SCHENCK

Balancing Module CAB 41

Programme Instructions

3370.038

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Programme Instructions

C O N T E N T S

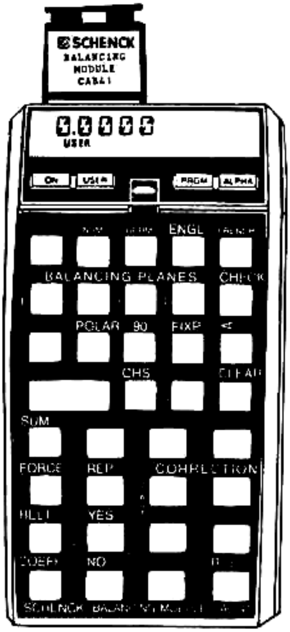
The programs described in this manual have been carefully generated and tested. CARL SCHENCK AG cannot assume any guarantee regarding their successful use in any particular case of application. In particular, we cannot accept any liability for claims resulting from the use of the programs.

1. GENERAL INFORMATION

The Schenck balancing module CAB 41 is conceived for use in Hewlett Packard pocket calculators type 41CV and CX, and contains all essential arithmetic programs for field balancing of rotors. The use of the programs is described in detail in this manual. For details regarding the measurement of unbalance vibrations, and theoretical aspects on field balancing, please refer to the operating manual of the balancing instrument.

By inserting the SCHENCK CAB 41 module, the HP 41 pocket calculator can be converted into a specialist instrument for field balancing. Each of the program modules to be inserted in the calculator comes with an interchangeable overlay on which the names of the different keys are marked either above, or to the left of the corresponding key (see Fig. 1).

<u>The program data of the CAB 41 module are permanently recorded in the module. They cannot be deleted, nor can the CAB 41 module lose its memory.</u>



Once the CAB 41 balancing module has been inserted into one of the four slots of the calculator, it is automatically ready for operation (USER mode), and the dialog program for balancing can be started immediately.

When the calculator has been switched on, an arbitrary number will be displayed, along with the message "USER".

If the battery charge is getting too low, the message "BAT" will be displayed additionally.

I m p o r t a n t:

Always switch off the pocket calculator before inserting the module. Failure to do so may cause damage to the calculator as well as the module.

Fig. 1: HP 41 pocket calculator with SCHENCK CAB 41 balancing module.

2. PROGRAMS

The SCHENCK CAB 41 module contains the following programs:

Balancing programs

- Single-plane balancing
- 2-plane balancing
- 3-plane balancing
  isotropic and anisotropic rotors
- 4-plane balancing
  isotropic and anisotropic rotors
- Inspection run program for 1, 2, 3 and 4 planes

Output programs

- Distribution of the unbalance correction weight to fixed locations
- Calculation of the splitting angle of 2, 3 and 4 defined correction weights (e.g. for balancing grinding wheels)
- Input and output of influence coefficients

Subroutines

- Addition of several correction weights
- Calculation of centrifugal force
- Calculation of belt speeds

Dialog language

- German
- Englisch
- French

3. DESCRIPTION OF FUNCTION KEYS

Selection of dialog language

GERM	German
ENGL	English
FRENCH	French

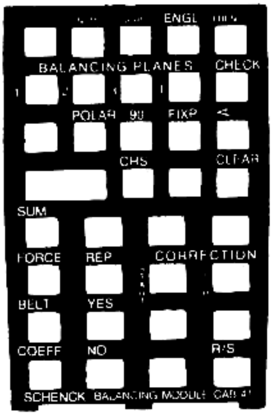


Fig. 2: Labelling of function keys - CAB 41 (English)

Selection of balancing programs:

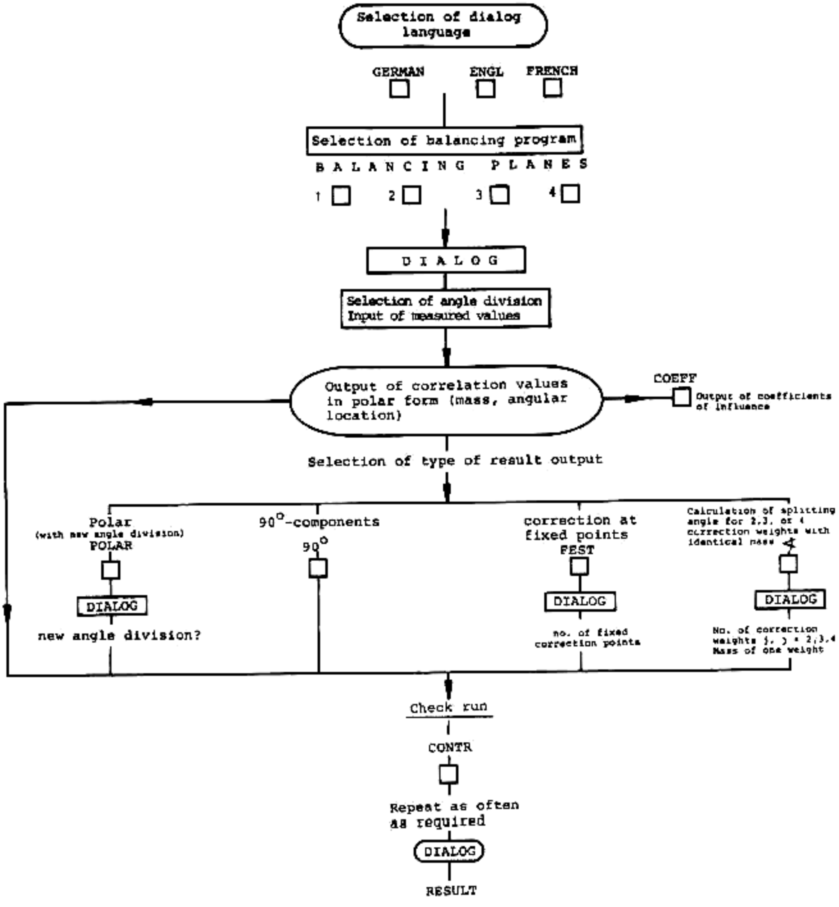
UNBALANCE CORRECTION PLANES

1	1-plane balancing
2	2-plane balancing
3	3-plane balancing
4	4-plane balancing

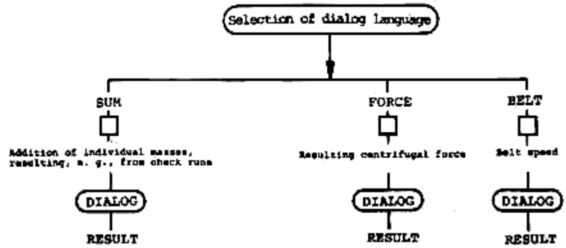
Selection of subroutines and additional functions:

