INSTRUCTIONS

for

MEAR'S

WARM AIR HEATING CALCULATOR

METRIC MODEL

•

FOR DOMESTIC INSTALLATIONS

and

SMALL COMMERCIAL INSTALLATIONS

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CALCULATOR DESIGNERS & MANUFACTURERS
FINE ENGRAVERS ON PLASTIC

MEAR'S

WARM AIR HEATING CALCULATOR

for Domestic Installations

METRIC MODEL

This calculator determines air requirements, velocities, duct sizes, register sizes and heater sizes for warm air domestic heating systems. As these calculations fully occupy the available space on the instrument, it is necessary to determine separately the heat requirements of each room and for this purpose the metric Domestic Central Heating Calculator may be used, or the requirements calculated by the usual methods. Some designers allow for 2 air changes per hour in Warm Air installations as against the usual $1\frac{1}{2}$, which increases heat requirements by about 5%.

The calculator can also be used for the smaller installations in other types of building where these fall within the range of duct sizes and air volumes calibrated on the instrument. In many of these the velocities will exceed those normally recommended as suitable for domestic premises on which the preliminary duct sizing scales are based, as higher noise levels may be tolerated.

In designing the calculator reference has been made to various authorities and also to manufacturers practice both in this country and in America, and in purely technical calculations of air requirements, pressure losses in straight ducting, etc. agreement is very close. In several respects however practice varies, particularly in regard to the choice of duct velocities, equivalent length of duct fittings and heater sizing. These variations are mentioned in greater detail in the appropriate sections below and where recommendations are given on the calculator, these are normally reasonable averages of British practice and information.

The calculator is divided into sections each dealing with particular aspects of the complete calculations and these sections are numbered for easy reference.

Air Volumes and Velocities.

In a Warm Air System, the air changes in volume in its passage through the system. It expands around 12% in passing through the heater and contracts again on cooling in the room before returning through the return air system to the fan inlet. The fan therefore handles cold air, the distribution ducts pass warm air expanded due to temperature rise and the return ducts pass cold air.

To avoid confusion all volumes on the calculator are in cubic metres of cold air at 16°C and all velocities are nominal velocities on the same basis.

MAIN INSTRUCTION SECTION.

This is coloured black and details the sequence of the calculations, each numbered step (except No. 1) corresponding to the numbered segment dealing with that step.

SECTION 2. HEATER SIZE.

In sizing the heater, allowance must be made for heat losses from any ducting passing through unheated spaces (which may amount to 5 or even 10% of the total heat), a normal small contingency, and also an allowance to deal with the very cold weather conditions when the external temperature is below the design figure of —1°C. Any excess capacity is also useful in bringing the temperature up quickly when required.

It is however often practice even with whole house heating to use warm air installation "selectively" and so long as the user understands that diverting the heat to one set of rooms will denude others, then the smaller margins can be used.

In addition, selective heaters are often used having an appreciably smaller capacity than the total heat requirements, but with ducting sized so that a large proportion of the total heat can be supplied to any room needed for occupation to bring the temperature up quickly.

American practice is to allow 17 to 20% margin when sizing the heater.

SECTION 3.

WARM AIR FLOW, PROVISIONAL DUCT SIZE, APPROX. REGISTER SIZE

a. Effect of Room Temperature.

The amount of heat supplied to a room by warm air issuing from a register depends upon the volume of the air and the temperature difference between this air (as it issues from the register) and the room.

Consequently, with equal register temperatures, rooms at low temperatures such as bedrooms require a smaller volume of air per kW heat loss than do rooms at say 20°C. This point is often not accounted for, particularly in American tabulations, but is easily taken into account on the calculator.

b. Determination of Register Temperature.

The temperature of the air coming from the register will be less than at the heater outlet by an amount depending upon the heat loss from the interconnecting ducting. The hotter the air and the greater the loss so that the temperature drop between heater and register can be taken as proportional to the length of ducting and the heater temperature rise. This temperature drop is therefore tabulated on the calculator as a percentage of the heater temperature rise. Thus the loss for 6m of duct is shown as 8% so that if the heater temp. rise were 50°C there would be a loss of 4°C and the temp. at the register would be 4° less than that at the heater outlet. Once register positions have been decided upon, the register temperature at each can be found in this manner.

c. Warm Air Flow.

