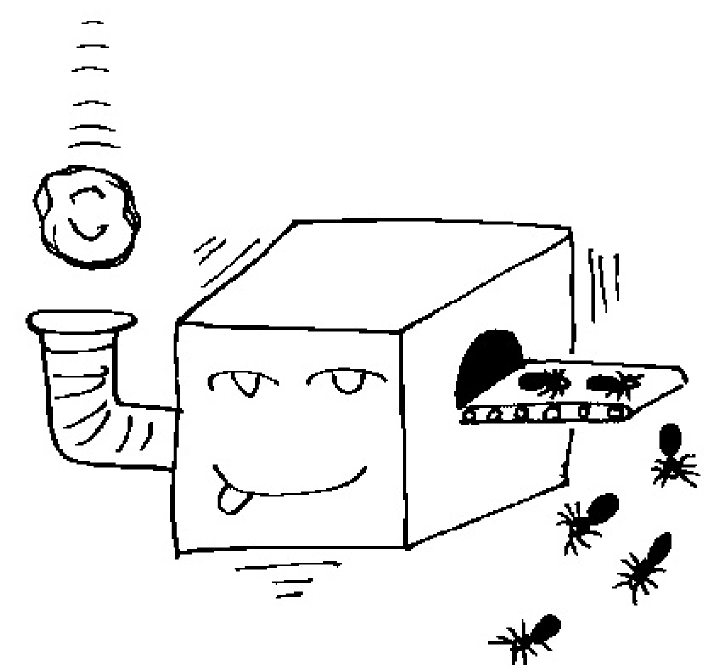
A MECHANICAL MOM FOR TARANTULAS



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A MECHANICAL MOM FOR TARANTULAS

Second Edition: January 31, 2007

by

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Figure 2

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We encourage you to use the blank spaces in this booklet for your own notes.

Introduction

Several methods have been tried for hatching the eggs of tarantulas. Among them are leaving the eggsac (egg case[1]) with the mother, removing the eggsac from the mother to a separate container, removing the eggsac from the mother and then removing the eggs from the eggsac to a cloth cradle in a separate container (Turbang, 1993), and finally, removing the eggsac to an artificial, mechanical incubator (McKee, 1984a, 1984b, 1986; Schultz and Schultz, 1998). Of these methods, an artificial, mechanical incubator is arguably the most reliable. A more complete discussion of these methods can be found in Schultz & Schultz, 1998.

The McKee Design

The design presented here is based on one first published by Mr. Al McKee (1986), but some important changes have been made.

The McKee design incorporated a nineteen liter (five gallon) aquarium as an "incubator containment housing" (his terminology, equivalent to our "primary enclosure"). The incubator containment housing served as an insulating interface between the surrounding room and an internal chamber. It also protected the working mechanism of the incubator from accidental mis-adjustment.

Within this enclosure was a wooden board acting as the central spine for the working mechanism. This mechanism was composed of a plug-in, electric timer switch, and an inner enclosure ("incubation chamber") made from a plastic box. A metal rod (hereinafter called the axle), was attached to the rotating face of the timer and passed through the side wall of the inner enclosure. Affixed to the inner end of

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[1] Arachnologists generally agree that the silken container produced by most spiders for their eggs is called an *eggsac*, as opposed to an *egg case* and *ootheca* that are firm walled containers.

the axle was a cylindrical plastic globe ("egg sac container"[2]). The incubation chamber also held an aquarium thermometer, night-light bulb, thermostat, humidity sensors, and a small dish of water.

The timer switch, a dimmer switch, the thermostat, a direct current converter and the night-light bulb were all wired in series to produce a controllable heat source. If an external, additional heat source was to be placed under the aquarium, a separate thermostat for it was also incorporated into the circuit.

In practice, the timer rotated the eggsac container once every twenty-four hours to prevent the egg mass from clumping. The thermostat, the ancillary electronics, and the night-light bulb maintained a constant temperature. Humidity was maintained by means of the water in the small dish.

The Fostaty/Schultz Modifications

In collaboration with a friend, Mr. Michael Fostaty, and through several different stages, these authors have made some important improvements in Mr. McKee's design. Practice has shown that most of the ancillary electronics used by McKee were not necessary. The single exception was the retention of a dimmer switch in the circuit to decrease the intensity of heat radiated by the light bulb.

Additional modifications included the following.

1. A larger primary enclosure allowed multiple eggsacs in the incubator at the same time.
2. The night-light bulb was replaced by a candelabra bulb because the larger incubator required more heat to maintain an adequate temperature, and night-light bulbs consuming more than eleven watts were not available.
3. An aquarium heater was substituted for the thermostat.

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[2] Current usage requires that the two words "egg" and "sac" be combined into one word.

4. The single eggsac container, suggested by McKee, was replaced by a stack of plastic, screw-together, cup-like, fishing tackle boxes, allowing incubation of several eggsacs at once.
5. A simple wet bulb-dry bulb hygrometer (humidity gauge) was added as a means of monitoring relative humidity. The humidifier dish was used as the source of water for the wet bulb thermometer.

A photo of a working incubator is given in the frontispiece and a drawing is given in **Figure 3**. A detailed discussion of its construction follows.

Basic Philosophy

The underlying philosophy in the construction and operation of this incubator is that it be as simple as possible and still accomplish the required tasks. Those tasks are

1. Protect the eggsac and its enclosed eggs from mechanical injury.
2. Maintain the eggsac at a temperature that facilitates embryonic development.
3. Maintain the eggsac at a minimum relative humidity to prevent the eggs' dessication and death.
4. Subject the eggs in the eggsac to a gentle stirring or jostling motion. (The exact reason why this is necessary is still being debated. Such stirring, however, has proven to be absolutely necessary.)

Important design considerations are that the incubator be as uncomplicated and non-technical as possible. For this we chose to incorporate (some would say "subvert") relatively common, off-the-shelf components available in almost any hardware or department store or pet shop. The idea was that almost anyone could build a serviceable incubator in their apartment with only a few very basic tools, and successfully run the mechanism with little or no expertise or intense training.

It is entirely possible to add feedback mechanisms and integrated circuits or connect the incubator to a computer for precise monitoring and control, use high-tech infrared heaters, fault alarms, remote controls, chrome plated components, a stereo system, vibrating bed, etc., etc., etc. (Just kidding on the last few items, but you get the point), but all of these are not only unnecessary, they're also undesirable and almost always inordinately expensive. The more complicated components that are added, the more things there are to go wrong and the more difficult and expensive the fault will be to repair.

SIMPLE IS BETTER.

A Word of Warning

Contained herein are descriptions of electric circuits, but the details of making the connections are intentionally omitted. The prospective builder is strongly urged to seek the help of a professional electrician in fabricating them. All electrical work should be inspected by a professional electrician and approved for safety before it is used.

These instructions are clearly biased towards North American voltages, electric codes, and equipment. Many other parts of the world use different voltages, codes, and equipment, and modifications will have to be made to accommodate these differences. Professional electricians and certified electrical engineers are the only people qualified to make such design modifications safely.

The enthusiast who undertakes to construct this equipment must assume the responsibility for the safety of the circuits produced. Because the details of construction are not controllable by the authors, they cannot assume liability for them.

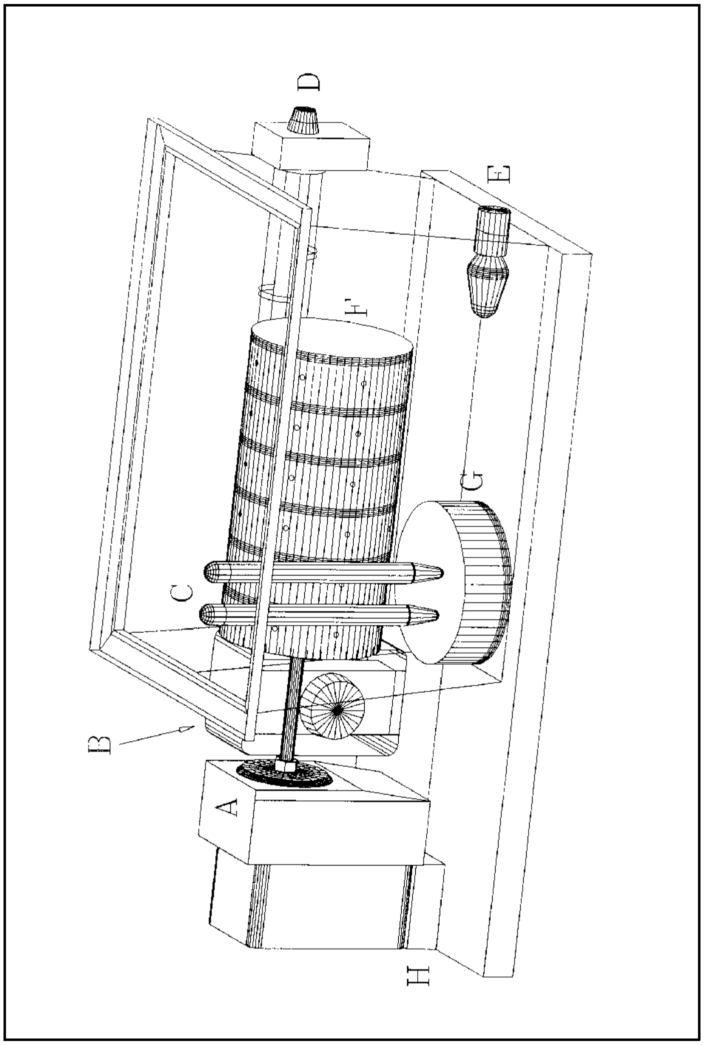

Figure 3

We encourage you to use the blank spaces in this booklet for your own notes.

Chapter 1: Parts List

Following is a parts list for the major items required in the manufacture of an incubator. It is not exhaustive because it is assumed that the builder will have most of the minor items available in the workshop. A full description and the significance of each item will become apparent during the following discussion.

- Aquarium, fifty by twenty five by thirty centimeters (twenty by ten by twelve inches, nominally a ten gallon aquarium) or larger, referred to as the primary enclosure in the discussion. We used a ten gallon aquarium in our examples.
- Rectangular box with lid. Transparent plastic. Referred to as the inner enclosure in the discussion that follows. We used a "Kritter Keeper" in our examples. See pages vii, 34 and 46.
- Glass plate, large enough to cover the aquarium. See page 16.
- Plywood board. Referred to as the baseboard in this discussion. See page 21.
- Duplex electrical boxes. Two are required. See page 21.
- Duplex outlet with third conductor grounding and a matching duplex box cover. See pages 21, 23 and 24.
- Dimmer switch and a matching duplex box cover. See pages 21 and 51.
- Timer Switch or clock motor assembly. See pages 21 and 24.
- Duplex box blind plate, required only if a clock motor assembly is used instead of the timer switch.
- Electric wire, at least two meters (seven feet) of sixteen gauge insulated copper wire colored green, and four meters (fourteen feet) in some other color. If possible, choose the multi-stranded variety because it is much more flexible and easier to work with.
- Electric power cord, three conductor, approximately two meters (six to seven feet) long. See pages 22 and 53.
- Alcohol, at least seventy percent isopropyl, methyl, or ethyl. Ninety or ninety-five percent alcohol is better.
- Adhesives. Epoxy glue, silicone aquarium sealer, and PVC plumbing cement are all used in the construction.

DO NOT USE SILICONE BATHTUB SEALER. The mildewcide in this preparation is guaranteed to kill the tarantula's eggs.

DO NOT USE SILICONE CONSTRUCTION CAULK. These products do not have sufficient bonding properties, and they may also contain mildewcides to prevent mildew growth.

