Question 1:

Using a company's MARR is a reasonable substitute for the TVM for as it represents the minimum acceptable rate of return on an investment. If the NPV of an investment is greater than or equal to zero, the investment is worthwhile. Furthermore, any TVM that is less than the MARR will yield a higher NPV value, signaling a more profitable investment.

Question 2: Used with permission from group B4

Turn over ration = 0.5 in the process industries, assume this number is similar in

Argentina

predicted gross annual sales = CAD $32 million

(Fixed capital cost)(TR) = gross annual sales

(Fixed capital cost) = $\frac{gross\ annual\ sales}{(\text{TR})}$

(Fixed capital cost) = $\frac{\$32\ M}{(0.5)}$

(Fixed capital cost) = $64 million

$$\text{CAD\$32 M} \leq \text{Fixed Capital Costs} \leq \text{CAD\$128 M}$$

This represents a lower bound of -50% and upper bound of +100% for this rough capital

cost estimation method.

Question 3: Used with permission from group B4

8 - Step Method

1. Look up the correlation to estimate the capital cost. Is it the one that applies to your case?

   Corrections
   Bare Tubes x 1
   Carbon Steel x 1
   Floating Heat x 1
   No corrections for pressure or temperature x 1

2. Does the range match the situation we are dealing with?

   Yes

3. Read of the value of the base cost and base year for the correlation.

Base Cost = $8000

n = 0.71

4. It's unlikely the capacity matches your case. Inflate for capacity, using the exponent n.

FOB = $\$8000(\frac{200}{100})^{0.71} = \$13086$

5. Adjust the price, if required, for materials of construction, pressure, and temperature.

Temperature, Pressure and Material match - no correction required

6. Calculate the bare module cost, using the bare module factor.

   Bare Module = $13086 \times 3.14 = \$41090$

7. The last calculation is to inflate the price into today's dollars.

   Marshall Swift1970 = $\frac{301}{301}$ x 41090

8. Finally, report the value as a range, rather than a point estimate. Note, these are just estimates, so they have error.

   Final installed cost = $41090 in 1970
   Error bounds of +/- 40%:

$$\$24,655 \leq \text{Capital Cost} \leq \$57,528$$

Included in the error is uncertainty in capacity correlations, material corrections, pressure and temperature adjustments, the labour and installation fees, and shipping.

When inflating the cost for inflation, it is assumed that the cost of the heat exchanger will increase in price at the same rate as the overall index.

Question 4: Used with permission from group B4

8 - Step Method

1. Look up the correlation to estimate the capital cost. Is it the one that applies to your case?

   Correlation Range
   $0.02 \leq \frac{Area}{100} \leq 20$

   $\frac{100}{100}$

   $0.02 \leq 1 \leq 20$

   Corrections
   Finned tube exchanger
   Carbon Steel x 1
   Floating Heat x 1
   No corrections for pressure x 1

2. Does the range match the situation we are dealing with?

   Yes

3. Read of the value of the base cost and base year for the correlation.

Base Cost = $5000

n = 0.57

4. It's unlikely the capacity matches your case. Inflate for capacity, using the exponent n.

FOB = $\$5000(\frac{100}{100})^{0.57} = \$5000$

5. Adjust the price, if required, for materials of construction, pressure, and temperature.

Temperature, Pressure and Material match - no correction required

6. Calculate the bare module cost, using the bare module factor.

   Bare Module = 5000x3.14 = $15,700

7. The last calculation is to inflate the price into today's dollars.

   Marshall Swift 1970 = $\frac{1490}{301}$ x $15,700

   Final installed cost = $77,718 ± 20%

   $62,174 ≤ Final installed Cost ≤ $93,261

   CEPCI 1970 = (586/126) x $15,700

   Final installed cost = $73,017 ± 20%

   $58,414 ≤ Final installed Cost ≤ $87,62

8. Finally, report the value as a range, rather than a point estimate. Note, these are just estimates, so they have error.

When inflating using the MS index, the reported cost is about 7% higher than the CEPCI cost. However, the two costs are contained within each other's 20% confidence intervals. Therefore, the cost ranges are in agreement with each other.

