Let your imagination soar, and you'll never look at high-flying antennas in the same way again. K9ES and AD4ES reached for the stars with this antenna for the CQ 160 Meter DX Contest this year.

A Balloon-Lifted Full-Wave Antenna for 160 Meters

BY ERIC SMITT*, K9ES, AND CHUCK GREEN**, AD4ES

About a month before the 1998 January CQ 160 Meter DX Contest, Chuck, AD4ES, mentioned to me that he had never been on 160 meters in his almost 40 years of operating. He wondered if I would be able to assist him in developing an antenna that he could use to get in the contest.

Chuck has his station at his office, which is located in Melbourne, Florida. The roof space was sufficient to place a full-wave loop on the roof, but my concern was the effect of the roof on a loop's performance. We both pondered how to raise the antenna at least 25 feet above the roof. We looked at PVC piping, electrical conduit, and inexpensive TV mast. We looked into the push-up poles that were available free from the Wireless Cable. Then I came up with the idea of supporting the corners of a full-wave loop with weather balloons, and getting the loop up 40 feet above the roof. With balloons, why not go up a quarter wavelength?

The idea was born—and died—when we saw all the high-tension lines around his building. We knew we could really run into danger should the balloon drift due to wind and move the antenna into a 40 KV line. A quick look at power distribution lines and public parks gave us our location for operating this contest in a "field day" manner. We selected Pelican Beach Park, in Satellite Beach, Florida.

With this idea now a goal, it was necessary to find information on balloon-lifted antennas. One of the earliest articles on the subject appeared in *QST* in the November 1940 issue. R. Carlton Green, W8PWU,[1] discussed using weather balloons as "sky hooks" for vertical antennas. His article included data on lifting capacities for helium- and hydrogen-filled balloons. While the article is over 50 years old, it still provided some interesting physics about lighter than air devices, and their use as lifting devices for antennas using Litz wire, a common wire used in those days.

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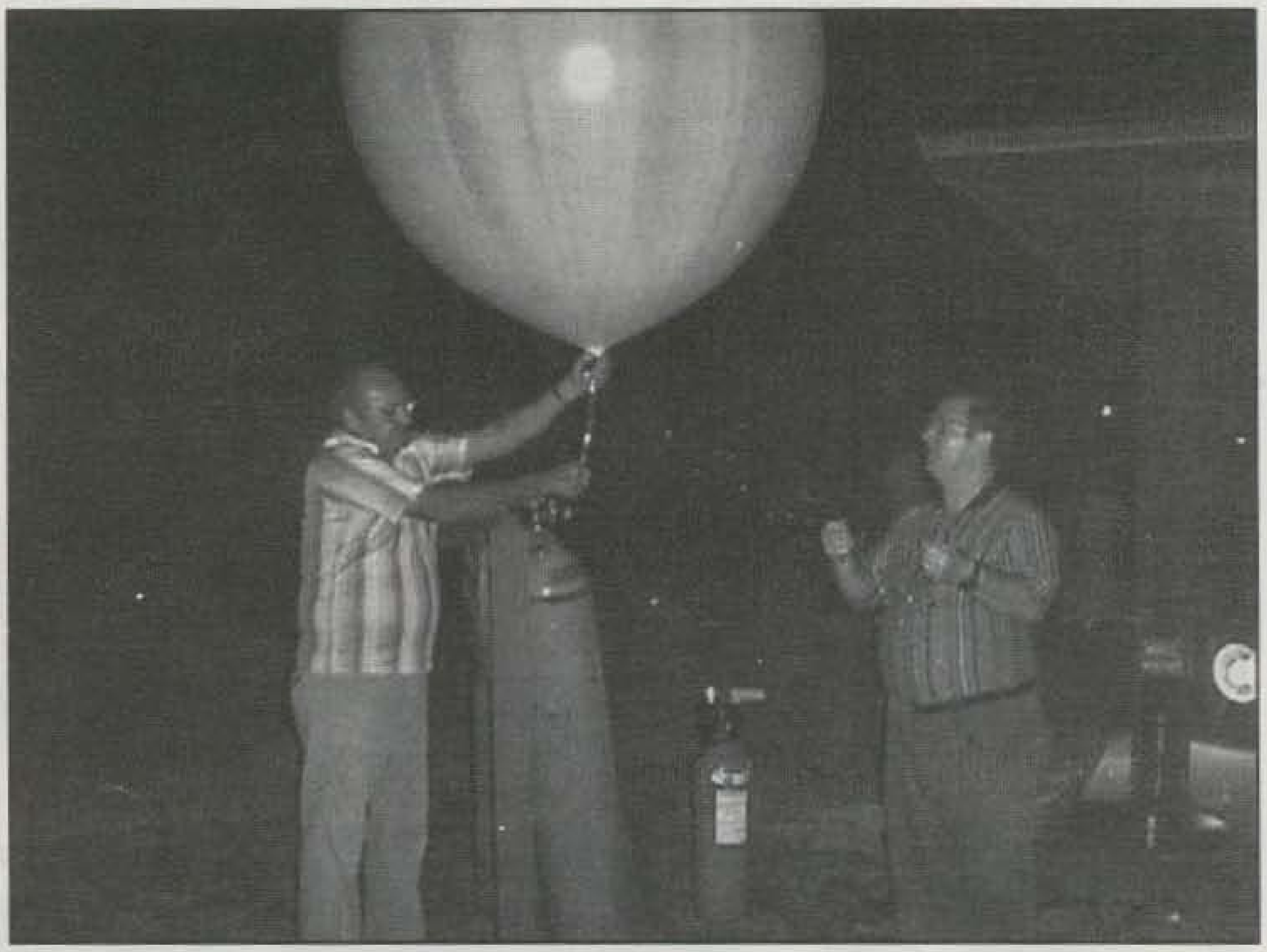

Photo A– AD4ES and KF4RYE are shown here filling the balloon.

