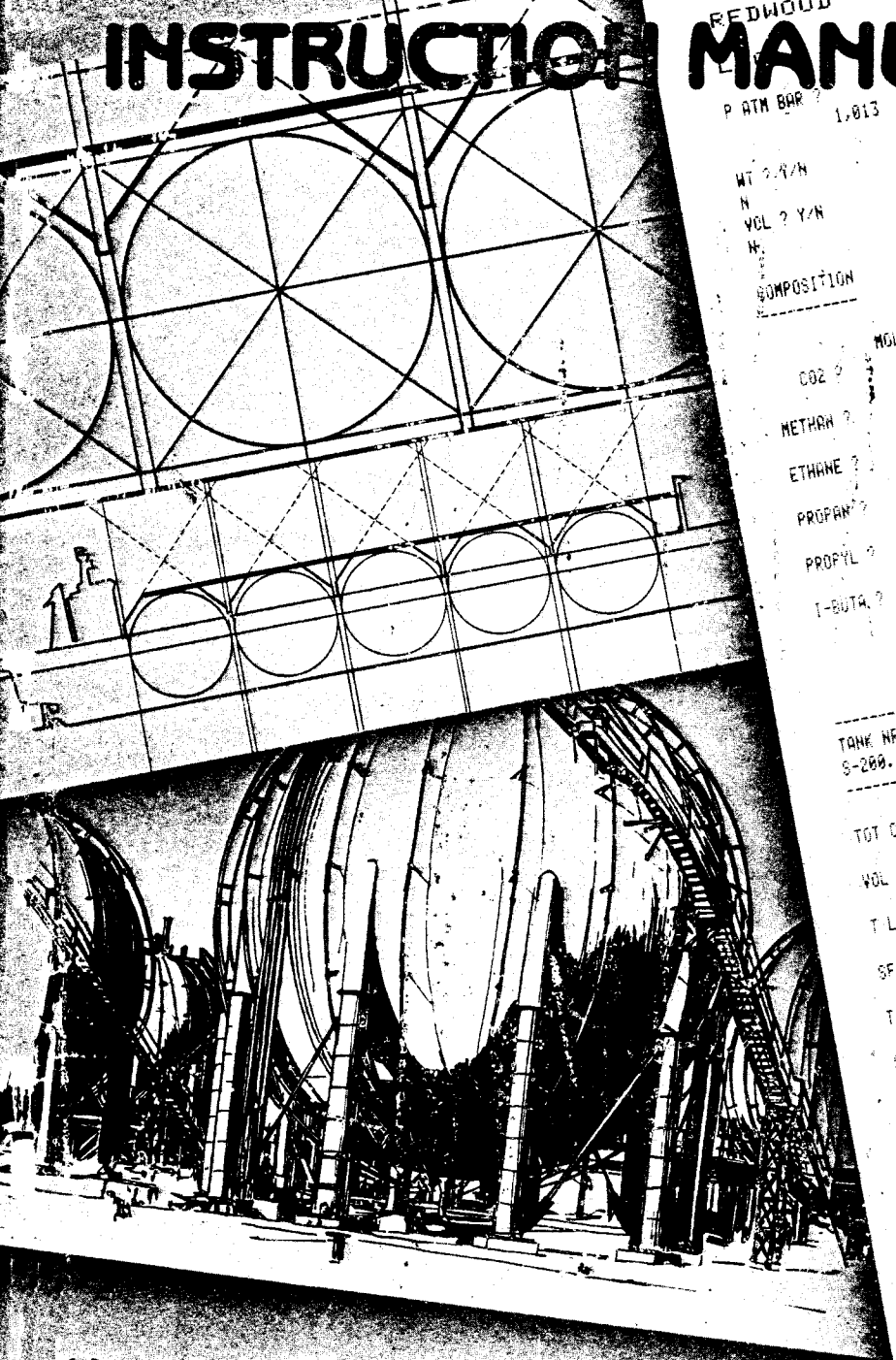
INSTRUCTION MANUAL



REDWOOD

P ATM BAR ? 1,013 RUN

WT ? Y/N RUN
N
VOL ? Y/N RUN
N

COMPOSITION

MOL %

CO2 ? RUN
METHAN ? RUN
ETHANE ? 1,730 RUN
PROPAN ? 61,250 RUN
PROPYL ? 35,960 RUN
I-BUTA ? 1,060 RUN
Σ 100,000

TANK NR RUN
S-200.1

TOT CAP M3 ? 3314,936 RUN
VOL L M3 ? 1025,089 RUN
T L DEG C ? 2,0 RUN
SF L ? RUN
T V DEG C ? 5,0 RUN
SF V ? RU
P REL BAR ? 4,5 R
% INERT V ?

P ABS =5,513
P SAT =5,582
SAT ? Y/N

VOL V =2289,847
SF V =1,0000000
VOL V C =2289,847
DEN V =11,857
M V =27,151

VOL L =1025,089
SF L =1,0000000
VOL L C =1025,0

SGS REDWOOD
PETROLEUM AND PETROCHEMICAL SERVICES

Depauw & Stokoe

1. INTRODUCTION

The SGS REDWOOD GAS CALCULATOR represents a unique concept offering advanced calculation procedures in the custody transfer of liquefied petroleum and chemical gases.

The ROM-type GAS CALCUL MODULE stores 32 programmes permanently. They may be run independently or consecutively to simplify and to accelerate the complex quantity calculations related to the custody transfer of L.P.G., chemical C4-mixtures, ethylene, propylene, butadiene 1-3, anhydrous ammonia and VCM.

The GAS CALCULATOR is the first portable computerised system STANDARDISING gas quantity calculations.
The scientific references used for the calculation of liquid and vapour phase density, the determination of saturated vapour pressure and the calculation of other physical properties, have been carefully selected by a competent REDWOOD staff in order to ensure the recognition of the MODULE contents on a world-wide basis.

In addition to its comprehensive scientific base, the system offers many important technical features which will be of interest to your field personnel. Spot calculations and print-out are not limited to air-conditioned offices but can be carried out where and whenever required. The display "talks" to the operator, signalling mistakes and prompting input. The colour-coded overlay tells the operator which key is to be pressed to obtain the various applications.

Clearing or adapting programmes stored in the ROM is impossible, even with loss of power or in the case of misuse.

Furthermore, the GAS MODULE's flexibility is maximized by means of spaces which are designed into the module software, allowing the user to INSERT or ADD his OWN APPLICATIONS (e.g. calibration tables). In addition, the SGS REDWOOD GAS CALCULATOR can be linked with the HP-IL cassette drive, providing on-line mass storage.

The GAS CALCULATOR will make field as well as office personnel more independent and efficient but its most important function is to ensure consistently accurate results in the custody transfer of liquefied petroleum gases.

2. OPERATING INSTRUCTIONS

2.1. Initializing

> CAUTION !
> Before getting started it is very important to keep in mind that the calculator should always be turned off before inserting or removing the module or other peripherals ! Otherwise, both the calculator and the accessories may be seriously damaged.

a. Check for batteries and battery power.

b. Remove the cap of port no. 1 (upper left corner) of your calculator. Insert the module with the legend facing up until it snaps firmly into place.

c. Put the overlay on the calculator and lock it in place by pulling down the switch between the USER and the PRGM key.

d. If your calculator has only been used for normal calculation (no programming involved) continue on the next page, otherwise read the following carefully.
The automatic key assignment of the GAS CALCUL programmes uses 16 registers, another 46 are required for internal storage and calculations.
Consequently :
- If an HP 41 C is being used clear its complete memory of 63 registers by holding down simultaneously for a few seconds the [ON] and the [←] key. "MEMORY LOST" will be displayed. Continue on next page.
- If an HP 41 CV or CX is being used, check that 16 memory registers are available.
When switching the calculator on, "WORKING" should be displayed. Verify that a size of 046 can be allocated by pressing [XEQ] ; "REDWOOD/LPG/WT Y/N ?" should be displayed.
In case one of the above tests results in "NO ROOM", "PACKING" or "TRY AGAIN", clear one or more programmes until this procedure can be accomplished.

e. When the calculator is switched on, "WORKING" is displayed and the "USER" annunciator is automatically turned on, showing that the GAS CALCUL programmes have been automatically assigned to the 4 upper rows of the keyboard.

f. If an OIL CALCUL module is (or has been) inserted in your HP 41 the assignments have to be nullified by means of the clear key function.
Press [USER] [XEQ] [ALPHA]
Type "CLKEYS"
Press [ALPHA]
Switch the calculator off and on again. The OIL CALCUL module can stay inserted in port no. 2, 3 or 4 or may be stored in the protective booklet delivered with your HP 41.

g. The original number display of the HP 41 is the American mode (I,III.F). Two flags, the decimal point flag (28) and the digit grouping flag (29), are used to control how numbers appear in the display.

	CF 28	SF 28
CF 29	IIII,F	IIII.F
SF 29	I.III,F	I,III.F

I = integer part
F = fraction part

To obtain the CF and SF function, press first the yellow shift key, followed by [8] or [7].

2.2. Getting started

All programme possibilities are listed in the following table. After having read the remarks on this table, continue by using the examples given in section 3.
Furthermore, remember that to continue the programme you have to press [R/S] - after each input
- after each output if no printer is used.

