FACHHOCHSCHULE KIEL
University of Applied Sciences

Particular Design of Turbo Machines

Final Report - Team EDUR

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Division of Content

The work and written content of this report was divided as follows:

- Carlos Albareda
  - 7.1.1 Cover Disks
  - 7.5 Patents
  - 10. Competitors
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- Andreas Bethke
  - 8. Life Cycle Cost Analysis

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Abstract

This paper details the design process of a pump impeller for use in transporting a three-phase product stream. This design is to be provided to EDUR-Pumpenfabrik and will assist them in creating a new pump for use in a specialized market. Discussed in this paper are various aspects of design including cover disks, dimension calculations, material of construction selection, component selection, and motor selection. The anticipated life cycle costs of this newly designed pump have been estimated and are included. Also detailed in this report is a view of the pump markets with emphasis on European markets, information regarding the competition of EDUR-Pumpenfabrik, information about a potential customer of EDUR, and a web-page design to market the new product.

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4. Preface

This report has been written to EDUR Pumpenfabrik Eduard Redlien GmbH & Co. KG, Kiel, Germany. EDUR agreed to work with the EPS group of Fachhochschule Kiel for the summer 2010 semester program. EDUR has worked with Professor Jensen in the past and this relationship has served team EDUR well while working on this project.

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Andreas Bethke	Carlos Albareda
Ümit Günes	Ryan Ziegler

5. Introduction

The main task of team EDUR was to develop an innovative impeller design that is optimized for pumping a multiphase stream comprising solids, liquids, and gases. Currently there are no pump designs that are fully optimized for handling a stream with three phases and this is why an innovative design is required.

The impeller design process that team EDUR followed is outlined in this report with detailed descriptions of each portion of the design process. Every step of the design phase included consideration of the final intent of the pump design. This was obviously essential because the newly designed pump must be capable of handling three-phase streams and this fact affects every step in the design of the impeller. The impeller design then affects the design and selection of the other components of the pump.

We have conducted a life cycle cost analysis for our newly designed pump. This includes details and descriptions of the many areas that are considered to be a portion of the life cycle costs of a pump. Life cycle costs are an important part of pump design at the pump being manufactured must be reasonably priced so that it can be competitive within the market.

We have researched the global markets relevant to our new pump. As the newly designed pump will be introduced into the German pump market first and then the European market after success in Germany, most of the global marketing research is focused primarily on European markets. However, we have also briefly researched the two largest pump markets outside of Europe as EDUR may desire to enter these markets at a later time.

In an effort to assist EDUR become more competitive within the pump market for three-phase pumps we have collecting information about EDUR's top competitors. The comparison between EDUR and its top-performing competitors may help EDUR recognize some areas that it can improve in. We have also considered the methods that EDUR's competitors use to advertise its multiphase pumps and also gather information about the pumps that EDUR's competitors sell for use in three-phase applications. We have developed a web-page that can be used to advertise our pump design and inform potential customers about the three-phase pump.

6. Background

6.1 EDUR-Pumpenfabrik

EDUR-Pumpenfabrik has been manufacturing pumps since 1927. EDUR manufactures highly specialized pumps that are used in a wide variety of applications, including: water supply, industrial technique, energy technology, cooling technique, process technology, waste water treatment, and marine applications. EDUR has capability to manufacture up to 60,000 different types of pumps and therefore, EDUR can meet almost any customer's needs. [1]

EDUR uses the latest technology in manufacturing its pumps and each pump produced at EDUR is subjected to a series of elaborate tests before it is delivered to the purchaser. These tests are computer controlled and include tests of pressure, tightness, and power input. As a part of the testing process a true characteristic curve is created. Because every pump sold by EDUR is subjected to these tests there is no chance for malfunctioning pumps to be sold. [2]

EDUR is continually working to improve its products and to develop new designs that can be added to its product line. EDUR was awarded the process innovation award during the 2009 ACHEMA for having the most innovative design for a multiphase pump. This is clear evidence of EDUR's dedication to innovation. [2]

The service offered by EDUR-Pumpenfabrik is also a major reason for EDUR's success in the pump manufacturing industry. EDUR provides immediate assistance to existing customers and offers solutions to any problems that may occur. Consulting for the selection of the most suitable pump for specific applications is also provided. EDUR provides quality throughout the entire pump selection and manufacturing process and also offers service to customers that require assistance.

EDUR-Pumpenfabrik has been very successful in the development of multiphase pumps for dissolved air flotation applications. Dissolved air flotation pumps are used to separate suspended solids and emulsified oils from waste streams. EDUR's pump is unique because it is capable of creating air saturated water without the use of an air compressor and this greatly improves the efficiency of the system. [3]

6.2 Application

The application that EDUR would first like to use a three-phase pump for is in a milling machine. More specifically, in a milling machine that is used to create metal parts for the automobile industry. These parts are milled in large quantities and the machine milling process of these parts are often performed in campaigns. Because of the need to successively produce parts within a short time the milling machine uses a cutting fluid to keep the drill from overheating. The cutting fluid is also used as a lubricant and to prevent rusting of the machine parts and thus greatly extends the life of the drill.

Figure 1: Machine Milling Lubrication [3]

The cutting fluid is sprayed onto the drill and the part being machined as can be seen in Figure 1. The milling takes place within an area that contains the cutting oil and allows the oil to collect in the bottom of the machine. Typically, the cutting fluid is then reused after being filtered of debris. After being exposed to the cutting process the fluid contains metal shards from the milling process and air that has been mixed into the solution. This fluid must be pumped from the basin to the location where it is filtered and returned to a reservoir so that is can be used again. Team EDUR has designed a pump that can be used to pump the cutting fluid from the basin to the filtering system. Therefore, the stream that the pump will be used for will contain the cutting fluid, metal shards, and air; a three-phase stream.

The composition of the oil and water mixture that is used in this application is unknown because this information is considered confidential. As the exact cutting fluid that is used in this application is unknown, we assumed that it is similar to common cutting fluids and therefore comprises 80% water and 20% lubricating oil. The composition of the stream has been approximated to contain 85% cutting fluid, 10% solids, and 5% gas. It is expected that the temperature will vary between 15 and 60 degrees Celsius. The pump has been designed for a flow rate of 60 cubic meters per hour and to produce a head of 30 meters.

6.3 Three-Phase Pumps

Pumps exist that are capable of effectively and efficiently transporting streams containing liquids mixed with gases. EDUR is one of the most successful pump manufacturing companies in the field of transporting liquid/gas mixtures. For streams consisting of solids and liquids methods have been developed and improved to be efficient and effective as well. However, when it comes to transporting a stream consisting of the three phases simultaneously there is no method that is both effective and efficient. Pumps that are currently used in three-phase system are either inefficient or incapable of transporting a three-phase system effectively.

When a stream contains solids, liquids, and gases it then contains substances with three different sets of properties. In the application that team EDUR has been asked to design a pump for, the density of the solid is the greatest, the liquid density is the second greatest, and the density of the gas is the smallest. Because of these differences in density the different phases will separate within the stream. The solids will sink and the gases will rise. This is undesirable because it is best if the stream is well-mixed when it enters the eye of the impeller. If the solids enter at the bottom of the eye and the gases at the top the effectiveness of the pump is reduced. Team EDUR has developed a solution to this problem and it can be seen in Figure 8 on page 17.

The pumps used for transporting solids typically require frequent repair and cleaning because solids damage the internals of the pumps. Damage is caused by the solids that flow to the lower pressure areas within a pump. As the stream that is being transported flows through a pump the pressure increases so narrow clearances are required in order to prevent backflow within a pump. As solids move backward through a pump, flowing from high pressure areas to low pressure areas, the clearances within the pump are enlarged as the solids damage the pump internals while being pressed between the moving and stationary parts of the pump essentially grinding the impeller or casing and causing damage that increases the clearances of the pump. The increases clearances greatly reduce the efficiency of the pump as more fluid will be allowed to flow backward through the pump. It will also decrease the outlet pressure of the pump and if the outlet pressure is decreased by too much the pump will no longer produce the required pressures. Solids also cause damage by impacting the pump internals. The extent of the erosive effects depends primarily on the size, material, and impact velocity of the solid particles. Team EDUR has offered a solution to erosion problems; please refer to the impeller material section for details. [4]

7. Pump Design

Pumps are often manufactured to meet specific needs. Because of this there are millions of pump designs. However, every pump fulfills the same basic task of transporting a material stream and because of this there are many common components that are shared among pump designs.

There are two primary types of pumps that operate on different principals. Positive displacement pumps are limited because they have little flexibility in the deliverable capacity. EDUR produces pumps that operate on the principal of kinetics and more specifically, EDUR produces centrifugal pumps.
Centrifugal pumps offer many advantages over other pump designs, some of which are:

- Simplicity
- Low first cost
- Uniform flow
- Low maintenance expense
- Flexibility [5]

Because of these advantages, centrifugal pumps are the pumps most commonly manufactured by EDUR. Centrifugal pumps can also be created to handle a great variety of capacities and materials and this versatility makes this type of pump common in various industries and services. The advantages of centrifugal pumps coupled with EDUR's focus on centrifugal pumps narrowed our focus to designing an impeller for a centrifugal pump.

7.1 Impeller Design

We had the necessity to work with a three-phase flow stream (liquid-solid-gas). Knowing the volume of flow, the required head and the rotational velocity requirements of our pump we were able to discard many designs and focus on designing the necessary attributes of our pump.

7.1.1 Cover Disks

Three types of centrifugal impellers exist: closed, open, and semi-open. The major factor that effects the decision about which impeller to use is that the impeller must be ideal for handling a three phase stream that includes solid components.

We chose not to use a closed impeller because this design could lead to the creation of plugs and lumps. If plugs were to occur, the pump would become inoperative. Also, the pumped material tends to settle out forming a cover on the working surfaces. This leads to a gradual decrease in the area of the passage and a reduction in the capacity of the pump. Please see Figure 2 for an example of a closed impeller. [6,7]

Alternatively, open impeller designs do not suffer as much from these clogging disadvantages because with the rotational movement, the front side of the vanes is continuously self-cleaning. But if scaling and build-up occurs, it is very easy to clean because the vanes are exposed. Please see Figure 3 for an example of an open impeller. [6,8]

Figure 2: Closed Impeller [9]

Figure 3: Open Impeller [10]

Figure 4: Semi-open Impeller [11]

Finally, taking into consideration that the open impellers are mechanically too weak and they are typically lower in efficiency, the best impeller choice for our pump is a semi-open impeller. The vanes are attached to the shaft and strengthened by a backing plate without a cover disk on the front of the impeller. Thus the vanes are exposed on the front of the impeller and shielded at the rear. Please see Figure 4 for an example of a semi-open impeller. [6, 12, 13]

7.1.2 Motor Selection

We were provided with the specific parameters that our pump must operate within and also with the particular service that our pump will be used for. Using the specifications that we have been provided with, we were able to calculate the power that is required to operate our pump. From this we were able to select the appropriate motor to be used for our pump. Our calculation shows us we need 13.15 kW. We chose the "Siemens 1LA6 164 Electric Motor". Power of the electric motor is 15 kW and is suitable for our pump. Also, Siemens is a supplier of EDUR-Pumpenfabrik and is a well known and respected manufacturing company. Please see Tables 1-7 and Figures 5 and 6 below for the details of our selection.

Rated output at		Frame size	Operating values at rated output					
50 Hz	60 Hz		Rated Speed at 50 Hz	Rated torque at 50 Hz	Efficiency Class according to CEMEP	Efficiency at 50 Hz 4/4-load	Efficiency at 50 Hz 3/4-load	Power factor at 50 Hz 3/4-load
P_{rated} kW	P_{rated} kW	FS	n_{rated} rpm	T_{rated} Nm	EFF2	η_{rated} %	η_{rated} %	$\cos\phi_{rated}$
15	17.3	160M	2940	49	EFF2	90	90.2	0.9

Table 1: Electric Motor Selection and Ordering Data [14]

Operating values at rated output	Price	Locked-rotor torque	Locked-rotor current	Breakdown torque	Torque class	Moment of inertia
Rated current at 400V 50 Hz	Weight IM B3 type of construction approx.	with direct starting as multiple of rated				
I_{rated} A	kg	T_{LR}/T_{rated}	I_{LR}/I_{rated}	T_B/T_{rated}	CL	J Kgm^3
40324	105	2.2	6.6	3	16	0.043

Table 2: Electric Motor Selection and Ordering Data 1 (continued)

Noise at rated output	
Measuring surface sound pressure level at 50 Hz	Sound pressure level at 50 Hz
L_{pfA} dB(A)	L_{WA} dB(A)
70	82

Table 3: Electric Motor Selection and Ordering Data 1 (continued)

Penultimate position: Voltage code					
50 Hz				60 Hz	
230VΔ/400VY	400VΔ/690VY	500VY	500Δ	460VY	460VΔ
O	O	O	O	O	O

O Without additional charge

Table 4: Electric Motor Selection and Ordering Data 1 (continued)

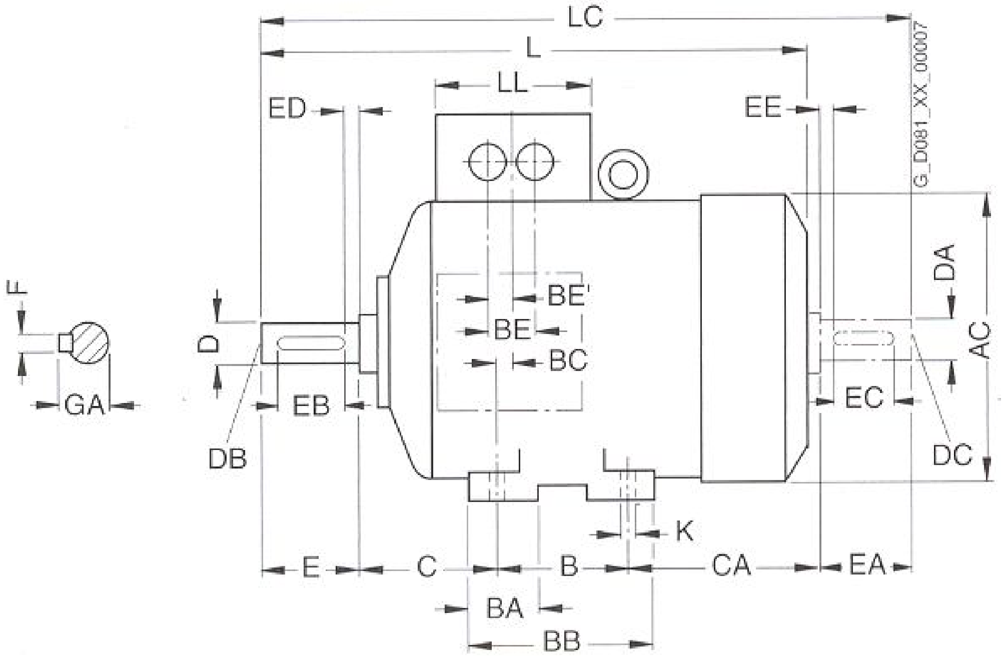

Figure 5: Technical Drawing of Electric Motor 1 [14]

