User guide for the balancing spreadsheet *MiniBalance*

Peter G. Schild
SINTEF Building & Infrastructure, Norway
v.2018-08-10

Fig. 1 *MiniBalance spreadsheet on smartphone*

1 Functionality

MiniBalance is a tiny (hence its name) yet smart spreadsheet to assist balancing of air flows in mechanical ventilation systems, i.e. adjusting dampers and air terminal devices. It is a timesaving tool for HVAC/TABS contractors, using a smartphone, tablet or laptop. *MiniBalance* applies the accurate proportional method of balancing, in combination with other fluid dynamics theory.

Functions include:

- Built-in 'expertise' tells you what to do at any time. For example, it advises you which airflow or pressure setting to set, which can be especially time-saving if you are alone on the job. This function is self-learning, giving progressively better suggestions.
- Either "quick and approximate" or "slow and accurate" balancing is possible. Quick balancing involves fewer measurements and adjustments. See page 6.
- You may choose any terminal/damper as the reference for a balancing group, not necessarily the end damper/terminal. Nor do you have to use the same terminal as reference for the whole balancing group.
- It can handle different units of measurement when you use different measurement instruments at the air terminals or dampers in ventilation system. Units include cfm, ℓ/s, m³/h and pressure (by providing the *k*-factor for e.g. air terminals).
- *MiniBalance* works equally well with any fan curve, i.e. anything between constant pressure and constant volume.
- The spreadsheet can be printed out to serve as commissioning documentation.
- No software installation is needed. Simply open the small file in a spreadsheet application.
- The spreadsheet contains no macros. Instead, the calculations are done in formulae in cells in a hidden worksheet. It can thus be used on smartphones and imported into non-Microsoft spreadsheet applications.
- Column headings have popup comments (in English) that explain the meaning of the parameters in the column. This helps to make the spreadsheet self-explanatory.
- The spreadsheet layout is kept simple so that many columns can be viewed on small screens.
- The spreadsheet is limited to 50 dampers/terminals. This is so that it can be used on smartphones with slow processors. For large duct systems, simply use multiple copies of the spreadsheet file.
- Presently, 9 languages are supported. See the table in the appendix. The chosen interface language affects all headings and output, but not the popup comments.

2 Versions & updates

MiniBalance has been developed at SINTEF. The latest version is distributed at https://github.com/SchildCode together with this user guide.

MiniBalance can be opened in any application that can open Microsoft Office® Excel XLSX files. It can for example be opened in non-Microsoft spreadsheet applications such as OpenOffice (PC/linux/Mac), and spreadsheet apps designed for iPhone/iPad and Android hendheld devices.

3 Scope of this user guide

This user guide explains how to use the *MiniBalance* spreadsheet, with step-by-step examples.

It is highly recommended that you also read a good guidebook on commissioning/TAB (testing, adjusting & balancing) of duct systems, such as references [1] to [4]. The literature not only gives a good understanding of how to successfully apply the Proportional Method of balancing, but also other related issues such as proper preparation and measurement methods. AIVC Bibliography 11 [5] gives an overview of literature on the topic.

4 Glossary

See the table at the end of this paper for keywords translated into different languages.

Terminal: Air terminal device (e.g. supply diffuser or exhaust terminal / grille). Such devices should have a means of throttling (i.e. adjusting the flow resistance) that can be fixed after it has been adjusted.

Damper: In-duct device for throttling (adjusting flow resistance), such as butterfly device or adjustable iris orifice.

Group: A row or collection of air terminals or dampers that are balanced with each other, and for which their total flow rate is collectively adjusted by a common balancing damper (or fan) at the root of the duct. Examples of a balancing group are: a main duct with a string of branches each with a balancing damper, or a branch duct feeding a string of air terminals. For example, the red boxes in Fig. 2 are different balancing groups. At least one member of each group (the ‘critical’ one) should be left fully open.

Critical (C): This is the member of a balancing group that has the highest pressure drop between itself and the fan (also called the ‘critical path’). Critical terminals/dampers should therefore be left fully open (i.e. not throttled). See for example balancing group C in Fig. 2.

Reference (R): This is the terminal/damper in the group that is furthest from the fan, e.g. the last diffuser at the end of a duct. This is often also the group’s critical terminal/damper.

%Design: Is the measured flow rate though a terminal or damper as a percentage of the designed flow rate though the terminal/ damper. A group is balanced when all of its terminals/dampers have the same %design value.

$$\%Design = \frac{measured\ flow\ rate}{design\ flow\ rate} \times 100\%$$

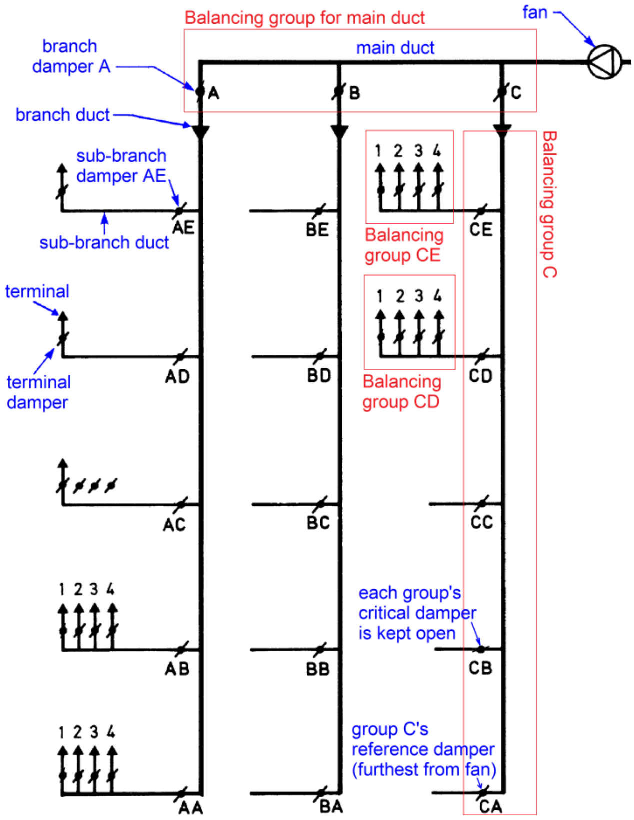


Fig. 2 *Schematic of supply duct system illustrating some glossary definitions*

PART 1: Step-by-step examples using *MiniBalance*

5 Simple duct with five terminals — Accurate balancing

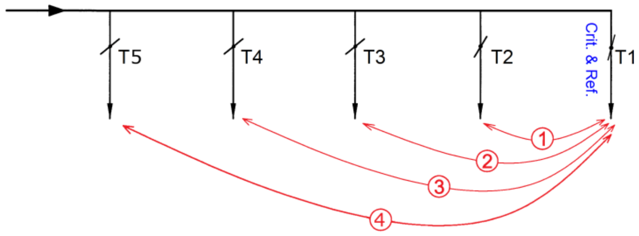


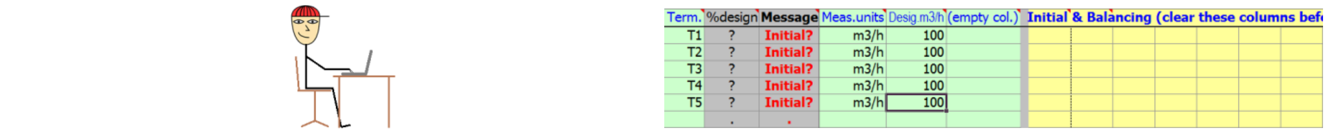
Fig. 3 *Schematic of simple duct with four terminals. Red arrows indicate order of balancing.*

Here we will illustrate the basic application of *MiniBalance* to accurately balance a group (or a 'string') of 5 terminals. Exactly the same principle is used when balancing any group, irrespective of whether it is a group of terminals or dampers, along any duct (a main duct, branch duct, or sub-branch duct etc.).

In this case (Fig. 3), the critical terminal is at the end of the duct, and is thus also the reference terminal. Terminals T2 to T5 are all balanced with the reference terminal (T1) in turn, as illustrated with the red numbered arrows.

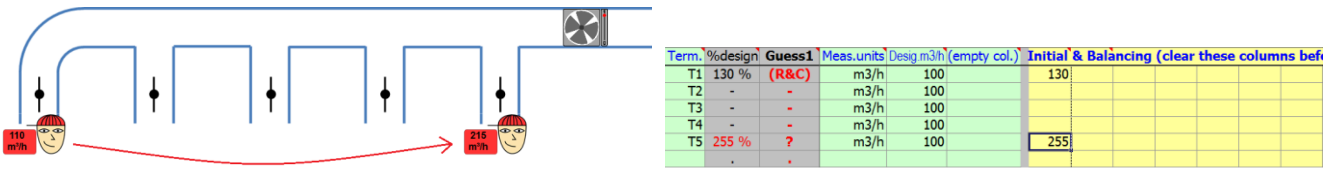
Below is shown *MiniBalance* screen-dumps from different steps in the balancing process:

ACTIVITY **_MINIBALANCE_ SCREEN VIEW**



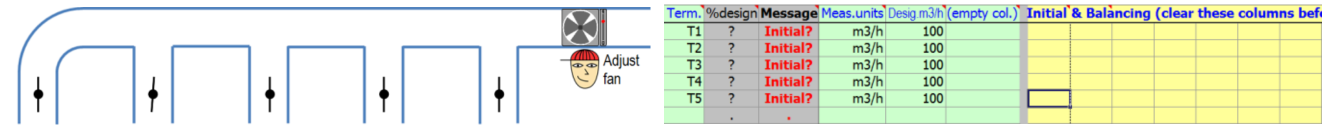
Term.	%design	Message	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns bef
T1	?	Initial?	m3/h	100		
T2	?	Initial?	m3/h	100		
T3	?	Initial?	m3/h	100		
T4	?	Initial?	m3/h	100		
T5	?	Initial?	m3/h	100		

Fig. 4 *The green columns can be filled out beforehand in the office. The message "*`Initial?`*" means that MiniBalance is waiting for initial measurements to be input.*



