

# Estimating with DACE Price Booklet and Labour Norms

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# Estimating with DACE Price Booklet and Labour Norms

## 1. Summary

Purpose of this paper is to show the use of the DACE Price Booklet [28<sup>th</sup> edition, May 2011] and DACE Labour Norms V2 [2<sup>nd</sup> edition, November 2011] when estimating the costs of a distillation unit for a fatty acids installation. The DACE Price Booklet and the Labour Norms are composed by the Special Interest Group Cost Engineering Process Industry [SIG CEPI] of the Dutch Association Cost Engineers [DACE]. The DACE Price Booklet has been published every 18 months since 1959; the costs have been established from judgement of actual costs of recently finished petro chemical plants in North West Europe. Basically the mentioned prices are for supply only except for the equipment, piping and civil section which also gives costs for installation, for this reason the SIG CEPI started to compile Labour Norms in 2008, which resulted in the first edition of the Labour Norms followed up by an extended and updated edition in November 2011.

From now on the DACE Price Booklet [28<sup>th</sup> edition, May 2011] will be referred to as Price Booklet and DACE Labour Norms V2 [2<sup>nd</sup> edition, November 2011] as Labour Norms.

## 2. Introduction

This paper shows the use of Price Booklet and Labour Norms to estimate a chemical unit.

Besides converting the given information into the required cost information also requires knowledge of estimating and a dose of common sense. Where sources other than the Price Booklet and the Labour Norms are used it will be indicated. In paragraph 3 a brief process description with associated drawings within the battery limit of the plant is presented which form the bases of the estimate.

Battery Limits of plants comprises one or more geographic boundaries, imaginary or real, enclosing a plant or unit being engineered and/or erected, established for the purpose of providing a means of specifically identifying certain portions of the plant, related groups of equipment, or associated facilities. It generally refers to the processing area and includes all the process equipment, and excludes such other facilities as storage, utilities, administration buildings, or auxiliary facilities. The scope included within a battery limit must be well-defined so that all personnel will clearly understand it. On drawings, this is often referred to in the phrase: inside/outside battery limits or ISBL/OSBL.

In section 4.1 the price of the equipment is estimated. This price is the basis for other cost-determining factors. Then installation and insulation costs of the equipment for labour and the necessary accessories are estimated. Successively, the amounts for process control, electrical-, civil-, painting-work and spare parts are estimated. In paragraph 4.10 the amounts, prices and costs, are then summarised. The determination of other prices such as the costs of temporary building facilities, general costs, engineering and unforeseen of the project are determined in paragraph 4.11. In paragraph 4.12 a final overview of the above prices, costs and the total investment amount is presented. The commentary and conclusion follow in paragraphs 5 and 6.

In estimating the cost of a distillation unit of a fatty acid installation, the Price Booklet will be followed as much as possible. The Price Booklet does not indicate prices and / or costs for each and all sizes of equipment the intermediate sizes of equipment prices and prices / costs are determined by interpolation / extrapolation. For sizes of equipment that fall outside the values of the Price Booklet the best possible approach will be selected.

All estimates are based on the cost level that is indicated in the **directions for users** in the Price Booklet, unless otherwise stated. The costs are expressed in Euros and are exclusive of VAT.

In this paper the terms price[s] and cost[s] are used and defined as follows:

- Price is for materials only;
- Costs[s] are costs for material and labour.

### 3. Distillation process of fatty acids unit

#### 3.1. Description

This section briefly describes how a distillation process of fatty acids evolves. Firstly some remarks to the equipment list, the Process Flow Diagram [PFD] [Figure 1] and layout drawings [Figure 2 and 3]. These are meant to clarify the process description and to give a better substantiated estimate at the end of this chapter. They should therefore be read in combination with the process description.

#### 3.2. Equipment list

An equipment list describes all involved process equipment and installations, such as type, dimensions, equipment number and characteristics or peculiarities are briefly mentioned. The original equipment list of the fatty acids distillation unit consists of three pages; these are not included in this article, but included in the cost estimate of the equipment paragraph 4.1.

#### 3.3. Process Flow Diagram [PFD]

Project design starts with composing a PFD. The PFD shows schematically the different process flows. The PFD for the fatty acids distillation unit is included in paragraph 3.5 [Figure 1]. On this PFD the main control loops are indicated. By means of this PFD the distillation process description of fatty acids will be developed see paragraph 3.5.

#### 3.4. Layout drawings

In order to obtain a clear picture of the final unit, two layout drawings of the distillation unit are included in paragraph 3.5 [Figure 2]. Not all cross-sections of the distillation unit are presented, only the top views. An isometric view of the entire unit is shown in figure 3. Taking the cross-sections at storey floor level it is possible to determine at each storey floor, whether sufficient space is available for the equipment. For the sake of clarity the equipment numbers are not included on figure 3.

#### 3.5. Process description

The purpose of a distillation process is to split crude fatty acid into:

- Pure fatty acid;
- Top product;
- Bottom product.

Crude fatty acid is a mixture of all kinds of acids such as stearin acid and linoleum acid with impurities such as water. The pure fatty acid is used in the paint-, plastics- and coating industry.

The top product is sold as lower quality fatty acid or, if this is not possible, burned. The bottom product is applied as an addition in road asphalt.

##### Crude fatty acid

Crude fatty acid is intermittently pumped into feed tank T-01. The temperature in the feed tank is heated by means of a heating coil [low pressure steam at 50 °C]. The crude fatty acid is pumped [P-01A] through 2 heat exchangers [H-01 & H-02] as feed into the distillation column. The feed pump [P-01A] capacity is 5,000 kg/hour crude fatty acid. P-01S serves as spare pump for P-01A. In heat exchanger [H-01] heat is exchanged between hot distillate [220 °C] and crude fatty acid [50 °C]. The temperature of the crude fatty acid is increased from 50 °C to 155 °C. In heat exchanger [H-02] the crude fatty acid is further heated by hot oil [320 °C] up to 240 °C. The heated fatty acid then goes into the distillation column [C-01]. Upon entry into the column, due to the prevailing circumstances, a portion of the crude fatty acid evaporates. In the distillation column [C-01], a combined mass and heat transfer takes place.

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### Pure fatty acid

Pure fatty acid leaves the column [C-01] through sieve trays and is collected in distillation tank T-11. This tank has a buffer function; the level is kept at a constant level in order to provide adequate suction pressure to pump P-11A. After the distillation pump P-11A [spare P-11S] pumps the pure fatty acid into heat exchanger H-01 and a portion of the heat is exchanged to the crude fatty acid. The temperature of the pure fatty acid of 220 °C is in this way reduced to 160 °C. The pure fatty acid temperature [160 °C] is further decreased in the water cooler H-06 to 50 °C. After the cooler the fatty acid flows into one of two distillation tanks T-03A or T-03B, which act as intermediate storage tanks. For quality control, samples from these tanks can be drawn. If the quality of the fatty acid does not meet the specifications, it is recycled to feed tank T-01. This recirculation is not indicated on the PFD. The storage capacity of tanks T-03A and T-03B is 30 m<sup>3</sup> each. For quality reasons liquid fatty acid may not be contaminated with air, therefore tanks T-03A and T-03B are blanketed with nitrogen. If pressure increases in the tanks [e.g. by solar radiation] the nitrogen is ventilated into the atmosphere or drained to an incineration plant. By means of buffer pumps P-03A [from T-03A] or P-03B [from T-03B] the pure fatty acid distillate is pumped into the final storage/offloading.

### Top product

Vapours rising in the column [C-01] go to the top to condenser H-04. The vapours are condensed with cooling water. The condensate flows into top product tank T-12. Pump P-12A [P-12S is spare] pumps the distillate into the column as reflux. This reflux is needed to maintain a balance between vapour and liquid in the distillation column. A small portion flows into top product storage tank T-04, which serves as a buffer tank. The temperature of the top product in tank T-04 is held at 100 °C by means of low-pressure steam. From tank T-04 the top product is pumped by pump P-04 as top product.

### Bottom product

In the lower section of the column [C-01] steam, at a pressure of 5 bar and temperature of 150 °C, is supplied through a coiled steam distributor. Bottom product pump P-13A [P-13S is spare] pumps the bottom product from the lower section of the column through the bottom product heater H-03 back into the column [C-01]. In heat exchanger H-03 the bottom product is heated by 320 °C hot oil to a temperature of 240 °C. A small portion of the bottom product is led via the bottom product cooler H-05 into bottom product buffer tank T-02 as end product. In bottom product cooler H-05 the bottom product is cooled from 240 °C to 100 °C by cooling water. The 100 °C temperature is necessary to be able to pump the product. For the same reason low pressure steam is used to keep the temperature the product in tank T-02 the coagulation temperature. The bottom product is pumped with bottom product pump P-02.

### Vacuum generator

The pressure at the top of the column [C-01] is 10 mbar, which is obtained using vacuum generator P-20. This is a 5-stage vacuum unit with 3 intermediate coolers. The drain of the 5<sup>th</sup> stage is split into two flows; however they are excluded from the estimate.

