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ANALYSIS OF A DESIGNED LABORATORY CULTURE INCUBATOR

by

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Abstract
In biology, an **incubator** is a device used to grow and maintain microbiological cultures or cell cultures. The incubator maintains optimal temperature, humidity and other conditions such as the carbon dioxide (CO_2) and oxygen content of the atmosphere inside. Incubators are essential for a lot of experimental work in cell biology, microbiology and molecular biology and are used to culture both bacterial as well as eukaryotic cells. Louis Pasteur used the small opening underneath his staircase as an incubator. Incubators are also used in the poultry industry to act as a substitute for hens. This often results in higher hatch rates due to the ability to control both temperature and humidity. Various brands of incubators are commercially available to breeders. This work covers the design of a typical incubator for microbiological cultures.

Keywords: Analysis, designed, laboratory, culture and incubator

Introduction

The simplest incubators are insulated boxes with an adjustable heater, typically going up to 60 to 65 °C (140 to 150 °F), though some can go slightly higher (generally to no more than 100 °C). The most commonly used temperature both for bacteria such as the frequently used E. coli as well as for mammalian cells is approximately 37 °C, as these organisms grow well under such conditions. For other organisms used in biological experiments, such as the budding yeast Saccharomyces cerevisiae, a growth temperature of 30°C is optimal.

More elaborate incubators can also include the ability to lower the temperature (via refrigeration), or the ability to control humidity or CO_2 levels. This is important in the cultivation of mammalian cells, where the relative humidity is typically >80% to prevent evaporation and a slightly acidic pH is achieved by maintaining a CO_2 level of 5%.

In microbiology and various other related fields temperature control up to 100°C plays an important role in incubation processes and for a variety of medical applications. A practical application of a culture incubator is stated below.

Design of culture incubator

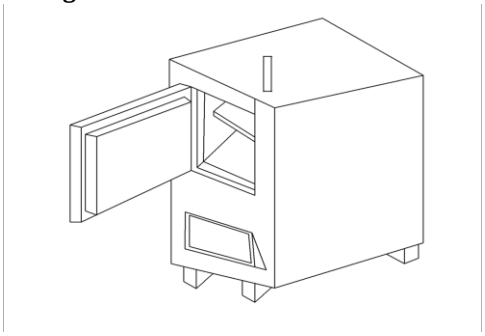

Fig.1: A Medical Laboratory culture incubator

In designing any given culture incubator, it is required among other things, that the main feature mentioned below should conform to international standards.

1. An Exterior steel body (mild steel, stainless steel etc) coated by enamel.
2. In interior chamber of electro-polished or enhanced enamel, corrosion- resistant metal alloy of low density and high melting point (stainless steel, Aluminum alloy etc).
3. Adequate insulation provision (Air Cooled-fan propelled, mineral wool, fiber glass, wood etc, insulation).
4. A safety cut-out thermometer -thermostat to safeguard samples.
5. A glass thermometer to facilitate temperature monitoring and calibration.

- A temperature control/setting unit (thermostat) with a clear display of set temperature.

