Direct-Heat vs Water-Jacket CO_2 Incubators

Which One is the Best Fit for Your Research?

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CO_2 incubators are key equipment for biological labs. They enable the necessary environmental control and isolate cell cultures from external conditions and contamination. Control focuses on three major factors:

Temperature

Normal temperature for the human body, 37 degrees Celsius, is an optimum temperature to grow most cell cultures. Cells must stay within a narrow temperature range – plus or minus a few tenths of a degree – to avoid conditions that threaten the viability of the cell culture or create a significant delay in growth and impact on schedules.

Relative Humidity (RH)

Inadequate relative humidity (RH) within the growth chamber causes medium desiccation. Minimum RH can be as low as 75-80%; more commonly, RH must remain above 90%.

Carbon Dioxide (CO_2)

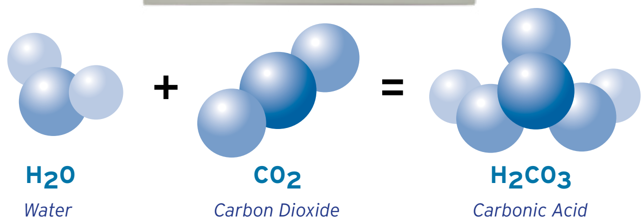
Cells require environments within a specific pH range, typically around 7.0 to 7.7, for optimal growth. Growth medium includes a pH buffer, often CO_2-bicarbonate based, to aid in maintaining stable pH levels. Atmospheric CO_2 interacts with humidity to create carbonic acid which can raise growth medium pH. Control of atmospheric CO_2 helps maintain steady growth medium pH.

Temperature Control Technologies

Two main technologies for temperature control – direct-heat and water-jacket – each offer advantages for specific operations and conditions. This paper focuses on choosing the type of temperature control for CO_2 incubators.

CO_2 Incubator Structure

A CO_2 incubator is essentially a box within a box. The outermost shell is what remains visible when the door is closed and the system is operating. Within the shell is the growth chamber, in which temperature, CO_2, and relative humidity are controlled.



Direct-Heat Temperature Control

In a direct-heat CO_2 incubator, heating elements surround and contact the top, bottom, sides, and back of the growth chamber, warming it by conduction. The inner surface of the growth chamber heats the atmosphere inside the chamber, and convection transfers the heat to the samples.

Insulation covers the heating elements so the growth chamber can better retain heat. Some vendors embed heating elements in the incubator door to avoid a significant temperature gradient between the heated growth chamber walls and the unheated door area. A temperature gradient can cause uneven growth of cells based on their position in the chamber.

With static heat elements, there is a possibility of stratification of the heat – concentration in and around the heating elements. Stratification can also cause temperature gradients and result in uneven growth among cell cultures.

Some vendors include an internal fan in incubators to draw air through vents in the top of the shell and down between the insulation and the growth chamber or between the insulation and the outer shell. The moving air uses convection to help transfer heat and helps equalize the temperature around the outer wall of the growth chamber.

Advantages:

- Faster Temperature Start Up and Recovery Time
- High-Heat Decontamination Cycle
- Lighter than Water-Jacket Models

Drawbacks:

- More Affected by Power Outages

Water-Jacket Temperature Control

In a water-jacket CO_2 incubator, the growth chamber sits within a water-filled container called the water-jacket that, in turn, is surrounded by the outer shell.

Rather than the direct application of heat to the walls of the growth chamber, the water in the jacket is heated, which, in turn, warms the growth chamber through conduction. As with direct-heat CO_2 incubators, the growth chamber's inner surface heats the air and convection transfers the heat to the cultures.

This is similar to the ordinary kitchen use of a double boiler to apply moderated heat to mixtures which otherwise might be spoiled by direct contact with the heat source.

The properties in question are specific heat and thermal capacity. Specific heat is the amount of heat energy required to raise the temperature of a unit of mass of a given material by 1 degree Celsius. Thermal capacity, also called heat capacity, of a material is that material's specific heat multiplied by the volume and density of the amount of material.

Advantages:

- Higher Level of Temperature Accuracy and Uniformity
- Lower Vibration
- Less Affected by Power Outages

Drawbacks:

- Heavier than Direct-Heat Models
- Slower Start-Up and Recovery Times
- No Integrated Decontamination Cycle

Comparing & Contrasting CO_2 Incubator Types

The different ways in which water-jacket and direct-heat CO_2 incubators control internal temperature have implications for conditions inside the growth chamber and for use, operations, and maintenance.