On the basis of the above information and the kW requirements, the calculator will determine the warm air flow to each register. This is shown against the arrow and an auxiliary scale is provided alongside so that a contingency margin can be added to suit requirements, e.g. selective heating where margins of 50% may be allowed, or buildings requiring a rapid recovery from cold.

d. Provisional Duct Size.

At the same time as the warm air flow is read off, this section indicates a provisional size for the duct. This size is given in terms of diameter of a round duct and lengths of sides of square or rectangualar ducts.

All the rectangular sizes shown are the preferred sizes for economical manufacture recommended by the Heating and Ventilating Contractors' Association and shown in the I.H. V.E. Guide. Only two or three of the square ducts are recommended sizes and these are shown in bold figures. Alternative sizes can of course be used if desired providing they are of equal area.

The sizes selected are approximately the minimum sizes which are permissible without using excessive velocities. They will be closely correct but may have to be increased slightly at a later stage in the case of the longer runs where pressure drops may be too high. They should not however be subsequently reduced without giving careful consideration to the noise which may result from higher velocities.

Alternative sizes are indicated for terminal branch ducts and for risers where the velocities should be lower than in main ducts, again to reduce the possibility of noise.

Typical maximum velocities included in this provisional duct sizing section are:

Duct Dia. mm	Velocity, m/s Main Ducts	Terminal Ducts
100		2.2
200	3.0	2.4
300	3.2	
450	3.6	

These are nominal velocities not allowing for expansion of the air due to temperature rise.

This procedure sizes the terminal ducts to the registers directly from the kW output of each. The flow in the main and the branch ducts is obtained by totalling the flows in the terminal ducts which they serve and to size these it is only necessary to set the Warm Air Flow arrow to the flow and read off the provisional duct size.

e. Approximate Register Free Area.

At the same setting as the warm air flow is found, an indication is given of the approximate free area of the register. This is given for two alternative velocities of 1.5 and 1.75 m/s. The actual velocity through the register finally chosen can be checked using section 6.

SECTION 4. EQUIVALENT LENGTH OF DUCT FITTINGS.

As a preliminary to determination of the pressure losses in the duct system it is necessary to consider the effect of the various bends, branches and fittings, as on small installations their losses are usually much greater than the losses in the straight portions of the ducting.

It is possible to express the loss through each type of fitting as being equal to the loss in a certain length of straight duct of the same size. This is termed the Equivalent Length of the fitting, is usually expressed in metres and varies according to the type of fitting and its size.

Once the equivalent lengths of the fittings are known, these are added to the actual length of the duct and fittings to obtain the Total Equivalent Length of the Duct, on which pressure loss calculations are based. Where changes of size occur, the duct must be split into sections and each portion of the same size treated separately

The calculator gives the equivalent lengths of a wide variety of fittings and the following notes on each may be useful.

Bends and Elbows. There are two main categories, bends which have a round internal corner and elbows which have a square corner normally used for convenience in circumventing corners of building work. It will be seen that square cornered elbows have large equivalent lengths and consideration should always be given to the use of turning vanes in conjunction with them. Two turning vanes will reduce the equivalent length by 40% and seven will reduce it by 70%.

For bends, figures are given for two different radii in each case and it will be seen that losses can be minimised by avoiding small radii. It will also be seen that round mitre bends with 2 or 3 mitres should always be used in preference to single mitre round elbows.

Rectangular bends are taken as having sides in the ratio of 2.5 : 1. For smaller ratios, the equivalent lengths will be nearer those of square bends. For greater ratios equivalent lengths will be larger, but ratios above 4 : 1 are not recommended.

Branches.

The loss in the straight through portion of branch pieces is so small that it can be ignored except in the occasional case where the straight through portion is very small in area relative to the inlet (less than 20% of the inlet area).

The equivalent lengths for branches are in terms of the branch size and are to be added to the branch length.

