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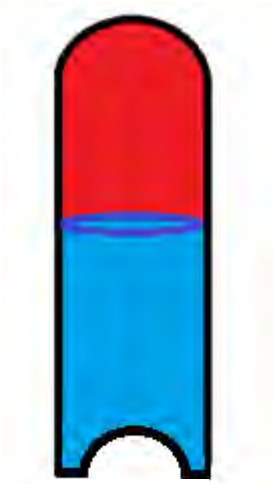
Instructions for Calculation of Mass or Liquid Level of Agent

Before beginning any calculations, please note whether the bottom of the cylinder is similar to

Cylinder 1 or **Cylinder 2**. This is important because the set of instructions for the calculations depend on the type of cylinder. Below is a list of agents which are usually found in each type of cylinder:

- **Cylinder 1** – CO_2
- **Cylinder 2** – NOVEC™ 1230, FM-200™, FE-13™, FE-25™, FE-36™, NAF-S-111, 125 & 127, Halon 1301



Cylinder 1

Cylinder 2

- **Numbers should be rounded for accuracy, for example 1473 rounded to 3 figures is 1470 (it has three numerical figures in). However 0.05968 would be rounded to 0.0597 as the two 0 figures at the beginning of the number do not count. 103.8 would be rounded to 104 because a 0 figure does count as soon as it appears *after* another number.**

Type all calculations into a calculator as displayed.

Units

- All the distance measurements in this document are in centimetres (cm) and all the mass measurements are in kilograms (kg).

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- To convert a value in metres (m) to centimetres (cm), multiply the value by 100. (1m=100cm).
- To convert a value in millimetres (mm) to centimetres (cm), divide the value by 10. (1cm=10mm).
- To convert a value in grams (g) to kilograms (kg), multiply the value by 1000. (1kg=1000kg).

Cylinder 1 - Calculating Mass of Agent from Liquid Level

Initially several measurements need to be taken and written down:

1. Liquid level, ***l***, this should be measured from the base of the cylinder in centimetres. (The liquid level can be measured using a Portalevel)

2. Circumference of the cylinder, ***c***, in centimetres. This is the distance all the way around the cylinder.

3. Thickness, ***t***, which is the thickness of the wall of the cylinder in centimetres. This can be measured using a thickness gauge.

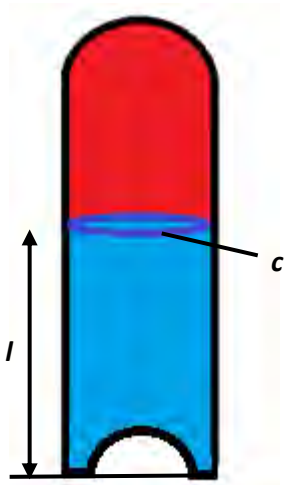

Figure 1.

The overall equation used to calculate the mass is:

$$m = (d \times 3.14 \times (r - t) \times (r - t) \times l) \div 1{,}000{,}000$$

The steps below explain how to use this equation

a) Calculate the radius of the cylinder: divide the measured value of circumference, ***c***, by 6.28 and write this down

b) Subtract the value of the thickness from the radius: radius – ***t*** and write this down

c) Square the number calculated in (b): multiply it by itself (e.g. (b) x (b)) and write this down

d) Look at the table on the last page. Find the correct agent and temperature and identify the value of density, ***d***, to use

e) Then calculate: density x 3.14 x the value from (c) x liquid level and write this down

f) Divide the value calculated in (e) by 1,000,000 and this is the agent mass in kilograms.

Example Calculation

An example is given below

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The measurements used in the example are displayed in the table below.

c	*t*	*d*	*l*
85 cm	0.7 cm	773	106

a) Calculate the radius: circumference divided by 6.28

$$r = c \div 6.28 = 85 \div 6.28$$
$$= 13.5$$

Write down: r = 13.5

b) Subtract the value of the thickness from the radius

$$r - t = 13.5 - 0.7$$
$$= 12.8$$

Write down: (b) = 12.8

c) Multiply the number calculated in step (b) by itself

$$(b) \times (b) = 12.8 \times 12.8$$
$$= 163.8$$

Write down: (c) = 163.8

d) Identify the correct value of density to use from table (page 10). For example, a cylinder of CO_2 at a temperature of 68 ^{o}F has ***d*** = 773

e) Calculate: density x 3.14 x (c) x liquid level

$$d \times 3.14 \times (c) \times l = 773 \times 3.14 \times 163.8 \times 106$$
$$= 42,143,335$$

Write down: (e) = 42,143,335

f) Divide the number in (e) by 1,000,000

$$42,143,335 \div 1,000,000 = 42.1$$

The mass of agent in the cylinder is <u>42.1 kg</u>. It has been rounded to 3 figures.

