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# **MEMO**

## **Version 2.0 Manual**

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**KERNFORSCHUNGSZENTRUM KARLSRUHE**

**Institut für Angewandte Informatik**

**KfK 5077**

**MEMO VERSION 2.0 MANUAL**

**U. Bicking, W. Golly, R. Seifert**

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## ABSTRACT

This report includes a comprehensive manual of the PC program MEMO Version 2.0 which illustrates the handling and functioning of MEMO. In an Appendix the more theoretical background is described. The MEMO program package is a tool to calculate the sequence of material balance results (MUF values) from single measurements and the related measurement model (variance/covariance matrix COVA) from the single measurement values, the measurement uncertainties and the related propagation of variances. MUF values and related variance/covariance matrix COVA are essential input parameters for materials balance evaluation programs like PROSA. MEMO Version 2.0 is a menu-guided computer program and, therefore, very user-friendly and applicable in real field use. MEMO Version 2.0 is applicable whenever the amount of material in an inventory component or in a transfer batch is the result of a single measurement or the product of two measurements. The propagation of variances can be performed through the systematic error component as well as through the random error component. MEMO Version 2.0 has the capability to determine MUF and COVA sequentially. This provides a very fast determination in real field use. MEMO Version 2.0 is written in FORTRAN 77 and the program modules are compiled and linked with the Ryan Mc-Farland Compiler. The MEMO Menu Guide uses the 'Ask Utility' of NORTON Utilities.

## MEMO VERSION 2.0 HANDBUCH

### ZUSAMMENFASSUNG

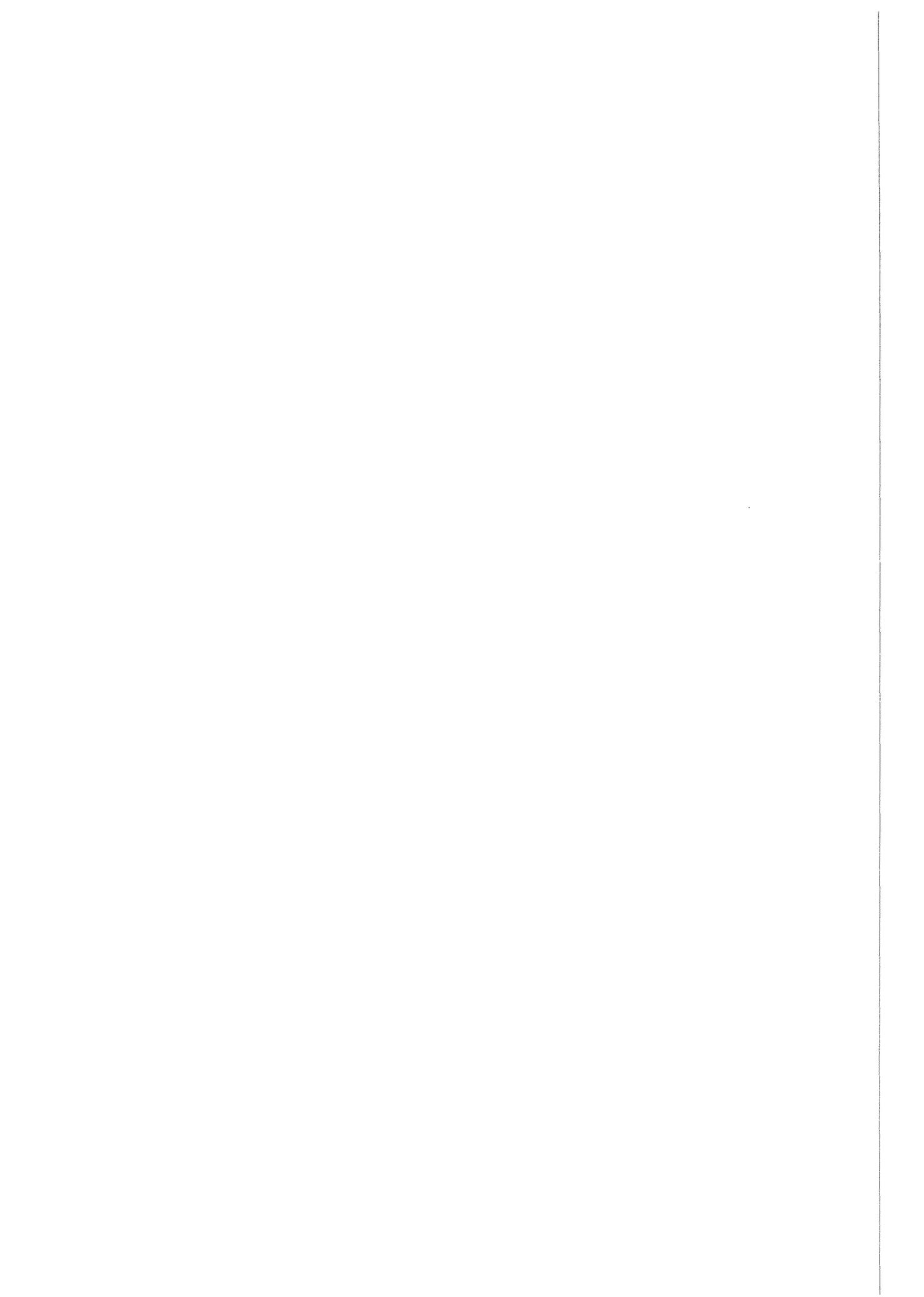
Dieser Bericht beinhaltet ein umfangreiches Handbuch des PC-Programms MEMO Version 2.0, das die Handhabung und die Funktionsweise von MEMO erläutert. In einem Anhang wird der mehr theoretische Hintergrund beleuchtet. Das MEMO-Programm-Paket ist ein Werkzeug, um eine Folge von Materialbilanzergebnissen (MUF Werte), ausgehend von Einzelmessungen, und das zugehörige statistische Meßmodell (Varianz/Kovarianzmatrix COVA), ausgehend von den Einzelmessungen, den einzelnen Meßungenauigkeiten sowie den entsprechenden Fehlerfortpflanzungen, zu bestimmen. MUF Werte und die zugehörige Varianz/Kovarianzmatrix COVA sind wesentliche Eingabegrößen für Auswerteprogramme wie PROSA. MEMO Version 2.0 ist menü-geführt und deshalb sehr bedienerfreundlich und im Routinebetrieb einsetzbar. MEMO Version 2.0 ist immer dann anwendbar, wenn der Materialgehalt einer Inventarkomponente oder eines Transferbatches das Resultat einer Einzelmessung oder das Produkt zweier Messungen ist. Die Fehlerfortpflanzung kann sowohl über den systematischen wie über den zufälligen Fehler erfolgen. MEMO Version 2.0 ist in der Lage, MUF und COVA sequentiell zu bestimmen. Dies ermöglicht eine sehr schnelle Bestimmung im Routinebetrieb vor Ort. MEMO Version 2.0 ist in FORTRAN 77 geschrieben. Die Programmmodule sind mit dem Ryan Mc-Farland Compiler übersetzt und gebunden.

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**Chapter 1:**

**Introduction**

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## 1. Introduction

### 1.1 MEMO Summary

The manual MEMO describes the PC Program Moduls Version of MEMO Version 2.0. In an Appendix the more theoretical background is described.

The MEMO program package is a tool to calculate the sequence of material balance results (MUF values) from single measurements and the related measurement model (variance/covariance matrix COVA) from the single measurement values, the measurement uncertainties and the related propagation of variances.

MUF values and related variance/covariance matrix COVA are essential input parameters for materials balance evaluation programs like PROSA.

MEMO Version 2.0 is a menu-guided computer program and, therefor, very user-friendly and applicable in real field use.

MEMO Version 2.0 is applicable up to 50 balance periodes in a campaign and up to 100 components (inventory components and transfer batches) per period.

MEMO Version 2.0 is applicable whenever the amount of material in an inventory component or in a transfer batch is the result of a single measurement or the product of two measurements. By no means a steady-state operation of the facility is necessary.

The error components of the various measurements can be split into so-called systematic and random components. Furthermore, all these components can be split into multiplicative and additive components.

The propagation of variances can be performed through the systematic error component as well as through the random error component.

#### 4 Chapter 1: Introduction

MEMO Version 2.0 has the capability to determine MUF and COVA sequentially. That means that the results of a balance period - MUF values as well as related covariances - can be recalculated very fast whenever there was a change. Furthermore, if a new balance period is added, only the results related to this new period have to be calculated and added to the existing MUF and COVA data set. This provides a very fast determination in real field use.

##### 1.2 Generalities

MEMO Version 2.0 is written in FORTRAN 77 and the program moduls are compiled and linked with the Ryan Mc-Farland Compiler. The MEMO Menu Guide uses the 'Ask Utility' of NORTON Utilities.

##### 1.3 System Support

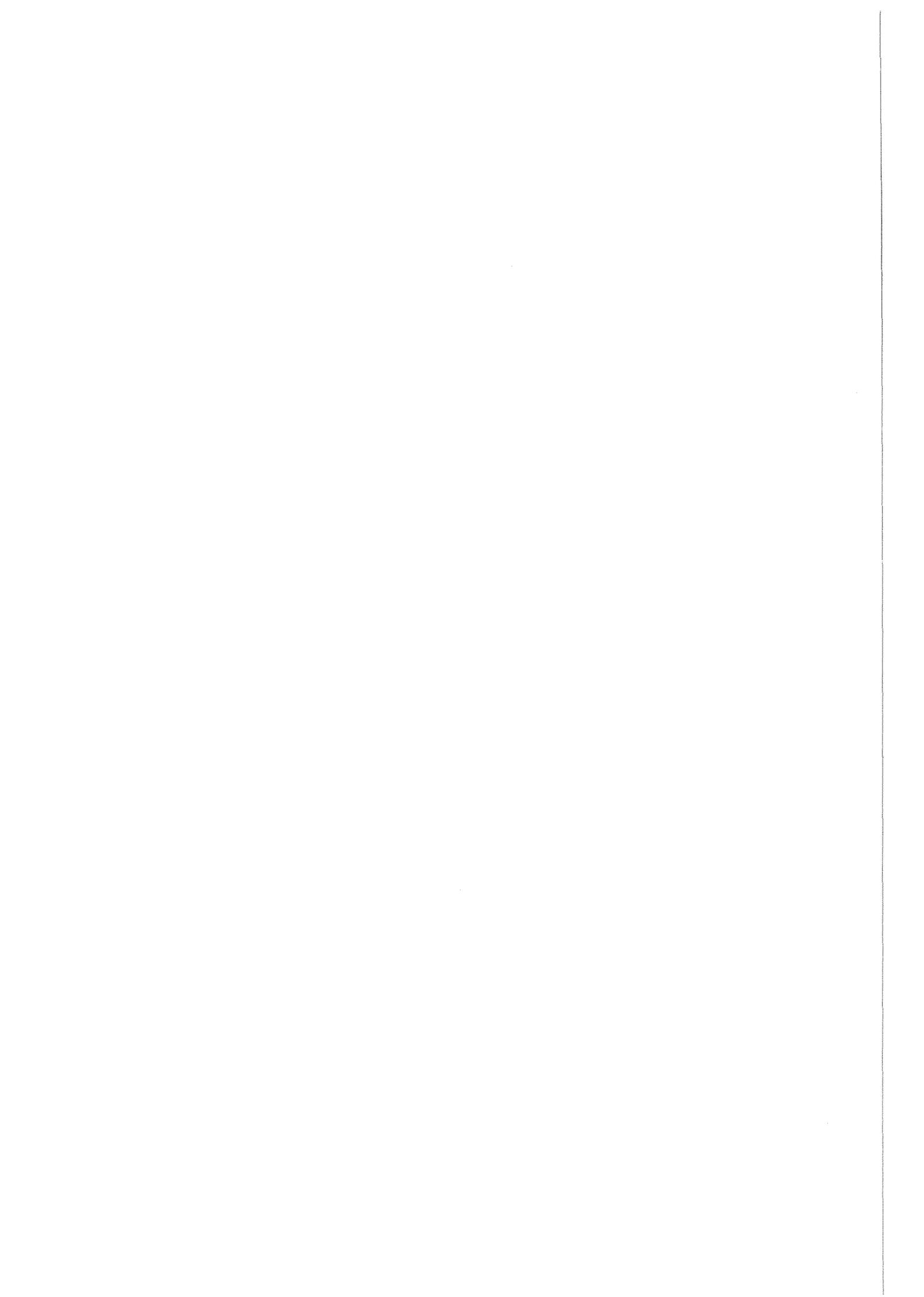
The MEMO numerical program moduls need a minimum of hardware system configuration:

- a computer system (AT-compatible) with at least 256 kByte memory, including a mathematical coprocessor
- a Hard Disk drive
- a Floppy Disk drive (at least 360 kByte)
- an output device
- a PC-DOS Version 3.0 or higher

**Chapter 2:**

How to Install and to Start MEMO

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2. How to Install and to Start the Program MEMO

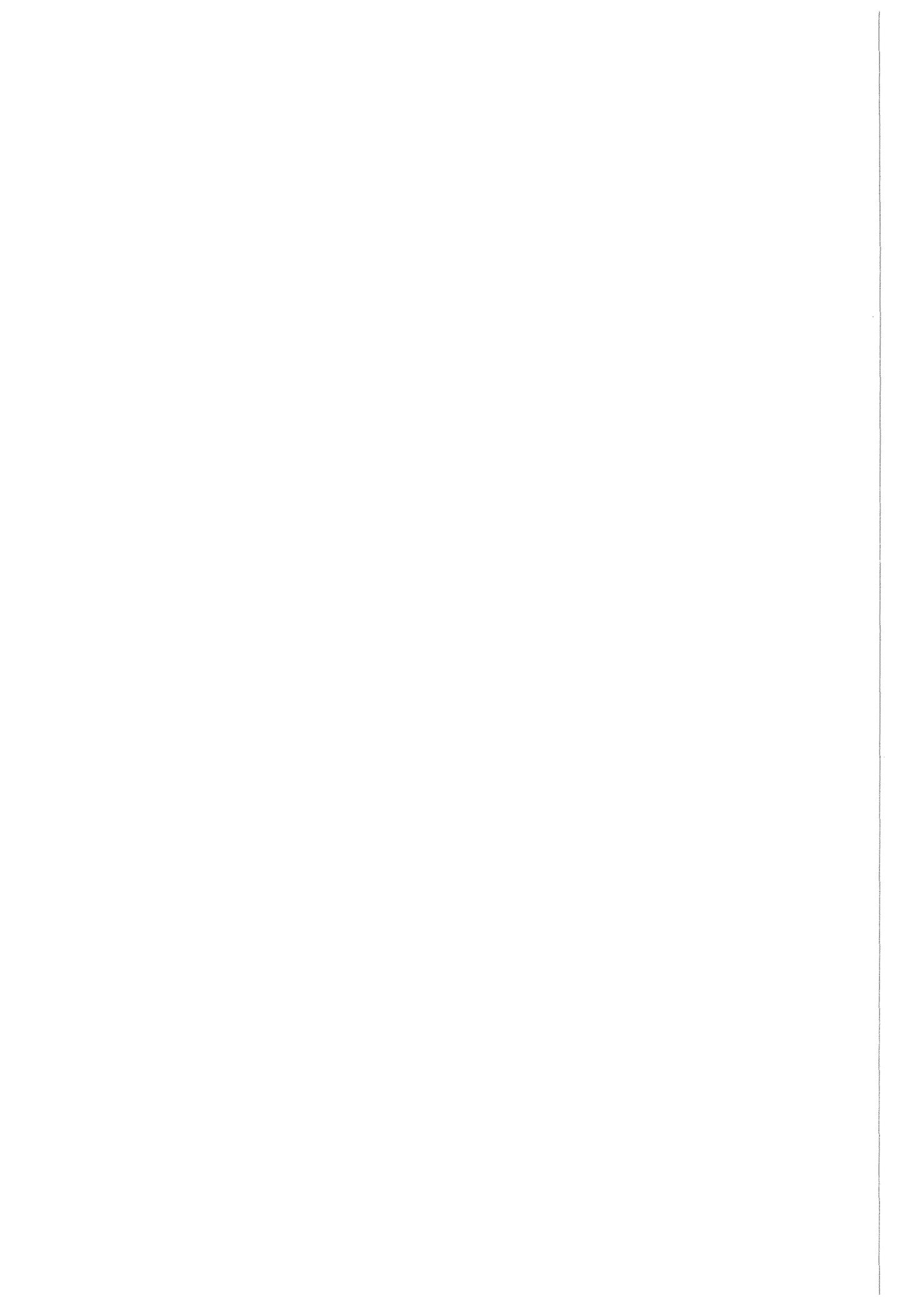
First of all, it should be checked that the following data sets are on the original MEMO disk:

- MEMONEU.EXE
- READ.EXE
- ASK.EXE
- TRANSFER.EXE
- MEMO.BAT
- DES.DAT
- MEA.DAT
- RET.COM

For optimization of the performance of the MEMO program moduls the MEMO program should be installed on the hard disk of the computer system. This can be easily performed from the original MEMO disk by a simple COPY command to an appropriate directory.

For example: copy a:\memo\\*.\* c:\memo\.

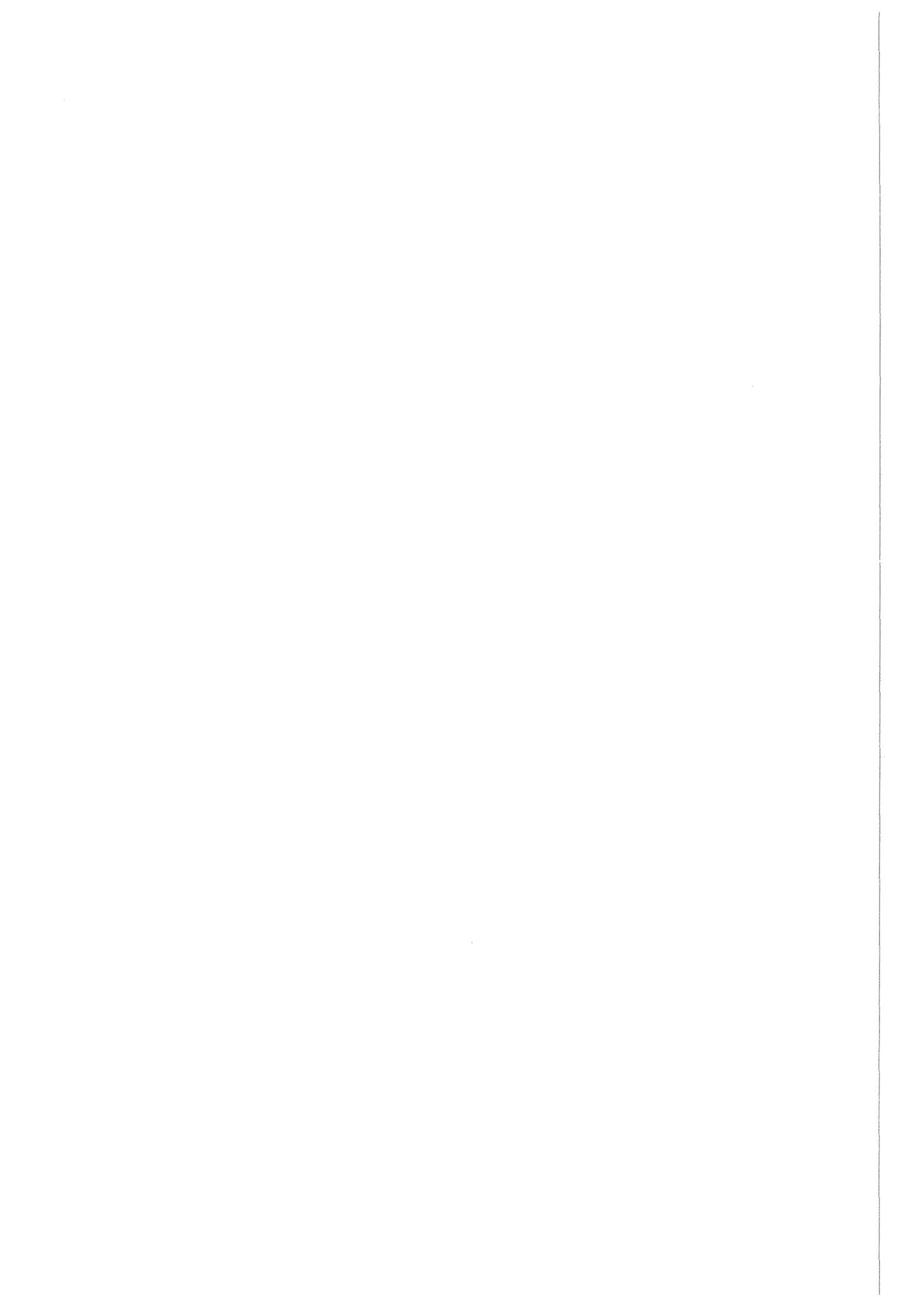
In either case the program MEMO can be started (from floppy disk or from hard disk) by the command MEMO. After this command the MAIN MENU of MEMO appears on the screen.



**Chapter 3:**

**Description of the MEMO Menus**

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### 3. Description of the MEMO Menus

The computer program MEMO is menu-guided and therefore very user-friendly. This chapter describes the various MEMO menus.

#### 3.1 MAIN MENU

In the following the MEMO MAIN MENU is displayed:

```
MEMO-VERSION 2.0

MAIN MENU

MEMO Program:
Enter the Number of Your Choice

    1 == Read/Browse/Print Input Data
    2 == Run MEMO
    3 == Browse Results
    4 == Data Transfer to PROSA
    Q == Quit the Session

Your Choice:
```

By choosing one of the options above the MEMO menu guide system offers various submenus to the user to complete the task successfully.