Temperature Stability and Setup Speed

Direct-Heat

The direct contact of heating elements with the exterior of the growth chamber enables a direct-heat CO_2 incubator to change temperatures in a relatively short time. A "relatively" short time, in the context of a direct-heat CO_2 incubator, could be eight hours to reach a stable temperature of 37°C and be calibrated for use. By comparison, a water-jacket incubator will typically take three times as long, or 24 hours (usually with an overnight period to stabilize temperature), to prepare.

The ability of a direct-heat incubator to relatively quickly adjust internal temperature is not necessarily an advantage in all labs. If a laboratory is, for example, in a building which shuts down air temperature controls at night, the temperature in the growth chamber can drop faster in relation to the ambient temperature. Similarly, a direct-heat incubator operated in an area prone to power outages or brownouts may be less reliable for maintaining stable internal temperature than its water-jacket counterpart.

Water-Jacket

The thermal capacity inherent in a water-jacket CO_2 incubator will moderate the effects of ambient changes or the loss of power. Also, if work requires low temperature levels, a water-jacket incubator can bring temperatures down to 5 degrees Celsius through the use of cooling coils. A direct-heat incubator is limited to a low temperature of approximately 5 degrees Celsius above ambient temperature.

Temperature Uniformity

A water-jacket incubator heats the growth chamber evenly; as opposed to a direct-heat incubator where the heating elements have discrete contact points with the chamber. As a result, a water-jacket incubator has fewer temperature gradients inside the chamber. Cultures placed on a top shelf are more likely to be at the same temperature as those on a bottom shelf.

The greater uniformity in a water-jacket CO_2 incubator also allows higher RH levels, between 95 and 98 percent, because a difference in temperature within the chamber will not lead to condensation. The RH level can be high enough to use 96-well plates for cultures without growth medium desiccation.

Vibration

Direct-Heat

Vibration can cause sensitive cell types to detach from the growth medium. Components frequently associated with direct-heat incubators, such as a motorized fan to aid internal air circulation, can cause excess vibration if not properly balanced. Some direct-heat incubators aid internal circulation using an air pump, as air pumps are less prone to cause vibration.

Water-Jacket

Water-jacket CO_2 incubators are less susceptible to excess vibration. The water surrounding the growth chamber dampens vibrations which might otherwise affect the growth chamber.

Maintenance

Decontamination

The growth chamber of a CO_2 incubator is, by design, an optimal environment for biological growth. While this is desirable for cell cultures, this environment also promotes the growth of undesirable contamination such as bacteria or mold. Because of this, periodic decontamination is necessary.

Most direct-heat incubators can offer convenient and effective decontamination options using the built-in heat source. Higher quality CO_2 incubators even offer dual decontamination cycles, a 145°C high-temperature dry cycle, and a 95°C high-temperature humidified cycle to address potential contamination.

Water-jacket CO_2 incubators are not designed to operate at the high temperatures necessary for decontamination, so a third-party gas decontamination service is acceptable if necessary.

Replenishing Water for Humidity

Both types of CO_2 incubators require the addition of water to water pans or RH reservoirs to maintain humidity. Water-jacket incubators, in addition, will require infrequent replenishment of water levels within the jacket, using specific types of distilled water; availability of the right type of water may be restricted.

Movement

Maintenance requiring the incubator to be moved is more convenient with a direct-heat model, due to that design's lower weight. A water-jacket incubator of similar capacity will be much heavier due to the mass of the water-jacket.

Costs

Water-jacket incubators are usually more expensive than direct-heat models of similar capacity due to the additional construction needs to hold the additional weight of the water.

Choosing the Correct CO_2 Incubator for Your Laboratory

The choice between water-jacket and direct-heat CO_2 requires balancing practices and needs of a laboratory against the cost and convenience of each incubator type.

Reasons for Choosing a Water-Jacket CO_2 Incubator:

- Use of cell types requiring higher humidity
- The need to use shallower wells without desiccation
- Potential for ambient temperature or power fluctuations
- Flexibility to operate at lower temperatures
- Sensitivity to vibration
- Reducing temperature gradients in the growth chamber
- Potential for future projects necessitating a water-jacket CO_2 incubator

Reasons for Choosing a Direct-Heat CO_2 Incubator:

- Current and potential future projects unlikely to require a water-jacket CO_2 incubator
- Personnel will open the door for longer periods of time, requiring more frequent re-establishment of operating temperature
- Setup time is more critical than growth chamber conditions
- Need for a decontamination cycle

Balance your needs and conditions with available budget and operational constraints to find the type of incubator that will be best for you. Work with a knowledgeable vendor that can help you make the right decision.

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