Question 5: Used with permission from group B4

Part 1

8 - Step Method

Vertical Cylinder – Atmospheric Vessel, in 1970 dollars. (Dr. Woods Table 2-5)

1. Look up the correlation to estimate the capital cost. Is it the one that applies to your case?

   Height = 3m
   Diameter = 0.5m
   Volume = 0.589m^3
   Correlation Range

   $0.1 \leq \frac{Volume}{100\ US\ Gal} \leq 20$
   $\frac{155.673}{100} = 1.55$
   $0.1 \leq 1.55 \leq 20$

Corrections

Carbon Steel x 1

2. Does the range match the situation we are dealing with?

   Yes

3. Read of the value of the base cost and base year for the correlation.

Base Cost = $1000

n = 0.58

4. It's unlikely the capacity matches your case. Inflate for capacity, using the exponent n.

FOB = $\$1000(\frac{155.673}{100})^{0.58} = \$1293$

5. Adjust the price, if required, for materials of construction, pressure, and temperature.

Temperature, Pressure and Material match - no correction required

6. Calculate the bare module cost, using the bare module factor.

Bare Module = 1293 x 1.96 = $2534 $\pm$20%

$2027 ≤ Final installed Cost ≤ $3041

7. The last calculation is to inflate the price into today's dollars.

8. Finally, report the value as a range, rather than a point estimate. Note, these are just estimates, so they have error.

Inflation 2011

Marshall and Swift

Final installed cost = $12,539 ± 20%

$10,031 ≤ Final installed Cost ≤ $15,047

Chemical Engineering Plant Cost Index

Final installed cost = $11,780 ± 20%

$9,424 ≤ Final installed Cost ≤ $14,137

Part 2

Vertical Cylinder – Atmospheric Vessel, in 1970 dollars. (Dr. Woods Table 2-5)

Height = 20 ft

Diameter = 3ft

Volume = 141.428 ft3

Correlation Range

0.1 < Volume/100 US Gal < 20

$\frac{1\,057.955}{100} = 10.58$

0.1 < 10.58 < 20

Corrections

Carbon Steel x 1

FOB

FOB = $\$1000\left(\frac{1\,057.955}{100}\right)^{0.58}$ = \$ 3928

Bare module cost: sum of the direct and indirect expenses for purchasing and installing equipment

Bare Module = 3928×1.96 = \$7699$\pm$20%

= 1 057.955 US Gal

\$6159 ≤ Final installed Cost ≤ \$9239

Inflation 2011

Marshall and Swift

Final installed cost = \$38,103 ± 20%

\$30,483 ≤ Final installed Cost ≤ \$45,724

Chemical Engineering Plant Cost Index

Final installed cost = \$35,799 ± 20%

\$28,639 ≤ Final installed Cost ≤ \$42,959

<u>Question 6:</u> Used with permission from group B4

The CEPCI is a composite index, meaning that at its highest level it is composed of 4 sub-indices, shown below:

- equipment index
    - heat exchangers and tanks
    - process machinery
    - pipes, valves, and fittings
    - process instruments
    - pumps and compressors
    - electrical equipment

    - structural supports and miscellaneous
- construction labour index
- buildings index
- engineering and supervision index

The value of each sub-index is given a weight which determines how significantly it will affect the CEPCI composite index.

Each of these sub-indices is subdivided further into specific components, whose total weighted sum is used to calculate the value of the sub-index. For example, some of the specific components in the heat exchangers and tanks index are storage tanks, metal tanks, and pressure tubing; each of these components has a unique weight, which determines how significantly changes in its price affect the sub-index to which the component belongs.

The component values are mostly derived from Producer Price Indices, which are made available by the US Department of Labor's Bureau of Labor Statistics (BLS). These values are calculated as the average price for a large number of transactions in the component's industry.

Labour rates also play a role in the calculation of the CEPCI; several component values are calculated as the average labour rate in different roles, such as engineering, contracting, manual labour, and so forth.

Finally, the last set of components is related to the average price of buildings, construction materials.

Source: William M. Vatavuk, "Updating the CE Plant Cost Index", Chemical Engineering Magazine, pp 62-70, 2002.

Question 7: Used with permission from group B4

In order to determine capital costs Aspen uses a weighted factor method. The total capital cost estimate is expanded from the equipment cost with multipliers to account for service costs, site costs, installation costs, indirect costs such as contractor expenses, and contingency allowances. For example, the material installation cost is calculated using an Aspen factor that relates it to the equipment costs. Equipment costs are obtained from the database of industry information. Aspen contains default values for all the factors used for capital cost estimation and were derived by combining experience with several sources. James Douglas the author of Conceptual Design of Chemical Processes affirms that Aspen contains some of the most accurate correlations for determining capital costs.