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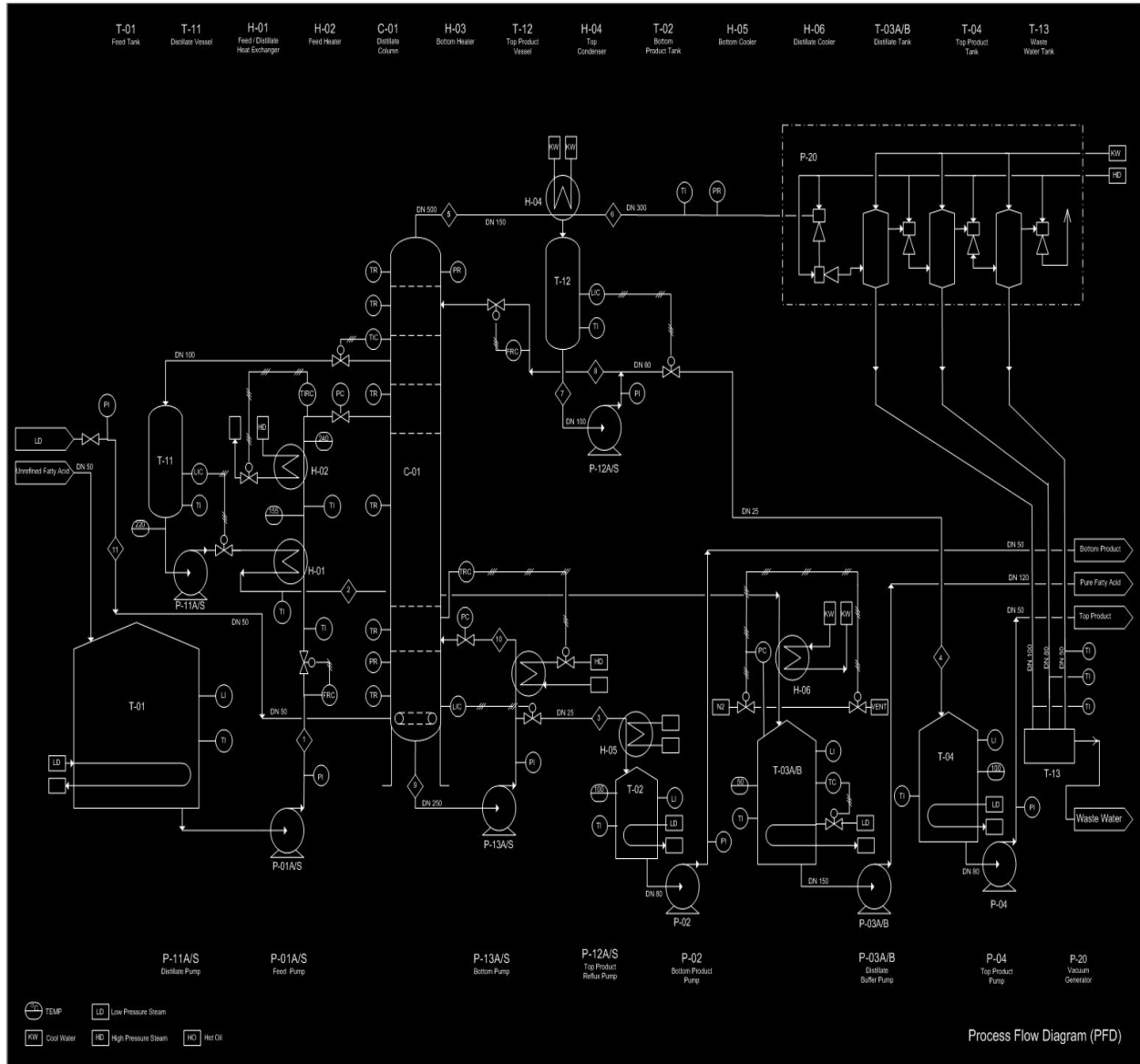


Figure 1 Process Flow Diagram [PFD]

## Estimating with DACE Price Booklet and Labour Norms

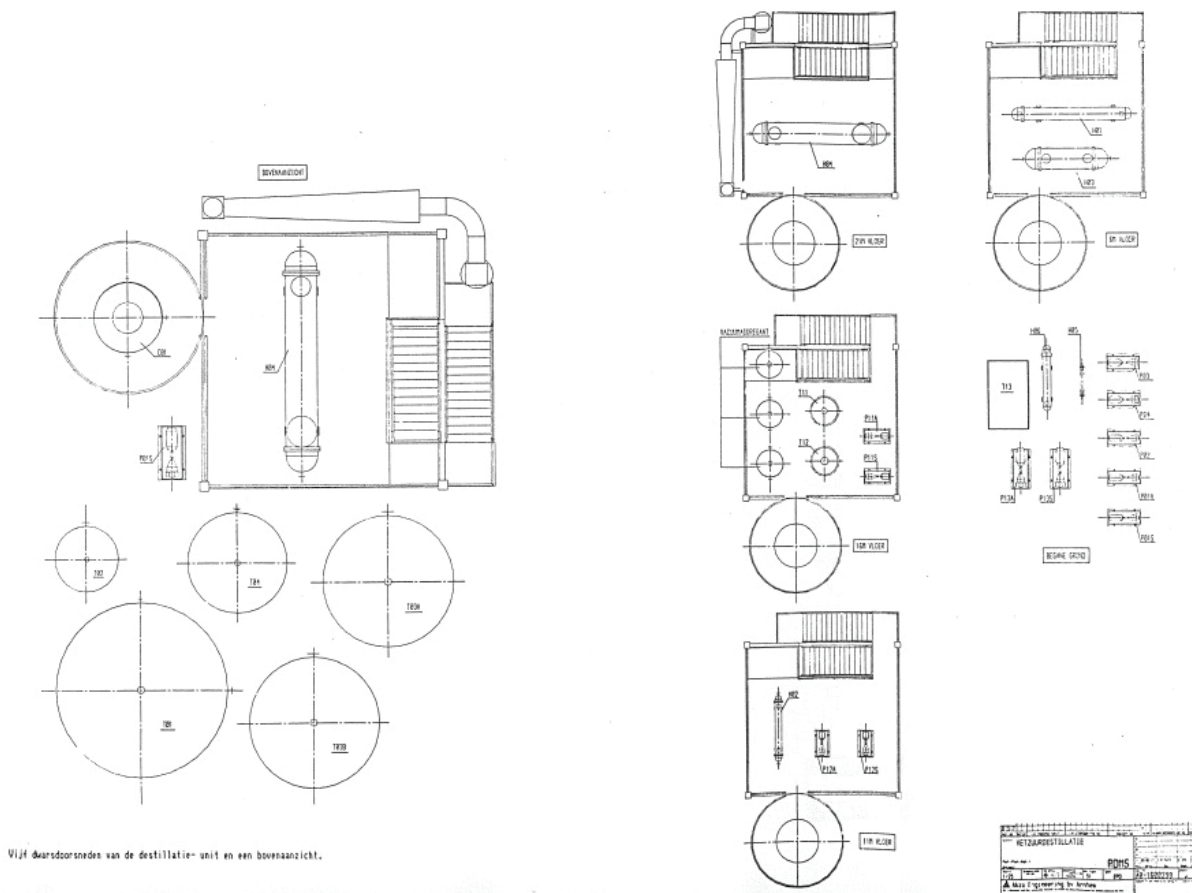


Figure 2 Lay out

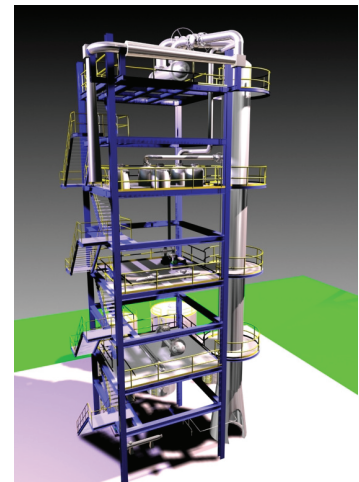
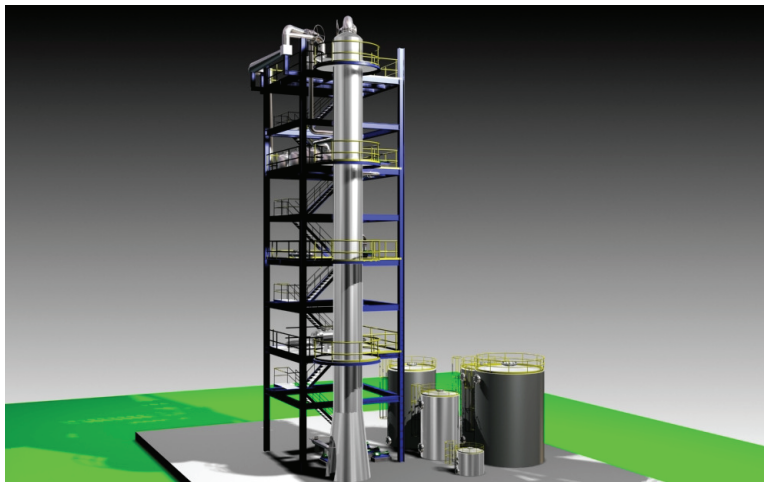


Figure 3 Distillate unit in isometric view.