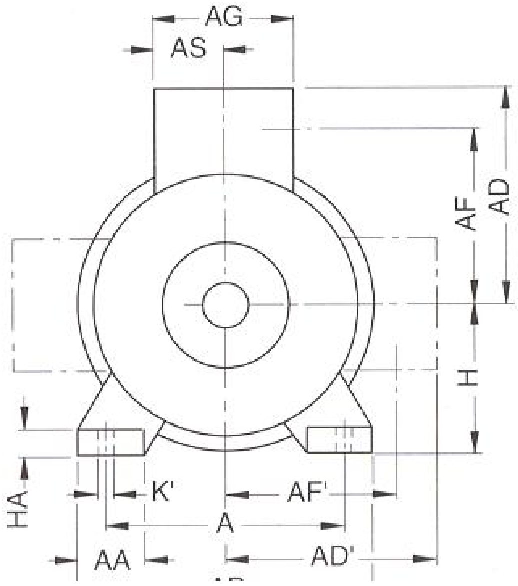

Figure 6: Technical Drawing of Electric Motor 2 [14]

For motor			Dimension designation acc. To IEC									
Frame size	Type	Number of poles	A	AA	AB	AC1)	AD	AD'	AF	AF'	AG	AS
160M	1LA6 164	2,8	254	60	300	320	226	226	183	183	166	83

Table 5: Electric Motor Dimensions [14]

Dimension designation acc. To IEC															
B	BA	BB	BC	BE	BE'	C	CA	H	HA	HH	K	K'	L	LC	LL
210	63	256	52	54	27	108	183	160	18	160	14.5	18	588	721	166

Table 6: Electric Motor Dimensions (continued)

DE shaft Extension							NDE shaft extension				
D	DB	E	EB	ED	F	GA	DA	DC	EA	EC	EE
42	M16	110	90	10	12	45	42	M16	110	92	10

Table 7: Electric Motor Dimensions (continued)

7.1.3 Calculations

From the provided specifications and the requirements of our pump, we were able to calculate the dimensions of our impeller. Professor Jensen provided us with the following formulas and equations.

Given data:

$$n_q = 27$$

$$n = 2900 \frac{1}{min}$$

$$\dot{V} = 0{,}01666 \; \frac{m^3}{s}$$

$$\rho = 1080 \frac{kg}{m^3}$$

$\eta = 0.8$ (Estimated)

1. Specific work Y

$$Y = \sqrt[3]{\left(\frac{333 \cdot n \cdot \sqrt{(\dot{V}}}{60 \cdot n_q}\right)^4} = \sqrt[3]{\left(\frac{333 \cdot 2900 \cdot \sqrt{0{,}01666}}{60 \cdot 27}\right)^4}$$

$$Y = 327.25 \; \frac{Nm}{kg}$$

2. Delivery height H

$$H = \frac{Y}{g} = \frac{327.25}{9.81} = 33.36 \text{ m}$$

3. Requested fluidic power P

a) $\rho = \rho_W \cdot \% + \rho_S \cdot \%$

$$\rho = 1000 \cdot 0.85 + 7200 \cdot 0.15 = 1930 \; \frac{kg}{m^3}$$

b) $P\,[kW] = \left(\rho \cdot \dot{V} \cdot Y\right)^{\pm}$

$$P = (1930 \cdot 001666 \cdot 327.25) = 10.52 \text{ kW}$$

4. Min. Power input

$$P = \left(\frac{\rho \cdot \dot{V} \cdot Y}{\eta}\right) = \left(\frac{1080 \cdot 001666 \cdot 327.25}{0.8}\right) = 13.15 \text{ kW}$$

5. Diameter Number δ (From Figure 7: Cordier Diagram)

$$\delta = 140{,}89 \cdot n_q{}^{-0{,}9648}$$

$$\delta = 140{,}89 \cdot 27^{-0{,}9648} = 5{,}86$$

6. Outer diameter d_2

$$d_2 = \frac{\delta}{1{,}054} \cdot \sqrt[4]{\frac{\dot{V}^2}{Y}}$$

$$d_2 = \frac{5.860}{1{,}054} \cdot \sqrt[4]{\frac{001666^2}{327.25}} = 0.169 \text{ m}$$

7. Outer rotational velocity u_2

$$u_2 = \frac{\pi \cdot d_2 \cdot n}{60} = 25.66 \frac{m}{s}$$

$$u_2 = \frac{\pi \cdot 0.169 \cdot 2900}{60} = 25.66 \frac{m}{s}$$

- $u_{2(\max)} = 35 \frac{m}{s}$
- $u_2 \leq u_{2(\max)}$
- $u_2(\max) = 35 \frac{m}{s}$

8. τ_{zul} of shaft

[Material of shaft = E295]

$$\tau_{zul} = \frac{R_m \text{ of material}}{\text{Ductile yield in [\%]}}$$

$$\tau_{zul} = \frac{490}{20} = 24.5 \frac{N}{mm^2}$$

9. Diameter of shaft d_w

$$\left[R_m \text{ of material} = 490 \frac{N}{mm^2}\right]$$

$$d_w = \sqrt[3]{\frac{16 \cdot P}{\pi^2 \cdot \eta \cdot \tau_{zul}}}$$

$$d_w = \sqrt[3]{\frac{16 \cdot 13.15}{\pi^2 \cdot 2900 \cdot 24.5}} = 0.026 \text{ m}$$

10. Chosen = 0.030 m

[Ductile yield in [%] = 20%]

11. Hub diameter d_n

$$[\beta_0 = 17.5° \text{ (water)}]$$

$$dn = \text{Chosen} + 0{,}01$$

$$dn = 0.030 + 0{,}01$$

$$dn = 0.040 \text{ m}$$

12. Design flow rate

$$\dot{V}^I = 1{,}05 \cdot \dot{V}$$

$$\dot{V}^I = 1{,}05 \cdot 0{,}01666 = 0.0175 \frac{m^3}{s}$$

13. Hub contraction k_n

[Vortex number $\delta = 1$ for perpendicular inflow]

$$k_n = 1 - \left(\frac{d_n}{d_s}\right)^2$$

$$k_n = 1 - \left(\frac{0.022}{d_s}\right)^2$$

14. Inlet diameter d_s

$$d_s = \sqrt[3]{\frac{4 \cdot \dot{V}^I \cdot 60}{\pi^2 \cdot k_n \cdot n \cdot \tan \cdot \beta_0}}$$

$$d_s = \sqrt[3]{\frac{4 \cdot 0.0175 \cdot 60}{\pi^2 \cdot 0.74 \cdot 2900 \cdot \tan \cdot 17.5°}} = 0.086 \text{ m}$$

15. Inlet velocity c_{0m}

$$c_{0m} = \frac{\dot{V}^I}{\frac{\pi}{4} \cdot \left(d_s{}^2 - d_n{}^2\right)}$$

$$c_{0m} = \frac{0.0175}{\frac{\pi}{4} \cdot (0.086^2 - 0.040^2)} = 3.84 \frac{m}{s}$$

16. Impeller width b_1

$$b_1 = \frac{\dot{V}^I}{\pi \cdot d_s \cdot c_{om}}$$

$$b_1 = \frac{0.0175}{\pi \cdot 0.086 \cdot 3.84} = 0.017\ \text{m}$$

17. Inlet vane angle β_1

$$\beta_1 = \arctan\left(\frac{ds \cdot 60}{\pi \cdot C_{0m} \cdot n}\right) \cdot \frac{180}{\pi}$$

$$\beta_1 = \arctan\left(\frac{0.086 \cdot 60}{\pi \cdot 3.84 \cdot 2900}\right) \cdot \frac{180}{\pi} = 16.40°$$

18. Number of vanes z (Pfleiderer)

[$\beta = 30°$]

$d_1 = d_s$

$$z_P = 17 \cdot \sin\beta \cdot \sqrt{\frac{d_1}{d_2}}$$

$$z_P = 17 \cdot \sin 30° \cdot \sqrt{\frac{0.086}{0.169}}$$

$$z_P = 6$$

19. Number of vanes z (Lewinsky)

[k_z=6,5]

$$z_L = k_z \cdot \left(\frac{d_2 + d_1}{d_2 - d_1}\right) \cdot \sin\frac{\beta_1 + \beta_2}{2}$$

$$z_L = k_z \cdot \left(\frac{0.169 + 0.086}{0.169 - 0.0.86}\right) \cdot \sin\frac{16.40° + 28.75°}{2}$$

$$z_L = 8$$

20. Averaged number of vanes (Approximated)

Averaged number of vanes = [z(P leiderer) + z(Lewinsky)]/2 = 7

21. Statical moment of area (SMA)

$$SMA = \frac{1}{2} \cdot (d_2{}^2 - d_s{}^2)$$

$$SMA = \frac{1}{2} \cdot (0.169^2 - 0.086^2) = 0.003\ \text{m}^2$$

22. Unsuf icient output factor (UOF)

$$\text{UOF} = \frac{0.347}{\text{Averaged number of vanes} \cdot \text{Statical moment of area}}$$

$$\text{UOF} \frac{0,6 \cdot \left(1 + \frac{\beta_2}{60}\right) \cdot \left(\frac{d_2}{2}\right)^2}{\text{Averaged number of vanes} \cdot \text{Statical moment of area}}$$

$$\text{UOF} = \frac{0,6 \cdot \left(1 + \frac{28.75^\circ}{60}\right) \cdot \left(\frac{0.169}{2}\right)^2}{7 \cdot 0.003} = 0.347$$

23. Impeller width b_2

$$b_2 = \frac{\dot{V}^I}{\pi \cdot d_2 \cdot c_{0m}} \cdot \frac{t_2}{t_2 - \sigma_2}$$

$$b_2 = \frac{0.0175}{\pi \cdot 0.169 \cdot 3.84} \cdot 1.025 = 0.009 \text{ m}$$

24. Spec. work on vanes (SWV)

$$\text{SWV} = Y \cdot \frac{1 + \text{unsuf icient output factor}}{\text{hyd. Ef iciency}}$$

[hyd. Ef iciency = 0.85 (choosen)]

$$\text{SWV} = Y \cdot \frac{(1 + \text{unsuf icient output factor})}{\text{Hyd. Ef iciency}}$$

$$\text{SWV} = \frac{327.25 \cdot (1 + 0.347)}{0.85} = 518.60 \frac{\text{Nm}}{\text{kg}}$$

25. Outer rotational velocity u_2

$$u_2 = \sqrt{\left(\frac{C_{0m}}{\tan\beta_2}\right) + \left(\frac{C_{0m}}{2 \cdot \tan\beta_2}\right)^2 + \text{spec. work on vanes}}$$

$$u_2 = \sqrt{\left(\frac{3.84}{\tan 28,75^\circ}\right) + \left(\frac{3.84}{2 \cdot \tan 28,75^\circ}\right)^2 + 518.60} = 26.34 \frac{\text{m}}{\text{s}}$$

- $u_{2(\mathrm{max})} = 35 \frac{\mathrm{m}}{\mathrm{s}}$
- $u_2 \leq u_{2(\mathrm{max})}$

26. Inner rotational velocity u_1

$$u_1 = \frac{\pi \cdot d \cdot n}{60}$$

$$u_1 = \frac{\pi \cdot 0.086 \cdot 2900}{60} = 13.06 \frac{\text{m}}{\text{s}}$$

27. Outlet vane angle β_2

$$\beta_2 = \arctan\left(\frac{\dot{V}^I \cdot \eta}{b_2(u_2^2 - (Y_{sch\infty} + u_1 \cdot c_{ou}))} \cdot \frac{t_2}{t_2 - \sigma_2}\right) \cdot \frac{180}{\pi}$$

$$\beta_2 = \arctan\left(\frac{0.0175 \cdot 2900}{0.009 \cdot (26.34^2 - 518.60)} \cdot \frac{t_2}{t_2 - \sigma_2}\right) \cdot \frac{180}{\pi} = 28.75°$$

$$\overline{OM}^2 = r_1^2 + \rho^2 - 2 \cdot r_1 \cdot \cos\beta_1$$

$$\overline{OM}^2 = r_2^2 + \rho^2 - 2 \cdot r_2 \cdot \cos\beta_2$$

$$\rho = \overline{MA} = \frac{1}{2} \cdot \left(\frac{r_2^2 - r_1^2}{r_2 \cdot \cos\beta_2 - r_1 \cdot \cos\beta_1}\right)$$