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Programme description	Overlay name	Key(s)	Example
1. Gas calculation			
LPG short	LPG S	XEQ	page 14
TAIT option	TAIT	EEX	page 16
C4MIX option	C4MIX	CHS	page 17
C4MIX/TAIT	C4MIX/TAIT	CHS / EEX	page 18
LPG long	LPG L	XEQ	page 15
TAIT option	TAIT	EEX	page 16
VCF option	VCF	←	page 19
C4MIX option	C4MIX	CHS	page 17
C4MIX/TAIT	C4MIX/TAIT	CHS / EEX	page 18
C4MIX/VCF	C4MIX/VCF	CHS / ←	page 21
Ethylene short	$C_2^=$ S	x≷y	page 22
long	$C_2^=$ L	x≷y	page 23
Propylene short	$C_3^=$ S	R↓	page 22
long	$C_3^=$ L	R↓	page 23
Butadiene 1,3 short	$C_4^=$ S	SIN	page 22
long	$C_4^=$ L	SIN	page 23
Ammonia short	NH_3 S	COS	page 22
long	NH_3 L	COS	page 23
Vinyl chloride short	VCM S	TAN	page 22
long	VCM L	TAN	page 23
2. Laboratory interconversions			
LPG			
liq. volume to mole %(*)	VOL ▶ MOL	STO	page 24
mole to liq. volume %	VOL ◀ MOL	STO	page 24
weight to mole %	WT ▶ MOL	RCL	page 24
mole to weight %	WT ◀ MOL	RCL	page 24
liq. volume to weight %	VOL ▶ WT	SST	page 24
weight to liq. volume %	VOL ◀ WT	SST	page 24
C4 MIX option		CHS	page 25

(*) mole % equals gas volume %

Programme description	Overlay name	Key(s)	Example
3. Unit conversion			
°F to °C	°F ▶ °C	[Σ+]	page 26
°C to °F	°F ◀ °C	[ ] [Σ+]	page 26
kg/cm^2 to bar	KG ▶ BAR	[1/x]	page 26
bar to kg/cm^2	KG ◀ BAR	[ ] [1/x]	page 26
atomosphere to bar	ATM ▶ BAR	[√x]	page 26
bar to atmosphere	ATM ◀ BAR	[ ] [√x]	page 26
mm Hg to bar	HG ▶ BAR	[LOG]	page 26
bar to mm Hg	HG ◀ BAR	[ ] [LOG]	page 26
psi to bar	PSI ▶ BAR	[LN]	page 26
bar to psi	PSI ◀ BAR	[ ] [LN]	page 26
4. Interpolation	INTERPOLATION	[ ] [ENTER ↑]	page 27

Remarks :

1) [ ] stands for the yellow shift key.

2) C4MIX TAIT and VCF are "option toggle" keys. "Option" stands for the possibility of selecting a variation on the standard calculation procedure. The option programmes are not input/output programmes but their only function is to introduce the main programmes to the option conditions.
Therefore, pressing an option key should always be followed by pressing a main programme key.
"Toggle" indicates that the optional calculation procedure can be nullified simply by pressing the option key for a second time.

3) When you press and hold a programme key down for longer than half a second, "NULL" appears in the display. This means that the programme has been cancelled.

4) The GAS CALCUL software package is private. Programme lines cannot be displayed, printed out or modified. When the calculator is in PRGM-mode or the printer is in TRACE or MAN-mode, the calculator will not execute the programme and displays "PRIVATE".

2.3. Use as ordinary calculator

2.3.1. The original calculator functions can be obtained simply by pressing USER . The word "USER" then disappears from the display. The normal HP-keybord is activated so that the 130 HP standard functions become available.

2.3.2. To switch from the GAS CALCUL to OIL CALCUL programmes (or vice versa), the following key-strokes have to be executed :

* GAS CALCUL ▶ OIL CALCUL

- ensure that your GAS CALCUL module is still inserted in port no. 1
- execute a "CLKEYS"
- switch the calculator off
- pull the GAS module out and switch it to port 2, 3 or 4
- insert the OIL CALCUL module in port no. 1

* OIL CALCUL ▶ GAS CALCUL

- switch the calculator off
- pull the OIL CALCUL module out and switch it to port 2, 3 or 4
- insert the GAS CALCUL module in port no. 1
- switch the calculator on
- execute a "CLKEYS"
- switch the calculator off and on again.

Follow the procedure very strictly, otherwise completely erroneous assignments will occur.

2.3.3. When the GAS CALCUL module is pulled out, the assignments of the programmes remain stored in the calculator.
When an assigned key is pressed in USER mode, XROM 21.01 to XROM 21.51 will be displayed shortly, followed by "NONEXISTENT".
These assignments can be removed by executing a "CLKEYS".

2.3.4. For personal programming, 257 registers are still available on a 41 CV (none on a 41 C).
When your personal programmes are executed consecutively with module programmes, interaction can occur in the following cases :

a) The module software uses the general user flags 00 through 10. The status of these flags is changed after running a module programme.

b) Never label one of your programmes or subroutines with the same string of ALPHA characters as indicated in table 5.12. Otherwise, a erroneous execution of the programmes is possible.

c) Never assign one of your own programmes to the keys used by the GAS CALCUL Module. Otherwise, your programmes will have priority and will always be executed instead of the module programme.

2.4. Standard calculation procedures

The following three menus represent the basic lay-out of the various gas calculation programmes. The examples in section 3 always refer to one (or more) of these menus.

Menu 1 : LPG / C4 MIX composition

```
WT ? Y/N ──────┐  Input composition in weight % ? If so,
N              │  press Y(es) (or only [R/S] ); if not press N.
VOL ? Y/N ─────┼──  Input composition in volume liquid % ? If so
N              │  press Y(es) (or only [R/S] ); if not press N.
               │
COMPOSITION ───┼──  In case these two basic compositions do not
-----------    │  fit completely with your existing composition,
          MOL %  WT %  VOL %   read carefully the explanation of table 5.8.
                               or 5.9. (only liquid density calculation and
  CO2 ?        ETHANE ?        input in mole %).
METHAN ?       PROPAN ?
ETHANE ?       PROPYL ?   In case a component is not present press only
PROPAN ?       I-BUTA ?   [R/S] ; 0 is automatically selected as input
PROPYL ?       N-BUTA ?   value.
I-BUTA ?       BUTE-1 ?
N-BUTA ?       BUTE-2 ?   At the moment Σ = 100 the other components
BUTE-1 ?       I-BUTY ?   are not asked anymore.
I-PENT ?       BTD-12 ?
N-PENT ?       BTD-13 ?
N-HEXA ?       N-PENT ?

    -------
  Σ 100,000 ──────────  In case Σ ≠ 100 an audible alarm
                        (3 X TONE 0) will sound and the programme
  CO2=         ETHANE=  pointer will return to the first component
METHAN=        PROPAN=  input (CO2 or ETHAN).
ETHANE=        PROPYL=
PROPAN=        I-BUTA=
PROPYL=        N-BUTA=
I-BUTA=        BUTE-1=
N-BUTA=        BUTE-2=  The interconversion is calculated (cfr.
BUTE-1=        I-BUTY=  table 5.1.) with a precision of 3 decimal
I-PENT=        BTD-12=  places.
N-PENT=        BTD-13=
N-HEXA=        N-PENT=  After interconversion, the Σ can differ
                        ± 0,001 from 100 due to rounding differences.
```

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Menu 2 : Short version LPG / Chemical Gases.

T L DEG C ? —— Temperature of the liquid phase in °C (1)

DEN L = ———— Liquid vacuo density in kg/m^3 rounded off to 0,1 kg/m^3(2)(3)
P SAT = ———— Saturated vapour pressure in bar rounded off to 0.001 bar (3)
DEN V = ———— Vapour vacuo density in kg/m^3 rounded off to 0,001 kg/m^3(3)

T L DEG C ? ———— New temperature

Remarks :

(1) If the temperature is out of range (table 5.11.), an audible alarm (3 X TONE 0) sounds and "T OUT OF RANGE" is displayed.

(2) Summary of references can be found in table 5.1.
Saturated liquid densities at boiling point and at 15°C can be found in :
table 5.2. - pure components of LPG and C4 MIX
table 5.3. - chemical gases

(3) Values of DEN L, P SAT and DEN V are printed as a table for the commercial temperature ranges for :

- ethylene : table 5.3.
- propylene : table 5.4.
- butadiene-1,3 : table 5.5.
- ammonia : table 5.6.
- VCM : table 5.7.

(4) Calculation time will differ :
- LPG : 3 components : ± 45 sec.
  9 components : ± 1 min. 20 sec.
  From a second temperature onwards, the calculation time is reduced to ± 15 sec.
- Chemical gases : ± 20 sec.

Depauw & Stokoe

Menu 3 : Long version LPG / Chemical gases

P ATM BAR ? ——— Atmospheric pressure in bar.

(TANK NR / IP) ——— Shore or vessel tank number. (A)
An input is not necessary, press only R/S

TOT CAP M3 ? ——— Total capacity of tank in m^3.

VOL L M3 ? ——— Volume of liquid phase in m^3. If zero press only R/S (1)

T L DEG C ? ——— Temperature of the liquid phase in °C. (3a)

SF L ? ——— Shrinkage factor of the liquid phase. If SF L = 1 press only R/S .