## 12 Chapter 3: MEMO Menus

### 3.2 INPUT MENU: Menu 1

Choosing option '1' in the MAIN MENU the following MENU 1 appears on the screen:

```
MEMO-VERSION 2.0

MENU 1:

MEMO Program:
Enter the Number of Your Choice

    1 == Read Input Data
    2 == Browse Input Data
    3 == Print Input Data
    E == Goto MAIN MENU

Your Choice:
```

Choosing the 'READ' option in MENU 1, submenu 1.1 appears on the screen:

```
MEMO-VERSION 2.0

MENU 1.1:

MEMO Program:
Enter the Number of Your Choice

    1 == Delete Existing MUF/COVA Data Sets
    2 == Keep Existing MUF/COVA Data Sets
    E == Goto Previous Menu

Your Choice:
```

Choosing the 'BROWSE' option in MENU 1, submenu 1.2 appears on the screen:

```
MEMO-VERSION 2.0

MENU 1.2:

MEMO Program:
Enter the Number of Your Choice

    1 == Browse Design Data
    2 == Browse Measure Data
    E == Goto Previous Menu

Your Choice:
```

Choosing the 'PRINT' option in MENU 1, submenu 1.3 appears on the screen:

```
MEMO-VERSION 2.0

MENU 1.3:

MEMO Program:
Enter the Number of Your Choice

    1 == Print Design Data Set
    2 == Print Measure Data Set
    E == Goto Previous Menu

Your Choice:
```

## 14 Chapter 3: MEMO Menus

### 3.3 RUN MENU: Menu 2

Choosing option '2' in the MAIN MENU the following MENU 2 appears on the screen:

```
MEMO-VERSION 2.0

MENU 2:

MEMO Program:
Enter the Number of Your Choice

    1 == Run MEMO (Display)
    2 == Run MEMO (Printer)
    E == Goto MAIN MENU

Your Choice:
```

After the choice of SCREEN or PRINTER, the user is asked for two integer values: kb for the beginning inventory taking and ke for the ending inventory taking. (Both within the range of k which is an input value of MEASURE.DAT, see Chapter 4).

### 3.4 BROWSE MENU: Menu 3

Choosing option '3' in the MAIN MENU the following MENU 3 appears on the screen:

```
MEMO-VERSION 2.0

MENU 3:
MEMO Program:
Enter the Number of Your Choice

    1 == Browse Results (Display)
    2 == Browse Results (Printer)
    E == Goto MAIN MENU

Your Choice:
```

### 3.5 TRANSFER MENU: Menu 4

Choosing option '4' in the MAIN MENU the following MENU 4 appears on the screen:

```
MEMO-VERSION 2.0

MENU 4:

MEMO Program:
Enter the Appropriate Number

1 == PROSA Directory Exists and Path Name Known
2 == No PROSA Directory Exists Or Path Name Unknown

Your Choice:
```

If a PROSA environment is installed, an appropriate sub-directory is created and the proper path name is known, the user may proceed by entering option '1'.

After this he is asked for the proper path name and the two data sets MUF and COVA will be transferred to the desired sub-directory of the PROSA environment.

If either no PROSA environment is installed, or no appropriate sub-directory is created or the proper path name is not known, the user has to enter option '2'.

16 Chapter 3: MEMO Menus

Then the following announcement appears on the screen:

```
MEMO-VERSION 2.0

***** Create a PROSA Directory *****
                And/Or
*****      Look for Path Name      *****
```

Hitting any key brings the user to the MAIN MENU.

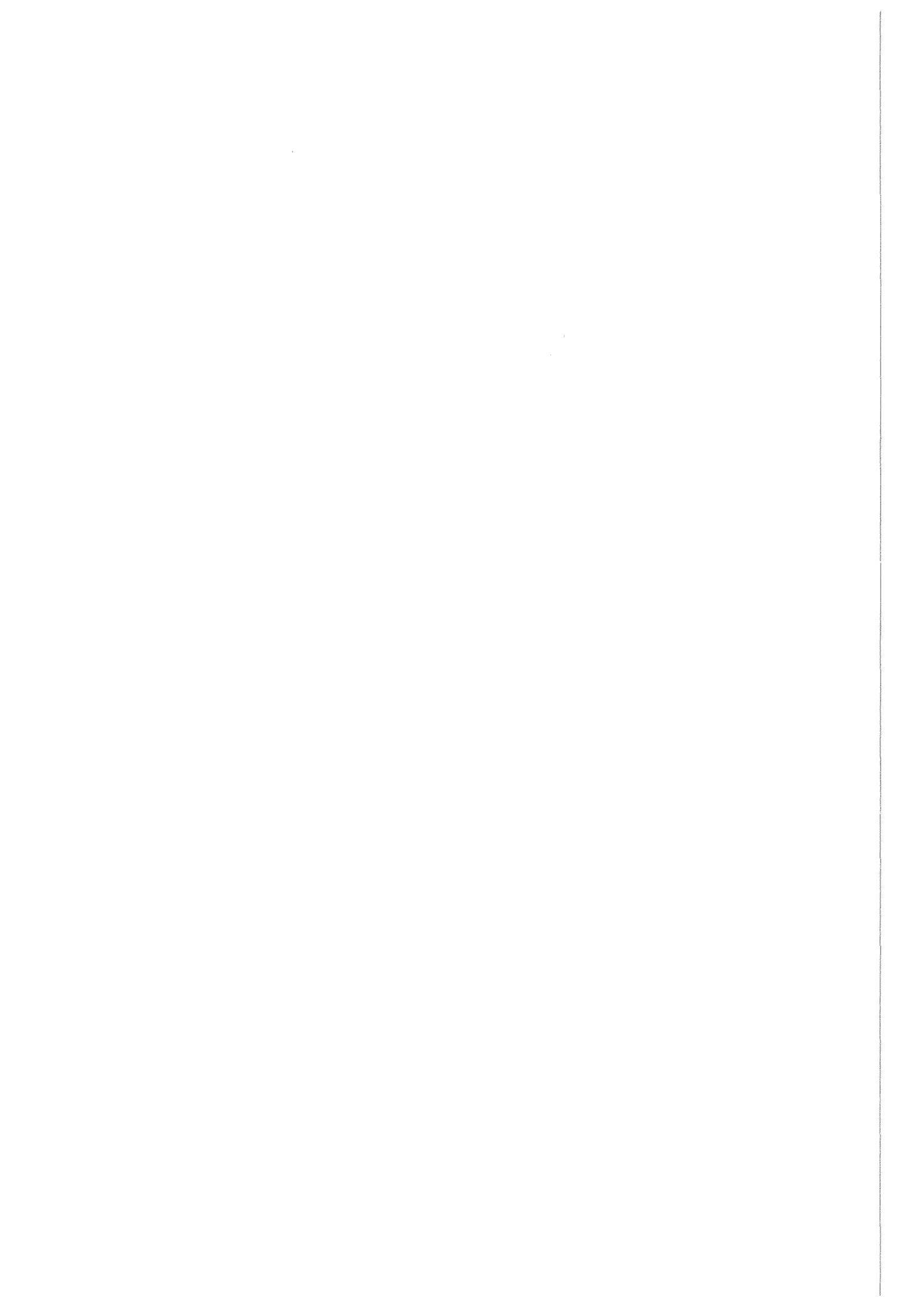
NOTICE:

The string 'PROSA\' must be part of the path name.

**Chapter 4:**

**Input Handling**

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#### 4. Input Handling

To calculate the MUF sequence and the related variance/covariance matrix COVA, two input data files are necessary: a DESIGN data set and a MEASUREMENT data set.

The DESIGN data set describes:

- the number of volume measurement methods
- the error structure of various volume measurement methods
- the number of concentration measurement methods
- the error structure of various concentration measurement methods.

The MEASUREMENT data set describes:

- the number of balance periods and the facility model
- the various measurement results with the related measurement methods and parameters for strong correlation.

#### NOTICE:

How to create these two data sets see Chapter 9 "Example".

For a more comprehensive description of the two input data sets see Chapter 5 "Structure of the Input Data Sets".

These data sets can be read by using submenu 1.1 of MENU 1. Choosing this submenu, all data sets which are already existing in the directory under consideration are listed. To load these data sets, only the listed name has to be entered. But data import can be performed from anywhere from the hard disk or floppy disk by entering the complete path name.

#### NOTICE:

Using the read option data sets from outside of the sub-directory under consideration will not be saved in this directory. They only will be copied to the standard data sets DESIGN.DAT and MEASURE.DAT which are in some sense temporary data sets. That

## 20 Chapter 4: Input Handling

means DESIGN.DAT and MEASURE.DAT will be overwritten whenever the read utility is used.

To save the original input data sets in the sub-directory under consideration the DOS command COPY has to be used.

Using submenu 1.1 the user is asked whether the existing data sets of MUF and COVA should be deleted. This should be done, whenever a new campaign is started or some values in the existing DESIGN data were changed. But this should not be done when only corrections in the MEASUREMENT data set (of the same campaign) were performed or when a new period (of the same actual campaign) was added to the MEASUREMENT data set.

The user is asked for two data sets: firstly the DESIGN data set and secondly the MEASUREMENT data set.

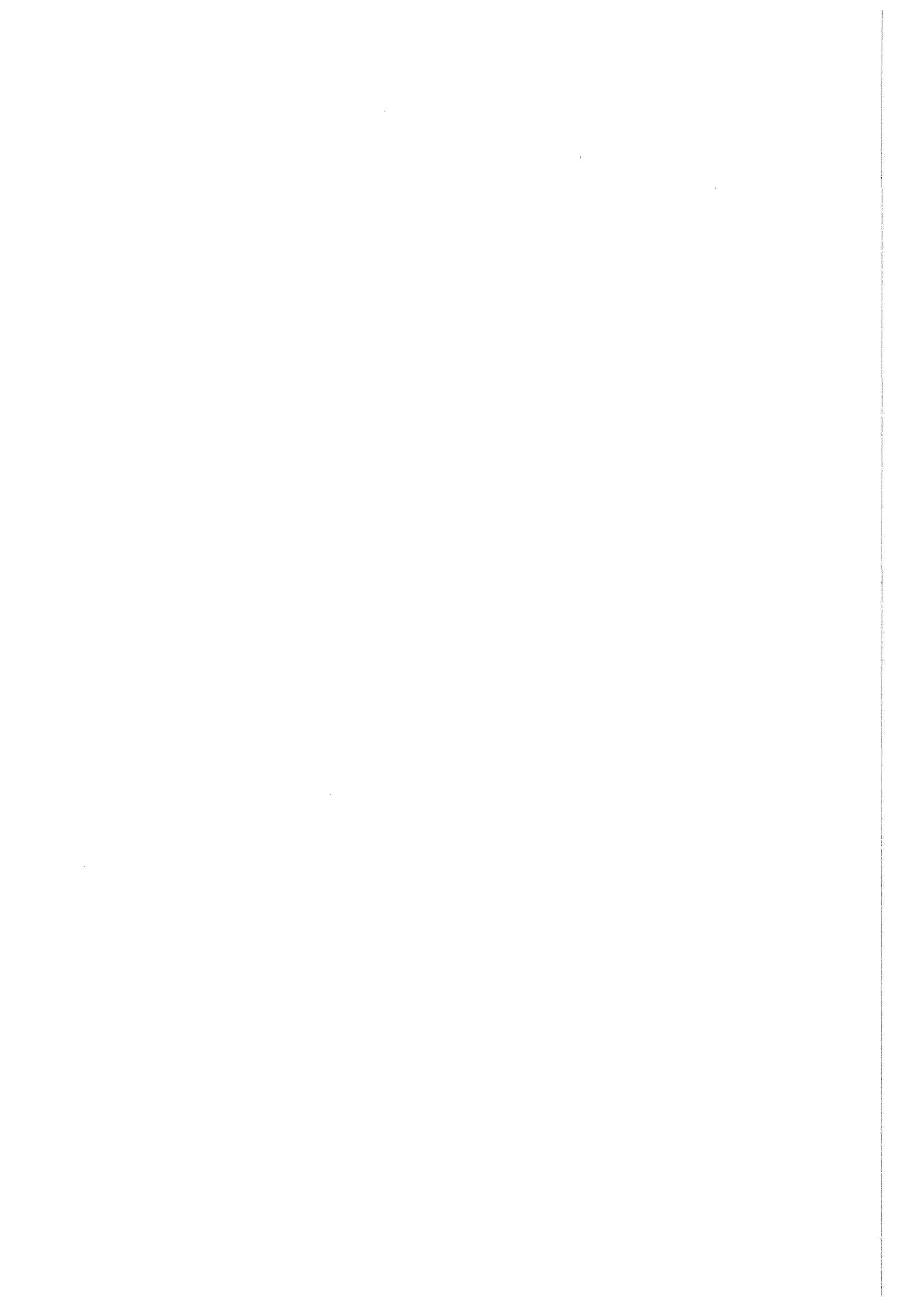
Using submenu 1.2 of MENU 1, the current active data sets - DESIGN.DAT and MEASURE.DAT - can be browsed.

