Mansoura Engineering Journal

Volume 13 | Issue 1 Article 15

5-27-2021

Energy Conservation in the Petroleum Industry: Process Heat Integration for a Vapour Recovery Unit using the Pinch Technology.

Seham El-Temtamy
Petroleum Research Institute Nas City, Cairo, Egypt

Salah Khalil
Egyptian Petroleum Research Institute NasR City, Cairo, Egypt

Recommended Citation
El-Temtamy, Seham and Khalil, Salah (2021) "Energy Conservation in the Petroleum Industry: Process Heat Integration for a Vapour Recovery Unit using the Pinch Technology.," *Mansoura Engineering Journal*: Vol. 13 : Iss. 1 , Article 15.
Available at: https://doi.org/10.21608/bfemu.2021.172788

ENERGY CONSERVATION IN THE PETROLEUM INDUSTRY: PROCESS HEAT INTEGRATION FOR A VAPOUR RECOVERY UNIT USING THE PINCH TECHNOLOGY

ترشيد استهلاك الطاقه فى الصناعات البترولية : عملية التكامل الحرارى لوحده لاسترجاع الغازات باستخدام طريقة لينهوف

Seham A. El-Temtamy and Salah A. Khalil
Egyptian Petroleum Research Institute Nasr City, Cairo-Egypt

خلاصة : يهدف هذا البحث الى حساب أحمال التسخين والتبريد لوحده لاسترجاع الغازات انتاجها اليومى ١٠٠ طن وذلك باستخدام طريقة لينهوف · ويتضح من البحث أن أحمال التسخين والتبريد المحسوبة باستخدام هذه الطريقة تمثل ٧٨٫٦٪ و ٧٨٫٤٪ فقط من الاحمال النظريه الحاليه · كذلك يوضح البحث كيفية تحقيق هذا الوفر فى استهلاك الطاقه باعادة تصميم شبكة المبادلات الحرارية للوحده طبقا لطريقة لينهوف ·

ABSTRACT - The pinch technology for energy targetting is utilized to calculate target heating and cooling loads for a 100 t/d vapour recovery unit. Target heating and cooling loads of 78.4% of the present theoretical values were respectively calculated. These target heating and cooling loads could be achieved by redesigning the heat exchange train utilizing the pinch technology rules.

INTRODUCTION:

A vapour recovery unit (VRU) is supplementary to crude distillation units in order to separate liquified petroleum gas (LPG) commercially known as butagas from vapours leaving the distillation unit. In the present (VRU) belonging to "Cairo Company for Petroleum Refining", vapours are compressed and dissolved in light naphtha. Butagas is separated from this mixture by successive distillation. In this unit part of the heat required to heat up the feed to the desired temperature is supplied by exchanging heat with the hot streams leaving the distillation towers. According to the theoretical heat balance extracted from the plant flowsheet, this part represents 27.4% of the total heat required. Generally speaking, the more heat is recovered from the hot streams, the lower will be the energy supplied by hot utility.

Utilizing the pinch design technology it is possible to calculate the maximum value for heat recoverable from hot streams or the minimum energy required from hot utility, and the way that these target values can be practically achieved.

The pinch design technology was developed by Linhoff et al., (1,2,3). The fundamentals underlying this technology are published in reference (4). The calculation procedure has been computerised. The computer program "Target II" developed by Linhoff March Co.(5) performs this calculation, and produces other outputs that are helpful for the design of maximum energy recovery(MER) heat exchanger network. EPRI has access to this facility and it has heen successfully utilized in this work, as well as in another investigation(6), to produce the energy targetting values for hot and cold utility requirements and therefore the MER network. A summary for the pinch design technology and how to use it is presented in references(6).