## Estimating with DACE Price Booklet and Labour Norms

### 4. Costs of the distillation unit

Firstly the total price for equipment is determined. The remaining installation costs are then determined. A clear insight is obtained from PFD [figure 1] and layout [figure 2]. The prices of equipment together with their installation costs are the hardware costs [paragraph 4.10, table 10]. The hardware costs for ISBL increased with costs for temporary facilities at the construction site, general costs, engineering and unforeseen constitutes the final amount of the estimate. When the Price Booklet is used it refers to table letter and number. By referring to the equipment cost-defining characteristics and further description if necessary, one can eventually check the listed prices. When referring to a previous calculation methodology this calculation is not elaborated for the new amounts, the final result will suffice. The scope should be clearly defined, in order to assess the contents of the estimate.

#### 4.1. Prices for equipment

Distillation column C-01

- Material: AISI 316 L
- Dimensions: diameter 1,6 m; height 20 m
- Design pressure: 0 bar [fully vacuum ]
- Design temperature: 260 °C
- Insulation: thermal insulation
- Internals: 40 sieve trays and a steam distributor

The Price Booklet includes prices for distillation columns in table A 1008. We assess an average wall thickness of 14 mm. The operating pressure and temperature is not indicated; it is assumed that the column meets our specifications. For a stainless steel [AISI 316 L] column with a diameter of 1.5 m the price is € 492,000 [table A 1008] and for a diameter of 2.0 m € 569,000. By linear progression between 1.5 m and 2.0 m to a diameter of 1.6 m, we find the basic price for the distillation column of € 507,400 including: nozzles, manholes and skirt. Excluding costs for: fillings, internals, platforms, cage ladders, transportation, assembly, x-ray and authority/Notified Body.

Sieve trays

There are 40 sieve trays in the distillation column. Price Booklet, table A 1009 includes prices for internals of columns. The price for a sieve tray out of AISI 316 material and a diameter of 1.0 m is € 580 per m<sup>2</sup> and for a diameter of 2.0 m € 524 per m<sup>2</sup>. We determine the price for the necessary sieve tray of 1.6 m by interpolation based on the surface of the trays and not on the basis of the diameter. The surface of a tray with a diameter of 1.0 m is 0.785 m<sup>2</sup> and of a diameter of 2.0 m 3.142m<sup>2</sup>, while the required tray surface of 1.6 m diameter equals 2.011 m<sup>2</sup>. The price per m<sup>2</sup> for a tray with a diameter of 1.6 m is:  $([2.011 - 0.785] / [3.142 - 0.785]) \times [524 - 580] + 580 = € 551$ . The price for the required tray is:  $2.011 \text{ m}^2 \times € 551/\text{m}^2 = € 1,108$ . The cost of 40 sieve trays  $40 \times € = 1,108 = € 44,320$ . Rounded up to € 44,350.

Steam distributor

The price of a steam Distributor is assessed to be € 13,000

#### **Total price of C-01**

- Supply of column C01 [base cost]	€ 507,400
- Supply of sieve trays	€ 44,350
- Supply of steam distributor	€ 13,000
- Transport costs [assessed]	€ 22,000
- X-ray cost [assessed] costs and authority/Notified Body	€ 14,750
Total	€ 601,500

The cost for platforms and cage ladders will be included in the cost of steel construction and are excluded from the above total.

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### Feed tank T-01

Type of tank: cone roof.

- Tank material: AISI 316
- Dimensions: diameter 4 m; height 5 m; capacity 62.5m<sup>3</sup>
- Tank design pressure: atmospheric
- Design temperature: 70 °C
- Insulation: PP [Personal Protection] = insulation to protect against touching hot surfaces
- Heating coil: surface 5 m<sup>2</sup> [A], material: AISI 316

The Price Booklet only includes for carbon steel storage tanks [table A 1003]. For storage tanks of AISI 316 no costs are mentioned. According to the global price ratios of various materials in table A 1001 the price factor H II [carbon steel] to AISI 316 = 100 / 278. It is assumed that the tank in table A 1003 meets our specifications. For a storage tank out of H II material [carbon steel] with a capacity of 50 m<sup>3</sup> the cost is € 62,000 and for a capacity of 100 m<sup>3</sup>, the cost is € 74,000. By linear progression between these two to 62.5 m<sup>3</sup>, we find the cost for a storage tank. For H II material the cost of tank T-01 is € 65,000 and by multiplying with the factor H II / AISI 316, the cost of the tank, executed in AISI 316, amounts to: € 65,000 × [278 / 100] = base cost € 180,700.

Inclusive: local installation, nozzles, steel cage ladder and steel railing.

Exclusive: internals [heating coil] and civil work.

#### Heating coil:

- Material: material equal to tank
- Diameter pipe DN 50 mm, outer diameter [D] is 60.3 mm.
- Length is 30 m [from the calculation  $A = \pi \times D \times [L + 10\% \text{ cutting loss}]$  L is 26.4 m], however, one will have to buy 5 lengths of 6 m.

Pipe material cost, meter cost pipe is € 44 [table B 1005]	€ 1,320
Flanges DN 50 mm, stub-end € 22 [table B 1006]	€ 44
1 flange for installation on the tank [assessed]	€ 683
Mounting materials [assessed]	€ 407
Material handling and installation costs; sawing, pipe bending, welding and assembling in the tank [30 m pipe bending, 8 butt welds, 7 bends, 2 nozzle welds]	€ 1,410
<b>Total heating coil</b>	<b>€ 3,864</b>

#### **Total costs of T-01**

Supply tank T-01 [base cost]	€ 180,700
Heating coil	€ 3,864
<b>Total</b>	<b>€ 184,564</b>
Rounded off to	€ 185,000

### Bottom product tank T-02

Type of tank: cone roof.

- Material: carbon steel
- Dimensions: diameter 1.5 m buffer; height 2.3 m; capacity 4 m<sup>3</sup>
- Tank design pressure: atmospheric design temperature: 120 °C
- Insulation: thermal insulation
- Heating coil: surface 1 m<sup>2</sup> [A], material: carbon steel

Remark: a corrosion surcharge of 3 mm on wall thickness tank is applicable.

The Price Booklet, table A 1003 only mentions costs of cone roof tank with a capacity of 50 m<sup>3</sup> or larger. Estimating a cone roof tank with capacity of 4 m<sup>3</sup> is almost impossible. Table A 1006, cylindrical tanks with spherical heads, mentions cost for tanks with a smaller capacities. The costs of a cone roof tank with a capacity of 4 m<sup>3</sup> is to be determined by the cost of a 4 m<sup>3</sup> tank with spherical heads by multiplying with a cone roof / spherical heads ratio. The ratio cone roof / spherical heads are determined as follows:



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Firstly we determine the cost for equal capacity and wall thickness for both tanks of cone roof and spherical heads.

A cone roof tank with a capacity of 50 m<sup>3</sup> and wall thickness of 6 mm of carbon steel according Price Booklet, table A 1003 costs € 62,000. This amounts to € 1,240 per m<sup>3</sup>.

A cylindrical tank with spherical heads according Price Booklet, tables A 1006 and A1007 with a capacity of 50 m<sup>3</sup> is not mentioned however those of 40 m<sup>3</sup> and 60 m<sup>3</sup> with a wall thickness of 5 mm are mentioned. By interpolation, the cost of a cylindrical tank of 50 m<sup>3</sup> tank with a wall thickness of 6 mm is € 30,650, amounting to € 613 per m<sup>3</sup>.

The ratio cone roof / spherical heads amount to  $1,240 / 613 = 2.02$ .

The cost of a tank with spherical heads and capacity of 4 m<sup>3</sup> and 6 mm wall thickness is to determine with the cost of a 1 m<sup>3</sup> and 5 m<sup>3</sup> tank [Price Booklet table A 1006], amounts to € 13,377.

A cone roof tank costs: € 13,377 × [1,240 / 613] = € 27,060.

A corrosion surcharge of 3 mm is required; we determine the extra cost of wall thickness from 4 m<sup>3</sup> tank with spherical heads.

The pricing is equal to the previously, a tank of 1 m<sup>3</sup> capacity and 9 mm wall thickness costs € 8,636 and of 5 m<sup>3</sup> capacity and 9 mm wall thickness costs € 16,764, so the cost of a tank of 4 m<sup>3</sup>; 9 mm wall thickness will amount to € 14,732.

The additional cost relative to a 4 m<sup>3</sup> tank with 9 mm and 6 mm wall thickness tank is:  
€ 14,732 - € 13,377 = € 1,355.

The heating coil is calculated on the same way as at T 01, however, with a smaller pipe diameter DN 40 [48.3 mm]. Cost heating coil: € 1,996.

### **Total cost of T-02**

Cost feed tank T-02 [base cost]	€ 27,060
Corrosion allowance	€ 1,355
Cost heating coil	€ 1,996
Total	€ 30,411
Rounded off	€ 31,000

Distillate tank T-03 A/B

Type of tank: cone roof.

- Material: AISI 316
- Dimensions: diameter 3 m; height 4.5 m; capacity 30 m<sup>3</sup>
- Design pressure: atmospheric
- Design temperature: 70 °C
- Insulation: PP [Personal Protection]
- Heating coil: surface 2,5 m<sup>2</sup> [A], material: AISI 316

Taking decreasing capacities with the same [assumed] wall thickness of 6 mm in table A 1003 we calculate a trend table for carbon steel tanks:

m <sup>3</sup>	€	€/m <sup>3</sup>
250	102,000	408
200	94,000	470
150	84,000	560
100	74,000	740
50	62,000	1,240

We estimate that the cost for a 40 m<sup>3</sup> tank will be in the range of € 1,300. So for one tank [T-03] with the material factor [table A 1001] as used with T-01, will be: € 1,300 × 40 × [278 / 100] = € 144,560.