- $r_1 = \frac{d_1}{2} = \frac{0.086}{2} = 0.043$ m
- $r_2 = \frac{d_2}{2} = \frac{0.169}{2} = 0.086$ m

$$\rho = \overline{MA} = \frac{1}{2} \cdot \left(\frac{0.086^2 - 0.043^2}{0.086 \cdot \cos(28.75°) - 0.043 \cdot \cos(16.40°)}\right)$$

$$\rho = \overline{MA} = 0.081 \text{ m}$$

e (thickness of the impeller plate) = 0.004m

s (thickness of the impeller vane) = 0.004m

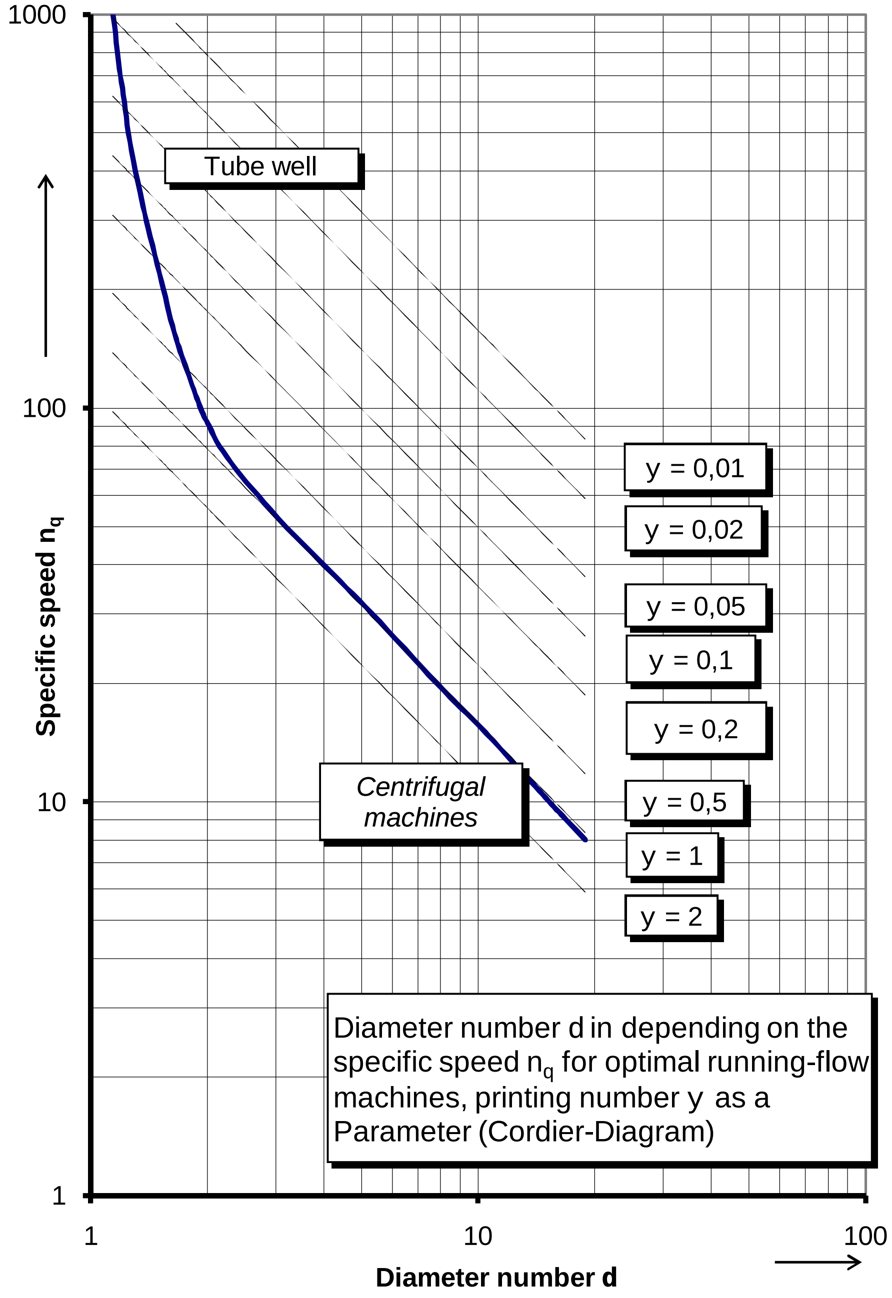

Figure 7: Cordier Diagram [Provided by Professor Jensen]

7.1.4 Drawings and Features

From Figure 8 it is obvious that our design is unique. Firstly, the eye of the impeller is shaped so that gas will not be able to accumulate at that point and will be transported with the solid and liquid materials. Also note that the inlet to the pump has a slightly decreased diameter so that the velocity of the incoming stream is increased before entering the impeller. This is so that the solids are set of a trajectory towards the eye of the impeller at an increased speed. This will ensure that the solids are transported along with the liquids and gases in the stream.

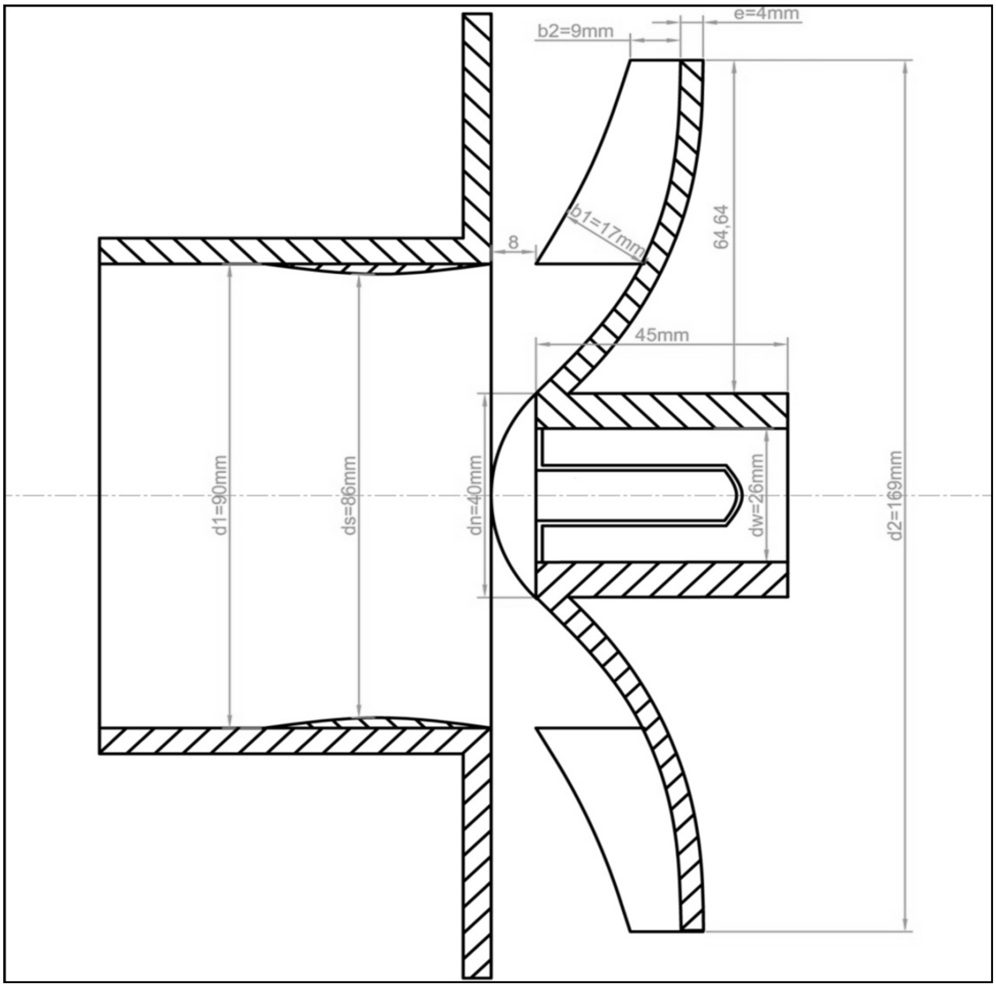

Figure 8: 2D Drawing of Impeller

We have also drawn a 3D version of our impeller that can be seen in Figure 9 and Figure 10.

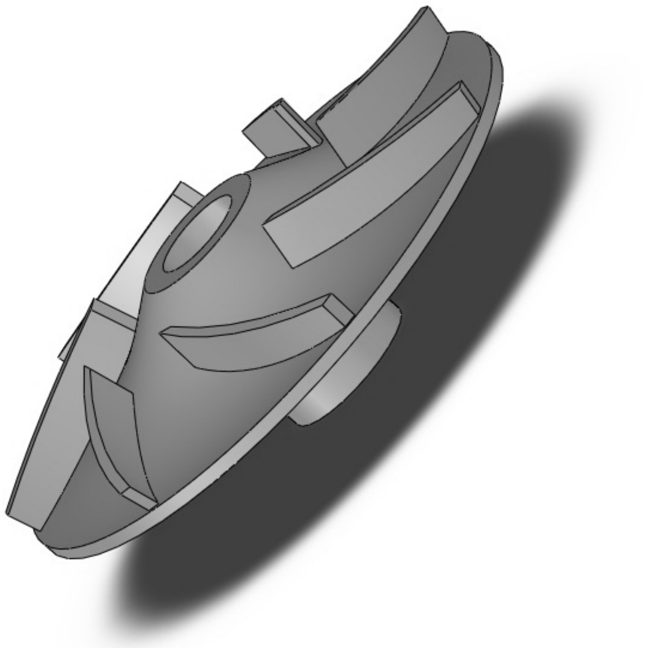

Figure 9: 3D Drawing of Impeller

Figure 10: 3D Drawing of Impeller (Alternate View)

7.2 Impeller Material

Material selection is an essential aspect of pump design because if the wrong material is selected it can lead to rapid destruction of the pump. Improper selection that leads to the destruction of the pump incurs many costs. There is of course the direct cost of repairing the existing pump or purchasing a new pump. There are many more indirect costs that can often cost more than the direct costs. These include: production losses due to outage, products that are of low quality, and possibly contamination of products. Corrosion is the most common cause of pump destruction and was the most important consideration of team EDUR in the material selection process. [15]

7.2.1 Corrosion

Corrosion can be defined as the "destructive attack upon a metal by its environment or with sufficient damage to its properties, such that it can no longer meet the design criteria specified"-[15, pg 25-4]. In its most common form this is known as rust. Any non-alloyed ferrous material will experience corrosion when exposed to water. Iron ions break off of the material and connect with hydroxide ions that are provided by the water. This process creates iron hydroxide which, if the water is calm, will form a protective layer over the material. However, if the water is not calm, this process will continue because a level of saturation is never reached and the reaction continues. The continual loss of iron atoms from the material is what destroys the structure and renders the structure ineffective. [15, 16]

The rate at which corrosion takes place is based on several factors. The temperature of the water has an important role in the rate of corrosion. At increased temperatures the corrosion is more aggressive. This is because the solubility of oxygen increases with increasing temperature. The proportion of oxygen in the water also impacts corrosion rates and severity. The pH value also has a major role and the greater the pH value the lower the rate of corrosion. This can be seen in Figure 11. The dashed line in the figure demonstrates the increased corrosion that occurs with very high temperatures. [15]

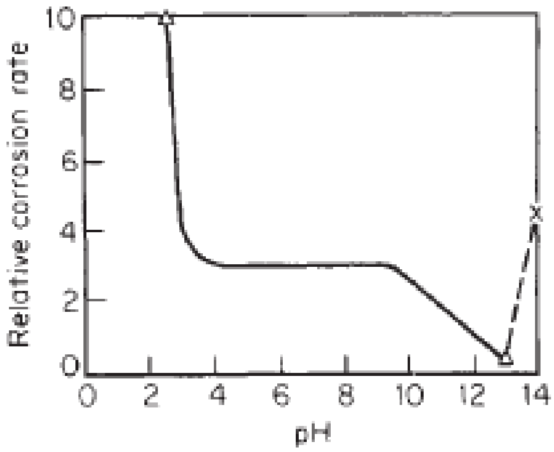

Figure 11: pH versus Corrosive Rate [15]

EDUR also offers a copper-tin-bronze material. This material is suited for water systems as it is not subject to rust as it contains no iron. Bronze is only subject to corrosion when: the pH value is below 3, ammonia is present in the water, or if the material is in the presence of desalted water at a temperature above 70 degrees Celsius. There is no limit on high pH values. [16]

Stainless steel is the third material commonly offered by EDUR. This material contains a portion of chrome. The chrome oxidizes when exposed to oxygen and creates a layer over the material. This layer is impermeable and provides much greater protection than the layer that can be created from an iron-oxide. Corrosion can still take place if the layer is not created and in another form termed crevice corrosion. Crevice corrosion can take place if there is insufficient oxygen to create the protective layer within narrow gaps. There are also issues with corrosion in the presence of chloride ions. The presence of chloride ions becomes a greater problem at higher temperatures. [15, 16]

EDUR uses three primary types of material for the production of its impellers. Material selection is particular to every pump that is produced by EDUR as the contents and conditions of every material to be transported by the pump must be considered. The next sections provide more detail about the material categories offered by EDUR.

7.2.2 Gray Cast Iron

Gray cast iron is a material that is commonly used for impellers and casings. The material is the least expensive among the materials offered by EDUR and it can be shaped into nearly any form. It comprises carbon, silicon, manganese, and iron and the strengths of these castings are varied by varying the size, amount, and distribution of the carbon within the cast iron. Gray cast iron has a great ability to absorb vibration and has a large resistance to wear. It is a brittle material with little tolerance for impact. It must be considered that gray cast iron is subject to corrosion when exposed to water and oxygen. [15, 16]

7.2.3 Bronze

The bronze used by EDUR is a pure copper-tin bronze. The composition is approximately 86% copper, 12% tin, and 2% mixture of several other elements. [8] 17 This bronze is known to have a good resistance to wearing and corrosion. It is known as a cast phosphor bronze because phosphorus is used as a deoxidizing agent in the casting process. An important factor to consider when considering the use of bronze in a process is that it cannot be used in combination with pipes made of iron. [16, 18]

7.2.4 Stainless Steel

Stainless steel is an alloy that is iron based with chromium as the two primary additions. Stainless steel is easily fabricated into complex shapes and is very popular within process industries. EDUR offers a super duplex stainless alloy that is 25 percent chromium. With this amount of chromium comes an excellent resistance to stress-corrosion resistance. [15]

7.2.5 Coatings

There is also the possibility of coating the materials that are used for this application. Coatings serve as a layer of protection against corrosion as no liquids will come into contact with the material and thus not allow oxidization to occur. In addition to protecting against corrosion, the coating also protects against the damage of erosion. There are also coatings available that improve the efficiency of the pump as they provide a smooth surface that allows fluids to pass easily over the coated surfaces. [19]

A wide variety of coating materials are available. Many are hard coatings made of various metals such as chrome, aluminum, tungsten, and ceramic. These materials are commonly used to repair impellers and pumps to their original dimensions and performance. There are also softer materials that can be used as coatings, such as polymers and rubbers that can be applied to pump internals. [20]

From an experiment performed testing thirteen materials and studying the effects they had on reducing abrasion and erosion of the impeller we were able to learn of the performance of the available coating materials. Three materials proved to be effective in resisting wear during preliminary tests and further tests were conducted for these materials. A polyurethane material with a hardness of 83 (Shore A scale), a fluid elastomer with a hardness of 85, and a rubber material with a hardness of 62 were selected. See Table 8 for further properties. A martensitic stainless steel (SUS403) was used as a reference material.

Properties of lining materials

Material		Detail	Density ($g\ cm^{-3}$)	Shore hardness A	Tensile strength (MPa)	Tear strength ($N\ cm^{-1}$)	Elongation (%)
B	Polyurethane	Two-liquid mixture	0.57	83	10	160	400
F	Fluid elastomer	Two-liquid mixture	0.95	85	14	600	550
H	Rubber	Synthetic soft rubber	1.11	62	16	780	400

Table 8: Properties of Lining Materials [21 pg. 213]

From Figure 12 we can see the profiles of the surface of the materials that were subjected to a jet test with silica as the abrasive agent. We can see from this figure that rubber suffered the least during this test while the elastomer had slightly worse performance. Note that the polyurethane was only tested for a duration of 1.5 hours and the steel had a duration of only 0.75 hours under the same conditions.