- Threaded rod. This is referred to as the axle in the discussion. Acquire a piece at least thirty centimeters (one foot) long. A diameter of about eight millimeters (five-sixteenths inch) is satisfactory. Also acquire at least three hexnuts and three washers to fit this rod. See pages vii and 24.
- Drilling lubricant. Either a mild, liquid dish detergent, or salad oil. Not necessary if holes in plastic are melted.
- Stacking, small parts boxes. Referred to as brood cups in the discussion. Purchase two sets of these, at least five individual cups are needed and more are very handy. One may be used as a humidifier dish. See pages ix and 33 for more details.
- Candelabra lamp socket. Try to acquire one with as compact a means of attachment as possible. See pages 47 and 73.
- Low wattage candelabra bulbs. Twenty-five watts is usually adequate for an incubator of the size made here. A larger incubator may require a higher wattage bulb. More information is available on pages viii, 42, 47, 59, 71 and 73
- Aquarium heater. Any wattage is acceptable because the heating element will be discarded. Details on pages viii and 41.
- PVC pipe. Used in both the plumbing and electrical trades. Acquire a piece at least as long as the longest dimension of the inner enclosure (see above). This should have an inner diameter sufficient to safely accommodate the internal parts of the aquarium heater. An explanation can be found on page 43.

- Aquarium thermometers. Two identical ones are required. A commercial, electronic humidity gauge will also serve. See pages 47 and 61 for more information.

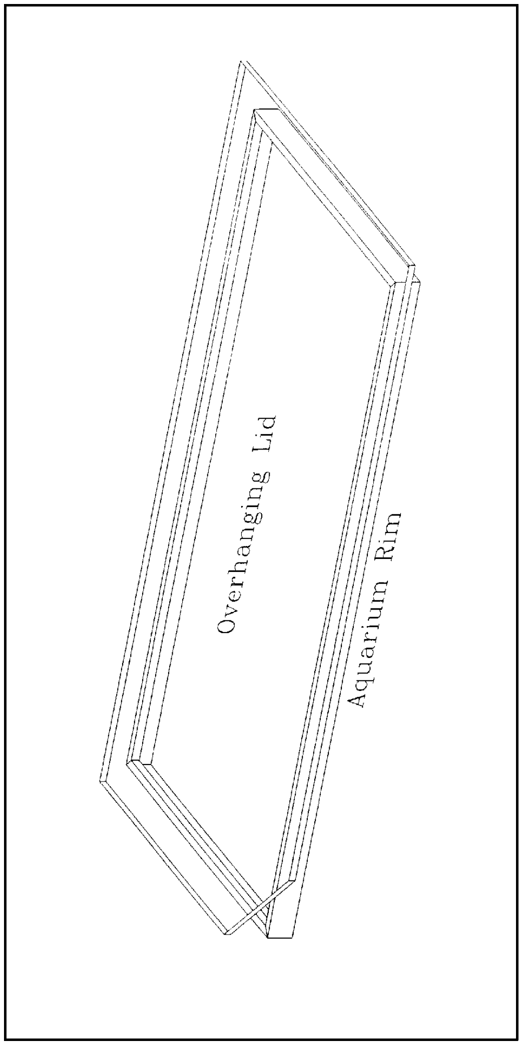

Figure 4

Chapter 2: Primary Enclosure

The primary enclosure's (equivalent to McKee's incubator containment housing) principal purposes are to prevent accidental contact with potentially dangerous parts (e.g., bare wires), to be a convenient receptacle for holding the whole mechanism, to protect the mechanical and electrical parts from damage or accidental mis-adjustment by either the enthusiast or the cleaning lady, and to allow extra insulation against the ambient environment.

An aquarium makes a serviceable primary enclosure, and the following discussion will assume one will be used. An aquarium with a cracked (but not missing) pane will work. At the very least, a cracked pane should be securely taped to prevent a loose piece of glass falling out, and to protect people moving around the incubator. If at all possible, repair a broken aquarium instead.

A glass plate is used as a lid for the aquarium. It should be of rather strong glass to prevent breakage. The minimum thickness is three millimeters (one-eighth inch), but five or six millimeter (three-sixteenths or one-fourth inch) is better. Some glass and glazing shops sell salvaged glass from broken patio doors and store fronts at reduced prices. Such discolored or scratched glass, cut to the appropriate size, is completely satisfactory. The novice who has little or no experience with cutting glass, should consider having someone at the hardware store or glass shop cut it to the correct size. All sharp corners and edges must be removed with sandpaper or a fine emery stone as a safety measure.

In one arrangement, the lid will merely rest on top of the aquarium (**Figure 4**). The advantage with this arrangement is that the glass plate need not be cut to some specific size. The disadvantage is that it may slide or be knocked off. An alternate arrangement consists of a glass plate that is cut to fit inside the lip of the frame of those aquaria that possess such a lip. The advantage here is that the glass plate will never slide off the top of the aquarium and shatter. The disadvantage is that this will require precision glass cutting, usually beyond the expertise of non-professionals.

To allow a place for the electric cord to pass through without inordinately disturbing the lid, cut off one corner of the glass plate. The exposed opening should not be unduly large, however. A minor leak of cool air is acceptable. A major breach is not permissible.

Multiple layer plywood will also work as a cover. However, single ply veneers, most solid wooden boards, chipboard, fiber board or sheets of acrylic plastic (e.g., Plexiglas or Perspex), will quickly warp and become unserviceable.

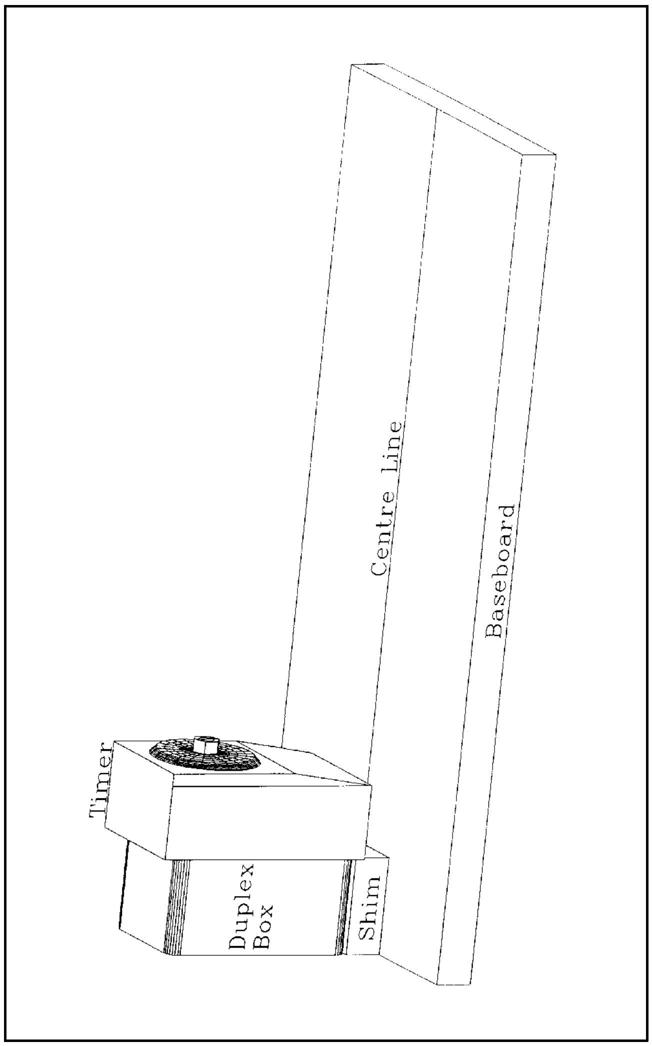

Figure 5

We encourage you to use the blank spaces in this booklet for your own notes.

Chapter 3: Baseboard and Timer Assembly

Baseboard

The spine of the mechanism is made of a piece of wood and is called the baseboard. Nineteen millimeter (three-quarters inch) plywood is best because it is dimensionally stable under varying temperatures and humidity, and also because it won't bend or distort when picked up or moved. Its length and width should be such that it will lay flat on the bottom of the aquarium and still leave at least a nineteen millimeter (three-quarters inch) margin of the aquarium's bottom exposed on all four sides. Sand or plane all edges to remove all roughness and slivers. Varnishing or painting is ordinarily not required, but if it is done, spar varnish, urethane varnish, or a moisture resistant paint should be used. Allow the finish to cure thoroughly before proceeding with construction, permitting any residual, potentially harmful solvents to dissipate before using the incubator.

Duplex Boxes

Standard, duplex, electrical boxes are used to securely hold the duplex outlet and timer or clock motor assembly, and the dimmer switch. Metal boxes are assumed here. If other varieties are used (e.g., PVC) appropriate alterations in this design must be made to allow for adequate grounding and to allow for the other details of construction.

Metal duplex boxes normally have several holes incompletely stamped in their sides. Each hole is still plugged with the metal disk that would be expected to be removed during the stamping process. The metal disks that plug them are called *knockouts* or *slugs*. These are intended to allow the worker to determine the location of exit ports for wires from the box for any particular electrical project. PVC duplex boxes have similar arrangements for producing the required holes.

Remove one of the knockouts from the side or back of one of the duplex boxes. All electrical wiring should be run through this hole.

To protect the insulation on the wires that will be passing through these openings, any remaining burrs may carefully be filed away with a rat tail file. However, while using a file to remove burrs from the edges of the knockout holes will work, it isn't optimal because the edges of the metal can still abrade the insulation on the electric wires over time. A much preferable method is to use rubber grommets in these holes, available from electronics supply and hardware stores.

This box should be installed on one end of the baseboard. It should be oriented with its long axis vertical and its open side facing the opposite end. It should be centered exactly on the center line of the baseboard.

Use two small wood screws to secure the duplex box and to allow for future adjustments. If the duplex box does not already have acceptable holes punched for the purpose, they must be drilled. These holes should be large enough to easily pass the screws that will be used. Drill the holes adjacent to the open side to allow easy access with a screwdriver.

The duplex box may have to be raised with shims to allow a minimal clearance between the subsequent electrical parts and the baseboard. See **Figure 5** and the discussion on pages 24, 37 and 38.

An additional duplex box to hold a standard household dimmer switch will also be fastened to the baseboard, but its position must be determined later. This second box should be prepared in the same manner as the first.

Grounding

An electrical grounding wire is strongly recommended for all actual and potential electrical conductors. This amounts to all metallic objects in the incubator. A three wire, grounded power cord should definitely be used. At the very least, the third grounding wire should be attached to the duplex box by way of one of the box' mounting screws. Duplex outlets should possess grounding capability and a jumper wire should connect the grounding screw to the same mounting screw on the duplex box. All grounding wires should be green or the color mandated by local electrical codes. (Green is the color specified by the electrical code in North America.)

Figure 9 is a schematic for the wiring of this incubator. It is presumed that the aquarium heater (used only for its thermostat) will also have a third wire ground, although this is not always so. In that figure, the ground wires are represented by dashed lines.

If the home wiring system does not include a third wire as a ground, use a special grounding adapter to ground the power plug to the electric mains box. If this is not possible, it is extremely important that a professional electrician by consulted.

Recent reports by enthusiasts are that many electrical timers currently available (winter of 2006-2007) are made overseas and are not sturdy enough to last in this application more than a few weeks or months. The prospective builder should plan ahead for this eventuality by stocking several, identical, customized timers for an emergency replacement, and closely monitor the incubator daily or more frequently to confirm proper rotation.

If timers manufactured in the United States or more serviceable heavy duty timers can be found, they should be substituted instead.

If none of this is possible, a free standing synchronous motor (described below) may be the best alternative option.