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The heating coil is calculated in the same manner as at T-01. Cost heating coil € 3,076.

### **Total cost of T-03 A/B**

Costs of 2 tanks [base cost]		€ 289,120
Costs of 2 heating coil		€ 6,152
	Total cost	€ 295,272
	Rounded off	€ 295,500

Top product tank T-04

Type of tank: cone roof.

- Material: carbon steel
- Dimensions: 2.3 m diameter; height 3.5 m; capacity 15 m<sup>3</sup>
- Design pressure: atmospheric
- Design temperature: 120°C
- insulation: thermal insulation
- Heating coil: surface 2 m<sup>2</sup> [A], material: carbon steel

Remark: a corrosion allowance of 3 mm on wall thickness tank is applicable.

### **Total cost of T-04**

The cost calculation of this tank is equal to T-02, including corrosion allowance

		€ 45,725
The heating coil same way as T 01		€ 2,690
	Total costs	€ 48,414
	Rounded off	€ 48,500

Distillate tank T-11

- Material: AISI 316
- Dimensions: diameter 1 m; height 1,2 m; capacity 1 m<sup>3</sup>
- Design pressure: 0 bar [absolute]
- Design temperature: 240°C
- Insulation: thermal insulation

Remark: in connection with vacuum is assumed to be 8 mm wall thickness.

The price for this tank according Price Booklet, table A 1006 in AISI 304 is € 12,000.

According to the global costs of ratios of various materials in table A 1001, the price for this tank manufactured out of AISI 316 material amounts to € 12,000 × [278 / 254] = € 13,134.

### **Total price of T-11**

The cost of the tank		€ 13,134
	Rounded off	€ 13,200

Top product tank T-12

Same as tank T-11, except for a lower design temperature [120°C]

		€ 13,200
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Waste water tank T-13

The waste water tank [dimensions 2 × 1 × 1 m] consists of an excavated concrete casing with acid-resistant tiles. Wall thickness = 25 cm.

Price Booklet, table F 6009 excavation under paragraph earthwork by hand costs are € 41.50 – 61.50 per m<sup>3</sup>, since we only have a small amount, we take the highest cost 10 m<sup>3</sup> × € 61.50 = € 615. Backfilling of 8m<sup>3</sup> [10m<sup>3</sup> – 2m<sup>3</sup> of concrete] at € 30 per m<sup>3</sup> = € 240. Bottom layer of sand [assessed] € 300.

Price Booklet, table F 4007 concrete work foundation with heavy reinforcing steel costs € 610 per m<sup>3</sup>. Required is 2 × 1 × 1 m; 0.25 m thick, resulting in a volume of 2 m<sup>3</sup> at € 610 = € 1,220.

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Finishing the concrete tank with acid-resistant tiles [Price Booklet, table F 4022] costs € 240 per m<sup>2</sup> resulting in 10 m<sup>2</sup> x € 240 = € 2,400

### **Total cost of T-13**

Excavation	€ 615
Backfilling	€ 240
Sand	€ 300
Concrete work	€ 1,220
Finishing with acid resistant tiles	€ 2,400
Total	€ 4,775
Rounded off	€ 4,800

Heat exchangers H-01 H-6 tables A 1011, A 1012 and A 1013.

The Price Booklet mentions costs for heat exchangers, however the only difference is in material specification. No correction factors for difference in temperatures and/or pressures are given. It is assumed that the heat exchangers comply with our requirements. If required, interpolation will be used to estimate the cost of a heat exchanger.

Feed /distillate exchanger H-01

Type of heat exchanger: shell and tube

- Design pressure bar [abs.] shell / tube: 6.7 and 5.7
- Design temperature shell / tube: 240°C and 240°C
- Material shell / tube: AISI 316 L and AISI 316 L
- Heated surface: 40 m<sup>2</sup>

**Total price of H-01** € 53,000

Feed exchanger H-02

Type of heat exchanger: and shell and tube

- Design pressure bar [abs.] shell / tube: 6 and 6.7
- Design temperature shell / tube: 320°C and 320°C
- Material shell / tube: Carbon steel and AISI 316 L
- Heated surface: 5 m<sup>2</sup>

**Total price of H-02** € 16,500

Bottom product exchanger H-03

Type of heat exchanger: shell and tube

- Design pressure bar [abs.] shell / tube: 6 and 3.7
- design temperature shell / tube: 320°C and 320°C
- Material shell / tube: Carbon steel and AISI 316 L
- Heated surface: 60 m<sup>2</sup>

**Total price of H-03** € 32,500

Top condenser H-04

Type of heat exchanger: shell and tube

- Design pressure bar [abs.] shell / tube: 0 and 6.0
- Design temperature shell / tube: 140°C and 30°C
- Material shell / tube: AISI 316 L and AISI 316 L
- Heated surface: 130 m<sup>2</sup>

**Total price of H-04** € 116,700

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Bottom product cooler H-05

Type of heat exchanger: shell and tube

- Design pressure bar [abs.] shell / tube: 3.7 and 6
- Design temperature shell / tube: 260°C and 30°C
- Material shell / tube: Carbon steel AISI 316 L
- Heated surface: 0.1 m<sup>2</sup>

The smallest heat exchanger in the Price Booklet has a heating surface of 2 m<sup>2</sup>.

**Total cost of H-05** [assessed] € 14,000

Distillate cooler H-06

Type heat exchanger: shell and tube

- Design pressure bar [abs.] shell / tube: 6 and 5.7
- design temperature shell / tube: 30°C and 180°C
- material shell / tube: Carbon steel and AISI 316 L
- Heated surface: 6 m<sup>2</sup>

**Total cost of H-06** € 17,000

Pumps

Price Booklet, table A 2006 includes in the prices for single stage-centrifugal pumps. For this estimate we take prices of pumps with a speed of 2,900 rpm. We find the prices of corresponding electrical motors in table D 2007. The price for standard electric motor is included in the estimate.

Feed pump P-01 A/S

Type of pump: centrifugal

- Material: AISI 316
- Capacity: 8 m<sup>3</sup>/hour
- Head: 50 meters
- Power: 2,2 kW
- Drive: electric motor
- Seal: gland

For a pump with a gland we take the pump whose capacity, head and power are the closest to the desired values. For pump P-01 A/S this is pump type 32 -125 [Price Booklet, table A 2006].

The price for these pumps, out of AISI 316 material: € 12,000

Because the price is based on a mechanical seal instead of a gland, we apply an assessed discount of:

€ - 380

Electric motor 2.2 kW [Price Booklet, table D 2007]: € 680

**Total price P-01 A/S** € 12,300

Bottom product pump P-02

Type of pump: centrifugal

- Material: cast iron
- Capacity: 10 m<sup>3</sup>/hour
- Head: 30 meters
- Power: 2,2 kW
- Drive: electric motor
- Seal: gland

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Pump type: 32 -160 [Price Booklet, A 2006].	
The price for this pump:	€ 5,300
Because the price is based on a mechanical seal in stead of a gland, we apply an assessed discount of:	€ - 190
Electric motor 2.2 kW [Price Booklet, table D 2007]:	€ 340
<b>Total price P-02</b>	<b>€ 5,450</b>
Distillate buffer pump P-03 A/B	
Pump type: centrifugal	
– Material:	AISI 316
– Capacity:	50 m <sup>3</sup> /hour
– Head:	30 meters
– Power:	7.5 kW
– Drive:	electric motor
– Seal:	double mechanical seal
Pump type: 40 – 200 [Price Booklet, table A 2006]	
Price as pump P-01 A/S:	€ 15,400
Electric motor 7.5 kW [Price Booklet, table D 2007]	€ 1,648
Additional for double mechanical seal [assessed]:	€ 7,202
This is for a double slip ring seal, buffer tank and accessories.	
<b>Total price P-03 A/B</b>	<b>€ 24,250</b>
Top product pump P-4	
Pump type: centrifugal	
– Material:	cast iron
– Capacity:	20 m <sup>3</sup> /hour
– Head:	30 meters
– Power:	3 kW
– Drive:	electric motor
– Seal:	gland
Pump type: 32 – 160 [Price Booklet, table A 2006]	
Price as pump P-01 A/S:	€ 5,300
Because the cost is based on a mechanical seal in stead of a gland, we apply an assessed discount of:	€ - 177
Electric motor 3 kW [D 2007]	€ 427
<b>Total price P-04</b>	<b>€ 5,500</b>
Distillate pump P-11 A/S	
Pump type: centrifugal	
– Material:	AISI 316
– Capacity:	8 m <sup>3</sup> /hour
– Head:	30 meters
– Power:	1.5 kW
– Drive:	electric motor
– Seal:	double mechanical seal
Pump type: 32 – 125 [Price Booklet, table A 2006]	
Price as pump P-03 A/B:	€ 12,000
Electric motor 1.5 kW [Price Booklet, table D 2007]	€ 556
Additional for single mechanical seal [assessed]. This includes for a double slip ring seal, buffer tank and accessories:	€ 7,244
<b>Total price P-0 11 A/B</b>	<b>€ 19,800</b>

## Estimating with DACE Price Booklet and Labour Norms

Top product pump Post P-12 A/S

Pump type: centrifugal

- Material:	AISI 316
- Capacity:	8 m <sup>3</sup> /hour
- Head:	25 meters
- Power:	1.5 kW
- Drive:	electric motor
- Seal:	single mechanical seal

Pump type: 32 – 125 [Price Booklet, table A 2006]

Price as pump P-01 A/S: € 12,000

Additional for single mechanical seal [assessed]: € 7,144

Electric motor 1.5 kW [D 2007] € 556

**Total price P-12 A/S** € 19,700

Bottom product pump P-13 A/S

Type: canned centrifugal pump

- Material:	cast iron
- Capacity:	130 m <sup>3</sup> /hour
- Head:	20 meters
- Power:	11 kW
- Drive:	electric motor

Note: no price for canned (seal less) pumps is included in the Price Booklet.

