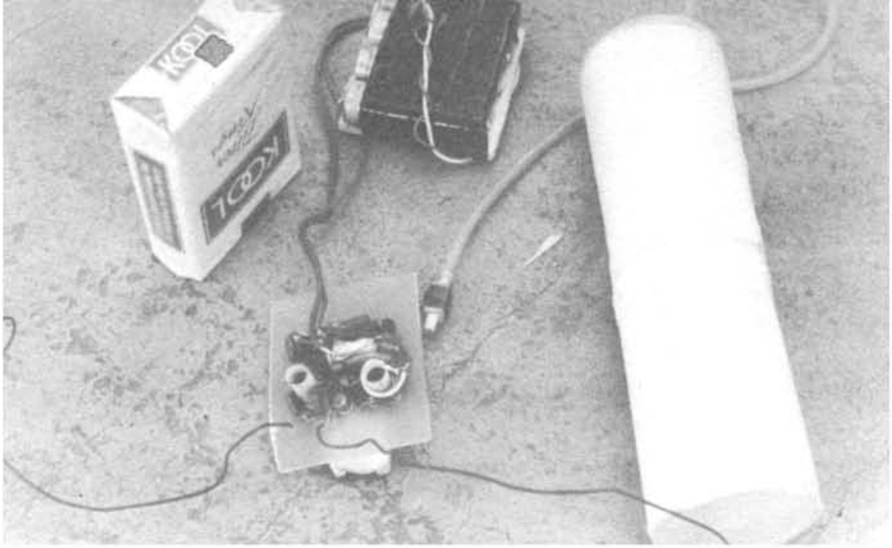
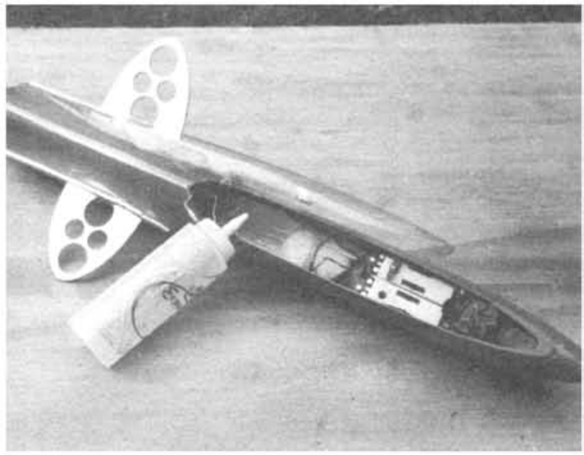


Complete Thermal Sensor system from Hill's glider. Transmitter and audio circuits are on small board at left center. Sensor is just to right of circuit board. Batteries (4 Nicads) and an air bottle made from two foam coffee cups are also shown. A dipole antenna is used for efficiency. This is taped to wing along leading or trailing edge.

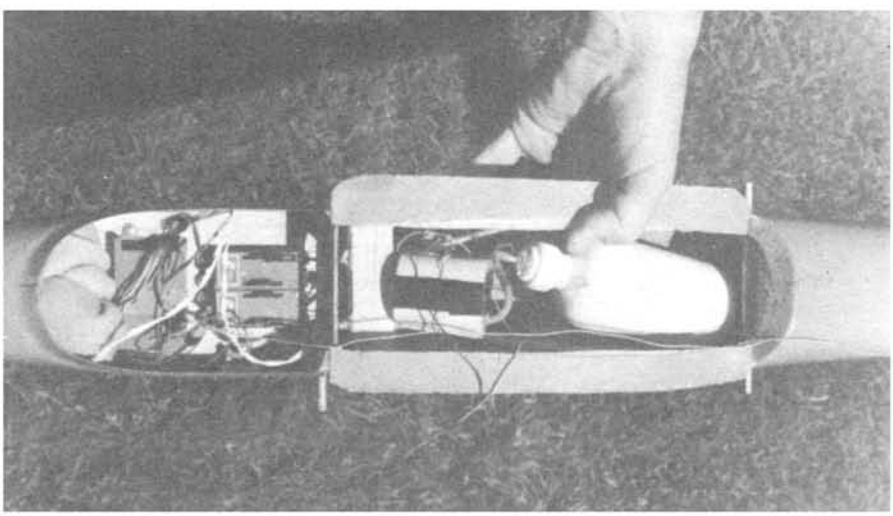
Walt Good's skinny "Kurwi" was pretty tight for space, so he mounted the Sensor, Transmitter and audio system inside a Honeybee bottle! Uses the receiver batteries to also power the telemetering as it only draws 15 ma at 4.8 volts. Hardly noticeable!