PROCESS DESCRIPTION:

The present VRU contains two main distillation towers: a debutanizer and a depropanizer. In the debutanizer butane and lighter hydrocarbons are separated as the distillate product . Pentane and heavier hydrocarbons form the bottom product. Butane and lighter hydrocarbons are then fed to the depropanizer where LPG is separated as the bottom product. Some C_3 and lighter hydrocarbons leave as vapour distillate. A flowsheet for the unit is given in Fig. 1.

In this flowsheet two additional towers are shown, namely C-6, an absorber to catch any C_3 and C_4 and vapours escaping from the condensers of the debutanizer and depropanizer, and C-7 the naphtha stabilizer. Its function is to adjust the initial boiling point of the heavy naphtha before it is directed to the naphtha reformer. Vapour and liquid distillates from C-7 are fed to the accumultor T-8.

PROCESS HEAT INTEGRATION:

Examination of the process flow sheet reveals that the circulating bottom of the column C-4 which according to the "pinch" design technology is considered a cold stream because it should gain heat in the column reboiler before it re-enters the column below the bottom plate, is used to deliver heat in the depropanizer reboiler, and further in the exchanger E7/5.i.e. it is considered as being a hot atream. One of the golden rules of the pinch design technology is KHH and KCC or KEEP HOT STREAMS HOT and KEEP COLD SREAMS COOL. It is clear that the situation here is contrary to this rule. Although the total net firing load in this unit is relatively small 39.285 GJ/h, it is interesting to see what the pinch technology can offer to us. The program Target II is utilized to calculate the target heating and cooling loads. Stream data, problem table and target report are given in Tables 1,2 and 3 respectively. They show that for $\Delta T_{min.}$= 20°C the target cooling load of 27.808 GJ/h i.e. 78.6% of the present theoretical heating and cooling loads as given in Table 4. The composite curves in Fig. 2. show that the recycled process heat is 23.5 GJ/h Instead of 15.23 in the present design.

Following the pinch design technology rules for stream matching a heat exchange network design represented on the grid diagram (Fig. 3) is obtained which satisfies the energy target values. This design also ensures the maximum compatibility with the existing design, three heat exchangers are already existing the only new heat exchanger match is between streams 7 and 5, all six coolers are already existing. It is only requested to add a hot utility supply to the depropanizer. The resulting flowsheet is shown in Fig. 4. It is more elegant than the original one. Adopting the new design will save 9 GJ/h or 71280 GJ/y= 1620 TOE/y= $200000/y and costs about $800000*, i.e. there will be a payback period of 4 years.

CONCLUSION:

Heating and cooling loads could be much reduced by redesigning the heat exchanges train for a VRU utilizing the pinch technology rules. The new design saves about 200000$/y.

NOMENCLATURE:

GJ/h = Giga Joul hour.

$\Delta T_{min.}$ = Minimum approach temperature.

ACKNOWLEDGEMENT:

The financial support of the Academy of Scientific Research and Technology to project No. 93/84/3 is gratefully acknowledged.

REFERENCES:

1. Linhoff, B., "Thermodynamic Analysis in the Design of Process Networks" Ph.D. Thesis, University of leeds, U.K.(1979).

2. Linhoff, B., and Flowers J.R., "Synthesis Heat Exchanger Networks: 1. Systematic Generation of Energy Optimal Networks", AICHE, 24, PP.633-642 (1978).

3. Linhoff, B., and Hindermarsh, E., "The Pinch Design Method for Heat Exchanger Networks", Chemical Engineering Science. 30, PP. 745-763(1983).

4. Linhoff, B., et al., "A User Guide on Process Integration for the Efficient Use of Energy", The Institution of Chemical Engineers, Rughy, Britan(1982).

---

* Quatation to CORC.

5. TARGET TI OPERATING MANUAL, Linhoff March Co., 33 King street, Manchester, U.K.

6. El-Temtamy S.A. and Khalil S.A. "Energy Conservation in Petroleum Industry, Part IV: Energy Targetting Using The Pinch Technology For Process Integration", Proceedings of the 3rd conference of Chemical Engineering, Cairo, 19-21 March 1988.

