Down, But Not Out

Are they heavy, expensive and unnecessary

adjoining structures requires some forethought before proceeding. Remember, it must be mounted with the arrow on the unit facing forward and preferably parallel to the plane's line of flight. The rack will be fastened with either rivets or conventional fasteners such as screws, washers and nuts, but not before you incorporate some important bonding procedures.

The ELT's arm/on/off switch must be readily accessible to the pilot through an access panel or inspection plate. On most factory-built planes, a ¾-inch, spring-loaded button similar to those used for a static port unlocks the door to the arm/on/off switch located inside the rear of the fuselage. If your plane has gone down and you are not sure the ELT activated, it's easy to turn on manually. If the tail section of the plane is accessible, depress the button on the access panel, reach inside and throw the toggle switch to the on position. Factory specifications for many ELTs allow for a remote arm/on/off switch as well. Contact the manufacturer to confirm this and to request parts and drawings for the installation,

Effective corrosion control may require the assistance of an experienced avionics technician or mechanic who has some specialized knowledge of the subject. Unfortunately, people with such experience are not as easy to find as you might think. But without proper corrosion prevention, you can encounter problems with your ELT ranging from poor transmission to corrosion and even lightning damage.

Because the effectiveness of an ELT depends to a large degree on its antenna and its low impedance to the aircraft structure, the same bonding procedures used in sealing the rack installation must be also applied when attaching the antenna to the fuselage. In addition to a poor impedance path, the capacitive effect of gaskets, corrosion or any other nonconductive dielectric films will cause inefficient antenna operation. Because they usually cause more problems than the good for which they were intended, gaskets and paint are often removed as a good way to increase the potential for a better RF bond. Spacer-type gaskets are recommended only if you should encounter irregular fuselage contours or antenna bases, and then only if bonding washers that reach through the gasket to the airframe are provided.

ELT antennas are located often within the dorsal fin of an aircraft, which is RF-invisible and reasonably well protected from the weather, but if it is located elsewhere, in a more hostile environment, special precautions are necessary. To ensure the efficiency of your ELT antenna, the same procedures used to install communication and navigation antennas should be used. An important rule to remember: Locate the antenna as far as possible from other antennas to prevent interference and loss of efficiency.

Because an ELT operates on only one frequency, it requires nothing more than the small whip antenna normally supplied with the transmitter. In spite of its simplicity and inexpensive looks, the whip is quite efficient and does not need to be replaced because of mere cosmetic or aesthetic appeal.

To get the most from the antenna, it must be joined as smoothly as possible to the aircraft fuselage. If an antenna comes with a gasket already attached to the base, remove it and bond the antenna directly to the airframe. But first, remove the surface published a document (AN 05-10-24) that specifies the airspeed that will be generated by a given water column. A little mathematical manipulation and interpolation gives us an amazingly simple formula:

Airspeed in mph = square root of (inches of water times 1980.0).

Thus, for a column of water 5 inches high, the airspeed indicator should read 100 mph. For an indication of water pressure versus airspeed, see Table 1.

The formula, by the way, was optimized for 100 mph and there will be minor errors as you proceed up and down from this value. For example, at 70 mph, the actual value from AN 05-10-24 gives 2.35 inches, or an error of about −1.5 mph. Similarly, at 150 mph, the error is about +2 mph. If you demand split-hair accuracy, I refer you to the table below that gives the value direct from the government publication.

The problem now resolves itself into finding a way of achieving a water column of the desired height. The way I chose to do it was to go down to my local hardware store and buy a few feet of clear plastic tubing of an inside diameter that made a snug fit onto the airspeed indicator pitot port fitting. That same hardware store gives out wooden rulers that I used to make the inch-meter.

Bend that plastic tubing into a U-shape and lash it securely to the wooden ruler. Fill the U-tube part-way up the ruler to a known starting point, then connect one end of the U-tube to the pitot port fitting. Fill the open end of the tube with water so that the *difference* in the height of the water columns is one of your calibration points. Keep increasing the height differential until you have calibrated the ASI at as many points as you choose.

Write down the indicated airspeed (read on your ASI) versus the calibrated airspeed (determined from the pressure-differential chart) about every 10 mph and you have an accurate calibration chart for use in your aircraft.

That pretty much does it for the project. Normally at this time, I launch into the song and dance that Radio Systems Technology [*author Jim Weir's Grass Valley, California, kit avionics company —Ed.*] will sell you a parts kit for this project for only $399 and two Cessna parts boxtops. Unfortunately, RST is not in the hardware business, so I suggest you find all these parts locally.

Some fine points— I almost always use red food coloring in the water so that I can clearly see the height difference between the columns. The ultimate California snob will use Gamay Beaujolais instead of water (with the usual −1.345% wine-correction factor). A drop of dishwashing detergent in the water acts as a wetting solution and makes the meniscus (curved surface of the top of the water column) a bit flatter. I use an eyedropper (or a turkey baster for large tubing) for my water filler, but you can use anything you choose.

There is no reason not to use the same setup to test the ASI installed in an airplane; the only thing you have to do is to make the plastic tubing fit over the pitot tube. It is also true that if you fill the tubing to a given airspeed and the airspeed slowly bleeds down, there is a leak in your pitot plumbing or your test setup. The sharp A&P now sees that with a rubber suction cup and a little work, he can make a calibrated static port tester for IFR tests.

Caution: Make certain you never get the level of the water above the pitot fitting, or you might just as well start pricing a new airspeed indicator. □

Data from AN 05-10-24

Speed knots	Pressure inches of water
50	1.63
60	2.35
70	3.21
80	4.19
90	5.31
100	6.56
110	7.95
120	9.48
130	11.14
140	12.94
150	14.87
160	16.95
170	19.17
180	21.54
190	24.05
200	26.71
210	29.51
220	32.47
230	35.58
240	38.84
250	42.27

Table 1. Water Pressure vs. Airspeed.

Airspeed mph	Airspeed knots	Inches water	PSI pressure
50	43	1.26	0.042
70	60	2.47	0.084
90	77	4.09	0.139
110	95	6.11	0.207
130	112	8.53	0.290
150	129	11.4	0.388

How to Calibrate Instruments

With some effort, every pilot can own a panelful of accurate instruments.

124
,25

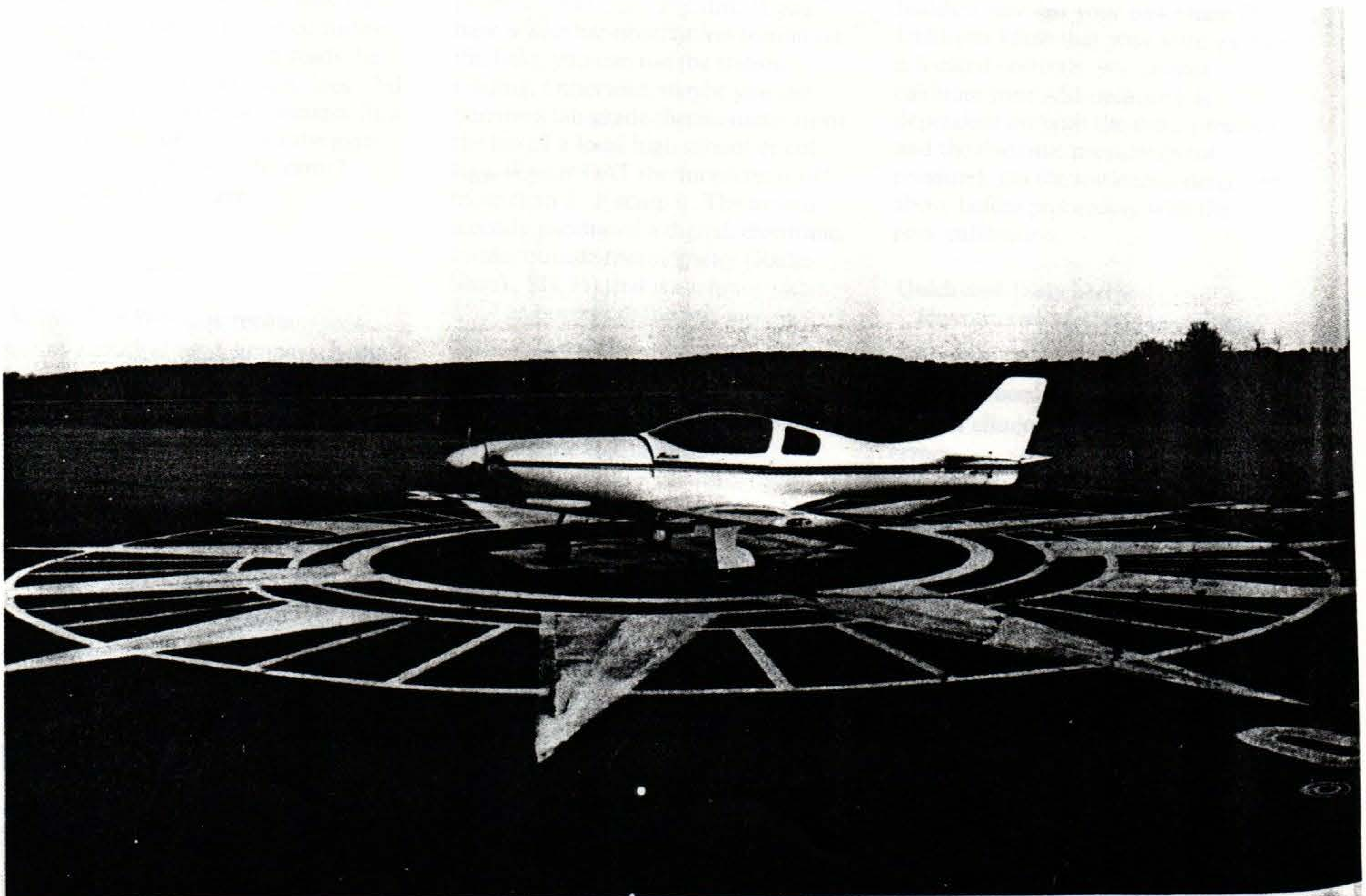
BY TOM WILLIAMS

Flight instruments that give wrong readings can be worse than no instruments at all, especially if the errors are unknown. And if the unknown error is great enough, it can be deadly. An airspeed indicator, new or yellow-tagged and accurate on the bench, may not be even close to correct after installed.