CHECK	Check run for subsequent inspection
POLAR	Polar correction (mass and phase angle)
90°	Unbalance correction in a system with components arranged at 90 ° (X- and Y-components)
FIXP	Distribution of unbalance correction weight to fixed locations
∢	Calculation of the splitting angle of existing correction weights
CHS	Alteration of arithmetic sign for data input
CLEAR	Deletion of characters entered (possible only prior to operation of R/S key)
SUM	Addition of several correction weights
FORCE	Calculation of centrifugal force resulting from the weight attached.
REP	Repetition of result (text and number).
BELT	Calculation of the belt speed
YES	YES command during the dialog program
COEFF	Input/output of influence coefficients
NO	NO command during the dialog program
RUN/STOP	Start/stop command
CORRECTION	Correction of faulty values already stored in the calculator
START	Input of the new value
STOP	Abortion of correction program

Fig. 3 **Flow Chart for Field Balancing**



Auxiliary programs



5. SINGLE-PLANE FIELD BALANCING

To eliminate the unbalance of a rotor, the symmetry of its mass has to be restored by adding or removing rotor mass.

In accordance with the distinction between static and couple (or dynamic) unbalance, we are also talking of static and dynamic balancing. Static balancing eliminates only the static portion of the rotor's unbalance. This is, in general, sufficient in the case of narrow rotors rotating without axial runout. The static unbalance of a rotor can be eliminated by mass correction in one radial rotor plane.

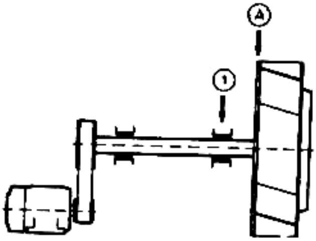


Fig. 4: Unbalance vibrations of a blower are measured at the bearing (1) ("measuring point") and the unbalance determined is corrected in the plane of the center of gravity A ("balancing plane").

The balancing process includes two measuring runs and an inspection run.

Measuring run 1, Initial run (UU):

The rotor is accelerated to service speed. Amount and angular position of unbalance vibrations are measured at one measuring point, with the help of a balancing instrument.

Measuring run 2, Trial run (T1):

A test weight is attached in the rotor's balancing plane, or an existing weight is removed. (In the latter case, enter weight mass value with minus sign.)
The rotor is once more accelerated to service speed (same speed as in measuring run 1), and measurement of amount and angular position of unbalance vibrations is repeated.

Depending on the program selected, the trial weight can either be removed from the rotor or left in place.

The measurement values obtained during measuring runs 1 and 2, i.e., in each case, amount and angular position of unbalance vibrations, the magnitude of the trial weight and the place at which it was attached are then keyed into the calculator. The evaluation program then calculates the required unbalance correction weight and the location at which it has to be attached.

Check run: (CONTR)

When the correction weight has been attached, the rotor is once more accelerated to service speed, and unbalance vibrations are measured once more.

If these unbalance vibrations are still too large, an additional correction is required. The results of the check run can be entered directly into the calculator, without any new trial runs being required.

These additional corrections can be performed as often as required, until the specified tolerances have been reached.

5.1 Example

A disc-shaped blower wheel is to be balanced in-situ, and with a single balancing plane. The circumference of the rotor is marked with angle divisions of 0 to 360 °.

The measurement values obtained during the initial run and the trial run are shown in the table below:

	Magnitude	Angle
Initial unbalance	12 mm/s	40°
Trial run Trial weight of 10 g at 0°	14 mm/s	120°

The "Single-plane Balancing" Program calculates the unbalance correction weight and the location at which unbalance correction has to be performed:

Operation of the calculator

Sequence of keys	Readout	Indication
ON	WORKING	Calculator switched on
	0.0 USER	Arbitrary numerical value
ENGL	COPYRIGHT BY SCHENCK	Selection of dialogue
	CHOOSE PROG.	Selection of correction planes
1	ANGLE DIV. =?	1-plane balancing Angle division
360	3 6 0	
R/S	IR:AMPL. A = ?	Unbalance amplitude
12	1 2	Measured amplitude of initial unbalance
R/S	IR:ANGLE A =?	Angular position of initial unbalance
40	4 0	Value measured for initial unbalance
R/S	T1:MASS A = ?	Trial weight
10	1 0	Selected mass
R/S	T1:LOCAT. A =?	Location of trial weight
0	0	Trial weight applied, in this instance, at 0°
R/S	T1:AMPL. A = ?	Amplitude measured during trial run

Sequence of keys	Readout	Indication
14	1 4	Value measured in 2nd measuring run
R/S	T1:ANGLE A =?	Angular position of unbalance determined during trial run
120	1 2 0	Value measured in 2nd measuring run
R/S	T1:MASS PERM ?	Is the trial weight to remain on the rotor ?
NO	0	Answer yes/no; in this instance: NO
R/S	CORRECTION	Is a correction of input data required?
NO	0	Answer yes or no; in this instance: NO
R/S		

The calculator then automatically processes the program. On completion of the calculations, the calculator outputs an acoustic signal and displays the result.

Output:

Sequence of keys	Readout	
	MASS A =	Is displayed for a short period only
	7.15	Correction mass
R/S	LOCAT. A =	Is displayed for a short period only
	55.24	Location at which the correction mass has to be attached.

Result:

A correction mass of 7.15 g has to be attached at 55.24 °.

The nature of the value displayed as result is only displayed temporarily, and changes automatically to the respective numerical value. To ascertain what sort of value is being displayed, the last result displayed can be reproduced as often as desired, by actuating the following keys.

Sequence of keys	Readout
	7.15
[REP] [R/S]	MASS A = 7.15
[R/S]	Next result

6. TWO-PLANE FIELD BALANCING

In the case of long, cyclindrical rotors, couple unbalance cannot be neglected. In general, such rotors require dynamic balancing.

Dynamic or couple unbalance of a rigid rotor is corrected by altering the distribution of its mass in two radial planes.

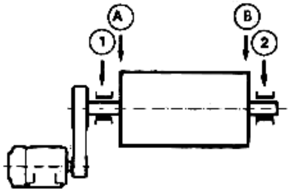


FIG. 5: General design principle of a centrifuge.Unbalance vibrations are measured at the two bearings (1) and (2). Unbalance correction is performed at the two end planes A and B of the rotor by addition or removal of mass.

Typical rotors which almost without exception require dynamic two-plane balancing are:

electric armatures, generator rotors, compressor rotors, turbine rotors, pump impellers, wide fan wheels, grinding cylinders, centrifuge drums, beaters, spindles etc.

The balancing procedure in general comprises three measuring runs and a check run.

1st measuring run initial run (UU):

The rotor is accelerated to service speed. With the help of the balancer, magnitude and angular position of unbalance vibrations are measured at two points.