Timer Assembly

If a timer is to be used, it should be a type that bears a circular, rotating dial revolving every twenty four hours. No other variety will work in this application. The timer does not turn the unit on or off, as one might at first assume, and any switch mechanisms are completely irrelevant. It is used solely for its built-in synchronous motor as a convenient source of rotary power for tumbling the eggsac on a twenty-four hour schedule. Set the appropriate switch for permanent "on," "override," or "continuous" operation and secure it with a piece of tape if necessary.

The timer is plugged into a standard, duplex electrical outlet that is, in turn, mounted in the first standard, duplex electrical box. Compare the timer/outlet assembly to the duplex box. If the box requires shimming to allow the timer to clear the baseboard, do it now. (See **Figure 5** and the discussion on pages 22, 37 and 38.) Use small rectangles of veneer, plywood, or solid wood for shims. The top and bottom surfaces of the shims must be parallel (as opposed to wedge-shaped) to ensure that the duplex box remains exactly vertical. See **Figure 5**. Be forewarned that further shimming adjustments will probably be necessary later. Do not permanently fasten these parts in place.

If conditions necessitate, it is possible to mount the timer upside down or in some other orientation with no ill effects so long as the center of the timer's dial remains exactly above the baseboard's centerline.

> ***BEWARE:*** Alcohol at 70% strength is dangerously flammable. At 90% strength, it is explosive, akin to gasoline. Do not use alcohol in the presence of any source of ignition (e.g., flames or pilot lights, lit cigarettes, sparks from electrical equipment, etc.). Use only in an area of good ventilation.

A hexnut must be attached to the center of the timer's face to accept the threaded axle rod. If the timer has a stationary central hub, a bridge must be improvised that will allow the face to turn but still provide support for the hexnut over the exact center of the dial. A small strip of acrylic plastic, Perspex or Plexiglas will accomplish this if it is shimmed to miss the hub's surface. First clean all affected surfaces with alcohol to remove oil residues remaining from its manufacture, then use epoxy or cyanoacrylate glue to attach the bridge. Because most petroleum based solvents (including acetone) will dissolve the plastic, use only alcohol to clean the dial. See **Figure 6**.

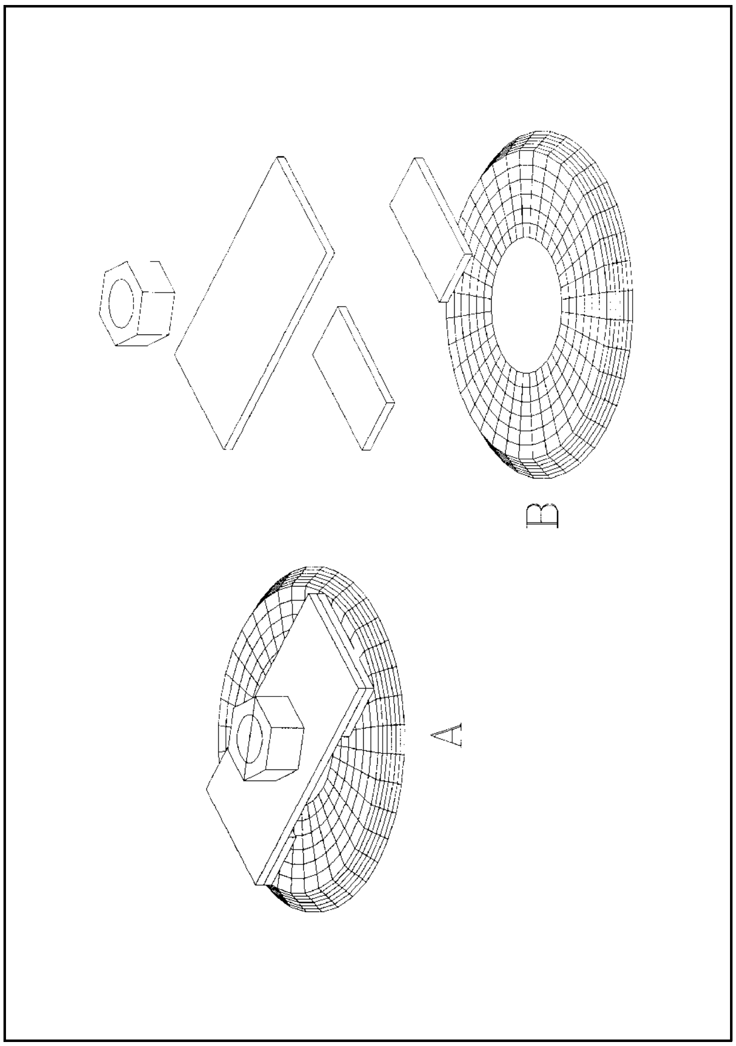

Figure 6

To attach the hexnut, use a cotton swab and alcohol to clean the plastic on the center of the dial or bridge. As above, petroleum based solvents such as acetone will not work here because they will dissolve the plastic. Wash the hexnut with clean alcohol to remove all traces of oil. Apply a thin layer of epoxy glue to the back side of the hexnut. Be very careful at all stages not to get any of the glue into the threads of the hexnut. Apply another thin layer to the center of the dial's face or the bridge. Carefully position the hexnut in the dial's center. Prop the timer up so that the dial is perfectly horizontal, and carefully apply a small piece of tape to stabilize the hexnut. This will prevent it from slipping off center before the glue sets. After the bond is secure (wait at least twenty four hours), apply a little more glue around the periphery of the hexnut. Allow the bond to cure an additional twenty four hours.

After the glue is thoroughly set, carefully plug the timer into the duplex outlet in its preferred orientation.

Clock Motor Assembly

In essence, the timer switch is used only for its synchronous motor, and such motors with the associated gear works are available in a variety of other forms (e.g., salvaged from an old clock or purchased from local electronics, clock repair, hobby, or crafts stores). If such a clock motor assembly is available, it may be used in place of a timer. Given a choice, choose one that produces the most rotational power or torque.

It is difficult to give precise instructions when using clock motor assemblies because of their many different sizes and designs, and the builder must exercise some ingenuity in installing them.

The face of the clock motor assembly usually has a central pin and two concentric sleeves of descending lengths on which the clock's hands would normally be attached. The outer sleeve usually moves the hour hand, and this is the one of interest to us.

The entire assembly is very fragile and great care must be exercised when working with it. The tolerances between the sleeves and the central pin are very close. Deforming them in any way will cause them to bind, stopping the motor. No adhesive must be allowed to bind the sleeves to the outer casing, to each other, or to the center pin during fabrication.

Attaching the axle to the outer sleeve so that it will rotate every twelve hours poses a difficult engineering problem. One possible strategy utilizes a short piece of vinyl tubing of just large enough diameter to fit snugly over the end of the axle. ***WITH GREAT CARE*** the hour hand sleeve can be shimmed up with vinyl tape to the appropriate diameter to snugly accept the piece of vinyl tubing. Alternatively, two or three sizes of vinyl tubing of descending inner and outer diameters may be stacked within each other to produce a shaft of the proper diameter.

A more professional appearing arrangement might be had by soldering several copper or brass tubes (available from hobby and crafts stores) of varying diameters inside each other as an adapter. Attach the adapter to the hour hand sleeve with a small drop of epoxy or cyanoacrylate glue. This adapter should be threaded to accept the axle on the other end. It is absolutely imperative that this adapter be as small and light as possible. Again, be very careful not to glue the motor's sleeves together.

Installing the clock motor assembly on the duplex box should be postponed until later because the exact position of the motor is not yet predictable. For now, set the clock motor assembly aside, in a safe place, cover the face of the duplex box with the blind plate, and proceed with the construction of the remainder of the incubator.

Chapter 4: Inner Enclosure

Specifications

The inner enclosure is a constant environment chamber, the "incubation chamber" of McKee. McKee recommends a plastic food container, and most enthusiasts who have built these incubators use just that. It is also possible for the enthusiast to build one from Perspex or Plexiglas to custom dimensions. In the example given here, a seven and one-half liter, rectangular, plastic, aquarium (e.g., "Kritter Keeper," readily available from pet shops) was used. Note that this container (**Figure 7** and **Figure 8**) has sloping walls, adding another level of complexity to the construction. The distinct advantage to using one of these is that they are readily available at almost any pet shop or pet department.

The minimum size is fifteen centimeters wide by fifteen centimeters long by twenty centimeters high (six by six by eight inches). The height of the inner enclosure must allow at least nineteen millimeters (three quarters inch) clearance between its lid and any of its contents, and at least nineteen millimeters (three quarters inch) clearance between the inner enclosure lid and the glass plate covering the aquarium when the inner enclosure is setting on the baseboard. The maximum allowable width must allow at least a two and one-half centimeter (one inch) insulating space between the inner enclosure and the aquarium walls on both sides. The inner enclosure should be as long as possible and still allow ample room between it and the timer for the dimmer switch's duplex box, and allow at least a two and one-half centimeter (one inch) space between the end of the inner enclosure and the corresponding end of the aquarium (primary enclosure).

If the head of the aquarium heater protrudes beyond the end of the inner enclosure (see below), additional space must also be apportioned to allow appropriate clearance.

Keeping a Lid on It.

The inner enclosure must have an environmentally tight lid, but not so tight as to make it difficult to open in cramped quarters. Many plastic containers come with serviceable lids from the manufacturer. However, the plastic aquarium that was used in our example had a lid made in the shape of a domed grid that was completely unsatisfactory. In this instance, a new lid had to be made. Any convenient material that wouldn't warp or degrade on exposure to warmth and humidity could have been used. See page 18 for a discussion of acceptable materials.

In our example, a piece of nine or ten millimeter (three-eighths inch) thick, all weather plywood, just large enough to completely cover the inner enclosure, was used. A rabbet was cut around its circumference on the bottom side in such a way that it was partly inset into the top of the inner enclosure. This prevented the cover from accidentally becoming misaligned or sliding off.

The Art of Making Holes

At several points during the construction of the inner enclosure it will be necessary to make holes or perforations in the plastic. McKee (1986) recommends drilling them. If these holes are to be drilled, to prevent the plastic from breaking, use a little salad oil or liquid dish detergent as a lubricant (McKee, 1986). Use a new, sharp drill bit. Advance the drill bit very slowly. It must shave a hole in the plastic, not gouge it. A drill press is strongly recommended for this task.

The holes were melted in the example shown here. Nails and metal rods were used to make the smaller holes (less than five millimeters, three-sixteenths inch). The larger holes were melted with metal tubes and plumbing adapters. The metal pieces were heated on a kitchen range, but a propane torch will also work. Use a pair of stout pliers to hold the hot metal and be ever cautious of burning yourself or setting flammable clothing, tools and furnishings on fire. There is a strong argument in favor of keeping a fire extinguisher handy.

When melting such holes, the side of the hole from which the hot metal enters will have a small, elevated ring of plastic encircling it where molten plastic is pushed aside by the advancing metal. Where flat surfaces are required, melt the hole from the opposite side or carefully shave the ring off using a stout, sharp knife or a file.

Air Conditioning

Drill or melt at least eight ventilation holes in each of the four sides of the inner enclosure. At a minimum, arrange them with one close to each corner and one along the middle of each side's edge. Place them about twenty millimeters (three-quarters inch) from the edges of the face. Refer to **Figure 7** and **Figure 8** for illustrations of their suggested positions. Additional holes may be placed where convenient. It is better to make too many than too few. If too many holes are melted or drilled, the extras may be easily covered with tape. However, if too few are made, correcting the error may require dismantling the incubator and upsetting all the adjustments.

Make these holes two millimeters (approximately one-sixteenth inch) in diameter. Making the holes larger than this may allow the smaller, newly hatched tarantulas enough room to escape. It is better to make more holes than to make them too large.