Those of us who build our own aircraft pick up instruments from many sources. Some have been bench-tested, others have not. But no matter where or how we come by our instruments, no matter how expensive they were, the accuracy of many instruments is dependent on the installation. An airspeed indicator's accuracy is more a function of the pitot and static installation than the instrument. So it is with a magnetic compass. Even the cheapest compass is more accurate than the most expensive one that is subjected to local magnetic fields.

Electric engine instruments are notoriously inaccurate, regardless of what make. In a nutshell, you cannot count on the accuracy of even the best instruments installed in a new aircraft until they have been calibrated in that installation. Inaccurate engine-temperature instruments can ruin or severely shorten the life of your engine. An inaccurate instrument can be worse than no instrument at all, and it might endanger your life.

If you are building an experimental aircraft and have a lackadaisical attitude about safety, then skip this article and may God be your copilot! By the same token, if you are one of those perfectionists who insist on absolute accuracy, this article is not for you either. But for the rest of us who want the safety of reasonable accuracy without spending more to calibrate your instruments than you did to buy them, read on!



Swinging a compass and correcting or noting errors can be a time-consuming effort. But especially for the cross-country pilot, the results can be worth the work.

The instruments most likely to be inaccurate and most likely to cause us problems due to this inaccuracy are altimeter, airspeed indicator (ASI), cylinder-head temperature (CHT), oil temperature, outside air temperature (OAT) and magnetic compass.

The average homebuilt airplane is likely to need all of these instruments. To the novice, selection becomes the first problem. Select an altimeter that you believe is accurate, a new one or a yellow-tagged instrument. The airspeed indicator is an inherently simple and accurate instrument if in good condition. Select a new or yellow-tagged instrument.

Most of us will purchase electric temperature instruments both for their size, simplicity of installation and cost. Even the best ones are probably not going to please you with their accuracy but, when calibrated, even the economy models will do the job well enough.

If you have any extra money to spend on instruments, I suggest you consider a vertical-card compass. The non-TSO one (same accuracy as the most expensive one) is less than $200, and that's only about $100 more than a wet compass with all of its problems. Although the east/west turning error is the same as with the wet compass, the overshoot is less and it reads the same way the gyro compass does. Did you ever read your mag compass, finding it 10° left of south, set the gyro 10° left of south for a 20° error? Many good pilots have.

Altimeter

The altimeter that reads correctly on the ground and has no internal problems will read right in the air only if the static line does not introduce an error. That is very easy to verify. After checking that the static line is not clogged, has no leaks and is connected to the altimeter, go to a flat airport. With the engine off, read the altimeter. Rev up the engine and note any change in reading (assumes static line is in propwash). If there *is* any change, move the static-tube inlet position. Note the reading at takeoff. There should be no change. These two simple checks are sufficient. Buzzing the top of a radio tower also works but can be very dangerous and is probably illegal as well. A bad location of the static port will cause inaccurate airspeed, rate of climb and altimeter readings.

Outside Air Temperature

Knowing the outside air temperature is essential to the ASI calibration. Calibration of the OAT is indeed simple, but there are some pitfalls to avoid. Make sure the OAT probe and dial are not in direct sunlight and insure that nothing is touching the probe such as bugs and dirt. If you have a weather-observation station on the field, you can use the station reading. Otherwise, maybe you can borrow a lab-grade thermometer from the lab of a local high school or college. If your OAT thermometer is off more than 3° F scrap it. The author recently purchased a digital, electronic, inside/outside thermometer (Radio Shack, $14.95) that is accurate within 2°. The outside probe was mounted inside a NACA cabin inlet air duct. Neat, attractive, no drag and effective.

Engine Temperature Instruments

Electric temperature instruments are subject to two errors that may be additive or may cancel out. One method of calibrating these is simple and accurate enough for most purposes. Place a coffee can of motor oil on a hot plate and put a candy thermometer in the oil, keeping the bottom of the thermometer off the bottom of the can. Remove the CHT sensor and the oil temperature sensor from the engine. A good ground is very important. Turn on the master switch and start heating the oil. Record the readings from 150° to 300° on the oil temp and from 150° to 600° on the CHT. If the error is excessive, you may want to complain, buy new senders and/or instruments, do your own instrument repairs or whatever is right for you.

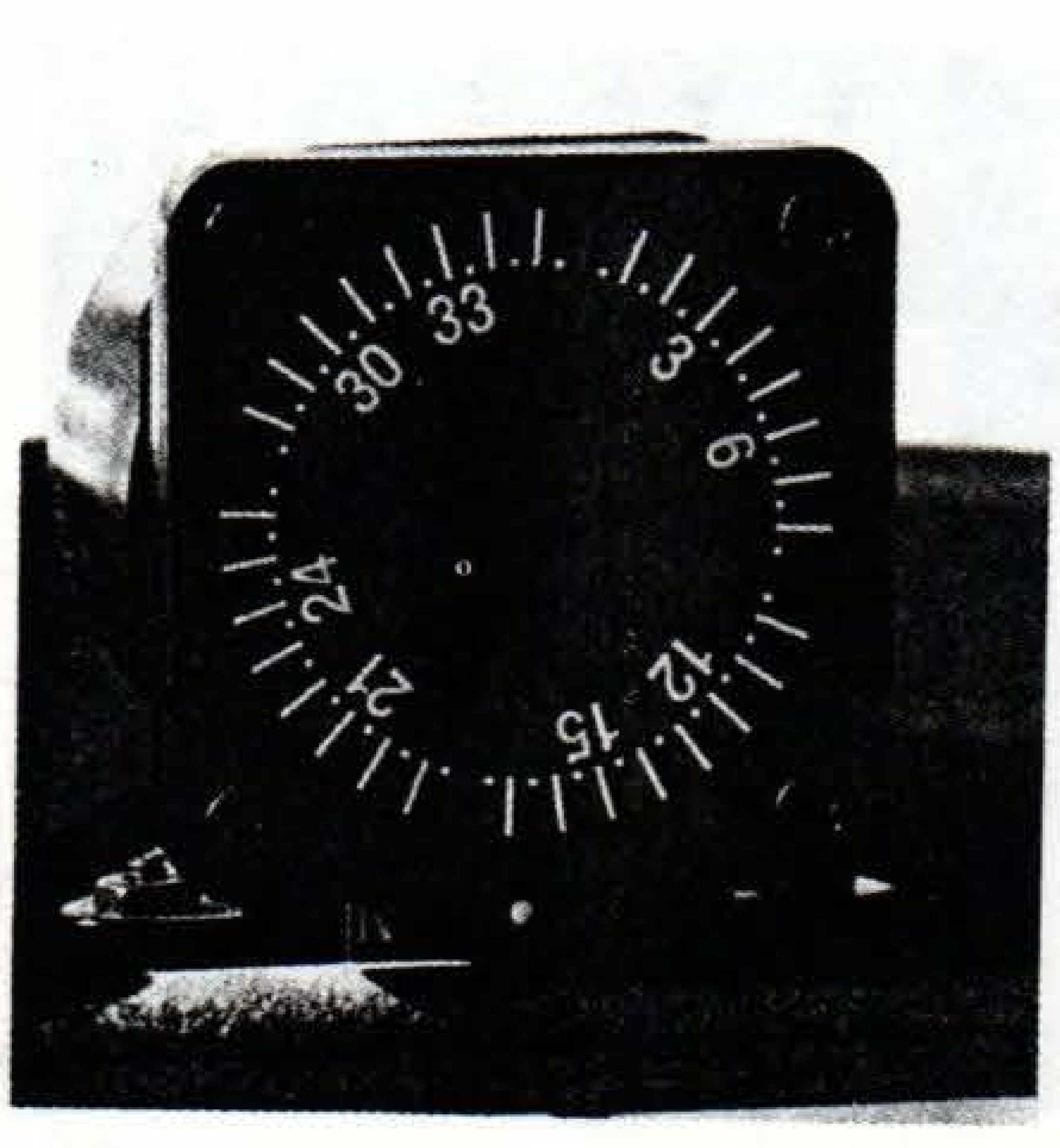
Airspeed Indicator

Airspeed indicators should be calibrated for many reasons, not the least of which is to make sure you are telling the truth when you tell your buddies how fast your new plane flies. Until you know that your static pickup is located correctly, you cannot calibrate your ASI because it is dependent on both the static pressure and the dynamic pressure (pitot pressure). Do the static tests described above before proceeding with the pitot calibration.

