor 1 Supervisor 2
	8	Self-studying	
	9	Writing papers	
	10	Check the correction of the paper	Engineer Supervisor 1
Synthesis and assessment of results	11	Evaluation of the effectiveness of the results. Team working	
	12	Determining the feasibility of simulation process	engineer
Development of technical documentation and design	13	Translate foreign materials Attend in conference	

4.2.2 Gantt Diagram

As a part of the planning of a research project, it is necessary to build a calendar graphic.

Diagram Gantt – this is a type of bar charts (histogram) which is used to illustrate the planned schedule of project, in which the works can be shown the extensive length of time, characterized by the dates of beginning and end of the implementation of these works [19].

The graph is constructed under the form of Appendix A by month and ten-day periods (10 days) during run-time of project. On the chart should make different hatching, depending on the performer responsible for a particular work.

According to the new Salary System for Employees from 17th May 2017, the wage people, who are working in university can be determined by:

Salary of supervisor 1 per 30hrs): 9 000,00rubles;

Per hour: 300 rub

Salary of supervisor 2 per 2,6): 780 rubles

Per hr: 300 rub

Total: 12032 hrs

Ntiwaah Stella: 12 000hrs;

Supervisor 1: 30hrs;

Wage: $30 \times 300 = 9\ 000{,}00$

Supervisor 2: 2,6hrs.

Wage: $2{,}6 \times 300 = 780$ rub

4.2.3 Raw materials, purchased products and semi-finished products

This item includes the cost of all kinds of purchasing materials, components and semi-finished products necessary for the implementation of works on the subject. Number of required material values determined by the norms of consumption.

where:

$$\text{Additional salary} = \text{basic salary} \times (12\text{-}15\%); \quad (4.1)$$

$$\text{Benefit expenses} = (\text{basic salary} + \text{additional salary}) \times 30{,}01\%; \quad (4.2)$$

$$\text{Overhead cost} = \text{basic salary} \times (60\text{-}70\%). \quad (4.3)$$

Calculating the expenses of material costs based on the current price list or negotiated prices. The expenses of material costs include transportation and procurement costs (3 – 5% of the price). In the same item, includes the expenses of paperwork (stationery, copying materials). The results of this term are presented in the Table 4.1 below.

Table 4.1 – Raw materials, components and semi-finished products

Title	Mark, size	Quantity	Price per each, ruble	The sum, ruble
Computer	Toshiba	1	25 000	25 000
Notebook	Flower	5	30	150
Pen	Znos	10	15	100
Printing		10	300	3000
Total of materials				28 250
Transportation and procurement expenses (3.5%)				990,5
Total items $C_{м}$				29 240,5

4.2.4 Special equipment for scientific (experimental) work

In this subsection shows all of the costs associated with the acquisition of special equipment (instruments, test equipment, test benches, devices and tools or even some special documents and books) necessary for work on a particular subject. Determining the cost of special equipment based on the current price list, and in some cases at a bargain price.

Table 4.2 – Expenses for item “Special equipment for the scientific work”

№ п/п	Name of equipment	Number of units of equipment	Price per each of equipment, thousand rubles	Total cost of equipment, thousand rubles
1.	Scientific book	1	2,5	2,5

When purchasing special equipment, it is necessary to take into account the expenses of delivery and installation. This expense costs 15% of its price. The expense of the equipment is calculated due to the performance of a specific research project in the scientific and technical organizations. It is also attended to depreciation or inflation. All payments for the acquisition of special equipment and existed equipment in the organization, but used to perform a specific term, summarized in Table 4.2.

4.2.5 The basic wage

In this subsection shows the basic wage of the scientific and technical employee, the normal or experienced laborer, directly involved in the implementation of the work. The amount of expenditure on wages is determined based on the complexity of the work and the current system of remuneration. The structure of the basic salary includes premium tax, payroll monthly (determined by the Regulations on wages). The calculation of the basic salary is presented (produced) in the Table 4.3 below.

Table 4.3 – The calculation of the basic salary

№ п/п	Stage	Performers by Category	Laboriousness, Number of people×days	Salary per one person×days, thousand rubles	Total salary under the tariff (wage), ruble
		Supervisor 1/Docent	1×30	300×30	9,000
		Supervisor 2/Scientific staff	1×26	300×2.6	780
Total: 9 780					

The item includes basic wages of workers directly involved in the implementation of the project (including premiums, bonuses) and additional wages.

$$C_{зп} = З_{осн} + З_{доп} \qquad (4.4)$$

where:

$З_{осн}$ – the basic wage;

$З_{доп}$ – the additional wage.