A follow-up article, written by David Ferrier, W1LLX, and William Baird, W9RCQ,[2] was the first to mention a device called the Kytoon—a hybrid of a lighter than air balloon shaped aerodynamically to provide lift from the displacement of heavier air with helium or hydrogen, and the aerodynamic lift provided by the airfoil shape. Their article also mentioned the possibilities of using these balloons to lift a long wire. Of interest is the fact that this very support is presently available from Fair Radio Supply[3] as a "Lifting Body" Balloon.

Due to the physical properties of helium, hydrogen was often used as lifting gas. Helium finds the finest pores, even through latex rubber, and leaks out. Helium, in liquid form, will even flow up the side of a dewer flask if left unattended.

Hydrogen is less expensive than helium, but it has a major drawback: It is highly flammable. Hydrogen burns with air in a colorless high-temperature flame, pro-

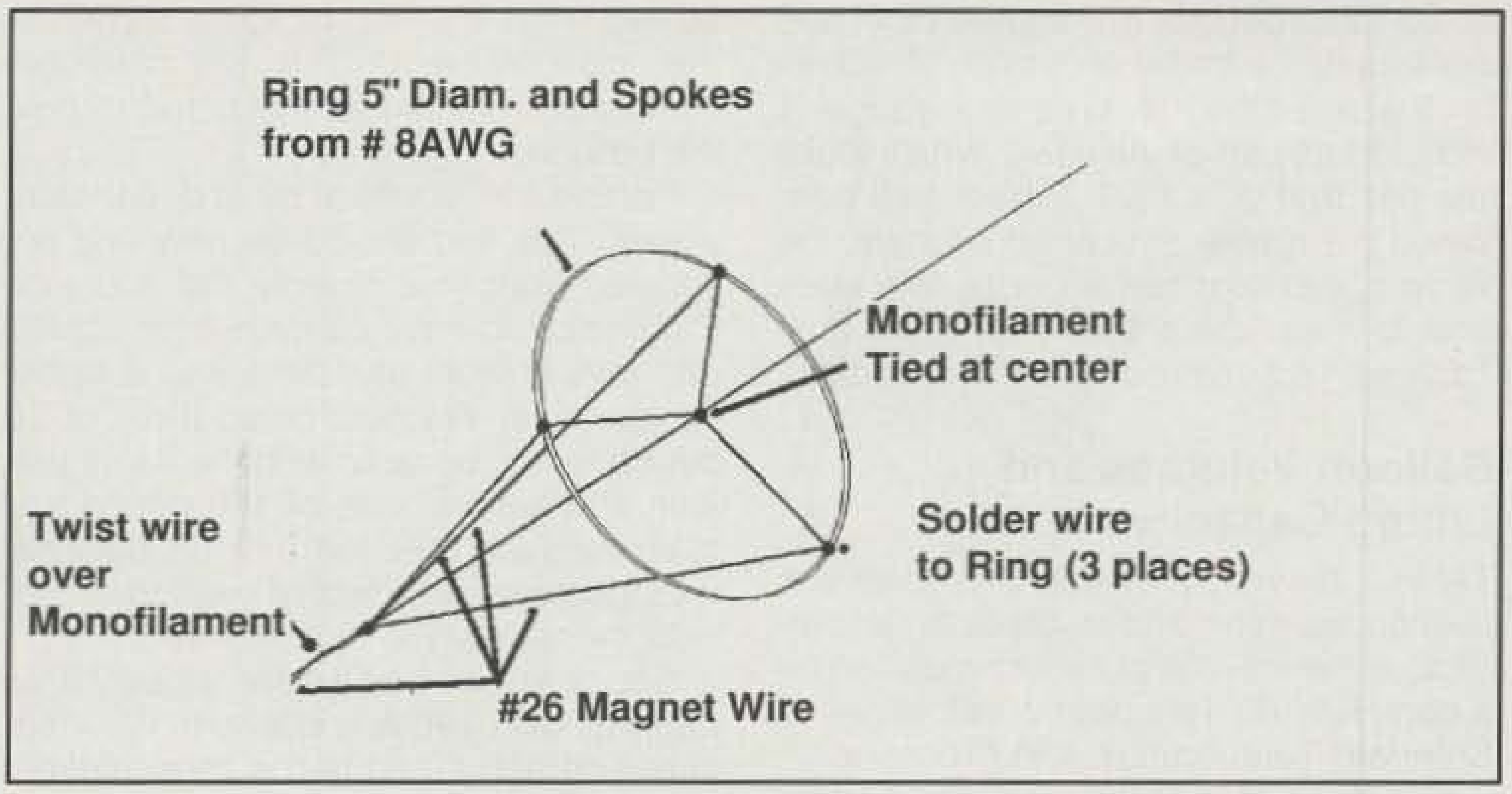

Fig. 1– Corona ring structure.

