OPTIMAL SYNTHESIS OF COOLING WATER PUMPING AND DISTRIBUTION SYSTEMS

Report

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INTRODUCTION

The most straightforward design concept for a cooling water distribution system consists of a main pumping system distributing water to several cooling water consumers (heat exchangers) through a supply header. The heated water returns to the cooling tower through a return header. This concept has the disadvantage that there might be high energy losses in some control valves due to the uneven head losses throughout all the branches [1]. Different design concepts can reduce the overall energy consumption of the distribution system [1,2], but the use of additional equipment and piping has an effect on the overall costs of the system.

The overall costs for the distribution system can be divided into capital (non-recurring) and operating (recurring) costs. The capital costs of any industrial process are calculated as a function of the purchase costs of the equipment. Several indirect costs have to be considered, and for large pieces of equipment these indirect costs even surpass the purchase costs. As for the operating costs, in the cooling water distribution system, the major cost is the consumption of electrical energy. However, even if different design concepts decrease the energy consumption, they usually increase other operating costs such as maintenance costs [3].

For distribution systems where the consumers are arranged in parallel, the design concept that is most cost effective might not be necessarily the one that has the lowest energy consumption, but the one that has the lowest overall costs. The Preliminary Report [1] presented different design concepts, and the respective estimated energy consumption. This work intends to assess the costs for those different concepts.

OBJECTIVES

Given the different design concepts presented in the Preliminary Report, this work estimated the capital and operating costs for each concept. These costs considered the direct and indirect costs involving the purchase and operation of pumps, motors and piping. For each case presented in the Preliminary Report, the pumping selection was reviewed in order to maximize the pump efficiency. The overall costs are then calculated to assess the concept design that is most cost efficient.

This study obtained price values for the equipment of the cooling water distribution system from Brazilian suppliers. For equipment with different capacities or attributes, a methodology was developed to estimate the costs.

A sensitivity analysis was performed to assess how electrical energy prices, interest rates and plant horizon affect overall costs. Another sensitivity analysis was performed considering that two major consumers have their position exchanged.

The ANS Module of the AFT Fathom software was used to perform the cost estimation.

METHODOLOGY

Capital Costs Estimation

This study considers as capital (non-recurring) costs of the cooling water systems the purchase of pumps, motors and piping, and the indirect costs related to equipment installation.

There are several available models for centrifugal pumps that can be used for the distribution of cooling water. It is somewhat difficult to obtain precise quotes from pump suppliers in the early stages of a project, therefore it is necessary to estimate pumps prices by extrapolation from price of a reference pump. Turton et al. [4] use the following equation to correlate equipment prices for different capacities:

$$\frac{C_1}{C_2} = \left(\frac{A_1}{A_2}\right)^{0.6} \tag{1}$$

where C_1 and C_2 are the purchase prices of equipment 1 and 2

A_1 and A_2 are the attribute values of equipment 1 and 2

For centrifugal pumps, the correlated attribute used by literature [4] is the pump's consumed power at the operating point. However, despite the availability of several commercial pump models, there is a finite number of models. Many times, the same pump model and size can be used for pumps with different operating points, but with flow rate and head values in the same order of magnitude. For these cases, the impeller size varies, and although larger impellers are slightly more expensive than smaller ones, the difference in price of these two pumps is reduced. Hence, even pumps with different power values can basically have the same price. Therefore, this work uses the weight of the pump as an attribute to correlate different pump sizes. The pump model used in this study is the 3196 Goulds Pumps [5], which offers different sizes for a range of operating points. The pump size for each design concept is selected using the Pump Selection Software (PSS) from Goulds Pumps.

For motors, a price list from Weg was obtained by personal conversation. This work has as premise that the prices given are applicable to 4- and 6-pole motors.

The purchase (materials) cost for the pump set, C_{pur}, is the sum of pump and motor prices.