We assess a price of € 12,200 per pump.

**Total price P-13 A/S** € 24,400

Vacuum unit P-20

Type: 5 steam-extractors and mixing condensers

Material:	cast iron
Capacity/hour:	180 kg H <sub>2</sub> O + 10 kg of product + 5 kg of air
Suction pressure:	5 mbar [absolute]
Press pressure:	1 bar [absolute]

Note: no price for vacuum units is included in the Price Booklet.

We assess the prices of € 72,000 for a vacuum unit.

**Total price P-20** € 72,000

All prices of equipment are now determined and tabled in table 1 at the end of paragraph 4.2.

### 4.2. Costs for installation of equipment

The column C-01 will be placed on its concrete foundation by two cranes. Firstly we must calculate the weight that has to be hoisted. The weight of the column, diameter of 1.5 m, according Price Booklet, table A 1008 is 15,600 kg and for a diameter of 2.0 m: 20,600 kg. For a diameter of 1.6 m the weight is about 16,600 kg. The weight of the support of the trays is estimated at 2,300 kg, making the total weight of the empty column 18,900 kg. On the basis of crane tables [weight about 20 tons, a hoisting height of approximately 30 m and a range of 10 m] at least a 100-tonne main crane and a second tail crane of 45-tonne, for assistance, is required for lifting the column. The estimated assembly time to place the column onto the concrete foundation is 8 hours. For unloading the column of the means of transport 4 hours are assessed. The installation and removal time for installation and dismantling the 100-tonne crane we assess 12 hours. Price Booklet, table F 3005 does not include costs for a 100-tonne hydraulic crane therefore we take the cost of a 120-tonne crane of € 260 per hour and for the 45-tonne crane of € 115 per hour.

## Estimating with DACE Price Booklet and Labour Norms

The estimated cranes costs are:

–	120-tonne crane	$[4 + 8 + 12] \times 260 =$	€ 6,240
–	45-tonne crane	$[4 + 8 + 12] \times 115 =$	€ 2,760
		Total	€ 9,000

We estimate the man-hours according to the Labour Norms chapter 2.2 Installation of Vessels/ Columns and Columns to be 48 man-hours

Price Booklet, table H 2001 gives an average hourly rate of € 42.50 for labour including costs for travel and expenses

The average hourly rate has to be corrected for working in confined spaces, cellars, height, etc. Since these are not given in table H 2001 the best approach is: Price Booklet, table H 2002 and Labour Norms General chapter 13 Corrections to the Labour Norms i.e. conditioning of Labour Norms.

In this case the following corrections apply:

–	Height:		20%
–	Walking distance to the construction site 750 m:		10%
		Total	30%

Cost for installation man-hours for column C-01:  $48 \times € 42.50 \times 1.30 = 2,652$ . Rounded off € 2,680

Furthermore materials and services are necessary whose costs are assessed at € 11,500.

Costs for the fitting of sieve trays in column C-01

Since no better information is available for hourly rates of craftsmen, we take the man-hour rates of Price Booklet, table H 2001. The installation time of a sieve tray on the basis of Labour Norms, chapter 2.3 installation equipment clipped sieve trays and by interpolation is 9 hours and an addition 2 man hours for closing the tray manhole.

In this case the following corrections to the Labour Norms apply:

–	Low room space:		5%
–	confined space:		25%
–	Height [average]:		15%
–	Walking distance to the construction site 750 m:		10%
		Total	55%

The installation costs per sieve tray are:  $11 \times € 42.50 \times 1.55 = € 725$ .

The installation of 40 pieces of sieve trays:  $40 \times € 725 = € 29,000$

Total Cost for installation of C-01

–	Crane costs		€ 9,000
–	Installation of C-01		€ 2,680
–	Other materials and services		€ 11,500
–	Installation of sieve trays		€ 29,000
		Total	€ 52,180

Because the tanks T-01, T-02, T-03 A/B, T-04 and T-13 are site installed costs are already included.

The installation costs of the remaining equipment are determined in the same way by using the Labour Norms however for simplicity sake we take an average of 6 hours for heat exchangers and 12 hours per pump and a 20-tonne crane for 6 hours per equipment. In this case a correction of 10% applies for a walking distance to the construction site of 750 m.

The total costs for equipment installation amounts to: € 69,480.

## Estimating with DACE Price Booklet and Labour Norms

Table 1 Prices and costs of equipment

Equipment №	Description	Prices and costs €	Costs €	Man-hours
C-01	Distillation column	601,500	52,180	745
T-01	Feed tank	185,000	Included in supply	-
T-02	Bottom product tank	31,000	Included in supply	-
T-03 A/B	Distillate tank	295,500	Included in supply	-
T-04	Top product tank	48,500	Included in supply	-
T-11	Distillate tank	13,200	750	7
T-12	Top product tank	13,200	750	7
T-13	Waste water tank	4,800	Included in supply	-
H-01	Feed /distillate exchanger	53,000	750	7
H-02	Feed exchanger	16,500	750	7
H-03	Bottom product exchanger	32,500	750	7
H-04	Top condenser	116,700	750	7
H-05	Bottom product cooler	32,500	750	7
H-06	Distillate cooler	17,000	750	7
P-01A/S	Feed pump	12,300	1,600	27
P-02	Bottom product pump	5,450	1,100	14
P-03 A/B	Distillate buffer pump	24,250	1,600	27
P-04	Top product pump	5,550	1,100	14
P-11 A/S	Distillate pump	19,800	1,600	27
P-12 A/S	Top product pump	19,700	1,600	27
P-13 A/S	Bottom product pump	24,400	1,600	27
P-20	Vacuum unit	72,000	1,100	14
	<b>Total</b>	<b>1,625,650</b>	<b>69,480</b>	<b>978</b>

Total [rounded off] amount for prices of equipment is € 1,630,000 and € 69,500 for installation thereof.

### 4.3. Costs for insulation of equipment

Price Booklet, tables C 2001 up to and including C 2005 include costs for thermal insulation. These costs should be increased with a correction factor for the various working conditions, as mentioned in General chapter 13 Corrections to the Labour Norms i.e. conditioning of Labour Norms.

Applicable corrections:

- Height [average]	15%
- Walking distance to the construction site 750 m	10%
Total	25%

Before we can determine the cost for insulating column C-01 we have to establish the surface to be insulated.

- Surface of the shell =  $\pi \times d \times l = \pi \times 1.6 \times 20 = 101 \text{ m}^2$
- Surface spherical heads = surface of the column diameter  $\times 2$  [top and bottom]  $\times 3.0$  [factor as listed in Price Booklet, table C 2001] =  $[\pi/4] \times 3.0 = 1.62 \times 2 \times 12 \text{ m}^2$ .

The highest temperature in the column is 260 °C. According to the Price Booklet, table C 2005 and Labour Norms Insulation chapter 6.0 insulation thicknesses a thickness of 140 mm with aluminium plate cover is required.

Total cost insulation of C-01

- Shell insulation of the column	101 x 131 x 1.25 =	€ 16,539
- Spherical heads insulation	12 x 131 x 1.25 =	€ 1,965
	Total	€ 18,504
	Rounded off	€ 18,500



## Estimating with DACE Price Booklet and Labour Norms

The remaining equipment to be insulated can be estimated using the same method. All costs are rounded off to hundreds.

Table 2 Costs and man-hours of equipment insulation

Equipment №	Quantity	Surface m <sup>2</sup>	Insulation thickness [mm]	Description	Costs	Man-hours
C-01	1	131	140	Distillation column	18,500	651
T-01	1	88	30	Feed tank	10,500	149
T-02	1	15	60	Bottom product tank	1,800	38
T-03 A/B	2	57	30	Distillate tank	11,800	193
T-04	1	57	60	Top product tank	6,700	146
T-11	1	6	100	Distillate tank	1,100	23
T-12	1	6	100	Top product tank	900	23
T-13	1	-	-	Waste water tank	-	-
H-01	1	7	120	Feed /distillate exchanger	900	31
H-02	1	3	140	Feed exchanger	500	15
H-03	1	6	140	Bottom product exchanger	900	29
H-04	1	11	80	Top condenser	1,100	35
H-05	1	2	30	Bottom product cooler	200	3
H-06	1	3	30	Distillate cooler	300	5
				<b>Total</b>	<b>55,200</b>	<b>1,341</b>

### 4.4. Costs for installation of pipe work

For calculation of these costs a number of considerations are elaborated below, the layout of the unit and consequently the cost of the pipe work

- To keep the operating temperature of fatty acids low, the process operates under vacuum. Nevertheless high temperatures are necessary, hence insulation is applied. To maintain the high process temperatures in the pipe work during operation and in the event of a failure in production; the pipe lines are traced [steam/electric heating]. Please note that tracing will affect the selected insulation type for example due to provisions for vapour barriers.
- To avoid sagging of pipes a pipe should be supported at regular distance. The distance between the pipe supports depends on the diameter of the pipe, the weight of the liquid that flows through the pipes and the pipe material. Usually the pipe supports for carbon steel pipes is 3 to 6 meters between supports.
- Steam enters into a pipe at the highest possible point. After entry of steam and cooled down against a surface the steam condensate can be drained with steamtraps.
- Maintenance requirements are a factor when creating a lay out plan. At the design stage it must be checked whether there is adequate access for example for cranes, or space to remove the pipe bundles of heat exchangers, etc. Also with the pipe work design the point of maintenance is important.
- The provision of removable of pipe spools, platforms, tackle and hoist provisions for the removal of heavy parts or part[s] of equipment, as well as the correct placement of hose connections for compressed air, [for pneumatic tools], water and steam pipes can significantly facilitate the maintenance work.
- Accessibility is a major factor that affects the cost of the pipe work design. It is important to know how often a certain valve has to be operated or maintained.