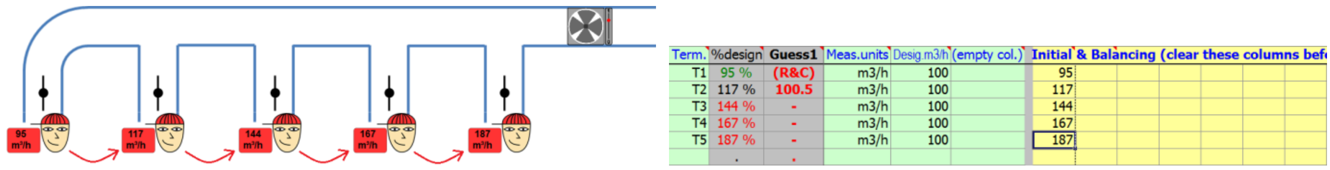
Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns bef
T1	130 %	(R&C)	m3/h	100		130
T2	-	-	m3/h	100		
T3	-	-	m3/h	100		
T4	-	-	m3/h	100		
T5	255 %	?	m3/h	100		255

Fig. 5 *On the building site, firstly all the terminals are fully opened. Then spot measurements of the first and last terminals are taken (first yellow column).These measurements indicate that the flow rate is too high for accurate balancing (reference terminal has 30% over design).*



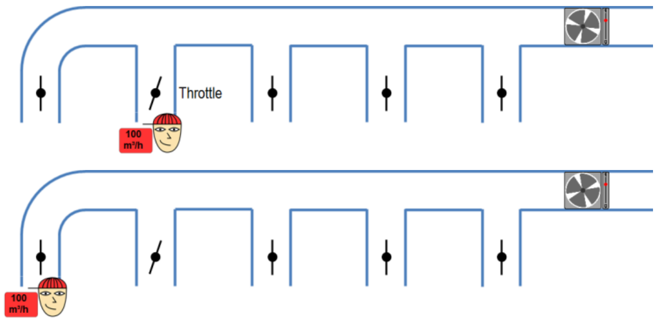
Term.	%design	Message	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns bef
T1	?	Initial?	m3/h	100		
T2	?	Initial?	m3/h	100		
T3	?	Initial?	m3/h	100		
T4	?	Initial?	m3/h	100		
T5	?	Initial?	m3/h	100		

Fig. 6 *Therefore the flow rate into the duct is reduced (e.g. by throttling the fan or the branch damper) and the measurements in the first column are cleared. In Excel, you can clear a whole column in one go by selecting the column header.*



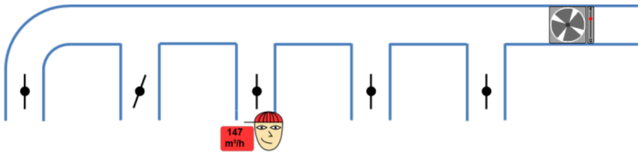
Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns bef
T1	95 %	(R&C)	m3/h	100		95
T2	117 %	100.5	m3/h	100		117
T3	144 %	-	m3/h	100		144
T4	167 %	-	m3/h	100		167
T5	187 %	-	m3/h	100		187

Fig. 7 *Complete initial measurements of all the terminals the group, this time with an acceptable flow rate (critical terminal is just below 100% of design). MiniBalance calculates that T1 is the critical terminal (i.e. the terminal with lowest % of design flow rate, 95%). In the grey message column, the text "*`(R&C)`*" means that terminal T1 is both the Reference terminal and Critical terminal. The text "*`100.5`*" in the same column suggests that T2 can be throttled to 100.5 m³/h. This is an approximate first guess ("*`Guess1`*").*



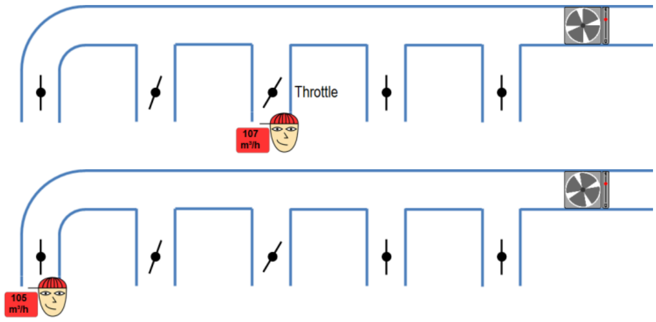
Term.	%design	Guess2	Meas.units	Desig m3/h	(empty col.)	Initial & Balancing (clear these columns bef			
T1	100 %	(R&C)	m3/h	100		95	100		
T2	100 %	100	m3/h	100		117	100		
T3	-	Next>	m3/h	100		144			
T4	-	-	m3/h	100		167			
T5	-	-	m3/h	100		187			

Fig. 8 *This is step ① in Fig. 3: T2 has now been manually throttled to approx. 100 m³/h. The flow rate in the reference terminal (T1) is also measured. The two measured values are entered in the spreadsheet. A new yellow column was used because the flow rates have been changed after throttling, and each column must contain simultaneous flow rates in terminals. Both terminals T1 and T2 now have the same %design value, i.e. they are balanced with each other. The message "*`Next>`*" means that MiniBalance therefore suggests that you go to the next terminal (T3) and measure its present value (without throttling it).*



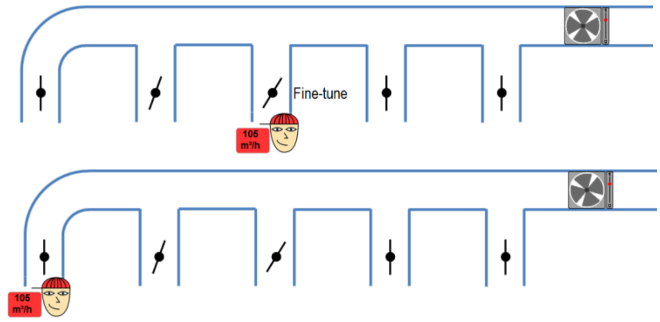
Term.	%design	Guess1	Meas.units	Desig m3/h	(empty col.)	Initial & Balancing (clear these columns bef			
T1	100 %	(R&C)	m3/h	100		95	100		
T2	100 %	-	m3/h	100		117	100		
T3	147 %	106.61	m3/h	100		144	147		
T4	-	-	m3/h	100		167			
T5	-	-	m3/h	100		187			

Fig. 9 *Terminal T3's flow rate has been measured and typed in. MiniBalance now suggests that it can be throttled to 106.61 m³/h. Obviously, one cannot adjust T3 to the precision of 2 decimal points, but somewhere near. The user can use their own judgement and experience to choose which value they want to adjust T3 to.*



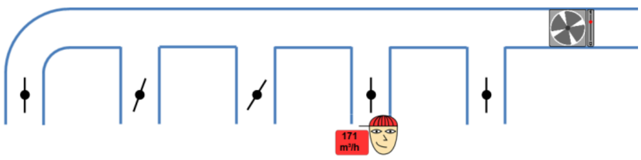
Term.	%design	Guess2	Meas.units	Desig m3/h	(empty col.)	Initial & Balancing (clear these columns bef			
T1	105 %	(R&C)	m3/h	100		95	100	105	
T2	-	-	m3/h	100		117	100		
T3	107 %	105.22	m3/h	100		144	147	107	
T4	-	Next>	m3/h	100		167			
T5	-	-	m3/h	100		187			

Fig. 10 *This is step ② in Fig. 3: Terminal T3 has now been throttled to 107 m³/h, and its measured value is entered into a new column in the spreadsheet together with the simultaneous flow rate in the reference terminal (T1). Terminals T1 to T3 are now almost balanced; they have 105% and 107% of design flow respectively. The message "*`Next>`*" means that MiniBalance accepts this as good enough, and suggests that you move on to measure T4. However, you may nevertheless choose to fine-tune T3 if you wish. If so, MiniBalance has calculated a more accurate second guess ("*`Guess2`*") to nudge T3 to 105,22 m³/h.*



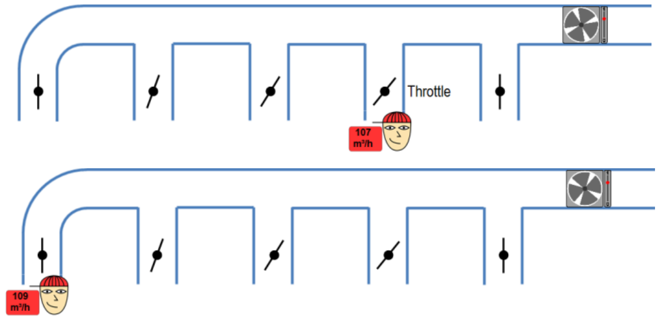
Term.	%design	Guess3	Meas.units	Desig m3/h	(empty col.)	Initial & Balancing (clear these columns bef			
T1	105 %	(R&C)	m3/h	100		95	100	105	105
T2	-	-	m3/h	100		117	100		
T3	105 %	105.11	m3/h	100		144	147	107	105
T4	-	Next>	m3/h	100		167			
T5	-	-	m3/h	100		187			

Fig. 11 *After having fine-tuned T3, it is now perfectly balanced with the reference terminal. This is the end of step ②. Again, the message "*`Next>`*" means that MiniBalance accepts suggests that you move on to measure T4.*



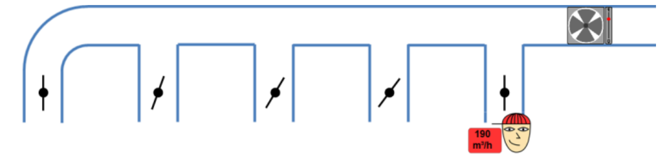
Term.	%design	Guess1	Meas.units	Desig m3/h	(empty col.)	Initial & Balancing (clear these columns bef			
T1	105 %	(R&C)	m3/h	100		95	100	105	105
T2	-	-	m3/h	100		117	100		
T3	105 %	-	m3/h	100		144	147	107	105
T4	171 %	106.94	m3/h	100		167			171
T5	-	-	m3/h	100		187			

Fig. 12 *The simultaneous flow rate in T4 has now been measured and typed in the same column. MiniBalance suggests that it be throttled to 106.94 m³/h. This is a first guess ("*`Guess1`*")*



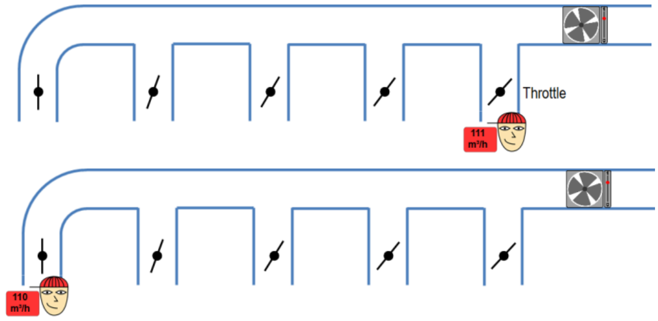
Term.	%design	Guess2	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns bef						
T1	109 %	(R&C)	m3/h	100		95	100	105	105	109		
T2	-	-	m3/h	100		117	100					
T3	-	-	m3/h	100		144	147	107	105			
T4	107 %	108.88	m3/h	100		167			171	107		
T5	-	Next>	m3/h	100		187						
	.	.										