In this work, the indirect (installation) costs for the pumps are obtained by the following equation [4]:

$$C_{inst} = C_{pur}.(B_1 + B_2.F_M.F_P - 1) \quad (2)$$

where C_{inst} is the installation cost (BRL)

B_1 and B_2 are adimensional factors

F_M is a correction factor for material

F_P is a correction factor for pressure

The values for B_1 and B_2 are respectively 1.89 and 1.35 [4]. For cooling water pumps, operating below 10 bar and made of cast iron, F_M and F_P are 1.

The piping prices were estimated using price values from personal conversation with local engineering contractors. To extrapolate the purchase costs for piping with different diameter sizes and estimate installation costs, the Cooling System Costs ANS sheet was used.

The prices used for the capital costs estimation are given in the Appendix.

Operating Costs Estimation

Operating costs are considered the sum of electrical and maintenance costs. The electrical costs were calculated by estimating the energy consumption of the motor. This work stipulates a motor service factor of 1.1. For maintenance costs, it was considered that 6% of the equipment purchase cost is spent yearly on maintenance [4].

The following base parameter values were stipulated for this work:

- 10 years horizon for plan operation
- 10% annual interest rate
- Electrical energy price of BRL0.159/kWh

Evaluated Design Concepts

Three design concepts were evaluated in this study to assess the overall costs. Table 1 describes all evaluated concepts.

Table 1 – Design Concepts for Cooling Water System

Design Concept	Characteristics
C1	One main pumping system Single circuit for cooling water distribution
C2	One main pumping system One auxiliary pumping system after major consumer Single circuit for cooling water distribution
C3	Two main pumping systems One circuit for cooling water distribution to major consumer, another circuit for distribution to other consumers

The case study was presented in the Preliminary Report and the design developed for each concept are shown in Figures 1 to 3.