Diameter (ft.)	Helium Capacity (cu. ft.)	Lift Capacity (lbs.)
2	4.19	0.28
3	6.28	0.42
4	33.51	2.25
5	65.45	4.40
8	268.08	18.00
16	2144.66	144.04

Table I– Lifting capacity for helium-filled balloons.

ducing water. However, it is easily ignited, even by static electricity, and should never be used in a lifting balloon. During World War I, the German Zeppelin proved a major problem for the air war. They traveled rather quickly, with winds aloft and their own power. They could remain aloft longer than the aircraft trying to shoot them down. Because of their huge size, even bullets had difficulty bringing them down. However, once the Allied forces placed white phosphorous tips on their bullets, the Zeppelin became easy prey.

During World War II, the British used tethered balloons to carry antenna wires, and also to provide some form of obstruction for the bombers that were targeting England. These aerostats[4] were special-purpose aerodynamic balloons that maintained tolerable internal pressures by the concept of a balloon within a balloon, or a *ballonet.* At sea level, the balloon chamber was filled with helium (or hydrogen) and the ballonet was pressurized with air, to maintain shape for the aerostat. As the balloon rose, the external atmospheric pressures decreased and the helium naturally expanded. Without additional volume capacity, the expansion could burst the balloon's outer skin. By venting the air within the ballonet, the helium expanded in the volume previously containing ballonet air volume. This allowed operation at higher heights than previously available. If not for the ballonet feature, the aerostat would have burst, as will meteorological balloons, as they soar to altitudes where external atmospheric pressure drops.

Even today, these aerostats are used to carry both military payloads as well as antennas. Lockheed Martin and TCOM currently manufacture and sell them to government agencies and commercial companies. One of the earliest discussions of 160 meter antennas being lifted with Kytoon Balloons comes from the Ohio State University Radio Club (W8LT) experience in the 1975 ARRL 160 Meter Contest, written up in the 160 Meter Contest Results column in *QST.*[5] There are both pictures and text.

Articles have been written on their use as supports for long antennas. In the *ARRL Antenna Compendium Volume 2,* Stan Gibilisco, W1GV,[6] furnishes an overview of balloon-lifted antennas. Don Daso, K4ZA,[7] wrote a rather detailed article about balloon-lifted antennas called "A Skyhook for the 90's." In his article, Don described the operation of what appears to be the CQ 160 Test for N4ZC's contest station. While the article does not mention an actual contest, it does mention specifically a 160 meter quarter-wave vertical. As recently as during this past CQ-160 Meter Contest, several amateurs (including our station) used balloons as supports for long verticals. However, all other applications used quarter-wave verticals, as evident by the discussions about radials.

Design Goals

It was our intent to produce a half- or full-wave antenna. This antenna would have several advantages over a quarter-wave antenna. The first advantage was slight gain over a quarter-wave antenna. A half-wave antenna has a theoretical 3 dB gain over a quarter-wave antenna, and a full-wave vertical has an approximate 4.5 dB gain over a quarter wave.

The second advantage was the absence of a radial system. A half-wave antenna feeds with a high voltage instead of a high current (as found in quarter-wave designs). With the computer modeling program NEC, the antenna displayed an impedance ranging from 1400 ohms to 4500 ohms, depending on how the antenna deviated from vertical (due to wind on the balloon). But the ground path also required the same level of feed impedance. Even an 8 foot ground rod in sandy soil produces a lower resistance than 4500 ohms. Without radials, the antenna design was rather an easy task. However, the physics became interesting.

Another design goal was the requirement to handle at least 1 KW RF output.

Physical Reality

When we attempted to find a balloon to hold the antenna, we tried several paths. The Air Force routinely launches weather balloons at the Cape Canaveral Air Station for range safety information for the Kennedy Space Center. Another amateur in the area (who shall not be mentioned) offered us a meteorological balloon which claimed to have a 5 foot diameter with a 4.5 pound lift capacity.

Edmond Scientific [8] lists Giant Weather Balloons in their catalog. The problem we ran into was one of availability, as the balloon was on back order and would not be available for our effort in the CQ 160 Meter CW Contest. However, we were able to order two of them for the phone contest.

As mentioned earlier, Fair Radio Supply lists their Kytoon. However, it too was on back order and not available when we tried to get a balloon.

Helium is readily available from industrial gas companies, welding supply houses, and party outlets. We were fortunate to have all three sources in Melbourne, and selected an industrial gas supply house, part of Praxair Corporation. Their Industrial Helium comes in tanks that contain 250 cubic feet of helium (called K tanks). These tanks are pressurized to about 2200 pounds per square inch, and are supplied with the necessary fill valves for balloon filling. A pressure gauge is included as part of the valve, which looks like the end of a thick rubber ball pen. When the rubber is pushed laterally, the valve opens and helium exits. We were able to negotiate a $ 50 charge for a K-Tank with a deposit of $ 300 for the tank.

Balloon Volumes and Lifting Capacity

Table I shows the relationship between balloon diameter and lift capacity, and indicates the volume of helium required for a complete fill. This data is calculated at Standard Temperature and Pressure.

Our first balloon was a 5 foot diameter meteorological balloon supplied by the Air Force. This balloon only could lift 4.4 pounds. The second balloon was a an 8 foot balloon by Edmond Scientific, and it had a 18 pound lift capacity. However, it did require an entire K-tank to fill it.

Antenna Design for Low Weight

The goal was to make an antenna that could handle at least 1 KW without destroying itself and that would be less than a pound in weight. Most amateurs use large wire, copper weld, for antennas to prevent stretching and lowering of resonant frequency. Since the small balloon can only lift 4.5 pounds, large, heavy wire was out of the question for use in this design. After looking at wire capacities, we determined that magnet wire, 26 gauge or thinner, would be adequate, since the weight would be less than a half pound. However, this wire has a tendency to stretch, so a reinforcing method had to be devised.