Fig. 13 *This is step ③ in Fig. 3: Terminal T4 has now been throttled to 107 m³/h. Simultaneous measured values for T4 and the reference terminal (T1) are entered in a new column. They are now acceptably balanced (109% and 107% of design, respectively). The message "*`Next>`*" means that MiniBalance accepts this as good enough, and suggests that you move on to measure T5. This time, we ignore the temptation to fine-tune terminal T4 by opening it slightly to 108.88 m³/h to perfectly balance it. Such a small adjustment may be smaller than the instabilities caused by the turbulent flow in the duct, or the sensitivity of the flow measurement instrument.*



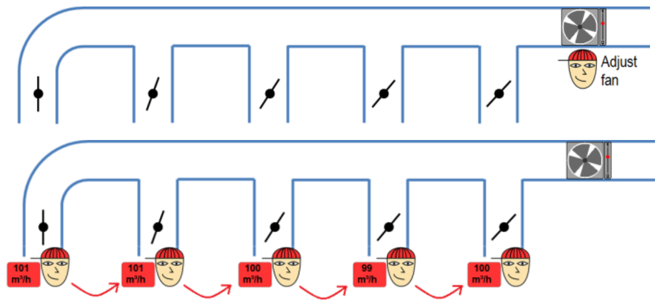
Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns bef						
T1	109 %	(R&C)	m3/h	100		95	100	105	105	109		
T2	-	-	m3/h	100		117	100					
T3	-	-	m3/h	100		144	147	107	105			
T4	107 %	-	m3/h	100		167			171	107		
T5	190 %	108.9	m3/h	100		187				190		
	.	.										

Fig. 14 *The simultaneous flow rate in T5 (190 m³/h) has now been measured and typed in the same column. MiniBalance suggests that it be throttled to 108.9 m³/h. This is a first guess ("*`Guess1`*")*



Term.	%design	Guess2	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns bef						
T1	110 %	(R&C)	m3/h	100		95	100	105	105	109	110	
T2	-	-	m3/h	100		117	100					
T3	-	-	m3/h	100		144	147	107	105			
T4	-	-	m3/h	100		167			171	107		
T5	109 %	109.99	m3/h	100		187				190	109	
	.	.										

Fig. 15 *This is step ④: T5 has now been throttled and measured. This group is therefore now acceptably balanced (T5 and T1 have 109% and 110% respectively)*



Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns bef						
T1	101 %	(R&C)	m3/h	100		95	100	105	105	109	110	101
T2	101 %	-	m3/h	100		117	100					101
T3	100 %	-	m3/h	100		144	147	107	105			100
T4	99 %	-	m3/h	100		167			171	107		99
T5	100 %	OK!	m3/h	100		187				190	109	100
	.	.										

Fig. 16 *Final commissioning measurements of all the terminals after the whole duct system has been balanced, and the fan's total flow rate has been adjusted to bring all terminals to design flow rate. The "*`OK!`*" message means that the whole group is within the user-specified tolerance limits.*

6 Simple duct with five terminals — Quick balancing

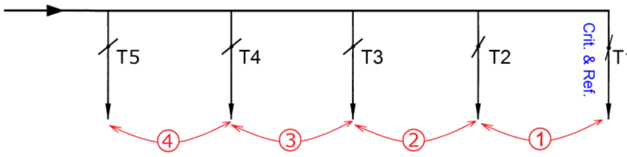


Fig. 17 *Schematic of simple duct with four terminals. Red arrows indicate order of balancing.*

The duct system in this example is identical to the previous one (Fig. 3). This example shows how to quickly balance the group with fewer adjustments and measurements, and without having to measure the reference terminal T1 after every adjustment.

Here we speed up balancing by using a "daisy-chain" approach, whereby after a terminal has been balanced, it is used as a reference for balancing its neighbour.

The disadvantage of this quick approach is that balancing deviations can accumulate as you progress along the duct. It is therefore sensible to occasionally revisit terminal T1 (e.g. every 3rd terminal). Nevertheless, this example shows that the system of 5 terminals can be balanced with negligible accumulated error.

This example starts in exactly the same way as the previous one (i.e. Fig. 4 to Fig. 9). We therefore show below just how to continue after Fig. 9:

ACTIVITY — ***MINIBALANCE* SCREEN SHOT**

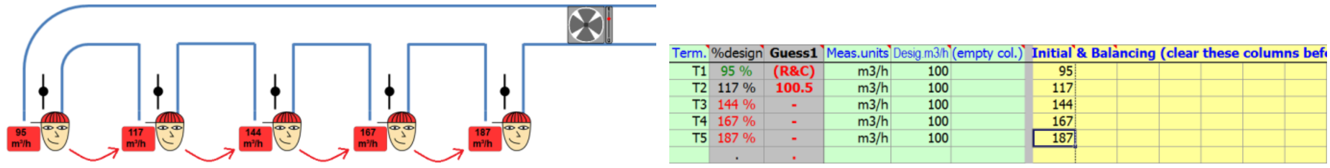


Fig. 18 *Complete initial measurements of all the terminals the group, this time with an acceptable flow rate (critical terminal is just below 100% of design). MiniBalance calculates that T1 is the critical terminal (i.e. the terminal with lowest % of design flow rate, 95%). In the grey message column, the text "*`(R&C)`*" means that terminal T1 is both the Reference terminal and Critical terminal. The text "*`100.5`*" in the same column suggests that T2 can be throttled to 100.5 m³/h. This is an approximate first guess ("*`Guess1`*").*

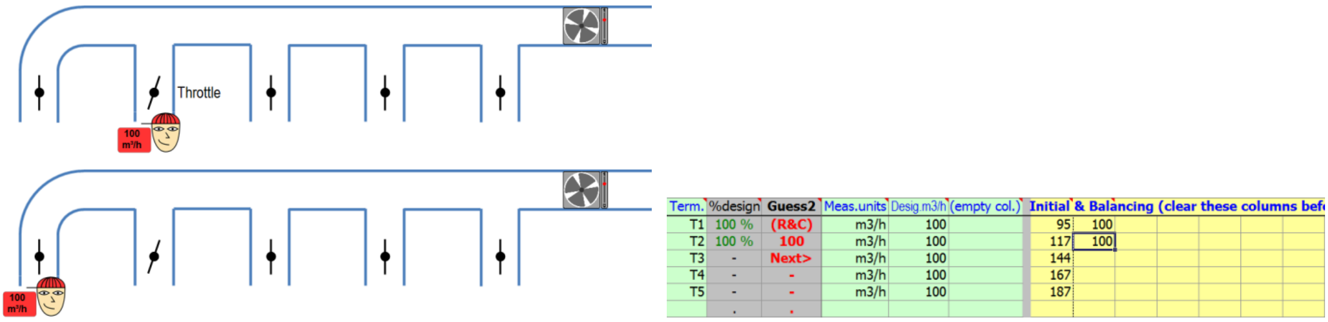


Fig. 19 *This is step ① in Fig. 3: T2 has now been manually throttled to approx. 100 m³/h. The flow rate in the reference terminal (T1) is also measured. The two measured values are entered in the spreadsheet. A new yellow column was used because the flow rates have been changed after throttling, and each column must contain simultaneous flow rates in terminals. Both terminals T1 and T2 now have the same %design value, i.e. they are balanced with each other. The message "*`Next>`*" means that MiniBalance therefore suggests that you go to the next terminal (T3) and measure its present value (without throttling it).*

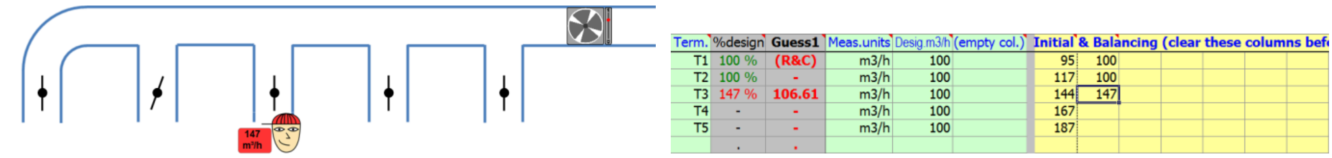
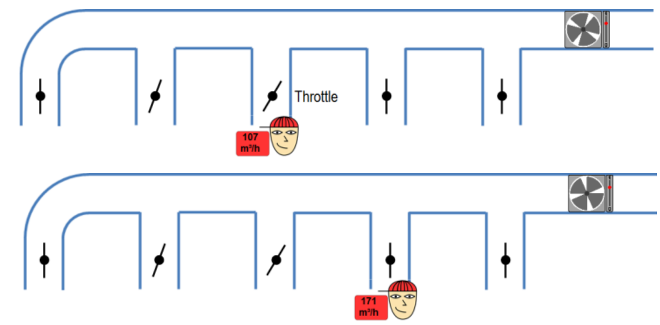
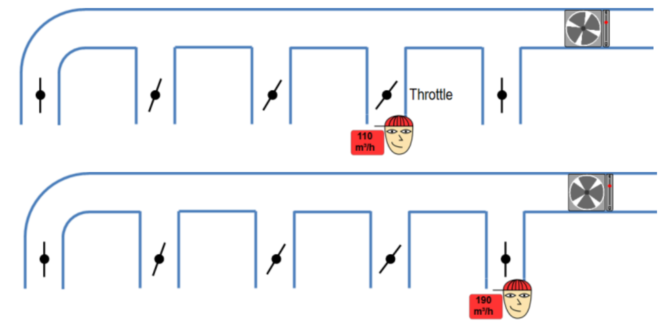


Fig. 20 *Step ①: The simultaneous unthrottled flow rate in terminal T3 has just been measured and typed into the spreadsheet. MiniBalance suggests that T3 now be throttled to approximately 106.61 m³/h.* (Same as *Fig. 9*)



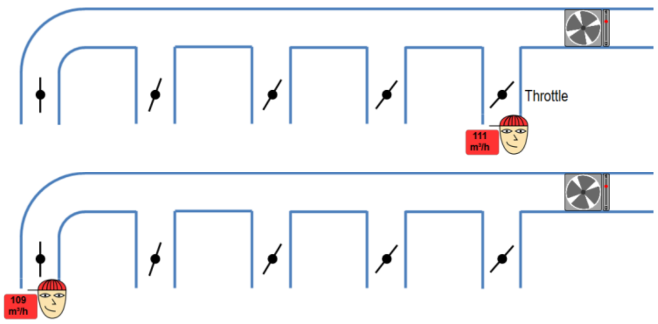
Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial	& Balancing (clear these columns bef					
T1	-	(R&C)	m3/h	100		95	100					
T2	-	-	m3/h	100		117	100					
T3	107 %	-	m3/h	100		144	147	107				
T4	171 %	110.13	m3/h	100		167		171				
T5	-	-	m3/h	100		187						
	.	.										