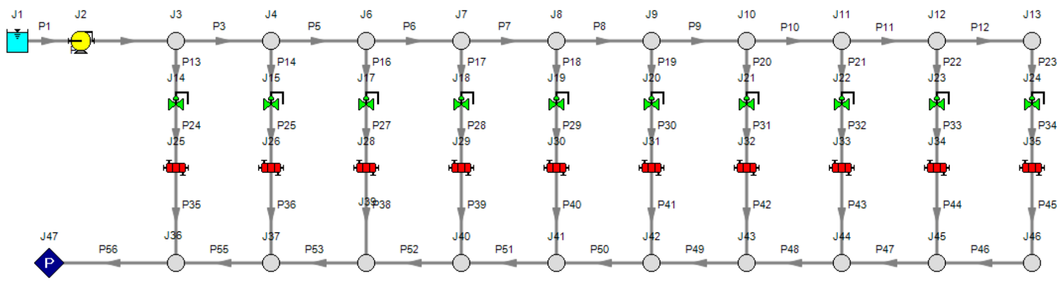

Figure 1 – Design Concept C1

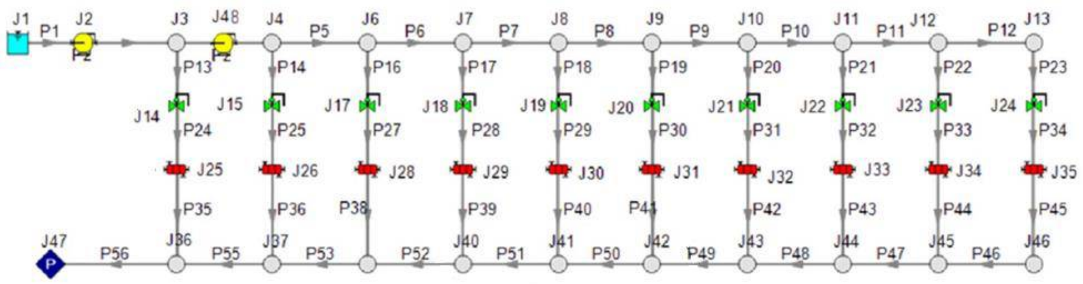

Figure 2 – Design Concept C2

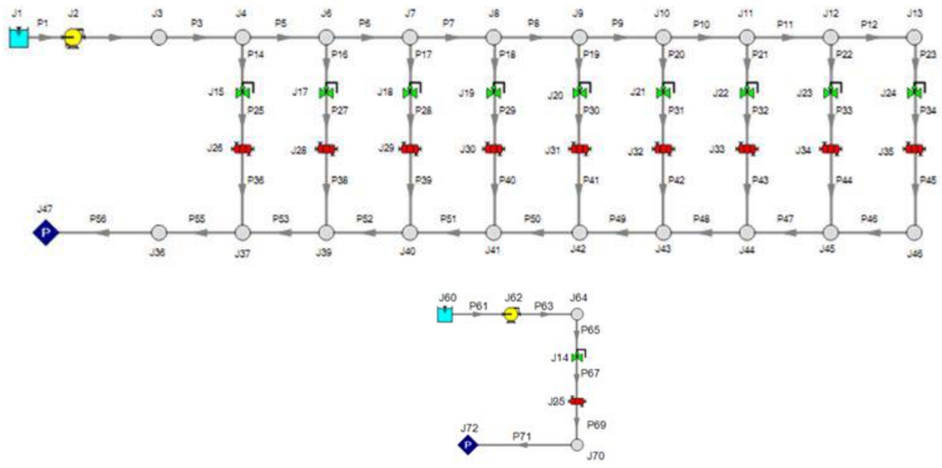

Figure 3 – Design Concept C3

Table 2 lists the cooling water consumption for each consumer.

Table 2 – Individual cooling water consumption

Consumer	Cooling Water consumption ($m^3.h^{-1}$)
J25	4100
J26	200
J28	1100
J29	2400
J30	1000
J31	1100
J32	32
J33	400
J34	800
J35	400
Total	**11532**

Pump Selection

In chemical plants, the cooling water distribution is generally one of the systems with the highest flow rates, if not the highest. The volumetric flow rates in cooling water systems can be significantly higher than 1,000 m^3/h, as the one presented in the case study, 11,532 m^3/h. Most centrifugal pump suppliers do not offer pump models with capacities as high as this figure. Some selected suppliers may offer large pumps, requiring large motors. However, if a plant decides to install such large pump and related motor to comply with high flow rates, it is very likely that this set would have a low turndown, hence presenting operational challenges. Therefore, as a good engineering practice, cooling water distribution systems are composed of multiple pumps of lower capacity. This poses a design challenge, since it is necessary not only to determine the most adequate pump model and size to use, but also how many pumps to install. A methodology to determine the optimal number of pumps and the optimal pump model is described in Pontes et al. [3].

The required pump head values used in the pump selection were calculated using at first the AFT Fathom sizing option. Then, with the calculated head, different pump sizes were selected using the PSS Software, which gives the pump curves for head and power. From this data, the optimal pump model and size was selected, as well as the number of pumps to install.

The following constraints are applied to the pump selection:

- Maximum required NPSH: 8.5 m
- Design point within the 70-120% range of the BEP

<u>Sensitivity Analysis</u>

Any cost estimation study is bound to several conditions, such as global and local market prices that impact equipment and energy prices. In addition, interest rates change from country to country. To assess the impact of these factors, a sensitivity analysis was performed for different values of energy prices, interest rates, and plant horizon.

All concepts of the distribution system were designed in a manner previewing that the major consumer (heat exchanger J25) would be the closest consumer to the cooling tower. In many occasions, this is not possible, and the major consumer might not be the closest, but seldom would be far from the cooling tower. A sensitivity analysis was also performed to evaluate the costs for all design concepts if the positions of consumers J25 and J29 are exchanged.

RESULTS

Determination of the Number of Pumps

Using AFT Fathom, the calculated head for the pumping systems in each concept is given in Figures 4 to 6. First, for each concept, four pump sizes are selected, varying the number of pumps to install in each system, and the corresponding motor models are also selected. For each pumping system, using the PSS software, the results present the minimum number of pumps that did not violate the constraints established by this work.

Using the ANS Module, the costs were estimated for each pump size selected. The results are given in Tables 3 to 12.