Using submenu 1.3 of MENU 1, the current active data sets - DESIGN.DAT and MEASURE.DAT - can be printed.

**Chapter 5:**

**Structure of the Input Data Sets**

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5.2	MEASUREMENT Data Set	24



## 5. Structure of the Input Data Sets

All relevant input information must be written in two input data sets. The first input data set (DESIGN data set) describes the measurement methods, the second input data set (MEASUREMENT data set) the so-called facility model, the actual measurements and key parameters for the propagation of variances. In the following the structure of these two input data sets will be described.

### 5.1 DESIGN Data Set

The DESIGN data set describes all relevant measurement methods. Each measurement method - volume measurement as well as concentration measurement - is completely described by four real numbers:

- the additive error (absolutely) of the systematic error component
- the multiplicative error (relatively) of the systematic error component
- the additive error (absolutely) of the random error component
- the multiplicative error (relatively) of the random error component.

The DESIGN data set has to have the following structure:

```

nv
sav(1)      smv(1)      rav(1)      rmv(1)
...
...
sav(nv)     smv(nv)     rav(nv)     rmv(nv)
nc
sac(1)      smc(1)      rac(1)      rmc(1)
...
...
sav(nc)     smv(nc)     rav(nc)     rmv(nc)

```

## 24 Chapter 5: Input Data Sets

In the first line appears `nv`, the number of volume measurement methods. In the next lines (one method one line) follows the description of the `nv` volume measurement methods with

- `sav(i)` additive error of the systematic error component of the `i`-th volume measurement method
- `smv(i)` multiplicative error of the systematic error component of the `i`-th volume measurement method
- `rav(i)` additive error of the random error component of the `i`-th volume measurement method
- `rmv(i)` multiplicative error of the random error component of the `i`-th volume measurement method.

In the next line appears `nc`, the number of concentration measurement methods. In the next lines (one method one line) follows the description of the `nc` concentration measurement methods with

- `sac(i)` additive error of the systematic error component of the `i`-th concentration measurement method
- `smc(i)` multiplicative error of the systematic error component of the `i`-th concentration measurement method
- `rac(i)` additive error of the random error component of the `i`-th volume concentration method
- `rmc(i)` multiplicative error of the random error component of the `i`-th concentration measurement method.

### 5.2 MEASUREMENT Data Set

The MEASUREMENT data set contains all necessary information about facility model, actual measurement values and key parameters for the propagation of variances.

The MEASUREMENT data set has the following structure:

<code>k</code>	<code>ni</code>	<code>nr</code>	<code>no</code>		
<code>mv</code>	<code>v1</code>	<code>v2</code>	<code>mc</code>	<code>c1</code>	<code>c2</code>
<code>...</code>					
<code>...</code>					

In the first line the four integer values  $k$ ,  $n_i$ ,  $n_r$  and  $n_o$  appear with

- $k$  : number of inventory takings
- $n_i$ : number of inventory components per period
- $n_r$ : number of input batches per period
- $n_o$ : number of output batches per period.

In the next  $n_i$  lines the measurement results of the inventory components of the first inventory taking are written (one line per inventory component), followed by  $n_r$  lines with the measurement results of the input batches of the first balance period (one line per input batch), followed by  $n_o$  lines with the measurement results of the output batches of the first balance period (one line per output batch), followed by  $n_i$  lines with the measurement results of the inventory components of the second inventory taking (one line per inventory component), and so on till the  $k$ -th inventory taking.

In each line the measurement results of one inventory component / transfer batch are listed together with key parameters for the propagation of variances:

- $mv$ : measurement result of the volume measurement
- $v1$ : refers to the  $v1$ -th volume measurement method described in DESIGN data set
- $v2$ : parameter for "strong correlations" between volume measurements
- $mc$ : measurement result of the concentration measurement
- $c1$ : refers to the  $c1$ -th concentration measurement method described in DESIGN data set
- $c2$ : parameter for "strong correlations" between concentration measurements.

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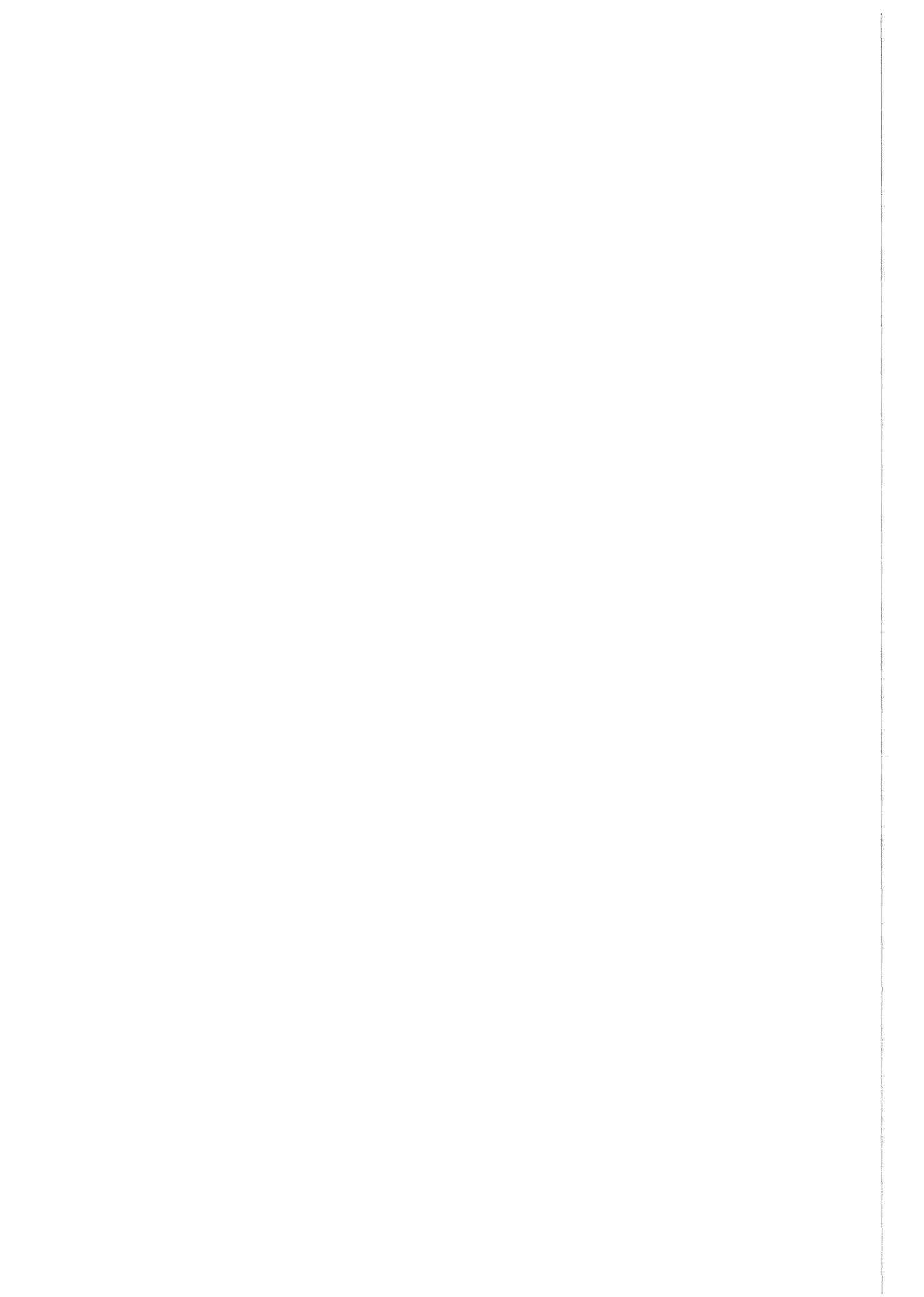
The key parameters v1 and v2 (rsp. c1 and c2) have the following effect to the propagation of variances:

- with v1 (rsp. c1) the measurement value is linked with the associated measurement errors described in DESIGN data set
- all measurements with the same value v1 (rsp. c1) are correlated through the systematic error component,
- all measurements with the same value v1 (rsp. c1) and the same value v2 (rsp. c2) are correlated through the systematic error component and through the random error component.