Fig. 21 *Step ②: T3 has been manually balanced against T2 by throttling it to approx. 107 m³/h. We just assume that it is properly balanced, and do not bother measuring terminal T1 to check. Then the simultaneous unthrottled flow rate in terminal T4 is measured and typed into the spreadsheet. MiniBalance now uses T3 as a "reference" for adjusting T4, and guesses that T4 should be throttled to 110.13 m³/h. MiniBalance namely uses the topmost measurement in each yellow column as the "reference" for checking the measured terminals listed below in the same yellow column.*



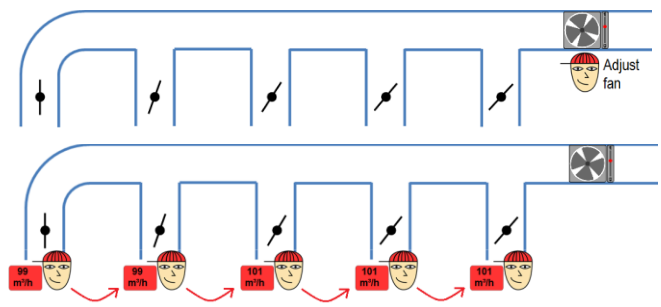
Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial	& Balancing (clear these columns bef					
T1	-	(R&C)	m3/h	100		95	100					
T2	-	-	m3/h	100		117	100					
T3	-	-	m3/h	100		144	147	107				
T4	110 %	-	m3/h	100		167		171	110			
T5	190 %	110.85	m3/h	100		187			190			
	.	.										

Fig. 22 *Step ③: T4 has been manually balanced with T3 by throttling it to approx. 110 m³/h. Then the simultaneous unthrottled flow rate in terminal T5 is measured and typed into the spreadsheet. MiniBalance now uses T4 as a "reference" for adjusting T5, and guesses that T5 should be throttled to 110.85 m³/h.*



Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial	& Balancing (clear these columns bef					
T1	109 %	(R&C)	m3/h	100		95	100			109		
T2	-	-	m3/h	100		117	100					
T3	-	-	m3/h	100		144	147	107				
T4	-	-	m3/h	100		167		171	110			
T5	111 %	110.85	m3/h	100		187			190	111		
	.	.										

Fig. 23 *Step ④: T5 has been manually balanced with T4 by throttling it to 111 m³/h. All the terminals have now been balanced. Just as a final check, to validate that the accumulated errors are minimal, we finish off by measuring terminal T1 and compare it to T5 (109% and 111% of design , respectively).*



Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial	& Balancing (clear these columns bef					
T1	99 %	(R&C)	m3/h	100		95	100			109	99	
T2	99 %	-	m3/h	100		117	100				99	
T3	101 %	-	m3/h	100		144	147	107			101	
T4	101 %	-	m3/h	100		167		171	110		101	
T5	101 %	OK!	m3/h	100		187			190	111	101	
	.	.										

Fig. 24 *Final commissioning measurement of all terminals after the rest of the whole duct system has been balanced, and the fan's total flow rate has been adjusted to bring all terminals to design flow rate. Compare this figure with Fig. 16.*

All the remaining examples, below, apply the "accurate" approach, i.e. with repeat visits to the end terminal.

7 Duct with four terminals, and the end terminal is not the critical terminal

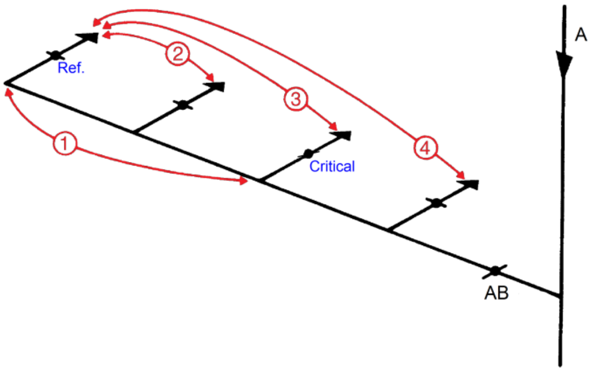


Fig. 25 *Schematic of a duct with 4 terminals. Terminal 3 is the critical one. Red arrows indicate order of balancing [6].*

Here we illustrate the application of *MiniBalance* for a branch duct for which the index terminal is not the last terminal. The main difference compared to the previous example (page 3) is that there is an additional first step whereby the reference terminal must first be throttled to balance it with the index terminal. After this, one follows the same procedure as the example 5, whereby the terminals are balanced in turn with the reference.

Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns befo		
AB1	126 %	117.5	m3/h	100		126		
AB2	154 %	117.5	m3/h	100		154		
AB3	95 %	(Crit.)	m3/h	200		190		
AB4	220 %	-	m3/h	100		220		
	.	.						

Fig. 26 *Initial measurements are taken. The total flow rate in the duct is acceptable, as the critical duct has a flow rate slightly below 100% of design. It will rise to over 100% when the other terminals are throttled. The message "*`(Crit.)`*" means that Terminal AB3 is the critical terminal and must not be throttled. This is because terminal AB3 has a design flow rate (200 m³/h) which is twice that of the other terminals. MiniBalance suggests that the first two terminals be throttled to 117.5 m³/h in order to balance them with the critical terminal.*

Term.	%design	Guess2	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns befo		
AB1	117 %	(Ref.)	m3/h	100		126	117	
AB2	118 %	?	m3/h	100		154	118	
AB3	-	Check>	m3/h	200		190		
AB4	-	Next>	m3/h	100		220		
	.	.						

Fig. 27 *We start step ① as shown in Fig. 25: The first two terminals have now been throttled, and their simultaneous measured values are entered in a new column. The message "*`Check>`*" means that MiniBalance suggests that you now measure the simultaneous flow rate in the critical terminal (AB3) to check that it is balanced with the reference terminal.*

Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns befo		
AB1	117 %	99.5	m3/h	100		126	117	
AB2	118 %	-	m3/h	100		154	118	
AB3	100 %	(Crit.)	m3/h	200		190	199	
AB4	-	-	m3/h	100		220		
	.	.						

Fig. 28 *The flow rate through the Critical terminal (AB3) has now been measured and entered in the same column. The critical terminal is still fully open. Terminals AB1 and AB2 are not yet completely balanced with AB3 (they have 117%, 118% and 110% of design flow respectively). MiniBalance suggests therefore that terminal AB1 be further throttled to 99.5 m³/h.*

Term.	%design	Guess2	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns befo		
AB1	100 %	100.47	m3/h	100		126	117	100
AB2	-	Next>	m3/h	100		154	118	
AB3	101 %	(Crit.)	m3/h	200		190	199	201
AB4	-	-	m3/h	100		220		
	.	.						

Fig. 29 *Terminal AB1 has now been throttled to 100 m³/h, and the simultaneous flow rate in the critical terminal is entered in a new column in the spreadsheet. According to the messages column, there are now two options:* **(*i*)** *fine-tune terminal AB1 to 100.47 m³/h, or* **(*ii*)** *move on to measure the present flow rate in AB2. The latter option is best because it is unnecessary to fine tune AB1. The remaining terminals can now be balanced to AB1.*

Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns befo		
AB1	100 %	(Ref.)	m3/h	100		126	117	100
AB2	121 %	100.5	m3/h	100		154	118	121
AB3	101 %	(Crit.)	m3/h	200		190	199	201
AB4	-	-	m3/h	100		220		
	.	.						

Fig. 30 *The simultaneous flow rate in terminal AB2 is measured. MiniBalance suggests that it now be further throttled to 100.5 m³/h.*

Term.	%design	Guess2	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns befo						
AB1	104 %	(Ref.)	m3/h	100		126	117	100	104			
AB2	101 %	103.5	m3/h	100		154	118	121	101			
AB3	-	Check>	m3/h	200		190	199	201				
AB4	-	Next>	m3/h	100		220						
	.	.										

Fig. 31 *This is step ② shown in Fig. 25: Terminal AB2 has just been throttled to near 100.5 m³/h. Its measured flow rate is entered in a new column together with the simultaneous flow rate in the reference terminal AB1. According to the messages column, there are now two options:* ***(i)*** *fine-tune terminal AB2 to 103.5 m³/h, or* ***(ii)*** *move on to measure the current flow rate in the neighbouring terminals AB3 and AB4.*

Term.	%design	Guess3	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns befo						
AB1	103 %	(Ref.)	m3/h	100		126	117	100	104	103		
AB2	103 %	103.3	m3/h	100		154	118	121	101	103		
AB3	-	Check>	m3/h	200		190	199	201				
AB4	-	Next>	m3/h	100		220						
	.	.										

Fig. 32 *Here we chose the option of fine tuning terminal AB2 to 103 m³/h. Its measured flow rate is entered in a new column together with the simultaneous flow rate in the reference terminal AB1. According to the messages column, no further fine tuning is needed, so one can move on to measure the simultaneous flow rates in the neighbouring terminals AB3 and AB4.*

Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns befo						
AB1	103 %	(Ref.)	m3/h	100		126	117	100	104	103		
AB2	103 %	-	m3/h	100		154	118	121	101	103		
AB3	102 %	(Crit.)	m3/h	200		190	199	201		204		
AB4	226 %	110.25	m3/h	100		220				226		
	.	.										

Fig. 33 *The simultaneous flow rates in AB3 and AB4 have been measured. The measurements confirm that the Critical terminal is now fully balanced with the downstream terminals (step ③ in Fig. 25). MiniBalance suggests therefore that the next terminal, AB4, can be throttled to 110.25 m³/h.*

Term.	%design	Guess2	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns befo						
AB1	108 %	(Ref.)	m3/h	100		126	117	100	104	103	108	
AB2	-	-	m3/h	100		154	118	121	101	103		
AB3	-	(Crit.)	m3/h	200		190	199	201		204		
AB4	110 %	108.08	m3/h	100		220				226	110	
	.	.										