2nd measuring run 1st trial run (T1):

A trial weight A is attached to the rotor in correction plane A. The rotor is once more accelerated to service speed (same speed as during the first measuring run) and unbalance vibrations are measured once again at the same two measurement positions.

3rd measuring run 2nd trial run (T2):

The trial weight in balancing plane A is removed and a trial weight is applied in balancing plane B. The rotor is once more accelerated to service speed and the unbalance vibration at the two measuring points are measured.

The trial weight in balancing plane B is removed.

Measurement values resulting from the measuring runs 1, 2 and 3, i.e., in each case, magnitude and angular position of unbalance, are keyed into the calculator. The program then calculates, for the two correction planes, the correction weight and the location at which unbalance correction has to be performed.

The two calculated correction weights are then attached to the rotor.

Check run: (CONTR)

When the correction weights have been attached, the rotor is once more accelerated to service speed.

Unbalance vibrations are measured at the same two measuring points.

In the event that the unbalance vibrations measured are still too high, an additional correction is required. The results obtained in the check run can be used directly for calculating the additional correction weights, without any new trial runs being required.

These additional corrections can be repeated as often as desired, until the specified tolerances have been reached.

6.1 Example

A generator rotor is to be balanced in-situ, with two balancing planes and with the help of balancing instrument. Angle divisions of 0 to 360 ° are marked on the rotor.

Measurement values obtained during the initial run and the two trial runs are shown in the table below:

	Plane A		Plane B	
	Magnitude	Angle	Magnitude	Angle
Initial unbalance	150 mm/s	340°	135 mm/s	333°
1st trial run with 200 g trial weight at 90° in Plane A	100 mm/s	336°	115 mm/s	308°
2nd trial run with 150 g trial weight at 180° in Plane B	110 mm/s	202°	45 mm/s	243°

Operation of the calculator

Sequence of keys	Readout	Indication
ON	WORKING	Calculator switched on
	0.0 USER	Arbitrary numerical value
ENGL	COPYRIGHT BY SCHENCK	Selection of dialogue language
	SELECT PROG	Selection of correction planes
2	ANGLE DIV.= ?	2-plane balancing Angle division
360	3 6 0	
R/S	IR:AMPL A = ?	Unbalance amplitude
150	1 5 0	Measured amplitude of initial unbalance, Plane A
R/S	IR:ANGLE A =?	Angular position of initial unbalance, Plane A
304	3 0 4	Meas. angular position of initial unbalance

.
.
.

All further data are keyed into the calculator as prompted by the program.

.
.
.

45	4 5	Value measured in 2nd trial run Plane B
R/S	T2:ANGLE B = ?	Angular position of unbalance measured in plane B
243	2 4 3	Value measured in 2nd trial run, Plane B

Sequence of keys	Readout	Indication
R/S	T2:MASS PERM.?	Is the trial weight in plane B to remain on the rotor ?
NO	0	Answer yes/no, in this instance: NO
R/S	CORRECTION?	Is a correction of input data required?
NO	0	Answer yes or no: in this instance: NO
R/S		

The calculator automatically processes the program. On completion of the calculations, the calculator outputs an acoustic signal and displays the result.

Output:

	MASS A 86.2	Correction mass for plane A
R/S	LOCAT. A 33.5	Location of correction mass for Plane A
R/S	MASS B 116.	Correction mass for plane B
R/S	LOCAT.B	Location of correction mass for Plane B

Result:

A correction weight of 86.2 g has to be attached at 33.5° in balancing plane A.
A correction weight of 116.2 g at 161.3 ° is required in balancing plane B.

The nature of the value displayed as a result is only displayed temporarily, and changes automatically to the respective numerical value. To ascertain what sort of value is being displayed, the last result displayed can be reproduced as often as desired, by actuating the following keys.

	86.2	Numerical value of result
REP R/S	MASS A 86.2	Repetition of result
R/S		Next result

7. Multiplane field balancing

7.1 Fundamentals

7.1.1 Multi-plane balancing of rigid rotors

The state of balance and the vibratory behaviour of rotor systems mounted on multiple bearings can be systematically improved by multi-plane in-situ balancing. To perform unbalance correction, one balancing plane has to be allocated to each bearing position. Hence, a rotor mounted on four bearings, as shown in Figure 6, requires 4 balancing planes.

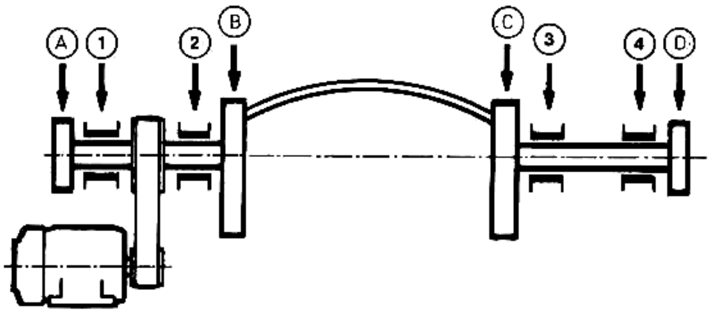


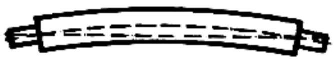
Fig. 6.: Basic design principle of the rotating parts of a stranding machine. Balancing planes A, B, C, and D are allocated to the measuring positions (1) to (4).

Typical examples of machines of this class are machines for the production of wire ropes, cables and stranded wire. Such machines feature rotor systems mounted on multiple bearings, consisting of two or more rotor sections which are in a fixed angular relationship with each other. Multi-plane balancing differs from two-plane balancing only in the number of trial runs and the way in which the measured results are processed.

To balance, for example, a rigid rotor similar to the one shown in Figure 6, the "4-plane balancing" program has to be called. The measured values are then fed into the calculator as prompted in the dialogue.

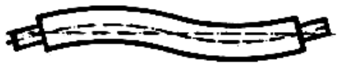
7.1.2 Multi-plane balancing of flexible rotors

A rotor can be regarded as rigid if, once it has reached a stable condition, this condition is maintained at various speeds and for different bearing conditions. If its running condition changes as a function of speed, or - often neglected - as a function of different bearing conditions - the rotor is considered as being flexible. Balancing of flexible rotors requires unbalance correction in 3, 4 or more planes, depending on which of its flexural modes become effective at its service speed.



a) Flexural of a rol at the first critical speed

3-plane problem



b) Flexural of a rol at the second critical speed

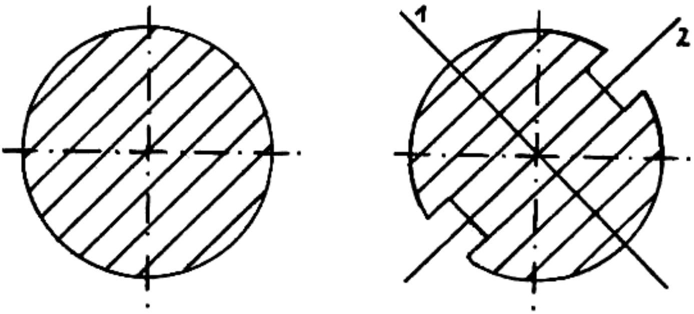
4-plane problem

FIG. 7 : Flexural modes

The arithmetic program determines correction weights and angular locations for 1, 2, 3 or 4 balancing planes for flexible rotors with isotropic or anisotropic stiffness (Figs. 8a and 8b).