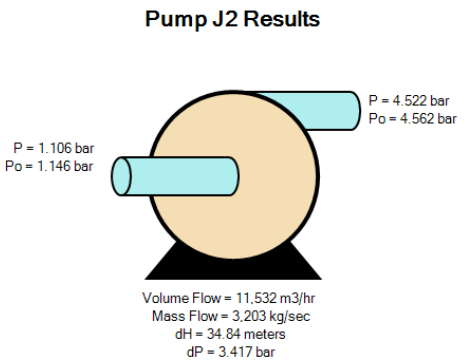

Figure 1 – Concept C1 main pumping system calculation

Table 3 – Selected Pumps for Concept C1

Pump								Motor	
Number of Pumps	Flow Rate ($m^3.h^{-1}$)	Size	Impeller Size (mm)	Speed (rpm)	Weight (kg)	Power (kW)	Efficiency (%)	Model	Design Power (kW)
13	887	8x10-13	333	1785	304	101.62	82.5	315SM175	132
14	824	8x10-13	329	1785	304	94.02	83.5	280SM150	110
15	769	8x10-13	324	1785	304	90.59	84.0	280SM150	110
16	721	8x10-13	319	1785	304	85.84	84.0	280SM150	110

Table 4 – Concept C1 Costs (in thousands of BRL) for the Pumping System

Number of Pumps	Material	Installation	Maintenance	Energy	Total
13	1,062	2,379	411	13,039	16,891
14	**973**	**2,178**	**376**	**12,960**	**16,488**
15	1,042	2,334	403	12,851	16,631
16	1,111	2,490	430	12,713	16,744

The selected pump size for a system with 14 pumps present the lower costs, about 2.4% less than the costs for a system with 13 pumps. As the number of pumps increases, the pump efficiency increases. This can be seen by the decreasing energy costs shown in Table 4. However, the material costs tend to increase with the number of pumps, except when the pump number is increased from 13 to 14, due to the use of a cheaper motor model in the 14 pumps system.

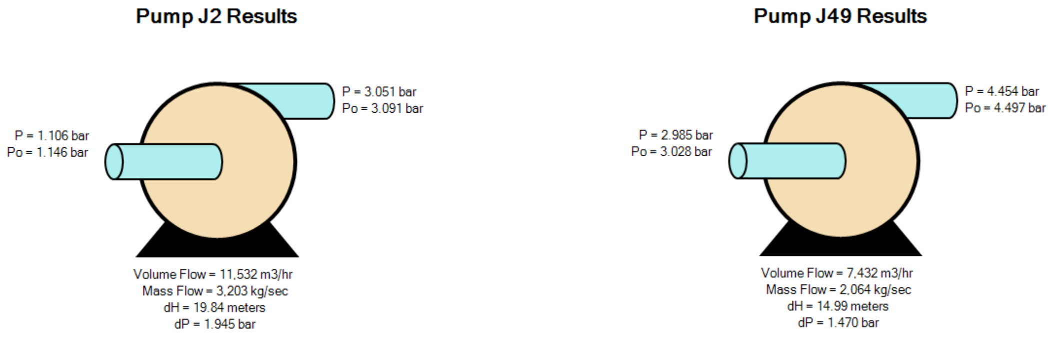

Figure 2 – Concept C2 main (J2) and auxiliary (J49) pumping system calculation

Table 5 – Selected Pumps for Concept C2 (Main Pumping System)

Pump								Motor	
Number of Pumps	Flow Rate ($m^3.h^{-1}$)	Size	Impeller Size (mm)	Speed (rpm)	Weight (kg)	Power (kW)	Efficiency (%)	Model	Design Power (kW)
12	961	8x10-16H	397	1185	385	65.42	80.5	250SM	75
13	887	8x10-16H	387	1185	385	58.93	81.0	250SM	75
14	824	8x10-16H	381	1185	385	54.72	81.5	250SM	75
15	769	8x10-16H	376	1185	385	51.84	81.0	250SM	75

Table 6 – Concept C2 (Main Pumping System) Overall Costs (in thousands of BRL)

Number of Pumps	Material	Installation	Maintenance	Energy	Total
12	**694**	**1,555**	**269**	**7,643**	**10,161**
13	752	1,685	291	7,498	10,226
14	810	1,814	314	7,537	10,475
15	868	1,944	336	7,638	10,786

For Concept C2, in the main pumping system, the selected pump size and motor model is the same regardless of the number of pumps in the system. This reflects in the considerable difference of 5.8% between the 12- and 15-pump systems.