Quick-and-Dirty Method

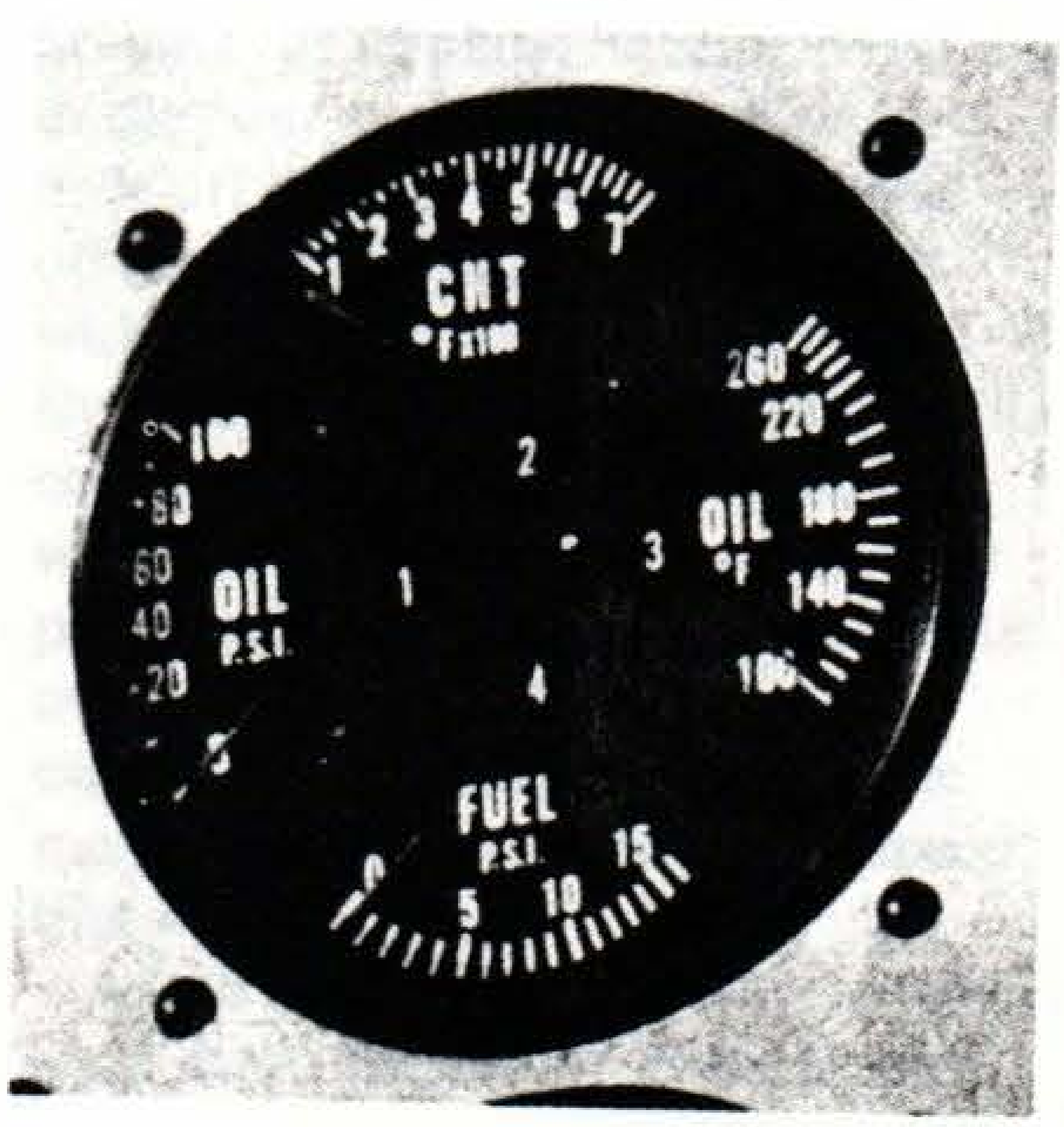
Here are two methods to calibrate

Author Tom Williams recommends use of a vertical-card compass. Some errors are less than with a standard wet compass, and they are easier to read correctly.

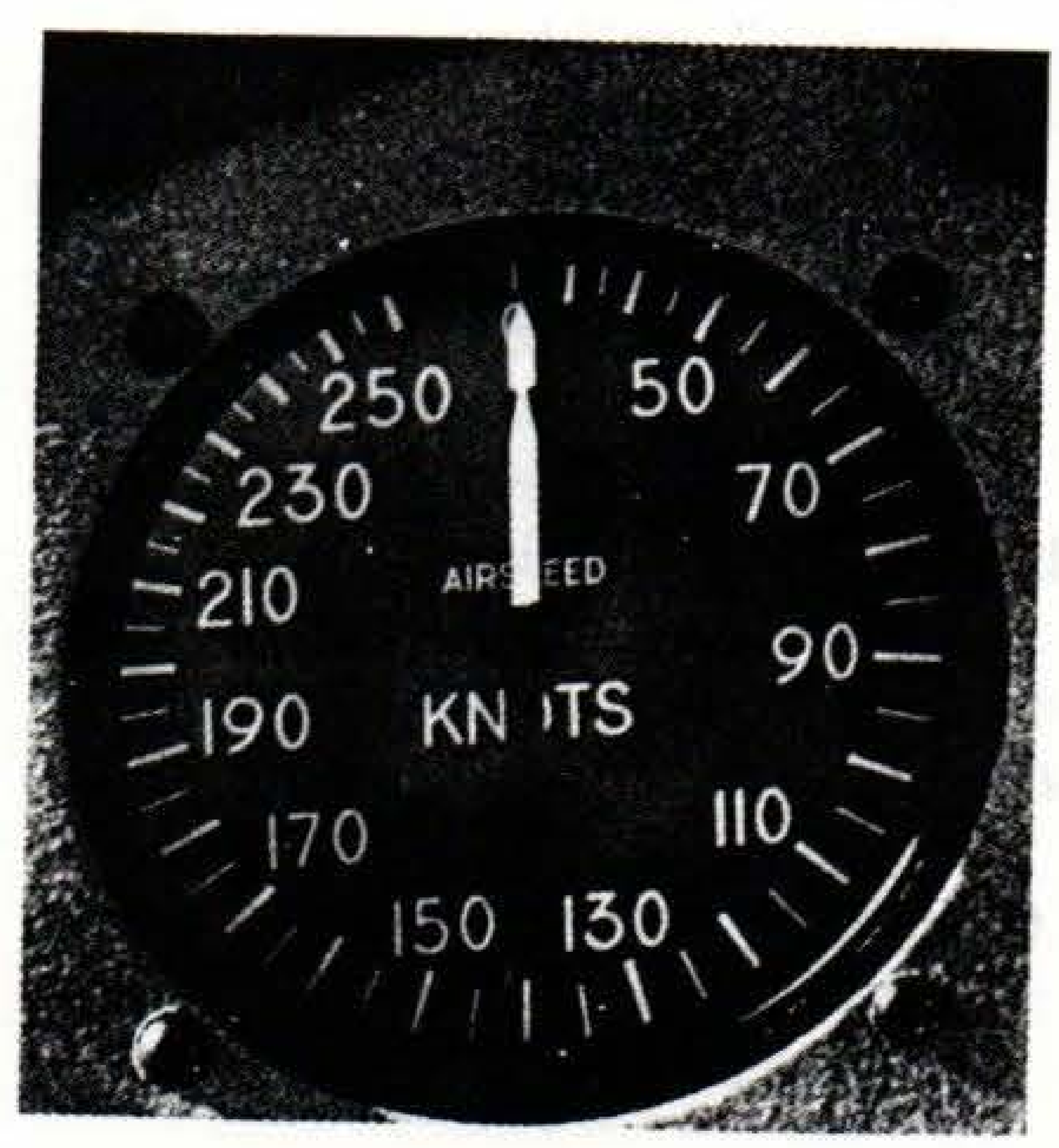


Photos: Tom Williams

Both cylinder head- and oil-temperature gauges can be calibrated using fairly simple techniques.



Various procedures can greatly reduce or even eliminate airspeed indicator errors.



Vur airspeed indicator. The first is quick and dirty. It will get you in the ball park (within 5 knots), but is really not accurate enough for navigational purposes. You must have a loran C installed and working and be in a very good signal area. It should be noted, however, that loran receivers tend to lose their signals during turns and time to stabilize must be allowed after each turn.

The first premise in ASI calibration is that true airspeed (TAS) is equal to groundspeed when the wind component is eliminated. This can be done by flying four legs on the four cardinal headings (north, south, east and west) and averaging the ground speeds. It's that simple. Set the altimeter to 29.92 inches. Climb to an altitude where the air is very stable. A good choice is 7500 feet because 75% power is available at full throttle on a normally aspirated engine. Open the throttle wide open and fly *level* on a north heading. When all has stabilized, read your IAS, OAT, pressure altitude (altimeter set at 29.92) and loran groundspeed. Repeat this on the other cardinal headings.

Using a navigation computer, calculate the TAS. It should be the same on all four headings. Average the four groundspeed readings. The average groundspeed is the corrected TAS. Working backwards on the computer, calculate the CAS (calibrated airspeed). CAS - IAS = Correction.

Williams recommends using a $14.95 Micronta indoor/outdoor thermometer from Radio Shack. It is switchable for Celsius or Fahrenheit.

Accurate Method

To do the job right involves the most work of all the calibrations in this article, but it is also the most fun and rewarding. It is a flying exercise and is best accomplished with a passenger, although I have done it solo more than once.