Fig. 34 *This is step ④ in Fig. 25: Terminal AB4 has now been throttled as recommended, and is acceptably balanced. Its new flow rate is entered in a new column together with the simultaneous flow rate in the reference terminal. MiniBalance suggests that AB4 can be adjusted slightly to 108.08 m³/h if one wishes to fine tune it. However it is unnecessary to fine tune it further. This group is therefore now fully balanced.*

Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these columns befo						
AB1	100 %	(Ref.)	m3/h	100		126	117	100	104	103	108	100
AB2	100 %	-	m3/h	100		154	118	121	101	103		100
AB3	99 %	(Crit.)	m3/h	200		190	199	201		204		198
AB4	103 %	OK!	m3/h	100		220				226	110	103
	.	.										

Fig. 35 *A final check of all the terminals in the group, after the fan's total flow rate has been brought down to design flow rate. The "*`OK!`*" message means that the whole group is commissioned within the tolerance limits.*

8 System with branch ducts, each with branch dampers

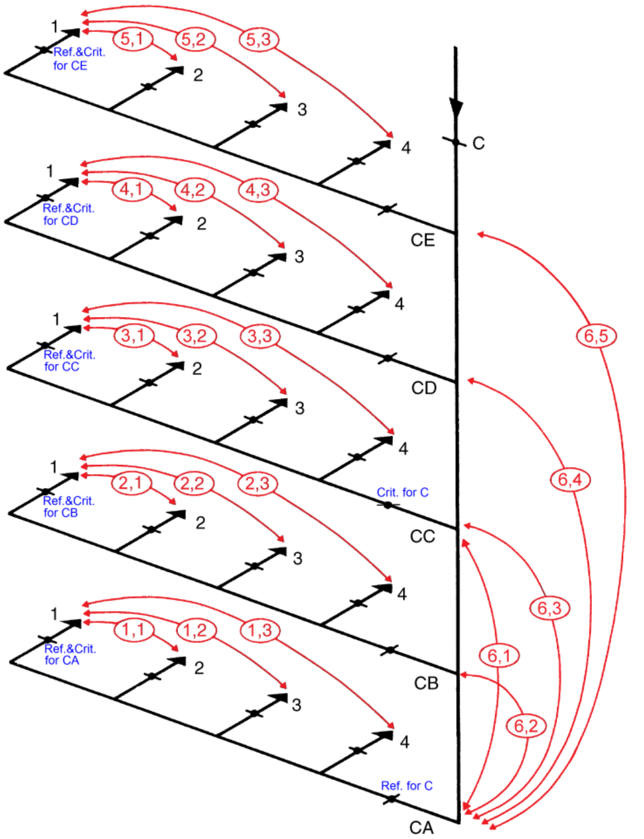


Fig. 36 *Schematic of a duct riser with 5 branches, each with 4 terminals. Red arrows indicate order of balancing [6].*

This example illustrates the balancing procedure for a whole duct system. The principle is to balance the groups in order of hierarchy, starting with the terminals on the lowest level ducts, and finishing with the branch dampers on the main duct. In this particular case (Fig. 36) firstly 5 independent groups, each consisting of 4 terminals, are balanced. Finally, the group of 5 branch dampers on the main duct (dampers, CA to CE) are balanced. After this, the fan's total flow rate is adjusted such that all terminals settle on their design flow rates and the final checks on all terminals are conducted to confirm that the whole system is commissioned.

Term.	%design	Guess2	Meas.units	Desig.m3/h	(empty col.)	Initial & Balancing (clear these colum					
CA1	-	-	m3/h	100							
CA2	-	-	m3/h	100							
CA3	-	-	m3/h	100							
CA4	-	-	m3/h	100							
CB1	110 %	(R&C)	m3/h	100		96	101	106	110		
CB2	-	-	m3/h	100		118	102				
CB3	-	-	m3/h	100		145.5	148	106.5			
CB4	109 %	109.91	m3/h	100		168		173	108.5		
CC1	-	-	m3/h	150							
CC2	-	-	m3/h	150							
CC3	-	-	m3/h	150							
CC4	-	-	m3/h	150							
CD1	-	-	m3/h	80							
CD2	-	-	m3/h	80							
CD3	-	-	m3/h	80							
CD4	-	-	m3/h	80							
CE1	-	-	m3/h	100							
CE2	-	-	m3/h	100							
CE3	-	-	m3/h	100							
CE4	-	-	m3/h	100							
CA	-	-	m3/h	400							
CB	-	-	m3/h	400							
CC	-	-	m3/h	600							
CD	-	-	m3/h	320							
CE	-	-	m3/h	400							
	.	.									

Fig. 37 *Here, group CB is has now been balanced (Step ② in Fig. 36). Note that the yellow cells have been cleared in the rows belonging to all the other balancing groups. The five groups of terminals (branches CA to CE) can be balanced in any order (steps ① to ⑤).*

Term.	%design	Guess2	Meas.units	Desig.m3/h	(empty col.)	Initial	& Balancing (clear these colum				
CA1	-	-	m3/h	100							
CA2	-	-	m3/h	100							
CA3	-	-	m3/h	100							
CA4	-	-	m3/h	100							
CB1	-	-	m3/h	100							
CB2	-	-	m3/h	100							
CB3	-	-	m3/h	100							
CB4	-	-	m3/h	100							
CC1	-	-	m3/h	150							
CC2	-	-	m3/h	150							
CC3	-	-	m3/h	150							
CC4	-	-	m3/h	150							
CD1	96 %	(R&C)	m3/h	80		66.5	70	74	77		
CD2	-	-	m3/h	80		83	71.5				
CD3	-	-	m3/h	80		101.5	103.5	75			
CD4	96 %	76.968	m3/h	80		118		121	76.5		
CE1	-	-	m3/h	100							
CE2	-	-	m3/h	100							
CE3	-	-	m3/h	100							
CE4	-	-	m3/h	100							
CA	-	-	m3/h	400							
CB	-	-	m3/h	400							
CC	-	-	m3/h	600							
CD	-	-	m3/h	320							
CE	-	-	m3/h	400							
	.	.									

Fig. 38 *Here, group CD has now been balanced (Step ④ in Fig. 36).*

Term.	%design	Guess2	Meas.units	Desig.m3/h	(empty col.)	Initial	& Balancing (clear these colum				
CA1	-	-	m3/h	100							
CA2	-	-	m3/h	100							
CA3	-	-	m3/h	100							
CA4	-	-	m3/h	100							
CB1	-	-	m3/h	100							
CB2	-	-	m3/h	100							
CB3	-	-	m3/h	100							
CB4	-	-	m3/h	100							
CC1	-	-	m3/h	150							
CC2	-	-	m3/h	150							
CC3	-	-	m3/h	150							
CC4	-	-	m3/h	150							
CD1	-	-	m3/h	80							
CD2	-	-	m3/h	80							
CD3	-	-	m3/h	80							
CD4	-	-	m3/h	80							
CE1	-	-	m3/h	100							
CE2	-	-	m3/h	100							
CE3	-	-	m3/h	100							
CE4	-	-	m3/h	100							
CA	102 %	(Ref.)	m3/h	400		392	396	388	392	404	408
CB	-	-	m3/h	400		456	392	388			
CC	-	(Crit.)	m3/h	600		568	580	580			
CD	-	-	m3/h	320		660		664	552	324	
CE	101 %	407.95	m3/h	400		736				744	404
	.	.									

Fig. 39 *Step ⑥: Balancing the riser duct.*

Term.	%design	Guess1	Meas.units	Desig.m3/h	(empty col.)	Initial	& Balancing (clear these colum				
CA1	101 %	OK!	m3/h	100		101					
CA2	98 %	-	m3/h	100		98					
CA3	102 %	-	m3/h	100		102					
CA4	101 %	-	m3/h	100		101					
CB1	101 %	-	m3/h	100		101					
CB2	97 %	-	m3/h	100		97					
CB3	100 %	-	m3/h	100		100					
CB4	100 %	-	m3/h	100		100					
CC1	96 %	(Crit.)	m3/h	150		144					
CC2	100 %	-	m3/h	150		150					
CC3	102 %	-	m3/h	150		153					
CC4	100 %	-	m3/h	150		150					
CD1	99 %	-	m3/h	80		79					
CD2	100 %	-	m3/h	80		80					
CD3	100 %	-	m3/h	80		80					
CD4	101 %	-	m3/h	80		81					
CE1	100 %	-	m3/h	100		100					
CE2	100 %	-	m3/h	100		100					
CE3	100 %	-	m3/h	100		100					
CE4	102 %	OK!	m3/h	100		102					
CA	-	-	m3/h	400							
CB	-	-	m3/h	400							
CC	-	-	m3/h	600							
CD	-	-	m3/h	320							
CE	-	-	m3/h	400							
	.	.									

Fig. 40 *Finally, the fan has been adjusted so that all terminals settle on their respective design flow rates. The spreadsheet is cleared again and all the terminals are measured to check that they are within the accepted tolerance limits.*

9 What to do when there is no means of measuring flow rate through branch dampers

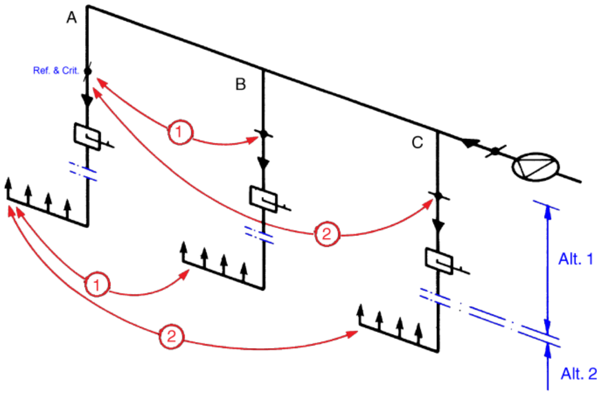


Fig. 41 *Schematic of a main duct with three branches, showing two alternative locations for measuring the %design flow for each of the three branches. [6]*

In the previous example, it was possible to measure total flow rate entering each branch duct (i.e. branches CA to CE in Fig. 39). However, if there is no means of measuring the branch flows easily & accurately (e.g. with an iris damper or BAAS flow measurement station or probe), then one can alternatively measure the %design value at a representative terminal in each branch duct (preferably the reference terminals). It is unnecessary to measure all the terminals and summate their flow rates for each branch — This is because all the terminals in each branch duct are already balanced, i.e. have the same %design ratio, so it will suffice to measure just one terminal per branch. When applying this second alternative, one still adjusts the branch dampers (as for the first alternative), despite measuring flow rate at the terminals without tampering with them.