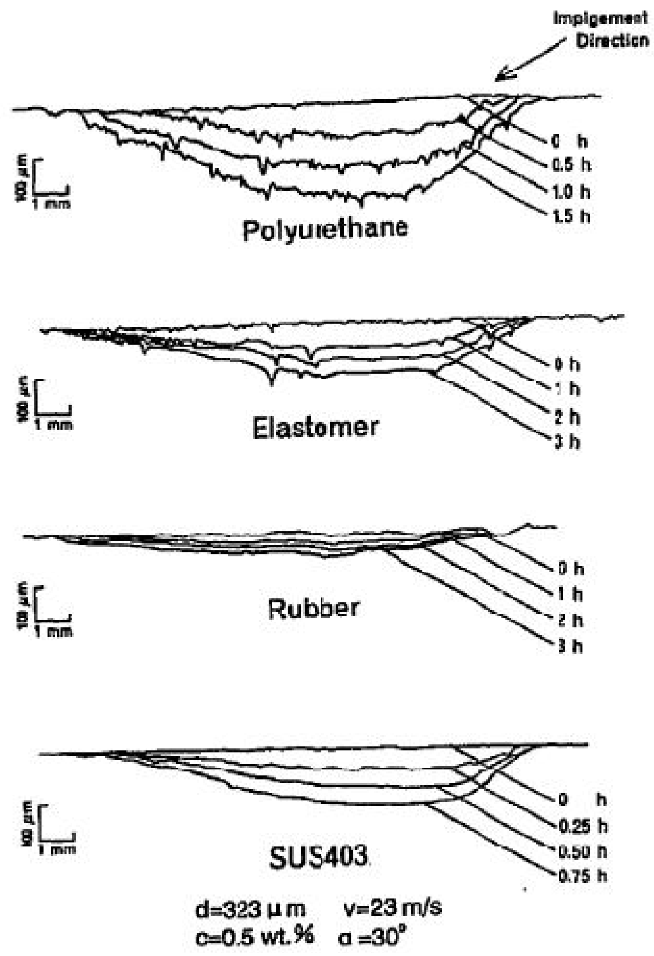

Figure 12: Wear Depths [21 pg. 213]

From Figure 13 one can compare the maximum wear depths as a function of time for the different materials. Figure 14 shows the impact that varying the diameter of the solid particle has on the wear rate of the various materials.

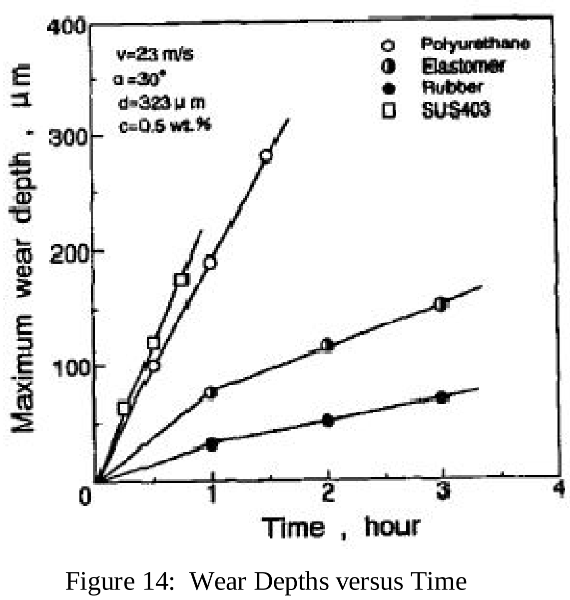

Figure 14: Wear Depths versus Time [21 pg. 213]

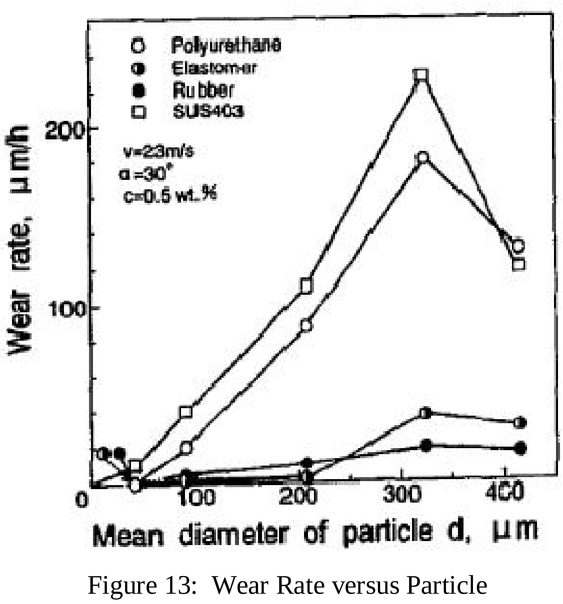

Figure 13: Wear Rate versus Particle Diameter [21 pg. 214]

In comparing the materials tested, rubber consistently outperformed the polyurethane and elastomer materials. Rubber has the greatest ability to absorb impact energy and the ability to stretch before failure. The tear strength is what makes rubber the best suited material for use in abrasive applications with the elastomer being the second best performing material. Both the elastomer and the rubber demonstrated better performance than the stainless steel. [21]

7.2.6 Impeller Material Conclusion

Upon consideration of the construction materials most commonly offered by EDUR, team EDUR has chosen to use a nodular cast iron (EN-GJS-400-15) as the material for the impeller. EN-GJS-400-15 cast iron is usually the least expensive material offered by EDUR. The prices of the materials vary depending on the quantity of material purchased by EDUR as well as with market changes; this is why the term “usually” is used.

EN-GJS-400-15 cast iron is characterized as having a very good machinability. But it is also noted as having a low resistance to wear. Because of the material’s low resistance to wear and its susceptibility to corrosion the impeller will be coated with an elastomeric material. An elastomeric material was chosen because natural rubber is not suitable for use with oils while elastomers tend to have more tolerance to process streams containing oils [22 pg 9,55]. We expect the coating will protect the impeller from the effects of erosion, improve the efficiency, and protect the impeller from experiencing the effects of corrosion. [23]

Bronze is typically more expensive than cast iron. The same is true for stainless steel, which is typically the most expensive. Bronze and stainless steel are both more resistant to corrosion than cast iron but it is expected that a coated impeller will show greater resistance to erosion than would an uncoated bronze or stainless steel impeller. Therefore, a cast iron impeller with an elastomer, such as Neoprene®, coating is the best choice for the material of construction for the pump internals.

7.3 Sealing Selection

The selection of the sealing method required consideration of the following items:

- Pressure

    - The pressure on the inside of the pump is expected to be approximately 68.3 psi (47.088 kPa). This allows the use of an unbalanced seal.
- Temperature
    - As the temperature of the stream is expected to be between 15 and 60 degrees Celsius, this will allow for almost any material to be used for the seal.
- Lubrication
    - The contact surfaces of the two plates of the seal will experience rubbing and lubrication is required for this contact. The fluid in the application of this pump contains a percentage of oil and this will act as the lubricant for the two surfaces.
- Abrasion
    - For most applications with fluids containing an abrasive it would be best to have a flushed seal. However, a flushed seal is not an option for this pump application because no further material can be allowed into the process stream.
- Corrosion
    - The same process can be used here as was used in the selection of the impeller material. As there is water in this application, cast iron must not be used in this application unless protected against the effects of corrosion. [24]

There are two classifications of mechanical seals; internal and external. Internal seals have all parts of the seal exposed to the fluid which allows for high pressure applications, protection of seal part from damage by external conditions, and this allows for a shorter shaft length than would be required from on external seal. [24]

External seals are not exposed to the process fluid. This protects the seal components from damaging process fluids and allows for the selection of internal seal components without paying consideration to the process fluid. [24]

7.3.1 Materials

Seal components are offered in an immense number of options. Material selection is again based on the process conditions (pressure, temperature, composition, etc.) with corrosion being a major consideration. Seal faces are commonly constructed of carbon. Carbon is widely compatible with chemicals and process components but special consideration is required when carbon will be exposed to strong oxidizing agents and/or air at above 316 degrees Celsius. [24]

7.3.2 Sealing Selection Conclusion

Team EDUR has decided that an internal simple mechanical seal will suffice for use within this application. Please see Figure 15 below for an illustration of a simple mechanical seal. A carbon face will be adequate for this application and the other seal components must be constructed of a corrosion resistant material.

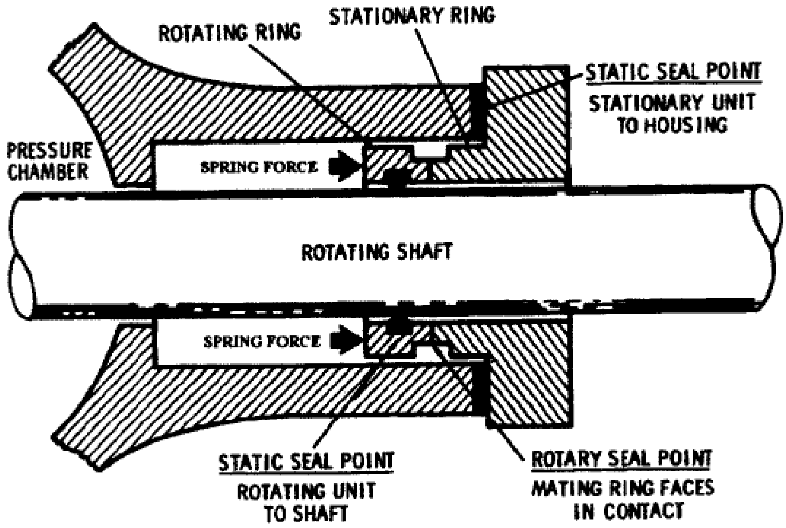

Figure 15: Diagram of Sealing [25]

As there are many types of seals available that meet these non-specialized requirements the choice of which particular seal to use will be determined by EDUR once the time for manufacturing of this pump has been decided. However, to provide a more detailed example of a seal that might be used in this application below is a picture in Figure 16 of a simple mechanical seal that is offered by EagleBurgmann®, a common supplier of seals for EDUR. [26]

Figure 16: EagleBurgmann H10 [26]

H10

- Single seal
- Balanced
- Multiple springs
- Compact

7.4 Bearing Selection

The purpose of a bearing is to provide a support for a rotating shaft. The bearing must offer low friction support in order to maintain efficiency within the system. Team EDUR was asked two select between two of the primary types of bearings that are commonly used for pump applications; plain bearings and bearings with a rolling element. [27]

Plain bearings are also commonly called sleeve bearings or journal bearings. They are the simplest type of bearing used and typically the less expensive option. They consist of a cylinder that surrounds the shaft that will the rotating and supported device. For a diagram see Figure 17 below [28]. Most plain bearings also have some form of lubrication, although dry bearings are available for specific applications. These bearings can be customized to any application and are available in many different types of materials. Plain bearings have advantages over rolling element bearings such as; quiet operation, predictable failure rates (determined only from experience), can be developed to tolerate excessive moisture and even submersion, and can also be used in applications with extreme temperatures. However, there are disadvantages such as greater friction and a smaller load capacity. [27]

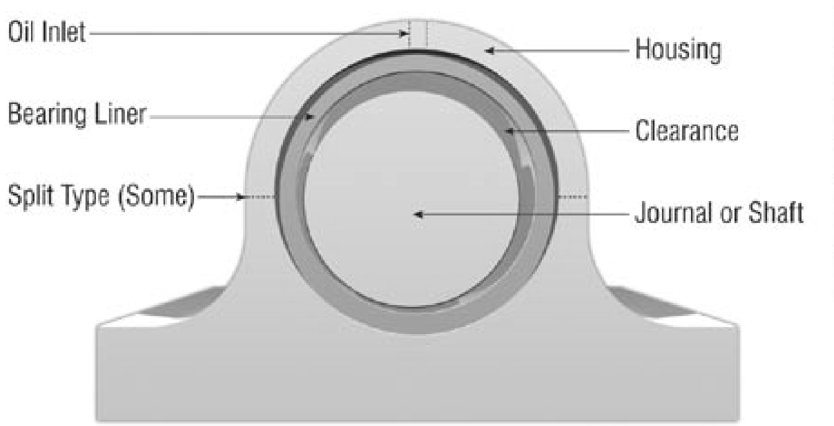

Figure 17: Diagram of Journal Bearing [28]

Rolling element bearings have an inner ring, outer ring, and rolling elements (balls or cylinders) that are held within a form of separator. There are advantages and disadvantages for ball bearings and roller bearings. The advantages of ball bearings are: low friction (and thus small amount of heat generation), capable of handling radial and thrust loads, and low cost. But in comparison to roller bearings, they also have a lower life expectancy. Roller bearings offer a greater load capacity and fatigue life. Examples of rolling element bearings can be seen in Figure 18 and Figure 19.

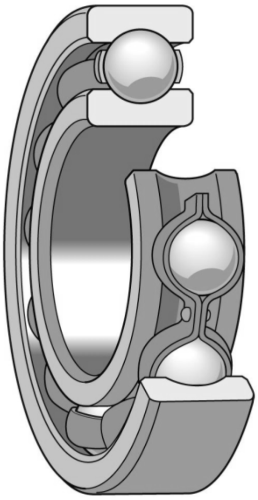

Figure 18: Ball Bearing [29]

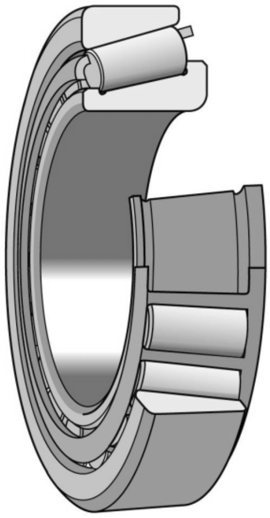

Figure 19: Tapered Roller Bearing [29]

Team EDUR has decided that a ball bearing used in combination with a tapered roller bearing is best for this application primarily because of the better efficiency in comparison to a sleeve bearing. As efficiency is becoming a more important factor in all manufacturing industries team EDUR decided optimal efficiency would be desired by anyone purchasing a pump from EDUR. A ball bearing used in combination with a tapered roller bearing will also have the capacity to handle both radial and axial thrust and as our pump design includes a semi-open impeller, both forms of thrust will be acting upon the bearing and must be accommodated. Please refer again to Figure 18 and Figure 19 for an example of a ball bearing and a tapered roller bearing.

7.5 Patents

Thousands of patents exist for pump designs that are specific to transporting multiphase streams. This great number of patents makes it difficult to determine if our design is guilty of infringement. We have researched many patents and have not found any that claim our ideas as intellectual property. However, we were unable to search and study every patent. This is an important item that professionals from EDUR-Pumpenfabrik will have to investigate further to ensure they will not be guilty of patent infringement if they produce our impeller design.