T V DEG C ? ——— Temperature of the vapour phase in °C.

SF V ? ——— Shrinkage factor of the vapour phase. If SF V = 1 press only R/S .

P REL BAR ? ——— Relative vapour pressure in bar.

% INERT V ? ——— % inert gas in the vapour phase (2). If not known, type 0 (or press only R/S). (2) (5)

P ABS = ——— Absolute vapour pressure (P ABS = P ATM + P REL).

P SAT = ——— Saturated vapour pressure rounded off to 0.001 bar (4)

SAT ? Y/N ——— Selection of actual or saturated conditions for calculation of DEN V. If saturated, press Y(es) (or only R/S); if actual press "N". (3b)

VOL V = ——— Volume of the vapour phase in m^3. (B)

(SF V =) ——— Shrinkage factor of the vapour phase.

VOL V C = ——— Vapour volume corrected for shrinkage factor.

DEN V = ——— Vapour vacuo density in kg/m^3 rounded off to 0.001 kg/m^3.

M V = ——— Mass of the vapour phase in kg rounded off to 1 kg.

(VOL L =) ——— Volume of liquid phase.

(SF L =) ——— Shrinkage factor of the liquid phase.

VOL L C = ——— Liquid volume corrected for shrinkage factor.

DEN L = ——— Liquid vacuo density in kg/m^3 rounded off to 0.1 kg/m^3

M L = ——— Mass of the liquid phase in kg rounded off to 1 kg.

M TOT = ——— Total mass liquid and vapour phase in kg.

MRE TKS? Y/N ——— Selection of more tanks. If calculation is finished, type "N"
N If there are more tanks to be calculated press Y(es) (or only R/S). The programme pointer will return to "TANK NR".

TOTALS

Σ M V = ——— Total mass of vapour phase in kg of all tanks.

Σ M L = ——— Total mass of liquid phase in kg of all tanks.

Σ M TOT = ——— Total mass in kg of all calculated tanks.

Remarks :

(A) If no printer is available, expressions between brackets are not displayed.

(B) If no printer is available, output expressions longer than 12 characters will cause shifting of the characters in the display; the 12 characters furthest to the right will remain visible.
To review the total expression, press [ALPHA] [ALPHA]

(1) If a tank is empty of liquid (VOL L = 0), the programme is adapted in such a way that the input "T L DEG C" and "SF L" are not asked and the output "VOL L" to "M L" are not displayed.

(2) The "% INERT ?" input gives you the flexibility of correcting wrongly inputted data by typing a value exceeding 100. The programme pointer will return to "TANK NR ?", overwriting all the input data of the last introduced tank.

(3a) If the temperature is out of range (cfr. table 5.11.), an audible alarm sounds (3 X TONE 0) and "T OUT OF RANGE" is displayed. A new input temperature is asked and the mass calculation of the tank in question may proceed.

(3b) If the compressibility factor z becomes very small ($\pm$ < 0,3) an audible alarm will sound (3 X TONE 0) and "Z NOT VALID" or "DATA ERROR" is displayed. This out of range condition should never be encountered on board refrigerated or pressurized tankers.

(4) Summary of references can be found in table 5.1.

(5) The calculation times from "% INERT" to "P ABS" will differ :
- LPG : 3 components : $\pm$ 45 sec.
  9 components : $\pm$ 1 min. 20 sec.
  From a second tank onwards, the calculation time will be reduced to $\pm$ 15 sec.
- Chemical gases : $\pm$ 20 sec.

3. EXAMPLES

3.1. LPG

A. Short version (normal execution)

```
                XROM "LPGS" ——— Press [XEQ]
REDWOOD

LPG

WT ? Y/N
                    RUN

COMPOSITION
-----------

             WT %
   CO2 ?
                    RUN
METHAN ?
                .010    RUN
ETHANE ?
               1.730    RUN
PROPAN ?
              61.520    RUN
PROPYL ?                          See Menu 1
              35.960    RUN
I-BUTA ?
                .580    RUN
N-BUTA ?
                .200    RUN
             -------
           Σ 100.000


          MOL %
METHAN= 0.027
ETHANE= 2.478
PROPAN=60.105
PROPYL=36.811
I-BUTA= 0.430
N-BUTA= 0.148


T L DEG C ?
               2.00    RUN

DEN L =530.2
P SAT =5.693                      See Menu 2
DEN V =12.052

          --------

T L DEG C ?
```

B. Long version (normal execution)

```
          XROM "LPGL" ———— Press  ☐ XEQ
REDWOOD

LPG

P ATM BAR ?
          1.013    RUN

WT ? Y/N
N                  RUN
VOL ? Y/N
                   RUN

COMPOSITION
-----------

          VOL %
   CO2 ?
                   RUN
METHAN ?
          .010     RUN
ETHANE ?
         1.730     RUN
PROPAN ?
        61.520     RUN
PROPYL ?
        35.960     RUN
I-BUTA ?
          .580     RUN
N-BUTA ?
          .190     RUN
BUTE-1 ?
                   RUN
I-PENT ?
                   RUN
N-PENT ?
          .010     RUN
        -------
      Σ 100.000


       MOL %
METHAN= 0.016
ETHANE= 1.733
PROPAN=59.894
PROPYL=37.713
I-BUTA= 0.475
N-BUTA= 0.162
N-PENT= 0.007

    See Menu 1
```

```
--------
TANK NR
1P                 RUN
--------

TOT CAP M3 ?
          953.2    RUN
VOL L M3 ?
          842.23   RUN
T L DEG C ?
            2.0    RUN
SF L ?
                   RUN
T V DEG C ?
            3.0    RUN
SF V ?
                   RUN
P REL BAR ?
            5.2    RUN
% INERT V ?
                   RUN

P ABS =6.213
P SAT =5.628
SAT ? Y/N
Y                  RUN

VOL V =110.970
SF V =1.0000000
VOL V C =110.970
DEN V =11.933
M V =1324

VOL L =842.230
SF L =1.0000000
VOL L C =842.230
DEN L =531.1
M L =447308

M TOT =448632

MRE TKS? Y/N
                   RUN

    See Menu 2
```

```
--------
TANK NR
2P                 RUN
--------

TOT CAP M3 ?
          959.62   RUN
VOL L M3 ?
          830.91   RUN
T L DEG C ?
            3.0    RUN
SF L ?
                   RUN
T V DEG C ?
            3.5    RUN
SF V ?
                   RUN
P REL BAR ?
            4.6    RUN
% INERT V ?
                   RUN

P ABS =5.613
P SAT =5.798
SAT ? Y/N
Y                  RUN

VOL V =128.710
SF V =1.0000000
VOL V C =128.710
DEN V =12.277
M V =1580

VOL L =830.910
SF L =1.0000000
VOL L C =830.910
DEN L =529.7
M L =440133

M TOT =441713

MRE TKS? Y/N
N                  RUN

TOTALS
------

Σ M V =2904
Σ M L =887441
Σ M TOT =890345
```

Depauw & Stokoe

C. TAIT option (pressure influence)

```
          XROM "TAIT"
SELECT PRGM

          XROM "LPGS"
REDWOOD

LPG

P ATM BAR ?
          1.015    RUN

WT ? Y/N
N                  RUN
VOL ? Y/N
N                  RUN

COMPOSITION
-----------

          MOL %
   CO2 ?
                   RUN
METHAN ?
          .010     RUN
ETHANE ?
          1.730    RUN
PROPAN ?
         61.520    RUN
PROPYL ?
         35.900    RUN
I-BUTA ?
          .640     RUN
N-BUTA ?
          .190     RUN
BUTE-1 ?
                   RUN
I-PENT ?
                   RUN
N-PENT ?
          .010     RUN
        -------
      Σ 100.000

T L DEG C ?
         16.50     RUN
P REL BAR ?
          3.60     RUN

DEN L =508.5 TAIT
P SAT =8.424
DEN V =17.597

        --------

T L DEG C ?
```

```
          XROM "TAIT"
SELECT PRGM

          XROM "LPGL"
REDWOOD

LPG

P ATM BAR ?
          1.02     RUN

WT ? Y/N
                   RUN

COMPOSITION
-----------

          WT %
   CO2 ?
                   RUN
METHAN ?
                   RUN
ETHANE ?
                   RUN
PROPAN ?
         91.250    RUN
PROPYL ?
          7.750    RUN
I-BUTA ?
          1.000    RUN
        -------
      - Σ 100.000

      MOL %
PROPAN=91.133
PROPYL= 8.110
I-BUTA= 0.758
```

"TAIT" is displayed as a reminder that the TAIT correction is executed.