This application of this alternative is shown below for the riser duct in the previous example (alternative to Fig. 39).

CD4	-	-	m3/h	80							
CE1	-	-	m3/h	100							
CE2	-	-	m3/h	100							
CE3	-	-	m3/h	100							
CE4	-	-	m3/h	100							
CA	102 %	(Ref.)	m3/h	100		98	99	97	98	101	102
CB	-	-	m3/h	100		114	98	97			
CC	-	(Crit.)	m3/h	150		142	145	145			
CD	-	-	m3/h	80		165		166	138	81	
CE	101 %	101.99	m3/h	100		184				186	101
	.	.									

Fig. 42 *This is an alternative to the method used in Fig. 39. In this case we avoid measuring the total flow rate entering each branch duct in the system in Section 8. Instead, the %design flow rates are measured indirectly by measuring the reference terminals in the five ducts CA to CE. Note that the values in the "*`Desig.m3/h`*" column are the design flow rates for the measured reference terminals in the respective branches, not the total design flow for each branch damper.*

10 System with branch ducts without branch dampers — Well designed

It is generally recommended to design symmetric duct systems such that terminals are intrinsically balanced or need minimal balancing, and branch dampers can be omitted. Examples of symmetric systems are shown below. The balancing groups are essentially balanced just as the example in Section 5 or 6, so *MiniBalance* screendumps are not shown here.

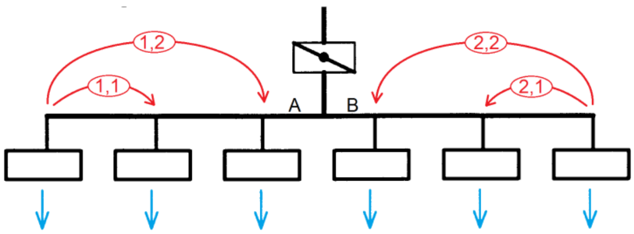


Fig. 43 *Two symmetric branches, each with equal design flow rates in all terminals. There is thus no need for balancing dampers at points A and B. Sub-branches A and B can be balanced independently of each other, just as two normal balancing groups. [7]*

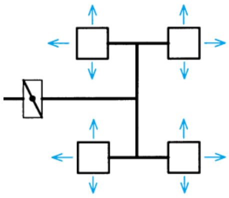


Fig. 44 *Symmetric bifurcated duct layout. No throttling is needed if the 4 terminals have the same design flow rate. If, however, the design flow rates are not equal, then the critical terminal is used as reference, and the other terminals can be throttled in order of decreasing %design, as described in the next example (11). [7]*

11 System with branch ducts without branch dampers — Poorly designed

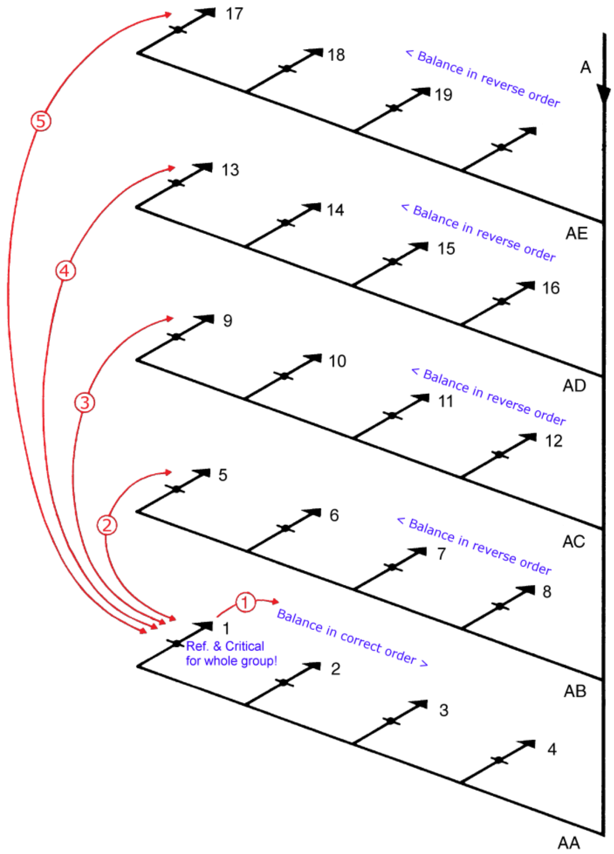


Fig. 45 *This schematic is similar to Fig. 36, but there are no branch dampers. All throttling must therefore be done at the terminals. This system is not ideal, as it is much harder to balance, and the terminals may generate more noise [6].*

Unfortunately, branch dampers are also commonly omitted from unsymmetrical duct systems. This means that one cannot use the proper proportional method when balancing branch ducts with each other (e.g. branches AA to AE in Fig. 45, which have no branch dampers). All the terminals are treated as one balancing group, even though they are on different branch ducts. The group has only one Reference terminal and one Critical terminal. From experience, a pragmatic procedure for balancing the group is as follows:

- Step ⓪: Conduct initial measurements of all the terminals in the whole group. (If the critical terminal is not on the last branch, then roughly balance all the branch ducts downstream of it and repeat)
- Step ①: Balance the terminals in the branch duct that is furthest from the fan, with the end terminal as reference, just as for balancing a normal group using the proportional method. See Fig. 46.
- Step ②: Balance the terminals in the next furthest branch duct. This time, balance the terminals <u>in order of how much they need to be throttled</u> (i.e. starting with the terminal that needs to be throttled most, which is often nearest the fan), and use the end terminal in end last branch as reference (i.e. Terminal 1 in Fig. 45). See Fig. 47. Once this is done, repeat the process to fine-tune the terminals until the whole branch is balanced with Terminal 1 in the end branch (Fig. 48).

- Conduct the previous step for each branch duct in turn, in order of how close they are to the fan. This is shown as steps ③ to ⑥ in Fig. 45.

The screen shots below show the application of *MiniBalance* to the duct system shown in Fig. 45 (but ignoring the top two branch ducts).

Term.	%design	Guess3	Meas.units	Desig m3/h	(empty col.)	Initial & Balancing (clear these columns before starting on new balan										
1	105 %	(R&C)	m3/h	100		62	71	70	90	87	106	105				
2	-	-	m3/h	100		82	67	70								
3	-	-	m3/h	100		141		144	78	87						
4	106 %	105.36	m3/h	100		261				270	102	106				
8	-	Next>	m3/h	100		281										
7	-	-	m3/h	100		152										
6	-	-	m3/h	100		88										
5	-	-	m3/h	100		67										
12	-	-	m3/h	100		300										
11	-	-	m3/h	100		170										
10	-	-	m3/h	100		98										
9	-	-	m3/h	100		75										
	.	.														

Fig. 46 *Initial measurements have been taken on all the terminals in the group (Step ⓪), and the 4 terminals on duct branch AA have been balanced (Step ①).*

Term.	%design	Guess2	Meas.units	Desig m3/h	(empty col.)	Initial & Balancing (clear these columns before starting on new balan										
1	109 %	(R&C)	m3/h	100		62	71	70	90	87	106	105	108	109	109	109
2	-	-	m3/h	100		82	67	70								
3	-	-	m3/h	100		141		144	78	87						
4	-	-	m3/h	100		261				270	102	106				
8	-	-	m3/h	100		281						290	107			
7	-	-	m3/h	100		152							185	109		
6	-	-	m3/h	100		88								134	110	
5	110 %	109.88	m3/h	100		67									118	110
12	-	Next>	m3/h	100		300										
11	-	-	m3/h	100		170										
10	-	-	m3/h	100		98										
9	-	-	m3/h	100		75										
	.	.														

Fig. 47 *Step ②: The terminals on the second from last branch duct (AB in Fig. 45) are balanced with terminal 1 in reverse order of how much they need to be throttled. Note that the terminals are listed in reverse order in the rightmost column.*

Term.	%design	Guess1	Initial & Balancing (clear these columns before starting on new balancing group)															
1	109 %	(R&C)	62	71	70	90	87	106	105	108	109	109	109	109	109	109	109	
2	-	-	82	67	70													
3	-	-	141		144	78	87											
4	-	-	261				270	102	106									
8	108 %	-	281						290	107			111	107			108	
7	112 %	-	152							185	109		114	114	110		112	
6	113 %	-	88								134	110	115		116	110	113	
5	110 %	110.64	67									118	110			114	110	
12	-	Next>	300															
11	-	-	170															
10	-	-	98															
9	-	-	75															
	.	.																

Fig. 48 *Fine tuning the terminals at the end of Step ②.*
Note: The "Freeze Panes" option in Excel is used for the three leftmost columns, so other input columns become hidden from view when you use progressively more yellow columns.

Term.	%design	Guess1	rting on new balancing group)															
1	111 %	(R&C)	109	109	109	109	109	109	109	110	111	111	111	111	111	111	111	
2	-	-																
3	-	-																
4	-	-																
8	-	-			111	107			108									
7	-	-	109		114	114	110		112									
6	-	-	134	110	115		116	110	113									
5	-	-		118	110			114	110									
12	113 %	-								112			116	112			113	
11	114 %	-								202	112		120	120	111		114	
10	116 %	-									147	112	124		125	111	116	
9	111 %	113.45										133	111			121	111	
	.	.																

Fig. 49 *Step ③: The terminals on the third-last branch duct (AC in Fig. 45) are balanced and fine-tuned with terminal 1. Note that the first few yellow columns are hidden from view, and that no yellow cells have been cleared when starting on the new branch.*

Term.	%design	Guess1	rting on new balancing group)															
1	100 %	(R&C)	109	109	109	109	109	109	109	110	111	111	111	111	111	111	111	100
2	100 %	-																100
3	99 %	-																99
4	100 %	-																100
8	98 %	-			111	107			108									98
7	101 %	-	109		114	114	110		112									101
6	103 %	-	134	110	115		116	110	113									103
5	100 %	-		118	110			114	110									100
12	102 %	-								112			116	112			113	102
11	103 %	-								202	112		120	120	111		114	103
10	105 %	-									147	112	124		125	111	116	105
9	100 %	OK!										133	111			121	111	100
	.	.																