Source: Douglas, JM, Conceptual design of chemical processes, McGraw-Hill: 1988

Source: The University of Alabama in Huntsville. "Using Aspen to Evaluate Process Economics." Internet:

http://www.che.uah.edu/courseware/toolbox/aspenplus/aspenplusexamples/costing/#_Toc394192520, [Sept. 30, 2013]

To account for different capacity units Aspen has an internal sizing algorithm where it has a base component size and scales according to the characteristic property of the newly specified unit. A way to determine this unknown sizing method, two identical (besides the characteristic factor) units could be constructed, one being larger than the other but everything else constant, then their costs could be correlated to a power law factor, based on the increase in the characteristic factor size.

Source: AspenTech. "Reduce Estimasting Uncertainty with a Model-Based Approach." http://www.aspentech.com/products/aspen-kbase.aspx, 2013 [Oct. 3, 2013].

This analysis would be assuming that the scaling factor in Aspen has the form.

$$\frac{Cost(b)}{Cost(a)} = \left(\frac{Factor(B)}{Factor(A)}\right)^n$$

Aspen calculates the material costs by multiplying the raw materials costs and the mass flow rates indicated by the flowsheet. Raw material price and date of the quote need to be entered by the user for each feed in the process, Aspen will then scale the prices accordingly using internal inflation indexes. Other costs in Aspen are inflated similarly using internal inflation indexes.

Source: AspenTech. "AspenTech Launches New Release of Aspen Icarus – the Process Industry Standard For Economic Evaluation." Internet: http://www.aspentech.com/publication_files/pr10-23-02.htm, Oct. 23, 2002 [Sept. 30, 2013].

The level of error associated with Aspen Icarus equipment costs is stated as +/- 40% by Versteeg in a Carnegie Mellon report on the economics of a CO_2 capture plant.

Source: AspenTech. "AspenTech Launches New Release of Aspen Icarus – the Process Industry Standard For Economic Evaluation." Internet: http://www.aspentech.com/publication_files/pr10-23-02.htm, Oct. 23, 2002 [Sept. 30, 2013].

Source: Peter Versteeg, "A Technical and Economic Outlook of A Technical and Economic Outlook of Ammonia-Based Post-Combustion CO2 Capture Capture," Engineering, Carnegie Mellon, Pittsburgh, 2008.

Question 8 Used with permission from group B4

The following graphs show $100 inflated using the Marshall and Swift price index and the Chemical Engineering Plant Cost index. Each graph also has a constant rate inflation curve. The rate of inflations was calculated to minimize the sum of squared difference between the inflated prices and the inflated prices using the price indices.

The calculated inflation rate for the Marshall and Swift was found to be 4.30% and the calculated inflation rate for the CEPCI was found to be 3.98%.