The basic wage ($З_{осн}$) of scientific supervisor (laboratory staff, student) from the enterprise (in case the scientific supervisor if from the enterprise) is calculated by the following formula:

$$З_{осн} = З_{дн} \cdot T_{раб} \quad (4.5)$$

where

$З_{осн}$ – the basic wage per employee;

$Т_р$ – the duration of work performed by scientific and technical employee, working days. (Table. 4.1);

$З_{дн}$ – the average wage per employee, ruble.

The average wage is calculated by the formula below:

$$З_{дн} = \frac{З_м \cdot М}{F_д} \quad (4.6)$$

where

$З_м$ – monthly salary of the employee, ruble.;

М – the number of working month without absence in a year:

When absence in a duration 24 of working days, then М =11,2 months, 5 – working days per week;

When absence in a duration 48 of working days, then М=10,4 months, 6 – working days per week;

$F_д$ – the annual fund in the actual working time for the scientific-technical personnel, working days (table 4.4).

Table 4.4 – Balance of working time

Indicators of working time	**Supervisor**	**Student**	**Supervisor 2**
Scheduled number of hrs.	30	12,000	2.6
Number of non-working hrs. - weekend - holidays	960	960	
Loss of working time - vacation - absence due to sick	120	0	0
Valid annual fund of working time	0	0	0

The monthly salary of the employee:

$$З_м = З_б \cdot (k_{пр} + k_д) \cdot k_р \tag{4.7}$$

where:

$З_б$ – basic salary, ruble.;

$k_{пр}$ – premium tax fee, (determined by the Regulations on Remuneration);

$k_д$ – surcharges and extra fees factor (in research institutes and in industrial enterprises – for the expansion of the service sector for the professional skills of harmful conditions: determined by the Regulations on the salary for the employee);

$k_р$ – regional factor, equals 1,3 (apply for Tomsk)

The basic salary for the scientific supervisor (in TPU) is based on the new salary system for laborers. The wage system in TPU shows the following composition of wages:

– Wage – determined by the enterprise. The TPU salaries are distributed in accordance with their positions, such as assistant, senior lecturer, associate professor, professor. The basic salary $З_б$ is determined based on the basic of salary, certain staffing enterprise. The basic salary of officers, who are working at TPU, can be found on the university’s portal;

– Incentive payments – determined by the director of enterprises for effective work, additional responsibilities, etc;

– other payments; regional factor;

Additional salary of the research-production personnel

This item includes the amount of benefits provided by the labor legislation, for example, payment for regular and additional holidays; charge time associated with the implementation of state and public duties; payment for compensation for years in service, etc. (on average – 12% of the basic salary).

Additional salary is calculated on the basis of 10-15% of the basic wage of workers directly involved in the implementation of jobs:

$$З_{доп} = k_{доп} \cdot З_{осн} \qquad (4.8)$$

where $З_{доп}$ – additional salary, ruble;

$k_{доп}$ – additional salary factor;

$З_{осн}$ – basic salary, ruble.

In the table 4.5 below shows the norm of calculations for basic and additional salary.

Table 4.5 – Amount of money has to pay for using the scientific and technological information

Wage	**Supervisor**	**Student**	**Supervisor 2**
Basic salary	9 000.00	0	780
Additional salary	1122,73	0	0
Salary of performer	15 713,3		780
Regional factor	1122,73		0
Total by items $C_{зп}$	16 493,3		

4.3 Conclusion

The dissertation was done in a period 12032.6 hrs. totally with the participation of master’s student and the support of two supervisors. In which, the researcher, i.e. the student, who carried out this thesis spending 12000 hrs for working on, the supervisor 1 is 30 hrs and supervisor 2 is 2.6 hrs.

The amount of money had been spent for doing this dissertation is 50 702 ruble totally. Particularly, 18156 ruble is the salary, which had to pay for the supervisor 1; 780 ruble is the wage, which had to pay for the supervisor 2. Overhead cost – 31 759 rubles.

In addition, there are some money also paid for some necessary equipment, which had been used for doing this research, such as computer, notebooks, pen, printing, specific textbook. Totally, it costs 31 790 ruble for all.