Depending on the number of different unbalance conditions to be influenced, the number of trial runs with trial weights, at which unbalance vibrations have to be measured, may vary.

During each trial run, only one trial weight is applied in a correction plane. For isotropic rotors, the number of trial runs required equals the number of balancing planes or rotor conditions. For anisotropic rotors, it is twice that number, whereby the trial weights have to be attached in each of the principal axes (cf. Fig. 8).



1,2 - principal axes

a) isotropic b) anisotropic

FIG. 8: Example of isotropic and anisotropic rotor

7.2 Recommendations for field balancing of flexible rotors

The service speed of the isotropic rotor shown in Fig. 9 is in the vicinity of its second critical speed. The flexure of the flexible rotor at service speed is shown in Fig. 7b. To balance this rotor correction weights have to be applied in four balancing planes.

To determine the correction weights required and the location at which they have to be attached, measurements have to be performed at three different balancing speeds.

Speed n_1 = low-speed balancing of the rotor still in its rigid condition

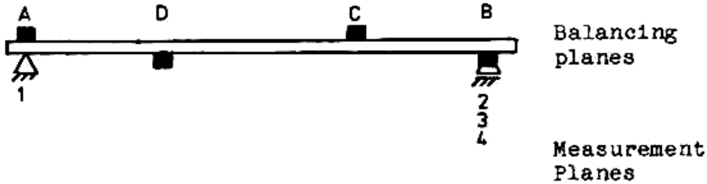
Speed n_2 = high-speed balancing of the deformed rotor, 1st flexural mode.

Speed n_3 = high-speed balancing of the deformed rotor, 2nd flexural mode

The first speed should be as low as possible ($<$ 50 % of the 1st critical bending speed), to prevent the effects of the internal bending moments causing a measurable deformation of the rotor.

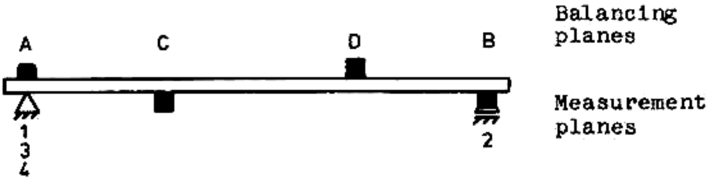
The 2nd balancing speed should definitely be in the bending range of the rotor (1st flexural mode), so that the internal bending moments will result in a measurable deformation of the rotor. The third balancing speed should be in the vicinity of the 2nd flexural mode.

(a)



or

(b)



7.3 FOUR-PLANE BALANCING

7.3.1 Measuring sequence: (4-plane, isotropic rotor)

Measuring run 1 (UU)
Measure magnitude and angular position of unbalance vibrations at subcritical speed (n_1) at measuring points 1 and 2 (initial run).

Measuring run 2 (UU)
Increase rotor speed to a speed in the vicinity of the first critical bending speed (n_2). Measure magnitude and angular position at measuring points 1 or 2. It is advisable to select that measuring position with the maximum change as against the first measurement. The measuring point thus selected is designated measuring point 3.

Measuring run 3 (UU)
Increase rotor speed to a value in the vicinity of the 2nd critical bending speed (n_3). Measure magnitude and angular position of unbalance at measuring points 1 or 2. It is advisable to select that measuring position with the maximum change as against the first and second measurements. This measuring point is designated measuring point 4.

Measuring run 4 (T1)
Fasten a trial weight in balancing plane A and measure magnitude and angular position of unbalance at subcritical speed (n_1) at measuring points 1 and 2. Increase the speed to a value in the vicinity of the first critical bending speed (n_2) and measure unbalance vibrations at measuring point 3. Increase speed to a value near the second critical bending speed (n_3) and measure unbalance vibrations at measuring point 4. Remove the trial weight

Measuring run 5 (T2)
Apply a trial weight in balancing plane B and proceed as described under item 4 above.

Measuring run 6 (T3)
Apply a trial weight in balancing plane C and proceed as described under item 4 above.

Measuring run 7 (T4)
Apply a trial weight in balancing plane D and proceed as described under item 4 above.

Call up the program "4-PLANE BALANCING" and enter the measurement values obtained in the order prompted by the dialogue.

7.3.2 <u>Example</u>: 4-plane balancing, isotropic rotor

Sequence of keys	Readout	
ON	WORKING 0.0 USER	Calculator switched on
ENGL	COPYRIGHT BY SCHENCK	Selection of dialogue language
	CHOOSE PROG.	Selection of balancing planes
4	ANISOTROP. ?	Is the rotor anisotropic ?
NO	0	
R/S	ANGLE DIV. = ?	
360	3 6 0	Angle division
R/S	IR:AMPL A = ?	Unbalance amplitude, plane A
12	1 2	Measured value, plane A, 1st measuring run
R/S	IR:ANGLE A =?	Angular position of initial unbalance, plane A
40	4 0	Measured value, plane A, 1st measuring run
R/S	IR:AMPL B =?	Unbalance amplitude, plane B

All further measuremment data for planes C and D are fed in analogously, in the order prompted by the calculator in the dialogue with the user.

The calculator then processes the program. On completion of the calculations, it outputs an acoustic signal and displays the result.

	MASS A = 22.5	Correction mass for plane A
[R/S]	LOCAT. A = 304.4	Location of correction mass for plane A

The remaining results are output by actuating the R/S key.

The nature of the result displayed, e.g. MASS A, is only displayed temporarily, and changes automatically to the respective numerical value. To ascertain what sort of value is being displayed, the last result displayed can be reproduced as often as desired, by actuating the following keys:

Sequence of keys	Readout	Indication
	22.5	Numerical result
[REP] [R/S]	MASS A = 22.5	Repetition of result
[R/S]		Next result

7.3.3 Recommendations for balancing anisotropic rotors

For anisotropic rotors, as shown in FIG. 8b, the number of trial runs is twice that for isotropic rotors. The trial weights have to be applied consecutively in the four principal axes, which are offset by 90°.

N.B.: The trial weights may be applied only in the principal axes.