#### Process piping

- All pipes work on the PFD will be estimated separately. Firstly we determine a cost per meter length and then multiply it with a required length. We keep the material identical to that of the nozzles of the equipment. In the case of equipment with two different materials the highest quality will be taken into account [usually stainless steel]. Price Booklet, tables B 4001 up to and including B 4005, B 4009 and B 4007 includes costs for pipe work installation. To maintain the high process temperatures in the pipe work during operation

## Estimating with DACE Price Booklet and Labour Norms

and in the event of a failure in production; the pipe lines are steam traced, we have selected steam tracing since low-pressure steam is already available in the process. The cost per meter pipe work is consequently increased for carbon steel tracing [Price Booklet, table B 4006]. We select carbon steel. We also determine the cost per meter of the pipe work insulation [Price Booklet, table C 2003]. Studying the layout we are able to determine the necessary lengths and type of pipe work type A or B [Price Booklet, table B 4002], complex or not complex type, which matches the best. The number of valves per line is determined.

The pipe work data is collected and costs are estimated and summarised.

Line 1: T-01 to P-01 A/S: total 10 m ND 50

- Material AISI 316L, type A [table B 4008]: € 283.00
- Paint work is not applicable since the line is of stainless steel.
- Insulation, table C 2003, thickness 25 mm thick: € 35.50
- Tracing, table B 4006, one string: € 137.50

The cost [rounded up] per meter of line 1: € 456.00

- Valves in Line 1 are not indicated on the PFD.  
A DN 50 valve on tank T 01 and for each pump at suction and discharge side and a drain valve ND 25 are needed.  
We select stainless steel gate valves, Price Booklet, table B 3008, for DN 50 and DN 25 table B 3009 table.

▪ The price for the valves in Line 1 are:  $3 \times € 900 + 1 \times € 375 = € 3,075$

Total costs for Line 1: € 7,635

- Line 2: from P-01 A/S to H-01: in the same manner we established the cost for this pipe work as in the previous pipe work and amounts to: € 5,460

Man-hours for installation for both type A and B [table B 4002] are estimated with the Labour Norms. As an example for both types, installation and insulation man-hours for a DN 50 line are estimated. In the same way one can determine the hours for other pipeline diameter.

Table 3 Type A and B DN 50 mechanical man-hours

	TYPE A				TYPE B			
	Nº	Labour Norm	Man-hours	Total	Nº	Labour Norm	Man-hours	Total
Pipe	10	0.34	3.40		10	0.29	2.90	
Butt weld	15	0.84	12.60		8	0.84	6.72	
Elbow	3	0.52	1.56		1	0.52	0.52	
TEE	1	0.67	0.67		1	0.67	0.67	
Reducer	1	0.52	0.52		0	0.52	-	
Flange	4	0.36	1.44		2	0.36	0.72	
Valve	2	0.70	1.40		1	0.70	0.70	
Flange connection	4	0.61	2.44		2	0.61	1.22	
				21.59				13.45

Insulation of pipe work [Price Booklet, table C 2003] is based on a system length of 150 meters with use of Labour Norms we can estimate the installation man-hours for insulation, see table below. Because there are no labour norms for 25 mm insulation available we select those of 30 mm.

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Table 4 DN 50, 30 mm thick insulation man-hours

	№	Labour Norm	Man-hours	Total
Pipe	150	0.11	16.50	
Elbow	40	0.20	8.00	
Tee	10	0.09	0.9	
Flange	40	0.14	5.60	
Valve	10	0.14	1.40	
				32.40

For the stainless steel line 1 the installation hours are:

- Piping, table 3	21.59 x 1.3 [material factor stainless/carbon steel]	28.70 hours
- Insulation, table 4	(32.40 / 150) x 10	2.16 hours
- Total		30.23 hours.

For the other process piping and other piping such as steam, condensate, air instruments and various process lines, drinking- and fire water the cost can be determined the same way. The supply and drain lines on pipes bridges are estimated according Price Booklet, table B 4002 type B. The lengths of the pipes to the bridge [and underground] depend on the tie-in points of the project. In this estimate, we assess a length of 30 metres.

It is assumed that all lines are above ground. The supply and drains for the tracing of the process piping must also be established. The supply line is branched from the low pressure steam line and equipped with a valve, in the drain line with a steam trap and connected to the central condensate drain line. For some accessories [steam traps, filters, etc.] the price / cost are not included in the Price Booklet; a price is assessed.

Table 5 Costs of supply, installation man man-hours of pipe work and insulation thereof

Line №	from	to	TYPE	Material	Dia DN	mtrs	€	Man-hours
1	T-01	P-01 A/S	B	ss	50	10	7,635	30.23
2	P-01 A/S	H 01	A	ss	50	10	5,460	30.23
3	H01	H02	A	ss	50	10	6,210	30.23
4	H02	C01	A	ss	50	10	7,200	30.53
5	T11	P11A/s	A	ss	100	10	12,495	52.77
6	P11A/S	H01	A	ss	50	10	5,470	30.23
7	H01	H06	B	ss	50	20	14,175	23.97
8	H06	T03A/B	B	ss	100	10	24,350	39.37
9	T11	C01	A	ss	100	10	10,155	52.77
10	C01	H04	A	ss	500	10	60,115	246.61
11	H04	T12	A	ss	150	10	14,145	82.31
12	H04	P20	B	ss	300	30	65,745	105.86
13	T12	P12A/S	A	ss	100	30	28,955	57.86
14	P12A/S	CO1	A	ss	80	30	20,535	51.50
15	P12A/S	T04	B	ss	80/25	30	17,685	32.90
16	C01	P13A/S	A	cs	250	10	13,730	111.76
17	P13A/S	H03	A	ss	200	10	21,595	101.61
18	H03	C01	A	ss	200	10	18,435	102.01
19	P13A/S-H03	T02	A	ss	25	10	4,745	68.85
20	T02	P02	B	ss	80	30	19,080	32.90
21	T03A/B	P03A/B	B	ss	150	30	33,675	53.20
22	T04	P04	B	cs	80	30	13,290	26.97
23	P20	T13	B	cs	50	30	11,260	19.93
24	P20	T13	B	cs	80	30	13,060	26.97
25	P20	T13	B	cs	100	30	18,550	32.05
	Supply tracing		B	cs	50	100	23,700	156.10
	Drain tracing		B	cs	50	100	23,700	156.10
					<b>Total</b>		<b>515,150</b>	<b>1,785.81</b>
					<b>Rounded off</b>		<b>515,000</b>	<b>1,786</b>

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No price / costs for supporting of pipe work, X-raying, pressure testing, pickling and passivation of stainless steel pipes and working at height is included in the Price Booklet. We assume a 15% on the pipe works costs to cover these costs.

The final amount for the pipe work is: € 592,250. The man-hours are also corrected by 15% for installing supports and are then 2,054.

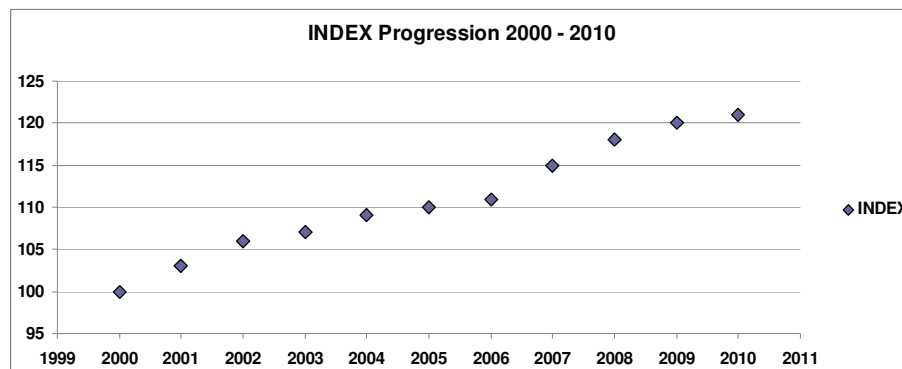
### 4.5. Costs for process control

In this paragraph costs are not according the Price Booklet. Costs have been escalated from the 21<sup>st</sup> edition to the 28<sup>th</sup> edition of the Price Booklet by using series 60. The published indices in the 21<sup>st</sup> edition are up till 1997, while all prices and costs in this edition are based on the third quarter of 2000. The first edition which mentions the 2000 index is 23<sup>rd</sup> edition.