8. Life Cycle Cost Analysis

8.1 What is Life Cycle Costing?

Life cycle costing is an instrument for controlling costs. It is a technique to establish the total cost of ownership. The two main results of a life cycle cost analysis are:

- the minimization of costs and optimization of revenues and
- the minimization of risks and effects on the environment.

The concept of the so called life cycle costing was initially used for the planning of very big projects like power stations. Nowadays the life cycle cost analysis is used to analyse the economy of products and also to decide between selections of big capital goods. Life cycle costing is a structured approach that addresses all the elements of this cost and can be used to produce a spend profile of the product or service over its anticipated life-span. Considered is the whole product lifecycle from “the cradle to the grave”. This makes sense nowadays, because the product life cycles have become short. Life cycles between two and five years are not rare. Only the negative cash flows (expenditures) are of interest and the proceeds (revenues) are neglected. The results of a life cycle cost analysis can be used to assist management in the decision-making process where there is a choice of options. The accuracy of a life cycle cost analysis diminishes as it projects further into the future, so it is most valuable as a comparative tool when long term assumptions apply to all the options and consequently have the same impact. [30, 31, 32, 33]

8.2 Why is Life Cycle Costing Important?

The visible costs of any purchase represent only a small proportion of the total cost of ownership. Total cost of ownership is an accounting method that helps consumers and businesses to estimate all its costs of capital goods. The idea is to get a statement that not only contains the initial costs but all aspects of a later use, for example energy costs and maintenance and repair costs of the relevant components. In many departments the responsibility for acquisition cost and subsequent support funding are held by different areas. There is less or no incentive to apply the principles of life cycle costing to purchasing the policy. Therefore, the application of life cycle costing does have a management implication, because the purchasing units are unlikely to apply the rigours of the life cycle cost analysis, unless they see the benefit resulting from their efforts. There are four major benefits of life cycle cost analysis:

- evaluation of competing options in purchasing
- improved awareness of total costs
- more accurate forecasting of cost profiles
- performance trade-off against cost

Evaluation of competing options in purchasing means that the life cycle cost analysis allows the evaluation of competing proposals on the basis of total life costs. The life cycle cost analysis is relevant to most service contracts and equipment purchasing decisions.

Improved awareness of total costs means that the application of the life cycle cost analysis provides management with an improved awareness of the factors that drive cost and the resources required by the purchase. It is important that the cost drivers are identified. In this way most management effort is applied to the most cost effective areas of the purchase. And the awareness of the cost drivers will also highlight some areas in existing items which would benefit from management involvement.

More accurate forecasting of cost profiles is the application of the life cycle cost analysis that allows the full cost associated with a procurement to be estimated more accurately. That leads to improved decision making at all levels, for example major investment decisions, or the establishment of cost effective support policies. The life cycle cost analysis also allows more accurate forecasting of the future expenditure to be applied to long-term costing assessments.

Performance trade-off against cost means that cost in purchasing decisions is not the only factor that is considered when assessing the options. There are other factors, such as the overall fit against the requirement, the quality of the goods and the levels of service which is provided. The life cycle cost analysis allows for a cost trade-off to be made against the varying attributes of the purchasing options. The figure below shows the most important costs of the life cycle cost analysis. [30, 34, 35]

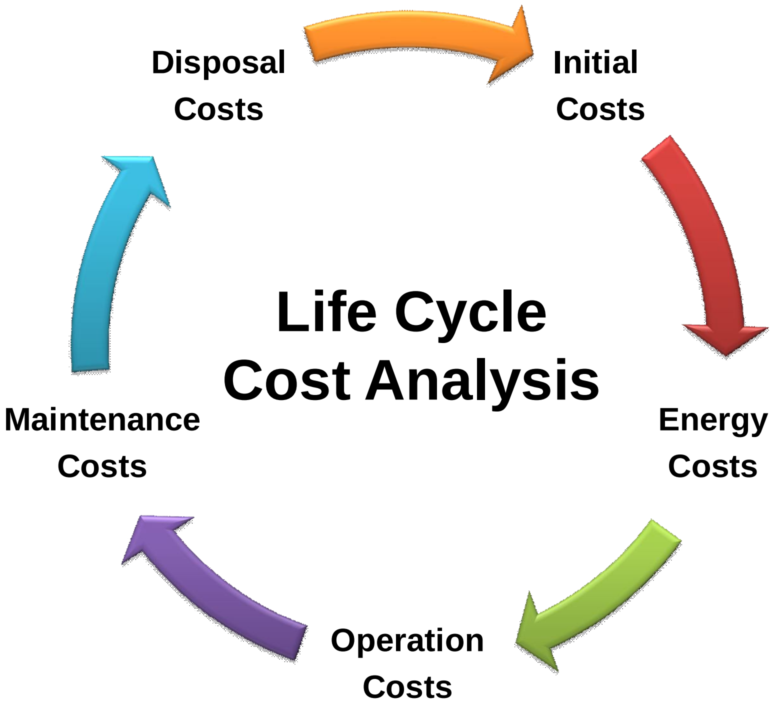

Figure 20: Life Cycle Cost Analysis

„The method of life cycle costing aims at the optimizing of the total costs and proceeds of a system and the those connected activities and processes that come into being in this Life cycle.“ [VDI 2884] [36]

8.2.1 Advantages

- Considers future periods and therefore creates a realistic picture of the deposits and payments or costs and revenues
- Provides support of strategic decisions in the earlier stages of the product life cycle
- Time value of money is taken into account (in the investment-approach)
- The concept of the contribution margin usually provides the requested information of the cost calculation

8.2.2 Disadvantages

- Product life cycle is an ideal concept but not always implementable
- Planning and forecasting of cash flows is fraught with uncertainties
- For IT systems and cost accounting procedures it is rather strange and may be implemented with more effort [37]

8.3 Perspectives

Life cycle costing can be viewed from two different perspectives, from the perspective of the producer or from the perspective of the customer. From producers' point of view one's own total costs and the costs incurred by the customer are identified. Even before production, the producer should consider several options and should choose the cheapest. Also of interest to companies is the perspective of the customer, which often is neglected despite increasing focus on customers. The customers are not interested in development costs or production costs but only their own costs from acquisition to disposal. Through targeted information, the economic and ecological benefits of the product can be communicated to the customer. One way to reduce the operating costs of customers could, for example, be a guarantee. It reduces the possible repair costs. To reduce the disposal costs back guarantees or recycling facilities could be contributed. But this decreasing in costs of the customer will increase the costs of the producer.

8.3.1 Producer's Perspective

- Product development and formulation
- Design
- Process development
- Production
- Logistics

8.3.2 Customer's Perspective

- Procurement
- Support of the manufacturer
- Training and testing
- Maintenance
- Disposal [32, 34, 35]

8.4 Procedure

At a purchasing there is often a selection of several options. Life cycle costing considers not only the initial costs, but also the cost of use (e.g. personnel costs, maintenance costs, repair costs, energy costs and consumption costs) and the disposal costs of a product.

8.4.1 The First Option

The first option appears at first glance quite favourable and the initial costs are low. The consumer buys this product but he is faced with high operating costs and disposal costs.

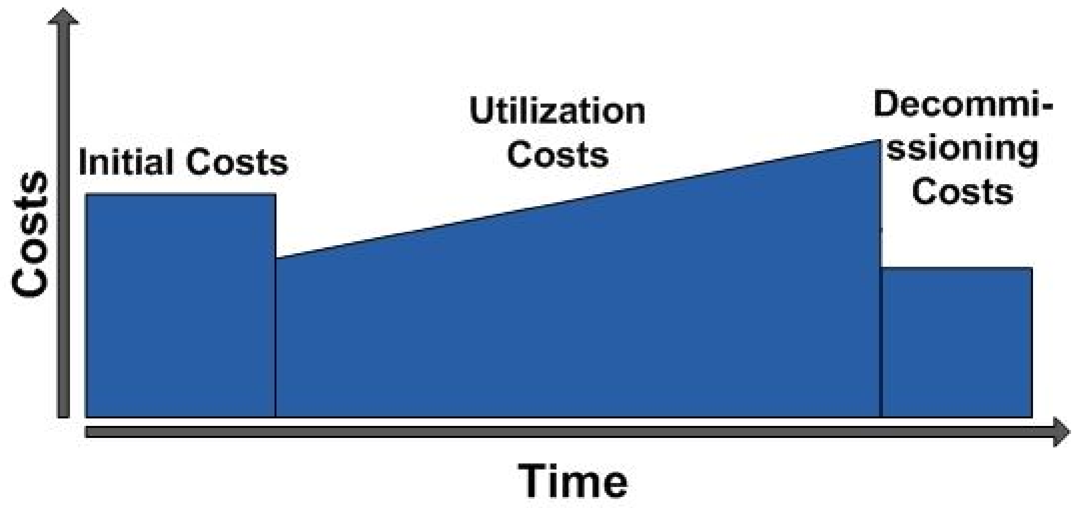

Figure 21: First Option of LCC

8.4.2 The Second Option

The second option makes a product appear more expensive because of the high initial costs. But because of the low following costs there is a balance, the so-called trade-off. This trade-off can only be detected by the life cycle cost analysis.

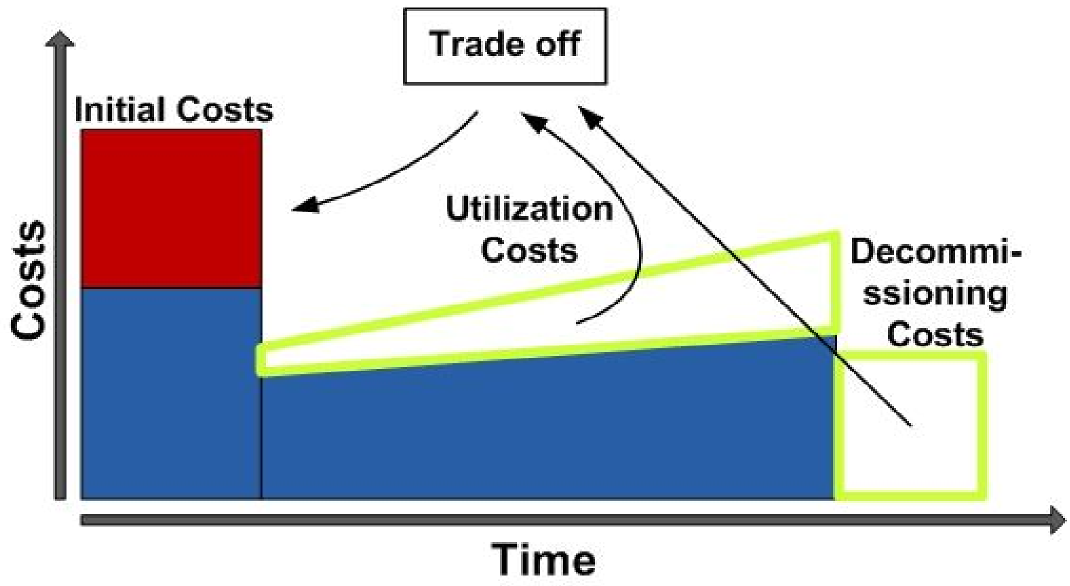

Figure 22: Second Option of LCC

8.5 The Calculations

This report describes the development of a technical product, a new pump system. Some studies have shown that 30% to 50% of the energy consumed by pump systems could be saved through equipment or control system changes. The life cycle cost process is a way to predict the most cost-effective solution. It does not guarantee a particular result, but it allows the plant manager to make a reasonable comparison between alternate solutions within the limits of the available data. Therefore the equation and defined terms below include the many areas of cost that must be considered. [38]

LCC = Life Cycle Cost

$LCC = C_{ic} + C_{in} + C_e + C_o + C_m + C_{env} + C_d$

C_{ic} = Initial costs, purchase price (pump, system, pipe, auxiliary services)

C_{in} = Installation and commissioning costs (including training)

C_e = Energy costs (predicted cost for system operation, including pump driver, controls, and any auxiliary services)

C_o = Operation costs (labor cost of normal system supervision)

C_m = Maintenance and repair costs (routine and predicted repairs)

C_{env} = Environmental costs (contamination from pumped liquid and auxiliary equipment)

C_d = Decommissioning/Disposal costs (including restoration of the local environment and disposal of auxiliary services)

For some calculations we must use values which be based on empirical coefficients. In some cases we didn’t get real numbers of the companies because of the confidentiality of private financial information. Because of this, some calculations are shown only to provide examples and are rough estimates of expected costs. The figure below shows the whole life cycle of a product and the several costs for each topic. [39]

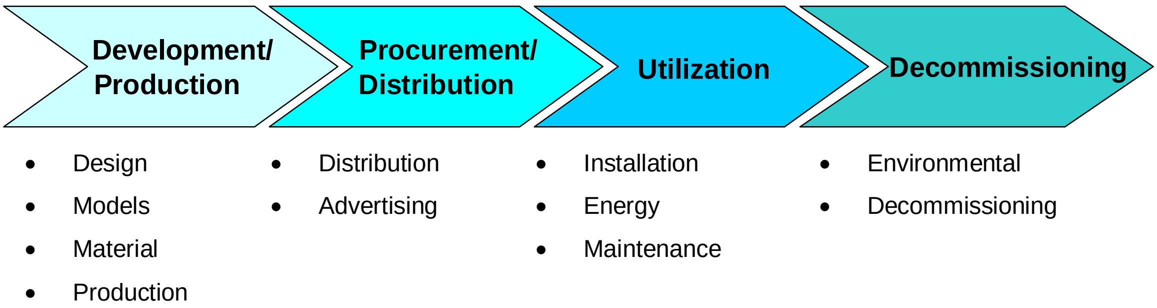

Figure 23: Life Cycle Costing

8.5.1 Initial Costs

The initial costs of a pump new pump design and installation will include the following items:

- Engineering (e.g. design and drawings, regulatory issues)
- The bid process
- Purchase order administration
- Testing and inspection
- Inventory of spare parts
- Training
- Auxiliary equipment for cooling and sealing water [39]

8.5.1.1 Design Costs

Design costs are a particular kind of development cost that arises at design and implementation of technical innovations, for example in the field of engineering or steel-construction. In many cases it is possible to load the individual contracts directly. These are special direct costs of production. Where this is not possible, the design costs will in proportion be charged as manufacturing overhead on the involved manufacturing jobs. In larger companies, which have their own design offices, the costs will be collected in an indirect cost center. The cost of design supplies will be an additional charge in the distribution costs. [40]