The interior chamber

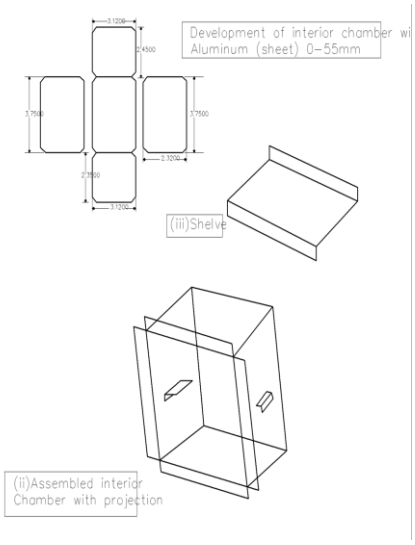

Fig 2: Interior views of a culture incubator

Aluminum sheet of 0.55mm thickness was selected to be used for making the interior chamber. Aluminum, which is a ductile material and melts at about a temperature pf 660°C in its pure form, it has a density of about one third that of iron and tensile strength of 60N/m^2 with a very high thermal and electric conductivity (next after copper and silver) a corrosion resistant metal with some proven germicidal properties and luster property hence a preferred material. The development of the interior chamber was done on paper and marking-out started in earnest on the Aluminum sheet of dimension 375mm by 275mm in two separated sheet. The folding and joining (scan) were done to form a rectangular box of 360mm x 305mm x 230mm [0.360m x 0.305m x 0.230rn] [Height x Width x Dept) with a 40mm projection at each open end, as shown in the diagram (fig. 3A) included was a shelve hanger. The Aluminum shelve has a dimension of 300mm by 210mm [0.300m x 0.210m] with 20mm right angled projection on both end.

(A) Design calculations for the interior chambers

(1) Aluminum Sheet (0.55mm) Sheet I

Sheet 1

(i) Area = L X W

= 0.235m X 0.275m = 0.064625

0.065m^2

(ii) Sheet 2

Area = 0.317m x0.375m = 0.118875

= 0.119m^2

(iii) Sheet 3

Area = 0.275m x 0.375m = 0.064625

= 0.065m^2

(iv) Sheet 4

Area = 0.315m x 0.235m = 0.074025

= 0.074m^2

(2) Shelve

Total area = [0.210 x 0.300] + 0.020 x 0.300] + 0.020 x 0.300]

= 0.063000 + 0.012000

= 0.075000 = 0.075m^2

Volume of the assembled interior chamber with projections (in-to-in)

Vol. = L x w x h 0.360x0.305x0.230

= 0.025204000

= 0.025m^3

Building the exterior frame work

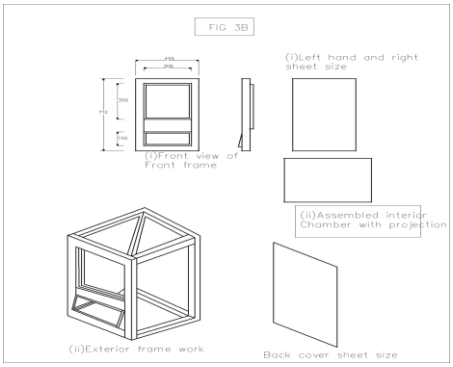

Fig 3: Exterior views of a culture incubator

The body framework is made up of mild steel. Mild steel is a tough material with a specific gravity of about 7.5, a tensile strength of about 206N/m^2. Material-make-up of the exterior body includes:

1. 2mm thickness mild steel sheet.
2. 2mm, (53mm x 26mm) Rectangular Hollow steel (RHS)
3. 1.5mm, (26mm x 26mm) square Hollow steel (SHS)
4. 1mm, mild steel sheet
5. 3mm (34) mild steel bar

In building the body frame work, RHS were cut into dimensions 455mm out to cut, chamfered at both ends and 712mm out with chamfer at ends, both in pairs. From a rectangle of dimension 712mm by 455mm, 3b (i) shows the frame work. The back side of the frame was constructed using the square Hollow steel (SHS) to form a rectangular of dimension 712mm by 455mm with four linking length of 330mm the from and back frame were wedded together to form the body frame as shown in fig. 3b(ii) The 2mm, mild steel sheet was cut to dimension 657mm by 330mm and another 405mm,330mm both in pairs for left hand side, right hand side and top, bottom of the exterior frame respectively as shown in diagram 3b (iv) the back cover steel has dimension of 657mm by 405mm.