Table 6 Indices

Series 60	year	Index	Base year index 100
23 <sup>rd</sup> edition	2000	122	1985
27 <sup>th</sup> edition	2000	100	2000
28 <sup>th</sup> edition	2010	107	2005

In order to escalate the costs we have to calculate the increase of the index between 2000 and 2010. Series 60 have an index of 100 in 2000 [the 27<sup>th</sup> edition] and an adjusted index [base year 2000] of 121 for 2010.



The prices of the Price Booklet [21<sup>st</sup> edition] have to be converted from Dutch guilders into Euros [NLG 2.20371 to € 1.00] and the adjusted index of 1.21.

The process control section consists of all types of control equipment, control valves and warning system with the corresponding connection cables and the central instrument panel. First the level measurement system of T-01 will be estimated. A transducer, display and alarm system is also needed. In Price Booklet 21<sup>st</sup> edition, page 145 costs for the supply are mentioned. The calibrated meter, density-, temperature measurements and inventory management system price [indexed] € 37,750. On the inventory management system multiple connections for tank signals are available. So this system is installed only once and all the other tanks can be connected onto the system. The indexed cost for installing a control loop [Price Booklet 21<sup>st</sup> edition, page 135] is assessed to be 50% of the level measurement system; so € 18,850 per loop. The price for three control loops is € 56,550.

The indexed price [Price Booklet 21<sup>st</sup> edition, page 143] for the level indicator controller of T-11 is estimated as follows: a stainless steel body internally installed at € 3,950. In the control panel a universal electronic designating drawer is needed [Price Booklet 21<sup>st</sup> edition, page 134] at € 2,100 manually operated panel an additional cost of € 600 plus a portion of the price of a complete frame for multiple instruments € 200. The control valve is a pneumatically operated control valve [Price Booklet

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21<sup>st</sup> edition, page 80] price for a flanged DN 50 valve with a stainless steel body € 3,900. The cost of installation [Price Booklet 21<sup>st</sup> edition, page 135] for this control loop is estimated at € 13,800. The total costs for this control loop are € 24,550.

The flow recording controller between P-01 A/S and H-01 is identical in price to that of the level indicator controller of T-11. In Price Booklet 21<sup>st</sup> edition, pages 139 to 143 and several solutions are given for control of volume and flow. For this project a floater / flow meter with stainless steel-measuring tube is selected. The prices of these together with the additional price for the electronic transmitter are € 3,100. A recording meter in the control panel costs € 1,325. The remaining equipment; panel, frame, hand-controlled valves are identical to that of the level control loop. For installation the same costs are assumed. The total cost for this flow loop system amounts to € 25,025.

The establishing of the costs of the other instruments is done in the same manner.

The instrument panel is assumed to be 2.5 m high and 5 m wide. The price for such an instrument panel amounts to 5 × € 8,030 [Price Booklet 21<sup>st</sup> edition, page 135] = € 41,500

Table 7 Costs for process control.

Process equipment	Component	Prices €	Installation €	Total €
T-01 level controller	Level controller	9,650		
	Calibrated meter	5,250		
	Density controller	1,300		
	Average temperature controller	5,800		
	inventory management system	15,750		
	Total	37,750	56,550	94,300
T-11 level controller	Level controller	3,950		
	Calibration meter	2,100		
	Panel	600		
	Frame [partly]	200		
	Control valve	3,900		
	Total	10,750	13,800	24,550
P-01 A/S flow measurement	Recorder	3,100		
	Recording meter	1,325		
	Indicator	2100		
	Panel [manual]	600		
	Frame	200		
	Control valve	3,900		
	Total	11,225	13,800	25,025
Etc.				

The total amount for process control is € 485,000.

Since no Labour Norms are available man-hours cannot be estimated.

### 4.6. Costs for electrical facilities

It is assumed that sufficient electrical power and the required voltage is available. All pumps must be powered, this is realised with one 55 kW motor control cabinet. In the Price Booklet, table D 2002, prices for low voltage motor switches including switch board are mentioned. For the required switch board of 55 kW the price amounts to € 35,600. Furthermore, for each pump, a number of switches, control lamps and junction boxes including cabling are necessary.

Per pump:

- Switches [two control and one safety switch]  
€ 700 each [Price Booklet, table D 2003]: € 2,100
- Five junction boxes including connecting cable
- € 175 each [Price Booklet, table D 2006] cost: € 875

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– Control lamp [assessed]:	€ 400
– Fifty meters of low voltage cable [Price Booklet, table D 2005] costs € 45 per meter:	€ 2,250
Total	€ 5,625

The costs for twelve pumps: € 35,600 + 12 × € 5,625 = € 103,100.

This amount has to be uplifted with costs for:

– Ten wall sockets [Price Booklet, table D 2016]	€ 4,740
– Necessary [assessed to be 500 meters] YmvK 2.5 mm <sup>2</sup> cabling [Price Booklet, table D 2004]	€ 3,740
– Ground cable to the central control cabinet [50 meter cable, digging and end connections] Price Booklet, tables D 1006, D 1007 & F4002	€ 5,543
Total	€ 117,132
Rounded off	€ 117,150

**Total cost electrical power supply € 117,150**

Electric lighting

At every covered workplace we assume eight fluorescent fixtures. The platforms are lit with four bended lamp poles with push up fixtures for 2 × 40 W fluorescent fixtures. The upper floor is equipped with six fixtures. For the illumination of a tank farm we assume a mast of eight meters with four push up fixtures. With the help of Price Booklet, tables D2004, D2017 D2018, F5006 and F4002 we estimate the costs for lighting of the installation:

- TL-work floors;
- TL-landings;
- TL-21 meter floor;
- Light mast including fluorescent lamps
- Cable Work;
- Junction boxes;
- Wall Sockets.

The total for the above including lightning protection, grounding and digging, amounts to € 38,500.

Table 8 Costs electrical facilities

Process equipment	Electrical component	Costs €	Installation €	Total €
P-01 A	Motor control cabinet [common ]	35,600	Included	35,600
	Switches 3 each	2,100	Included	2,100
	Junction boxes 5 each	875	Included	875
	Control lamp	400	included	400
	Cable 50 m	2,250		2,250
P-01S and remaining 11 pumps	Equal to P-01 A [excluding motor control cabinet]	61,875	Included	61,875
	Wall socket 10 each	4,740	Included	4,740
	Cable	3,740	Included	3,740
	Under ground cable	5,570		5,570
Electric lighting including lightning, grounding and digging				38,500
				155,650

**Total cost electrical facilities €155,650**

Since no Labour Norms are available man-hours cannot be estimated.

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### 4.7. Costs for civil work

The site preparation of the assigned land is not included in the estimate.

We assess 20 piles for supporting the steel construction and the distillation column C-01 and 16 piles for the tanks. For a pile up to a depth of 12 metres the costs are € 68 per meter length [Price Booklet, table F 4009], the total amount for piling is  $[20 + 16] \times 12 \times € 68 = € 29,376$ .

The steel construction, tanks and distillation column C-01 are supported by a concrete foundation.

Plinths for supporting columns, columns pump and tanks are considered concrete work. We assess a surface of 15 x 20 metres with an average thickness of 0.35 m as a foundation of the complete unit. By way of interpolation cost are € 170 per m<sup>2</sup> [Price Booklet, table F 4004] we reach an amount of € 51,000 for foundations.

- Piling:	€ 29,376
- Concrete Foundation:	€ 51,000
Total	€ 80,376
Rounded off	€ 80,000

**Total cost concrete work € 80,000**

The steel structure around the distillation column C-01 has four platforms of 6 x 6 meters and together with the ground floor the total surface is 180 m<sup>2</sup>. We select € 1,100 a square meter [Price Booklet, table F 1001 bare, multi layer], due to the height of the steel structure and the support of the equipment.

The cost for the steel construction then amounts to € 198,000.

The eight stairs [Price Booklet, table F 4014] at € 7,000 each amount to € 56,000. The four platforms with a total surface of 144 m<sup>2</sup> at € 150 per square meter [Price Booklet, table F 4013] for grating amounts to € 21,600. The steel structure is fenced off with a total length of 200 meter. The average cost of the fencing is €29 [Price Booklet, table F 6004] per meter and for poles € 122.50 per pole, the total amount is € 14,375.

The total for the steel construction comes on than € 350,600. The remaining costs are assessed to be € 40,000. These costs are for amongst others for earthworks, clean sand, connecting to sewers etc

- Steel construction:	€ 198,000
- Stairs:	€ 56,000
- Grating:	€ 21,600
- Fencing construction costs:	€ 14,375
- Other costs:	€ 40,000
Total	€ 329,975

**Total cost steel structure € 330,000**

- Concrete work:	€ 80,000
- Steel structure:	€ 329,975
Total	€ 409,975

**Total cost for civil € 410,000**

Since no Labour Norms are available man-hours cannot be estimated.

### 4.8. Costs for painting work

For painting work an assessed amount of € 70,000 is included in the estimate.