The losses in branches even of similar design vary considerably according to the relative areas of the branch and the main duct and also according to the relative velocities. Two figures are given on the calculator, one for equal velocities and one for branch velocities only 80% of the main duct velocity and the latter will occur in many cases.

All the figures allow for branch areas equal to 20% of the main duct area. For larger percentages the losses and equivalent lengths would be less.

Additional figures are given on p.8 for shaped branches, both rectangular and round These have somewhat smaller losses than branches without tapered entries and are less likely to cause noise.

Duct Entry.

This can be used for the entry of air to the return air duct and for the take off from the plenum at the heater outlet. Additional figures are given on page 8 for plenum take offs with tapered entries. These have a smaller loss than take offs having no taper.

Reducers, Enlargers and Transitions.

The included angle for these should be kept small when the losses will be nearly negligible. The equivalent lengths are given in metres of the smaller duct in each case. Enlargers with a smaller angle than 20° will have a loss similar to those tabulated for reducers.

As will be seen, transitions have quite small losses for gradual changes, losses can however be considerably increased for rapid changes such as occur in some boot forms.

Register Boxes, Boot Fittings.

The design of these is variable and some typical types are shown on the calculator. The equivalent lengths for these assume a depth from back to front of 90 mm. If this depth is reduced below 75 mm considerable increases in losses can occur. They also assume rounded internal corners on the bends, if these are made square as on many American tabulations then losses will be increased. As the losses in boot fittings and register boxes can be an appreciable proportion of the total system, the design should be carefully considered to minimise losses. Equivalent lengths of a further selection of boot fittings with angular corners are given on page 8.

Registers.

Figures are given for these but it is recommended that the actual loss should be determined from the makers catalogue when selecting them, on the basis of the actual flow.

Return Air Grilles.

Again the pressure loss through these should be obtained from the makers catalogue.

Breeches Pieces and Tees.

These can be looked upon as made up of two bends or in the case of unswept tees as formed from two single mitre elbows. The equivalent length is then taken as the same as that of a bend or elbow similar in size and radius.

Velocity Head Loss.

The losses in fittings can if desired be expressed in terms of velocity head instead of in terms of equivalent length. One velocity head is the pressure equivalent of the energy possessed by the air by virtue of its velocity and is proportional to the velocity squared.

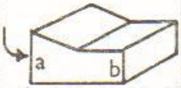
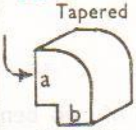
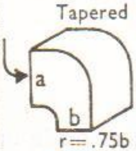
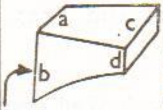
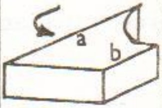
When expressed in terms of velocity heads, the losses in geometrically similar fittings are constant independent of size. They vary only with the type of fitting, and the losses in velocity heads for each type are given on the calculator.

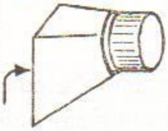
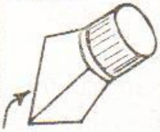
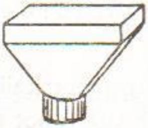
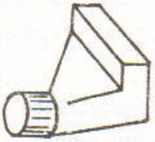
The dynamic equivalence of geometrically similar fittings and the consequent wide variation of equivalent length with size is not taken into account in many published figures of equivalent lengths.

American tabulations of equivalent lengths show apparent independence of size as a result of standardisation of duct sizes, and the figures usually refer to main ducts 200 mm deep and of varying widths, round ducts from 100 to 180 mm dia. and terminal ducts and risers 250 mm to 350 mm wide by 80 mm deep, different sets of figures being given for each of these three size ranges.

Additional Equivalent Lengths of Fittings.

The following tables give equivalent lengths of shaped starting collars and take-offs.
The figures for starting collars include the Duct Entry Loss from the plenum.
Figures are also given for boot fittings with angular corners.