Air to Ground 'THERMAL SENSOR'

by
Maynard Hill
and
R. Ben Givens

A high-pitched wail points you toward the high road. However, a low moan means you've had it.



A peek down into Ray Smith's record holding "Uranus" looks like a garbage can! There's lots of wires in there, but it all adds up to a winner. Logictrol Radio on 72mc., telemeter Sensor on 51mc. Ray flew two miles slant range, but 10 milliwatt signal came in strong all the way. Record probably would not have been broken without Sensor, as thermals were hard to find.

♦ You really must hear this device squeal in order to believe it. It is remarkably sensitive to small and slow vertical movements. If it is being raised, it squeals a high note and if being lowered, it squawks a low groan. When you get it into an R.C. soaring glider on a day with modest thermals, that's a day that will make you glad to be alive, glad to be a modeler, and glad you don't have a noisy engine on your sailplane. With your R.C. gear you go off searching for the high squeal. When you find it, you crank the bird over into a tight spiral and up she goes! If the low groan comes on, straighten out and fly upwind in search of some more high squeals.

How does it work? That's the purpose of the article, plus we hope to give you enough information so that you can build one if you would like.

This will not be a detailed construction article, but we will give you physical principles and enough guide lines in electronics to show you the route.

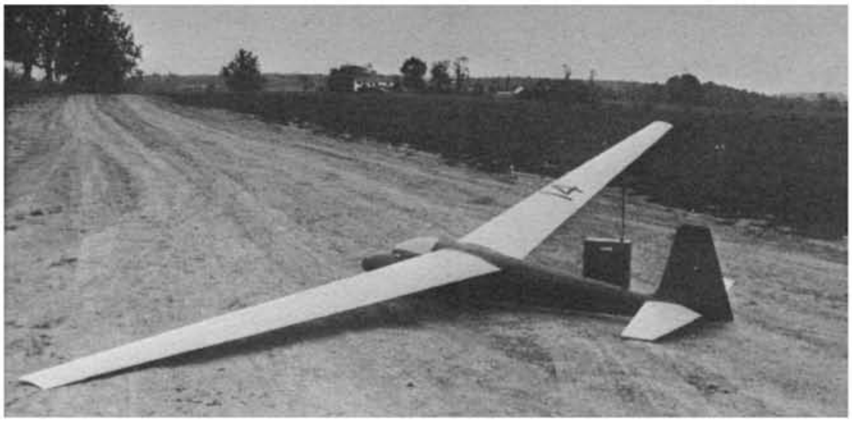
First, we should review some history on how this thermal sniffer was developed for model use. It was about 4 years ago when one of us (Hill) built a relatively simple device consisting of a very sensitive pressure switch hooked into a tone oscillator. This modulated a radio signal sent to a ground receiver to tell the pilot when a soaring glider was going up or down. The principle and ways of building this gadget were described in Model Airplane News, January 1966. Much of the principles of this present device are identical to the older system. The switch in the early device was a fussy thing to get working properly, but it did work and provided much fun in soaring. Bob Hooper of the DCRC worked out the telemetering system for this unit. It was an on-off device that beeped a pleasant note while going up and whooped a groan when coming down. It was flown for over a year in the 12-foot "Bong Boomer" Glider (FM—April 1967) and helped set a World Record for altitude (3660 feet) in July 1966.

This newer device is a big improvement over the diaphragm switch used then. The key component that leads to the improvement is the sensor, which is called a bi-directional flowmeter. As far as we know, Gene Moore, a full-scale soaring pilot from Cumberland, Maryland, was the originator of this type of sensor and the first to apply it in an instrument for soaring. Gene developed and now produces the Moore Variometer that is used by many full-scale soaring pilots. For convenience, some of the Moore Variometers were installed in lunch pails because they have a ready mount for thermos bottles. As pilots board their sailplanes, they give the impression of extreme confidence that they are going on a long flight, for they always stow that mysterious lunch pail in the cockpit. The irony of it all is that many pilots do in fact get very long flights because of this lunch pail, but there is nothing edible inside it so they sit up there in the sky and starve!