Calculation:

duration * hourly wage = **design costs**

10 h * 35 €/h = **350 €**

8.5.1.2 Model Costs

Model costs are counted to the growing costs of wages and material. For the calculation system they are seen as special single costs of production. If the models are used in several accounting periods, a temporal distinction is necessary if they will not be considered for the depreciation. [41]

Calculation:

duration * hourly wage = **model costs**

3 h * 35 €/h = **105 €**

8.5.1.3 Material Costs

Material costs belong to those costs that are incurred for the use of materials within the service. The use of material is the consumption of materials within an accounting period. The term material is used in manufacturing services, repair services, assembly services and in other service industries. Material costs consist of raw materials which are the major components of the product, and auxiliary materials which are important for the character of the product but not so important for the costs. The problem with the material costs is that the metal prices change every day. In our case for example the metal GGG 40 costs about 645 € per 100 kg. [42, 43]

The material costs are calculated from the sum of material costs:

Direct material costs:

Impeller: Weight * metal price (GGG40)
1.34 kg * 6.45 €/kg = 8.64 €
+ 50% of the impeller costs for the †coating:
0.5 * 8.64 € = 4.32 €
8.64 € + 4.32 € = 12.96 €

Casing: Weight * metal price (GGG40)
13.4 kg * 6.45 €/kg = 86.43 €
+ 50% of the casing costs for the †coating:
0.5 * 86.43 € = 43.22 €
86.43 € + 43.22 € = 129.65 €

†Shaft: ≈ 100 €
†1 Sealing: ≈ 165 €
†1 Bearing: ≈ 20 €
†1 Bearing: ≈ 25 €
†1 Motor: ≈ 130 €
→ Direct material costs: 582.61 €

†All these values are estimations provided by Professor Jensen

[†]Indirect material costs:

≈ 10% of direct material costs

0.1 * 582.61 € = 58.26 €

→ Indirect material costs: 58.26 €

Direct material costs:	582.61 €
+ Indirect material costs:	58.26 €
= Material costs:	640.87 €

8.5.1.4 Production Costs

Production costs are expenses that come into being at the production of goods and services. Production costs are influenced differently. Therefore they are usually divided into fixed costs and variable costs. The term "production costs" is from the cost accounting and describes the costs that are incurred at the manufacturing of a product. [44, 45]

The production costs are usually calculated from the sum of material costs and the several production costs:

Production costs per piece:
duration * hourly wage
1 h * 35 €/h = 35 €

Production overhead costs:
≈ 10% of production costs per piece
0.1 * 35 € = 3.50 €

Special direct costs of production:
≈ 5% of production costs per piece
0.05 * 35 € = 1.75 €

Material costs:	640.87 €
+ Production costs per piece:	35 €
+ Production overhead costs:	3.50 €
+ Special direct costs of production:	1.75 €

= Production costs: **681.12 €**

8.5.1.5 Advertising Costs

The prices for advertising depend on the size of the company and the size of the market. In the case of engineering companies advertising will be about 10-20% of the initial costs. [46]

Calculation:

Design costs:	350.00 €
+ Model costs:	105.00 €
+ Production costs:	681.12 €
= Initial costs:	1,136.12 € + 227.22 € = **1,363.34 €**

Advertising costs:
≈ 20% of initial costs
0.2 * 1,136.12 € = 227.22 €

8.5.2 Installation and Commissioning Costs

In determining the life cycle costs, the installation and commissioning costs of the pumping system must be considered. Installation and commissioning costs include the following:

- Foundations - design, preparation, concrete and reinforcing, etc.
- Setting and grouting of equipment on foundation
- Connection of process piping
- Connection of electrical wiring and instrumentation
- Connection of auxiliary systems and other utilities
- Provisions for flushing or ‘water runs’
- Performance evaluation at start-up [39]

Calculation:

Installation costs:

Duration * hourly wage = 3 h * 35 €/h = 105 €

+ transportation and miscellaneous expenses:

105 € + 110 € = 215 €

8.5.2.1 Distribution Costs

Distribution costs are all costs come up in the sales area. There are costs incurred in selling the products. Some examples are: personnel costs, packaging costs, customs costs, freight costs, and advertising costs. Depending on accountability to the cost it is separated into the special direct costs of distribution and the selling expenses which will be considered with 10% of the initial costs. [47]

Calculation:

†**Distribution costs:**

≈ 10% of initial costs

0.1 * 1,363.34 € = 136.33 €

Installation costs:	215 €
+ Distribution costs:	136.33 €
= Installation and commissioning costs:	**351.33 €**

8.5.3 Energy Costs

Energy spending is often one of the larger costs and may be the predominant cost. This is especially true if the pump will be used for more than 2,000 hours per year. As stated earlier, the estimated power required for our pump design is 13.15 kW. [39]

Some facts:

- The current energy price is 0.20 € / kWh
- The pump will operate 3,000 hours a year
- Our calculations showed us a real power of 13.15 kW

Calculation:

energy price * power * operating process = **energy costs**

0.20 €/kWh * 13.15 kW * 3,000 h/year = **7,890 €/year**

8.5.4 Operation Costs

Operation costs are the recurring expenses and labour costs which are related to the operation of a pumping system. These vary widely depending on the complexity and duty of the system. For a commercial enterprise there are two categories for operation costs:

- Fixed costs, which are the same whether the operation is closed or running at 100% capacity and
- Variable costs, which may increase depending on whether more production is done and how it is done

In calculating the life cycle costs, the factor of ownership refers to the personnel costs in the operation of the pump system. But in most cases the personnel costs for operating a pump are low and they are not significant enough to consider them in this case. So they can be neglected. [48, 49]

8.5.5 Maintenance and Repair Costs

Maintenance costs are costs incurred for the maintenance of the equipment to ensure it remains in effective condition. Included are also inspection fees and repair costs. In order to maximize the working life of a pump, the owner must continually maintain the pump and the associated system. The pump manufacturer will provide the customer with a manual including a recommended maintenance schedule with instructions for completing the maintenance. There are two methods of maintenance and the owner of the pump must choose which maintenance method they will follow. Pumps can either be serviced frequently in a relatively simple manner or they can be serviced with less frequency but with more major maintenance tasks. Sometimes the more major maintenance tasks require that the pump is removed from service and sent to a workshop thus requiring more time. Customers will choose the method based on their own individual needs. The maintenance and repair costs will be about 20% of the initial costs and all three years there will be expenses of 80% of the initial costs. The anticipated life time of our pump will be 12 years. [39, 50]

Some facts:

- The company has a cost for maintenance of 20% of the initial costs, with a repair cost of 80% of the initial costs every third year
- The new pump will have a 12-year life

Calculation:

1x 20% of initial costs
0.2 * 1,363.34 € = 272.67 €
4x 80% of initial costs
4 * 0.8 * 1,363.34 € = 4,362.69 €
Maintenance and repair costs: 272.67 € + 4,362.69 € = **4,635.36 €**

8.5.6 Environmental Costs

Environmental costs are separated into internal environmental costs (within the company) and external environmental costs (outside the company). Often considered are only costs that are known and which have measurable impacts on the environment or the reduction of environmental impacts. But the modern understanding comprises environmental costs, all emission costs and the decommissioning costs. The environmental costs are all costs which are incurred with the damage caused by contaminated fluids and for the environmentally disposal of contaminated components. Environmental costs of about 20% of the initial costs will be expected. The cost of contaminant disposal during the lifetime of the pumping system varies significantly depending on the nature of the pumped product. Examples of environmental contamination can include:

- Cooling water and packing box leakage disposal
- Hazardous pumped product flare-off
- Used lubricant disposal and
- Contaminated used parts such as seals [39, 51, 52]

Calculation:

Environmental costs:

≈ 20% of initial costs

0.2 * 1363.34 € = 272.67 €

8.5.7 Decommissioning/Disposal Costs

In determining the life cycle costs of pumping systems, the cost of decommissioning and disposal compared to the other costs are so low that they can be neglected. That is different for pump systems which promote dangerous liquids. Otherwise, the construction and design of the pump system has a negligible impact on the decommissioning and disposal costs. In our case and for our pump we decided to estimate decommissioning costs. And decommissioning costs for pumps are usually about 5% of the initial costs. [53]

Calculation:

†**Decommissioning/Disposal Costs:**

≈ 5% of initial costs

0.05 * 1,363.34 € = 68.17 €

Initial costs:	1,363.34 €
+ Installation and commissioning costs:	351.33 €
+ Energy costs:	7,890 €/year
+ Maintenance and repair costs:	4,635.36 €
+ Environmental costs:	272.67 €
+ Decommissioning/disposal costs:	68.17 €
= Life cycle costs in total:	**14,580.87 €**

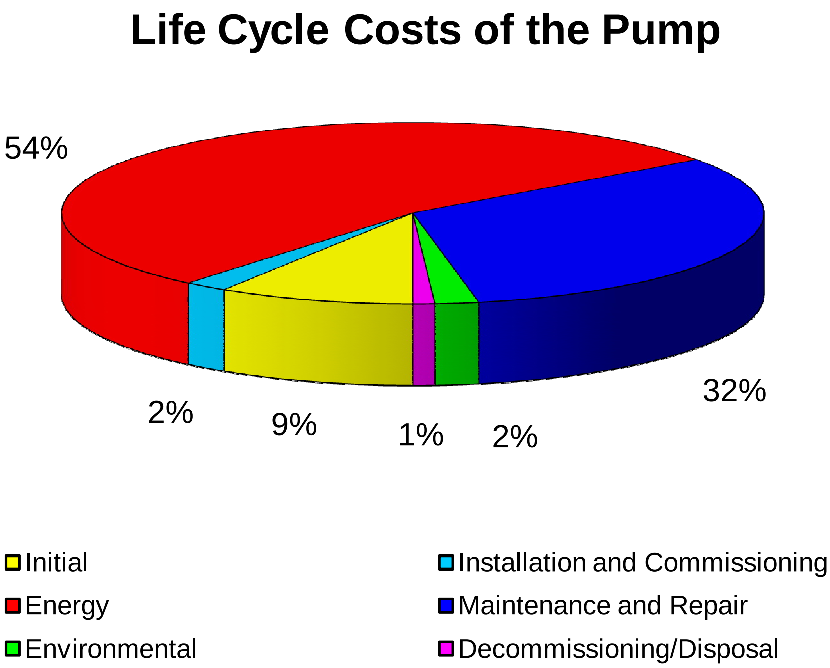

Figure 24: Life Cycle Costs of Pump Graph

Striking in this chart are the very high energy costs. That is typical for the life cycle costs of technical systems. Energy costs are always over 50% of the whole life cycle costs. This is because technical systems are permanent in operation. Factories, for example, often operate 24 hours a day and so continuously consume power and electric current all over the year.

8.6 Life Cycle Cost Analysis Conclusions

The life cycle cost analysis provided by team EDUR can be used by EDUR-Pumpenfabrik as a starting point for deciding if it is practical to build our designed pump. EDUR-Pumpenfabrik must determine if the costs are reasonable and if it would be profitable to manufacture this pump. In making this decision, EDUR must also investigate the pump market where it plans to sell this product.

9. Pump Markets

There is a growing interdependence of national economies and global marketing has become an important aspect of every global companies business. It is also a very complex task to successfully market products in other countries and it becomes increasingly complex as the number of countries that a product is sold in grows. This is because each market in which the product is introduced will have a different climate, a different language, and a different culture and the company must adapt to each market individually and respond to their specific needs. To successfully implement a global marketing plan for the newly designed pump for EDUR, we must have an understanding of the pump market on a global scale. Team EDUR has briefly researched the US and China pump markets. [54]

9.1 US Pump Market

The market for pumps in the US is the largest in the world. The US has had almost a decade of consecutive years with growth in the pump market. The current crisis has affected the market in the US but the effects are not expected to last beyond five years. It is also expected that US customers will see more computer controls integrated into pump equipment. This will result in an increased use of the internet to monitor and control equipment. The demand for this sort of technology must be recognized by companies hoping to sell pumps in the US market. Because of the difficulty in entering the US market caused by tough competition, brand loyalties, and the many expenses incurred from using non-metric units, EDUR does not currently have plans to sell our design in the United States. [55]

9.2 China Pump Market

China has become a main force in the pump export market throughout the world since its reintroduction into the global economy in 1978. Because of China's exportation of pumps it can be challenging to import pumps to China. EDUR does not plan to sell our designed pump in China at the beginning and will consider this market at a later time. [56]

9.3 European Pump Market

The information about pump markets is very specific. We could not get enough information about the pump market. Most firms keep their information from their competitors. Generally the information about pump market belongs to a specific research company and they give the information to their member with payment. Due to limited information, we focused on the British and Polish pump markets. [57]

The market for energy-efficient pumps in Europe has shown strong growth over the past few years. The systems passed by the various European governments are the biggest driver for the use of energy-efficient pumps. The system bodies in these countries have advance system and procurators that need industries and uptown and profitable buildings to optimize their energy usage. With almost one-third of all set up pumps being energy-efficient; Europe is a biggest market for energy-efficient pumps. The most important growth is found in the larger markets of France, Norway, Finland, Italy and Austria, while the markets in Germany and Switzerland are joining. [57]

Tax repayments, public assistance and financial support by the governments are driving the market for energy-efficient pumps. The governments in these countries suggest significant tax repayments and financial support for using these pumps. The French market is currently profiting from a liberal financial support method offered by the French government, which offers financial incentives and tax repayments for using energy-efficient pumps. In consequence of these hold and financial supports, the market has a growth rate of 14.3% in 2008. Similar financial supports and public assistance for the system of energy-efficient pumps are being offered by the Swedish government. These financial supports, along with a likely raise in the production action in the future, are likely to drive the sales of energy-efficient pumps. Switzerland also procures tax reduce for funds towards the use of energy-efficient pumps. With admiration to market size, Switzerland has one of the most industrial pump markets in Europe, with a majority of them being energy-efficient. [57]

For many years, Sweden and Germany have been the highest increasing markets for energy-efficient pumps. However, the market in these countries has seen a decline. After long years of unusual growth, the Swedish market faced a 21% fall in sale during 2008. This decline in the Swedish market was owing to several reasons; the most important of which is the reality that the energy-efficient pump market in Sweden is in the grown-up point, especially in the building services part. [57]

The high growth in the market until 2006 was owing to high energy prices and was driven more by a financial support method for phasing out oil-boilers. The financial support method was originally planned for five years, but as all the income set aside for the plan were spent in less than one and a half years, the method was stopped in March 2007. This had a main negative shock on the market, as there were no financial inducement and financial supports for end-users to install energy-efficient pumps. Also, the German market has viewed a pointed decrease in the sales of energy-efficient pumps from 2007. This hold up was mainly owing to an augment in the value additional tax that came into energy starting January 1, 2007. Nevertheless, the German market is expected to view a positive development in the future. Given the significant size of this market, which is still subjugated by the highly energy-inefficient oil and gas boilers, it is likely that the rule and information will have a positive impact on the energy-efficient pump market. [57]