Press ☐ EEX
TAIT correction is executed. The influence of the pressure on the liquid density is taken into account in the main LPG S (XEQ) or LPG L (☐ XEQ) programme.

```
        --------
TANK NR
1P                 RUN
        --------

TOT CAP M3 ?
         2500.58   RUN
VOL L M3 ?
          1652.4   RUN
T L DEG C ?
            24.0   RUN
SF L ?
                   RUN
T V DEG C ?
            26.0   RUN
SF V ?
                   RUN
P REL BAR ?
             6.2   RUN
% INERT V ?
            10.5   RUN

P ABS =7.220
P SAT =9.487
SAT ? Y/N
N                  RUN

VOL V =759.121
SF V =1.0000000
VOL V C =759.121
DEN V =14.429
M V =10953

VOL L =1652.400
SF L =1.0000000
VOL L C =1652.400
DEN L =494.9 TAIT
M L =817773

M TOT =828726

MRE TKS? Y/N
N                  RUN
```

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D. C4MIX option

```
          XROM "C4MIX"
SELECT PRGM

          XROM "LPGS"
REDWOOD

C4 MIX

WT ? Y/N
N                    RUN
VOL ? Y/N
N                    RUN

COMPOSITION
-----------

             MOL %
ETHANE ?
             .020    RUN
PROPAN ?
           26.320    RUN
PROPYL ?
           10.840    RUN
I-BUTA ?
           23.100    RUN
N-BUTA ?
           10.800    RUN
BUTE-1 ?
            7.830    RUN
BUTE-2 ?
           14.490    RUN
I-BUTY ?
            6.350    RUN
BTD-12 ?
                     RUN
BTD-13 ?
             .200    RUN
N-PENT ?
             .050    RUN
           -------
         Σ 100.000

T L DEG C ?
            3.50     RUN

DEN L =578.3
P SAT =2.381
DEN V =5.780

        --------

T L DEG C ?
```

```
          XROM "C4MIX"
SELECT PRGM

          XROM "LPGL"
REDWOOD

C4 MIX

P ATM BAR ?
           1.025     RUN

WT ? Y/N
                     RUN

COMPOSITION
-----------

             WT %
ETHANE ?
             0.020   RUN
PROPAN ?
           26.320    RUN
PROPYL ?
           10.840    RUN
I-BUTA ?
           23.100    RUN
N-BUTA ?
           10.800    RUN
BUTE-1 ?
            7.830    RUN
BUTE-2 ?
           14.490    RUN
I-BUTY ?
            6.350    RUN
BTD-12 ?
                     RUN
BTD-13 ?
             .200    RUN
N-PENT ?
             .050    RUN
           -------
         Σ 100.000


       MOL %
ETHANE= 0.034
PROPAN=30.552
PROPYL=13.184
I-BUTA=20.341
N-BUTA= 9.510
BUTE-1= 7.143
BUTE-2=13.219
I-BUTY= 5.793
BTD-13= 0.189
N-PENT= 0.035
```

Press ☐ CHS : C4MIX components are selected for calculation in the main LPG S (XEQ) or LPG L (☐ XEQ) programme.

```
        --------
TANK NR
200                  RUN
        --------

TOT CAP M3 ?
          3314.005   RUN
VOL L M3 ?
          2562.267   RUN
T L DEG C ?
             3.5     RUN
SF L ?
                     RUN
T V DEG C ?
             5.0     RUN
SF V ?
                     RUN
P REL BAR ?
             3.5     RUN
% INERT V ?
                     RUN

P ABS =4.525
P SAT =2.609
SAT ? Y/N
N                    RUN

VOL V =751.738
SF V =1.0000000
VOL V C =751.738
DEN V =11.382
M V =8556

VOL L =2562.267
SF L =1.0000000
VOL L C =2562.267
DEN L =574.1
M L =1470997

M TOT =1479553

MRE TKS? Y/N
```

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E. C4MIX / TAIT option

```
XROM "C4MIX"                    XROM "C4MIX"
SELECT PRGM                     SELECT PRGM

XROM "TAIT"                     XROM "TAIT"
SELECT PRGM                     SELECT PRGM

XROM "LPGS"                     XROM "LPGL"
REDWOOD                         REDWOOD

C4 MIX                          C4 MIX

P ATM BAR ?                     P ATM BAR ?
          1.005    RUN                  1005.0    RUN

WT ? Y/N                        WT ? Y/N
N                  RUN          N                  RUN
VOL ? Y/N                       VOL ? Y/N
N                  RUN          N                  RUN

COMPOSITION                     COMPOSITION
-----------                     -----------

           MOL %                           MOL %
ETHANE ?                        ETHANE ?
                   RUN                             RUN
PROPAN ?                        PROPAN ?
                   RUN                             RUN
PROPYL ?                        PROPYL ?
                   RUN                             RUN
I-BUTA ?                        I-BUTA ?
          4.130    RUN                   4.130     RUN
N-BUTA ?                        N-BUTA ?
         10.540    RUN                  10.540     RUN
BUTE-1 ?                        BUTE-1 ?
         25.530    RUN                  25.530     RUN
BUTE-2 ?                        BUTE-2 ?
         11.250    RUN                  11.250     RUN
I-BUTY ?                        I-BUTY ?
         48.370    RUN                  48.370     RUN
BTD-12 ?                        BTD-12 ?
                   RUN                             RUN
BTD-13 ?                        BTD-13 ?
           .180    RUN                    .180     RUN
        -------                         -------
      Σ 100.000                       Σ 100.000

T L DEG C ?
         -1.50     RUN
P REL BAR ?
          1.50     RUN

DEN L =617.7 TAIT
P SAT =1.169
DEN V =3.048
```

"TAIT" is displayed as a reminder that TAIT correction is executed.

Press ☐ CHS

Press ☐ EEX or vice versa. Both the C4MIX components a the TAIT correction is selected for calculation into the main LPG S (XEQ) or LPG L (☐ XEQ) programme.

```
--------
TANK NR
1                  RUN
--------

TOT CAP M3 ?
        3518.936   RUN
VOL L M3 ?
        2517.356   RUN
T L DEG C ?
            -1.5   RUN
SF L ?
                   RUN
T V DEG C ?
             0.0   RUN
SF V ?
                   RUN
P REL BAR ?
             1.5   RUN
% INERT V ?
            15.5   RUN

P ABS =2.505
P SAT =1.169
SAT ? Y/N
N                  RUN

VOL V =846.335
SF V =1.0000000
VOL V C =846.335
DEN V =6.829
M V =5780

VOL L =2517.356
SF L =1.0000000
VOL L C =2517.356
DEN L =617.7 TAIT
M L =1554971

M TOT =1560751
```

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F. VCF option

```
                XROM "VCF"
SELECT PRGM
                XROM "LPGL"
REDWOOD

LPG

P ATM BAR ?
          1.013    RUN

DEN L 15 ?
          570.2    RUN
WT ? Y/N
N                  RUN
VOL ? Y/N
N                  RUN

COMPOSITION
-----------

          MOL %
  CO2 ?
                   RUN
METHAN ?
                   RUN
ETHANE ?
                   RUN
PROPAN ?
         55.500    RUN
PROPYL ?
                   RUN
I-BUTA ?
                   RUN
N-BUTA ?
         44.500    RUN
        -------
      Σ 100.000
```

Press □ ← . VCF calculation procedure is selected. No liquid density is calculated, composition is used for calculation of the vapour density.

Density of the liquid phase at 15°C in kg/m^3

see Menu 1

(continued on next page)

```
 --------
(TANK NR  )
(5P       )          RUN
 --------

 TOT CAP M3 ?
        3314.958    RUN
 VOL L M3 ?
           2802.5   RUN
 T L DEG C ?
              3.5   RUN
 SF L ?                        see Menu 3
                    RUN
 T V DEG C ?
              5.0   RUN
 SF V ?
                    RUN
 P REL BAR ?
              2.5   RUN
 % INERT V ?
                    RUN
 VCF ? ---------------------   Volume correction factor derived from
           1.024    RUN        petroleum tables.

 P ABS =3.513

 VOL V =512.458
(SF V =1.0000000 )
 VOL V C =512.458
 DEN V =8.423
 M V =4316
(VOL L =2802.500 )
(SF L =1.0000000 )
 VOL L C =2802.500
(VCF =1.02400 )
 VOL L 15 =2869.760 ------   Volume of the liquid phase at 15°C in m3
(DEN L 15 =570.2 )           rounded up till 1 m3
 M L =1636337

 M TOT =1640653

 MRE TKS? Y/N ------------   Selection of more tanks with the same DEN L 15.
 N                  RUN

 TOTALS
 ------

 Σ M V =4316
 Σ M L =1636337
 Σ M TOT =1640653
```

G. VCF / C4MIX option

```
                XROM "VCF"
SELECT PRGM
              XROM "C4MIX"
SELECT PRGM
              XROM "LPGL"
REDWOOD

C4 MIX

P ATM BAR ?
            1.013    RUN

DEN L 15 ?

            582.3    RUN
WT ? Y/N
N                    RUN
VOL ? Y/N
N                    RUN

COMPOSITION
-----------

              MOL %
ETHANE ?
             .020    RUN
PROPAN ?
            1.000    RUN
PROPYL ?
             .170    RUN
I-BUTA ?
            7.550    RUN
N-BUTA ?
           88.940    RUN
BUTE-1 ?
             .100    RUN
BUTE-2 ?
             .340    RUN
I-BUTY ?
             .200    RUN
BTD-12 ?
             .400    RUN
BTD-13 ?
            1.280    RUN
           -------
         Σ 100.000
```