The first step is to pick a flight course. The course should be about six miles long for a 200 mph craft or three miles for a 100 mph plane—about a two-minute run. The course must be perpendicular to the wind. Ideally the wind would be calm. I did this in California's Mojave Desert along a north/south freeway with a westerly wind and in South Carolina along and east/west railroad with a slight northerly wind. The course must be straight, easy to see, and perpendicular to the wind. The length need not be exactly three or six miles, so long as you know its length exactly, but it should be terminated on each end with a road or something crossing it perpendicular to the course. Once the course is picked, measure it on a sectional chart in statute or nautical miles commensurate with mph or knots on your ASI. (Instrument pilots use knots and nautical miles, and once you get used to these units, you'll never use statute miles in the air again.) If you have a copilot, give him the stopwatch so you can concentrate on the heading and altitude.

The accuracy of the calibration procedure depends on the ability of the pilot to hold altitude within 20 feet and heading within 5°. Select an altitude of 100 to 500 feet. Set the altimeter to 29.92. *Do not use the local altimeter setting*. The timing should be sighted off a wing, and the time should be recorded to within one second. The runs are to be made in 5-knot or 5-mph increments from pattern speed to top speed. *Do not crab into the wind*. Make each run holding the airplane heading parallel to the course, allowing the plane to drift off course. If you have a wind off your left wing, you would start with the course off your right wing. By holding the heading the plane will end up with the course off your left wing having drifted to the right. The plane will have gone a longer distance over the ground but will have gone exactly course-distance through the mass of moving air, and it is airspeed that we are after.

Make the run up the course, then back down the course, twice at each airspeed. Example: at 90 knots IAS, run south, then north, then south, then north. Set up at 95 knots and make two more runs each way, and so on. When you change airspeeds, retrim as necessary and allow the plane to settle down before you make the runs. Make standard-rate turns smoothly and hold the altitude at all times. The altimeter should be set at 29.92 regardless of the barometric pressure. Having a timer on board really helps the pilot concentrate on his heading, altitude and speed. On each run record the time, IAS, altitude and OAT.

After all the runs have been completed, average the four runs at each airspeed. This is done by adding the numbers and dividing by 4. Then using your E6B or electronic navigation computer, calculate the true airspeed for these average runs. Since your distance traveled through the air on each run is equal to the length of the course, the groundspeed is equal to the airspeed and any difference is the instrument/pitot error. Average the times for the four runs at each IAS by adding the times and dividing the total by 4. Convert the seconds to fractions and minutes by dividing the seconds by 60. Example: 2:15 (2 minutes 15 seconds) = 2 + 15/60 = 2.25 minutes. Use the following formula to find the groundspeed: 60 × D/T = GS. Example: course length = 6.40 miles, average time = 2:15 D = 6.4 T = 2.25 GS = 60 × 6.4/2.25 = 170.67 mph (or knots if distance is in nautical miles).

Make a table and record for each set of runs the average IAS, GS and error. Make a graph with IAS along the bottom and error up the side. Plot all the points and draw a line between the points. Draw a second line, missing some or all of the points as necessary to make the line smooth. Don't be surprised if the line is flat or nearly so. Do be surprised if the line goes from negative to positive or even if it forms a hill or valley. If the line is not nearly straight and nearly flat, you probably have bad data or a defective calculator. Some airplanes change angle of attack considerably with speed changes. This can cause a curved line. Airplanes like a Cessna 152, which can slow to 60 and go all-out to 100, are likely to have a flat curve with that narrow speed range. But a Lancair, which can fly from a speed of 70 mph to a top speed of over 225 and require as much as 8° of negative

THE FASTEST, EASIEST AND MOST ACCURATE WAY TO ADJUST A COMPASS

By SYL HEUMANN
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Hillsborough, CA 94010

There is no mystery to adjusting a magnetic compass. The only things needed are a non-magnetic screwdriver and maybe some masking tape. No compass rose, no pelorus, no special equipment. Just follow the instructions below. These adjustments should be made away from any hangar buildings or other possible sources of magnetism. They should also be made with the engine running at enough rpm to ensure that the voltages are at cruising levels, and with all radios and normal electrical equipment turned on. If the airplane has a canopy, it should be closed.

It is important in the following steps that the 180 degree turn be done as precisely as possible. If you have a gyro, use it. If not, mark left and right wing shadows with tape on the ground, and make the turns using the shadow. If this is the case, be aware that the sun moves 1/4 degree each minute.

1. Go north (or south) by the magnetic compass.
2. Zero the gyro (unslaved) or put masking tape on the ground.
3. Do a 180 degree turn by the gyro or shadow.
4. Halve the compass error using the N-S adjustment screw (non-magnetic screwdriver).
5. Repeat steps 1 through 4 until there is no error.
6. Go east (or west) by the compass.
7. Zero the gyro - or use tape.
8. Do a 180 degree turn by the gyro or tape.
9. Halve the error using the E-W adjustment screw.
10. Repeat steps 6-9 until there is no error.

Now, go north by the compass and zero the gyro if necessary. Make turns of 15 degrees by the gyro and note any errors on the magnetic compass. These errors should be recorded for the compass correction card.

The compass is now adjusted as accurately as it can be without changing external factors. Never change the adjustments except when on a N-S or E-W heading, and then only the proper screw. It is not possible to adjust headings other than the cardinal ones without upsetting the entire adjustment of the compass.

If these adjustments won't correct the compass on N-S and/or E-W headings, then something in the airplane is amiss. You will have to research whether the problem is with the airframe, under the panel, or elsewhere. There is a strong magnetic field lurking in there someplace.

Don't even try to adjust your compass using an airport compass rose because of the difficulty of aligning the airplane accurately. The method outlined above will produce better results in a fraction of the time!

Now, why does this method work? It's easy. Look at Figure 1. The magnetic disturbance in the airplane is to the right of the compass so the compass has a clockwise error. Figure 2 shows that in doing a 180 degree turn, the disturbance is now on the left of the compass and it now has a counter-clockwise error. This explanation is for the N-S errors, but applies equally well to the E-W ones.

If the compass is adjusted so that when you do an exact 180 degree turn by the gyro or shadow, and the magnetic compass also makes a 180 degree turn, then all of the magnetic forces or disturbances inside the airplane must be balanced on both sides of the compass. The adjusting of the N-S screw made the compass think that there was an equal and opposite force on the other side of the airplane (see Figure 3). The magnetic compass is now acted upon only by forces outside the airplane - and that force is the earth's magnetic field.

Now you can go and check the compass rose at your airport. If it doesn't agree with your compass, then the compass rose is probably wrong! ◆