Table (1): Stream data for VRU

Target II — Copyright Linnhoff March, Stream Data-File vru2.dat — Serial No. EGY. PET-01

Stream	Specific heat * mass flow (CP) GJ/hr	Enthalpy change GJ/hr	Supply Temp. °C	Target Temp. °C	Contri-bution to MAT	Name
1 Cold	.15450	6.71000	40.0	90.0	10.0	4c-4 feed
2 Cold	220.48700	22.05000	159.0	159.1	10.0	4c-4 reboil
3 Cold	.02223	.43900	40.0	62.0	10.0	feed to 4c-5
4 Cold	16.97030	1.69700	85.0	85.1	10.0	4c-5 reboil
5 Cold	.24336	17.03540	40.0	110.0	10.0	feed to 4c-7
6 Cold	65.33601	6.55400	128.0	128.1	10.0	4c-7 reboil
7 Hot	.12950	-15.29200	159.0	40.0	10.0	4c-4 bottoms
8 Hot	.74634	-14.19000	59.0	40.0	10.0	4c-4 cond.
9 Hot	.01967	- .88500	85.0	40.0	10.0	4c-5 bottoms
10 Hot	.15510	-15.47300	128.0	40.0	10.0	4c-7 bottoms
11 Hot	.33691	- 5.89600	57.5	40.0	10.0	4c-7 condenser
12 Hot	.30304	- 1.69700	45.6	40.0	10.0	4c-3 condenser

Table 2. Problem table for VRU.

Target II Copyright Linhoff March Serial No:
EGY.PET-01

Problem Table-File vru2.dat
GT = 20.0

Interval Temperature °C	Heat Flow GJ/hr
169.1	30.89096
169.0	8.84091
149.0	8.84091
138.1	10.24161
138.0	3.72045
120.0	6.03353
118.0	5.80361
100.0	6.49219
95.1	6.02200
95.0	4.31540
75.0	2.39626
72.0	2.16739
50.0	.00000
49.0	.30127
47.5	1.87345
35.6	18.35529
30.0	27.80845

Table 3: Energy target report.

```
Target II          Copyright Linhoff March          Serial No.
                                                    EGY.PET-01
              Energy Target Report-File vru2.dat
Minimum hot utility = 30.89096 GJ/hr
Minimum cold utility= 27.80645 GJ/hr
Global minimum apprach temperature= 20.0°C
There is 1 pinch
Pinch at interval temperature= 50.0
Cold stream 1 pinched at 40.0
Cold stream 3 pinched at 40.0
Cold stream 5 pinched at 40.0
Hot stream  7 pinched at 60.0
Hot stream  9 pinched at 60.0
Hot stream 10 pinched at 60.0
```

Table 4: Summary of theoretical energy balance for VRU.

A- Before redesigning the heat exchange train.

Entering			Leaving		
Item	GJ/h	%	Item	GJ/h	%
Heat recycled	15.23	27.4	Heat recycled	15.23	27.4
Fuel fired	39.285	70.68	Product enthalpy gain	4.877	8.77
Enthalpy gain due to compression	1.07	1.92	Coolers and condensers	35.478	63.83
Total	55.585	100.0	Total	55.585	100.0

B- After redesigning the heat exchange train

Entering			Leaving		
Item	GJ/h	%	Item	GJ/h	%
Head recycled	23.625	42.50	Heat recycled	23.625	42.50
Fuel fired	30.89	55.58	Product enthalpy gain	4.152	7.47
Enthalpy gain due to compression	1.07	1.92	Coolers and condensers	27.808	50.03
Total	55.585	100.0	Total	55.585	100.0