DUCT SIZE		EQUIVALENT LENGTH OF FITTING - METRES				
Square Duct Length of side mm	Rect. Duct. Area m^2	STARTING COLLAR Tapered  a=1.5b	SHORT STARTING ELBOW Tapered  a=1.5b	STARTING BEND Tapered  r=.75b a=1.5b	TRANSITION STARTING COLLAR  ab=1.5cd	RECTANGULAR SIDE TAKE OFF  a=1.5b
100	0.01	1.2	3	1.6	2.5	1.9
125	0.016	1.5	5	1.9	3.5	2
150	0.023	1.8	6	2.5	5	3
200	0.04	2	8	3.5	6	4
250	0.063	3	10	5	7	5
300	0.09	4	13	6	9	6
350	0.123	5	17	7	11	7
400	0.16	5	20	9	13	9
450	0.203	6	23	10	15	11
500	0.25	7	27	12	17	
600	0.36	9	34	15	22	
Velocity Head Loss		0.25	0.95	0.39	0.65	0.42

DUCT. DIA.	EQUIVALENT LENGTH OF FITTING ~~FEET~~ METRES				
mm	SIDE TAKE OFF Tapered 90° 	SIDE TAKE OFF Tapered 45° 	UNIVERSAL BOOT 	ANGLE BOOT 	END BOOT 
100	4	3	1.3	6	10
125	5	4	1.6	8	14
150	6	5	2.2	10	18
175	7	5	2.5	13	22
200	8	6			
250	10	7			
Velocity Head Loss	1.0	0.7	0.3	1.7	3.0

SECTION 5. PRESSURE LOSS IN DUCTING.

Having determined the provisional duct sizes it is necessary to check them finally for pressure loss and adjust if necessary. The losses within the complete duct system including the losses at register, air filter if fitted and in the return air duct should when totalled be within the capacity of the fan after allowing a margin of say 20% for contingencies. On domestic installations a fan pressure of about 0.6 mbar is usual in which case calculated losses should not exceed 0.5 mbar.

The pressure loss given by the calculator allows for the expansion of the warm air and consequently is about 10% higher than normal tabulations for cold air.

It is usual to design the return air system so that it has a relatively low pressure loss, about 25% of the available fan pressure. This will often be so automatically because of short lengths, but somewhat larger sizes to reduce pressure loss do not increase the heat losses as they would on the warm air ducts.

Equivalent Duct Size. The duct size scale on this section of the calculator is calibrated for round and rectangular ducts and can be used to read off equivalent sizes of each which will give the same pressure loss.

Long Vertical Ducts. If warm air has to flow downwards through a duct it has to overcome the natural tendency of warm air to rise. This causes a pressure loss due to thermal head of approximately 0.12 mbar for each 10m of height. Where applicable this should be added to the ducting pressure loss. Conversely there is an equivalent gain when the flow is upward.

SECTION 6. VELOCITY IN DUCTING, REGISTERS AND GRILLES.

This section is a straight forward conversion from flow and size to velocity. The duct size scale is calibrated for rounds, squares and rectangles and can be used to convert from one to the other on an equal area or an equal velocity basis.

When checking velocities through registers and grilles use the free area not the total area.

Certain maximum velocities are suggested in this section which are an average of various British Authorities. The principal factor restricting velocities is noise and keeping velocities reasonable will assist in keeping noise down to an acceptable level (unfortunately it increases heat losses from the ducting). American sources give somewhat higher figures than these for domestic installations as follows:

Main ducts - 3.6/4.6 m/s   Branch ducts - 3.1 m/s   Risers - 2.5 m/s

SECTION 7. HEAT LOSS OR TEMPERATURE DROP IN DUCTS.