Table 7 – Selected Pumps for Concept C2 (Auxiliary Pumping System)

Pump								Motor	
Number of Pumps	Flow Rate ($m^3.h^{-1}$)	Size	Impeller Size (mm)	Speed (rpm)	Weight (kg)	Power (kW)	Efficiency (%)	Model	Design Power (kW)
9	825	8x10-16H	359	1185	385	43.58	77.0	225SM75	55
10	743	8x10-16H	349	1185	385	39.19	77.5	225SM60	45
11	676	8x10-16H	341	1185	385	35.80	77.0	225SM60	45
12	619	8x10-15	325	1185	336	31.52	77.5	200L	37

Table 8 – Concept C2 (Auxiliary Pumping System) Overall Costs (in thousands of BRL)

Number of Pumps	Material	Installation	Maintenance	Energy	Total
9	**486**	**1,089**	**188**	**3,880**	**5,644**
10	519	1,162	201	3,873	5,754
11	571	1,278	221	3,890	5,960
12	524	1,173	203	3,907	5,807

For the auxiliary system, despite the 12-pump system having a smaller motor than the others, it still presents a larger cost than the 9- and 10-pump systems. The cost difference between the 9- and 11-pump systems is 5.4%.

Combining the lowest costs for the main and auxiliary pumping systems, the costs for Concept C2 is 15,805 kBRL, which is 4.2% less than the lowest costs found for the optimal pumping system in Concept C1.

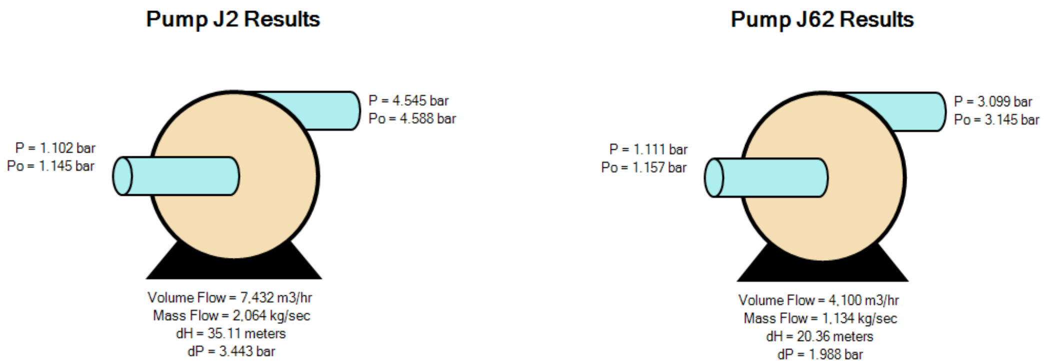

Figure 3 – Concept C3 primary (J2) and secondary (J62) pumping system calculation

Table 9 – Selected Pumps for Concept C3 (Primary Pumping System)

Pump								Motor	
Number of Pumps	Flow Rate ($m^3.h^{-1}$)	Size	Impeller Size (mm)	Speed (rpm)	Weight (kg)	Power (kW)	Efficiency (%)	Model	Design Power (kW)
9	825.8	8x10-13	329	1785	304	95.90	83.5	280SM150	110
10	743.2	8x10-13	322	1785	304	84.85	83.6	280SM150	110
11	675.6	8x10-13	316	1785	304	76.84	83.2	280SM125	90
12	619.3	8x10-13	311	1785	304	71.00	83.0	280SM125	90

Table 10 – Concept C3 (Primary Pumping System) Overall Costs (in thousands of BRL)

Number of Pumps	Material	Installation	Maintenance	Energy	Total
9	**625**	**1,400**	**242**	**8,336**	**10,604**
10	695	1,556	269	8,323	10,843
11	726	1,627	281	8,274	10,908
12	792	1,775	307	8,350	11,224

The lowest costs for the primary pumping system are obtained for a 9-pump system. The pump sizes are the same regardless of the number of installed pumps. The difference in cost between the 9- and the 12-pump system is 5.5%.