Press ☐ ←

Press ☐ CHS or vice versa. Both C4MIX components as VCF procedure are selected for calculation into the main LPG L (☐ XEQ) programme.

```
--------
TANK NR
S12                  RUN
--------

TOT CAP M3 ?
         2559.856    RUN
VOL L M3 ?
          502.596    RUN
T L DEG C ?
              3.0    RUN
SF L ?
                     RUN
T V DEG C ?
              3.5    RUN
SF V ?
                     RUN
P REL BAR ?
               .2    RUN
% INERT V ?
                     RUN
VCF ?
            1.023    RUN

P ABS =1.213

VOL V =2057.260
SF V =1.0000000
VOL V C =2057.260
DEN V =3.194
M V =6571

VOL L =502.596
SF L =1.0000000
VOL L C =502.596
VCF =1.02300
VOL L 15 =514.156
DEN L 15 =582.3
M L =299393

M TOT =305964

MRE TKS? Y/N
N                    RUN
```

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3.2. Chemical gases

A. Short version

```
                XROM "ETS"
REDWOOD

ETHYLENE ———————— or PROPYLENE/BUTADIENE-1,3/AMMONIA/VCM

T L DEG C ?
        -103.50    RUN

DEN L =567.5
P SAT =1.030                See Menu 2
DEN V =2.124

       --------

T L DEG C ?
```

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B. Long version

```
                XROM "PRL"
REDWOOD

PROPYLENE ———— or ETHYLENE/BUTADIENE-1,3/AMMONIA/VCM

P ATM BAR ?
          1.013    RUN

--------
TANK NR
                   RUN
--------

TOT CAP M3 ?
         922.158   RUN
VOL L M3 ?
         758.459   RUN
T L DEG C ?
           -44.5   RUN
SF L ?
         .999875   RUN
T V DEG C ?
           -41.0   RUN
SF V ?
         .999158   RUN
P REL BAR ?
              .3   RUN
% INERT V ?
                   RUN

P ABS =1.313
P SAT =1.170                        See Menu 3
SAT ? Y/N
                   RUN

VOL V =163.699
SF V =0.9991580
VOL V C =163.561
DEN V =2.692
M V =440

VOL L =758.459
SF L =0.9998750
VOL L C =758.364
DEN L =605.0
M L =458810

M TOT =459250

MRE TKS? Y/N
N                  RUN

TOTALS
------

Σ M V =440
Σ M L =458810
Σ M TOT =459250
```

3.3. Laboratory interconversions

A. Normal execution

All interconversion programmes have the same input/output configuration. In this example an interconversion from Weight to Volume liquid % (WV) is executed.

```
                XROM "WV"
REDWOOD

* INTERCONVERSION *

COMPOSITION
-----------

              WT %
   CO2 ?
                      RUN
METHAN ?
             .010     RUN
ETHANE ?
            1,730     RUN
PROPAN ?
           61,520     RUN
PROPYL ?
           35,960     RUN
I-BUTA ?
             .580     RUN
N-BUTA ?
             .150     RUN
BUTE-1 ?
                      RUN
I-PENT ?
                      RUN
N-PENT ?
             .050     RUN
           -------
         Σ 100,000


        VOL %
METHAN= 0,017
ETHANE= 2,473
PROPAN=61,724
PROPYL=35,091
I-BUTA= 0,525
N-BUTA= 0,131
N-PENT= 0,040
```

See Menu 1

B. C4MIX option

All interpolation programmes have the same input/output configuration. In this example an interconversion from liquid Volume to Weight % is executed.

```
          XROM "C4MIX"
SELECT PRGM
            XROM "VW"
REDWOOD

* INTERCONVERSION *

COMPOSITION
-----------

          VOL %
ETHANE ?
           .020    RUN
PROPAN ?
         26,320    RUN
PROPYL ?
         10,840    RUN
I-BUTA ?
         23,100    RUN
N-BUTA ?
         10,800    RUN
BUTE-1 ?
          7,830    RUN
BUTE-2 ?
         14,490    RUN
I-BUTY ?
          6,350    RUN
BTD-12 ?
                   RUN
BTD-13 ?
           .200    RUN
N-PENT ?
           .050    RUN
         -------
       Σ 100,000


        WT %
ETHANE= 0,013
PROPAN=23,867
PROPYL=10,106
I-BUTA=23,233
N-BUTA=11,273
BUTE-1= 8,409
BUTE-2=16,010
I-BUTY= 6,809
BTD-13= 0,224
N-PENT= 0,056
```

Press [ ] [CHS] : C4MIX components are selected for calculation into the main programme.

See Menu 1

3.4. Unit conversions

All unit conversions have the same input/output configuration.

```
                5. ———————— 5°C ⟶ ? °F
               XROM "C10"    Type input value
41.00 DEG F                  Press the assigned key (1)
                             The converted value is displayed

               1.5 ———————— 1,5 bar ⟶ ? kg/cm²
               XROM "K11"    kg/cm² is displayed as "AT"
1.530 AT

               2.5 ———————— 2,5 atm ⟶ ? bar
               XROM "C12"
2.533 BAR

            1.021 ———————— 1,021 bar ⟶ ? mm Hg (2)
             XROM "K13"
765.82 MM HG

              1.50 ———————— 1,5 bar ⟶ ? psi
              XROM "K14"
21.756 PSI
```

Remarks :

1) The number of decimal places can be adapted by means of the FIX function after the result value is displayed.
   Press ☐ [FIX] X = with X number of desired decimal places.

2) CAUTION !
   A pressure higher than 13.332 bar (9 999 mm Hg) converted to mm Hg will cause shifting of characters in the display, leaving only IIII,FF mm Hg visible.

   e.g. 13,366 bar ⟶ 10025,35 mm H is displayed momentarily
   ⟶ 0025,35 mm Hg is displayed permanently
   To review the total expression, press [←] or [ALPHA] [ALPHA] .

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3.5. Interpolation

The interpolation programme can be used for one- or two-dimensional interpolations in all kind of tables (not limited to gas application).
The following nomenclature has been used :

	.....	limit X1	input X	limit X2	.....
.....	.....	.....		.....	.....
limit Y1	.....	value V1	result 1,2	value V2	.....
input Y			final result		
limit Y2	.....	value V3	result 3,4	value V4	.....
.....	.....	.....		.....	.....

One-dimensional :

GAUGE CORRECTION IN MILLIMETRES

LEVEL METRES	LIST TO PORT (DEGREES) 4.0	3.0	2.0	1.0	0.0	LIST TO STARBOARD 1.0	2.0	3.0	4.0
.20	198	149	99	50	0	-44	-86	-105	-113
.40	195	146	98	49	0	-47	-95	-142	-185
.60	205	154	102	51	0	-49	-98	-147	-197
.80	209	157	104	52	0	-51	-102	-153	-204
1.00	214	161	107	53	0	-52	-104	-157	-209

XROM "IN" —— Press ☐ ENTER ↑

```
REDWOOD

* INTERPOLATION *

    +   X1     X       X2
+---+---+-------------+-
Y1  +   V1     R1,2    V2
Y               RES
Y2  +   V3     R3,4    V4

DECIMALS ?
                0      RUN

        -------
LIM X1 ?
                3      RUN
LIM X2 ?
                2      RUN
VAL V1 ?
              154      RUN
VAL V2 ?
              102      RUN
X ?
              2,9      RUN
RES 1,2 =149

VAL V3 ?
```

If a printer is used a summary of the nomenclature is printed.

Number of decimals of the output value is selected.

"NOT VALID" will be displayed when : $X_2 < X < X_1$

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Two-dimensional :

GAUGE CORRECTION IN MILLIMETRES

LEVEL METRES	LIST TO PORT (DEGREES) 4.0	3.0	2.0	1.0	0.0	LIST TO STARBOARD 1.0	2.0	3.0	4.0
.20	198	149	99	50	0	-44	-86	-105	-113
.40	195	146	98	49	0	-47	-95	-142	-185
.60	205	154	102	51	0	-49	-98	-147	-197
.80	209	157	104	52	0	-51	-102	-153	-204
1.00	214	161	107	53	0	-52	-104	-157	-209

XROM "IN" —— Press ☐ ENTER ↑

REDWOOD

* INTERPOLATION *

```
    +  X1     X        X2
+---+---+-------------+-
Y1  +  V1.    R1,2     V2
Y              RES
Y2  +  V3.    R3,4     V4
```

If a printer is used, a summary of the nomenclature is printed.

```
DECIMALS ?
                0   RUN

       -------
LIM X1 ?
                3   RUN
LIM X2 ?
                2   RUN
VAL V1 ?
              154   RUN
VAL V2 ?
              102   RUN
X ?
              2.9   RUN
RES 1,2 =149

VAL V3 ?
              157   RUN
VAL V4 ?
              104   RUN
RES 3,4 =152
```

"NOT VALID" will be displayed when : $X_2 < X < X_1$ or $Y_2 < Y < Y_1$

```
LIM Y1 ?
               .6   RUN
LIM Y2 ?
               .8   RUN
Y ?
              .77   RUN
RES =151
```

4. EXTENSIONS OF THE "GAS CALCUL" MODULE

4.1. Gas properties storage registers

Some important scientific information can be obtained by means of recalling specific storage registers after running a gas calculation programme.
Select your desired figures after the decimal point first by means of the [FIX] function.
Then recall the required figure data by pressing [RCL] , followed by the register number specified below.