(B) Design calculations for the frame

Area =Lxw

- Area = 0.712 x 0.455
- = 0.323960
- = 0.324m^2

Top and Bottom sheet size

Area = 0.405 x 0.330 = 0.148.500
= 0140m^2

Left hand and Right sheet size

Area = 0.657 x 0.330 0.216810
=0.21 7m^2

Back cover sheet size

Area = 0.405 x 0.657 = 0.266085
= 0.266m2

Vol. of frame work

Vol. =Lxwxh
= 0.382 x 0.712 x 0.455
= 0,123752720 = 0,124m^2
= 1.24 x 101m^2

The door

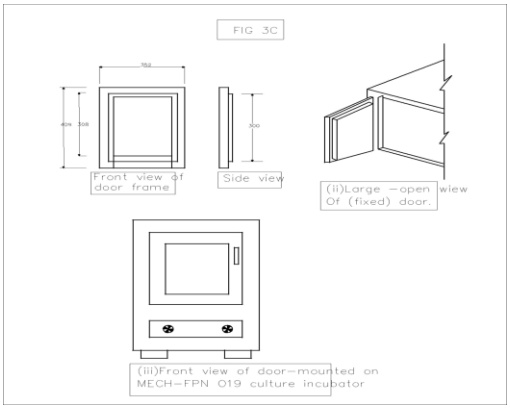

Fig. 4: Various views of the door

The door just like the exterior frame work was constructed to fit into the space created on the front side of the exterior frame work. It comprised of rectangle made from RHS with dimensions 409mm by 352mm out to out on another rectangle (imposed) of SHS of dimension 300mm by 240mm into with a mild steel sheet 1mm thickness placed in between before welding together as shown in fig. 3c.

Design calculation for the door frame

Area =L x w
0.409 x 0.352 = 0.143968
Area = 0.409 x 0.352 = 0.143968 = 0.144m^2

Design of electrification process

Heat, being the major requirement in the construction of any incubator, is a major priority in building the culture incubator. Heat could be produced by friction, chemical reaction (e.g. combustion) electrically or via solar energy. The method of heat production depends on the usage effect, requirement and availability.

Electric heating

When electric pass through molecules and atoms of a substance, they collide with other electrons, this electrons collision results in the production of heat. This explains why passage of current is always accompanied by the generation of heat. Joules law of electric heating states that the amount of work required to maintain a current of I Amperes through a resistance of R ohms fir t seconds if given by work done (W.D.) = l^2Rt joules = VIt joules where R = V/I (ohm's law)

= V2 t/R joules; where I = V / R

This work is converted into heat and is dissipated away, the amount of heat produced is $H = \frac{W.D}{\text{Mechanical equivalent of heat}}$

$$\frac{W.D}{J}$$

J = 4,200 joules / kcal

Heat $= \frac{W.D}{4,200} = \frac{I^2Rt}{4,200}$

Since $W = I^2R$

Transducers are used to convert electric energy into heat which is required in a mild form in the building of the culture incubator.

Electrical (electronics) material

In the course of carrying out this project, Electrical materials used include:

1. Thermostat switch (Adjustable to appropriately 300°C)
2. Transducers (240v, 50Hz)
3. A plug (250v, 50Hz, 13A with grounded earth terminal)
4. Wire 0.003m^2 thickness.

Electrification Connection

Since heat is required in the interior chamber, hence transducer was decided. On the back side of the interior transducer were placed at the top, right hand side, bottom and the left hand side, they were connected in series so as to ensure uniformity of heating in the incubator. The 0.003m2 wire was used in connecting the transducer in series due to the heating effect that will arise.

Characteristics of a series circuit

1. Same current flows through all parts of the circuit.
2. Different resistors have their individual voltage drops.
3. Voltage drops are additive.
4. Applied voltage equals the sum of different voltage drops.
5. Resistance are additive

The transducers were mounted directly on the back side of the interior to achieve a high efficiency of heat production and transfer by conduction. The power switch was connected in series with a LED indicator to show the operator/ user the presence of electric power. The thermostat switch is to the act as a safety device which is to cut out at set stage, preferably when the transducer attain a certain temperature when the circuit is on and is adjustable to approximately 300°C with a sensitive terminal, since all four (4) transducers are connected in series and have equal power rating they experience equal heating, hence any reading taken from any one is equivalent to the value of others.