7.3.4 Example: 4-plane balancing, anisotropic rotor

Sequence of keys	Readout	Indication
	CHOOSE PROG.	
4	ANISOTROP. ?	Is the rotor anisotropic ?
[YES]	1	Answer yes/no, in this instance: YES
[R/S]	ANGLE DIV = ?	
360	3 6 0	Angle division
[R/S]	IR:AMPL A = ?	Unbalance amplitude, plane A
28	2 8	Measured amplitude, plane A, 1st measuring run

Input of magnitude and angular position of unbalance vibrations at subcritical speed, for measurement positions A to D. Subsequently, apply a trial weight in measurement plane A, in the first principal axis and enter the measured values for the different measurement positions in succession. Remove trial weight from the first measurement plane, and attach it in planes B, C and D successively, in each case in the first principal axes. Feed the measured data into the calculator.

Sequence of keys	Readout	Indication
[R/S]		
	T1:MASS A = ?	Mass of trial weight
56	5 6	Trial weight, Plane A
[R/S]	T1:LOCAT.A = ?	Location of trial weight
140	1 4 0	1st principal axis, plane A
[R/S]	T1:AMPL. A =?	Amplitude measured during trial run

Input of amplitudes and angular positions for measurement planes B, C, and D is performed analogously.

The trial weight is now attached in the second principal axis, successively in planes A, B, C, and D. To distinguish the new values from those obtained with the trial weight attached in the 1st principal axis, these values are identified A, / B, / C, / D,. The measured values are then entered as prompted in the dialogue with the user.

Sequence of keys	Readout	Indication
	T1:AMPL A, = ?	Amplitude of unbalance, plane A, trial run 1.
25	2 5	Value measured for plane A, 1st trial run
R/S	T1:ANGLE A, = ?	Angular position of unbalance, plane A, 1st trial run
230	2 3 0	Value measured for plane A, 1st trial run

Output of correction values takes place in the same way as for isotropic rotors.

7.4 Recommendations for 3-plane field balancing

Measurement and balancing planes and possible measurement positions for 3-plane balancing are shown schematically in FIG. 10.

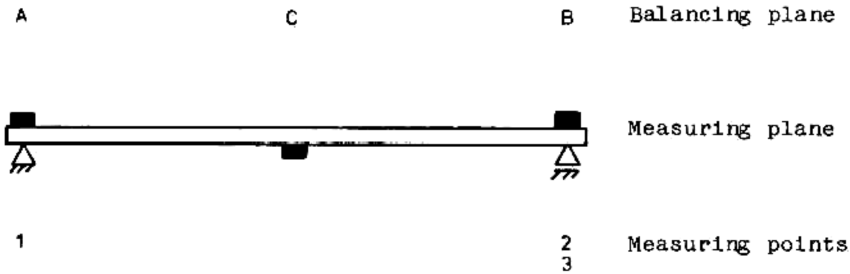


FIG. 10: Balancing planes and measurement planes for 3-plane balancing of a rotor.

A detailed description of the operation of the calculator will not be given in this manual, since the operation is basically the same as for 4-plane balancing, with the exception that plane D is omitted.

8. CORRECTION PROGRAM; INTERMEDIATE CALCULATIONS

8.1 Input in X- and Y- components.

In the preceding examples, it has always been assumed that the measured unbalance data is displayed by the balancer in the form of amount and angular position. If, however, the balancer displays the unbalance vibrations decomposed into X- and Y- components, these measurement values can be fed in directly, after pushing the following keys:

BALANCING PLANES

yellow	1 [ ]	(for 1 balancing plane)
yellow	2 [ ]	(for 2 balancing planes)

etc.

8.2 Correction of inputs

a) During any dialog program, input errors can be corrected by pressing the deletion key (CLEAR), following which the correct values can be entered. This, however, applies only if the input procedure has not yet been finished off by pressing the R/S key.

b) During the dialog of a main program (1-, 2-, 3-, or 4-plane Field Balancing), input errors already fed into the computer by the R/S command, can be corrected.

At the end of each balancing program, a question regarding corrections is output, which has to be answered by typing either yes or no. If the command is yes, input of the corrected word will be requested.

The input data are then displayed in the order in which they were entered, and the input data can then be compared to the measured data.

When the point at which the correction is to be made has been reached, press START and R/S, and then enter the new value. The correction dialogue can then be continued, if further corrections have to be made, or aborted by pressing the STOP key. A correction of the angle division is not possible, and would not be meaningful, since the angle division can be changed by the output program after calculation. This will be illustrated in one of the following sections, using the example of single-plane balancing (5.2).

Example

Following input of the measured values, the display of the pocket calculator reads "CORRECTION?"

Sequence of keys	Readout	Indication
	CORRECTION?	Have all values been fed in correctly, or are corrections required?
[YES]	1	YES/NO, in this instance: yes
[R/S]	ANGLE DIV. = 360	) Go through the program by pressing the R/S key until the value to be corrected has been reached.
[R/S]	IR:AMPL A = 12.00	)
[R/S]	IR:ANGLE A =	)
[R/S]	T1:MASS A = 10.00	This value is incorrect and has to be corrected
[START]	5	Start correction program
[R/S]	NEW VALUE = ?	Enter correct value.
20	2 0	The correct value is 20
[R/S]	T1:LOCAT. A = 0.00	Next value

The correction program can be aborted by pressing the [STOP] key.

	6	End of correction program.
[R/S]	CORRECTION	Re-call correction program ?
[NO]	0	Answer yes/no, in this instance : NO.

Continue input or give [R/S] command for display of the result.

9. Subsequent correction of balancing result

If the balancing result obtained is still unsatisfactory, i.e. if the unbalance vibrations are still too high, a subsequent additional correction will be required. For this purpose, the module is provided with the subroutine "CHECK", which enables the values obtained during the check run to be fed into the calculator directly, without any new trial runs being required, provided that the values of the last field balancing procedure are still stored in the memory of the calculator.

Sequence of keys	Readout	Indication
[CHECK]	CR:AMPL. A= ?	
3.2	3.2	Measured value
[R/S]	CR:LOC. A = ?	
135	1 3 5	Measured value
[R/S]	CORRECTION ?	
[NO]	0	Answer yes/no, in this instance : NO
[R/S]	MASS A = 1.91	Correction value obtained after check run
[R/S]	LOCAT. A = 150.24	Location of correction weight obtained in check run.

The calculated additional correction mass is attached at the specified location. Here too, the last result can be re-called as often as desired.

These corrections can be continued as often as required, until the specified tolerances have been reached.

10. OUTPUT VARIANTS

Example : 1-plane field balancing

10.1 POLAR

Output of correction values in polar form

with a new angle division, repetition of the entire calculation procedure.