Monofilament fishing line is also very low weight, and has low stretch coefficients if used with forces equal to or less than 20 % of the rated load. To allow wind loading effects as well as the free lift effects to be estimated, Chuck and I determined that the wind load could be as much as five times the free lift force applied to the monofilament. The monofilament could also be used as the tether to hold the balloon.

Fishing line is sold at most department stores. This line should be new and not spooled from your favorite rod and reel. Old line could have damage from ultraviolet rays or from use. New line is rather inexpensive. We purchased a roll of 30 pound test to be used with the 5 foot balloon and several rolls of 100 pound test to be used with the 8 foot balloon. But what was a proper and effective method to connect the wire to the monofilament?

Chuck's office had a clear, straight area that was over 140 feet in length. We measured off and taped to the floor markers every 25 feet, and even marked specific additional length to cover the 509 feet. We purchased a large (and heavy) spool of surplus 26-gauge wire, which weighed over 10 pounds.

At one end of this straight length the monofilament was attached and strung the entire length. Chuck and I then spiraled the magnet wire around the monofilament so that there were two turns per foot. Every 10 feet we secured the wire to the monofilament with light-weight 4 inch nylon tie wraps and cut off the free ends. When a length of 127 feet was completed, the length was rolled up on a large spool, and the process was then continued until four lengths were completed. At the end of the first length of monofilament, a loop was tied in the monofilament to secure the lifting balloon holding the first quarter-wave section from the tuner to 127 feet above the station. The remaining 382 feet of monofilament/wire wrap has no additional loops added. The end was soldered to a 5 inch corona hat (see fig. 1).

The corona hat was made from a 16 inch length of #8 AWG copper, like the kind sold for grounding at hardware stores. We bent the piece in a ring, and soldered the ends together. We then placed it on a table (that we could solder on without damaging it) and cut three more pieces of this wire into $2^1/_2$ inch lengths, which would become the spokes.

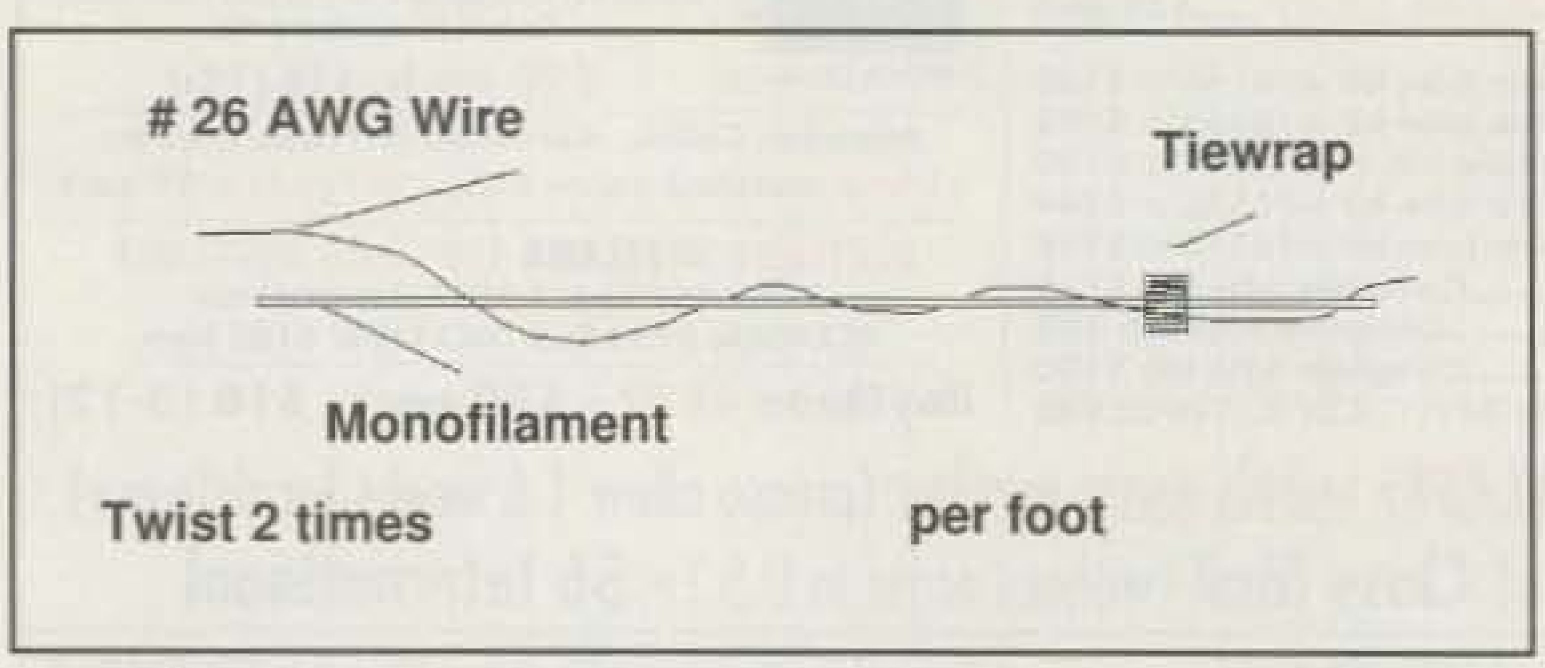

Fig. 2– Securing the wire to the monofilament.