Figure 7 and **Figure 8** are diagrams of the end of the inner enclosure that faces the timer. They indicate the relative positions of the aquarium heater thermostat, the candelabra bulb heater (as seen from the opposite end), and the small ventilation holes. The line scribed up the center of the face and points A and B are described below.

Initial Placement

Drill or melt two holes in the bottom of the inner enclosure. These should be just large enough to accommodate one and one-half centimeter long (five-eighths inch), round head wood screws. They may be placed anywhere convenient, but at least ten centimeters (four inches) apart.

Place the inner enclosure on the baseboard, exactly in its final position, keeping in mind the clearances mentioned several paragraphs earlier, square with the edges and centered on the baseboard's center line. Carefully mark the position of the screw holes in the bottom of the inner enclosure on the baseboard. Remove the inner enclosure and drill pilot holes in the baseboard on these marks. Replace the inner enclosure, double check the alignment, and lightly screw it back in place with the wood screws. Caution: over-tightening the screws can crack the plastic. While this is not a serious fault, it does detract from the appearance of the incubator and bespeaks of poor workmanship.

It is important not to permanently fasten the inner enclosure in place just yet. It will have to be removed and replaced several times before the incubator is completed.

Chapter 5: Brood Cups

Fishing tackle stores, craft stores and hobby shops sell small, inexpensive, styrene or acrylic screw-together jars for the purpose of storing small items such as fish hooks, pins and needles, and nuts and bolts. Each is a straight-sided cup, with male threading around the top, and an indented base with matching female threading. Thus, one cup will thread into the bottom of the next in a tubular series. One commercial name for these is Stacking Tackle Boxes. A minimum of five cups will be required, and two or three extra are a good idea. The medium size will work for smaller eggsacs, but the large (nine centimeters, or three and three-quarters inch diameter) is much more serviceable. If available, choose a brand that also supplies a matching lid. From this point forward we will call these *brood cups*.

MELTING HOLES is discussed in detail on page 30.

Drill or melt a ten millimeter (three-eighths inch) hole in the center of the lid. If a lid was not included, use one of the cups, instead. But, in the discussion that follows you must reverse the orientation of the remaining cups to compensate for the reversed gender of the threading.

Drill or melt eight holes, each one being two millimeters (one-sixteenth inch) in diameter, centered around the sides of all but two cups. These last, undrilled cups will be used as the humidifier dishes.

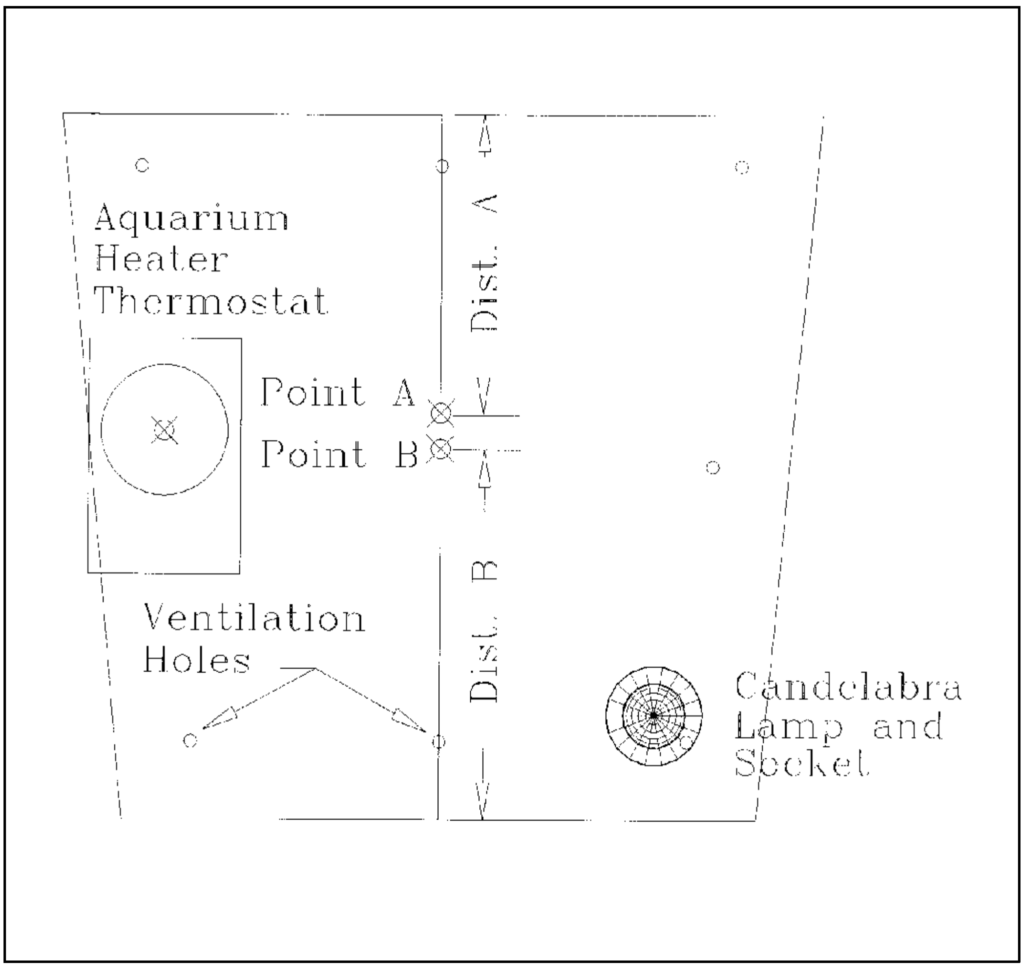
Aquarium
Heater
Thermostat
Point A
Point B
Dist. A
Dist. B
Ventilation
Holes
Candelabra
Lamp and
Socket

Figure 7

Chapter 6: Getting the Point

This section deals with the proper placement of the axle hole in the end wall of the inner enclosure and the proper placement of the timer or clock motor assembly. There seems to be no easy method for describing these procedures, at least in the English language, and the reader is advised to examine the following discussion one sentence at a time, to follow the meaning and directions.

Hole Placement

There are several distances that are critical in the placement of the hole through which the axle turns. The brood cups must be placed so that their rotation is not hindered by contact with any of the other objects within the inner enclosure. Because their position is uniquely defined by the placement of the axle that rotates them, the position of that axle is also critical. Because the position of that axle is determined almost solely by the position of the hole in the inner enclosure's wall, it follows that the position of that hole is equally critical.

Measure the diameter of the cups. Divide this measurement by two and add one centimeter (one-half inch). We will call this *distance A*. This is the minimum distance allowable between the axle and the lowest point on the inner enclosure's cover to allow adequate clearance for the brood cups.

MACHINIST'S AND CARPENTER'S LAMENT

Measure twice.

Cut once.

YOU'VE BEEN WARNED!

From the baseboard's center line, mark a line, at exactly a right angle to the baseboard, up the end of the inner enclosure that faces the timer switch. This is represented as the vertical center line in **Figure 8**. Place the lid on the inner enclosure and mark its lowest point on this center line. From that point, mark another point downward equal to distance A. We will call this *point A*. The axle can be placed no higher than point A.

Now measure the height of one cup as it rests flat on a table. Add distance A to this and call the sum *distance B*. This is the minimum distance between the inside, bottom of the inner enclosure and the axle hole. This distance is designed to allow adequate room so that water dishes and heaters may be installed without interfering with the rotation of the brood cups.

Inside the inner enclosure, mark a distance upwards from the bottom along that same center line equal to distance B. We will call this *point B*. The axle can be placed no lower than point B.

Distances A and B cannot overlap, i.e., point A cannot be below point B. If they do, several options are available. If the overlap is less than one centimeter (one-half inch), it may be possible to adjust the one centimeter clearance slightly to eliminate it. If that doesn't work, smaller brood cups, a taller inner enclosure and possibly a taller primary enclosure are the remaining options.

The part of the center line that lies between points A and B is the allowable range for placement of the center of a hole that the axle from the timer or clock motor assembly will pass through.

The Axle and the Timer Switch

We assume here that you are using a timer switch. If you are using a clock motor assembly instead, you may read this section for reference but follow the instructions in the next section "The Axle and the Clock Motor Assembly."

Carefully measure the distance between points A and B. Exactly midway between them, mark another point that we will call *point C*. Point C is the point on which we will center the hole for the axle. Measure the vertical distance between point C and the baseboard, and call this *distance C*. This is the distance that the center of the timer's dial must lie above the baseboard in order to ensure that the axle is exactly parallel to the baseboard.

If the center of the timer's dial lies below point C (i.e., the distance from the center of the timer's dial to the baseboard is smaller than distance C), any shims under the timer/duplex outlet/duplex box assembly must be adjusted to raise the timer to the appropriate level.

If the center of the timer's dial lies above point C, either the shims under the duplex box must be adjusted, the inner enclosure must be shimmed to increase it's distance above the baseboard, or a taller inner enclosure must be pressed into service. Watch carefully to ensure that adequate distance is maintained between the inner enclosure's lid and the lid of the primary enclosure. Another strategy to lower the timer is to mount it (and its associated duplex outlet and box assembly) upside down or on its side and shim it to the proper height.

After adjusting these heights with the various shims, the center of the timer dial must be exactly as high above the baseboard as point C. Remeasure the height of the center of the hexnut on the timer's face above the baseboard, and remeasure point C on the inner enclosure's face to confirm this.

The Axle and the Clock Motor Assembly

This section is important only if a clock motor assembly is used in place of a timer. Those using a timer can skip to the next section “Axle Hole” .

The axle linking the clock motor assembly to the brood cups must be exactly parallel to the baseboard. Mounting the clock motor assembly to achieve this will require some ingenuity.

If there are mounting screws at the back of the motor, drill corresponding holes in the duplex box' blind plate at the appropriate level and mount the clock motor assembly on its outside face. If the screws are on the front of the clock motor assembly, corresponding holes must be drilled into the blind plate, plus one additional hole for the pin and sleeves on which the axle will be fastened. In this case, the clock motor assembly would be mounted to the back of the blind plate, inside the duplex box with the pin and sleeves protruding through the extra hole.

If such screws do not exist or if there isn't enough room in the duplex box for the motor, improvise some other ***SECURE*** method of attachment at the correct height. If at all possible, any such attachment should allow for future adjustments in height above the baseboard.

The wires conducting electric power to the clock motor assembly should be threaded through one of the knockout holes in the duplex box' side.

KNOCKOUTS are discussed on page 21.

Mark a point midway between points A and B. We shall call this point C. Measure the distance from point C down to the baseboard. We shall call this distance C. This is the ideal height of the center pin (on which the second hand was mounted) of the clock motor assembly. Mount the clock motor assembly so that the center pin is exactly at this height. If for some reason, the clock motor assembly's center pin is higher than point A, the inner enclosure must be shimmed appropriately. (Watch the overhead clearance between the inner and primary enclosures!) If the center pin of the clock motor assembly is lower than point B, shim the duplex box, or remount the clock motor assembly a corresponding distance higher. Most clock motor assemblies will work in any orientation. Would mounting it upside down or on its side place the center pin the correct distance from the baseboard? Remeasure again to confirm that the axle will be exactly parallel to the baseboard.

Axle Hole

Remove the inner enclosure and drill or melt a hole approximately ten millimeters (three-eighths inch) in diameter at point C.

MELTING HOLES is discussed in detail on page 30.

To protect this hole from wear by the axle, glue a washer of appropriate inner diameter over the hole. This washer should be large enough to easily pass the axle through its center hole without excessive space. With this small embellishment, the axle will ride on the wear resistant washer rather than the plastic. This will prevent having to replace the entire inner enclosure once a year. Refer to **Figure 7** and **Figure 8**.