**Chapter 6:**

**RUN MEMO**

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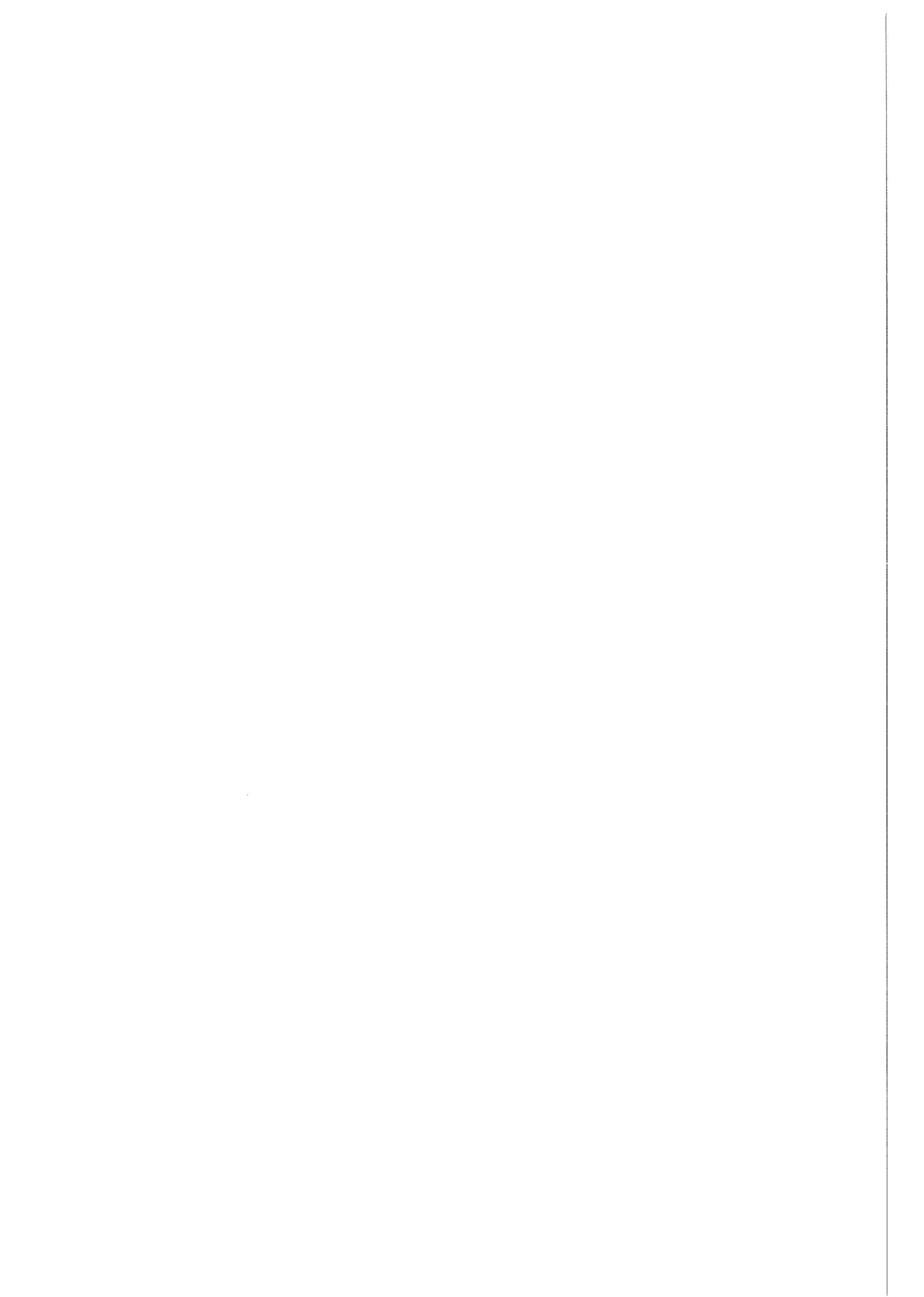


## 6. Run MEMO

The program MEMO can be started by choosing option '2' in the MAIN MENU of MEMO. It is possible to direct the results of the program to the screen or to a attached printer (submenu 2.1). In any way the actual number of total inventory takings  $k$  (see MEASUREMENT data set) is listed on the screen and the user is asked to input the desired beginning inventory taking  $k_b$  and the desired ending inventory taking  $k_e$  (both within the range of  $k$ ).

This possibility enables the user to recalculate some periods whenever there was a subsequent change in the MEASUREMENT data set or a new period was added in the MEASUREMENT data set. That means that only the MUF values and the related covariances of these balance periods will be recalculated or new calculated. This option results in an optimization of the run time. For more details see Chapter 9 "Example".

The results of the program that means the MUF values and the related variance/covariance matrix are listed in the data sets MUF and COVA for further application.



**Chapter 7:**

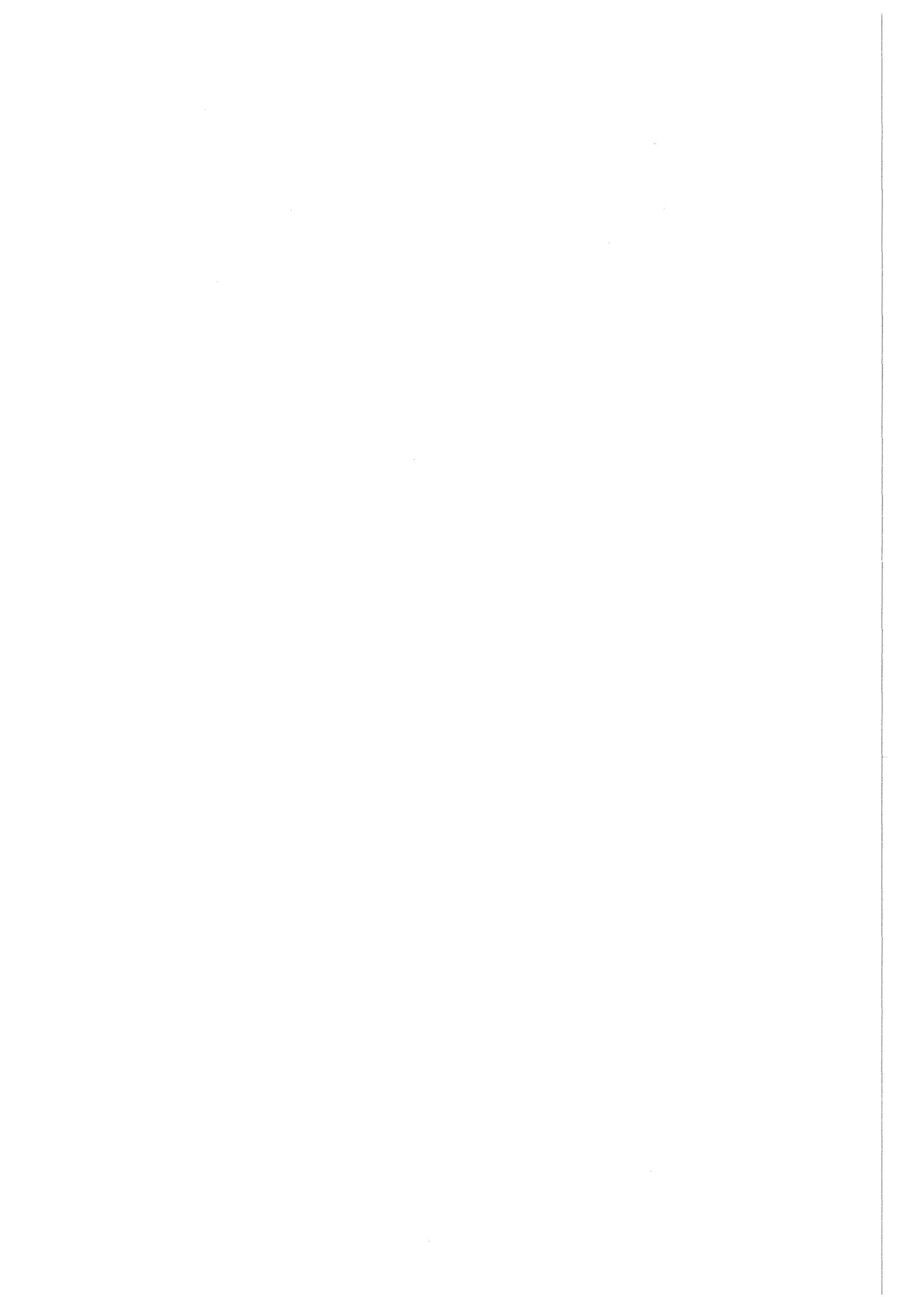
**Browse Results**

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7. Browse Results

The results of a MEMO run can be either displayed on the screen or printed on an attached printer using the 'BROWSE' option in the MAIN MENU.



**Chapter 8:**

**Data Transfer to PROSA**

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8. Data Transfer to PROSA

The results of a MEMO run, that means the MUF values and the related variance/covariance COVA, are essential input data sets for materials balance evaluation programs like PROSA. Therefore, a 'TRANSFER' option is available to export these data sets to an (existing) PROSA environment.

Submenu 4.1 asks the user whether or not such a PROSA environment and an appropriate sub-directory exist.

If a PROSA environment is installed, an appropriate sub-directory is created and the proper path name is known, the user may proceed by entering option '1'.

After this the user is asked for the proper path name and the two data sets MUF and COVA will be transferred to the desired sub-directory of the PROSA environment.

NOTICE:

Using this option, the units of MUF are changed into kilograms. Furthermore, the two data sets MUF and COVA are created in the proper data format to serve as input data sets for PROSA.

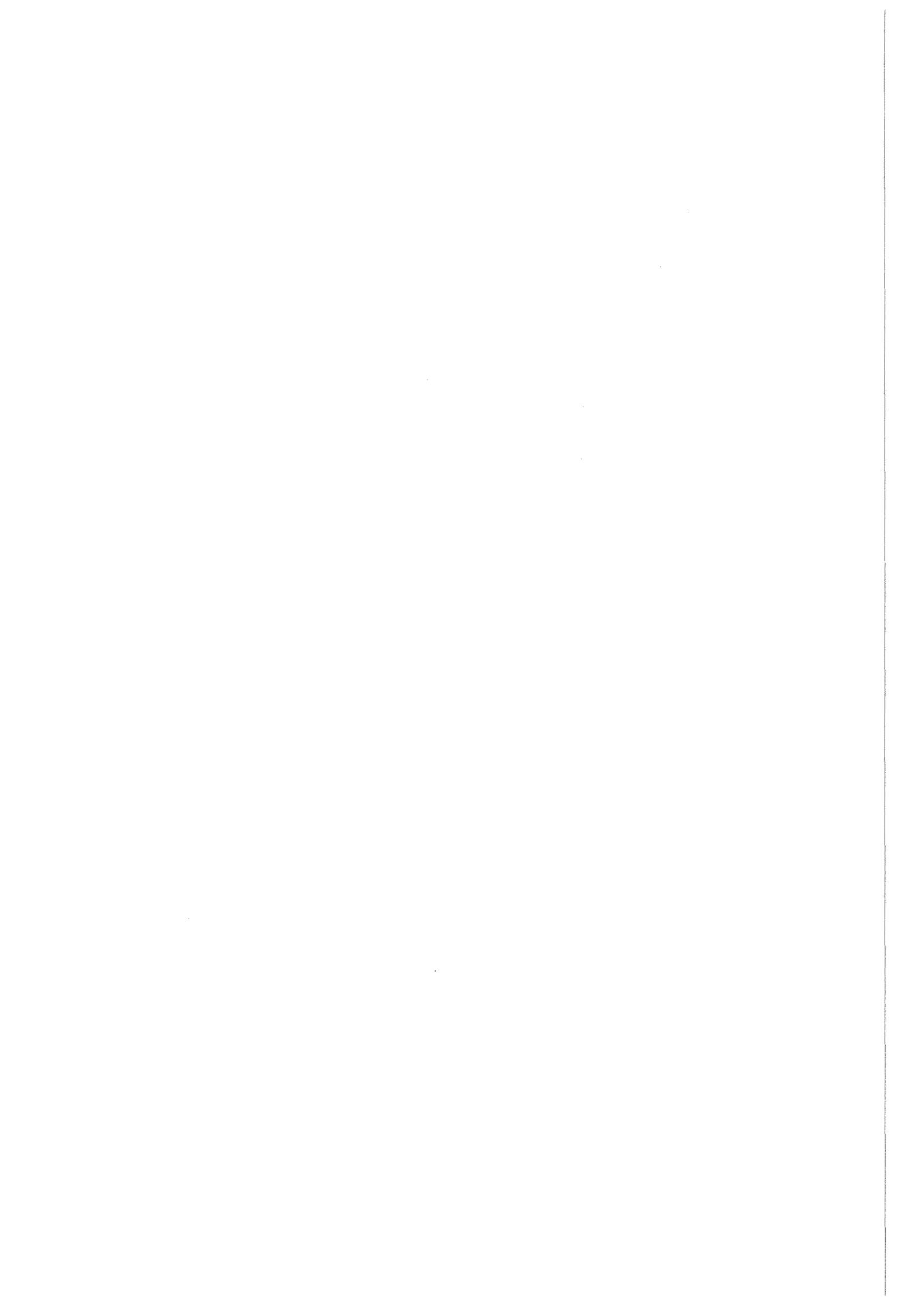
If either no PROSA environment is installed, or no appropriate sub-directory is created or the proper path name is not known, the user has to enter option '2'.