A. LPG (C4MIX)

ω_m	= acentric factor (1) (2)	register 00
V^*_m	= characteristic volume (1) (2)	register 08
V_{sm}	= saturated volume (1)	register 44
T^*_{cm}	= critical temperature in °K (1)	register 06
T_{cm}	= critical temperature in °K (2)	register 43
P^*_{cm}	= critical pressure (1)	register 38
P_{cm}	= critical pressure (2)	register 17
P^*_{red}	= reduced pressure (1)	register 35
P_{red}	= reduced pressure	register 19
MG_m	= molecular weight (2)	register 01
Z	= compressibility factor (3)	register 33

m = mean
(1) = Costald reference
(2) = arithmetic mean

B. Chemical gases

Z	= compressibility factor (3) (can only be obtained from actual conditions)	register 33

(3) Z reference : table 5.1. DEN V

4.2. Additional programmes

The GAS CALCUL module was designed with a few specific spaces allowing the user to add personal application programmes (only applicable on a 41 CV).

In conjunction with a HP-IL cassette drive a portable mass storage system is at your disposal with capabilities comparable with real micro-computer systems. In the scope of this manual it is impossible to give a summary and description of all extension possibilities. Nevertheless, we are pleased to draw your attention to some important features.

A. Calibration tables (without cassette drive)

1) Actual volume "VOL L" is calculated directly from the relevant programmed calibration tables.

2) Stop level calculations with high or low alarms.

B. LPG mixing programme (without cassette drive)

This programme is to be used jointly with calibration tables and is designed to calculate the stop level of shoretanks in which LPG's are blended in order to obtain the desired composition.

If you should need more information about your own application (with or without cassette drive), please do not hesitate to contact us.

C. Physical stock calculation

1) Results obtained from the module are used to calculate the physical stock, independently of the book stock, and the difference between the two.

2) Physical stock and book stock (or additional information) can be recalled from the cassette, day by day over a one-year period.

3) A protection code is incorporated, ensuring that unauthorised persons cannot adapt the stock figures.

D. Mass storage

Mass storage in the field, to be used later on for reporting in the office.

Each intermediate result of the GAS CALCUL module programme is stored on micro-cassette for further assimilation and can be retrieved any time to carry out reporting on other micro-computer systems. 20 data values of 100 vessels (with 6 tanks) can be stored on the micro-cassette.

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E. Examples

Calibration tables / LPG mixing

```
                    XEQ "PRL"
REDWOOD

PROPYLENE

AGT Y/N ?
                          RUN
P ATM BAR ?
                1.013     RUN

* TANK ? *
                    4     RUN

LEVEL MM ?
                 4589     RUN
VOL L =513.542


T L DEG C ?
                    1     RUN
SF L ?
                          RUN
T V DEG C ?
                  1.5     RUN
SF V ?
                          RUN
P REL BAR ?
                    5     RUN
% INERT V ?
                          RUN

P ABS =6.013
P SAT =6.033
SAT ? Y/N
                          RUN

VOL V =2803.314
SF V =1.0000000
VOL V C =2803.314
DEN V =12.719
M V =35655

VOL L =513.542
SF L =1.0000000
VOL L C =513.542
DEN L =543.2
M L =278956

M TOT =314611
```

```
                    XEQ "LV"
AGT

* TANK ? *
                    3     RUN

LEVEL MM ?
                 2453     RUN
VOL L =160.241

+/- VOL ?
               -50.000    RUN
STOP LEVEL =2017
```

```
                    XEQ "VL"
AGT

* TANK ? *
                    3     RUN

VOL ?
              160.241     RUN
STOP LEVEL =2453
```

```
                    XEQ "MIX"
AGT

* MIXING *

* TK OUT ?
                    1     RUN
LEVEL OUT ?
              11025       RUN
%C3 OUT ?
                41.25     RUN

* TK IN ?
                    3     RUN
LEVEL IN ?
               9014       RUN
%C3 IN ?
               50.95      RUN

* %C3 END ?
                   48     RUN

STOP OUT =8404
STOP IN =11666
```

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Physical stock calculation

```
            XEQ "RESET"
PRINTER IN MAN
CODE ?
PRINTER IN NORM

TANK ?
               4    RUN
DATE ?
           01.11    RUN
FYS STOCK ?
          415680    RUN
BOOKSTOCK ?
          415680    RUN
```

```
            XEQ "PRL"
REDWOOD

PROPYLENE

AGT Y/N ?
                    RUN
P ATM BAR ?
           1.013    RUN

* TANK ? *
               4    RUN

LEVEL MM ?
            4589    RUN
VOL L =513.542


T L DEG C ?
               1    RUN
SF L ?
                    RUN
T V DEG C ?
             1.5    RUN
SF V ?
                    RUN
P REL BAR ?
               5    RUN
% INERT V ?
                    RUN

P ABS =6.013
P SAT =6.033
SAT ? Y/N
                    RUN
```

```
VOL V =2803.314
SF V =1.0000000
VOL V C =2803.314
DEN V =12.719
M V =35655

VOL L =513.542
SF L =1.0000000
VOL L C =513.542
DEN L =543.2
M L =278956

M TOT =314611

STOCK
-----

DATE ?
              04.11    RUN
HOUR ?
              18.00    RUN

* FYS STOCK *
BEFORE =415680
AFTER =314611
DIF =-101069

*BOOK STOCK*
BEFORE =415680
+/- ?
             -19586    RUN
             -20147    RUN
             -21369    RUN
             -20785    RUN
             -20970    RUN
                  0    RUN
            Σ -102857
AFTER =312823

*DIFFERENCE*
DIF KG =-1788
DIF % =-0.57

STORE ? Y/N
                    RUN
```

```
            XEQ "PRINT"
* TANK ? *
               4    RUN

DATE ?
           01.11    RUN

1.11    0.00 H
FYS STOCK =415680
BOOKSTOCK =415680

DATE ?
           04.11    RUN

4.11    18.00 H
FYS STOCK =314611
BOOKSTOCK =312823

DATE ?
           06.11    RUN

4.11    18.00 H
FYS STOCK =314611
BOOKSTOCK =312823

DATE ?
```

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Mass storage

```
                XEQ "PRL"
REDWOOD

PROPYLENE

VESSEL ?
DESTGAS  2              RUN
INSTALLATION ?
DEST ANTWERP            RUN
DATE ?
 01.11.1983             RUN
SURVEYOR ?
PEETERS P.              RUN

P ATM BAR ?
            1.013       RUN

--------
TANK NR
1                       RUN
--------
ULL OR DIP ?U/D
D                       RUN
DIPP IN MM ?
              3489      RUN
TRIM CORRECTION ?
             -10        RUN
FLOAT CORRECTION ?
               0        RUN
TAPE CORRECTION ?
               0        RUN

TOT CAP M3 ?
            850.25      RUN
VOL L M3 ?
           700.289      RUN
T L DEG C ?
               2        RUN
SF L ?
                        RUN
T V DEG C ?
               4        RUN
SF V ?
                        RUN
P REL BAR ?
             6.5        RUN
% INERT V ?
                        RUN
```

```
P ABS =7.513
P SAT =6.213
SAT ? Y/N
                        RUN

VOL V =149.961
SF V =1.0000000
VOL V C =149.961
DEN V =13.090
M V =1963

VOL L =700.289
SF L =1.0000000
VOL L C =700.289
DEN L =541.7
M L =379347

M TOT =381310

MRE TKS? Y/N
N                       RUN

TOTALS
------

Σ M V =1963
Σ M L =379347
Σ M TOT =381310


SHIP KG =381310
SHORE KG ?
              382690    RUN
DIF KG =-1380
DIF % =-0.36
```

5. TABLES

5.1. Summary of references

Gas calculation

	DEN L	P SAT	DEN V (*)		Critical
			SAT	ACT	value & MW
LPG (C4 MIX)	(1)	(1)	(2)	(2)	(9)
(VCF)	-	-	-	(2)	(9)
(TAIT)	(1)	(1)	(2)	(2)	(9)
Ethylene	(3)	(3)	(3)	(2)	(3)
Propylene	(4)	(4)	(4)	(2)	(4)
Butadiene 1-3	(1)	(1)	(2)	(2)	(9)
Ammonia	(5)	(5)	(5)	(6)	(5)
VCM	(7)	(8)	(6)	(6)	(7)

(1) a. Costald / COrresponding STAte Liquid Density / R.W. Hankinson, G.H. Thomson / Hydrocarbon processing / 09.1979

b. An improved correlation for densities of compressed liquids and liquid mixtures / R.W. Hankinson, G.H. Thomson, K.R. Brobst / AIChE Journal Vol. 28, N°4) / 07.1982

(2) API Technical Data Book / 6.B1.1 / 1966 (1976)

(3) International Thermodynamic Table of the Fluid State, Ethylene (UIPAC) / S. Angus, B. Armstrong, K.M. de Reuck, W. Featherstone, M.R. Gibson / Butterworths London / 1972

(4) International Thermodynamic Tables of the Fluid State, Propylene (UIPAC) / S. Angus, B. Armstrong, K.M. de Reuck / Pergamon Press / 1980

(5) VDI-Forsch Heft 596 / J. Ahrendts, H. D. Baehr

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(6) Redlich Kwong equation of state (cubic form) / Applied Hydrocarbon Thermodynamics / Wagne C. Edmister / Volume II

(7) Adapted Goodrich formula

(8) Thermodynamic properties of vinyl cloride / British Chemical Engineering / Vol. 3-1958

(9) Engineering Data Book / Gas Processors Suppliers Association (G.P.A.) / Section 16 / 1970 with exemption of P_C for L.P.G. (C4 MIX, VCF, TAIT) where its value has been calculated by means of reference 1b.