<u>Cylinder 1 - from</u>

Measurements needed to calculate the mass of agent:

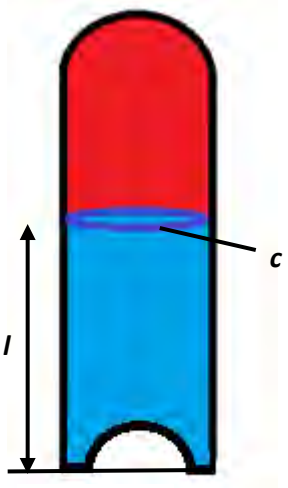

Figure 1.

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1. Mass of the full cylinder, w in kilograms, found by weighing the cylinder that has the agent in it
2. Mass of the empty cylinder (i.e. when it has no agent in it), e, in kilograms. This is often printed on the side of the cylinder or is available from the manufacturer.
3. Circumference of the cylinder, c, in centimetres. This is the distance all the way around the cylinder.
4. Thickness, t, which is the thickness of the wall of the cylinder in centimetres. This can be measured using a thickness gauge.

The overall equation used to calculate the liquid level is

$$l = m \times 1{,}000{,}000 \div (d \times 3.14 \times (r - t)^2)$$

The steps below explain how to use this equation

a) Calculate the radius of the cylinder: divide the measured value of circumference, ***c***, by 6.28 and write this down

b) Subtract the value of the thickness from the radius: radius – ***t*** and write this down

c) Square the number calculated in (b): multiply it by itself (e.g. (b) x (b)) and write this down

d) Look at table (page 10). Find the correct agent and temperature and identify the value of density, ***d***, to use

e) Calculate the agent mass, ***m***, subtract the empty cylinder mass from the full cylinder mass and write this down.

f) Then calculate: density x 3.14 x the value from (c) and write this down

g) Divide the value in (e) by (f) and write this down

h) Multiply the value in (g) by 1,000,000 and this is the liquid level in centimetres

<u>Example Calculation</u>

An example is given below. The measurements used in the example are displayed in the table below:

c	*t*	*d*	*w*	*e*
85 cm	0.7 cm	773	121 kg	76 kg

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a) Calculate the radius: circumference divided by 6.28

$$r = c \div 6.28 = 85 \div 6.28$$
$$= 13.5$$

Write down: r = 13.5

b) Subtract the value of the thickness from the radius

$$r - t = 13.5 - 0.7$$
$$= 12.8$$

Write down: (b) = 12.8

c) Multiply the number calculated in step (b) by itself

$$(b) \times (b) = 12.8 \times 12.8$$
$$= 163.8$$

Write down: (c) = 163.8

d) Identify the correct value of density to use from table (page 10). For example, a cylinder of CO_2 at a temperature of 68°F has ***d*** = 773

e) Calculate the agent mass, ***m***: full cylinder mass – empty cylinder mass

$$m = w - e = 121 - 76$$
$$= 45$$

Write down (e) = 45

f) Calculate: density x 3.14 x (c)

$$d \times 3.14 \times (c) = 773 \times 3.14 \times 163.8$$
$$= 397,579$$

Write down (f) = 397,579

g) Calculate (e) ÷ (f)

$$(e) \div (f) = 45 \div 397,579$$
$$= 0.0000113$$

Write down (g) = 0.0000113

h) Calculate (g) x 1,000,000

$$(g) \times 1,000,000 = 0.0000113 \times 1,000,000$$
$$= 113$$

The liquid level of agent in the cylinder is <u>113 cm</u>. It has been rounded to 3 figures.

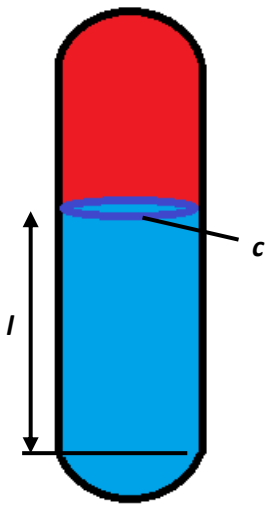

Figure 2.

Cylinder 2 - Calculating Mass of Agent from Liquid Level

Initially several measurements need to be taken and written down:

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1. Liquid level, ***l***, this should be measured from the base of the cylinder in centimetres. (The liquid level can be measured using a Portalevel)
2. Circumference of the cylinder, ***c***, in centimetres. This is the distance all the way around the cylinder.

The overall equation used to calculate the mass is:

$$m = \left(d \times 3.14 \times r^2 \times l\right) \div 1{,}000{,}000$$

The steps below explain how to use this equation

a) Calculate the radius of the cylinder: divide the measured value of circumference, ***c***, by 6.28 and write this down

b) Square the number calculated in (a): multiply it by itself (e.g. (a) x (a)) and write this down

c) Look at table (page 10). Find the correct agent and temperature and identify the value of density, ***d***, to use

d) Then calculate: density x 3.14 x the value from (c) x liquid level and write this down

e) Divide the value calculated in (d) by 1,000,000 and this is the agent mass in kilograms.