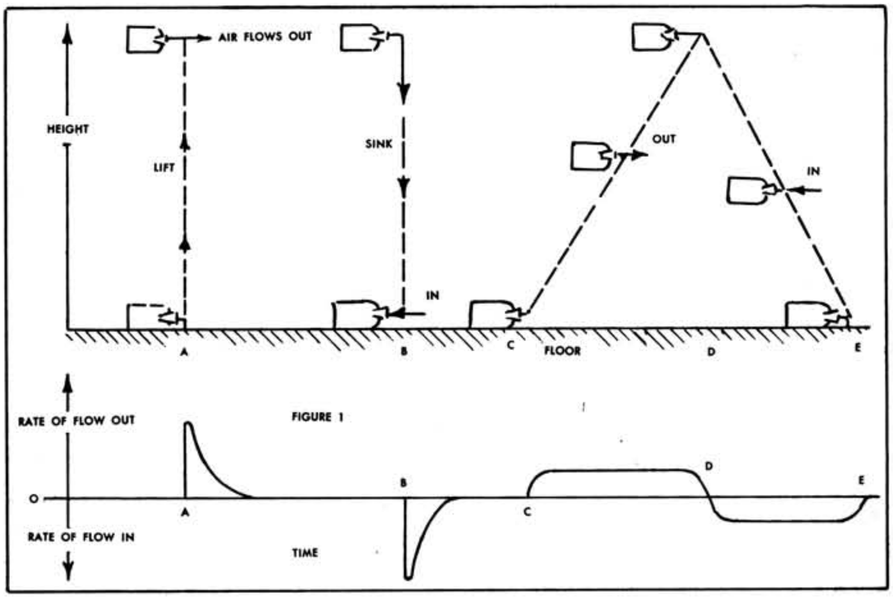
The sensor to be described here is similar in principle to the Moore sensor. Using a cut and try method and after several versions, we arrived at a sensor that is responsive to sink and climb rates of typical R.C. gliders. The concept of telemetering the information to the ground so as to permit its use in R.C. soaring had already been tested and proven by Hill and Hooper with the earlier diaphragm type sensor. Bob Hooper was again very helpful in the early stages of development of suitable circuitry for changing this sensor output into an intelligible telemetering signal. The version described here is the result of refinements and improvement of the sensor and circuitry by the present writers. We would be amiss if we did not acknowledge that a number of other members of the DCRC glider guiders also contributed to its development and successful application. In particular, Tom Rankin, Jerry Moran, Walt Good and Ray Smith are part of the team of people who worked on it and are now enjoying the fruits of their labor!

It should be stated that there are original inventions involved in this device. You may build such a device for your own use, and we hope you will, for you'll find it a most enjoyable gadget! However, we would advise you not to build it for sale without making requisite legal arrangements.

Before getting to the meat of the device, it should also be pointed out that F.C.C. regulations do not permit the use of any frequencies on citizens bands for sending the signal back to the ground, as the regulations for these specifically call for ground based trans-



Maynard Hill's KA-6 fibreglass 12 foot soarer, by Nelson Model Products. Fitted with a Thermal "Sensor" this is a tremendously exciting machine to fly.



Schematic diagram of how air flows in and out of a bottle with a small hole in its stopper when the bottle is lifted quickly (A) to an altitude several feet above the floor (B). There is no flow if the bottle is kept stationary. If lifted slowly, (C to D) air flows out slowly while being lifted and air flows back in slowly, when it is lowered slowly (D to E). The amount of air flow is extremely small, but the sensor described here can detect it easily. A combination of special aerodynamics and modern electronics does the trick.

Crew at Dahlgren Naval Weapons Laboratory, Sept. 3, 1968. Ray Smith holding "Uranus" glider after record flight to 4,991 feet. Entire flight was on thermals, lasted about 1 hour and 20 minutes. Thermal Sensor used to find three different thermals during flight. Tom Rankin also holds a Record Holder, his Speed Seaplane. Others in crew are (Left to right) Doug Smith, Harry Remmers, Ernie Conrad and Roger Boutchyard (Radar operators), Carlton Middle brook C.D., Jack Newman and Dr. Jack Symborski C.D.