**Chapter 9:**

**Example**

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## 9. Example

The following serves as a tutorial for the application of MEMO. The various steps from creating the input data sets from a measurement situation to the determination of MUF and COVA are comprehensively described.

### **9.1 Creating the Input Data Sets**

Let us assume that there are 4 measurement methods for the determination of volume ( $n_v=4$ ) and 3 measurement methods for determination of concentration ( $n_c=3$ ).

Each single measurement method - volume as well as concentration - is described by the relative standard deviation (rsd) of the

- multiplicative component of the systematic measurement uncertainty
- multiplicative component of the random measurement uncertainty

and the standard deviation (sd) of the

- additive component of the systematic measurement uncertainty
- additive component of the random measurement uncertainty

So we get the following DESIGN data set (see Chapter 5 "Structure of the Input Data Sets"):

42 Chapter 9: Example

4			
1.3	0.01	0.1	0.05
2.3	0.02	2.2	0.06
1.2	0.03	1.7	0.07
1.1	0.04	1.9	0.08
3			
3.1	0.09	2.9	0.12
1.6	0.10	2.8	0.13
1.3	0.11	2.7	0.00

That means, for example, that the additive error of the systematic error component of the 2nd volume measurement method is 2.3 or that the multiplicative error of the random error component of the 3rd concentration measurement method is 0.0.

To establish the MEASUREMENT data set, let us assume that we have 3 inventory takings ( $k=3$ , i.e. number of balance periods =2), that we have 2 inventory components ( $n_i=2$ ), 1 input batch per period ( $n_r=1$ ) and 1 output batch per period ( $n_o=1$ ).

For all inventory components and for all transfer batches we need the values of the volume measurement and of the concentration measurement. Furthermore, we need knowlegde with which method the measurements were performed. Additionally, we have to know which measurement values are the result of an identical measurement. (For example, the concentration is measured in a vessel and the same concentration measurement value is attached to the following pipe).

With this information we can establish the MEASUREMENT data set (see Chapter 5 "Structure of the Input Data Sets"):

3	2	1	1		
23.1	1	0	1.1	1	0
17.3	2	1	0.9	2	0
21.4	1	1	1.3	1	1
17.3	2	1	1.4	3	0
21.4	1	1	1.3	1	1
15.2	2	2	1.2	2	1
9.5	3	0	0.8	1	0
7.5	4	0	1.4	3	0
11.3	1	0	1.5	1	0
15.2	2	2	1.2	2	1

That means, for instant, that the result of the volume measurement of the first inventory component in the first inventory taking is 23.1 and the first volume measurement method was used ( $v_1 = 1$ ). This first volume measurement method was used 4 times in our example. That means all these measurements are correlated through the systematic error component. But furthermore the same measurement result (21.4) is attached the the first inventory component in the second inventory taking and to the input of the first balance period. Therefor, the two  $v_2$ -values in the associated lines are also identical. That means these two measurements are correlated through the random error component too.

NOTICE: Whenever a  $v_2$ -value or  $c_2$ -value is zero there is no correlation through the random error component.

## 9.2 Importing the Input Data Sets

After having created the Input Data Sets outside of the MEMO environment they have to be imported to the MEMO sub-directory under consideration.

There are two possibilities:

- 1) copy the data sets into the appropriate MEMO sub-directory using the DOS command COPY
- 2) import the data sets using the 'read option' of Menu 1.

On the original MEMO disk two input data sets are prepared. d1.dat contains the DESIGN data set m1.dat contains the MEASUREMENT data set, described above.

These input data sets can be loaded by choosing option 1 in the MAIN MENU and option 1 in the following 'input menu'. When the user is asked whether to delete or to keep existing MUF/COVA Data-Set, he should choose option 1 for deleting because in this case a new campaign will be calculated.

Then an information about all existing data sets in this sub-directory occurs on the screen.

If the desired data sets are already in the sub-directory under consideration (like in this case) only the data set names have to be entered, otherwise the full path name.

At first for the file name of the DESIGN data set is asked then for the file name of the MEASUREMENT data set.

After having entered (in this case):

```
    des.dat  
and  
    mea.dat
```

the input data sets are loaded.

### 9.3 Determination of MUF and COVA

The determination of the MUF values and the related variance/covariance matrix can be performed using option 2 in the MAIN MENU. In a submenu the user can choose between RUN MEMO on the screen (display) or on an attached printer. In the following RUN MEMO (Display) will be explained.

Next the number  $k$  of inventory takings occurs on the screen (in this example  $k=3$ ) and the user has to enter the number of the first inventory taking  $k_b$  (in this example  $k_b=1$ ) and the number of the last inventory taking  $k_e$  (in this example  $k_e=3$ ). Both,  $k_b$  and  $k_e$ , must be in the range of  $k$ .

When the determination of MUF and COVA is completed a time table is displayed on the screen which gives information about date and computing time. Then the names of the active input data files and some important parameter values are listed followed by a table of volume measurement errors and concentration measurement errors as well.

Finally the results of the determination are listed on the screen. In this case the results are:

```
var(MUF(1))          = 0.01653
cov(MUF(1),MUF(2))  = 0.00458
var(MUF(2))          = 0.00992
```

and

```
MUF(1) = -1.0
MUF(2) = 8.0.
```

NOTICE: The units of the MUF values are gram, the units of the variances and the covariances are kilograms in square.

Furthermore two output data sets are established called MUF and COVA for further application in evaluation programs like PROSA.

## 46 Chapter 9: Example

### 9.4 New Balance Period

If a new balance period is performed, the MEASUREMENT data set has to be updated. To do this, the k value has to be increased by 1. Furthermore, all measurement results - for input, output and last inventory taking as well - must be written in this data set linked with associated key parameters for error propagation (see Chapter 9.1).

Then the input data sets can be loaded as described in Chapter 9.2. The only difference is that when the user is asked whether to delete or to keep existing MUF/COVA Data-Set, he has to choose option 2 for keeping because in this case an existing campaign will be extended.

After this, the determination of the MUF values and the related variance/covariance matrix can be performed like in Chapter 9.3. But when the user is asked for the beginning resp. ending inventory taking he has to input only  $k_b=k-1$  and  $k_e=k$ . (In this case:  $k = 4$ ,  $k_b = 3$ ,  $k_e = 4$ ).

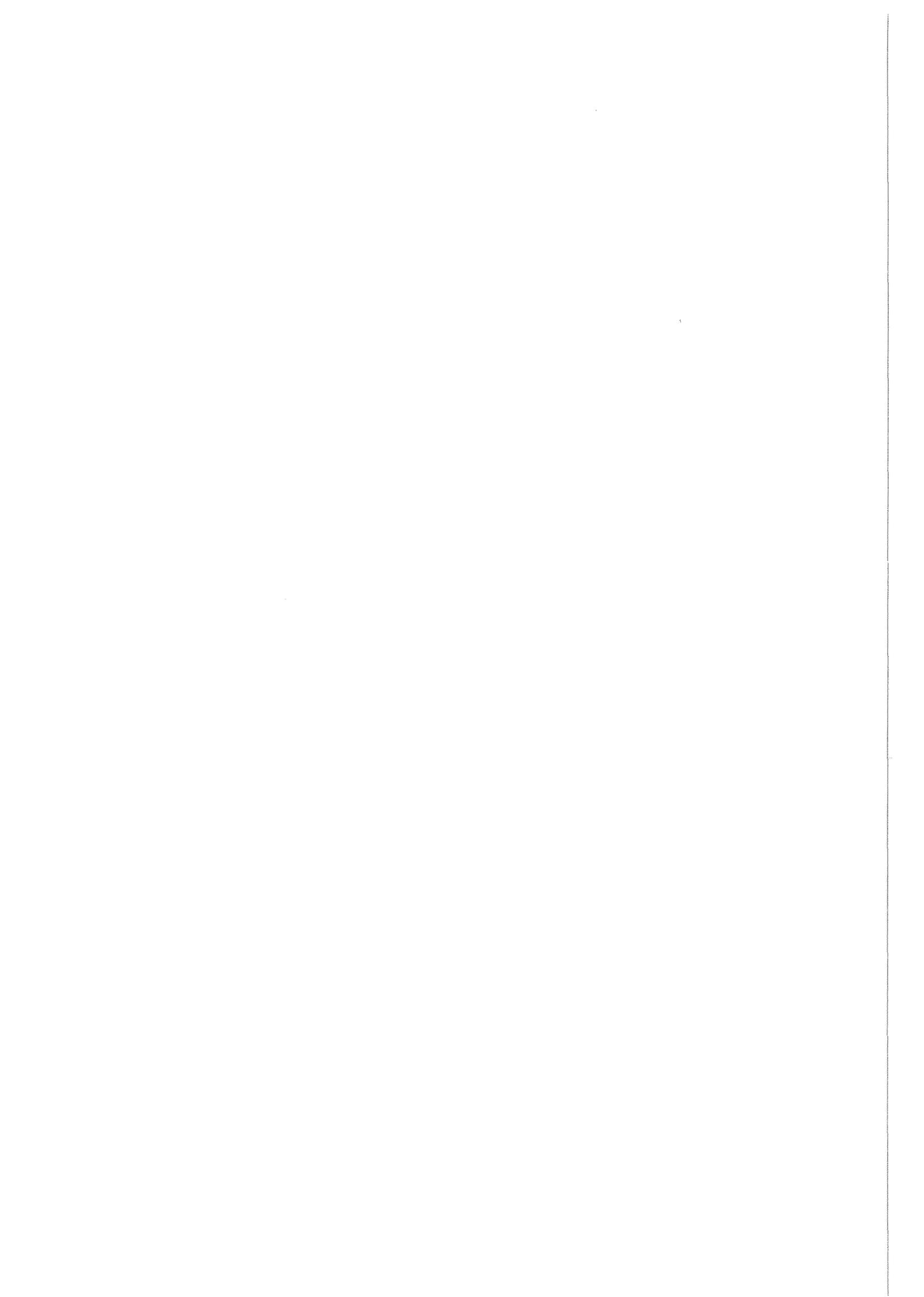
That means only the results related to this new period have to be calculated and are added to the existing MUF and COVA data set. This provides a very fast determination which is very important in real field use.