(*) DEN V SAT = real gaslaw with saturated conditions (P SAT, T L DEG C)
DEN V ACT = real gaslaw with actual conditions (P ABS, T V DEG C)

Laboratory interconversions

ASTM D 2421-74 (79) extended with following values for carbon-dioxide and hexane.

	Molecular weight	Relative density 60/60°F vac	Liquid volume in millilitre of 1 ml of ideal gas at 60°F and 760 mm Hg
CO_2	44.010	0.827	0.002249
Hexane	86.178	0.6640	0.005483

Unit conversions

ASTM D 380-79

5.2. Saturated liquid densities at boiling point and at 15°C of the pure components of LPG and C4 MIX

Component	Boiling point °C (1)	Density at boiling point kg/m^3	Density at 15°C kg/m^3
carbon dioxyde	- 78.51 (2)	1 246.9	827.5
methane	- 161.52	423.3	(4)
ethane	- 88.58	545.2	359.4
propane	- 42.07	581.3	507.6
propylene	- 47.72	608.9	523.0
i-butane	- 11.81	594.0	562.9
n-butane	- 0.49	601.7	584.5
butene-1	- 6.23	622.8	598.1
butene-2 (3)	+ 2.30	634.9	620.4
i-butylene	- 6.91	625.1	599.3
butadiene-1,2	+ 10.85	655.9	651.1
butadiene-1,3	- 4.41	650.3	627.2
i-pentane	27.84	613.2	626.6
n-pentane	36.06	609.3	630.7
n-hexane	68.74	614.3	665.9

(1) Table 1, ref (9).

(2) Sublimation point.

(3) Based upon equimolar mixture of cis- and trans-butene-2.

(4) Temperature out of range.

5.3. Saturated liquid densities at boiling point and at 15°C of chemical gases.

Component	Boiling point °c (1)	Density at boiling point kg/m^3	Density at 15°C kg/m^3
Ethylene	- 103.77	567.9	(2)
Propylene	- 47.72	609.0	521.3
Butadiene-1,3	- 4.41	650.3	627.2
Ammonia	- 33.43	681.9	617.5
Vinyl Chloride	- 13.72	971.8	919.6

(1) Table 1 ref (9)

(2) Temperature out of range.

5.4. Table of ethylene

-T	L--P	SAT-DEN	V--DEN	L
-105,0	0,94	1,954	569,7	
-104,5	0,97	2,009	569,0	
-104,0	1,00	2,066	568,2	
-103,5	1,03	2,124	567,5	
-103,0	1,06	2,183	566,8	
-102,5	1,09	2,244	566,1	
-102,0	1,12	2,306	565,4	
-101,5	1,16	2,369	564,7	
-101,0	1,19	2,434	564,0	
-100,5	1,22	2,500	563,2	
-100,0	1,26	2,567	562,5	
-99,5	1,29	2,636	561,8	
-99,0	1,33	2,706	561,1	
-98,5	1,37	2,778	560,4	
-98,0	1,41	2,851	559,6	
-97,5	1,45	2,925	558,9	
-97,0	1,48	3,001	558,2	
-96,5	1,53	3,078	557,5	
-96,0	1,57	3,157	556,7	
-95,5	1,61	3,238	556,0	
-95,0	1,65	3,320	555,3	
-94,5	1,70	3,404	554,5	
-94,0	1,74	3,489	553,8	
-93,5	1,79	3,576	553,1	
-93,0	1,83	3,664	552,4	
-92,5	1,88	3,754	551,6	
-92,0	1,93	3,846	550,9	
-91,5	1,98	3,939	550,1	
-91,0	2,03	4,035	549,4	
-90,5	2,08	4,131	548,7	
-90,0	2,13	4,230	547,9	
-89,5	2,19	4,330	547,2	
-89,0	2,24	4,432	546,4	
-88,5	2,30	4,536	545,7	
-88,0	2,35	4,642	545,0	
-87,5	2,41	4,749	544,2	
-87,0	2,47	4,859	543,5	
-86,5	2,53	4,970	542,7	
-86,0	2,59	5,083	542,0	
-85,5	2,65	5,198	541,2	
-85,0	2,71	5,314	540,5	
-84,5	2,78	5,433	539,7	
-84,0	2,84	5,554	539,0	
-83,5	2,91	5,676	538,2	
-83,0	2,98	5,801	537,4	
-82,5	3,05	5,928	536,7	
-82,0	3,11	6,056	535,9	
-81,5	3,19	6 187	535,2	
-81,0	3,26	6,319	534,4	
-80,5	3,33	6,454	533,6	

5.5. Table of propylene

T	L--P SAT	--DEN V	--DEN L
-50	0,91	2,136	611,9
-49	0,96	2,230	610,6
-48	1,00	2,327	609,4
-47	1,05	2,427	608,2
-46	1,09	2,530	606,9
-45	1,14	2,637	605,7
-44	1,20	2,748	604,4
-43	1,25	2,862	603,1
-42	1,30	2,979	601,9
-41	1,36	3,100	600,6
-40	1,42	3,225	599,4
-39	1,48	3,354	598,1
-38	1,54	3,487	596,8
-37	1,61	3,623	595,5
-36	1,68	3,764	594,2
-35	1,75	3,909	593,0
-34	1,82	4,058	591,7
-33	1,89	4,212	590,4
-32	1,97	4,370	589,1
-31	2,04	4,532	587,8
-30	2,12	4,699	586,5
-29	2,21	4,871	585,1
-28	2,29	5,047	583,8
-27	2,38	5,229	582,5
-26	2,47	5,415	581,2
-25	2,56	5,606	579,8
-24	2,66	5,803	578,5
-23	2,76	6,005	577,2
-22	2,86	6,212	575,8
-21	2,96	6,425	574,5
-20	3,07	6,643	573,1
-19	3,18	6,867	571,7
-18	3,29	7,097	570,4
-17	3,40	7,332	569,0
-16	3,52	7,574	567,6
-15	3,64	7,821	566,2
-14	3,77	8,075	564,8
-13	3,89	8,336	563,4
-12	4,02	8,602	562,0
-11	4,16	8,876	560,6
-10	4,29	9,156	559,2
-9	4,43	9,443	557,8
-8	4,58	9,737	556,4
-7	4,73	10,038	554,9
-6	4,88	10,346	553,5
-5	5,03	10,662	552,0
-4	5,19	10,985	550,6
-3	5,35	11,316	549,1
-2	5,51	11,654	547,6
-1	5,68	12,001	546,2
0	5,86	12,356	544,7
1	6,03	12,719	543,2
2	6,21	13,090	541,7
3	6,40	13,471	540,2
4	6,59	13,859	538,6
5	6,78	14,257	537,1
6	6,97	14,664	535,6
7	7,18	15,081	534,0
8	7,38	15,507	532,5
9	7,59	15,942	530,9
10	7,80	16,388	529,3
11	8,02	16,844	527,8
12	8,24	17,310	526,2
13	8,47	17,786	524,6
14	8,70	18,274	523,0
15	8,94	18,772	521,3
16	9,18	19,282	519,7
17	9,42	19,803	518,1
18	9,68	20,336	516,4
19	9,93	20,881	514,7
20	10,19	21,438	513,1
21	10,46	22,008	511,4
22	10,73	22,591	509,7
23	11,00	23,187	508,0
24	11,28	23,797	506,2
25	11,57	24,421	504,5
26	11,86	25,058	502,7
27	12,15	25,710	501,0
28	12,45	26,378	499,2
29	12,76	27,060	497,4
30	13,07	27,758	495,6
31	13,39	28,473	493,8
32	13,72	29,203	491,9
33	14,04	29,951	490,1
34	14,38	30,716	488,2
35	14,72	31,500	486,3
36	15,07	32,301	484,4
37	15,42	33,122	482,5
38	15,78	33,962	480,6
39	16,14	34,822	478,6
40	16,52	35,703	476,7