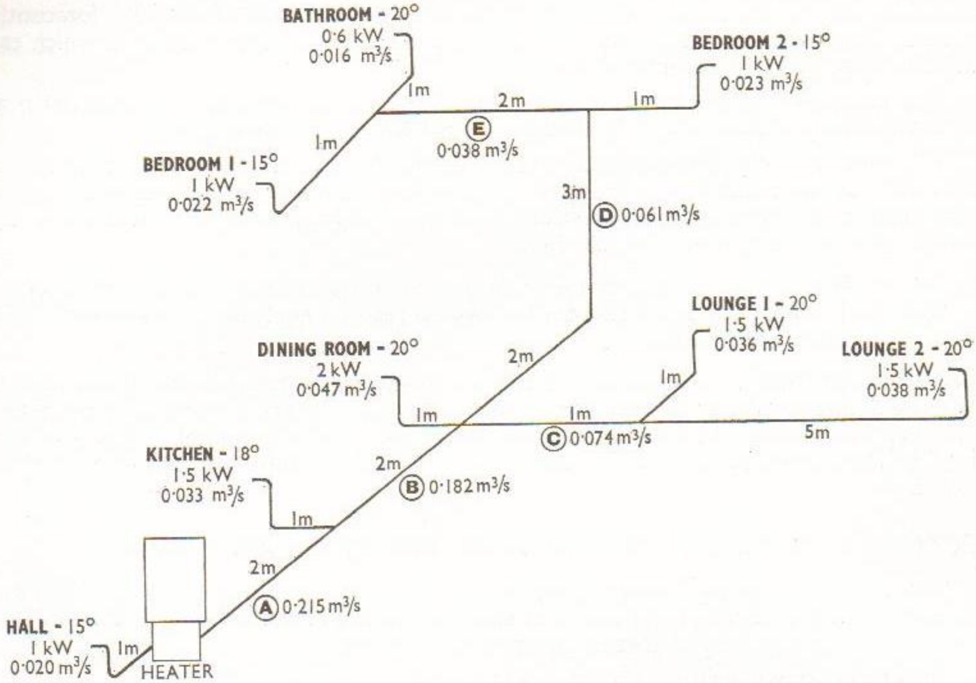
This section is designed to give a close indication of the amount of heat lost from the duct system. Whilst it is not necessary in every case to check this, the information can be useful if long ducts are used particularly where the diameter is small.

It is instructive in showing that low velocities result in a greater proportion of heat loss and that small diameter pipes also lose a greater proportion than large ones as is to be expected from the larger perimeter to area ratio.

Using this section a check can be made on the temperature drop between heater and register for which an approximation is made initially as mentioned on page 3 section 3b.

EXAMPLE

The sketch below shows the proposed run of ducting in a house, after having decided the position of the outlets and the heater. Room temperatures and kW heat requirements are indicated for each outlet. The warm air flows are also shown as calculated from the table below.



Determination of Air Flow, Provisional Duct Size and Approx. Register Size:—

1 ROOM	2 Room Temp. °C	3 Temp. Difference Heater to Room °C	4 Duct Length Heater to Register metres	5 Temp. Drop in Duct °C	6 Temp. Difference Register to Room °C	7 kW Requirement	8 Air Flow m³/s	9 Provisional DUCT SIZE mm	10 Provisional Register Free Area m² at 1.5 m/s
Hall	15	43	1	1	42	1.0	0.020	125 dia.	0.013
Kitchen	18	40	3	2	38	1.5	0.033	150 ,,	0.022
Dining Room	20	38	5	3	35	2.0	0.047	175 ,,	0.032
Lounge 1	20	38	6	3	35	1.5	0.036	150 ,,	0.024
Lounge 2	20	38	10	5	33	1.5	0.038	150 ,,	0.025
Bedroom 1	15	43	12	6	37	1.0	0.022	125 ,,	0.015
Bathroom	20	38	12	6	32	0.6	0.016	100 ,,	0.011
Bedroom 2	15	43	10	6	37	1.0	0.023	125 ,,	0.015
Return Air Temp. ...... say 18°			Total			10.1	0.235		
Heater Temp. Rise ...... 40°			Margin say 25%			2.5			
Heater Outlet Temp. ...... 58°			Required Heater Size			12.6 kW			

Calculation Procedure in preparing the preceding table:—

1. Tabulate room temperatures and kW requirements at each outlet. Columns 2 and 7.
2. Total heat requirements and add margin to find heater size.
3. By inspection of room temperatures and kW requirements, estimate the average return air temperature, in this case say 18°. (There are 3 kW returned at 15°C, 1.5 kW at 18°C and 5.6 kW at 20°C).
4. Add the temperature rise of the selected heater to the return air temperature to find the HEATER OUTLET TEMPERATURE.
5. Subtract room temperature from heater outlet temperature to obtain col. 3.
6. Note in col. 4 actual duct length from heater to each register.
7. From table on calculator section 3 find temperature drop in each duct. Enter in col. 5.
8. Subtract col. 5 from col. 3 to obtain col. 6.
9. Find Air Flow, Duct Size and Register Area from calculator. Enter in cols. 8, 9 and 10.