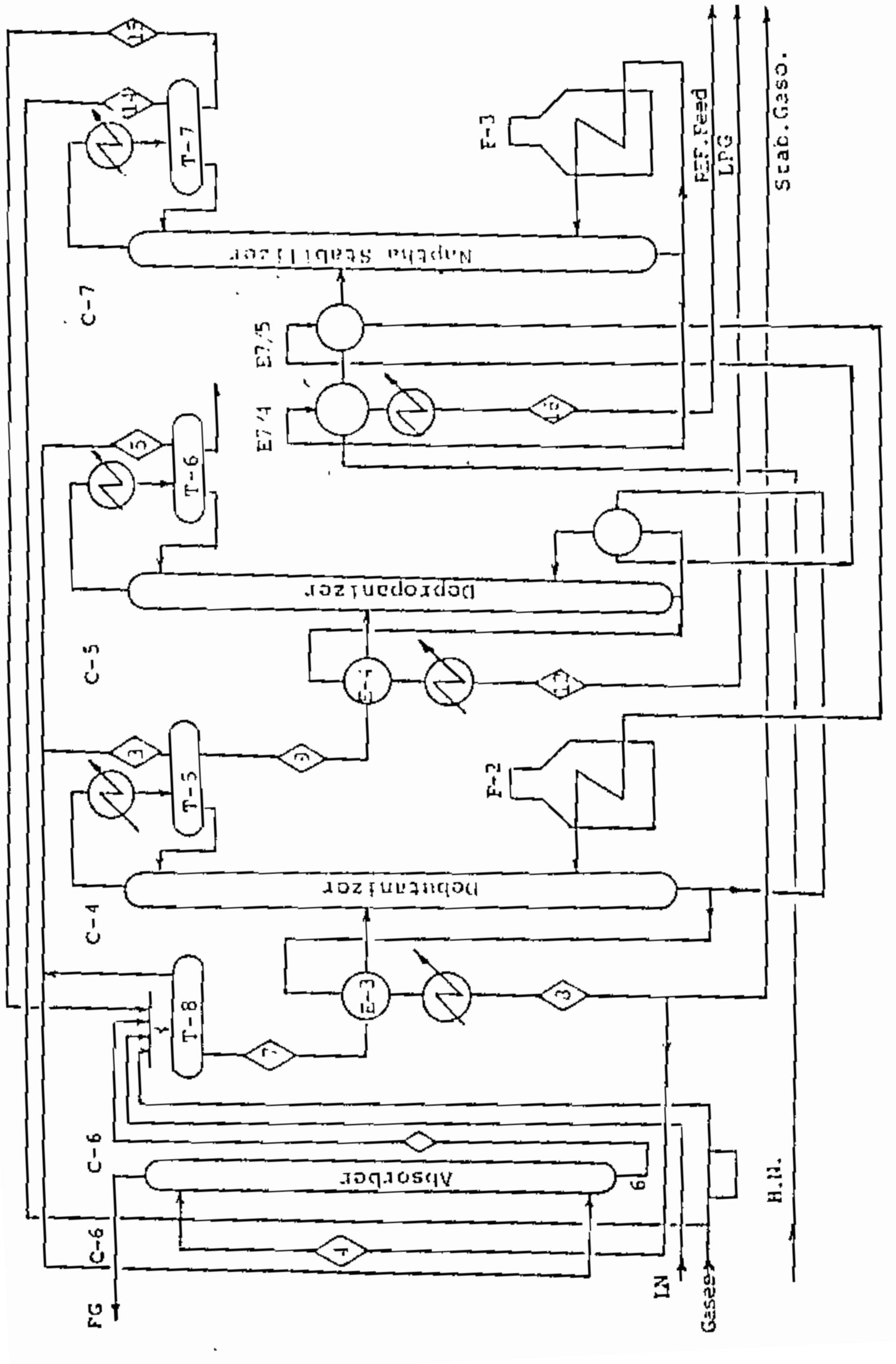

Fig. 1 : VRU Flow Sheet.