Fasten the washer in place with silicone aquarium sealant or epoxy glue. But first wash any oil residues or soil off the inner enclosure around the hole with alcohol. Also, rinse any oil residues off the washer with alcohol. As before, do not use acetone or any other petroleum based solvent on the plastic.

Axle Construction

With the inner enclosure screwed to the baseboard, measure the distance between the center of the hexnut that is glued to the timer dial, or the center pin on the clock motor assembly, and the near end of the inner enclosure. Add three centimeters (one and one-quarter inches), and cut the axle to this length. It is a good idea to screw two of the hexnuts onto this rod before making the cut. After making the cut, lightly file off any burrs. Then unscrew one of the hexnuts over the cut end. Remove any remaining burrs a second time with a fine file or fine emery cloth, then unscrew the second hexnut. This will help to maintain the threads on the rod.

Temporarily install the axle by feeding it through the hole in the inner enclosure and threading it into the timer dial hexnut or clock motor assembly's sleeve. Caution: Tightening the axle rod too forcefully into the hexnut can loosen the hexnut from the glue that fastens it.

On the rod, inside the inner enclosure, thread a hexnut almost all the way to the inner enclosure's wall. Leave about one centimeter (one-half inch) clearance. Slide on a washer. Slide on the brood cup lid (see page 33). The threaded side of the lid should be facing into the inner enclosure, not towards the wall. Slide on another washer, then the last hexnut. Adjust the position of the two hexnuts to allow only about one centimeter of clearance (about one-half inch) between the wall of the inner enclosure and the brood cup lid. No more than one-half centimeter (three-sixteenths inch) of the rod should protrude past the hexnut, into the brood cup. This may require cutting an additional short length from the axle. Carefully tighten the last hexnut finger tight. Screw as many of the brood cups onto the lid as room will allow.

Chapter 7: Thermostat Assembly

Preliminary Preparation

Acquire a common aquarium heater from a local pet or aquarium store. Choose one of medium price. Very low priced models will prove to be a continuing source of vexation, being difficult to adjust properly. Very high priced models have little to justify their added expense for our purposes. If possible before purchasing the heater, remove each brand of heater from its packaging and try to turn the temperature adjustment knob. Choose a heater that allows an easy, smooth adjustment without binding.

The rated wattage is irrelevant because of the alterations that will be made to it, but its length is critical. It can be no longer than the inside length of the inner enclosure. The aquarium heater should also have a glass test tube jacket that is easily removed. Finally, it is important that the aquarium heater parts be constructed to maintain their integrity without this jacket.

Carefully dismantle the aquarium heater's top housing (head), laying the parts out in some orderly fashion so as to allow easy reassembly later. Most aquarium heaters possess a clamping mechanism to secure them to the aquarium's edge. It will be necessary to remove those parts. On some units, the clamping mechanism will merely unscrew or drop out when the aquarium heater's casing is disassembled. With others, it will have to be removed using a fine toothed saw. Work slowly and carefully so as not to break the plastic parts. If necessary, file the remaining burrs from the aquarium heater's housing to create a flat, even surface.

Remove and discard the glass tube. If left on the aquarium heater it would insulate the thermostat from the temperature in the incubator. If the various parts of the aquarium heater tend to fall out of alignment without the glass jacket, try using some of the nylon cable ties used by electricians and handymen to secure the parts. If this doesn't work, purchase a different aquarium heater.

Electrical Preparation

Cut the wall plug from the end of the aquarium heater's power cord leaving a few centimeters of cord attached to the plug. Split the power cord on the heater lengthwise to separate the various electrical conductors all the way back to the heater's head. Be very cautious not to damage the insulation on any of these conductors; the insulation must remain intact around each separate conductor.

ELECTRICAL CONNECTIONS: See important comments regarding the construction of electrical connections on page x.

If the aquarium heater has a power cord with three conductors, one of them is surely a grounding wire. Some ingenuity and careful examination may be required to identify which one, but it ***MUST*** be identified if it exists. This may require dissecting the wall plug (hence our suggestion that you leave a few centimeters of the cord attached as you cut it off) or carefully dismantling the aquarium heater's mechanism to determine which conductor is not connected to the electric circuit. If in doubt, take the mechanism to a professional electrician for clarification. Once identified, this ground wire must be unambiguously labeled and later connected to the other ground wires in the incubator.

Remove the aquarium heater's heating element. In some models this will merely require unplugging it, in others it must be unsoldered. If all else fails, cut it off using wire cutters. In its place, insert a short, U-shaped, length of copper electrical wire as a jumper. Solder the connections to prevent accidental loosening. A little later, the missing heating element will be replaced with a low wattage bulb, but the bulb will occupy a different position in the electrical circuit.

From this point forward we shall refer to the aquarium heater as simply the *thermostat* because we have disabled all of its other functions, and because we do not wish to confuse it with the candelabra bulb that we will be improvising as a heat source.

Thermostat Position

We must now determine the position of the thermostat. In our example, the thermostat is mounted inside the inner enclosure in the end wall that is opposite the timer, and placed at about the same level as the brood cups, but behind them.

Two orientations of the thermostat were tried: with the head on the opposite end of the inner enclosure from the timer, and on the same end as the timer. Mounting the head away from the timer has the effect of uncluttering the area around the timer and possibly allowing easier adjustment of the thermostat, but exposes it to possible accidental misadjustment if the inner assembly should shift within the primary enclosure. Mounting the thermostat’s head on the same end as the timer could make it more difficult to adjust, but will also make a more compact assembly if space is at a premium. In this example, we place the thermostat’s head away from the timer, but this is matter of personal preference rather than rational engineering.

The thermostat will lie inside a piece of slotted PVC pipe (see below) and sufficient space must be allowed for the added diameter. In addition, it should not lie against the outside wall of the inner enclosure to avoid a perturbation in the temperature that it senses.

Pay particular attention to the position of the thermostat's head. It must not protrude far enough in any direction to obstruct or interfere with the placement of the incubator assembly in the aquarium, or with any of the other mechanisms in the incubator.

On both ends of the inner enclosure, lightly mark the center of the thermostat's proposed location, and draw circles around those points equal to the outside diameter of the PVC pipe. Verify that, when the pipe is installed in this position, it will not interfere with any of the inner enclosure's contents, particularly the brood cups, and there will be at least one centimeter (one-half inch) clearance between the pipe and the wall of the inner enclosure. If possible, a clearance of at least two centimeters (three-quarters inch) should also exist between the pipe and the brood cups.

Acquire a length of plastic or PVC pipe of the sort used in plumbing or electrical work. This pipe will be used as a protective covering to hold the exposed electrical parts of the thermostat. For safety's sake this must be a non-conductive plastic pipe, ***NOT*** a metal one. The pipe should have an inside diameter sufficient to accommodate the mechanism of the thermostat without disturbing or damaging it.

Cut a length from the stock piece of PVC pipe that is just slightly longer than the inside length of the inner enclosure at the level at which it will be mounted. Lay a piece of moderately coarse sandpaper or emery cloth (e.g., 80 grit) on a flat surface and rub the ends of the pipe across it to shorten the pipe in very small decrements. Test the length of the piece often. The ideal length will allow the pipe to fit into the inner enclosure snugly but without deforming the walls. In our example, the walls of the inner enclosure are slightly sloped, and the ends of the pipe were sloped to match.

Before installing the pipe, cut numerous slots in it with a saw for ventilation. These should be spaced approximately one centimeter (one-half inch) apart and should only extend half way through the diameter of the pipe. They should be staggered with one cutting into the pipe from one side and the next cutting from the other side a little farther along its length. Each slot need only be the width of one saw kerf. An alternate method is to drill a multitude of six millimeter (one-fourth inch) holes along the pipe's length. In either case, drilling or sawing on a curved surface, great care must be used to prevent your accidental injury. A simple jig constructed of two strips of scrap wood nailed to a board with the PVC pipe laid between them will work well to secure the pipe.

Using PVC plumbing cement or epoxy glue attach the piece of ventilated plastic pipe to the inside of the inner enclosure, centered over the locating marks. Make doubly certain that it lies in its intended position and orientation. Brace, tape, or clamp it while the adhesive cures. Give the adhesive plenty of time to cure before proceeding.

MELTING HOLES is discussed in detail on page 30.

A hole must now be made in the end of the inner enclosure, at one end of the PVC pipe, for the thermostat. After much experimentation (and many failures), these authors discovered that the best system employed a piece of thin walled, metal tubing of appropriate diameter to melt the hole. The most difficult part of the process was finding a piece of metal tubing of the correct diameter. In the example shown here, one end of a copper plumbing reducer coupling was the exact size needed, but any other thin walled metal pipe (e.g., a metal curtain rod) of the correct diameter would have worked. Allow plenty of time for the metal tube to reach a maximal temperature. Work slowly and carefully to produce a clean, round hole that opens directly into the inside of the PVC pipe.

Insert the thermostat assembly through the hole in the wall of the inner enclosure and into the pipe. The thermostat's control (head) should remain outside the inner enclosure for ease of adjustment, but the internal mechanism should lie entirely inside the PVC pipe, inside the inner enclosure. Refer to **Figure 7** and **Figure 8**. Fasten the thermostat securely in place using silicone aquarium sealant. This should be done in such a way as to exclude all cool air leaks from around its base or connection. Again, review the requirements for its position and tape or prop it securely while the silicone aquarium sealant cures.

We strongly recommend the use of silicone aquarium sealant in this application for two reasons. First, it is a space filling adhesive that will effectively seal any small leaks around the thermostat's head. And, it can be cut with a knife, scalpel or razor blade to remove the thermostat assembly in case it fails.

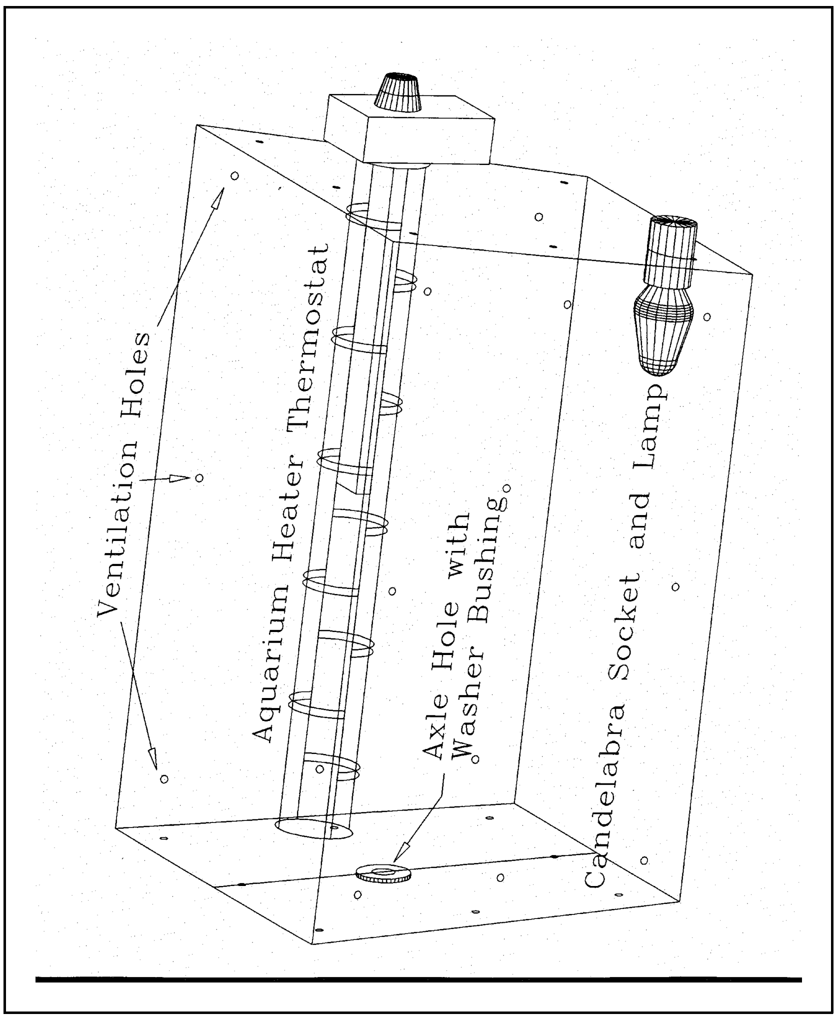
Ventilation Holes
Aquarium Heater Thermostat
Axle Hole with
Washer Bushing
Candelabra Socket and Lamp

Figure 8

Chapter 8: Heater Assembly

We are in danger of confusing the aquarium heater with the candelabra bulb because we will be using the candelabra bulb as a heater. In the discussion that follows, the aquarium heater will be referred to as the thermostat, and the candelabra bulb will be referred to as the heater, thus reflecting their functions in our usage rather than their original, intended purposes.