Air to Ground Thermal Sensor

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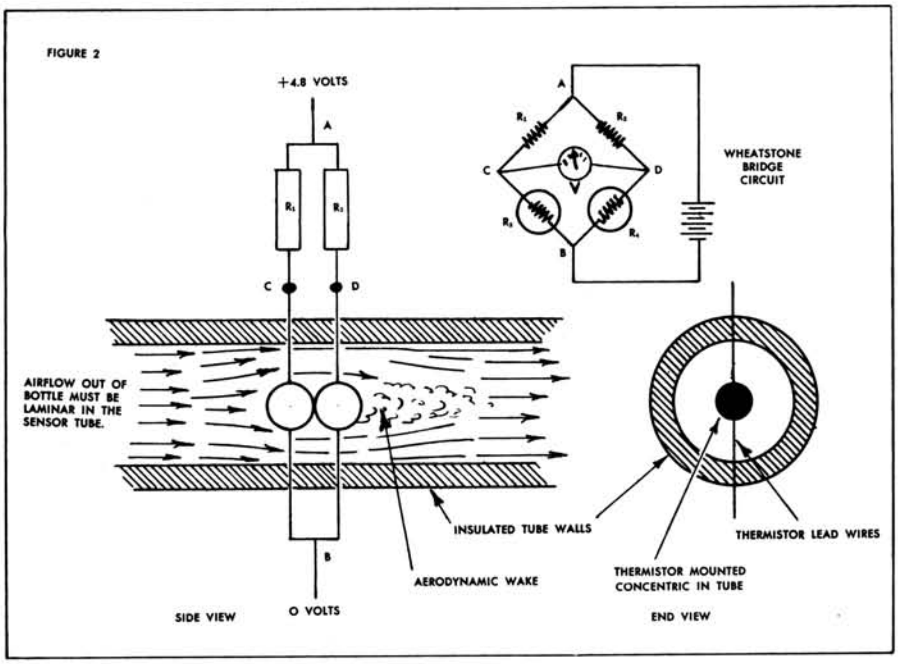
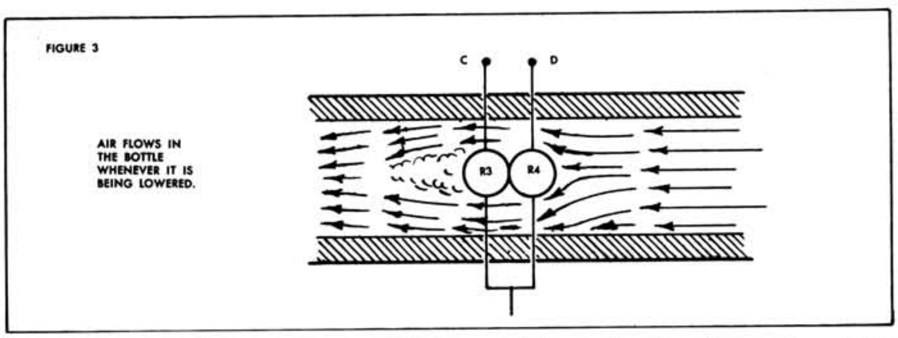
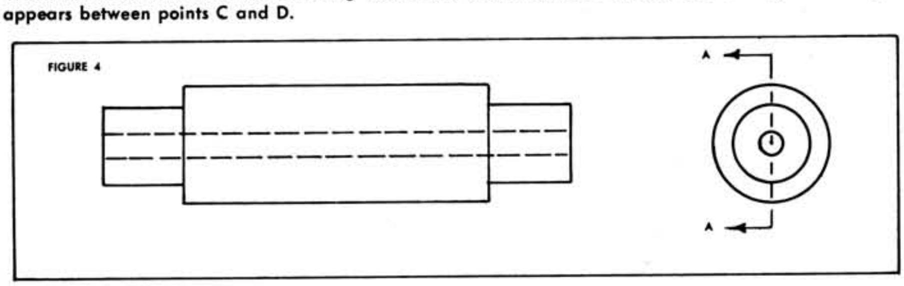


When R_3 thermister is cooled by air ramming and scrubbing along it, its resistance increases. This causes a positive voltage to appear between points C and D of the Wheatstone bridge network.



When air flows back into bottle during descent, R_4 is cooled more than R_3 and a negative voltage appears between points C and D.



Take a 1" long piece of 3/16" hardwood dowel. Drill a hole through it .060 inches in diameter. This must be done in a lathe. Turn ends down so that a 1/8" I.D. fuel tubing will fit over them. Then split in half with a razor blade along line A-A. Paint the hole with clear dope and polish surface with fine sandpaper.

mitters and antennae. It is permissible to operate on some amateur bands under regulations dealing with remote transmitters. If you do not have a ham license, your best approach is to find a ham friend who will work with you, or else do a little study and get your own license. You'll find the things you need to learn to get a ham license are both interesting and useful.