### 9.5 Change in Previous Period(s)

If there was a correction in the MEASUREMENT data set, i.e. a measurement result was corrected or a key parameter for error propagation was changed, the input data sets can be loaded as described in Chapter 9.2. The only difference is that when the user is asked whether to delete or to keep existing MUF/COVA Data-Set, he has to choose option 2 for keeping because in this case an existing campaign will be corrected.

After this the re-determination of the MUF values and the related variance/covariance matrix can be performed like in Chapter 9.3. But when the user is asked for the beginning resp. ending inventory taking he has to input only these balance periods in which a change has happened.

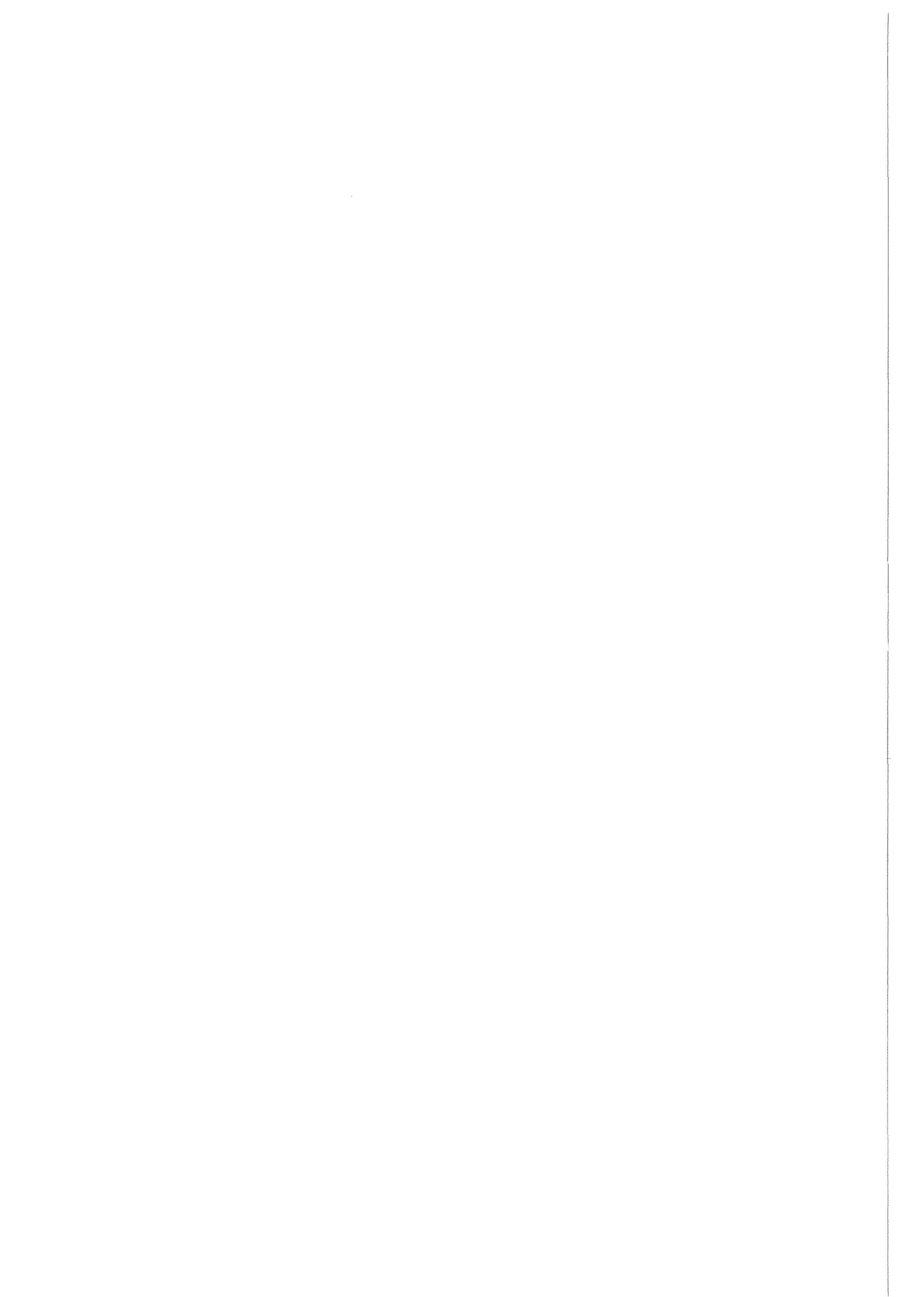
That means only the results related to these corrected balance periods have to be calculated and are copied to the existing MUF and COVA data set.



**Chapter 10:**

**Further Remarks**

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## 10. Further Remarks

### 10.1 Only One Measurement

If the amount of material in an inventory component or transfer batch is determined by only one measurement, attach this measurement value to the volume measurement value and attach a value of 1 to the associated concentration measurement value. Of course, the related measurement method errors must be described in the DESIGN data set. The associated errors of the "concentration measurement method" must be zero in all components.

### 10.2 Recalibration of Measurement Methods

The recalibration of a measurement method effects the error propagation through the systematic error. It has the same consequences as a new measurement method (but of course with the same measurement uncertainties). To incorporate this situation, this measurement method has to be added once again in the DESIGN data set and has to be referred in the following by its new number.

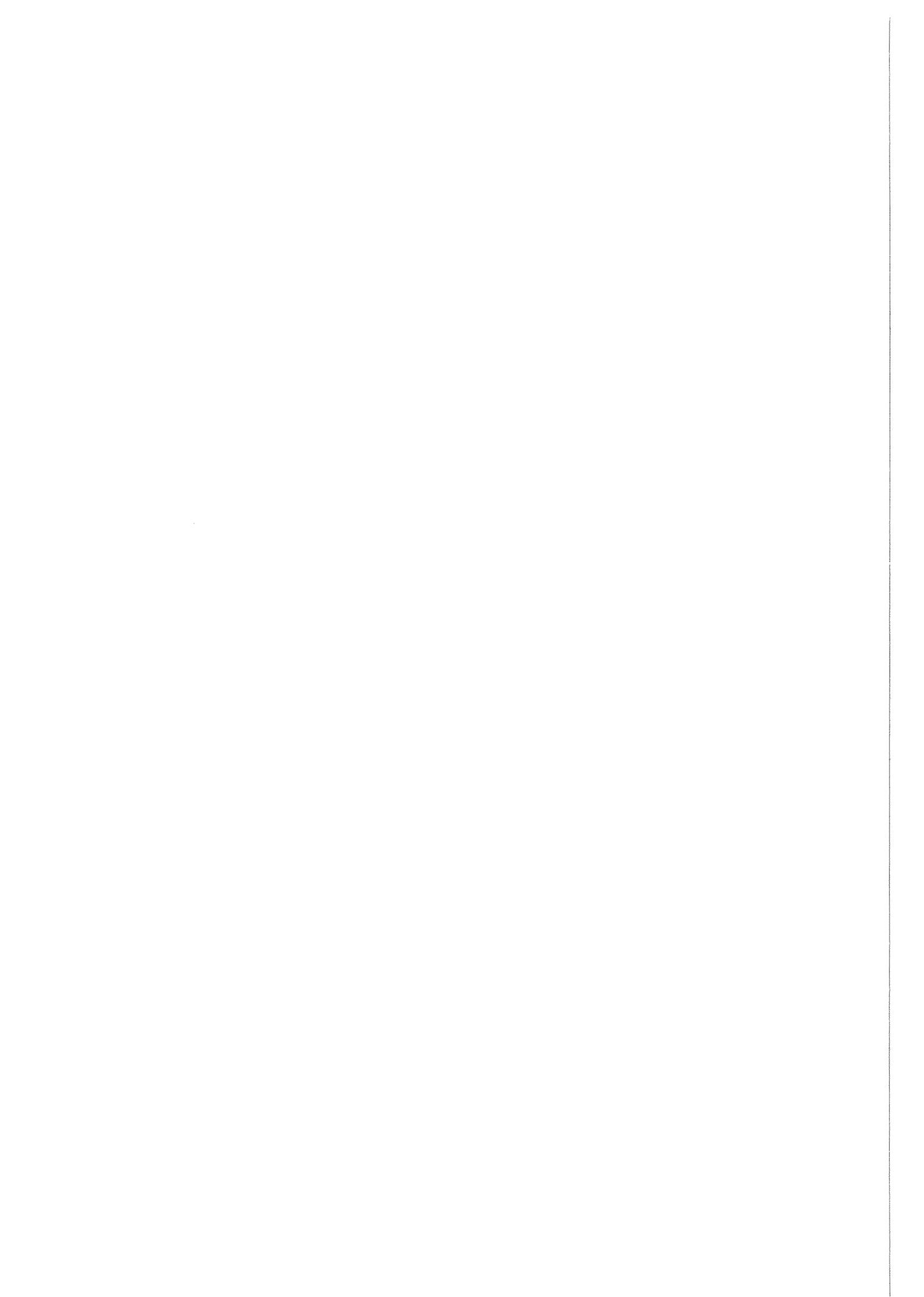
NOTICE: Don't forget to increase the number of measurement methods in the DESIGN data set.

### 10.3 Error Messages

There are only a few possibilities to handle MEMO in an incorrect manner, because the user is menu-guided. Examples of incorrect use of MEMO may be the missing of initial data sets. In these cases, the program system generates self-explanatory messages which give the user advice how to proceed correctly.

#### REMARK:

If there is any problem, please don't hesitate to contact one of the authors U. Bicking, W. Golly or R. Seifert, c/o Kernforschungszentrum Karlsruhe, P.O.B. 3640, Department IAI, D-7500 Karlsruhe, Telephone 0049-7247-82/3971, 2292 or 4411. We would appreciate any comment or proposal from users side which might improve the use of the program.



**Chapter 11:**

**Further PC-Program Packages in this Context**

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11. Further PC-Program Packages in this Context

11.1 PC-Program Package PROSA

The PROSA PC program package is a statistical tool to decide on the basis of statistical assumptions whether in a given sequence of material balance periods a loss of material might have occurred. The evaluation of the material balance data is based on statistical test procedures. In the present PROSA Version 4.0 the three tests CUMUF test, PAGE's test and GEMUF test are applied to a sequence of material balances. PROSA Version 4.0 supports a real sequential evaluation. That means, PROSA is not only able to evaluate a series of MUF values sequentially after the campaign has finished, but also real sequentially during the campaign. PROSA Version 4.0 is a menu-guided computer program and, therefore, very user-friendly and applicable in real field use. Data input can be performed either by diskette or by key-enter. Result output is primarily an information whether or not an alarm is indicated. This information can be displayed either numerically or graphically. Therefore, a comfortable graphical output utility is attached to PROSA 4.0. PROSA Version 4.0 is a real-sequential program. That means, PROSA is not only able to evaluate a series of MUF values sequentially after the campaign has finished, but also real sequential during the campaign.