A proper temperature is maintained in the inner enclosure with a low power heater made from a candelabra bulb and a candelabra socket. A candelabra socket can be obtained from a business that repairs lamps, or by finding an old used chandelier, perhaps in a second hand store. Some Christmas tree bulb sockets will also work. Given a choice, choose as compact a socket as possible. Be very careful that the selected socket is rated for the mains voltage in your area, and for at least 60 watts.

The details of installing the candelabra socket will depend largely on its construction. It should have some provision for securing it to the side of the inner enclosure with its wires passing through a hole in the enclosure's wall. Some ingenuity must be used; plan carefully. The essence is safety and reliability. At no time should bare conductors be exposed to touch, or should the inner enclosure or its contents be exposed to direct contact with the bulb.

In our example, the hole for the candelabra socket is located in the front, bottom of the end wall of the inner enclosure opposite the timer. In theory, it could be placed elsewhere, but we strongly recommend against it.

Following is an itemization of the factors controlling its placement. It should be placed at the bottom of the inner enclosure. The warm air rising form the bulb will tend to disrupt the layering of air of different temperatures, tending to keep the inner enclosure a uniform temperature.

The heater should be placed on the end opposite the hygrometer thermometers (see below) so as not to unduly perturb their temperatures.

It should be placed as far from the brood cups as possible, preferably on the end opposite the timer. Most especially, it should not be under or near the brood cups. If an eggsac is ever kept in the incubator, it will be at the end nearest the timer. If the candelabra socket is placed on the same end as the timer, the candelabra bulb’s heat rises or radiates too closely to the brood cups, posing a significant hazard to the eggsac. With the heater placed opposite the timer, only the very last eggsac placed in the incubator might be put in jeopardy.

The heater should be placed as far as possible from the thermostat. If the candelabra socket is placed too near the thermostat it will prevent the thermostat from accurately controlling the inner enclosure’s temperature.

Lastly, it should be placed so that the bulb is more than two centimeters (three-quarters inch) from any surface or any of the inner enclosure's other contents.

Mark the position and make the appropriate hole for its mounting. Using the appropriate couplings (e.g., small threaded pipe, washers, and nuts), epoxy glue, or silicone aquarium sealant, install the candelabra socket in its proper place. Of course, the bulb must be inside the inner enclosure.

The authors have used several incubators that have had the bulbs mounted in the top. In theory, this permits stratification of warm air at the top and cooler air at the bottom, introducing some uncertainty about the true temperature of the eggsacs in the brood cups. In fact, these incubators seem to work acceptably, anyway. Mounting the bulb towards the bottom of the inner enclosure will set up convection currents that will mix the warm and cool air. An adverse side effect is that this may increase the difficulty of maintaining a suitable relative humidity. A larger water dish may have to be substituted, or some of the inner enclosure's ventilation holes covered to compensate.

If epoxy glue or silicone aquarium sealer are used to fasten the bulb socket, make doubly certain that the bulb will be in its proper orientation and position as the adhesive sets. Once this has set, the assembly will be most difficult to change. To stabilize it while the bonding agent cures, braces made of small pieces of wood, cardboard and tape, or small clamps, may be used. It is best to wait overnight before proceeding, in order to allow the bonding agent to cure.

We encourage you to use the blank spaces in this booklet for your own notes.

Chapter 9: Dimmer Switch

Why use a dimmer switch? Incandescent light bulbs are manufactured to meet a set of rather extreme conditions. The hotter they burn, the brighter they are. That is, the more visible light they radiate. However, the hotter they burn, the more power they consume and the shorter is their life expectancy. Coincidentally, the hotter they burn, the more heat they radiate. In our application, the radiated light is an unnecessary artifact. We need only the heat and this must be gentle and exquisitely controllable. It is to our advantage, then, to reduce the power supplied to the light bulb to lower its operating temperature. This has several results. Because the bulb operates at a lower temperature, it lasts longer before burning out. Because it operates cooler, it radiates less visible light and more heat per unit of power.

Dimmer switches are normally designed to be mounted in a standard duplex electrical box, and we strongly recommend that this one be mounted in this way. Remove a knockout to allow the electrical wires easy passage out of the box.

> KNOCKOUTS ARE DISCUSSED ON PAGE 21. Refer to the sidebar on that page for important information about deburring these holes.

Refer to **Figure 3** for a suggested position and orientation for the dimmer switch's duplex box. The dimmer switch should be placed along the back side of the baseboard in a position that will not interfere with the other incubator parts. Its adjustment knob should face inwards, towards the center of the baseboard to avoid accidental contact with the primary enclosure's wall and subsequent misadjustment. In this application, shimming normally isn’t necessary unless the adjustment knob interferes with the other incubator parts.

See page 19 for details on its fastening to the baseboard.

We encourage you to use the blank spaces in this booklet for your own notes.

Chapter 10: Closing the Circuit

For a power source, use a standard, third wire ground, electric power cord. Because the power consumption of the incubator is relatively small, a light weight cord is acceptable. The third wire for grounding should be firmly attached to the duplex box, using the screw installed by the manufacturer expressly for this purpose, or one of the screws that hold the box to the baseboard. All other grounding wires from the remainder of the incubator should also connect, directly or indirectly, to this screw and the ground wire.

Wiring for a Timer

Because the timer is not wired directly into the circuit, but is merely plugged into a duplex outlet, this operation reduces to attaching the wires to the duplex outlet and plugging in the timer.

If a knockout has not already been removed from the first duplex box, do so now. Feed the power cord through this hole and connect the power conducting wires to the poles of the duplex outlet. Additionally, connect sixteen gauge, insulated wires to the same poles. These should each be about a meter (forty inches) long to allow ample material for making further connections. They can be shortened as appropriate later. Connect a short jumper from the grounding screw on the duplex outlet to the grounding screw installed in the duplex box by the manufacturer expressly for this purpose, or to one of the screws that attach the duplex box to the baseboard. Secure the duplex outlet in the box using the screws provided.

Wiring a Clock Motor Assembly

Connect one wire from the clock motor assembly with one of the power conducting wires from the power cord and one piece of one meter (forty inches) long, sixteen gauge insulated electric wire, inside the duplex box.

Connect the other clock motor assembly wire with the remaining power cord wire plus another piece of sixteen gauge insulated wire. Stated another way, each connection in the duplex box will be composed of three wires. One is from the power cord, a second is from the clock motor assembly, and a third extends to the rest of the incubator.

If the clock motor assembly possesses a third wire as a ground, connect it to the grounding screw in the duplex box or to one of the screws that attach the duplex box to the baseboard.

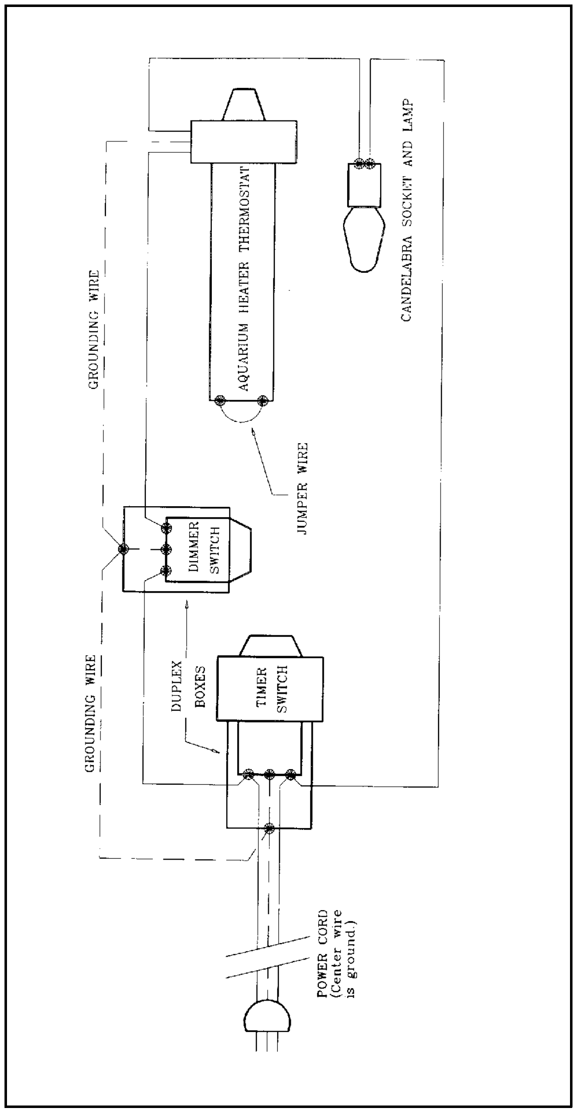
GROUNDING WIRE
AQUARIUM HEATER THERMOSTAT
CANDELABRA SOCKET AND LAMP
JUMPER WIRE
DIMMER SWITCH
GROUNDING WIRE
DUPLEX BOXES
TIMER SWITCH
POWER CORD (Center wire is ground.)

Figure 9

Continuing the Circuit

Figure 9 should be studied closely for this part of the project. Connect one of the meter long, sixteen gauge wires from the duplex outlet to one of the power poles or wires from the dimmer switch.

Connect one of the wires from the thermostat to the remaining pole or wire from the dimmer switch.

Connect the other power cord wire from the thermostat to one of the wires from the candelabra socket.

Connect the remaining wire from the candelabra socket to the remaining meter long, sixteen gauge wire from the duplex outlet on the other end of the baseboard.

Thus, we have constructed a complete loop of conducting wires from the power cord to the duplex outlet/timer switch to the dimmer switch, to the thermostat (modified aquarium heater) to the heater (modified candelabra socket) and back to the duplex outlet/timer switch and power cord. Because the electric current must travel through each part of this loop sequentially without missing any given part, they are said to be wired in a series.

Grounding

This series of steps is extremely important in the safe construction and operation of the incubator. For safety's sake, the builder is advised in the strongest possible terms not to ignore grounding all the electrical parts of the incubator.

Connect another meter long, sixteen gauge wire from the grounding screw of the initial duplex box to a mounting screw in the dimmer switch's duplex box. North American electrical code requires this wire to be green in color. Connect an additional, short jumper from the dimmer switch's grounding screw, if present, to the same screw.

If the thermostat (aquarium heater) was equipped with a third wire ground, this must be connected to the grounding screw in the duplex box of either the duplex outlet/timer switch or the dimmer switch.