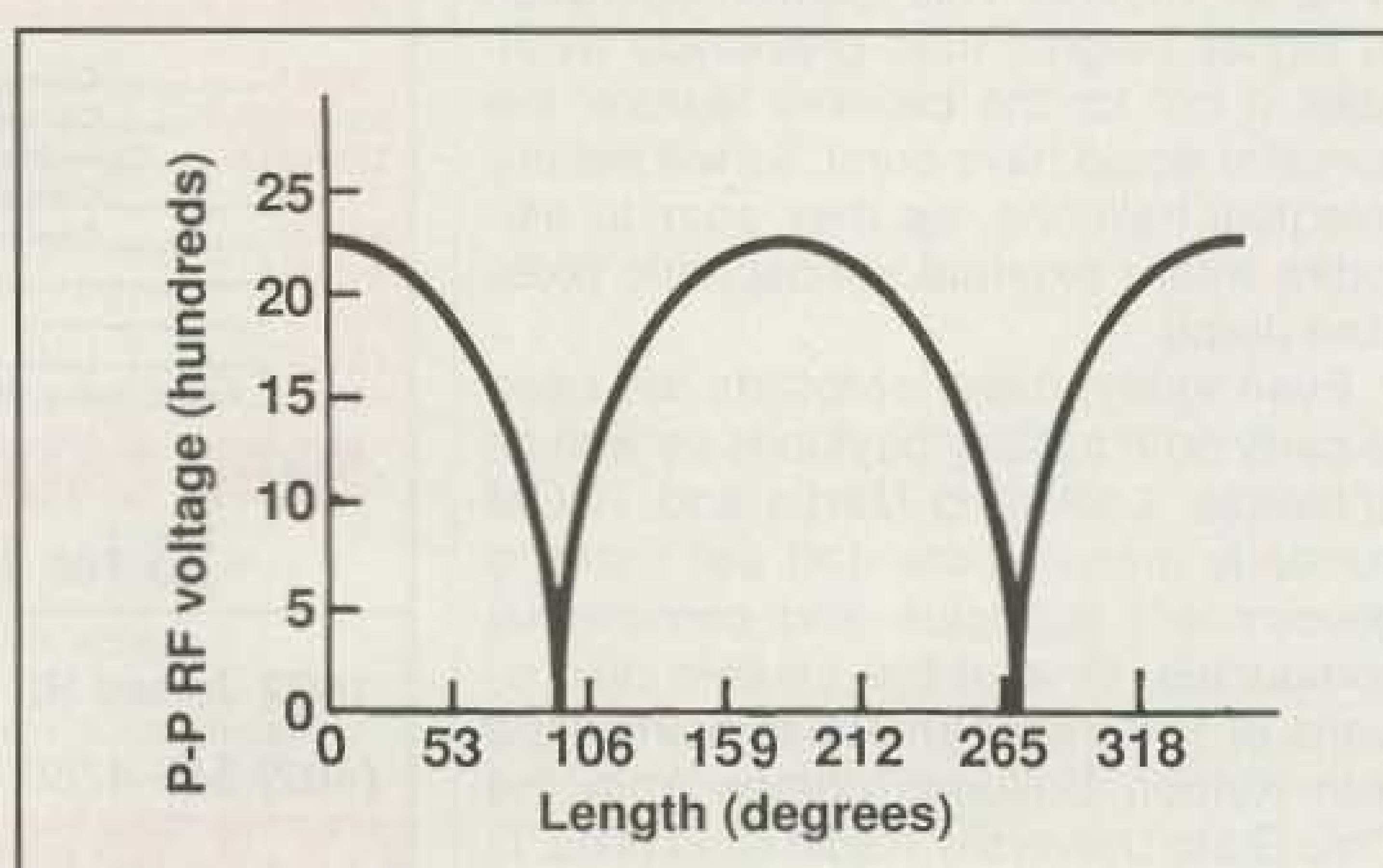

Fig. 3– Voltage distribution on the antenna.

Wire Size	Type	Weight per 600 ft.	Constant Current
30	Solid	0.18	0.3
	Stranded 7 × 38	0.20	0.339
	Stranded 19 × 42	0.22	0.359
28	Solid	0.29	0.48
	Stranded 7 × 36	0.32	0.529
	Stranded 19 × 40	0.33	0.553
26	Solid	0.46	0.77
	Stranded 10 × 36	0.45	0.757
	Stranded 19 × 38	0.55	0.92
	Stranded 7 × 34	0.50	0.841
24	Solid	0.73	1.22
	Stranded 7 × 32	0.82	1.36
	Stranded 10 × 34	0.72	1.2
	Stranded 19 × 36	0.86	1.43
	Stranded 41 × 40	0.70	1.16
22	Solid	1.17	1.95
	Stranded 7 × 30	1.27	2.12
	Stranded 19 × 34	1.37	2.28
	Stranded 26 × 36	1.18	1.97

Table II– Characteristics of small wire. (Information obtained from Belden Wire Technical Information Service.)

We placed them in a "Wye" inside the ring and carefully soldered the center together, and then soldered the ends to the ring at the three points. This became the corona ring.

At the end of the full wavelength antenna wire, we soldered three lengths of #26 AWG magnet wire 1 foot long. We carefully stripped 2 inches from the opposite ends, and wrapped these ends around the corona ring, approximately centered between the points where the spokes were soldered. All soldering to this ring was made so that there were no sharp points, as these would defeat the purpose of this corona hat. Where the end of the antenna (twisted to the monofilament) joined the three 1 foot lengths, we attached this splice to the monofilament with a tie wrap.