Fig. 50 *Final commissioning checks after all the terminals in the duct system have been balanced and the fan has been adjusted so that the terminals have 100% of design flow.*

PART 2: Fundamentals of using *MiniBalance*

12 Basics of the Proportional Method of balancing

12.1 Principle

The proportional method is based on the principle that the ratio between the air flow rates in two branch ducts remains constant even if flow rate in the main duct is changed somewhat. This principle is true for both supply and return duct systems.

This principle is illustrated in Fig. 51. The air flow rate in ducts *a* and *b* in will both fall by 20% if the damper in the main duct is throttled such that the total flow rate q_c falls by 20%. The same principle applies to all junctions in a duct system.

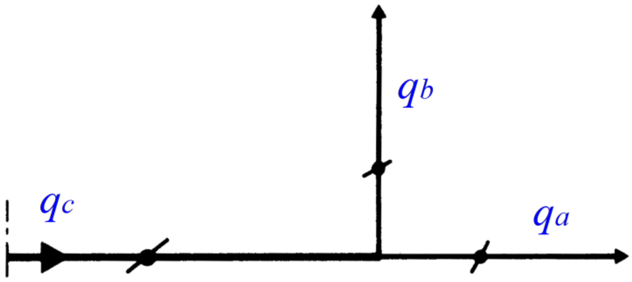


Fig. 51 *The flow rate ratio q_a/q_b remains constant even when flow rate q_c is changed. %design is thus also unchanged.*

The proportional principle applies only to those parts of the duct system that are further from the fan (downstream) than the adjusted damper. The principle must therefore be applied in a systematic manner during commissioning, whereby one starts at the most remote branches and work towards the fan, setting the correct proportional air flow at each junction in turn, such that all the ducts eventually end up with the same percentage of design flow rate (i.e. they are balanced). Once this has been completed, the flow rates throughout the whole system are brought to their design values by adjusting the fan(s) flow rate [5].

12.2 Range of validity and tolerances

If one adjusts a fan's flow rate by more than 50%, then the balance between the terminals in the duct system will deviate slightly (>2%). This is because the flow regime changes in components such as tee junctions. It is therefore recommended that the flow rates downstream of terminals/dampers that are being adjusted should be in the range ±50% of design value. This limits deviations to 2% from perfectly balanced, when the whole system is commissioned [6].

Ideally, that the total flow rate entering the group being balanced should not deviate more than ±30% from design. *MiniBalance* indicates when this is exceeded by showing red text in the %design column; see Fig. 54. If necessary, the damper at the root of the duct run being balanced can be roughly adjusted to within ±30% of design, for example by measuring the flow rate at the critical terminal. In that case, one must remember to open the root damper again when it is time to start balancing it as part of its balancing group.

Unless otherwise specified in a commissioning job, the allowed tolerance (ignoring measurement instrument uncertainty) should not exceed ±10% for individual flow rates at terminals or dampers. This user-input is called "`Balancing accuracy`" in the "`General`" worksheet (Fig. 53).

13 Structure of the workbook

MiniBalance consists of two worksheets (Fig. 52):

- *General*: Global settings, such as language
- *Balancing*: This is the main worksheet for user input and output during the balancing procedure

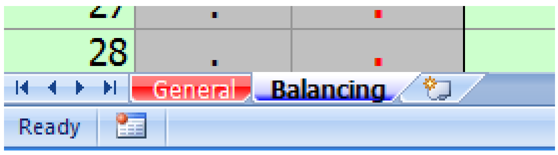


Fig. 52 *Tabs for switching between the two sheets, at the lower left corner of the Excel window*

13.1 Worksheet "General"

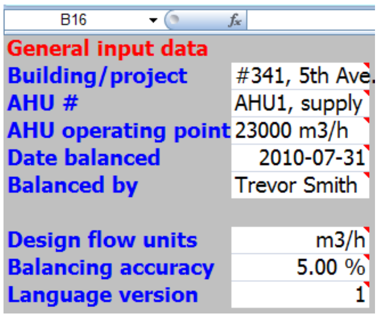


Fig. 53 *Worksheet "General" filled with example data*

See Fig. 53. This sheet is for global information about the specific balancing job. The white cells are for user-input.

- The first five input rows, from "`Building/project`" to "`Balanced by`" are optional user-information.
- "`Design flow units`" is the units of measurement of the design flow rate for all the terminals/dampers, i.e. column E in the "`Balancing`" worksheet. The alternatives are: "`pa`" (i.e. pressure measurement), "`cfm`" (i.e. cubic feet per minute), "`dm3/s`", "`l/s`", "`l/min`", "`m3/h`" or "`m3/s`".
- "`Balancing accuracy`" is the accepted tolerance. A higher percentage means that the spreadsheet will

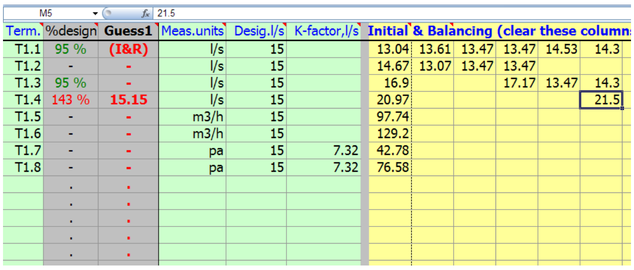
accept a higher percentage deviation from ideally balanced flow rate at each individual terminal/damper. Note that the *total* balancing error is the sum of the tolerance and the measurement error.

- "`Language version`" is a number between 1 (English) and 9 (Spanish). See the table at the end of this paper.

13.2 Worksheet "Balancing"

See Fig. 54. This spreadsheet has tree kinds of cells, as identified by their background colour:

- *Green*: Cells in green columns are to be filled out manually before commencing balancing. This can be done in the office before going out to the building site.
- *Grey*: The two grey columns contain spreadsheet equations that give you feedback, and must not be overwritten or deleted.
- *Yellow*: Cells in yellow columns are to be filled in manually as balancing progresses. The first (leftmost) yellow column is filled in first, and a new column is used after each adjustment.


M5 21.5

Term.	%design	Guess1	Meas.units	Desig.l/s	K-factor,l/s	Initial & Balancing (clear these column					
T1.1	95 %	(I&R)	l/s	15		13.04	13.61	13.47	13.47	14.53	14.3
T1.2	-	-	l/s	15		14.67	13.07	13.47	13.47		
T1.3	95 %	-	l/s	15		16.9			17.17	13.47	14.3
T1.4	143 %	15.15	l/s	15		20.97					21.5
T1.5	-	-	m3/h	15		97.74					
T1.6	-	-	m3/h	15		129.2					
T1.7	-	-	pa	15	7.32	42.78					
T1.8	-	-	pa	15	7.32	76.58					
	.	.									
	.	.									
	.	.									
	.	.									
	.	.									

Fig. 54 *Worksheet "Balancing" during balancing of 8 terminals*

The different columns are described here:

- "`Term.`" (green): Terminal/damper code. This column is just for your information; it is not used as input for calculations. Each terminal/damper in a balancing group is listed in order of distance to the fan, with the furthest listed first (i.e. 'Reference' terminal/damper). You can list all the terminals/dampers in the whole system, both supply and exhaust, in the same spreadsheet if you wish.
- "`%design`" (grey): Calculated percentage of designed flow rate through the terminal/damper. See the glossary for description. Green coloured percentages indicate nearly design flow rate (within the user-specified "`Balancing accuracy`" tolerance limits); black values are within ±30% of design, while red values deviate more than ±30% from design flow rate.
- The third column (grey) gives automatic messages that suggest what you should do. The column title may be one of the following:
  - "`Message`": A text message is given in the cells below. For example, "`Initial?`" means that you must start taking initial measurements in the chosen balancing group (after having ensured that all terminals/dampers in the group are fully open).
  - "`Guess1`": *MiniBalance* has calculated a first estimate of what value you should adjust the present terminal/damper to. The value is shown in the units of measurement that the user has declared in the "`Meas.units`" column. If the message "`Next>`" appears after you have adjusted the terminal/damper, then the measured flow is within accepted tolerance, so you can move on to the next terminal/damper in the group if you do not wish to fine tune the present terminal/damper any further. *MiniBalance* uses a basic self-learning algorithm to improve its guesses.
  - "`Guess2`", "`Guess3`", etc.: If the first estimate turned out to be inaccurate (i.e. not within the user-specified tolerance in the "`General`" worksheet) then *MiniBalance* calculates progressively more accurate estimates of what you should adjust the present terminal/damper to, until the message "`Next>`" finally appears or until you have balanced the last device in the group.
  - This column also shows the location of the reference and critical terminals/dampers in the group presently being balanced, with "`(Ref.)`" and "`(Crit.)`" respectively. "`(R&C)`" means that the end terminal/damper is also the critical one.
- "`Meas.units`" (green): Measurement units of the instruments used during the balancing process. Alternatives are: "`pa`", "`m3/h`", "`m3/s`", "`l/s`", "`dm3/s`", "`cfm`". This is specified individually for each terminal/damper, as different devices may require different measurement instruments. If you enter an unrecognized measurement unit, then the message "`Units?`" appears in the "`Message`" column.
- "`Desig.xx`" (green), where `xx` is the design flow units are declared in worksheet "`General`": Designed air flow rate through each terminal or damper.
- The fifth column (green) is titled either "`(empty col.)`" or "`K-factor,l/s`" depending on whether you have declared pressure measurement units ("`pa`") for any terminals/dampers. This column is only used for those terminals/dampers for which flow rate is measured using a manometer. Specify the k-factor for each air terminal (or in-duct flow measurement devices such as Pitot tube) such that *MiniBalance* can calculate the volume flow rate as a function of measured pressure. *MiniBalance* uses the following equation: $q_v = k\sqrt{\Delta p}$ where q_v and k both have units [ℓ/s] and Δp has units [pa]. The k-factor is usually provided by the manufacturer of the air terminals. For Pitot tube traverses the k-factor is approximately: $k \approx 1291 \cdot A$ where A is the duct cross section area [m²]. In this case, the pressure should be an area-weighted average from selected traverse points.
- The first yellow column ("`Initial..`") can be used in two ways:
  - It is used for the initial measurements before starting balancing. One reason for initial measurements is to discover which terminal/damper in the group is the critical path, and thus must remain fully open. Initial measurements should include all the terminals/dampers in just <u>one</u> balancing group (see Fig. 7). All

other cells in all the yellow columns shall be cleared. This tells *MiniBalance* which terminals/dampers belong to the group presently being balanced. When balancing is completed for that group, you should clear all the yellow cells in the spreadsheet and start again with measurements of a new group of terminals/dampers (see the example in section 8). These initial measurements generally start with all the terminals/dampers in the group being fully open.