Sequence of keys	Readout	Indication
POLAR	ANGLE DIV. = ?	
8	8	Input old/new value e.g. 8
R/S	MASS A = 7.15	
R/S	LOCAT. A = 1.23	

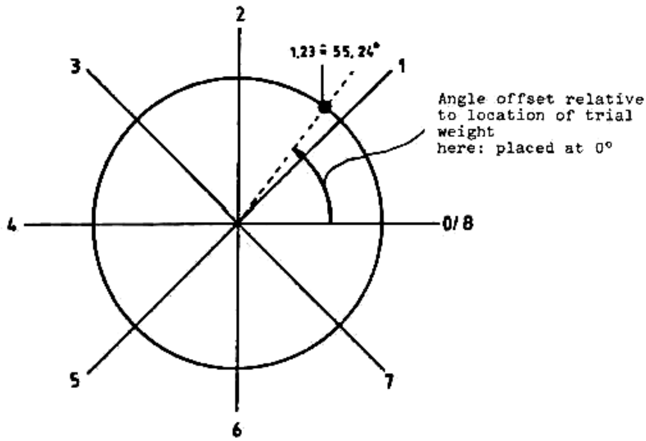


FIG. 11: Example for angle division 8

10.2 90°

Output of correction values in the form of 90°-components

If a rotor is provided with 4 holes arranged at right angles for fastening correction weights, the correction weight and its angular location, calculated in polar form, can be distributed over two correction weights.

Sequence of keys	Readout
90°	X-MASS A = 4.08
R/S	Y-MASS A = 5.87

If the numerical value is provided with a negative sign, the weights have to be attached at the respective negative axes.

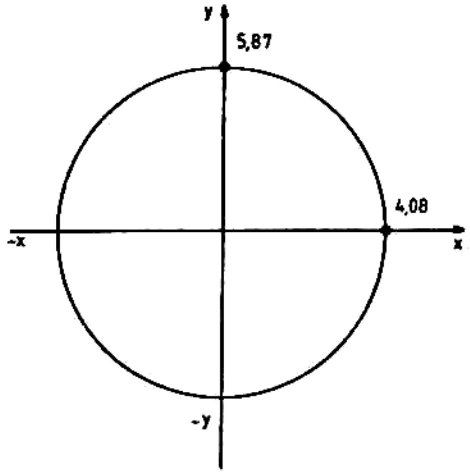


FIG. 12: Example of unbalance correction in 90 ° components, with X/Y output.

10.3 FIXED LOCATIONS

Output of correction values for pre-determined, fixed locations

If the rotor has, e.g., 8 equally spaced locations for unbalance correction (as, for example, in the case of fan blades), the correction weight calculated for polar correction can be distributed over two adjacent correction locations.

Sequence of keys	Readout	Indication
FIXP	CORR. POINTS ?	
8	8	No. of correction points
R/S	MASS A1 = 5.77	First correction value
R/S	LOCAT. A1 = 1.00	Location for 1st correction mass
R/S	MASS A2 = 1.80	2nd correction value
R/S	LOCAT.A2 = 2.00	Location for 2nd correction mass

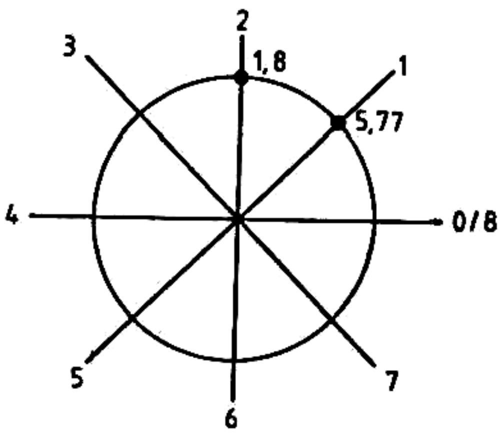


FIG. 13: Example of unbalance correction at fixed locations, with angle division 8

10.4 ∢

Unbalance correction by calculation of the splitting angle of existing correction weights of equal mass

- Balancing of grinding wheels -

To determine the initial unbalance, the "balancing weights" are arranged so as to cancel eachother, i.e. two weights are arranged at 180° opposite eachother, 3 weights at 120°, and 4 weights at 90°. Subsequently, two weights are displaced so as to act as trial weights.

After the trial runs, the locations of the defined balancing weights can be determined from the polar result.

Sequence of keys	Readout	Indication
	NO.BAL.WTS = ?	
3	3	Enter the number of balancing weights: 2, 3, or 4
R/S	MASS BAL.WT.=?	Enter the mass of one balancing weight
5	5	
R/S	LOCAT. A1 = 325.69	Location 1
R/S	LOCAT. A2 = 144.78	Location 2
R/S	LOCAT. A3 = 10.24	Location 3

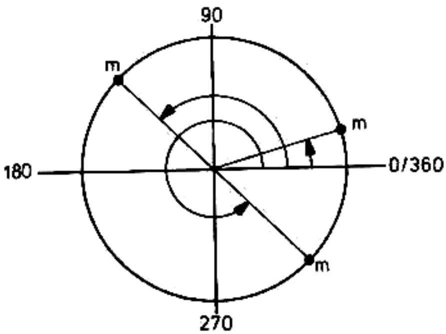


FIG. 14: Example for Angle Spreading at 3 Balancing Planes

10.5 SUM

Addition of several correction weights

The SUM (summing) subroutine enables the addition of several correction masses applied at different locations to obtain a single mass at a single location. This is an operation which is frequently desirable after the additional, subsequent unbalance corrections described under item 9.5 have been performed.

Sequence of keys	Readout	Indication
[SUM]	ANGLE DIV. = ?	Angle division
360	3 6 0	
[R/S]	MASS 1 = ?	
1.91		Correction mass obtained during field balancing
[R/S]	LOCAT. 1 = ?	Location of mass 1
150.24	1 5 0.2 4	
[R/S]	MASS 2 = ?	Mass obtained during subsequent correction
7.15	7.1 5	
[R/S]	LOCAT. 2 = ?	Location of 2nd mass
55.24	5 5.2 4	
[R/S]	MASS 3 = ?	
[R/S]		End

If there is no further mass, the program is started dirctly by the R/S command. The number of masses is not limited. Input is ended by mass = 0 or angle = 0.

	MASS = 7.24	Summed-up correction masses
[R/S]	LOCAT. = 7 0.4 8	Location of summed-up correction weight

11. FORCE

Calculation of the centrifugal force

The program calculates the centrifugal force acting upon the fastening of the correction weight as a result of the mass attached to the rotor, the correction radius and the rotor speed.

This information is particularly important in the case of rotors turning at high speeds ($F_z \sim \omega^2$), to be able to determine the fastening method and calculate its strength.