Developing markets like Ireland, the United Kingdom, the Netherlands and Eastern Europe are likely to view a rapid widen in revenues. The general market for energy-efficient pumps in the United Kingdom is small, but it has been increasing at a strong cadence over the last few years. Market growth is being mainly driven by the legislation to decrease carbon dioxide and greenhouse production from new buildings. The market is mainly subjugated by gas boilers, and end-users are not very excited to set up energy-efficient pumps owing to the high cost of savings disturbed. This is expected to change with a possible increase in energy prices in the future, firm enforcement of government rules and greater end-user knowledge about optimizing energy gathering. [57]

The future market projection for energy-efficient pumps in Europe looks hopeful. Government rules, consequence for non-installation of energy-efficient pumps, the growth of Eastern Europe, financial inducement, tax repayment and greater end-user knowledge are likely to more drive the market for energy-efficient pumps. There is a enormous scale for the manufacturers of energy-efficient pumps, as only 30 to 32 percent of the set up pumps in Europe are energy-optimized and there is greater require for energy-efficient pumps. [57]

9.3.1 British Pump Market

The British Pump Manufacturing Association stands for the important UK suppliers of fluid pumps, accounting for 85% of the UK market. Mainly driven by electric motors accounting for 40% of the UK's electricity spending, pumps are 32% of this (47TWh/year). Self-sufficient studies have shown that there is possible to save 1 million ton of carbon production a year by developing pump 'system' efficiency. [58]

Over the past four years the BPMA has unspecified a hands-on position with thought to the decrease of energy spending in pumps and systems, recognizing decreasing government and public disquiet with consideration to energy. The BPMA has been working with future

energy solutions to build up the pump system part of the UK government's market translation program. The BPMA led the growth of three energy savings guides for Euro pump which are used worldwide. A future energy clarification manager sits on the BPMA energy steering group to make sure short lines of contact to and from government.
BPMA has recently been given a command that specific aim for energy decrease for pumping systems have been set at 6TWh/a by 2020. The BPMA has imperfect funds and the management of an energy guide had started to put together some energy in actions to distribute the possible energy savings that have been well-known. [58]

9.3.2 British Market Opportunity

On an industrial site with an electricity bill of £150,000 a year, a normal of £100,000 a year will be pay out running electric motors. Pumps are the single largest user of electricity in industrial and profitable applications in the United Kingdom consuming 47.24TWh of electricity which in turn symbolizes some 32% of all electric motor spending in industry and trade. [58]

Energy costs have grown to be precipitate with Oil, Coal and Gas prices at record point and important viewpoint have been known to operate pump systems more competently, reducing energy spending and running costs by 30 to 50%. [58]

The UK government has set an objective to decrease production of carbon dioxide by 20% on 1990 levels by 2010 with 60% decrease by 2050. Motors version for 40% of total Electrical spending and with pumps including almost a third of this there is great variety to decrease carbon production through action to get better pump 'system' efficiency while reducing the cost of ownership for users. Energy describes 95% of a pump's life cycle cost so the opportunities for savings are significant. [58]

Energy efficiency support has been decided to business through the better capital payment method in the form of 100% first year capital payment for energy saving funds in customary proficient method and tools such as electric motors and changeable speed drives for pumps. [58]

High efficiency electric motors and the use of changeable speed confines has gained improved treatment in the usefulness and building services industries and their use on pumps has saved an likely £74M in energy costs since 1998, measure up to 3.5TWh of electricity. [58]

A considerably higher viewpoint to save energy exists through better pump choice, better system drawing, pump/system optimization and system control. Many systems were never calculated with energy efficiency in mind and untrue pump and system matching and process can result in significant total of wasted energy. [58]

There are many simple actions that can be taken to develop pump and system operation with up to 50% energy decrease possible without most important principal savings. [58]

The British Pump Manufacturers Association, its partners in Euro pump and the Carbon Trust have created a number of guides and tools to use to decrease the energy spending of pump systems. [58]

These tools are not widely practical and through its sustainable energy strategy the BPMA is dedicated to changing the habits of pump users in the way that they buy and operate pumps so that their energy use is reduced. [58]

9.3.3 Polish Pump Market

The Polish pump industry has a long association, dating back to the 19th century, of craftsmanship and unbelievable happenings. This is why the group consists of companies with histories of several achieving years-although the group itself is considerably young, well-known at the turn of the 20th century. At the top of the group is Powen SA, a company based in Zabrze in the Silesian region of southern Poland. [59]

Powen SA obtains from Powen Zabrze removal machines & equipment, a nationalized factory which started manufacturing of pumps and fans in 194, having taken over the manufacturing and social facilities of Reden steelworks (established in 1857). Up to 1994, its total productivity reached about 100,000 pumps. [59]

9.3.4 Focus on Pumps

The worth of the Polish pump market is estimated at €600 million per annual, out of which about 20 per cent comes from familial traders. These facts cover all variety of pumps, counting the import of small part for marital use. When only industrial pumps are measured, the Polish manufacturers have a higher deal out of the market. [59]

Powen shares 30-40 per cent of the Polish trade pumps market, allowancing only Polish producers. "Since the pumps import to Poland exceeds domestic production by three times our market share is lower and estimated at 10 per cent. The sales of the whole group reached €37 million in 2005 and the profit was €4 million. Pumps made about a half of the sales and profits," says Mr. Kantoch. [59] "As a group we sold about 11 per cent of the whole production abroad but the sell abroad of individual companies were higher: Powen Pump Factory in Zabrze and Wafa pomp SA in Warsaw each sold abroad 20 per cent of pumps produced and the Pump Factory Co. Ltd in Swidnica exported 30 per cent." [59]

The major products exported by Powen Pump Factory are high-pressure (over 300 ATM) feeding parts. Only a few companies throughout the world manufacture such parts. Pumps from Zabrze are sold generally to Russia, Kazakhstan, the Ukraine and Byelorussia and are used in coal mines. "These pumps are designed for pumping industrial water containing both mechanical and chemical contaminations. They demand modern technological processes, exceptional quality of manufacturing and wide experience. Our worldwide novelty is submersible pumps working in contaminated liquid. They were designed especially for the 'Belchatow' brown coal mine, the biggest mine of its kind in Europe, and remove water in their new opencast," says Mr Kantoch**.** [59]

The group Powen is undergoing the process of more addition, with its pivotal moment planned for October 2006 when the three main pumps plants from Zabrze, Warsaw and Swidnica will completely go into one establishment. It will allow the group to be more synergic, effectual, and focused on clients. [59]

But the translation is not performed only by improvement. The group has recently speeded in a new creation of 3D CAD software to widen the likely of R&D departments. Moreover, Teamcenter 2005 of UGS, the world's first included software details to close the gap between ideas confine and comprehensive manufactured goods lifecycle organization was acquired. [59]

Teamcenter powers new creation ideas from theory to certainty by integrating idea management and necessities planning into the total digital lifecycle management manufactured goods improvement and manufacturing method. It is exceptionally significant to the group to be modernized in terms of IT explanations as it has always accessible its clients only products developed by its own engineers. The quality of these products has been accepted by the ISO 9001:2000 certificate. The group provides production services, always choosing the most suitable pump design in agreement with the customers' necessities. [59]

"All our customers are provided with fast servicing and spare backup. With our long-term experience and regular contacts with the customers and users of pumps, we are able to solve any pump engineering problem. This is part of our long term strategy to cater for customers' needs. There is no mass pump production in our plants. The average annual production is about 1500 pumps and all of them are individually ordered," says Mr Kantoch. [59]

The beginning of the market economy has cause the official sales registration system to be stress-free and for that reason existing sales data can only be predictable. It become known from these estimated that the worth of the Polish pump market is ca. €600 million per annual, out of which about 20% comes from familial suppliers. These facts enclosed all type of pumps, counting the trade in of small parts for familial use. When only manufacturing pumps are measured, the Polish manufacturers have a much higher divide of the market. [60]

9.4 Global Marketing Conclusions

It is expected that the current economic crisis will lead to limited growth in the global pump market for an estimated five years. It is also expected that it will become more competitive between the pump producers as they seek to obtain agreements with the top pump consumers. Energy efficiency is becoming an ever-more important factor in pump manufacturing and the demand for energy efficient pumps is only expected to become more severe. [54]

10. Competitors

After the general analysis of the global pump market we have to focus the efforts into the most relevant market for us. To be successful in our task of introducing our product into the market we have to know about the pump market that is of concern to us. That includes knowing the most we can about who is selling products focused in do the same task as our pump. We have analyzed these brands taking into consideration in which country or continental pump market they are in and the sizes of the companies. We have found information about their products, the fields of application of these products, and determined what the specific range of products is that are able to do the same task as our pump. We focused on how they work, their technical specifications, and performances in order to compare with our product and to try to improve upon their ideas by creating a pump with better performance.

EDUR wants to begin selling the three-phase pump in the market in Germany, and once successful, then EDUR would move into other European countries with similar OEMs. Because of these guideline provided to us by EDUR we must start searching and analyzing the brands that are working and selling in the German pump market.

EDUR has three main competitors specific to the application of our pump:

schmalenberger strömungstechnologie
BRINKMANN PUMPS
varisco solid pumping solutions

Figure 25: Brand Logos

Owing to the fact that recently the pump brand Schmalenberger took over a previous customer of EDUR, because they offer a pump that performs better in this application and is also submersible, we consider it as the biggest competitor for us and we will begin by analyzing Schmalenberger.

10.1 Schmalenberger

10.1.1 Introduction

Schmalenberger is a German Firm founded in 1954 with their headquarters and installations situated in Tübingen, on the industrialized region of Baden-Württemberg. At present, they have 80 employees. Their products, primarily pumps, are focused in the field of pools (swimming pools, private baths, and adventure pools) and in the industrial field. They have in their catalog submersible and non submersible pumps suitable for a wide variety of applications. We can see in Table 9 the different pumps and their applications. [61]

Non-submersible pumps	Submersible pumps
Centrifugal Pump: Single Stage for - Metal Processing - OEMs/Machinery Manufacture - Building Industry/Services	**Centrifugal Pump: Single Stage** for - Metal Processing - OEMs/Machinery Manufacture - Building Industry/Services
Centrifugal Pump: Multi Stage for - Metal Processing - OEMs/Machinery Manufacture - Building Industry/Services	**Centrifugal Pump: Multi Stage** for - Metal Processing - OEMs/Machinery Manufacture - Building Industry/Services
Centrifugal Pump: Side Channel for - OEMs/Machinery Manufacture	

Table 9: Schmalenberger Non-submersible and Submersible [61, 62]

In Table 10 we can see the following specific pump products based on various principles of work.

Centrifugal Pumps	
	Applications:
Self – priming Pumps	For clean and polluted liquids or media with gaseous inclusions
Suction Pumps	For pumping strongly contaminated liquids which may also contain solids
Torque flow centrifugal Pumps	For delivery of strongly contaminated liquids which may also contain solids or long fibrous material. Tank installation
Single-stage centrifugal Pumps	For clean and polluted abrasive liquids. Tank Installation, Dry Installation
Multi-stage centrifugal Pumps	For clean and polluted abrasive liquids. Tank Installation, Dry Installation

Table 10: Schmalenberger Centrifugal Pumps [61, 62]

10.1.2 Presence in the Market

They are involved on the markets from almost all countries of Europe, selling too in a lot of countries from Asia like the very big and industrialized countries India and Israel. Outside Europe and Asia, Schmalenberger are distributing in Egypt and Australia too. [61]

10.1.3 Schmalenberger versus EDUR

In spite of the large market that they are covering the company is nowadays the most direct and strongest competitor for EDUR in the European market and even more so in the German market. The reason is that at present they are manufacturing and selling pumps addressed to do the same tasks as our pump with the additional advantage that the pumps are more efficient in this application. Furthermore, their products have the advantage that their pump is able to work submersed, while the pumps EDUR was selling for this application is only able to work outside the pumped solution.

The specific products are the Schmalenberger Torque Flow Centrifugal Pumps models FB and FZ. It is single-stage torque flow centrifugal pump and is designed for delivery of strongly contaminated liquids which may also contain solids or long fibrous material. Both models are equipped with an open impeller and constructed with materials able to resist neutral or aggressive media, such as alkaline, solvents, coolant and lubricants with sealing resistant against chemicals and abrasion. Furthermore, the FZ model is able to work at a depth up to 1030mm. [63]

Their performance can be seen in Table 11 below.

PERFORMANCE	
Model FZ	**Model FB**
Materials for temperatures max. 120°C	Materials for temperatures max. 90°C: Cast iron
Delivery up to 140 m^3/h	Delivery up to 200m^3/h
Delivery head up to 60 m	Delivery head up to 55 m

Table 11: Schmalenberger Performance [64, 65]

10.1.4 Summary

Before the start of our project, Schmalenberger was providing the market with a pump that is capable of pumping three-phase streams with a good performance. Because of this we have designed our new pump to be able to out-perform Schmalenberger in this field of the pump market.

10.2 BRINKMANN PUMPS

10.2.1 Introduction

Brinkmann Pumps is a German firm founded in 1950 by Karl Heinz Brinkmann with their headquarters in Werdohl, in the Nordrhein-Westfalen region. They manage their business in co-operation with smaller-sized agencies from Europe. Furthermore, they work with a subsidiary company, BRINKMANN PUMPS Inc., established next to Detroit, Michigan

(EEUU). The installations are located in Werdohl and in EEUU, where they are providing to North and South America pumping market. Nowadays the company has 150 employees distributed throughout the world. [66]

The products of Brinkmann are developed and focused to the industry field and all of them have the aim to delivering filtered lubricating media like cooling lubricants dedicated to refrigeration systems. We can say that they only produce cooling pumps to the machine-tool sector. [66, 67]

They have many different pumps based in different principles of working and equipped with different kinds of impeller. Most of them are able to work submerged as we can see from their applications in Table 12.