5.6. Table of butadiene-1,3

T	L--P SAT	--DEN V	--DEN L
-30	0,32	0,878	679,0
-29	0,34	0,919	677,9
-28	0,36	0,963	676,8
-27	0,37	1,007	675,7
-26	0,39	1,053	674,6
-25	0,41	1,101	673,5
-24	0,43	1,151	672,4
-23	0,45	1,203	671,3
-22	0,47	1,256	670,2
-21	0,50	1,311	669,1
-20	0,52	1,368	668,0
-19	0,54	1,427	666,8
-18	0,57	1,487	665,7
-17	0,59	1,550	664,6
-16	0,62	1,615	663,5
-15	0,65	1,682	662,4
-14	0,68	1,751	661,2
-13	0,71	1,823	660,1
-12	0,74	1,897	659,0
-11	0,77	1,972	657,8
-10	0,80	2,051	656,7
-9	0,84	2,131	655,5
-8	0,87	2,215	654,4
-7	0,91	2,300	653,3
-6	0,95	2,388	652,1
-5	0,99	2,479	651,0
-4	1,03	2,573	649,8
-3	1,07	2,669	648,6
-2	1,11	2,768	647,5
-1	1,15	2,869	646,3
0	1,20	2,974	645,1
1	1,24	3,081	644,0
2	1,29	3,192	642,8
3	1,34	3,305	641,6
4	1,39	3,422	640,4
5	1,44	3,541	639,3
6	1,50	3,664	638,1
7	1,55	3,790	636,9
8	1,61	3,920	635,7
9	1,67	4,052	634,5
10	1,73	4,189	633,3
11	1,79	4,328	632,1
12	1,85	4,471	630,9
13	1,92	4,618	629,7
14	1,98	4,769	628,5
15	2,05	4,923	627,2
16	2,12	5,081	626,0
17	2,19	5,242	624,8
18	2,27	5,408	623,6
19	2,34	5,577	622,3
20	2,42	5,751	621,1
21	2,50	5,929	619,8
22	2,58	6,110	618,6
23	2,67	6,296	617,3
24	2,75	6,486	616,1
25	2,84	6,681	614,8
26	2,93	6,880	613,6
27	3,02	7,083	612,3
28	3,12	7,291	611,0
29	3,21	7,504	609,8
30	3,31	7,721	608,5
31	3,41	7,943	607,2
32	3,51	8,170	605,9
33	3,62	8,401	604,6
34	3,73	8,638	603,3
35	3,84	8,879	602,0
36	3,95	9,126	600,7
37	4,06	9,378	599,4
38	4,18	9,635	598,0
39	4,30	9,897	596,7
40	4,42	10,165	595,4

5.7. Table of ammonia

T	L--P SAT	--DEN V	--DEN L
-40	0,72	0,645	690,8
-39	0,76	0,678	688,8
-38	0,80	0,712	687,5
-37	0,84	0,748	686,3
-36	0,88	0,785	685,1
-35	0,93	0,823	683,9
-34	0,98	0,863	682,6
-33	1,03	0,905	681,4
-32	1,08	0,948	680,1
-31	1,14	0,992	678,9
-30	1,19	1,039	677,7
-29	1,25	1,087	676,4
-28	1,32	1,137	675,2
-27	1,38	1,188	673,9
-26	1,45	1,242	672,6
-25	1,52	1,297	671,4
-24	1,59	1,354	670,1
-23	1,66	1,414	668,8
-22	1,74	1,475	667,6
-21	1,82	1,539	666,3
-20	1,90	1,604	665,0
-19	1,99	1,672	663,7
-18	2,08	1,742	662,4
-17	2,17	1,814	661,1
-16	2,26	1,889	659,8
-15	2,36	1,966	658,5
-14	2,46	2,046	657,2
-13	2,57	2,128	655,9
-12	2,68	2,213	654,6
-11	2,79	2,300	653,3
-10	2,91	2,391	652,0
-9	3,03	2,483	650,7
-8	3,15	2,579	649,3
-7	3,28	2,678	648,0
-6	3,41	2,779	646,7
-5	3,55	2,884	645,3
-4	3,69	2,992	644,0
-3	3,83	3,102	642,6
-2	3,98	3,217	641,3
-1	4,14	3,334	639,9
0	4,29	3,455	638,6
1	4,46	3,579	637,2
2	4,62	3,706	635,8
3	4,80	3,838	634,5
4	4,97	3,973	633,1
5	5,16	4,111	631,7
6	5,35	4,254	630,3
7	5,54	4,400	628,9
8	5,74	4,550	627,5
9	5,94	4,704	626,1
10	6,15	4,863	624,7
11	6,37	5,025	623,3
12	6,59	5,192	621,8
13	6,81	5,364	620,4
14	7,05	5,539	619,0
15	7,28	5,720	617,5
16	7,53	5,905	616,1
17	7,78	6,094	614,6
18	8,04	6,289	613,2
19	8,30	6,488	611,7
20	8,57	6,693	610,3
21	8,85	6,903	608,8
22	9,13	7,118	607,3
23	9,43	7,338	605,8
24	9,72	7,563	604,3
25	10,03	7,795	602,8

5.8. Table of vinyl chloride

T	L--P	SAT--DEN	V--DEN	L
-25	0,63	1,954	992,3
-24	0,66	2,036	990,5
-23	0,69	2,120	988,7
-22	0,72	2,207	986,9
-21	0,75	2,297	985,1
-20	0,79	2,390	983,2
-19	0,82	2,486	981,4
-18	0,86	2,585	979,6
-17	0,89	2,687	977,8
-16	0,93	2,792	976,0
-15	0,97	2,901	974,1
-14	1,01	3,013	972,3
-13	1,05	3,128	970,5
-12	1,10	3,247	968,7
-11	1,14	3,369	966,9
-10	1,19	3,494	965,1
-9	1,23	3,624	963,2
-8	1,28	3,757	961,4
-7	1,33	3,894	959,6
-6	1,38	4,035	957,8
-5	1,44	4,180	956,0
-4	1,49	4,329	954,1
-3	1,55	4,482	952,3
-2	1,61	4,639	950,5
-1	1,67	4,801	948,7
0	1,73	4,967	946,9
1	1,79	5,137	945,0
2	1,86	5,312	943,2
3	1,93	5,492	941,4
4	2,00	5,677	939,6
5	2,07	5,866	937,8
6	2,14	6,060	935,9
7	2,22	6,259	934,1
8	2,30	6,464	932,3
9	2,37	6,673	930,5
10	2,46	6,888	928,7
11	2,54	7,108	926,8
12	2,63	7,334	925,0
13	2,71	7,565	923,2
14	2,80	7,802	921,4
15	2,90	8,044	919,6
16	2,99	8,293	917,8
17	3,09	8,547	915,9
18	3,19	8,808	914,1
19	3,29	9,074	912,3
20	3,40	9,347	910,5
21	3,51	9,627	908,7
22	3,62	9,912	906,8
23	3,73	10,205	905,0
24	3,84	10,504	903,2
25	3,96	10,810	901,4
26	4,08	11,123	899,6
27	4,21	11,443	897,7
28	4,33	11,770	895,9
29	4,46	12,105	894,1
30	4,59	12,446	892,3
31	4,73	12,796	890,5
32	4,87	13,153	888,6
33	5,01	13,518	886,8
34	5,15	13,891	885,0
35	5,30	14,271	883,2
36	5,45	14,660	881,4
37	5,60	15,058	879,6
38	5,76	15,464	877,7
39	5,92	15,878	875,9
40	6,08	16,301	874,1

5.9. Input of a component not encountered in a LPG composition

This table gives for isobutylene, butadiene-1,3 and butene-2 (components not encountered in the LPG composition) the maximum molar concentration input of a replacable LPG module component, ensuring the DEN L obtained by replacement will not differ more than $\pm$ 0,1 kg/m^3 from the exactly calculated DEN L.

non LPG component	input as	max. concentration, mol %
1) isobutylene	butene-1	10,0
2) butadiene-1,3	n-butane	0,2
3) butene-2 (50% cis-, 50% trans-)	n-butane	0,4

The maxium concentration input has been verified for a typical LPG and commercial propane mixture at 0° and 15°C.

5.10. Input of a component not encountered in a C4 MIX composition.

This table gives for components normally not encountered in the C4 MIX composition the maximum molar concentration input of a replacable C4 MIX module component, ensuring the DEN L obtained by replacement will not differ more than $\pm$ 0,1 kg/m^3 from the exactly calculated DEN L.

non C4 MIX component	Input as	max. concentration, mol %
butene-2 (100% cis-)	butene-2 (50% cis-, 50% trans-)	1,0
butene-2 (100% trans-)	butene-2 (50% cis-, 50% trans-)	1,0
propadiene	propylene	0,2
methylacetylene	butene-2 (50% cis-, 50% trans-)	1,0
ethylacetylene	isobutylene	0,8

The maximum concentration has been verified for a typical Rich C4 and raffinate mixture at 0° and 15°C.

5.11. Temperature out of range conditions

LPG (C4 MIX)	0,25	<	T_r	<	0,95	(1)
Ethylene	- 128,0	≤	t	≤	9,5	(2)
Propylene	- 183,0	≤	t	≤	92,0	(2)
Butadiene-1,3	0,25	<	T_r	<	0,95	(2)
Ammonia	- 50,0	≤	t	≤	84,5	(2)
VCM	- 28,0	≤	t	≤	59,5	(2)

Remarks :

(1) : $T_r = T/T_c$
with T, T_c, T in °K

(2) : t in °C

5.12. Labels of module subroutines

WARNING !
DO NOT USE THE FOLLOWING "STRING OF ALPHA CHARACTERS"
FOR YOUR OWN PROGRAMME NAMES OR SUBROUTINES

A : AM
AML
AMS

B : BU
BUL
BUS

C : CO
COMP
C4MIX
C10
C11
C12
C13
C14

D : DEST
DLV1
DLV2
DMGW1
DMGW2
DP1
DP2
DSG1
DSG2
DTV1
DTV2

E : ET
ETL
ETS

I : IN

K : K
KBU
K10
K11
K12
K13
K14

L : LG
LPG
LPGL
LPGS

M : MT
MV
MW

N : NAME1
NAME2

O : OORT

P : PR
PRL
PRS

R : RESC
RK

S : SH

T : TA
TAIT

V : VAP
VC
VCF
VCL
VCS
VM
VMX
VW

W : W
WM
WMX
WV

X : X

Z : Z