Input in kg, meters and rpm:

Sequence of keys	Readout	Indication
[FORCE]	MASS/KG = ?	Mass of the weight to be attached to the rotor, in kg
0.5	0.5	0.5 kg
[R/S]	RADIUS/M = ?	Distance of the weight from the rotor's axis of rotation, in meters
0.3	0.3	0.3 m
[R/S]	REVOLUT./MIN ?	Rotor speed in revs per min
1500	1 5 0 0	1500 rpm
[R/S]	CENTR.FORCE/N 3701.10	Result: centrifugal force in Newton

Alternative: Input in ounces, inches and rpm:

[yellow FORCE]	MASS/OUNCE = ?	Mass of the weight to be attached to the rotor in ounces
17.64	1 7.6 4	17.64 ounces
[R/S]	RADIUS/INCH = ?	Distance of the mass from the radius in inches
11.81	1 1.8 1	11.81 inches
[R/S]	REVOLUT.MIN = ?	Rotor speed in revs per min.
1500	1 5 0 0	1500 rpm
[R/S]	CENTR.FORCE/N 3701.10	Result: Centrifugal force in Newton

12. BELT

Calculation of the belt speed

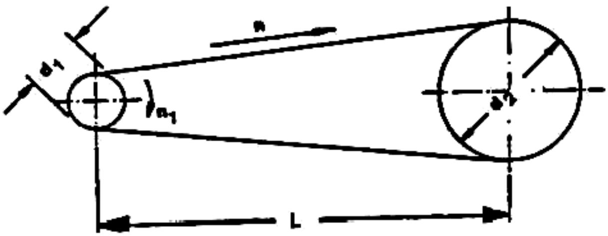
Within the framework of frequency analysis, the frequencies (i.e. the speeds) and the associated amplitudes of the component vibrations of a vibration mixture are determined.

It is often difficult to determine the source of excitation of a given component vibration, since the frequency of movement of the exciter is often unknown.

A typical example are vibrations caused by drive belts. Faulty drive belts are a frequent source of vibrations, whose frequencies correspond to the frequency of movement of the belt (i.e. the belt speed), or sometimes to twice the frequency of belt movement ($2 \times f_{belt}$).

The "BELT" subroutine is conceived such that it determines the belt speed exclusively on the basis of easily measured geometrical rotor data. The definition as to which of the belt pulleys is d1 or n1 is irrelevant.

Example 1:



Example 2:

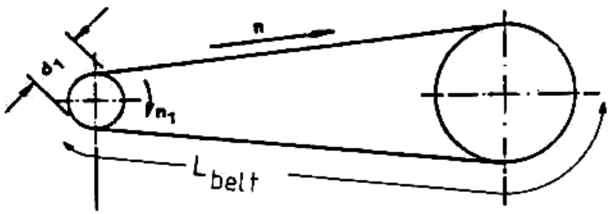


FIG.15: Parameters required for the calculation of the belt speed.

Example 1:

Sequence of keys	Readout	Indication
BELT	ROT.SPEED 1 = ?	Speed of 1st pulley
1500	1 5 0 0	
R/S	DIAMETER 1 = ?	Diameter of 1st pulley
100	1 0 0	
R/S	DIAMETER 2 = ?	Diameter of 2nd pulley
200	2 0 0	
R/S	1 - 2 DISTANCE?	Distance between pulleys
300	3 0 0	
R/S	BELT ROT.SPEED= 436.50	Belt speed
R/S	BELT LENGTH = 1 0 7 9.5 9	Length of belt

Example 2:

yellow BELT	ROT.SPEED 1 = ?	Speed of 1st pulley
1500	1 5 0 0	
R/S	DIAMETER 1 = ?	Diameter of 1st pulley
100	1 0 0	
R/S	BELT LENGTH.= ?	Length of belt
1080	1 0 8 0	
R/S	BELT ROT.SPEED= 436.33	Belt speed

13. COEFF

Repetitive balancing

13.1 Output/input of coefficients (influence factors)

Many rotors cannot be balanced once and for all, but have to be trim balanced at regular intervals. To simplify this trim balancing process, a simplified method of evaluation can be used, provided that the influence coefficients were recorded during initial balancing of the rotor. This repetitive balancing method can only be used if no changes have done to the machine in the meantime (such as removal and re-installation of the rotor, alterations to bearings, speed, etc.)

Following selection of the program and selection of the angular graduation, the influence coefficients have to be re-entered into the calculator. All further steps are the same as described for additional unbalance correction after field balancing (see cf. section 9).

On completion of a field balancing sequence, the influence coefficients obtained during this balancing procedure can be displayed or recorded on the following output devices:

Readout on display = output device No. 0
Recording by printer = output device No. 1
Recording by printer = output device No. 2
Recording on magnetic tape = output device No. 3

Output of the coefficients on printer, magnetic card and magnetic tape is possible on the appropriate Hewlett Packard supplementary device.

13.1.1 Output of the coefficients w i t h printer

Example:

Sequence of keys	Readout	Indication
[COEFF]	OUTP.DEVICE	Output device
1	1	Printer
[R/S]	PROBLEM NAME	for identification
PRO...FAN	PROCESS FAN 4 *)	
SPACE	[yellow] 4	
[R/S]		

*) Enter a maximum of 22 characters, e.g. PROCESS FAN 4 (13 characters), using the blue letters and symbols. The numbers are obtained by operating the yellow key. Where he HP digital cassette mechanism (accessory item) is employed, the name of the problem also serves as file name.

Example: Output and input of influence coefficients obtained during single-plane balancing of process fan 4.

13.1.2 Output of the coefficients on the display

In this case, the values can be recorded by writing them down.

Sequence of keys	Readout	Indication
COEFF	OUTP.DEVICE ?	
0	0	
R/S	D1 = 1.0	
R/S	D2 = 1.0	
R/S	D3 = 0.595857	
R/S	D4 = 15.23786	
R/S	0.0	End of output

13.1.3 Input of coefficients

To perform trim balancing, the coefficients have to be fed into the calculator. Input is performed immediately after the calculator has been switched on. As a result of the information content of the coefficients, the associated program is started immediately.

Input can be made in one of the following ways:

at the keyboard = input device No. 0 or No. 1
from magnetic card = input device No. 2
from magnetic tape = input device No. 3

Input of the coefficients for process fan 4

Sequence of keys	Readout	Indication
[ON]	0.00 USER	Calculator switched ON
[yellow] [COEFF]	INP. DEVICE ?	Select input device
0 or 1	0	Input 0 or 1; in this instance: "0"
[R/S]	D1 = ?	
1.0	1.0	
[R/S]	D2 = ?	
1.0	1.0	
[R/S]	D3 = ?	
0.595857	0.595857	
[R/S]	D4 = ?	
15.23786	15.23786	
[R/S]	CORRECTION ?	
[NO]	0	Answer yes/no, in this instance:NO
[R/S]	CR:AMP.A = ?	