Holding the end, we tied the monofilament to the center of the spokes and corona hat, so that under load, the monofilament would absorb the tension, and there would be minimal tension on the wire. We extended the monofilament another 2 feet past the corona hat attachment, and placed a strong loop that would not let go under tension. This point would attach to a line/snap swivel which would come from the balloon assembly.

This corona hat was determined necessary, due to the potential high voltage which would be found at the end of this full-wave antenna. Having a 1 KW (RMS) input, there could be as much as 2300 volts peak to peak RF present on the end. By adding a corona hat, the voltage would be distributed around the perimeter of the corona hat, and not at a point (which would produce sparks).

The entire antenna, with the 100 pound monofilament test, 509 feet of wire, corona hat, and all the tie wraps weighed less than 2 pounds (fig. 2). All of the wire was spooled on a large reel, with the corona hat at the free end.

Antenna Characteristics

A quarter-wave or three-quarter–wave antenna has a low-impedance feed point. A half-wave antenna (or multiple of half-wave antenna) has a high-impedance feed. Fig. 3 indicates the anticipated voltage that could be found along the antenna, assuming that the impedance is 4400 ohms (as indicated by NEC) and being fed with 1KW PEP power.

The current maximums occur at the one-quarter wavelength and three-quarter wavelength point. Assuming the KW PEP power level, the peak currents would be nearly 12 amperes, RMS. The maximum continuous current recommended for the wire is shown (Table II), along with the weight per 600 feet (a little longer than full wave on 160 meters) and type of wire used. This information was obtained from Belden Wire Technical Information Service. The only problem with the current ratings is that they were for a certain heat (temperature) increase which would occur in the wire, had the wire been covered with normal PVC insulation. There was no information available for temperature increase of wire suspended in air, without insulation. Our main concern was that the wire did not heat sufficiently high enough to stretch the copper or melt the monofilament.

Balloon Fabrication

The balloon was of prime concern, because we only had two balloons, and they were both required. We were told that the balloons could not be filled a second time. By proper engineering, the balloons were in fact filled for the second day, and at the end of our operating period (which was cut short by a severe thunderstorm and tornado watch), they were brought down and stored for next year's contest.

The balloon required a filling device, so that there would be almost no chance of damaging the balloon through holding the neck during filling (photo A). The attachment device consisted of a plug used to seal irrigation tubing for underground sprinklers (with a 1.25 inch diameter, ribbed surface). Also, a nozzle end piece, also purchased from the same hardware store, was used, along with a 1 foot length of 5/8 tygon tubing (fig. 4).

Using "Hot Glue", the nozzle was glued and sealed from the inside to prevent leaks. The ribs of the plug sealed the nozzle of the balloon. Tie wraps were used to secure the balloon throat to the plug, and then four lengths of 100 pound monofilament were wrapped in the rib indents and tied securely so that they could not slip free. The entire throat/plug area was then wrapped with electrical tape to hold any knots from unwrapping.

The ends were prepared to hold tethers and antenna ends (fig. 5). A pair of ends were cut to a 3 foot length, and the other ends were left at a 5 foot length. A snap swivel was used to hold the balloon to the tether or antenna. This swivel allows the balloon to rotate with the wind, without twisting up the antenna or tether. Each large snap swivel was secured with the very best "fisherman's knot" that can be tied. The snap swivel also allows easy attachment to the tether, especially in a windy situation when we are attempting to hold this large balloon to ensure it does not damage itself.

What About the FAA?

Tethered balloons are regulated by the Federal Aviation Administration in the United States. The regulations are found on the Internet, at this URL: <http://www3.landings.com/cgi-bin/get_file?/pass=8110791&FAR/part_101/toc.html>.

In brief, Part 101 covers Moored Balloons, Kites, Unmanned Rockets, and Unmanned Balloons. However, under subpart A, Section 101.1 (Applicability), there is a statement that describes the regulation as only governing a balloon with more than 115 cubic feet of helium, or diameter greater than 6 feet. Thus, except for part 101.7, covering hazardous operations, if your balloon is kept to under 115 cubic feet of helium volume, these regulations are not applicable.

Under part 101.7, covering hazardous operations, the emphasis is that a balloon must not be operated in a manner that creates a hazard to other persons or property. This includes operating the balloon with the possibility of a weight falling and injuring someone or breaking some property. Therefore, operating the balloon in a manner that presents no hazard to anyone, keeping the balloon to 6 feet or less, or keeping the helium volume to under 115 cubic feet, precludes the necessity for FAA approval (however, the FAA should be notified in all cases.)

If the balloon is going to be larger than 6 feet, and have more than 115 cubic feet of helium, the following regulations are applicable:

Section 101.13 has some major limita-

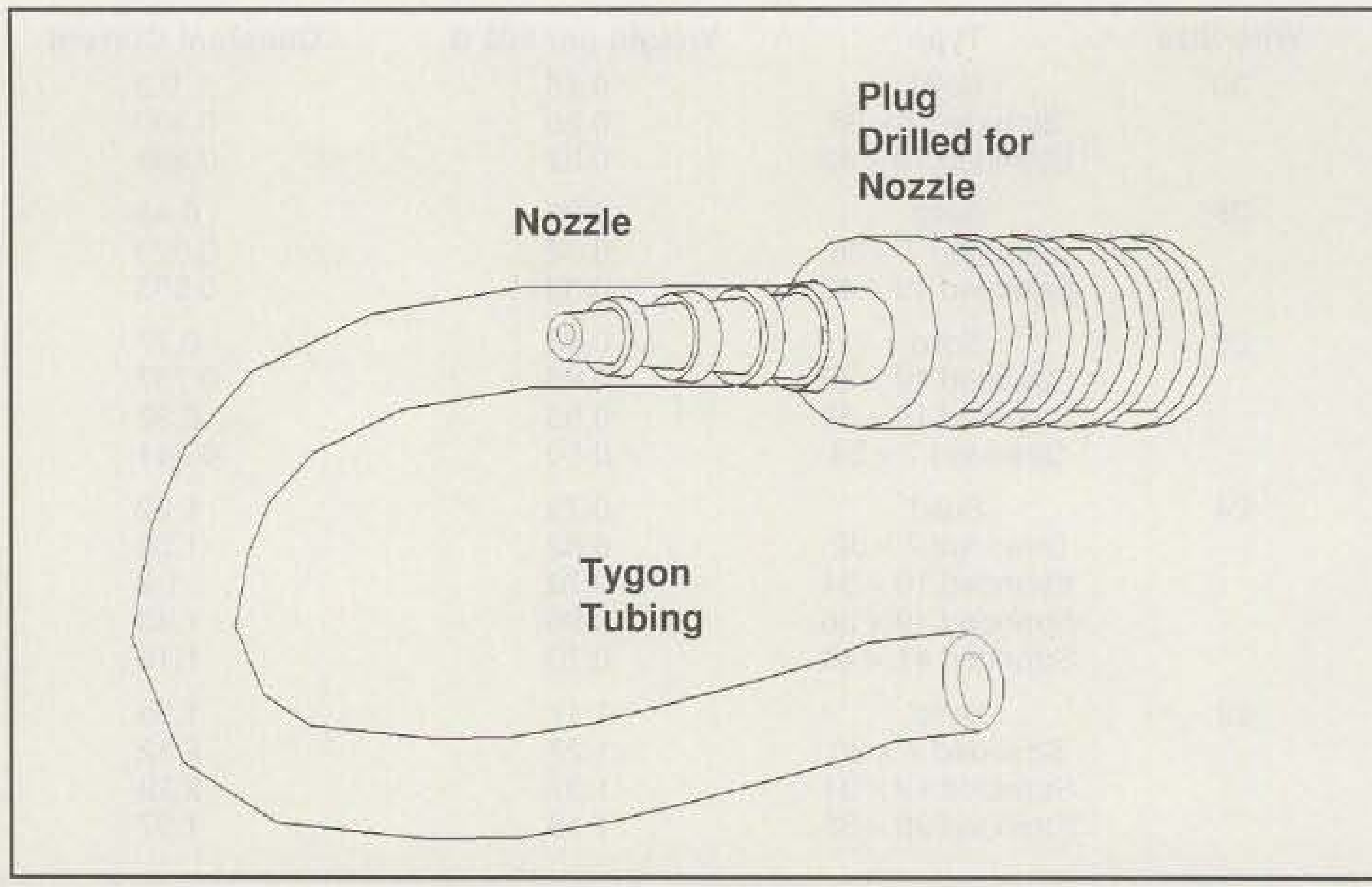

Fig. 4– The balloon filling adapter.