Determination of Pressure Losses in the Duct System:—

DUCT	Flow in Duct m^3/s	Provisional Duct Size mm	Equivalent Length of Duct Section Actual length + branch + bends + register box + register	Pressure Loss mbar	Velocity m/s
Section A	0.215	300 x 250	2 + 6 = 8	.034	2.9
" B	0.182	300 x 200	2 + 0.6 = 2.6	.015	3.1
" C	0.074	250 x 100	1 + 3 = 4	.040	3.0
" D	0.061	250 x 100	5 + 0.4 + 1.5 = 6.9	.050	2.5
" E	0.038	150 x 100	2 + 6 = 8	.079	2.6
to Hall	0.020	125 dia.			1.6
" Kitchen	0.033	150 "			1.9
" Dining Rm.	0.047	175 "			2.0
" Lounge 1	0.036	150 "			2.1
" Lounge 2	0.038	150 "	5 + 1.7 + 8 + 7 = 21.7	.124	2.2
" Bedroom 1	0.022	125 "	1 + 6 + 0.9 + 6 + 5 = 18.9	.095	1.8
" Bathroom	0.016	100 "			2.1
" Bedroom 2	0.023	125 "			1.9

Maximum Pressure Loss is to Bedroom 1 and is .034 + .015 + .050 + .079 + .095 = .273 mbar
(Calculations have only been completed for the two routes which appeared likely to give the largest pressure losses, i.e. Lounge 2 and Bedroom 1)

Plus Pressure Loss in return air duct to be similarly calculated-say = .120

.393

Contingency say 20% .079

REQUIRED FAN PRESSURE = .472 mbar

Calculation Procedure in preparing above table:—

1. Tabulate all sections of ducting together with their flows, provisional sizes and velocities.
2. List the length of each section of the index circuit including equivalent length additions for branch, reducer, bend, register box, register etc., as they occur and total for each section.
3. Find from calculator the pressure loss in each section and enter in table. Total these as necessary to find the line with maximum loss.

In the estimation of the equivalent lengths in the above table, simple register boxes have been allowed for but if end boots were necessary, equivalent lengths would be higher.

In practice it is not necessary to determine the pressure loss in all the branches but only in the ducts to the index register which can often be found by inspection.

For practical convenience some modifications could be made to the duct sizes, e.g. sections A and B could be the same size.

If a filter is fitted the loss through this would be included in the calculations.

METRIC CONVERSION FACTORS

LENGTH				
inches	x	25.4	=	millimetres
feet	x	.304 8	=	metres
AREA				
square inches	x	645.2	=	square millimetres
square feet	x	.092 9	=	square metres
VOLUME				
cubic inches	x	16.39	=	millilitres
cubic inches	x	.016 39	=	litres
cubic feet	x	.028 32	=	cubic metres
cubic feet	x	28.32	=	litres
cubic metres	x	1,000	=	litres
gallons	x	4.546	=	litres
VELOCITY				
feet/second	x	.304 8	=	metres/second
MASS				
pounds	x	.453 6	=	kilogrammes
FLOW				
gallons/minute	x	.075 77	=	litres/second
gallons/hour	x	.001 263	=	litres/second
pounds/hour	x	.000 126	=	kilogrammes/second
cubic feet/minute	x	.471 9	=	litres/second
PRESSURE				
pounds/square inch	x	.068 95	=	bars
pounds/square inch	x	68.95	=	millibars
inches of water	x	2.491	=	millibars
feet of water	x	29.89	=	millibars
HEAT and POWER				
Btu	x	1,055	=	joules
Therm (100,000 Btu)	x	105,500,000	=	joules
Therm	x	29.31	=	kilowatt hours
kilowatt hours	x	3,600,000	=	joules
Btu/hour	x	.293 1	=	watts
'U' VALUES – CONDUCTANCE				
Btu/hour/sq.ft./°F	x	5.678	=	watts/square metre/°C