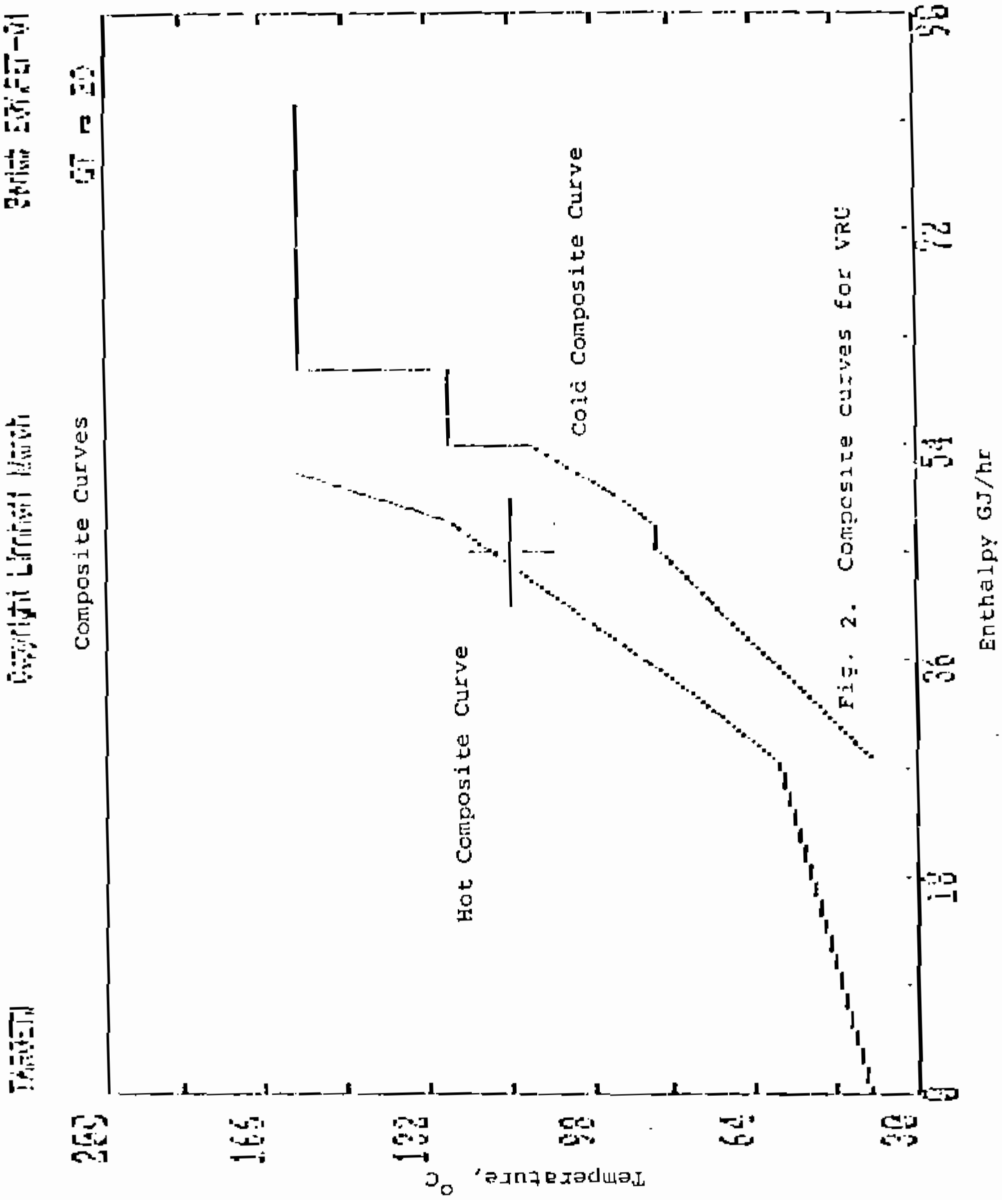

Fig.2. Composite Curves for VRU