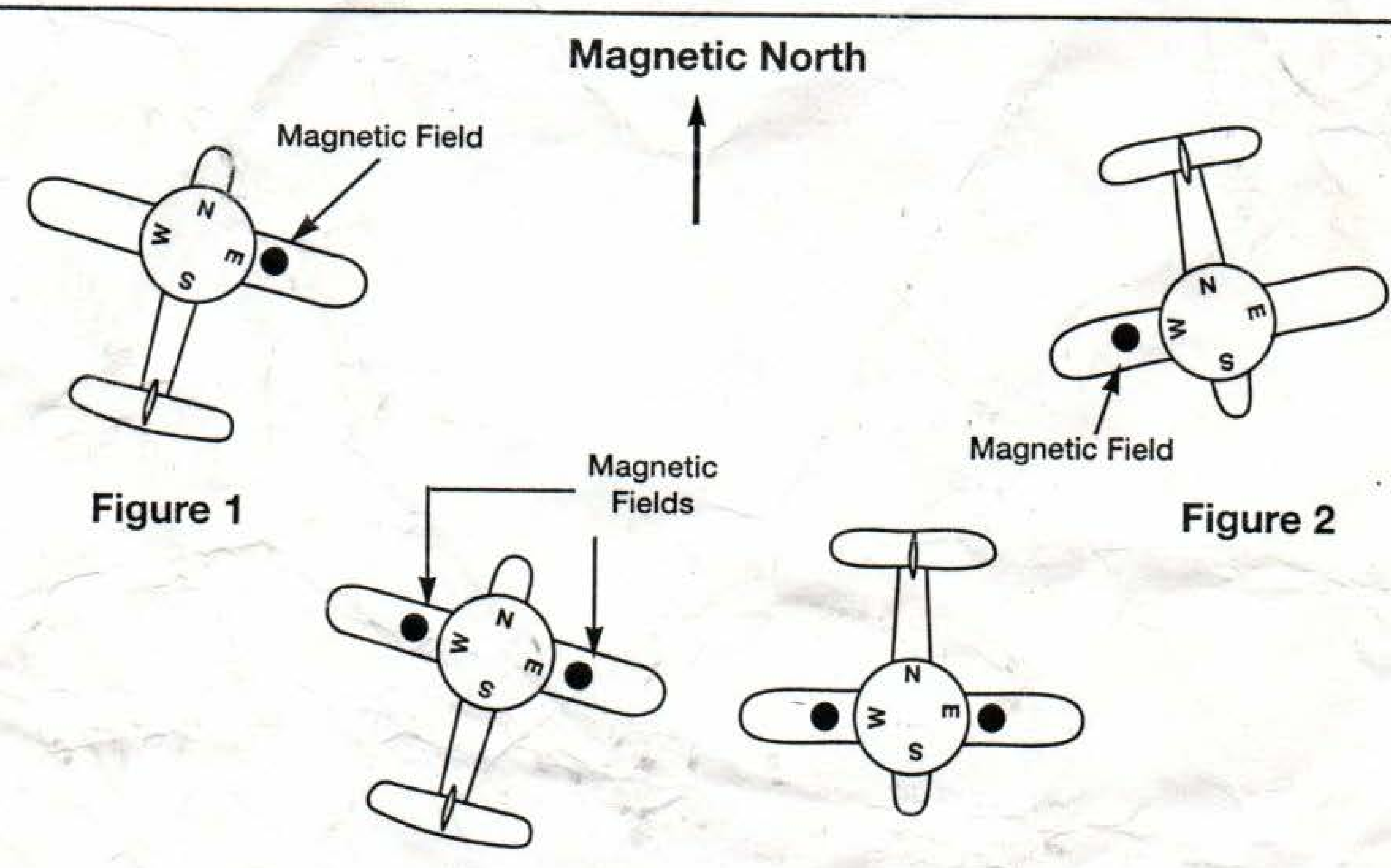
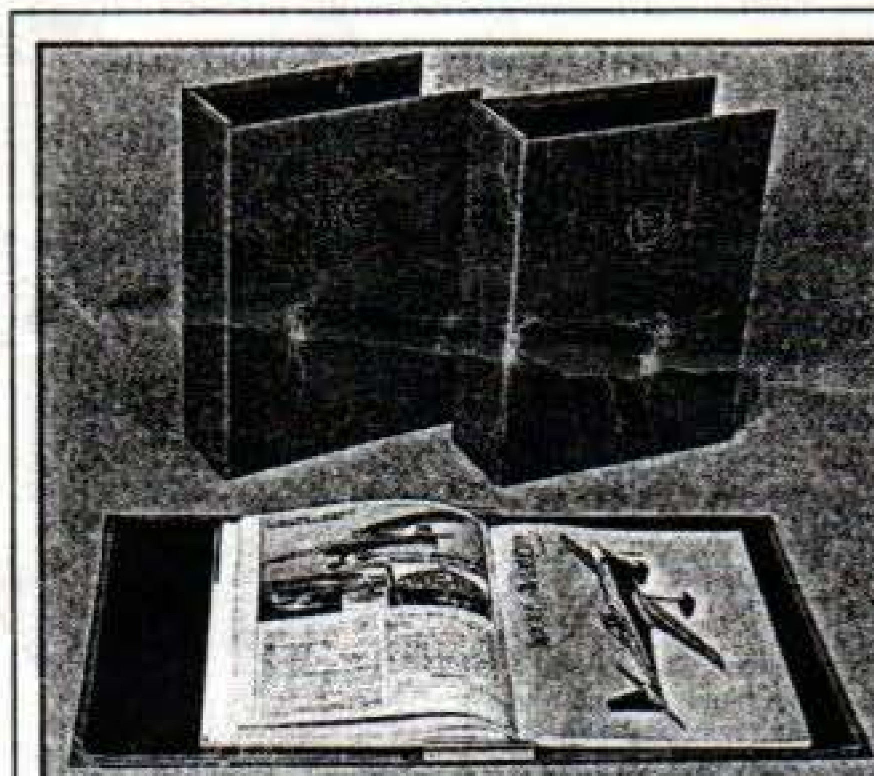


Figure 1

Figure 2

Figure 3



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Installing a Navcom

We put a KX 125 navcom where it belongs—in an aircraft —and find that it works well.

BY T.E. GILLAND

Last month, we described in some detail Bendix/King's KX 125 navcom. We installed it in an airplane and evaluated the results. In short, it performed better than advertised. This month we conclude with some details of the testing and installation tips that apply to avionics in general.

Because my home is under an air traffic corridor between San Francisco and several eastern ports of call, it's an ideal site for monitoring IFR frequencies. Using an old magnetic mount, I improvised a listening antenna for the Bendix/King KX 125 navcom described last month and used the roof of my car for a ground plane. Clear and crisp reception of the heavies flying overhead made every syllable distinct.

Airborne Checks

Later, with the help of several friends, we conducted an evaluation of this neat package in its element: along the airways. To give proper credit to all concerned requires listing many members of two local organizations: EAA Chapter 376 in Fresno and the Madera Amateur Radio Club. I would like to acknowledge by name all who contributed, but a space problem precludes it.

Three generous owners offered their airplanes for in-flight tests and, after resolving minor problems with schedules, the one I used is a Cessna 150. As the owner is a ham radio enthusiast, his airplane has a 2-meter amateur radio aboard, making his airplane an ideal platform. Another participating ham has a sophisticated communications receiver with an accurate signal strength meter in his shack, which is near the Madera airport where we conducted this review.

Despite my temporary wiring harness and somewhat primitive chassis mounting, the KX 125 performed like a champ. My friend on the ground

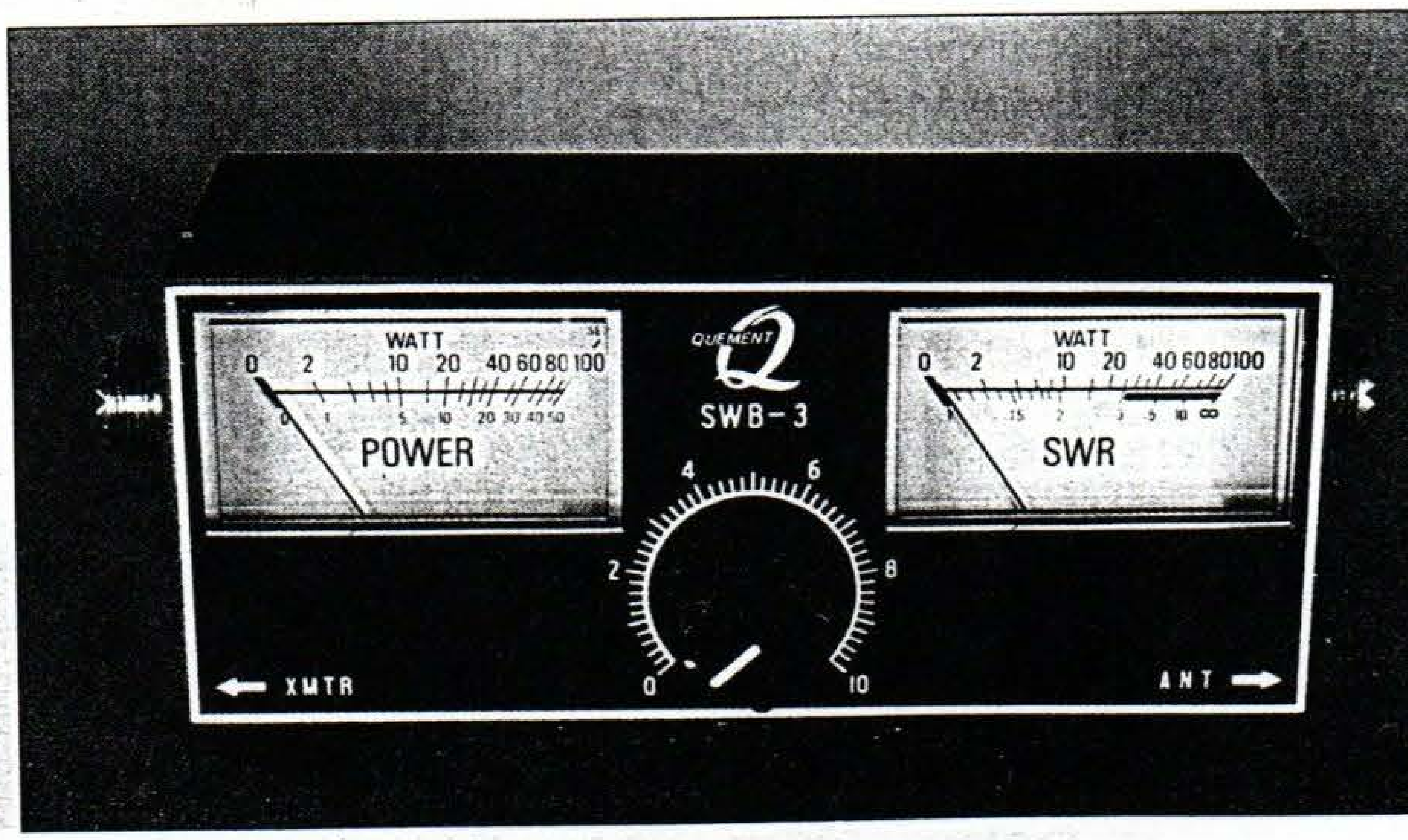

Photo 1. A simple SWR meter checks the efficiency of an antenna installation.

PHOTOS: T.E. GILLAND

monitored our transmissions while we made medium banked 360° turns about 30 miles away, and using ham vernacular, he reported a 59 signal on all headings (no blind spots detected). The first digit reports readability on a scale from 1 to 5 and the second one translates signal strength on a scale from 1 to 9. A strong, perfectly readable signal prompted a flattering comment from the ground station on 2 meters, "Hi-Q (for quality), communications-grade copy." During the same transmissions, I noted a reading of slightly more than 7 watts on the power meter installed for the occasion. Bendix/King factory specifications may be a bit conservative.