Table 11 – Selected Pumps for Concept C3 (Secondary Pumping System)

Pump								Motor	
Number of Pumps	Flow Rate ($m^3.h^{-1}$)	Size	Impeller Size (mm)	Speed (rpm)	Weight (kg)	Power (kW)	Efficiency (%)	Model	Design Power (kW)
4	1025.0	8x10-16H	406	1185	385	72.22	80.0	280SM125	90
5	820.0	8x10-16H	384	1185	385	56.56	81.5	250SM	75
6	683.3	8x10-15	359	1185	336	47.29	81.5	225SM75	55
7	585.7	8x10-15	348	1185	336	40.36	81.0	225SM60	45

Table 12 – Concept C3 (Primary Pumping System) Overall Costs (in thousands of BRL)

Number of Pumps	Material	Installation	Maintenance	Energy	Total
4	281	630	109	2,811	3,831
5	**289**	**648**	**112**	**2,770**	**3,819**
6	309	692	120	2,804	3,926
7	345	774	134	2,795	4,048

For the secondary pumping system, the lowest costs are obtained for a 5-pump system. The pump sizes and motor models vary according to the number of pumps. However, the difference in cost between a 5- and a 7-pump system is 5.7%, a figure similar to the one estimated for the primary system.

Combining the costs for both pumping systems, Concept C3 presents a tally of 14,423 kBRL, which is 13.5% less than the value for Concept C1 and 8.7% less than the value for Concept C2. However, the design concept for Concept C3 requires the use of more piping, since there are two separate supply headers and two separate return headers.

Cost Comparison for Design Concepts

Besides the pumping costs, this work also estimated the piping costs. Cost comparison for all three concepts is given in Table 13. Pumping costs in Table 13 consider the number of installed pumps that yielded the lowest costs for each concept.

Table 13 – Costs Comparison for Concepts C1 to C3 (in thousands of BRL)

Concept	Pump					Piping				Design
	Mat	Inst	Maint	En	Total	Mat	Inst	Main	Total	Total
C1	973	2,178	376	12,960	16,488	1,197	396	464	2,057	18,545
C2	1,181	2,645	457	11,523	15,805	1,197	396	464	2,057	17,862
C3	**914**	**2,048**	**354**	**11,106**	**14,423**	**1,198**	**425**	**463**	**2,087**	**16,510**

For the parameters set by this work, the results show that Concept C3 offers the lowest costs. Although the design for Concept C3 uses the same number of pumps as Concept C1, the pumps in Concept C3 consume less power and require smaller and less expensive motor models, yielding lower non-recurring costs, as well as recurring costs. In Concept C2, the pump recurring costs are lower than Concept C1, but the non-recurring costs are the highest for all concepts, about 21% higher than Concept C1. As for piping costs, although the design for Concept C3 uses more headers, the costs are about the same as Concepts C1 and C2. Therefore, the costs for Concept C3 are 11% lower than Concept C1 and 7.6% lower than Concept C2.

Sensitivity Analysis

Analyzing the results in Table 13, the energy costs make up the largest portion of the overall costs. Additional simulations were made altering parameters that directly affect the energy costs and can impact significantly on the cost estimation for all cases. Table 14 lists the sensitivity analysis cases for this work.

Table 14 – Sensitivity Analysis Cases

Case	Base parameter value	Altered parameter value
S1	10% annual interest rate	20% annual interest rate
S2	BRL0.159/kWh electrical energy price	BRL0.080/kWh electrical energy price
S3	10 years of plant horizon	20 years of plant horizon
S4	Consumer J25 is the closest to the cooling tower	Consumers J25 and J29 have positions exchanged, J25 becomes the fourth closest to the cooling tower

The first parameter altered was the interest rate in Case S1. Though a 10% annual interest rate is high, it is expected for developing countries such as Brazil. New simulations were performed for a 20% annual interest rate, which is compatible with a moderately risky investment. Table 15 compares the results for all cases.