The thermostat switch is connected in series with a separate LED indicator such that when the switch is on the LED comes on and goes off when the switch is put off.

Power is supplied from on alternating current supply of 240V, 50Hz by a plug of current rating 3A with a safety fuse and an earth terminal so as to correct any current leakage that may arise on any part of the equipment due to fail wires or opposite widen in contact.

Diagrammatically the whole electrical circuit can be represented as shown in the figure below.

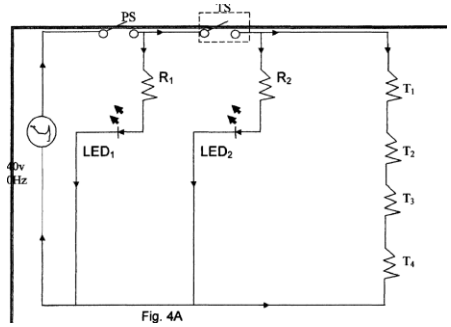

Fig. 5: Diagram showing the whole electric circuit.

Key – figure 4a

PS - Power switch
T S - Thermostat switch
LED 1 - Light emitting diode-indicating power
LED 2 - Light emitting diode indicating thermal control
T 1-Transducer I on the left hand side of the interior
T 2-Transducer 2 on the top side of the interior
T 3-Transducer 3 on the right hand side of the interior
Direction of flow (current) ⟶
R 1-Resistor connected in series with LED I
R 2-Resistor connected in series with LED 2
T4-Transducer 4 on the Bottom side of the interior

T4-Transducer 4 on the Bottom side of the interior

Power rating of the equipment

From the characteristic of series circuit it states that current flow in any circuit is constant, resistances are additive and powers are additive.
Since the power is additive, the total power consumed by the transducer in series is

$W = W_1 + W_2 + W_3 + W_4 = 1000 \div 1000 + 1000\ W = 4000W$

The value of R_1 and R_2 is resistance place in series with LED indicator
Colour code ($R_1 = R_2$) = Yellow, Purple, yellow, gold approximately value on translation

= 48000 Ω =480Ωgold = ± 5% tolerance
The value of the resistance R1 and R2 is
480 kΩ ± 5% 480 k ± 24k
$W_I = 1000 = lV_1\ V_1 = 240V$

$$1_1 = W_1 = \frac{1000}{V_1} = \frac{1000}{240} = 4.17A$$

$$W = 1^2R \longrightarrow R = \left(\frac{W}{I^2}\right)$$

Since current is constant in series connection 4.17A flows through all four transducer.

$$R = \frac{4000}{4.172} = \frac{230\Omega}{4.172} = R$$

$R = TR_1 + TR_2 + TR_3 + TR_4$ = Total resistance offered by all four transducer. From circuit diagram below.

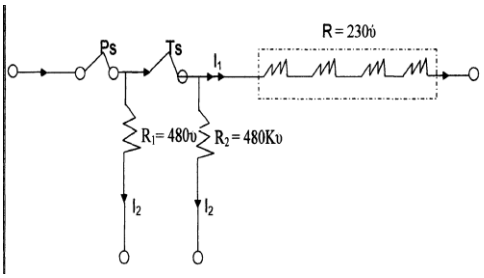

Fig. 6: Diagram showing resistance offered by four transducers

And $I \propto 1/R$ $I = C/R$
C = Constant
R = Total resistance by transducers
4.17 = C/230
C = 960.77
12 flowing through 480 k resistor and LED
$1_2\ C/R_2 = 960.77/480.000 = 0.002A$
0.00 2A flow through each 480KΩb resistors and LED

$1_2 = C/R_2\ 960.77/480{,}000 = 0.002A$

:. 0.002A flows through each 480kΩ resistor's and LED

Hence, 4.174A flow through Power switch 4.172A flows through thermostat switch.

Approximate power rating of the machine is 4000W (effect of 0.002A negligible)

Total **current** that flows through circuit is 4.1 74A from a 240v, 50Hz supply.

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