### 4.9. Price for spare parts

According Cost Engineering Handbook chapter Y-9050 paragraph 2.1 spare parts are those components, which have to be replaced during the commissioning and start-up phase of a new unit, the cost of raw materials and consumables are not included in the estimate. During start-up mainly small spare parts, such as gaskets for heat exchangers, reactors, columns and vessels, fans and gaskets for

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pumps and compressors, moving parts of valves, instruments and electrical safety materials have to be replaced.

Typically are the percentages in table 9 for prices of spare parts for equipment.

Table 9 Price of spare part

Description	Value €	%	Amount €
Heat exchangers, reactors, columns, vessels	1,451,600 [See 4.1]	1	14,516
Rotating equipment (incl. electrical motors)	183,400 [See 4.1]	10	18,340
Instruments	485,000 [See 4.5]	2	9,700
Electrical	€ 155,600 [See 4.6]	2	3,112
Total			45,668

**Total rounded off price spare parts**

**€ 50,000**

### 4.10. Total costs of hardware

Below follows an overview of the ISBL prices and costs as determined in the preceding paragraphs. The end results are rounded up to € 1,000.

Table 10 Total costs hardware

Paragraph	Description	Price €	Costs €	Installation man-hours
4.1	Cost for equipment	1,630,000		
4.2	Cost for installation equipment		70,000	978
4.3	Cost for insulation of equipment	56,000	included	1,341
4.4	Cost for pipe work	593,000	included	2,054
4.5	Cost for process control	233,000	253,000	not available
4.6	Cost for electrical facilities	156,000	included	not available
4.7	Cost for civil work	410,000	included	not available
4.8	Cost for painting work	70,000	included	not available
4.9	Cost for spare parts	50,000		
	Total	3,198,000	323,000	4,373

Total rounded off values of hardware: price € 3,200,000 and costs € 323,000

**Total cost hardware**

**€ 3,523,000**

### 4.11. Other costs of the unit

#### 4.11.1. Introduction

The other costs of the unit consist of costs that are necessary to install the unit. These costs are borne by construction budget of the unit; however "nothing" can be pinpointed afterwards. Below is described what still is necessary to install the distillation unit. The assessed construction time is 12 months.

#### 4.11.2. Costs for temporary site facilities

The temporary site facilities are materials and services which are necessary for the proper installation of the work and are removed after installation. At the construction site a number of facilities may already be available. A large number of facilities fall under temporary site facilities, only the first item is elaborated in this article. The costs of the other items can be determined in the same way:



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### Buildings:

- Site establishments: installation, rent of establishments, sheds and furniture;
- Connections for: heating, light and / or construction power, water, sewer, phone.

Price Booklet, table F 3001 site establishments' rental prices for a cabin, including furnishings are € 3.25 per m<sup>2</sup> per week, while the assembly and disassembly of the cabins, including the equipment amounts to € 125 per m<sup>2</sup> per occasion. This amounts for a cabin of 24 m<sup>2</sup> over a period of 12 months to € 7,134.

In order to estimate the rental of the site establishments we have to take into account that construction staff offices on an average are 10m<sup>2</sup> and by Dutch Law for labour change-, wash rooms and canteen a minimum of 3.6m<sup>2</sup> per labourer is required. We assume a construction staff of average 6 persons and 20 labourers. The total amount is: € 39,237

### Maintenance cabins:

- Use of energy, fuels, water and phone;
- Cleaning Costs.

### Temporary guarding:

- Surveillance and fencing [by client or contractor];
- Housekeeping such as: garbage collection, snow removal, road salt;
- Temporary roads, dock boards.

### Temporary facilities for the benefit of construction work:

- Hiring of scaffolding for general use;
- Renting cranes for general use.

### Climate-or winter provisions:

- Temporary workspace, shades, heating, renting of hot air cannons and renting of tarpaulins for covering up and protection of concrete during frost, etc.;
- Safety equipment during construction [by client or contractor]:
  - First aid post, traffic signs, special clothing, helmets, masks and goggles;
  - Temporary facilities for fire fighting.

### Temporary energy and chemicals facilities:

- Construction water connection;
- Connection for construction power, temporary lighting and gas;
- Connection of telephone, fax, data line[s];
- Consumption of power, gas and water consumption for construction;

### Installation services and small material consumption:

- Internal transport at the construction site;
- Transport and freight costs;
- Renting of cranes for unloading equipment and other heavy materials;
- Assistance activities by a technical services or third parties;
- Material consumption.

### Temporary storage:

- Renting of: warehouses[s] for storage, temporary storage sheds, tents for the benefit of the temporary accommodation of equipment, including the placement, connection and rent;
- Material management;
- Short and damage control of goods.

**Total cost for temporary site facilities**

**€ 375,000.**

### 4.11.3. General expenses

General expenses are depending on the kind of project and company.

These costs are often a percentage of the total construction costs of the project and include:

- General overheads;
- Insurance costs;
- Offsite transport costs, etc.

No price for general expenses is included in the Price Booklet. We assess € 320,000 for general expenses.

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### 4.11.4. Costs for engineering

The engineering costs are all costs incurred by an engineering firm for the implementation of the basic design and detailed engineering, specifications, calculations, preparation of technical evaluation of requisitions, quotes, meetings, etc., including process engineering, project management, cost, budget, planning, own cost monitoring and associated costs. The construction management of the contractor is separately estimated. Excluded are costs of the owner.

Price Booklet, table G 1005 gives a percentage of 12 - 20% of costs for purchase of materials, equipment and installation for onshore process unit.

This amount does not include for the costs mobilisation, demobilisation and induction costs of personnel and for the construction site management team, which exists out of the following officers [full time or part time]:

- Assembly Leader;
- Assembly supervisor, one for multiple trades for this project;
- Planning engineer;
- Cost engineer;
- Administrator; Safety Inspector;
- Typist.

These costs have a relationship with the construction time and the number of labourers on the project. The costs are assessed to be € 1,000,000

Engineering:	€ 700,000
Construction management [contractor]:	€ 1,000,000
Total	€ 1,700,000

**Total cost for engineering € 1,700,000**

### 4.11.5. Unforeseen

For this estimate we take a percentage of 15% of the cost for unforeseen resulting in € 540,000.

## 4.12. The total investment costs

Table 11 Total investment costs

The end results are rounded up to € 1,000.

Paragraph	Description	Supply €	Installation €	Installation man-hours
4.1	Cost for equipment	1,630,000	see 4.2	see 4.2
4.2	Cost for installation equipment		70,000	978
4.3	Cost for insulation of equipment	56,000	included	1,341
4.4	Cost for pipe work	593,000	included	2,054
4.5	Cost for process control	233,000	253,000	not available
4.6	Cost for electrical facilities	156,000	included	not available
4.7	Cost for civil work	410,000	included	not available
4.8	Cost for painting work	70,000	included	not available
4.9	Cost for spare parts	50,000	not applicable	not applicable
4.11.2	Costs for temporary site facilities	375,000	included	not available
4.11.3	General Costs	320,000	not applicable	not applicable
4.11.4	Costs for engineering	1,700,000	included	not available
4.11.5	Unforeseen	540,000	not applicable	not applicable
	Total	6,133,000	323,000	

The total costs, exclusive of VAT and based on the price level of the third quarter of 2010, for the investment of the distillation unit: € 6,500,000.

## Estimating with DACE Price Booklet and Labour Norms

This estimate is based on a PFD, equipment list and layout only and can be classified [see table below from the Handbook Cost Engineers chapter Y-4140] as a C/D level estimate and can only be used for comparison reasons with alternative process routes or for a very rough impression.

Table 12 Accuracy levels [Handbook Cost Engineers, DACE ]

Level	Type of estimate	Function	Range
A	Project budget	Budget control during installation	± 5%
B	Budget estimate	Final approval estimate	± 10%
C	Feasibility estimate	Feasibility study	± 25%
D	Order of magnitude estimate	Project definition	± 40%

### Exclusions

An estimate is only complete, if reflected on possible exclusions. This reflection also serves as a support to the description of the scope of work.

The following is an enumeration of exclusions, which is nowhere near complete but serves only as an example:

- Purchase of land;
- Raw materials and excipients;
- Utility facilities;
- Authorizations;
- Training of staff;
- Price Escalation, etc.

## 5. Commentary

For a number of items no price and / or costs are included the Price Booklet. A partial enumeration of items is tabulated below:

- X-ray costs;
- Cost by authorities, Notified Bodies and pipe work;
- Prices of small heat exchangers;
- For pumps the less cost and the additional costs for double mechanical seals;
- Special pumps such as canned pumps;
- Prices for some accessories of the pipe work,
- Supporting, pressure testing, pickling and passivation of stainless steel pipes;
- Prices for insulation of small equipment;
- General painting and necessary spare parts;
- General costs such as transportation and insurance;
- Site project team;
- Unforeseen costs.

## 6. Conclusions

1. With help of the Handbook Cost Engineers of DACE a number of costs that are not included in the Price Booklet can be determined.
2. The DACE Labour Norm publication can serve to create more detailed prices.
3. Although the Price Booklet is not complete, it can support in the preparation of estimates. An experienced estimator should be capable to prepare an estimate with an accuracy of ± 30%.
4. For the preparation of cost estimates for other chemical processes [comparison] the use of the Price Booklet and Labour Norms is a possibility.
5. The listed prices and / or costs are estimated / budget costs and are only valid for budget estimates purposes and comparing prices and /or costs at different implementation options.

## Estimating with DACE Price Booklet and Labour Norms

### 7. Literature

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