Table 15 – Results for Sensitivity Analysis Case S1 (values in thousands of BRL)

Concept	Pump					Piping				Design
	Mat	Inst	Maint	En	Total	Mat	Inst	Main	Total	Total
C1	973	2,178	269	9,262	12,682	1,197	396	331	1,925	14,606
C2	1,181	2,645	327	8,237	12,390	1,197	396	331	1,925	14,314
C3	**914**	**2,048**	**285**	**7,939**	**11,186**	**1,198**	**425**	**345**	**1,968**	**13,154**

Another parameter that affects the energy consumption costs is evidently the electric energy prices. Further simulations were made for a value of BRL0.08/kWh. The results are presented in Table 16.

Table 16 – Results for Sensitivity Analysis Case S2 (values in thousands of BRL)

Concept	Pump					Piping				Design
	Mat	Inst	Maint	En	Total	Mat	Inst	Main	Total	Total
C1	973	2,178	376	6,521	10,048	1,197	396	464	2,057	12,105
C2	1,181	2,645	457	5,798	10,081	1,197	396	464	2,057	12,138
C3	**914**	**2,048**	**354**	**5,588**	**8,904**	**1,198**	**425**	**463**	**2,087**	**10,991**

Even reducing energy costs by altering the parameters, Concept C3 still offers the lowest recurring and non-recurring costs, as shown in Tables 15 and 16. However, when the electrical energy price is reduced, Concept C1 is less costly than t Concept C2. This happens as non-recurring costs for Concept C2 are higher than Concept C1.

The third parameter analyzed was the plant horizon, increased from 10 to 20 years. The results are presented in Table 17.

Table 17 – Results for Sensitivity Analysis Case S3 (values in thousands of BRL)

Concept	Pump					Piping				Design
	Mat	Inst	Maint	En	Total	Mat	Inst	Main	Total	Total
C1	973	2,178	522	17,953	21,625	1,197	396	642	1,039	22,664
C2	1,181	2,645	633	14,514	18,973	1,197	396	642	1,039	20,011
C3	**914**	**2,048**	**490**	**13,243**	**16,697**	**1,198**	**425**	**643**	**1,068**	**17,764**

The increase in plant horizon also increases recurring costs. Concept C3 costs are now 22% lower than Concept C1 costs, and 12% lower than Concept C2 costs.

Finally, for Case S4, where J25 and J29 positions are exchanged, new pump sizes were selected for this case, and these selections are given in Table 18. For Concept C2, the position of the auxiliary pumping system is maintained after the first consumer (J29) between junctions J3 and J4. Case S4 results are given in Table 19.

Table 18 – Pump Size Selection for Sensitivity Analysis Case S4

Pump											Motor	
Concept	System	Number of Pumps	Flow Rate ($m^3.h^{-1}$)	Head (m)	Size	Impeller Size (mm)	Speed (rpm)	Weight (kg)	Power (kW)	Efficiency (%)	Model	Design Power (kW)
C1	Main	14	823.7	34.5	8x10-13	327	1785	304	92.2	83.5	280SM150	110
C2	Main	12	961.0	19.7	8x10-16H	395	1185	385	64.3	80.0	250SM	75
	Auxiliary	11	830.2	21.3	8x10-16H	360	1185	385	44.3	77.5	225SM75	55
C3	Primary	9	825.8	35.9	8x10-13	330	1785	304	95.9	84.0	280SM150	110
	Secondary	5	820.0	25.8	8x10-16H	405	1185	385	69.0	83.0	250SM	75

Table 19 – Results for Sensitivity Analysis Case S4 (values in thousands of BRL)

Concept	Pump					Piping				Design
	Mat	Inst	Maint	En	Total	Mat	Inst	Main	Total	Total
C1	973	2,179	376	11,558	15,086	1,310	409	507	2,226	17,312
C2	1,289	2,887	499	12,351	17,025	1,310	409	507	2,226	19,251
C3	**914**	**2,048**	**354**	**10,756**	**14,073**	**1,364**	**519**	**528**	**2,411**	**16,484**

The analysis of the results in Table 19 shows that still Concept C3 presents the lower costs, 4.8% lower than Concept C1, which becomes less costly than Concept C2. Despite the increased distance from the major consumer J25 to the cooling tower, the recurring and non-recurring costs for Concept C3 are still the lowest.