We have found that 5 milliwatts of RF power are adequate for the job, and there might be a temptation to think that this would be OK to do on a model control frequency. It really isn't OK. Apart from violating regulations, you'd find yourself losing friends if you do it, for they'll identify you as a frequency hog that needs two frequencies to fly one model. At the end of this article we will discuss telemetering a little more. For now, let's get to the principles of how the Variometer operates.

We'll start with the basics. All modelers know that as you go up in altitude, atmospheric pressure decreases. Right! For instance, at sea level, atmospheric pressure is usually about 14.7 pounds per square inch, while at 18,000 feet altitude, it is about ½ this value or 7 psi. Pressure does not decrease linearly with altitude, but it is a very dependable and continuous decrease that mother nature never fails to provide. While you ordinarily don't think about it, the facts are that atmospheric pressure at the ceiling of your workshop is ever so slightly, but nevertheless a little bit lower than at the floor of your shop. This device is plenty sensitive to detect this small difference in pressure. In reality, it doesn't detect the actual pressure, but rather it detects the rate of pressure change as you move it from the floor to the ceiling.

Let's think through a hypothetical experiment. Suppose we take a thermos bottle and put a piece of 1/8" dia. brass tubing through the stopper. Now if we set it on the floor and leave it there for a minute or so, will you agree that the pressure inside the bottle is exactly the same as outside and that there is no net flow of air through the brass tube? Look at Fig. 1. Suppose at time A we very quickly lift the bottle to ceiling height. Now because we have lifted the bottle to a height where the external pressure is lower than the pressure in the bottle, a small amount of air will flow out from the bottle through the brass tube. In a short time, however, the flow stops because the pressure in the bottle has now become equal to that outside. Now suppose we quickly set the bottle back on the floor. Pressure inside the bottle is now momentarily lower than that outside, so a small rush of air goes through the brass tube into the bottle (Point B, Fig. 1). Again after setting on the floor a moment, the flow stops as pressure inside and out becomes equal. In Fig. 1, we also show that if the bottle is lifted slowly, a lower rate of flow of air out of the bottle results, but the flow out

(Continued on Page 26)

Air to Ground Thermal Sensor

is sustained as long as the bottle is being elevated. Likewise, if the bottle is lowered slowly, a sustained slow flow into the bottle occurs. The amount of air that flows in or out while raising or lowering the bottle to ceiling height is very miniscule. It would make a soap bubble just a little bit larger than a drop of fog! However, this sensor not only can tell the direction of flow, but it also puts out a signal that is proportional to the rate of flow. The complete thermal sniffer is simply a gadget that measures the rate of flow in and out of such a bottle and converts it into an audio signal coming out of a radio receiver which you stick in your pocket as you fly your glider. Some of us have used earphones. They are a necessity if anybody is flying a power ship nearby. But when you are out on a slope with nothing but gliders, you can hear the receiver quite well even if it's setting on the ground aside of you.

To detect the very small rates of air flow, some special aerodynamic conditions must be developed in the sensor. In Fig. 2, we have sketched the principles of the sensor. It consists of two very small thermistor beads mounted one in back of the other in a tube. The size of the tube must be correctly chosen so that the flow through it is smooth and laminar. The thermistor beads are connected in a Wheatstone bridge circuit and enough current is passed through them to heat them to about 30 to 40 degrees F above the temperature of the ambient air. As sketched in Fig. 2, if air is flowing from left to right, then the thermistor on the left is directly in the air stream. Thus the air rams against this thermistor and flows around it. The tube is sized so that smooth laminar flow results at the bead station. This laminar flow separates off of the left bead near its maximum diameter. The right hand thermistor is thus sitting in the wake formed from the left hand thermistor. The velocity of air flow in the wake is much slower than it is across the face of the front thermistor. Thus the left thermistor is cooled by the air scrubbing around its front surface, but the right hand thermistor is not cooled nearly so much. This unequal cooling results in a positive voltage being developed between points C and D of the Wheatstone bridge. As long as there is flow from left to right, a positive voltage continues to be generated. If the flow rate increases, the amount of voltage increases. If the flow stops, the voltage difference disappears.