For more information see "PROSA VERSION 4.0 Manual", U. Bicking, W. Golly, R. Seifert, KfK report 4866, May 1991.

11.2 PC-Program Package MOCASIN

The MOCASIN PC program package is a statistical tool to determine the detection probabilities of underlied loss-patterns using Monte-Carlo simulations. Input of MOCASIN is the measurement model (variance/covariance matrix) of a facility and an underlied loss-pattern. Output are the detection probabilities of the three statistical test procedures included in MOCASIN, namely CUMUF test, PAGE's test and GEMUF test. MOCASIN 4.0 is a menu-guided computer program and, therefore, very user-friendly and applicable in real field use.

The program package and a manual will be available before long.

### 11.3 PC-Program Package DOD

The DoD method allows to derive an estimate of the standard deviation for data being inhomogeneous from the statistical point of view. The evaluation of data using DoD does not demand for prior rejection of suspicious values or outlier results. The DoD program package is a menu-guided tool to evaluate up to 200 measurement data. Results are the standard deviation and the median value of these measurement data. As an alternative, conventional evaluation using the Bartsch-outlier criterion is also possible and makes the user able to compare the result to that gained with DoD. The measurement data can be displayed numerically and by graphic, as well. The results can be displayed numerically. In addition, the distribution of differences can be displayed by graphic. Therefore, a comfortable graphical output utility is attached to DoD Version 2.0.

For more information see "DOD VERSION 2.0 Manual", U. Bicking, W. Golly, R. Seifert, KfK report, to appear.

**Appendix:**

**MEMO - A PC PROGRAM TO ESTABLISH MEASUREMENT MODELS FOR  
NRTA EVALUATION PROCEDURES**

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MEMO - A PC PROGRAM TO ESTABLISH MEASUREMENT MODELS FOR NRTA  
EVALUATION PROCEDURES

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ABSTRACT

The PC program MEMO for determining the dispersion matrix (statistical measurement model) of a series of materials balance results is introduced and described, including theoretical aspects of establishing measurement models. MEMO is a useful tool in international safeguards and provides the essential input data for the NRTA evaluation procedures as implemented in such programs like PROSA.

1. INTRODUCTION

International Safeguards is an important matter not only for the international safeguards authorities but also for the public acceptance of the peaceful use of nuclear energy. The aim of international safeguards is the timely detection of diversion of significant quantities of nuclear materials, and deterrence of such diversion by the risk of early detection.

In order to achieve these goals, as primary method nuclear materials balancing is applied, which essentially consists of the following principle:

The so-called book inventory - the beginning inventory  $I_B$  plus net transfers  $T$  - is compared with the physical inventory - the ending inventory  $I_E$ . This leads to the well-known materials balance equation:

$$(1) \quad MUF = I_B + T - I_E,$$

where MUF means material unaccounted for.

This so-called "classical" approach is capable of detecting a possible diversion with high probability.

But it is evident that this approach is not capable to meet the goal of timely detection due to the fact that the balance is closed only at the end of the reference time which is usually in order of half a year to one year.

To meet the criteria of timely detection advanced methods need to be applied which are usually referred to as "Near Real Time Accountancy" (NRTA).

The basic idea is to subdivide the total reference time into N several balance periods and to close the balance after each period. This procedure leads to a sequence of material balance results  $MUF(i)$ ,  $i=1, \dots, N$  with:

$$(2) \quad MUF(i) = I(i-1) + T(i) - I(i),$$

where  $I(i)$  is the ending inventory of period  $i$  as well as the beginning inventory of period  $(i+1)$ , and  $T(i)$  is the net transfer in period  $i$ .

Using this approach, at the end of the  $i$ -th balance period, a decision can be taken on whether or not there is a loss of material, based on all  $i$  balance results  $MUF(1), \dots, MUF(i)$ . Thus, trends can be recognized at an early stage and losses may be detected timely related to their occurrence.

But now a further problem occurs. On the first glance one tends to assume that each MUF value in Formula (2) should be zero if no loss of material has occurred, or, visa versa, if there are MUF values greater than zero, nuclear material is missing. However, as the terms in the materials balance equation are the results of several measurements - each of them connected to characteristic measurement uncertainties - the MUF values generally do not amount to zero even in the case of no loss of material.

That means, at the end of each balance period  $i$ , a decision has to be taken whether or not the deviations of the sequence  $MUF(1), \dots, MUF(i)$  from the expectation values zero can be explained by (known) measurement uncertainties.

To evaluate the series of MUF values in an objective and convenient manner the computer program PROSA /1,2/ was developed. Input of PROSA are the sequence of material balance results  $MUF(1), \dots, MUF(i)$  and the measurement model of the facility considered. Using sequential statistical test procedures PROSA evaluates the series of MUF values based on the measurement model. That means the output of PROSA is a decision on whether the series of materials balance results can be explained by the assumed measurement uncertainties or if not which among other reasons may be a hint of a possible diversion.

That means the determination of the measurement model is an essential step in data evaluation. This measurement model contains all individual measurement uncertainties with random and systematic components, including the appropriate propagation of variances. From the statistical point of view, the measurement model is described by a matrix which can be regarded as the variance/covariance matrix or dispersion matrix of the MUF series.

In the last several years a lot of R&D effort went into theoretical considerations about measurement models /3,4/, into establishing detailed measurement models based on real process data /5,6/ and into developing related computerized tools /7/. In the following, theoretical and fundamental aspects in this framework are discussed and the PC program MEMO for computerized establishing of measurement models is introduced.

## 2. SOME REMARKS TO THE MEASUREMENT MODEL

To determine the measurement model, first of all it is necessary to define the facility model. This is to declare the number of inventory components in which the considered material is contained, further the number of input and output batches per balance period. That means, for each balance period the facility model consists of a triple of integer values  $n_i, n_r, n_o$  where  $n_i$  refers to the number of inventory components,  $n_r$  to the number of input batches, and  $n_o$  to the number of output batches.

Next the error model has to be established. This model includes all measurement uncertainties for volume measurements as well as for concentration measurements.

Each single measurement - volume as well as concentration - is described by the relative standard deviation (rsd) of the

- multiplicative component of the systematic measurement uncertainty
- multiplicative component of the random measurement uncertainty

and the standard deviation (sa) of the

- additive component of the systematic measurement uncertainty
- additive component of the random measurement uncertainty

The facility model as well as the error model are constant as long as the facility design is not changed. The facility design could be changed either if a new component is added (change of facility model) or a new measurement procedure is introduced (change of error model).

The measurement model itself is affected by the measurement data through the relative error model. That means the measurement model is a function of the (long-term constant) facility model, of the (long-term constant) error model and of the (variable) measurement values, and, therefor, is not constant at all.

## 3. ASSUMPTIONS ON THE MEASUREMENT UNCERTAINTIES

We assume that the considered amount of material in each inventory component and in each transfer batch can be determined as the mathematical product of a volume determination and a concentration determination:

$$(3) \quad \text{amount} = \text{vol} * \text{con.}$$

Further we assume that each single determination (volume and concentration as well) can be conceived as a "measurement" with a systematic and a random error component as well.

Both, systematic and random error component, are assumed to belong to the relative error model; that means they have a multiplicative error component and an additive error component.

For example,

$$(4) \quad \text{con} = E(\text{con}) + E(\text{con}) * (\text{msc} + \text{mrc}) + \text{asc} + \text{arc},$$

with  $E(\text{con})$ : the true (but unknown) concentration value

$\text{msc}$  : the multiplicative component of the systematic error of the concentration determination

$\text{asc}$  : the additive component of the systematic error of the concentration determination

$\text{mrc}$  : the multiplicative component of the random error of the concentration determination

$\text{arc}$  : the additive component of the random error of the concentration determination.

The next assumption is that all error components are normally distributed with known standard deviation and mean zero. Mean zero means that all measurements are unbiased.

Volume measurements and concentration measurements are assumed to be mutually uncorrelated and also systematic error components and random components as well. Correlations may occur when the same measurement method is used several times (propagation of variances for the systematic error component) or when the same measurement is used to determine the content of material in two or more components (propagation of variances for the random error component). This may occur in the case that the concentration is measured in a vessel and the same measurement value also relates to the concentration in the connected pipe.

Another assumption is that the systematic error is constant during the reference time; that means, there is no recalibration of measurement methods and instruments.

#### 4. DETERMINATION OF THE MEASUREMENT MODEL

In the considered facility, each amount of material of each process component and of each transfer batch is calculated by the mathematical product of a volume measurement ( $\text{vol}$ ) and of a concentration measurement ( $\text{con}$ ).

Using truncated Taylor series expansion in the mean values  $E(\text{vol})$  and  $E(\text{con})$  leads to

$$(5) \quad \text{vol} * \text{con} = E(\text{vol}) * E(\text{con}) + (\text{con} - E(\text{con})) * E(\text{vol}) + (\text{vol} - E(\text{vol})) * E(\text{con}),$$

which results in the reasonable equation

$$(6) \quad E(\text{amount}) = E(\text{vol}) * E(\text{con}).$$

With regard to the variances, the following expression holds:

$$(7) \text{ var(amount)} = (E(\text{vol}))^2 * \text{ var(con)} + (E(\text{con}))^2 * \text{ var(vol)}.$$

On the right hand of Formula (7) the terms  $E(\text{vol})$  and  $E(\text{con})$  appear which represent the true but unknown values of volume and concentration measurements.

These unknown values can be substituted by the measurement values themselves, because each measurement is an unbiased estimate of the true value. With this procedure, the variance of each batch of material can be calculated. Furthermore, the variances can be split into random components and into systematic components.

With flow-sheet information provided by the operator all variance and covariance calculations can be summarized into the so-called dispersion matrix of the MUF series. For example, the  $(i,j)$ -th element of the matrix describes the covariance between  $\text{MUF}(i)$  and  $\text{MUF}(j)$ . The dispersion matrix is the condensed form of the measurement model and provides all necessary information to evaluate the sequential MUF series.

#### 5. THE COMPUTER PROGRAM MEMO

To facilitate the determination of the dispersion matrix, computerized procedures are unavoidable. Already in the early 80's, at the Kernforschungszentrum Karlsruhe a host version of a computer program to determine the measurement model was developed. But for routine field use a PC version of such a computer program is necessary. Therefore, in the last months, it was tried to transpose the host version into a PC version /7/. But some difficulties occurred. The greatest problem was the huge amount of memory needed by the old host version. The next problem was a run-time problem. The old program, fast on the host, was very slow on the PC. The third problem was that the old program was not able - neither on host nor on PC - to cover all correlations which may occur in practice.

Due to these reasons a completely new version was realized called MEMO 2.0 (Measurement Model). The computer program MEMO 2.0 runs on Personal Computers which need at minimum the following configuration of hardware system:

- AT compatible computer system
- mathematical co-processor
- at least 256 kbyte memory
- hard-disk drive
- operating system DOS version 3.0 or higher.

To make MEMO user-friendly for routine field application, the MEMO program modules are covered in a menu-guided user-shell. The entry to MEMO application is shown in Fig. 1 which displays the main menu.