CONCLUSIONS

The focus of the second part of this work was to assess the costs for the different cooling water distribution concepts developed in the Preliminary Report. The first step was to review all pump selections made previously, since as important as selecting the best pump size and model is determining the number of pumps to install. The optimal number of pumps might reduce the costs of a system up to 5%. Cooling water flow rates are considerably high; hence there is the need to use multiple pumps to distribute cooling water. As the number of pumps increases, the pumping system costs tend to increase. However, this work shows that for some cases this is not true, since a pumping system with an additional pump may require a pump size or motor model that is less costly, reducing the material and energy costs of the system.

With the reviewed pump selections for all concepts, the cost estimation for each concept was made using the ANS Module. The results show that Concept C3 offers the lowest, recurring and non-recurring costs. This is a widely used strategy in plants to distribute cooling water to a major consumer using devoted circuits. The increase in piping costs is low compared to the savings obtained in the pumping costs, since the pumps to be used are less expensive, and also the energy consumption is significantly reduced.

The results show that the use of auxiliary (booster) pumps, as in Concept C2, might be advantageous in some cases. The use of such pumps presents an expected increase in non-recurring costs, though most likely recurring costs are lowered.

Although these results are specific to the case study, this work proposed a methodology to design alternatives for a cooling water distribution system, and evaluate the costs in order to determine the best design in terms of costs.

Research topics to be pursued next include the elaboration of a new and refined methodology to determine the position of auxiliary pumps in the distribution system. In the Preliminary Report, different positions of the auxiliary pumping system were evaluated only in the distribution header, but not in the individual branches. Some plants use auxiliary pumps where there is more than one consumer in an individual branch. This assures that there is no short-circuiting in those branches. However, this strategy does not necessarily reduce costs, since its main purpose is to reduce operational challenges.

This work shows that devoted headers for major consumers are the less costly solution for the case study. However, the use of more than one devoted circuit is an alternative that should be investigated to assess cost impact.

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APPENDIX

Parameters for Pump Cost Estimation

Reference pump weight: 254 kg

Reference pump cost: BRL 25,000

Motor Models Table

Table A1 – Motor Model Costs from Weg

Model	Design power (kW)	Cost (BRL)	Model	Design power (kW)	Cost (BRL)
315SM200	150	56,509.30	225SM75	55	21,955.34
315SM175	132	53,846.06	225SM60	45	19,781.97
280SM150	110	41,619.90	200L	37	14,076.71
280SM125	90	38,175.40	200M	30	12,724.90
250SM	75	25,770.56	180M	22	9,522.65

Piping Costs Table

Table A2 – Piping Prices and Costs (Steel – ANSI STD pipes)

Nominal Diameter (in)	Material Costs (BRL)	Installation Costs (BRL)	Maintenance Costs (BRL)
1	3.4	11	0.2
1¼	4.2	12	0.3
1½	4.7	13	0.3
2	6.2	16	0.4
2½	10	21	0.6
3	13	24	0.8
3½	20	26	1.2
4	21	29	1.2
5	28	40	1.7
6	36	52	2.1
8	56	60	3.4
10	83	70	5.0
12	115	91	6.9
14	149	102	8.9
16	189	116	11
18	233	129	14
20	282	142	17
22	335	155	20
24	393	167	24
26	455	179	27
28	522	192	31
30	594	203	36
32	670	215	40
34	750	227	45
36	836	238	50
38	925	249	56
40	1020	260	61
42	1119	270	67
44	1222	280	73
46	1330	291	80
48	1443	301	87