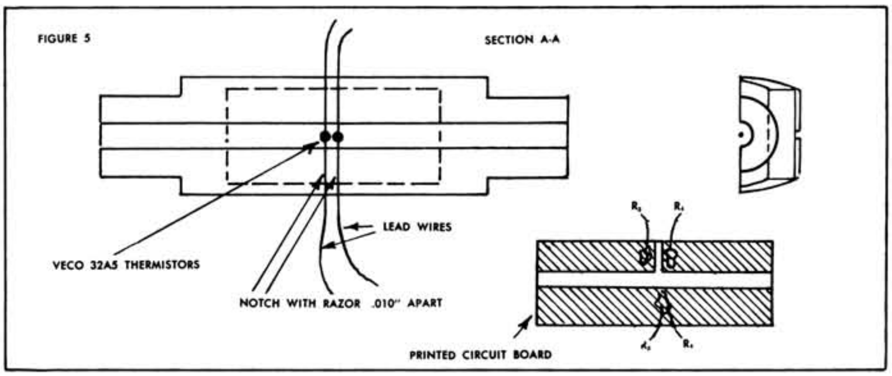
Exactly the opposite happens in the bridge circuit if the air flow goes from right to left. In this case, a negative voltage appears between C and D. How about that? No moving parts! Simplicity is a wonderful thing.

It is only necessary to (a) connect this sensor to a suitable air bottle, (b) to amplify the voltage signal and (c) convert it into a variable tone that modulates a small transmitter carried in the glider. Then with a receiver on the ground, you hear it squeal and groan in proportion to how fast the glider is going up or down. That's the complete setup. And it is fun! You will be amazed at what you can learn about thermals. Perhaps in a future article we will give you some of our theories about thermals that we've developed as a result of using this device. It's pretty evident that the oft published pictures of rising bubbles and columns don't tell the whole story.

The construction of the sensor is described in sequence with Figures 4, 5, 6 and 7. The thermistors employed are VECO 32A5 available from Newark Electronics. You should select a pair that have reasonably close resistance to each other when they are heated to operating temperature. How to do this? First you had best buy several spare thermistors, as they are very small and delicate. They are about .010" in diameter and have lead wires that are thinner than a human hair. Some people call them "fly specks." To get a suitable pair, measure the resistance of each unit by hooking it in series with a 1K potentiometer and 4 nicad batteries (4.8V). Adjust the pot until 2 ma is flowing and then measure the voltage drop across the thermistor. (Don't exceed 10 ma or blooey!) The thermistor must be protected from convective air currents in your shop while doing this. The easiest way to do this is to cover it with an inverted foam coffee cup while making the voltage measurement. You will have to build a small circuit board to mount the thermistors and bring suitable leads out from under the cup while measuring current and voltage. Record the observed voltage drop for each unit and mark it on its container. When you are finished, pick a pair having the most identical voltage drops at 2 ma current. It is not necessary that the resistances of the two thermistors be exactly matched. The device will work reasonably well even if they are 20% different. However, it works better if they are within 2 to 5% of each other.

The circuit for converting the sensor voltage into an audio tone for modulation as shown in Fig. 9. Inspection shows this to be a differential amplifier connected to a voltage controlled unijunction oscillator with suitable amplification to provide a low impedance source for modulation. Point x is the modulation output.

From this circuit, you may take an appropriate route to get a RF transmitter and receiver for telemetering. We have employed crystal controlled transmitters very similar to those used in model transmitters for the 6 meter amateur band. Typically we run these around 51 mc to stay away from the ham communications activity on the low end of the band. Our transmitters have been run at a maximum of 4.8 volts so that a common battery may be used for both the sensor audio circuit and the RF. Typically, we put out a maximum of 10 milliwatts of power, and with better receivers, 5 milliwatts has been found adequate. For a receiver, we have found that the Transistorized police band receiver sold by Radio Shack is quite suitable. This is intended to tune from about 46 to 50 megacycles, but we have found it will tune in up to 51.5 mc without any modification. Superhet model control receivers have also been used by modifying them to power a speaker. We



Make a small piece of circuit board with three copper lands on it. This can be done by slicing copper with razor blade and peeling away center copper. Glue PC chip to a flat face cut in back half of dowel piece. Notch the center face of the dowel with a razor blade at two places, .010" apart. Lay the resistor beads with lead wires in the notches. Coat notch area with clear dope to hold wires in place. When dry, solder lead wires to lands. Check with ohmeter for continuity. Note: laying the thermistors is very delicate. You will need a pair of magnifying glasses. See Fig. 6 for help. Thermistors must be directly aside of each other and at center of tube. Thermistors should touch each other.