Submersible Pumps	
Centrifugal Pumps	
	Applications
Lifting Pumps:	
· Suction Pumps: (Axial/Semi-Open Impellers)	-For pumping emulsions with large chips -To work for vacuum filter
· Quick Suctioning Pumps: (Axial/Semi-Open Impellers)	-For pumping emulsions with some percentage of air - For pumping oils with increased percentage of chips
Cutter Pumps: (Axial – Radial Impellers)	-Able to cutting aluminum chips and similar materials and pumping of these materials along with the coolant fluid
Torque flow centrifugal Pumps: (Semi-Open Impellers)	-To lift coolant for filtering, can be transport coarse shreds with liquids all together
Pressure Boosting Pumps: (Closed Impellers)	-To boost the pressure of flows with heavy loads of abrasive particles
Multi-stage Pumps: (Closed Impellers)	-Only to supply internally cooled tools with coolant fluid
Miniature Centrifugal Pumps:	-For pumping clean fluids with high temperatures

Table 12: Brinkmann Submersible Centrifugal Pumps [68, 69]

Furthermore, all of their Quick Suctioning Pumps are provided with their own newly-designed system: “BRINKMANN`s Suction De-aeration System.” This is said to improve their efficiency performance working with trapped air in cooling lubricants. [67]

10.2.2 Presence in the Market

The purpose of the firm as a distributor is to provide products to every part of the world where machine tools are built and used. In spite of that, their biggest market is founded in Europe, with their own country, Germany, as the primary market. They have a large number of customers in North and South America as well, which the subsidiary company BRINKMANN PUMPS Inc. is responsible for. Furthermore Brinkmann is present as a company in the newest industrialized countries like China, Japan, Korea, India and Taiwan, from where they are dealing with the Asian market. [66]

10.2.3 Brinkmann versus EDUR

Brinkmann is a significant competitor for EDUR inside the European market. Their products are narrowly focused in the industrial field. They offer a large range of products designed to pump three-phase flow and very able to compete against our pump doing the same task. These products are their range of "Horizontal End-Suction Pumps", with the models: SBA, BAL, SBG, BGL and BFL. [68]

Figure 26: Brinkmann Horizontal Suction End Pump [68]

All of them are single-stage centrifugal pumps where the impeller is a kind of semi-open impeller and is mounted onto the extended motor shaft. These pumps are not self-priming and because of that must be gravity fed. These pumps are designed to work in horizontal installations next to or just under a tank and optimum for pumping air entrained coolant fluids, such as water-soluble coolants or cutting oils mixed with a heavy chip load, as they occur in high speed turning, milling or grinding applications. In opposition with the products that actually are selling EDUR, these pumps are able to work in a submersed media, a fact which makes these pumps a valuable product. Furthermore the broad range of pumps that they have to do these tasks makes it possible to provide the customers with many different products capable of meeting the performance requirements. [68]

10.3 Varisco

10.3.1 Introduction

Varisco is the most significant competitor that is not from Germany. Varisco is an Italian pump manufacturing firm which was founded in 1932 but did not produce pumps until 1948. Its main headquarters is located in Padua (Padova), in the region of Veneto (Italia). Varisco also has subsidiary companies throughout the world, one of which was created in 2006 as an EEUU brand, VARISCO USA Inc. in Orlando Florida. [70, 71, 72]

Varisco has 3 subsidiary brands in Germany:

- IPT Industrie-Pumpen Tomiak GmbH, the first representation of Varisco in Germany was founded in 1982, and is located in Kirchheim bei München, in the German state of Bavaria;
- IPV Industrie-Pumpen Vertriebs GmbH, was created in 1994 and is located in Dresden;
- And the final one, founded in 2002, is IPV Industrie-Pumpen Vertriebs GmbH West and is located in Düsseldorf.

Production takes place in the installations which the company has in Italy. They also have a new installation in Tianjin (China) and with another factory building in Dresden providing for the German customers. [70]

Varisco is involved in many different fields, as we can see in Table 13.

Field of Application
Agriculture: To drainage, irrigate, delivery animal feed
Fire fighting
Waste treatment
Industry: Chemical and petrochemical Industry, Metal industry, Building Industry, food and drink industry
Civil Engineering: Groundwater dewatering, bentonite
Naval Engineering: To work with fuel and lubricants

Table 13: Varisco Applications of Pumps [70, 71, 73]

A major difference from the others brands and from EDUR, is that Varisco is designing and producing pumps based on the positive displacement principle of work. They are providing their customers with pumps able to work in a submerged media and with the following types of pumps focused on specific fields, as we can see in Table 14. [74]

Non-submersible pumps	Submersible pumps
Positive Displacement Pump: Gear or Vane for - Oil and Gas Production - Chemical Industry - Basic Chemicals - Chemical Industry - Downstream chemicals - Chemical Industry - Pharmaceutical, cosmetics - Petroleum Refining - Resale sales where end-user is unknown	**Centrifugal Pump: Single Stage** for - Mining and Quarrying - Petrochemicals - Chemical Industry - Basic Chemicals - Chemical Industry - Downstream chemicals - Chemical Industry - Pharmaceutical, cosmetics - Petroleum Refining - Metal Processing - Commercial Marine and Navy - Building Industry/Services - Defense (except navy) and other government - Sewage - Resale sales where end-user is unknown
Positive Displacement Pump: Screw for - Food and Drink - Chemical Industry - Basic Chemicals - Sewage	**Other types of pumps** for - Mining and Quarrying
Reciprocating Pump: Diaphragm for - Mining and Quarrying - Other manufacturing - Building Industry/Services	
Centrifugal Pump: Single Stage for - Mining and Quarrying - Petrochemicals - Chemical Industry - Basic Chemicals - Chemical Industry - Downstream chemicals - Chemical Industry - Pharmaceutical, cosmetics - Petroleum Refining - Metal Processing - Commercial Marine and Navy - Building Industry/Services - Defense (except navy) and other government - Sewage - Resale sales where end-user is unknown	

Table 14: Varisco Non-submersible and Submersible [73, 74]

Inside of these we have the following specific pump products based on various principles of work and focused on solving specific task as can be seen in Table 15.

Centrifugal Pumps	**Applications**
Self – priming Pumps	For pumping liquids with large solids in suspension.
End Suction Pumps	For pumping liquids without solids in suspension
Vertical Multi-stage Centrifugal Pumps	For pumping liquids without solids in suspension at high pressure
Submersible Centrifugal Pumps	For pumping liquids with solids in suspension.
Positive displacement Pumps	
Internal gear Pumps	For pumping lubricants or oils with any kind of viscosity, which do not contain solids in suspension
Progressive cavity screw	For pumping liquids with any kind of viscosity that contain abrasives and a high percentage of solids
Self-priming diaphragm Pump	For pumping dense liquids that contain abrasives and solids in suspension

Table 15: Varisco Centrifugal Pump Applications [73, 74]

10.3.2 Presence in the Market

Coming from Italy, their most important market is the Italian pump market. They are represented in every corner of Italy with distributors in almost every region. As a European brand, Varisco is a major force in the European pump market. They are present and very involved in many large European markets, proof of this is the three different brands that they have in Germany. But furthermore they have offices in Belgium and Netherlands and with all of these offices they are able to distribute in almost all of the countries throughout Europe. [70, 75]

In the rest of the world, Varisco is providing pumps to North and South America through its American subsidiary brand. The same is happening with Asia where they are competent because of their factory there. [76]

10.3.3 Varisco versus EDUR

Varisco does not have a real three-phase flow stream pump and they are not distributing any pump similar in terms of principle of working as our new pump. Still, they have a big presence in the German market and they have one range of models that are able to perform a task similar to our pump but with less efficiency. These pumps are their range "J" of self-priming pumps. These pumps are designed to work with an air-liquid mixture and able to pump these mixed with large pieces of solids.

11. Customers

After analysis of the three-flow stream pump market and of the brands that are selling it, is time to analyze which brands will be potential consumers in order to determine what possibilities we have to be successful selling our product after its commercialization. To do this we have determined the requirements of our potential customers and in which field potential consumers are in.

Taking into consideration that our pump is designed specifically to pump a mixture of liquid-gas with pieces of solid material; the most practical application for our pump will be as a part of a filtration system. Table 16 lists possible fields and applications where a filtration system is needed.

Field	Application
Agriculture	Drainage
	Irrigate
	Waste treatment
Environment	Groundwater dewatering
	Waste treatment of sewage
Industry	Automotive
	Building Industry
	Chemical
	Petrochemical
	Machinery Manufacture
	Metal Industry
Pools	Adventure pools
	Private baths
	Swimming pools

Table 16: Filtration Sytem Applications [77]

Because our design is complex and able to be successful in filtration applications, the field where it will be most effective is in the automotive manufacturing field, the field of machinery manufacturing, or in the metal industry. Wherever they are using machine-tools with detachment of swarf and lubricating liquids are needed. In these applications our pump will be used for the recirculation of this emulsion of lubricant to be filtered of the swarf material.

Furthermore, these sectors have a very large market consisting of a lot of different companies making a very big range of products. That fact makes our task of finding customers easier as there is a need for our pump. Based on that and taking into consideration the guidelines provided to us by EDUR we can consider "Dürr Ecoclean" brand as a potential consumer.

11.1 Potential Customer: Dürr Ecoclean

11.1.2 Introduction

First of all we must say that Dürr Ecoclean is only one part of the German firm Dürr. Dürr was founded in Cannstatt in 1895 by Paul Dürr and it began as only a metal shop and it was not until 1917 that he began sheet metal processing. Now it is an international company with its main headquarters located in its place of origin, Cannstatt. Dürr is present in 21 countries around the world with subsidiaries and installations distributed throughout with 5712 employees. [78, 79]

They have subsidiaries in EEUU, China and Japan. Within Germany, Dürr has 9 subsidiaries focused in doing two different general tasks: one brand is responsible of painting and assembly systems and the other one responsible of cleaning and filtration systems. Into the subsidiaries of the second brand is placed Dürr Ecoclean GmbH which, as a company, is responsible for the unit cleaning and filtration systems business. [78]

The company Dürr Ecoclean GmbH is present in Europe, America and Asia with subsidiaries in German, France, Russia, USA and Japan. Furthermore, they have offices distributed along these three continents increasing the ease of the management task in the countries where they are present.

Dürr Ecoclean has in their catalog three different fields of products. See Table 17 for more details.

- Cleaning: Products focused on solve tasks related with cleaning and treatment jobs in industrial production.
- Filtration: Products focused on filtering industrial fluids to separate contaminants from different machining media to extend the life of the fluid.
- Automation: Field focused on automating the manufacturing line in the industries using their products, to ensure an optimized production process.

Field	Application
Cleaning	Watery cleaning
Filtration	Drilling Machines
	Grinding Machines
	Honing Machines
	Micro-Sizing Machines
	Milling Machines
	Mixed Machining
	Turning
Automation	Conveyor technologies
	Gantry Systems
	Grippers and tooling
	Robot systems and integration
	Special applications
	Systems integration

Table 17: Dürr Fields of Products [77, 80, 81, 82, 83]

Products dedicated to filtration and to automation are being used to the automotive industry to improve their efficiency and reducing the costs of maintenance.

11.1.2 Summary

Dürr Ecoclean is a very competitive brand with a lot of systems and products that can need our pump to do their tasks. They are into a very big market with a lot of different industries on where we can work, providing to costumers along their experienced distributors. Furthermore it is a stable company because they belong to an international and consolidated big company with many years of experience.

For EDUR it would be a very great chance to be successful in the market of the three-phase flow stream pump if EDUR provides these pumps to Dürr. For that reason it would be very beneficial to deal with Dürr and to try to make a deal to work together.

12. Web-Design

In order to both introduce our pump into the market and to find customers, we must not forget the internet. Internet is a very big display cabinet (window shop) accessible for everybody from the entire world, where we can find a lot of potential new customers. If we want be successful with our product we must make an attractive and dynamic webpage and that is easy to understand and logical to navigate within. We have the task of designing a webpage in order to show our pump with the finality of making the information easily accessible by potential new customers.

Furthermore, after the website has been developed it must be distributed throughout the whole world web. Once we will have a website working on the net we have to start to advertise it. Firstly of all, our web-page must appear in as many internet search engines as possible, for example: Google, “yahoo! Search,” Bing, Excite or Hotbot (general search engines that are used frequently). We should also put our brand, our products, as a website in the specific councils that are internet portals dedicated to the pump market such as: www.pumps.org or www.europump.org . We also can and must include our website in other internet portals intended to be a virtual exhibition in the field of the industry, such as www.directindustry.com . This kind of portal is better for us because if anyone wants a product like ours and is using the internet to search, they can quickly find the product they are searching for.

EDUR firm already has their own website and because of that we decided to use this existing site as a model. We added a part focused on our new design that shows the advantages and details about our pump design. We used the general style of EDUR firma website in order that is might fit their website and simply be introduced as one more link. We added our product to the page with their list of products.

Figure 27: Web Link

We added a link (Figure 27) to access the file where our impeller design is shown (Figure 28). Included in our section is a brief description of the pump and its main applications, a description of the parts it is composed of, and the materials of construction for every part, as well as its performance and its design drawings in two and three dimensions.

We believe that this information is enough to show to our possible customers. Too much information cannot be included on the web-page as competitors could take this information and use it for their own benefit. However this is only a brief description to introduce the product and its possible fields of application. If somebody is interested in more information, it is easy to contact EDUR-Pumpenfabrik through e-mail or the distributor offices listed at the website. The page can be viewed at: http://edurteam.00server.com/

Figure 28: Web Page Design

13. Conclusion

EDUR-Pumpenfabrik is a top performer in the pump manufacturing industry and will hold this position by introducing innovative solutions to customers' problems. EDUR-Pumpenfabrik has asked our team to assist them by creating a new design for a pump that will be capable of handling a three-phase product stream. Team EDUR has completed a new design for a pump that can be produced by EDUR and give EDUR-Pumpenfabrik an advantage within the highly challenging pump market.

Team EDUR has also assisted EDUR-Pumpenfabrik in researching some of the aspects involved in pump manufacturing and has provided cost estimates for the life cycle cost analysis. These estimates will provide EDUR with a starting point for the expected costs involved in manufacturing and selling this pump.

The global marketing research performed by team EDUR will assist EDUR in introducing the new design into the European markets. Our focus was on the British and Polish pump markets due to the limited availability of information.

The research team EDUR performed concerning EDUR's competitors can be used to assist EDUR in outperforming its competition. This information can be used to learn from competitors and determine the best methods for being successful in the three-phase pump market.

The web design developed by team EDUR will give EDUR some ideas on how to design a web-page for advertising this new pump. Web-site sales are essential to almost any pump manufacturing company. Potential customers will visit EDUR's website in search of a three-phase pump and find the required information to make a well-informed decision.

Team EDUR has designed a new impeller specialized for transporting a three-phase product stream as well as researched and developed plans for introducing the pump into the market. As a result of our efforts, we have assisted EDUR-Pumpenfabrik in its efforts to maintain its status as a top performing company. EDUR now has the basis of what is required to introduce a new and profitable product into the pump market.

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