<u>Example Calculation</u>

An example is given below. The measurements used in the example are displayed in the table below.

c	*d*	*l*
85 cm	1400	61 cm

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c	*d*	*l*
85 cm	1400	61 cm

a) Calculate the radius: circumference divided by 6.28

$$r = c \div 6.28 = 85 \div 6.28$$
$$= 13.5$$

Write down: r = 13.5

b) Multiply the number calculated in step (a) by itself

$$r \times r = 13.5 \times 13.5$$
$$= 182.3$$

Write down: (b) = 182.3

c) Identify the correct value of density to use from table (page 10). For example, a cylinder of FM-200™ at a temperature of 20 °C has ***d*** = 1400

d) Calculate: density x 3.14 x (c) x liquid level

$$d \times 3.14 \times (b) \times l = 1400 \times 3.14 \times 182.3 \times 61$$
$$= 48,884,838$$

Write down: (d) = 48,884,838

e) Divide the number in (d) by 1,000,000

$$(d) \div 1,000,000 = 48,884,838 \div 1,000,000$$
$$= 48.8$$

The mass of agent in the cylinder is <u>48.8 kg</u>. It has been rounded to 3 figures.

<u>Cylinder 2 - from</u>

Measurements needed to calculate the mass of agent:

1. Mass of the full cylinder, ***w*** in kilograms, found by weighing the cylinder that has the agent in it

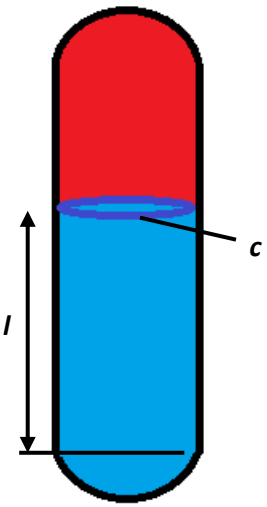

Figure 2.

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2. Mass of the empty cylinder (i.e. when it has no agent in it), ***e***, in kilograms. This is often printed on the side of the cylinder or is available from the manufacturer.
3. Circumference of the cylinder, ***c***, in centimetres. This is the distance all the way around the cylinder.

The overall equation used to calculate the mass is:

$$l = (m \times 1{,}000{,}000) \div (d \times 3.14 \times r^2)$$

The steps below explain how to use this equation

a) Calculate the radius of the cylinder: divide the measured value of circumference, ***c***, by 6.28 and write this down

b) Square the number calculated in (a): multiply it by itself (e.g. (a) x (a)) and write this down

c) Look at table (page 10). Find the correct agent and temperature and identify the value of density, ***d***, to use

d) Calculate the agent mass, ***m***, subtract the empty cylinder mass from the full cylinder mass and write this down.

e) Then calculate: density x 3.14 x the value from (b) and write this down

f) Divide the value in (e) by (f) and write this down

g) Multiply the value in (g) by 1,000,000 and this is the liquid level in centimetres

<u>Example Calculation</u>

An example is given below. The measurements used in the example are displayed in the table below.

c	*d*	*w*	*e*
85 cm	1400	120 kg	70 kg

a) Calculate the radius: circumference divided by 6.28

$$r = c \div 6.28 = 85 \div 6.28$$
$$= 13.5$$

Write down: r = 13.5

b) Multiply the number calculated in step (a) by itself

$$r \times r = 13.5 \times 13.5$$
$$= 182.5$$

Write down: (b) = 182.5

c) Identify the correct value of density to use from table (page 10). For example, a cylinder of FM-200™ at a temperature of 68°F has ***d*** = 1400

d) Calculate the agent mass, ***m***: full cylinder mass – empty cylinder mass

$$m = w - e = 120 - 70$$
$$= 50$$

Write down (d) = 50

e) Calculate: density x 3.14 x (b)

$$d \times 3.14 \times (b) = 1400 \times 3.14 \times 182.5$$
$$= 802,270$$

Write down (e) = 802,270

f) Calculate (d) ÷ (e)

$$(d) \div (e) = 50 \div 802,270$$
$$= 0.0000623232$$

Write down (g) = 0.0000623232

g) Calculate (f) x 1,000,000

$$(f) \times 1,000,000 = 0.0000623232 \times 1,000,000$$
$$= 62.3$$

The liquid level of agent in the cylinder is 62.3 cm. It has been rounded to 3 figures.

Appendix 1 : Table of Liquid Agent Densities

Table 1: Liquid Densities for different agents

All the densities quoted here are quoted to three significant figures only.

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Agent	Temperature (°F)	Density, ρ_l (kg m^{-3})
CO_2	41	896
	50	861
	59	821
	68	773
	77	710
FM-200™	41	1470
	50	1450
	59	1430
	68	1400
	77	1381
	95	1335
NOVEC 1230™	41	1660
	50	1645
	59	1630
	68	1615
	77	1600
	95	1570