We flew a triangular course of about 150 miles checking navigational features with three VORTAC stations and known landmarks for references. After the flight I used my notes, a sectional chart and a Weems plotter to check accuracy of OBS numbers. I found no discrepancy, suggesting that the VOR course accuracy limit listed for the KX 125 is another conservative specification.

Tweaking the knobs and punching the buttons allowed me to try the various features. Everything worked as the book says it should and as I outlined last month. With the transmitter tuned to an unused frequency, I tried the Stuck Microphone Alert feature. Any pilot who misses that distinctive warning needs refresher training—or something.

Localizer operation is the only feature we did not try. Monitoring traffic at the nearest airport with ILS, we noted several arriving and departing air carriers, plus Air National Guard jets. Prospects of maneuvering a C-150 in that congestion, and a possibility of turbulence on the runway, seemed like a frivolous adventure at the time, so we changed our minds about landing there.

Installation Tips

Electronic and communications technologies invariably produce a cloud of mysticism that, in the eyes of many, associates avionics with the occult. Homebuilders face many limitations concerning the goodies inside a black box, but they have considerable latitude when connecting that box into an integrated system. Perhaps the most predominant enigma is antennas and transmission lines, which are generally coaxial cable (called coax). Several good books clarify these alien subjects, and I have included a few recommendations for your technical library at the end of this article.

Installing radios and tuning stringed musical instruments have much in common. Unfortunately we cannot tune to each operating frequency in radio work like a musician tunes each of several strings on a guitar. Doing so requires a separate antenna for each frequency and, because the com radio alone operates on 760 frequencies, an antenna for each one seems ominous. Clearly, an airplane bristling with that many antennas would be an aerodynamicist's nightmare. Fortunately, aircraft antennas and feed systems are broadbanded enough to perform within limits throughout the range of operation when tuned to the center frequency. For the KX 125, those frequencies are: com = 127.4875 MHz, and nav = 112.975 MHz.

Musicians have the advantage of working with audio frequencies: something they can hear. Radio frequencies, on the other hand, are beyond audio range, so we must rely on dimensions and electronic instruments to harmonize.

One dimension that frequently comes up in antenna work is *wavelength.* A simple definition states, "One wavelength is the distance a radio signal travels in free space during one cycle of operation."

Visualizing an alternating current sine wave contributes to an understanding; the horizontal measurement of one cycle is one wavelength. Radio waves travel at lower velocities in an earth environment, making wavelengths shorter—through a conductor, for example. Standard practice in the industry uses a correction factor of 5% for approximations, producing results accurate enough for practical radio work; practitioners call this a *fudge factor.*

Several of the references include equations for determining wavelength, so I'll just give dimensions applicable to the KX 125. Computed for center frequencies, and taking the fudge factor into consideration, the physical (not electrical) wavelength dimensions are: com = 87.93 inches, and nav = 99.23 inches. Standard practice rounds these numbers off at two decimal places. An average installation requires physical dimensions only; finding electrical dimensions requires instruments.

Installations of antennas on (or in) airplanes present unique problems, making these vehicles the most difficult for mobile communications systems. Resulting from much research, development and experimentation, two general types of antennas evolved in avionics because they are the best compromise, with convenience and efficiency the prime considerations.

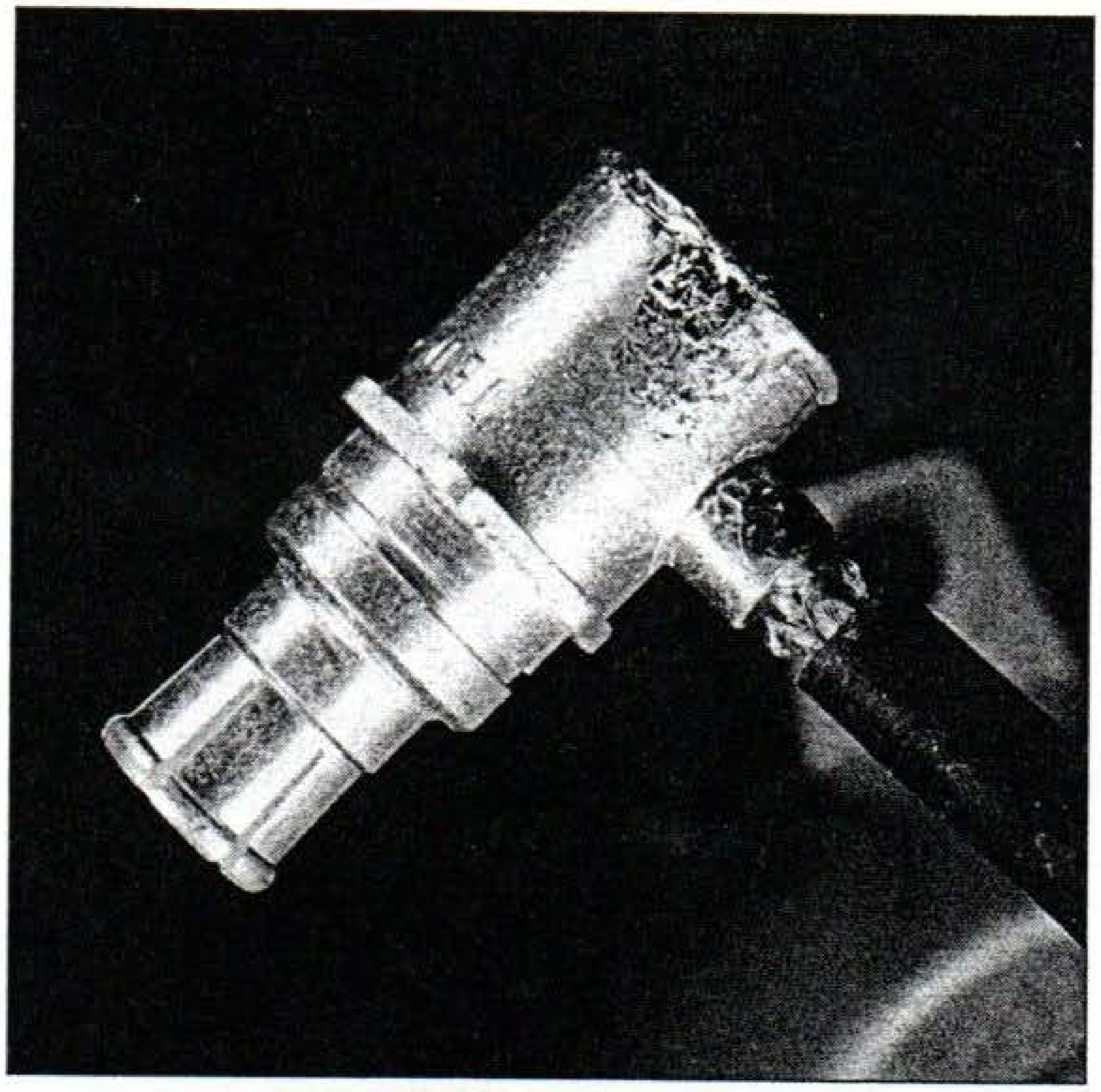

Photo 2. A coax elbow fitting eliminates the need to bend coax severely behind the panel.

First, the dipole, or two-element antenna, which is sometimes called a *Hertz antenna* in honor of the inventor. VOR receiving antennas exemplify this type. Second is the vertical—or whip antenna—that requires a ground plane (or radiating surface at the base), explaining another frequent expression: *ground plane antennas*. Another name, *Marconi Antenna,* also honors the inventor, and this type prevails in aircraft com systems. Development of both types took place around the turn of the century, and fundamental principles remain valid despite advances in communications technologies.

In aircraft systems, most dipole types became known as *half-wave antennas* because of the total length; two elements of one quarter wavelength each totals one half wavelength.