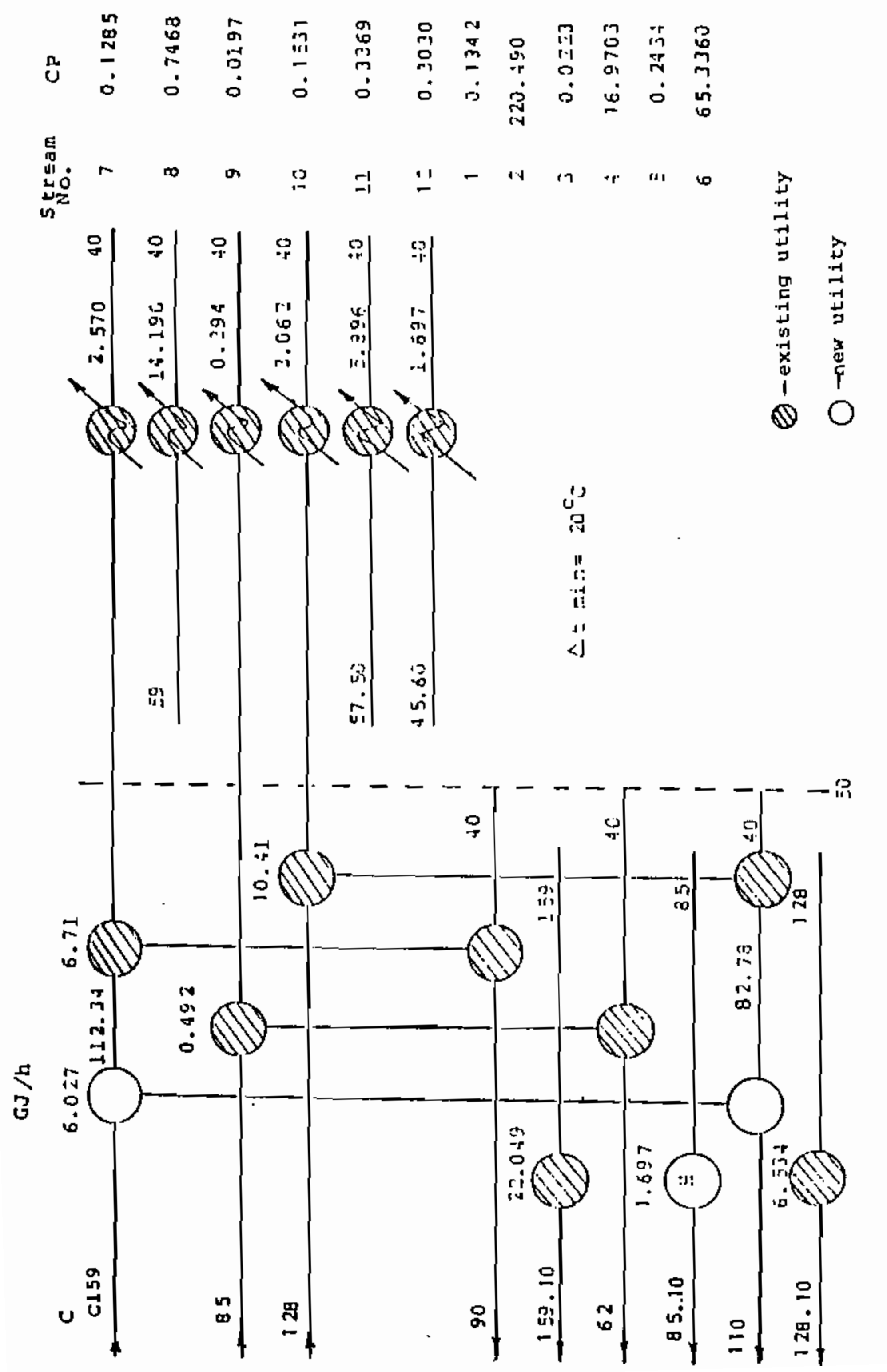

Fig. 3 : Design grid for VRU-2.