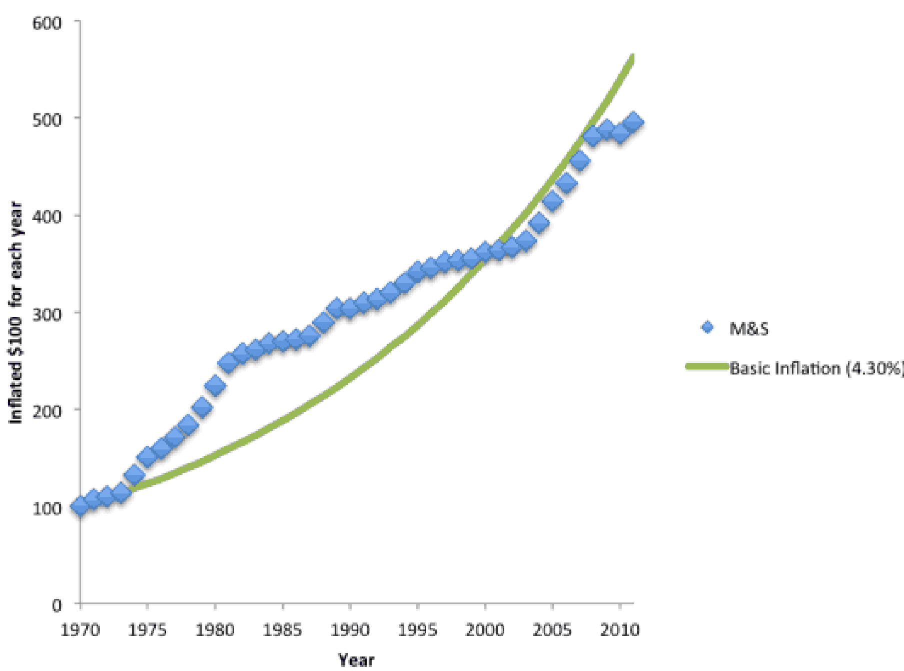

Figure 1. Marshall and Swift and a basic inflation estimation of $100 inflated over 41 years starting in 1970.

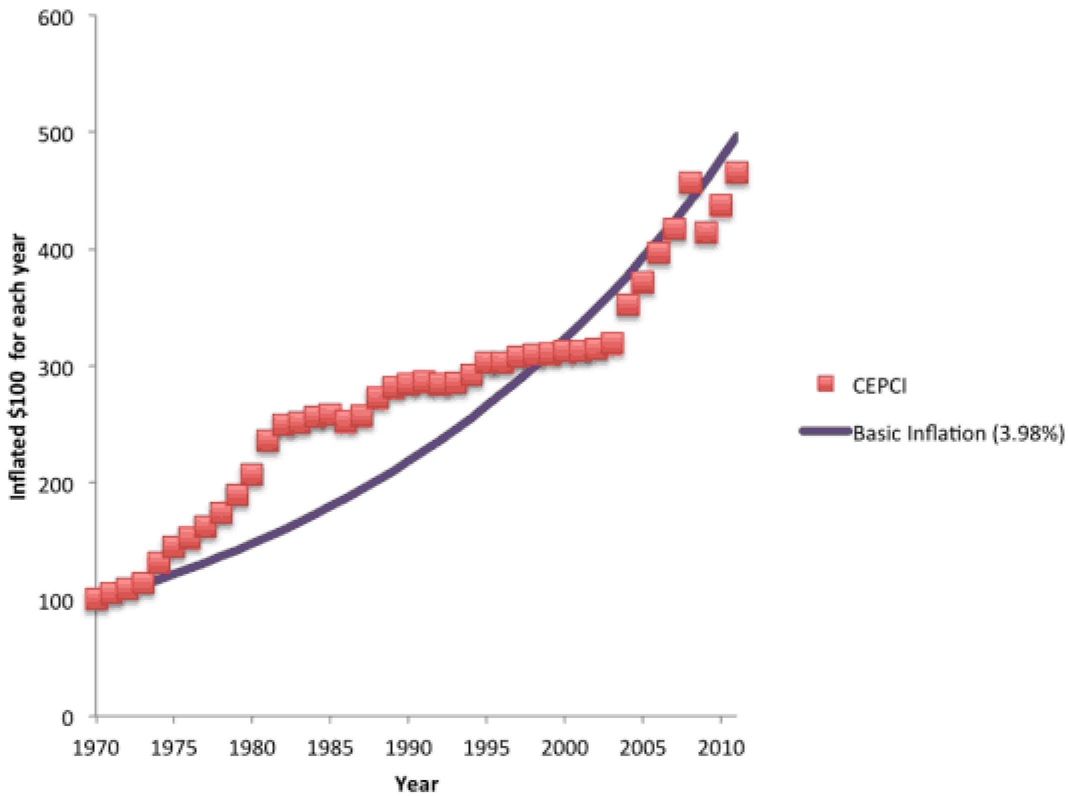

Figure 2. CEPCI and a basic inflation estimation of $100 inflated over 41 years starting in 1970.

<u>Question 9:</u> Used with permission from group B4

1. The average annual salary for a plant operator in the United States was $54,690 in 2012.

2. According to the same source, his or her supervisor, a chemical engineer, would typically earn $102,270 per year in 2012.

Source: United States Bureau of Labor Statistics. "May 2012 National Occupational Employment Wage Estimates." Internet: http://www.bls.gov/oes/current/oes_nat.htm#51-0000, May 2012 [Sept. 29, 2013].