The measured values are now entered in the dialogue program for single-plane field balancing, which should now be in progress:

Result:
Mass, angular position

Note: If a coefficient with a negative sign has to be entered, first change the numerical range by pushing the CHS key.

Sequence of keys	Readout	Indication
5 [CHS]	- 5	Reversal of arithmetic sign

14. ERROR CODES (specific to the balancing program)

Code	Cause	Remedy
101	No influence coefficients available	Feed in influence coefficients, if available
102	No balancing results available	Call up the corresponding balancing program and re-enter the appropriate values.
103	Weight, or no. of balancing weights too low to enable unbalance correction to be performed	Use heavier balancing weights or increase number of balancing weights
104	Distance between the two pulleys is less than the sum of the radii of the 2 pulleys.	Check the dimensions, re-enter the values.
105	Influence coefficient D1 = 0	Check wether D1 = 0; feed in again, if necessary.

Warning 11

In field balancing, from "2-PLANE BALANCING" onwards, "WARNING 11" may be displayed in the process of correction weight calculation.

"WARNING 11" conveys the message that the success of the balancing may be in jeopardy.

Typical initiation criterion:

A single-plane balancing problem is entered into the computer as a several-plane balancing problem.

In this case, the measured data for trial runs 1 and 2 are almost identical.

As the calculation of the correction weights and the locations of their application is based on the assumption that trial runs 1 and 2 yield measured data which are mutually independent, the calculated values may be incorrect on account of these linear relationships.

Action to be taken

In cases where "WARNING 11" is displayed:

- Check measured data for linearity and, where appropriate, use graphic representation of measured data (see description of graphic 2-plane balancing in operating instructions for balancing instruments).

  In general, a successful balancing result can then be achieved through single-plane balancing.

  As for "3-PLANE BALANCING" and "4-PLANE BALANCING", the same relationships apply.

  Here again check measured data for linearity and, where appropriate, reduce number of balancing planes.

ANNEX

The following pages show examples of print-outs received during processing of main programs and subroutines. Print-out of the data takes places synchronous with the readout on the calculator.

Data identified by *** are input data.

BALANCING. PLANE 2

```
2-PLANES BALANCING

ANGLE DIV. =?
        360.00   ***
IR: AMPL. A=?
         15.30   ***
IR: ANGLE A=?
         52.00   ***
IR: AMPL. B=?
         12.40   ***
IR: ANGLE B=?
        182.00   ***
T1: MASS A=?
         10.00   ***
T1: LOCAT. A=?
          0.00   ***
T1: AMPL. A=?
         17.50   ***
T1: ANGLE A=?
         99.00   ***
T1: AMPL. B=?
         10.50   ***
T1: ANGLE B=?
        210.00   ***
T1:MASS PERM.?
             0   ***
0 = NO
T2: MASS B=?
         10.00   ***
T2: LOCAT. B=?
          0.00   ***
T2: AMPL. A=?
         16.30   ***
T2: ANGLE A=?
         78.00   ***
T2: AMPL. B=?
         19.50   ***
T2: ANGLE B=?
        215.00   ***
T2:MASS PERM.?
             0   ***
0 = NO
CORRECTION?
             0   ***
0 = NO
CM =CONDIT.F.=0.640
```

Result

```
MASS A =
              8.20
LOCAT. A =
             66.35
MASS B =
              6.80
LOCAT. B =
            104.99
```

Output Variants

1) 90°

```
X-MASS A =
              3.29
Y-MASS A =
              7.51
X-MASS B =
             -1.76
Y-MASS B =
              6.56
```

2) FIXP

```
CORR. POINTS?
           8.00   ***
MASS A1 =
                  4.65
LOCAT. A1 =
                  1.00
MASS A2 =
                  4.22
LOCAT. A2 =
                  2.00
MASS B1 =
                  4.81
LOCAT. B1 =
                  2.00
MASS B2 =
                  2.49
LOCAT. B2 =
                  3.00
```

3) ∢

```
NO. BAL.WTS.=?
           2.00   ***
MASS BAL.WT.=?
         100.00   ***
LOCAT. A1 =
                338.70
LOCAT. A2 =
                154.00
LOCAT. B1 =
                 16.93
LOCAT. B2 =
                193.04
```

1a) SUM

```
ANGLE DIV. =?
           360.00    ***
MASS 1 =?
             5.80    ***
LOCAT. 1 =?
            88.00    ***
MASS 2 =?
             7.90    ***
LOCAT. 2 =?
           156.00    ***
MASS 3 =?
             9.50    ***
LOCAT. 3 =?
           354.00    ***
MASS 4 =?
             0.00    ***
MASS  =
                     8.38
LOCAT.  =
                    73.11
```

1b) yellow SUM

```
X-MASS 1 =?
             5.00    ***
Y-MASS 1 =?
             6.00    ***
X-MASS 2 =?
             7.00    ***
Y-MASS 2 =?
             8.00    ***
X-MASS 3 =?
             0.00    ***
Y-MASS 3 =?
             0.00    ***
X-MASS  =
                    12.00
Y-MASS  =
                    14.00
```

2a) COEFF

```
OUTP.DEVICE ?
             1.00    ***
PROBLEMNAME?
ROTOR

ROTOR
D1=2.0
D2=1.0
D3=1.07692
D4=-58.06073
D5=0.583875
D6=-247.597
D7=0.475137
D8=-90.38552
D9=0.922220
D10=36.78780
```

2b) yellow COEFF

```
INP. DEVICE ?
             1.00    ***

D1= ?
             1.00    ***
D2= ?
            45.00    ***
D3= ?
         0.617381    ***
D4= ?
          173.634    ***
CORRECTION?
                0    ***
0 = NO

1-PLANE  CORR. RUN

CR: AMPL. A=?
             5.00    ***
CR: ANGLE A=?
           125.00    ***
CORRECTION?
                0    ***
0 = NO

MASS A =
                     3.09
LOCAT. A =
                   112.86
```

3a) BELT

```
ROT.SPEED 1=?
         1000.00    ***
DIAMETER 1=?
          250.00    ***
DIAMETER 2=?
          380.00    ***
1-2DISTANCE?
          400.00    ***
BELTROT.SPEED
                 436.29
```

3b) yellow BELT

```
ROT.SPEED 1=?
         1500.00    ***
DIAMETER 1=?
          300.00    ***
BELTLENGTH=?
         1500.00    ***
BELTROT.SPEED
                 942.48
```

4a) FORCE

```
MASS/KG =?
          450.00    ***
RADIUS/M =?
            0.50    ***
REVOLUT./MIN?
         1500.00    ***
CENTR.FORCE/N
              5551652.42
```

4b) yellow FORCE

```
MASS/OUNCE?
          500.00    ***
RADIUS/INCH?
            5.00    ***
REVOLUT./MIN?
         3000.00    ***
CENTR.FORCE/N
               177675.08
```

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