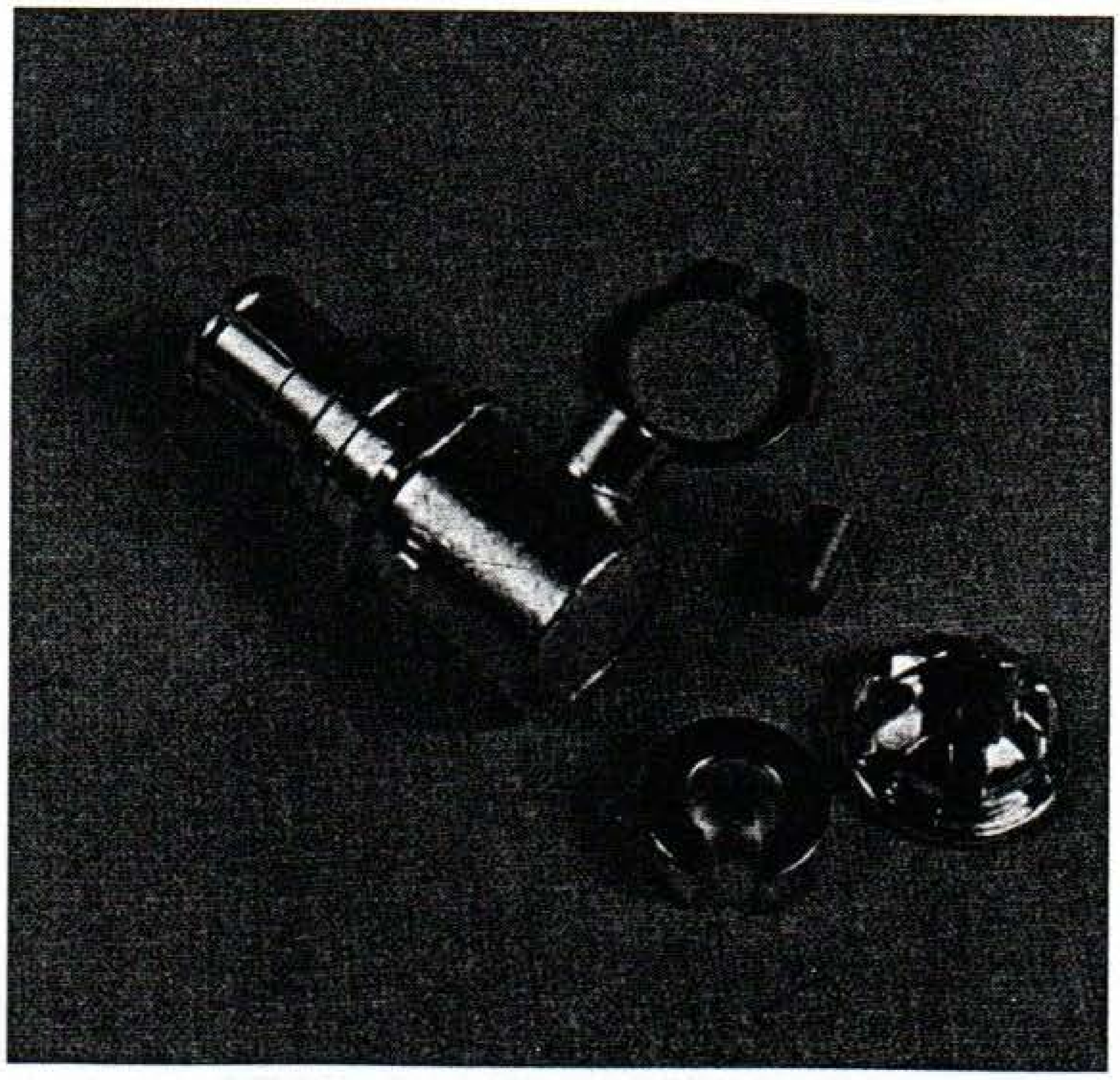

Photo 3. A coax elbow kit includes these parts.

Spacing between the elements is a critical dimension; anything more than half an inch vilifies the antenna's performance. Commercially manufactured antennas have elements cut to electrical dimensions, instead of physical, and present a 50-ohm balanced load. Coax, on the other hand, is an unbalanced load; therefore, a device called a *balun* (meaning balanced to unbalanced) matches the feed line to the antenna. Most commercial antennas with baluns have them sealed into the assembly.

Most vertical antennas used in airplanes have a single quarter-wave element and require a ground plane to complete a half-wave system. Thinking of the ground plane as a reflecting surface, like a mirror, helps to understand the Marconi principle. A radiating element looking into the mirror thinks it sees another quarter-wave element extending straight through the base, like a dipole. Ground plane antennas present a 50-ohm unbalanced load, eliminating the need for baluns.

Obviously, a proper ground plane is critical when installing vertical antennas. Outer skin on sheet metal airplanes makes an ideal surface providing that electrical connections are good; paint, for example, destroys electrical integrity. Tube and fabric airplanes require a ground plane inside the structure at the antenna base, usually a piece of aluminum sheet cut 18 inches square (324 square inches).

Composite airplanes made a profound impact on homebuilding, and antenna installations in these airplanes is a controversial subject. On one side of the issue, critics argue that modern streamlined antennas (mounted outside) offer superior communications efficiency, which compensates for the small aerodynamic trade-off. But another group claims that antennas mounted inside wood and fiberglass (not carbon fiber) airplanes offer the same electrical efficiency, providing the design and installation conform to established conventions.

RADIOS

continued

Jim Weir, a renowned electronic engineer, ham radio buff and homebuilder's pundit, is a staunch supporter of the second group. In 1975, the Bellanca Aircraft Company needed a complete IFR antenna package concealed in the Viking's wood wing; Weir's designs solved the problems. Perhaps his most famous accomplishment is the *Voyager*'s antennas, which contributed to the record-setting flight around the world without refueling. Who can argue with success?

Weir has another talent: He is a prolific author who wrote several magazine articles on the subject of hidden antennas. Now for the best news: Radio Systems Technology, Inc. (RST)—the company that Weir started and later sold—has compiled these articles into a brochure, which RST sells (see Reference 3). Although these articles are of primary interest to those building composite or wood airplanes, sections on antenna basics contain good information for any homebuilder. One section regarding loran receivers is especially informative.

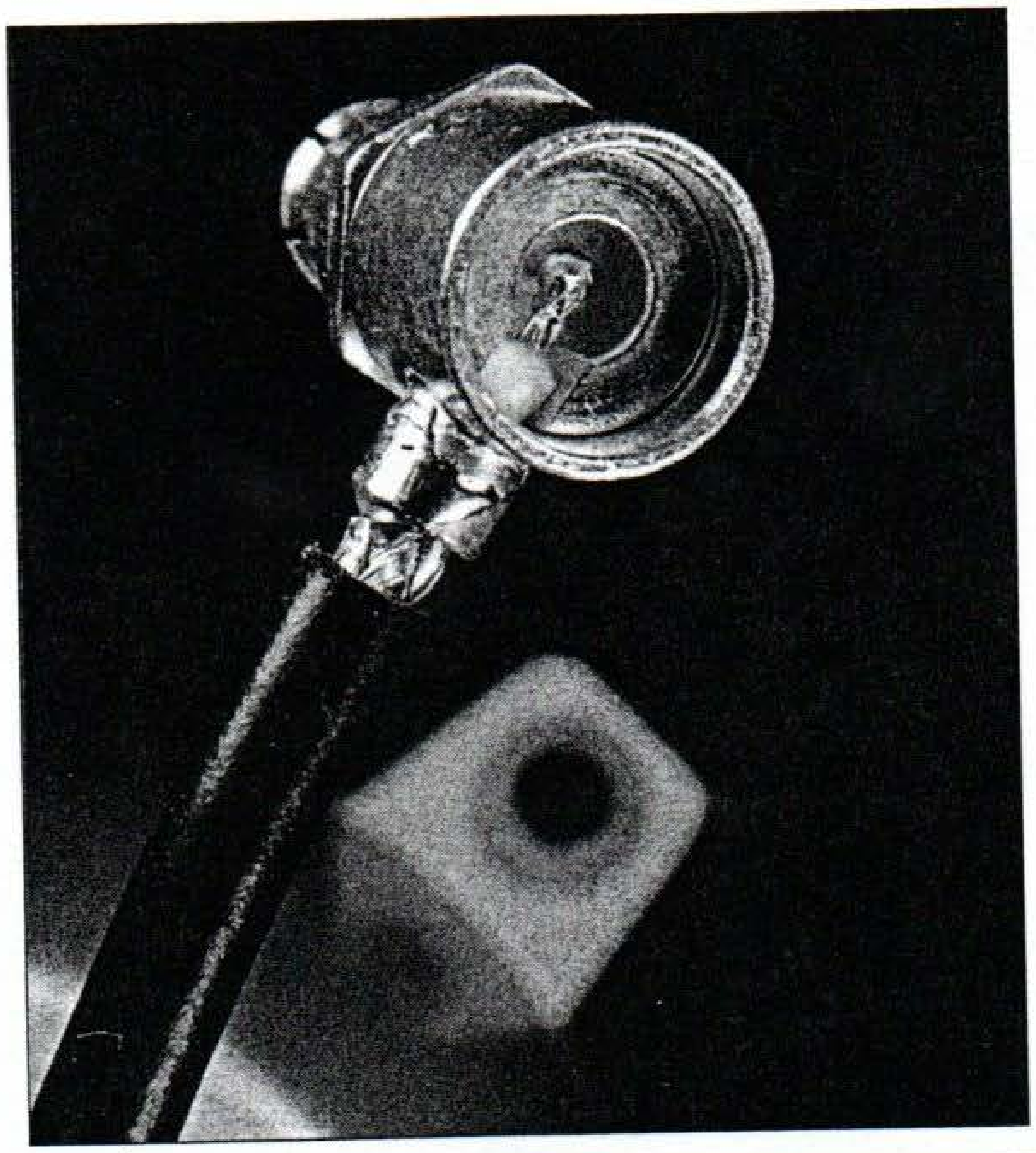

Photo 4. Before its end cap is attached, the assembled 90° coax elbow looks like this.

Novices who install antennas generally use a coax feed line just long enough to reach from the radio to the antenna. This frequently results in a mismatch that introduces line losses and degrades performance. Cutting the feed line one-half wavelength (or a multiple of it) amounts to tuning the circuit. Suppose, for example, the distance between a KX 125 com radio and the antenna is 10 feet (120 inches). Because one wavelength (87.93 inches) is a tad short, 1.5 wavelengths span the distance with some to spare (87.93 x 1.5 = 131.90 inches); 11.90 inches is left over.

Standard aircraft practice takes up that much slack, slightly less than a foot, by routing the transmission line in a serpentine fashion. I do not recommend coiling coax to take up slack; sometimes this detunes circuits. It's the same principle as failing to depress a guitar string firmly against the finger board. Who needs sour notes in an aircraft communications system?