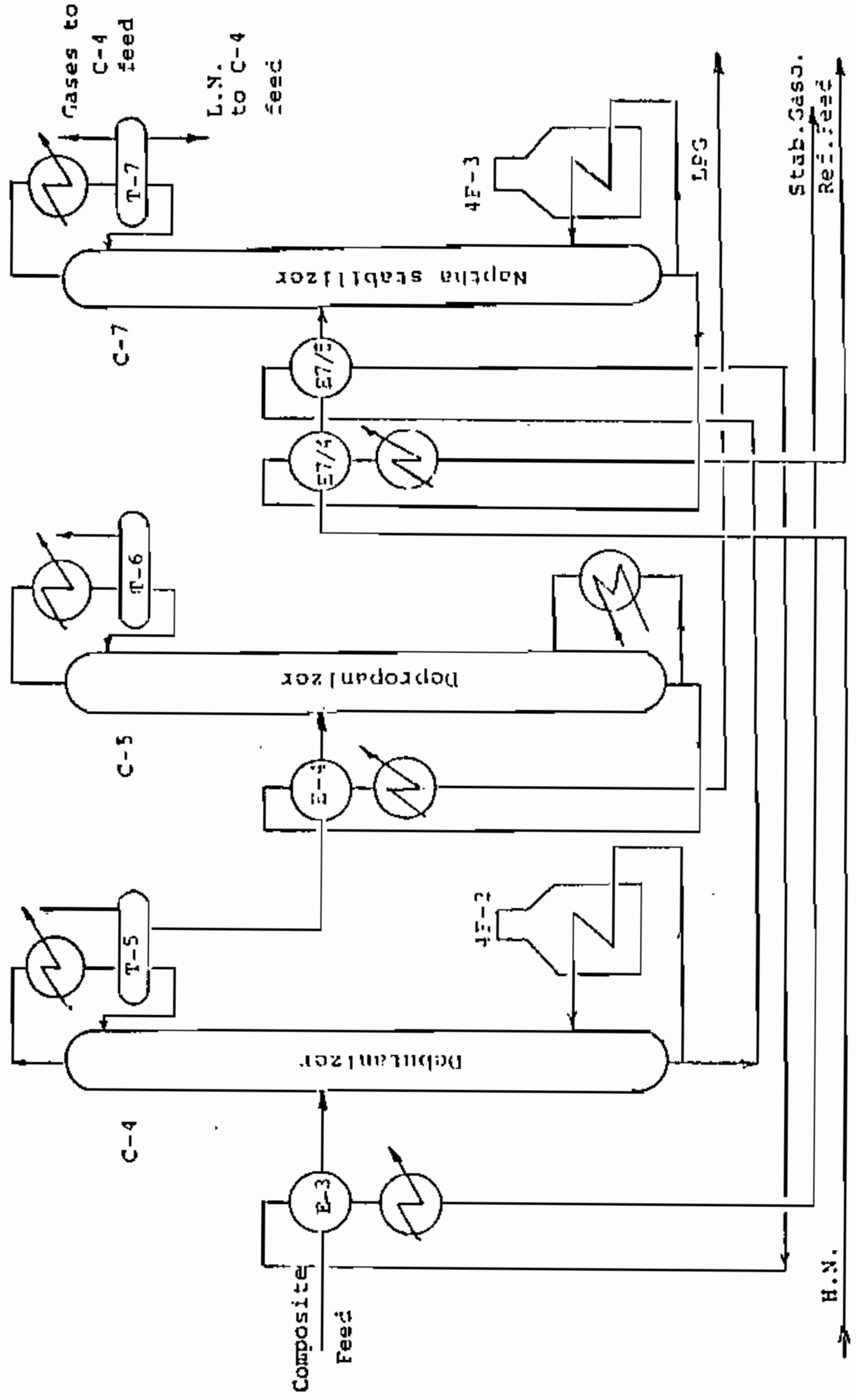

Fig. 4 : Proposed flow sheet for VRU