At each connection, the excess length of wire may be trimmed off, leaving only enough to allow safe and secure connections, and to allow the conductors to lie out of harm's way. All wires should be fastened to the surface of the baseboard to eliminate the possibility of accidentally loosening the connections. If small staples are used, extreme care must be exercised not to drive a leg of the staple through the conducting wire!

We encourage you to use the blank spaces in this booklet for your own notes.

Chapter 11: How It Works

In this configuration, the aquarium heater's purpose has been subverted and we now call it merely the thermostat. We have substituted a low wattage candelabra bulb (that we call the heater) in place of the high wattage heating element because the heating element produced heat that was too intense.

The thermostat will determine when the bulb will be on or off, based on the actual temperature of the inner enclosure. It will, therefore, determine the final temperature of the inner enclosure.

The dimmer switch will control the current delivered to the bulb, and thereby, its operating temperature. If the heat is too intense, it can damage neighboring parts of the incubator, including the eggsacs, as well as shorten the life expectancy of the bulb. If the electric current is diminished, somewhat less heat will be produced. The bulb will stay on longer but run slightly cooler, extending the bulb's service life and protecting the other parts of the incubator and the eggsacs from heat damage.

While the dimmer switch controls the operating temperature of the heater, it has absolutely no effect on the temperature of the incubator as a whole.

The thermostat, a dimmer switch and the heater are now wired in a loop or series. For electric current to pass through any part of the loop, it must pass through ***EVERY*** part of the loop. If one part fails, no current will flow. This basic concept is key to understanding the basis for the troubleshooting suggestions on page 69.

We encourage you to use the blank spaces in this booklet for your own notes.

Chapter 12: Hygrometer Assembly

Since the following passage was written several moderately accurate electronic relative humidity gauges (hygrometers) have appeared on the market at reasonable prices. For convenience's sake, the enthusiast may wish to use one of these instead of the wet bulb/dry bulb hygrometer described here.

Merely examine the entire lot that is on display and choose the one displaying a value closest to the average Rh.

Theory

The relative humidity (often called simply "humidity") of a sample of air is the amount of water that it actually holds, compared to the maximum amount of water it could hold at that temperature, expressed as a percent of relative humidity or Rh. This value is highly temperature dependent.

A wet bulb-dry bulb hygrometer is an instrument used to measure the relative humidity of a sample of air. Basically, it is composed of two accurate thermometers. One is kept dry and measures true air temperature, the other is kept moist and is cooled by the evaporating water.

The rate at which this water evaporates depends on the difficulty that the water experiences in leaving its liquid state and mixing as a vapor with the surrounding air. If the air is very dry, the water evaporates from the wet bulb thermometer rapidly, causing a significant cooling or depression in temperature. If the air is very wet, the water will not evaporate as fast, and the temperature of the wet bulb thermometer will not be depressed as much.

Therefore, the difference in the temperatures of the two thermometers is a convenient indicator of the dryness or wetness of the air around them. Tables have been drawn up that correlate the dry bulb temperature and the temperature depression to the relative humidity of a sample of air. Relative humidity tables are available from many sources, such as weather bureaus, libraries, and school science departments. One such table is presented on the inside of the front cover.

The hygrometer described here is only approximately accurate for a number of reasons. But, because the conditions in the incubator are relatively static, the actual relative humidity should not be significantly different from that which is indicated.

Thermometers

There are some rather rigid requirements for choosing the thermometers for the hygrometer, and installing them in the incubator.

The thermometers should be of the old fashioned red alcohol variety. While they will work, mercury thermometers should be avoided whenever possible unless there is some compelling reason for using them. If they break, the mercury poses a significant health and environmental hazard. The preferred type are standard, glass, aquarium thermometers.

Fever (medicinal) thermometers will not work. They usually are not sensitive in the preferred temperature range, and they are built to register the highest temperature since they were last reset, not necessarily the current temperature. They must be reset after each reading.

Neither are the newer, liquid crystal thermometers suitable. It is difficult to determine the exact temperature with these because there is no clear demarcation or line at which to read the temperature. Instead, there is a gradual color change over several degrees, introducing a potential for a substantial error. Also, it is difficult to improvise a method whereby the thermometer could be efficiently cooled by evaporating water, and still allow for reading the temperature.

For the purposes of discussion we will use standard, glass, floating, aquarium thermometers from the neighborhood aquarium shop. Before purchasing the thermometers, compare all of those in stock. Choose two that read exactly the same temperature, and that read closest to the average for the group. When choosing the thermometers, do not handle them by the bulb. The heat of your fingers will change the temperature they report, invalidating any further temperature comparisons. We will assume that these thermometers are reasonably accurate. If there is any question, they should be compared to calibrated laboratory thermometers in a school or college chemistry or physics laboratory or merely replaced with more trustworthy ones from the pet shop.

Installation

The position and orientation of the hygrometer thermometers is very important. They should be placed on the opposite end of the inner enclosure from the heater. This is to minimize the effects of the radiant heat from the heater.

Both thermometer bulbs should be at the same height in the inner enclosure. This is to minimize the stratifying effects of the warm air. Because warm air tends to rise, the warmer air will settle to the top of the enclosure, the cooler air to the bottom. Therefore, the higher thermometer would report a higher temperature than the lower, apart from the effects of evaporation, indicating an incorrect relative humidity.

The thermometer bulbs should be mounted very close to each other, ideally less than two centimeters (three-quarters inch) apart. The thermometers should be mounted so that the bulb of the wet bulb thermometer is suspended within one centimeter (one-half inch) of the top of the humidifier dish. The thermometers should be mounted so that their bulbs are at least twenty five millimeters (one inch) from the nearest wall of the inner enclosure to avoid temperature perturbations caused by the relatively cool wall.

Lastly, they should be oriented in such a position that they may both be read easily through the incubator's front, without craning one's neck or opening the primary or inner enclosures.

MELTING HOLES is discussed in detail on page 30.

Put the humidifier dish in the inner enclosure, nearest the front side of the incubator, and farthest from the heater. Install the inner enclosure's cover. Estimate the position of the holes for the two aquarium thermometers so that at least one is above the humidifier dish. Drill or melt these holes in the inner enclosure’s lid.

Use silicone aquarium sealant to fasten the thermometers in the holes[3] in the lid so that their bulbs are both at the same height in the inner enclosure, at least the minimum distance from the nearest wall, and the proper distance above the top of the humidifier dish.

In our example, the inner enclosure was too tall and the thermometers were mounted in an extra block of wood and suspended from the lid.

If necessary, some method should be used to tape, clamp, or prop the thermometers in their proper position while the bonding agent sets. Be cautious not to break the thermometers!

The dry bulb thermometer is used as it is. The wet bulb thermometer should have a small sleeve of cloth (e.g., a piece of polyester handkerchief or a section of a broad, nylon shoelace) tied to cover its bulb with the other end placed in the humidifier dish. This will act as a wick to keep the end of the thermometer moist and cool. It is important that the cloth sleeve is made of a synthetic fabric. Cotton, linen, and wool will support mold and bacterial growths, endangering the eggsacs and soon disintegrating. At first, make this sleeve ten centimeters (four inches) long.

[3] Silicone aquarium sealant can be cut away with a sharp knife, scalpel or razor blade if the thermometers must ever be replaced.

Application

To determine relative humidity, one notes the dry bulb temperature and the ***DIFFERENCE*** between the wet and dry bulb temperatures (as opposed to the wet bulb temperature alone). Consulting a relative humidity table (see the inside of the front cover), locate the row headed by the dry bulb temperature and read across to the column headed by the temperature difference. The number at the intersection is the relative humidity expressed as a percentage.

			WET BULB DEPRESSION				
	° F		8.1	9.0	9.9	10.8	11.7
		° C	4.5	5.0	5.5	6.0	6.5
D	70.7	21.5	64	61	57	54	50
R	71.6	22.0	65	61	58	54	50
Y	72.5	22.5	65	62	58	54	51
	73.4	23.0	65	62	58	55	51
B	74.3	23.5	66	62	59	55	52
U	75.2	24.0	66	63	59	56	52
L	76.1	24.5	66	63	60	56	53
B	77.0	25.0	67	63	60	57	53
	77.9	25.5	67	64	60	57	54
T	78.8	26.0	67	64	61	57	54
E	79.7	26.5	68	64	61	58	55
M	80.6	27.0	68	65	62	58	55
P	81.5	27.5	68	65	62	59	55
E	82.4	28.0	69	66	62	59	56
R	83.3	28.5	69	66	63	60	56
A	84.2	29.0	69	66	63	60	57
T	85.1	29.5	70	67	64	60	57
U	86.0	30.0	70	67	64	61	58
R	86.9	30.5	70	67	64	61	58
E	87.8	31.0	71	68	65	62	59

Table I Relative Humidity Table.

Chapter 13: Final Assembly

The time has now come to put the whole incubator together.

Double check the patency of all electrical connections. Make doubly certain that all metallic parts in the incubator are connected by a grounding wire, directly or indirectly, to the grounding wire of the power cord. If the home wiring system has no provision for a third wire ground, a professional electrician must be consulted to provide an alternate method of grounding.

Tighten all screws used to hold the various parts in place. Be cautious not to tighten screws against the plastic parts so tightly as to break the plastic. Screw as many of the plastic brood cups as possible onto the axle. Place the humidifier dish in its assigned position. Double check the position of all parts to ensure that there are no unwanted mechanical or electrical contacts. Carefully lower the whole inner assembly into the aquarium. Place the incubator in its permanent resting place. Pass the power cord out a rear corner of the aquarium.

Fill the humidifier dish almost full of water. Be careful not to splash any over its side into the inner enclosure. A twenty milliliter hypodermic syringe with a piece of thin vinyl tubing (e.g, aquarium, air line tubing) instead of a needle, works well for this purpose. Using distilled water is a good idea to avoid a buildup of mineral deposits in the dish.

Cut the cloth sleeve on the wet bulb thermometer so that it reaches to the bottom of the humidifier dish plus about a centimeter extra. Wet the sleeve with a few drops of water. Thereafter, the cloth is kept moist as capillary action draws water up to the thermometer bulb from the dish. Lower the lid onto the inner enclosure. Be certain that the cloth sleeve always lies in the water in the humidifier dish.

Never allow the humidifier dish to dry out when an eggsac is in the incubator. Under artificial heat, less than an hour may be required for the eggs to desiccate and die.

We encourage you to use the blank spaces in this booklet for your own notes.

Chapter 14: Loose Ends

Troubleshooting

Plug the incubator power cord into an electric outlet. Gently turn the knob on the thermostat. A small neon lamp will flicker on and off as a critical point is passed. The candelabra bulb should also go on and off with the neon lamp. The adjustment to use for now is one where the neon lamp and candelabra bulb are on, but very close to turning off.

Following are some troubleshooting suggestions. For troubleshooting any of the electrical parts, an ohmmeter or multimeter (combined volt, ohm, and amp meter) is an invaluable tool. Use the ohmmeter to check the electrical integrity of any suspect portion of the circuit. All professional electricians possess them and they are readily available from all hardware and electronics suppliers.

The thermostat's neon lamp fails to light altogether. First confirm that the power cord is securely plugged into an outlet. Then confirm that the outlet has electric power by plugging a table lamp or other appliance into it. Has a fuse or circuit breaker been blown or tripped at the mains panel? If so, it was probably a result of a fault in the incubator's circuitry. Do not replace the fuse or reset the circuit breaker until you unplug the incubator.

DO NOT TOUCH THE INCUBATOR OR ANY OF ITS PARTS UNTIL YOU HAVE UNPLUGGED IT FROM ALL SOURCES OF POWER! Then, go over the incubator's circuitry extremely carefully, comparing it closely with the diagram in **Figure 9** to determine where the fault lies. If you can not locate the fault do not plug the incubator back into the mains. Instead, take it to a professional electrician with these instructions for service.