Those who use a dealer-fabricated harness can specify lengths for coaxial cable. Tell the technician that you want circuits tuned to resonate at the center frequencies. Better yet, take your antennas to the shop and have them tune the entire system; good avionics shops have instruments for doing this electronically. An alternative is to solicit the help of an amateur radio operator who owns a grid dip oscillator (called a dip meter). Most hams enjoy "pruning and tuning" parties and take pride in their work. Perhaps the best part of this suggestion is that tuning takes place on the airplane, which compensates for unforeseen anomalies.

Many technicians scoff at the prac-

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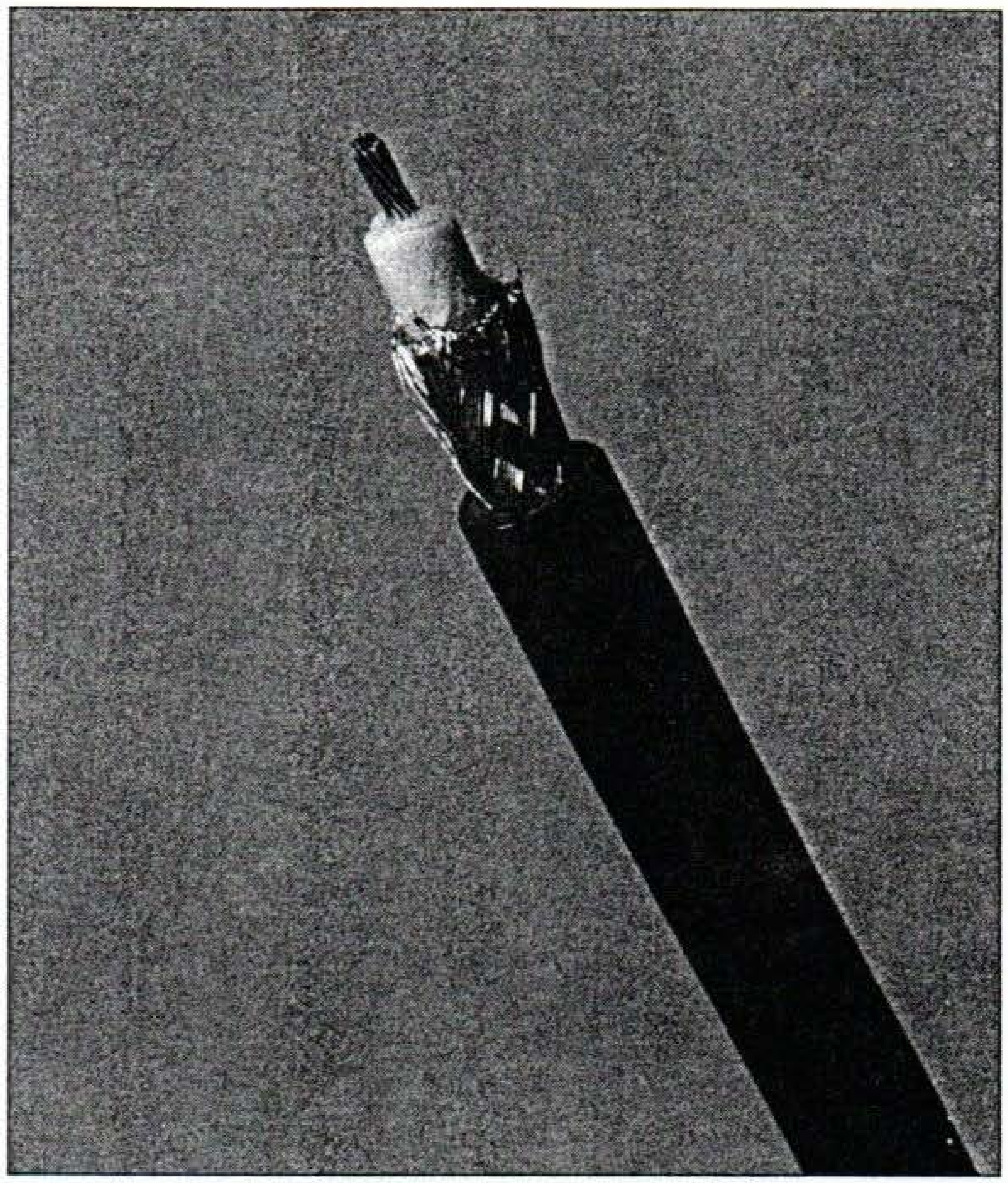

Photo 6. Good coax. Shield coverage is much better.

Industry standards dictate that ground stations radiate vertically polarized signals for communications and horizontally polarized signals for navigation. Therefore, aircraft standards install antennas in the same orientation for maximum efficiency.

Antenna location often makes the difference between good installations and bad ones. Bendix/King recommends separation distances of 6 feet from a DME and 4 feet from an ADF sense antenna. They also specify a minimum of 3 feet of separation between the KX 125, with its wiring harness, and an antenna. Besides equipment interference, any things detune antennas. Predominantly, metallic objects or structures disrupt radiation patterns and absorb energy; carbon fibers have the same effect. Any of these materials within one quarter wavelength of antenna tips deteriorates radio communications.

One of Weir's hidden antennas is a vertically polarized dipole communications type, which is something of a boomer. Yes, I said "boomer," not "bummer," because I have a high regard for dipoles; like many other ham operators, I frequently use this type for globe-circling communications. His design works very well inside vertical fins of some airplanes and winglets of others. They work so well that they captured the attention of other homebuilders.

Several who are building metal airplanes, such as RV-6s, frequently ask about installing one of these antennas inside a fiberglass wingtip and I have two objections. First, polarization of that installation is horizontal, or 90° out of phase with the rest of the world. Second, it's near a metal wing where I think it's physically impossible to have an antenna tip clearance of one quarter wavelength.

Admittedly, I have never installed or tested one of these wingtip antennas but reasoning tells me they exhibit eccentric performance and have weird blind spots. I hope somebody can prove me wrong because, after almost a century, we're past due for something new. Do we have any Hertz- or Marconi-type homebuilders out there?

Feedlines

Working with coax is something new for many homebuilders. Coax is a two-conductor transmission line in which one conductor surrounds the other, explaining the nomenclature *coaxial*. In the most common form, a continuous dielectric keeps the two conductors separated and maintains critical spacing, which determines characteristic impedance.

The outside diameter of the center conductor and inside diameter of the outer conductor are factors in a complex mathematical equation for computing impedance. In practical shop

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work, those computations are not necessary. Just use the type coax specified and handle it carefully. Negligence during shipping, handling and storage probably damages more coax than anything else; kinking makes for a heap of scrap. Careful attention to detail pays dividends when making installations; the minimum radius of a bend is six times the outside diameter of the coax.

Photo 2. Space-saving, 90° elbow coax connectors eliminate the need to make sharp bends in transmission lines behind the panel. This is fairly common hardware in the aircraft industry but is seldom used elsewhere.

Photo 3. Three of the five parts in the installation kit are easily identified. These include the fitting itself, a snap ring and a snap-on cover. A thick horseshoe-shape washer is a 50-ohm load, and a small piece of tubing is an adapter. The adapter is for small coax, which is not used in this installation.

Photo 4. Assembly amounts to slipping the coax into the fitting, with the braided shield inside, and soldering the center conductor. Also, the shield is soldered to the fitting, taking care not to melt the coax's dielectric. Then the 50-ohm load is slipped inside and tamped down; it's a snug fit. All that remains is to install the snap-on cover, solder it in two places and the fitting is ready to fly. See Photo 2.

Photo 5. Coax can be purchased in a variety of grades, and this picture illustrates one extreme. Shown here is a piece of RG-8/U purchased at an electronic supermarket for this article and typifies bargain-basement merchandise. I chose this type because of its size, which is large enough to show photographically what to look for when buying coax.

Skimpy braid used for the outside conductor (appropriately called the shield) identifies this sample for what it is: cheap coax (not discounted bucks but cheap). A careful look at the picture reveals many gaps in the braid; my estimate is only about 60% coverage. (Much greater shield coverage is much better.) Manufacturers who produce this grade coax generally use adulterated, reclaimed material and run their equipment at excessive speeds with little or no regard for quality.

Material used in the center conductor's insulator is another important consideration. Foam predominates the low-grade coax market, and a simple fingernail test identifies its soft and yielding nature. When installed in a hot environment, foam becomes plastic, allowing the conductor to sink toward the shield—playing havoc with characteristic impedance. In extreme cases, like inside aircraft structures on hot days, the foam becomes soft enough for the conductor to slump into the shield, causing an electrical short. This disables receivers and often cooks final stages of transmitters.

Photo 6. From my research of mail order catalogs, I find that most firms catering to homebuilders stock RG-58A/U like the example shown here, which Bendix/King recommends for the KX 125. Full coverage of the shield (96% in this case) is one hallmark of quality; solid polyethylene dielectric is another. Polyvinyl chloride (PVC) is the material used in the jacket of this sample for protection against scuffing. I used the coax pictured here for my review and I can recommend it for an average homebuilt project. This coax is also stocked in many electronic stores; ask for Belden Number 8259.

Despite merits of this coax, there are better grades that some homebuilders may wish to consider. One document in the military sector provides aircraft wiring guidelines that most avionic technicians find useful (see Reference 7). This reference is a road map for the Mil-Spec network, handbooks, technical manuals and technical orders. A customer number, assigned with the first order, makes it easy to use a computerized telephone for ordering additional references.

Summing Up

Evaluating the KX 125 was a fun project and I can recommend this navcom without reservation. Installed and maintained properly, it should give many years of reliable service. Happy homebuilding! ❑

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