– Alternatively, this column can be used just for control-measurements of the whole, or any part of, the duct system. In this case the dampers are obviously not tampered with before measuring.

- The second and consecutive yellow columns are for typing in measurements during the actual balancing process. As mentioned above, all cells in the yellow columns shall remain empty, apart from the cells that belong to the present balancing group. Use a new column after each adjustment. A terminal/damper can be adjusted any number of times (fine tuning), each time with a new column. Normally you enter two or three measurements in each column: (1) the terminal/damper being balanced, (2) the simultaneous measurement at the Reference terminal/damper, and (3) if the message "`Next>`" appears then give the simultaneous measurement in the next terminal/damper in the list. You do not strictly have to use the end terminal/damper as the reference (though this is normally most accurate). The only requirement is that it is a terminal/damper in the group that is further away from the fan. See, for example, the quick balancing method on page 6. You may enter any number of simultaneous measurements per column if you wish. *MiniBalance* shows the calculated %design value for all these measured terminals/dampers.

14 Acknowledgements

Writing this user guide was in part financed by Enova SF.

15 Bibliography

[1] ASHRAE Standard 111-1988 '*Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air Conditioning, and Refrigeration Systems*'. www.ashrae.org

[2] Parsloe, C. '*Commissioning Air Systems. Application procedures for buildings*' BSRIA publication AG 3/89.3 (2001). www.bsria.co.uk

[3] '*Commissioning Code A: Air Distribution Systems*', CIBSE, 1996/2004. www.cibse.org

[4] '*HVAC Systems Testing, Adjusting and Balancing*' SMACNA handbook 1780. August 2002. www.smacna.org

[5] Mark J. Limb, '*Balancing Ventilation Systems: An Annotated Bibliography*', AIVC publication BIB11, 2001

[6] Thunshelle, K. '*VENT 64.103 Innregulering etter proporsjonalmetoden*'. Oslo : SINTEF Building & Infrastructure. 2002

[7] Thunshelle, K. '*VENT 64.101 Utforming av anlegg for god innregulering: Prosjekteringsveiledning*'. Oslo : SINTEF Building & Infrastructure. 2002

Full text description	Langages used in software: English	Czech	Danish	Dutch	French	Greek	Korean	Norwegian	Spanish
Language name	English	Česky	Dansk	Nederlands	Francais	Ελληνικά	한국어	Norsk	Español
General input data	General input data	Obecné vstupní data	Generelle inputdata	Algemene invoergegevens	Données générales	Δεδομένα εισόδου	일반 입력 데이터	Generell inndata	Entrada general de datos
Building / project name or description	Building/project	Bodova/projekt	Bygning/projekt	Gebouw/project	Bâtiment / projet	Κτίριο/έργου	건물/프로젝트	Bygning/prosjekt	Edificio / proyecto
Description of duct system being balanced, i.e.air handling unit (e.g. number/code), and whether it is the supply or exhaust duct system	AHU #	Větrací jednotka #	System #	MVU #	Groupe n°	ΜΔΑ #	시스템 수	Anlegg #	Numero de unidades de tratamiento de aire (UTA)
Air handling unit setting during balancing: e.g. flow rate, fan speed, pressure rise, or variable frequency drive setting)	AHU operating point	Provozní bod	Aggregat innstilling	MVU volume	Position de réglage	Σημείο λειτουργίας ΜΔΑ	시스템 운전포인트	Aggregat innstilling	¿punto de operación de la UTA?
Date when balancing was conducted	Date balanced	Datum	Dato innregulert	Datum	Date d'équilibrage	Ημερομηνία	날짜	Dato innregulert	Fecha del equilibrado
Name of person who conducted the balancing	Balanced by	Vyvážena, jméno	Utført av	Ingesteld door	Nom de l'opérateur	Εξισορροπημένο από	밸런싱 수행자	Utført av	Nombre de la persona que realizó el equilibrado
SI units of design flow rate	Design flow units	Náv. jednotka průtoku	Prosj.måleenhet	Gebruikte eenheid ontwerp	Unité de débit	Μονάδες παροχής σχεδιασμού	설계유량 단위	Prosj.måleenhet	Unidades SI de diseño del flujo
Balancing accuracy (percentage)	Balancing accuracy	Přesnost vyvážení	Innreg.nøyaktighet	Nauwkeurigheid instelling	Précision requise	Ακρίβεια εξισορρόπησης	밸런싱 정확도	Innreg.nøyaktighet	Precisión del equilibrado
Different measurement units available	(alternatives: pa, cfm, dm3/s, l/s, l/min, m3/h, m3/s)	(alternativy: pa, cfm, dm3/s, l/s, l/min, m3/h, m3/s)	(alternativ: pa, cfm, dm3/s, l/s, l/min, m3/h, m3/s)	(alternatieven: pa, cfm, dm3/s, l/s, l/min, m3/h, m3/s)	(Alternatives: pa, cfm, dm3/s, l/s, l/min, m3/h, m3/s)	(εναλλακτικά: pa, cfm, dm3/s, l/s, l/min, m3/h, m3/s)	(대체 단위: pa, cfm, dm3/s, l/s, l/min, m3/h, m3/s)	(alternativer: pa, cfm, dm3/s, l/s, l/min, m3/h, m3/s)	(alternativas: pa, cfm, dm3/s, l/s, l/min, m3/h, m3/s)
Abbreviation for "Air terminal (or damper)"	Term.	Klapka	Spjeld	Ventiel	Bouch	ΤΔΑ	터미널(댐퍼)	Spjeld	Term.aire
Abbreviation for "% of design flow rate"	%design	%/Návrh	%/Prosj.	%/Ontwerp.	%/Proj	%/Σχέδιο	설계유량 비율	%/Prosj.	%/Diseño
"Message" to the user	Message	Message	Medling	Bericht	Message	Μήνυμα	메시지	Medling	Mensaje
Calculated "guess" by software	Guess	Odhad	Estim.	Raden	Estim.	Εκτίμηση	예측	Estim.	Estim.
Measurement units	Meas.units	Jed.	Måleenhet	Eenheid	Unité	Μονάδες μέτρησης	측정 단위	Måleenhet	Unid.de.Med
Abbreviation for "Design flow rate"	Desig.	Návrh,	Prosj.	Ontwerp,	Design,	Σχεδ.	설계유량:	Prosj.	Diseño,
K-factor for air terminals that are balanced by measuring pressure drop, and using the following equation: Flow rate [ℓ/s] = K·√(Δp)	K-factor: l/s	K: (l/s)?	K-faktor: l/s	K-fact?	K-fact.: l/s	Συντελεστής K	K-factor: l/s	K-faktor: l/s	factor-K: l/s
(empty/blank column)	(empty col.)	(mezera)	(tom kolonne)	(lege kolom)	(col. vide)	Κενή στήλη	(공란)	(tom kolonne)	(colum.vacia)
Initial & Balancing (clear these columns before starting on new string)	Initial & Balancing (clear these columns before starting on new string)	Počátek & Vyvážení (na počátku vymazat sloupce	Orient. & Innregulering (tøm disse gule kolonner før hver streng)	Initieel & instellingen(maak de colummen leeg voor aanvang)	Initial & Equilibrage (videz ces colonnes avant de commencer)	Αρχική τιμή και Εξισορρόπηση (Καθαρίστε αυτές τις στήλες πριν εισάγετε οτιδήποτε νέο)	초기&밸런싱(새로운 문장을 입력하기 전에 이 열을 지우시오)	Orient. & Innregulering (tøm disse gule kolonner før hver streng)	Inicial & Equilibrado (Borrar estas columnas antes de empezar una nueva serie)
"Do not change this worksheet !"	Do not change this worksheet !	Neměňte tento list!	Dette arket skal ikke endres !	Breng geen veranderingen aan in dit werkblad	Ne pas modifier cette feuille de travail!	Μην αλλάξετε αυτό το φύλλο εργασίας!	이 워크시트를 변경하지 마십시오!	Dette arket skal ikke endres !	No cambiar esta hoja de cálculo!
When the reference terminal is also critical terminal. R=reference terminal, which is the terminal at the end of the duct. C=critical terminal, which will be left fully open.	(R&C)	(R&C)	(R&K)	(R&C)	(R&C)	(Α&κ)	참조/임계	(R&I)	(R&C)
Abbreviation for "Reference" terminal/damper, i.e. the terminal/damper at the end of the duct, furthest from fan	(Ref.)	(R)	(Ref.)	(R)	(R)	(Αναφ.)	참조	(R)	(R)
Abbreviation for "Critical" terminal/damper, i.e. the "critical path" terminal/damper for the balancing group, defined as the one that will be left fully open after balancing	(Crit.)	(C)	(Krit.)	(C)	(C)	(κρί.)	임계	(I)	(C)
"Units" of measurement ?	Units?	Jednotka?	Enhet?	Eenheid?	Unités?	Μονάδες?	단위?	Enhet?	¿Unidades?
Short for "K-factor", where k is the flow coefficient, where: Flow rate [ℓ/s] = K·√(Δp)	K-fact?	K?	K-fakt?	K-fact?	K-fact?	Συντ. K?	K-fact?	K-fakt?	¿Fact-K?
"Design?" for design flow rate	Design?	Návrh?	Prosj?	Ontwerp.	Projet?	Σχεδιασμός?	설계유량?	Prosj?	¿Diseño?
"Initial?" for the first orienting measuremens that are conducted with all terminals fully open	Initial?	Poč.?	Orient?	Initieel?	Init.?	Αρχική?	초기측정치?	Orient?	¿Inicial?
"Next>" flags the next terminal to be measured	Next>	Další>	Måle>	Volgende	Suite>	Επόμενο>	다음>	Måle>	Siguiente>
"(no more rows)"	(no more rows)	(žádné další řádky)	(ikke flere rad)	(niet meer rijen)	(pas plus de lignes)	(δεν υπάρχουν περισσότερες σειρές)	(더 이상의 행이 없습니다)	(ikke flere rad)	(no hay más filas)
"(no more columns)"	(no more columns)	(žádné další sloupce)	(ikke flere kolonner)	(niet meer kolommen)	(pas plus de colonnes)	(δεν υπάρχουν περισσότερες στήλες)	(더 이상의 열이 없습니다)	(ikke flere kolonner)	(no hay más columnas)
"Check>" marks a terminal for which the flow rate should be measured and checked	Check>	Kontr.>	Sjekk>	Contr	Contr.>	Έλεγχος>	확인>	Sjekk>	Control>