> **WARNING: TO AVOID POSSIBLY FATAL ELECTROCUTION**, be absolutely certain that the incubator has been unplugged from the electrical mains before opening any of the duplex boxes, or testing or manipulating any of the electrical connections, or working with or near any exposed electrical conductors.

If electrical power is available to the incubator confirm that the dimmer switch is turned fully on. If the candelabra socket has an integral switch, be certain that it is turned on, as well. If the condition persists, try a different bulb, preferably one that is proven good. If there is no change, double check the wiring. Are all the connections sound? Are the circuits wired properly? If all else fails, disassemble and reconstruct the entire circuit a piece at a time, redoing each connection in turn. If the incubator still does not work, replace each piece of equipment with independently tested items.

The heater bulb remains on all the time. Either there is a serious fault in the incubator's circuitry or the thermostat is stuck or welded closed.

DO NOT TOUCH THE INCUBATOR OR ANY OF ITS PARTS UNTIL YOU HAVE UNPLUGGED IT FROM ALL SOURCES OF POWER! Then, follow the circuit path of the electrical power through the incubator, comparing it to the diagram in **Figure 9** to confirm its patency. If that does not reveal an error in the circuitry, either replace the thermostat entirely (strongly recommended) or disassemble it and carefully inspect it to determine the problem and a solution.

Either the brood cups or the axle persistently comes unscrewed. Place a few drops of cyanoacrylate glue on the axle where it enters the loosening nut. This will seal the thread so that the rod will not come undone. Doing this, however, will require breaking the nut off the timer or the brood cup lid and possibly replacing the entire assembly if the incubator must ever be dismantled for maintenance or repair.

Adjustments and Calibrations

Place the glass cover on the primary enclosure (aquarium), taking care to run the power cord through a triangular corner cut. Allow the incubator's temperature to stabilize at least eight hours. If the temperature is too low, turn the thermostat's adjustment knob approximately one-fourth turn clockwise. If the incubator is too warm, turn the thermostat's knob approximately one-fourth turn anticlockwise (counterclockwise).

Then allow the incubator to equilibrate for several hours. Rreadjust as necessary. If the heater is not powerful enough to heat the incubator, replace the bulb with one of higher wattage. After the temperature is properly adjusted, place a small piece of tape across the adjustment knob on the thermostat's head to prevent its accidental misadjustment. You have now adjusted the thermostat and heater to maintain a constant temperature in the incubator.

The dimmer switch should now be adjusted so that the heater is on one-third to one-half of the time when the surrounding room is at normal temperature. The dimmer the bulb, the longer it will remain on. If the dimmer switch is turned to its maximum setting and the bulb remains on too long, replace the bulb with one of a higher wattage rating. Note that this adjustment has absolutely no effect on the incubator's temperature, but rather only on the operating temperature of the heater bulb. See page 21 for a discussion of this.

After the temperature is correct and stable, allow the incubator to set unopened for at least eight hours. Then determine the relative humidity by comparing the two thermometers. The wet bulb thermometer should report a lower temperature than the dry bulb thermometer after the system has reached equilibrium.

Humidity is maintained by simple evaporation. The humidifier dish must be kept filled with water at all times. The wider the dish, the higher the relative humidity is likely to be, the deeper the dish the longer it will last before refilling is necessary. But, be cautious that this dish is not so wide or so deep as to interfere with the action of the other mechanisms in the incubator, particularly the brood cups.

If the relative humidity is too low, cover one ventilation hole on each side of the inner enclosure with a bit of tape. After an additional several hours, if the relative humidity is still too low, cover additional holes and allow the unit to equilibrate again. Leave at least six of the holes open (three towards the top and three on the opposite side towards the bottom). If the relative humidity is still too low, either a wider humidifier dish may have to be substituted or a second dish may be placed in the inner enclosure to maintain a proper relative humidity.

Obviously, this calibration may take several days of experimenting. The prospective tarantula breeder is strongly encouraged to build the incubator well in advance of its expected use, get it up and running, and allow it to run indefinitely until required. While this may be viewed as a flagrant waste of electrical power, it must be remembered that the total power consumption of this incubator is less than 25 watts. The expense of operating an empty incubator is minimal compared to the value of a successful hatch of tarantula babies.

Variations

Several variations have been suggested for this incubator. However, the authors have not had an opportunity to test them. Those adventuresome enthusiasts who have already made at least one working incubator and have successfully hatched tarantula eggs, may want to try these variations or some of their own on a second incubator.

- An inner enclosure can be constructed from thin plywood, Perspex or Plexiglas, gluing a piece of clear Perspex, Plexiglas or glass to the front to allow a clear view of the internal parts. Under any circumstances, it is imperative that at least the side of the container facing the front of the incubator be transparent to allow for easy reading of the thermometer scales and visual inspection of the eggsacs.
- Use another insulated container in place of the aquarium. Possibilities include a Styrofoam picnic cooler, a custom built wooden case, or a small discarded refrigerator (if a truly huge number of eggsacs is anticipated). If some other container is chosen in place of an aquarium, an important consideration would be the ability to install a transparent (Perspex, Plexiglas or glass) wall that

would allow reading the hygrometer and inspecting the eggsacs without opening the enclosure. If the enclosure is well insulated (e.g., a small upright deep freezer) a separate inner enclosure may not be necessary, but many other changes in construction may have to be made to compensate for the lack of associated supporting structures.

- A candelabra bulb was used here because of limited space. With a slightly larger inner enclosure, a standard household bulb socket and standard fifteen or twenty- five watt household bulb can be used. These will be easier to acquire and may be slightly less expensive. They pose no significant differences in wiring, placement or safety precautions. The larger size of the bulb does pose a problem with the amount of space required and its positioning from the eggsacs to prevent their dessication. Be very certain that the outer envelope of the bulb is no closer to any part of the incubator than at least twenty millimeters (three-quarters inch).
- Although the candelabra bulb will work, it throws intense heat directly at the brood cups. There is the danger that this may bake the eggsac closest to the heater. If this appears to be a problem in the incubator, instead of using a candelabra bulb, use a common medicinal heating pad placed inside the primary enclosure but under the baseboard. Before attempting this, compare the wattage rating of the dimmer switch with that of the heating pad. Do not proceed unless the dimmer switch is able to accommodate the current load imposed by the heating pad.

Cut the power cord of the heating pad and wire it into the circuit loop in place of the heater (candelabra socket/lamp). Many, if not most, heating pads have a three level switch for temperature adjustment. When cutting the cord for installation, the cut must be made between the wall plug and the three level switch, ***NOT*** between the switch and the heating pad. Seek the help of a professional electrician if this is not patently clear to you.

After installation, start on the lowest heat level and wait for eight hours. If the temperature does not stabilize at the appropriate level, move the heating pad switch to the next setting. As with the heater, the heating pad should be functional approximately one-third of the time. Most heating pads have a small neon lamp in the switch to indicate when they are on, but this may not work because of the dimmer switch. Watch the thermometer closely instead.

Set the whole incubator on a board to protect the table or shelf underneath. The heat from the heating pad can ruin the finish of the table on which it sets.

- If an adequate temperature in the incubator cannot be maintained because the unit is too large or the room around it is too cold, try clothing it with Styrofoam insulation. This is available from most building supply dealers. Cover all sides, including top and bottom. If a heating pad is used, be certain to put a board ***UNDER*** the aquarium, ***ABOVE*** the Styrofoam. If the Styrofoam becomes too hot, it will release poisonous fumes and could result in a fire.

Use tape to attach the Styrofoam to the sides and top of the incubator. Make some provision to allow easy removal of the lid and front piece of Styrofoam without dismantling the rest of the insulation during daily inspections.

- Use a commercial thermostat of the type used to control home heating plants (furnaces) instead of the aquarium heater/thermostat. Most such thermostats use twelve or twenty four volt electric power and will not work in this application. Make certain that the prospective unit is rated for the local mains voltage (nominally 120 volts in North America).
- Use a commercial, electronic humidity gauge. These are now becoming inexpensive enough that they may be economically used in place of the wet bulb-dry bulb hygrometer described here. They are also becoming more accurate. Do not trust mechanical (non-electronic) humidity gauges unless they can be calibrated against a known, accurate standard. Seek help for this from a school or college physics teacher or someone from the local weather bureau, or a heating/air conditioning/ventilation (HVAC) contractor.

Day To Day Operation

Humidity Requirements. Continuing experience with these incubators has shown that 60% Rh is the minimum allowable to ensure that an eggsac will not dessicate and the eggs die. However, contrary to prior "wisdom," it appears that the eggs will develop nicely at an Rh all the way up to 100% unless the silken eggsac itself becomes wet.

Whenever the incubator is opened, refill the humidifier dish. Use distilled water, if at all possible, to avoid a mineral build up.

Temperature Requirements. Continuing experience also indicates that the eggs will develop without incident at any temperature between about 75° and 90° F (24° and 32° C), although 80° F (26.7° C) seems to be a good compromise. At lower temperatures they will take longer to emerge from the eggsac and at higher temperatures they will tend to emerge sooner.

Eggsac Maintenance. Because arrangements have been made for more than one brood cup to be used at a time, it is possible to incubate more than one eggsac at a time. The exact number will depend on the size of the eggsacs, the size of the cups, and the size of the inner enclosure.

Once an eggsac is incubating, rotate the brood cup a full 360 degrees or more by hand at least once a day. This affords an added jostling to the eggs, and helps break up any clumping in the eggsac. With most timers, this may mean only rotating the dial by hand. With a clock motor assembly or some timers, this may require manually unscrewing and rescrewing the brood cups.

Mark each brood cup with a felt tipped marker so that you can always tell at a glance that it has rotated an appropriate amount since the last inspection.

Each eggsac should be able to roll freely in its brood cup without being wedged between the ends. If an eggsac is small enough to do this in only one brood cup, no alterations need be made. However, the eggsacs made by the larger females may be too large for a single brood cup. In that case, carefully remove the floor of a second brood cup, leaving only the cylindrical wall. Use a coping saw with a very fine toothed blade. Lubricate the saw blade with liquid dish detergent or salad oil. Work slowly and carefully. File away the coarsest burrs, first with a coarse and then a medium rat tail file, to produce a relatively smooth plastic cylinder. Be very cautious not to damage the threads. Thread the cylinder onto another brood cup to form a chamber twice the regular length. Now, place the large eggsac in this double brood cup.

A little roughness on the inside is desirable, catching the silken eggsac and turning it. Without some roughness, a heavy eggsac might merely slide along the inside wall. If this happens, a simple cylinder of a coarse mesh nylon fabric (available from a fabric store) can be inserted against the inner wall of each cup to increase friction for the eggsac. If it slides as well, tack it in place with one or two drops of cyanoacrylate glue.

Record Keeping. Be certain to record the parentage and dates of each eggsac in some completely unambiguous fashion. Keep accurate records for each one to determine appropriate hatching dates, and to track pedigrees for future generations.

Schultz and Schultz (1998) presents data on incubation times for a variety of species.

Remarks

The construction and initial set up of this incubator will require considerable work and time. It is obviously not a project to be assumed without some forethought and planning. Neither is it likely to be a casual weekend project. This will undoubtedly dissuade some enthusiasts from making one.

If the trouble and expense required to breed a pair of tarantulas, the rewards from the satisfaction of accomplishing the feat, and the monetary benefits from selling the babies are considered, the time and effort required to construct the incubator is actually quite small. And, once it is made it will likely last for years. It's all part of the fun of keeping and breeding pet tarantulas.

We encourage you to use the blank spaces in this booklet for your own notes.

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