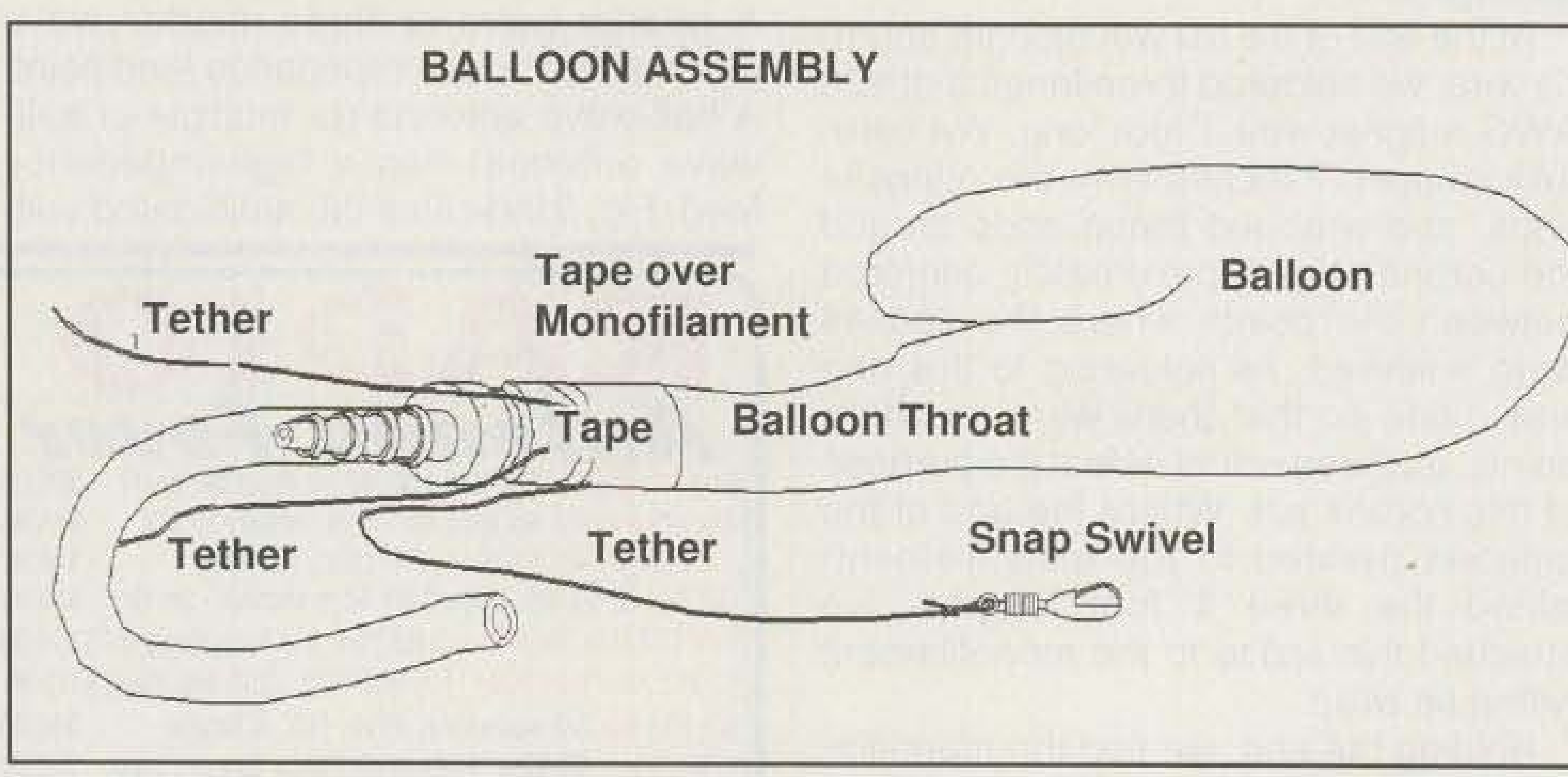

Fig. 5– Assembly of the balloon apparatus.

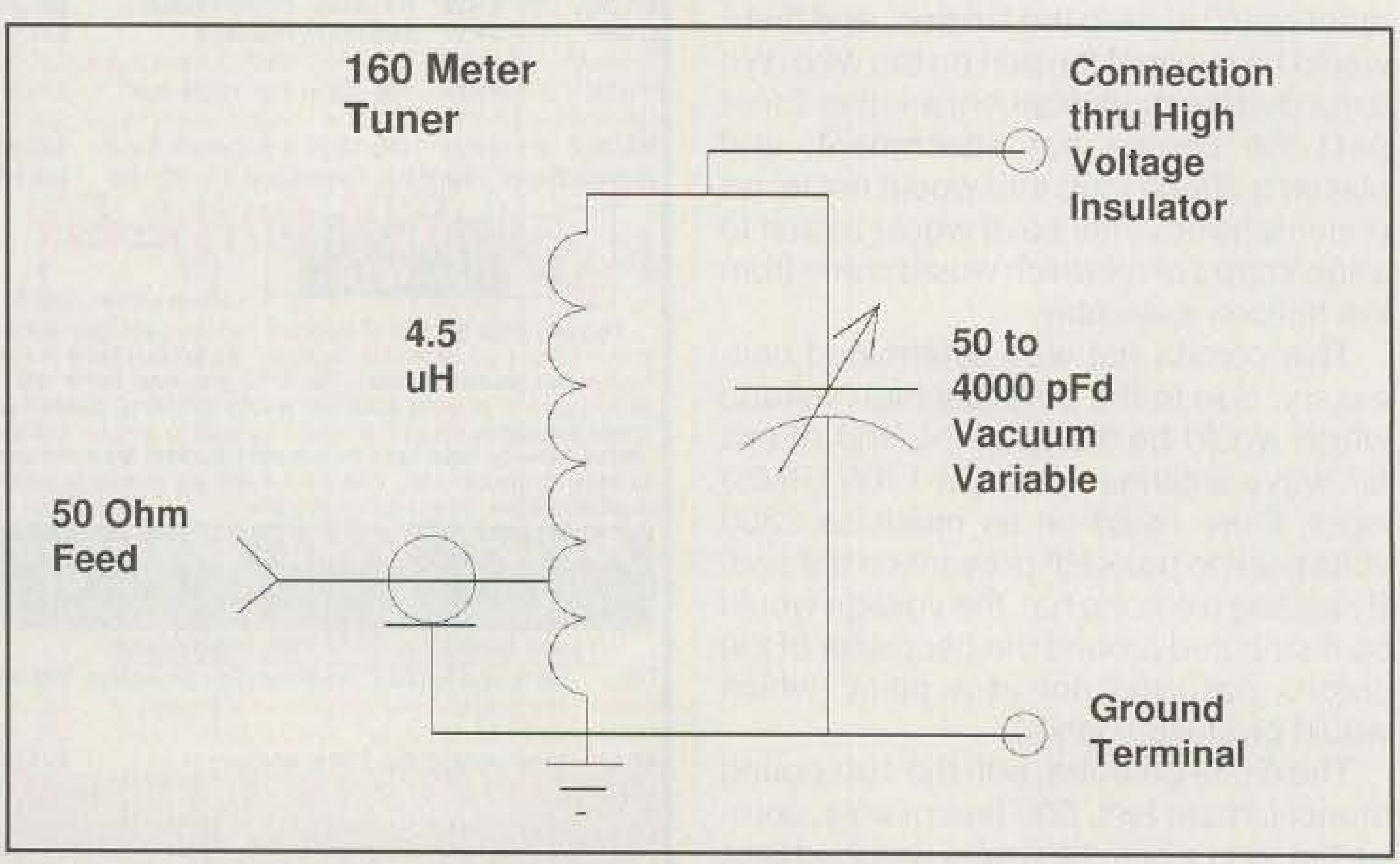

Fig. 6– Schematic of the 160 meter end-fed tuner.

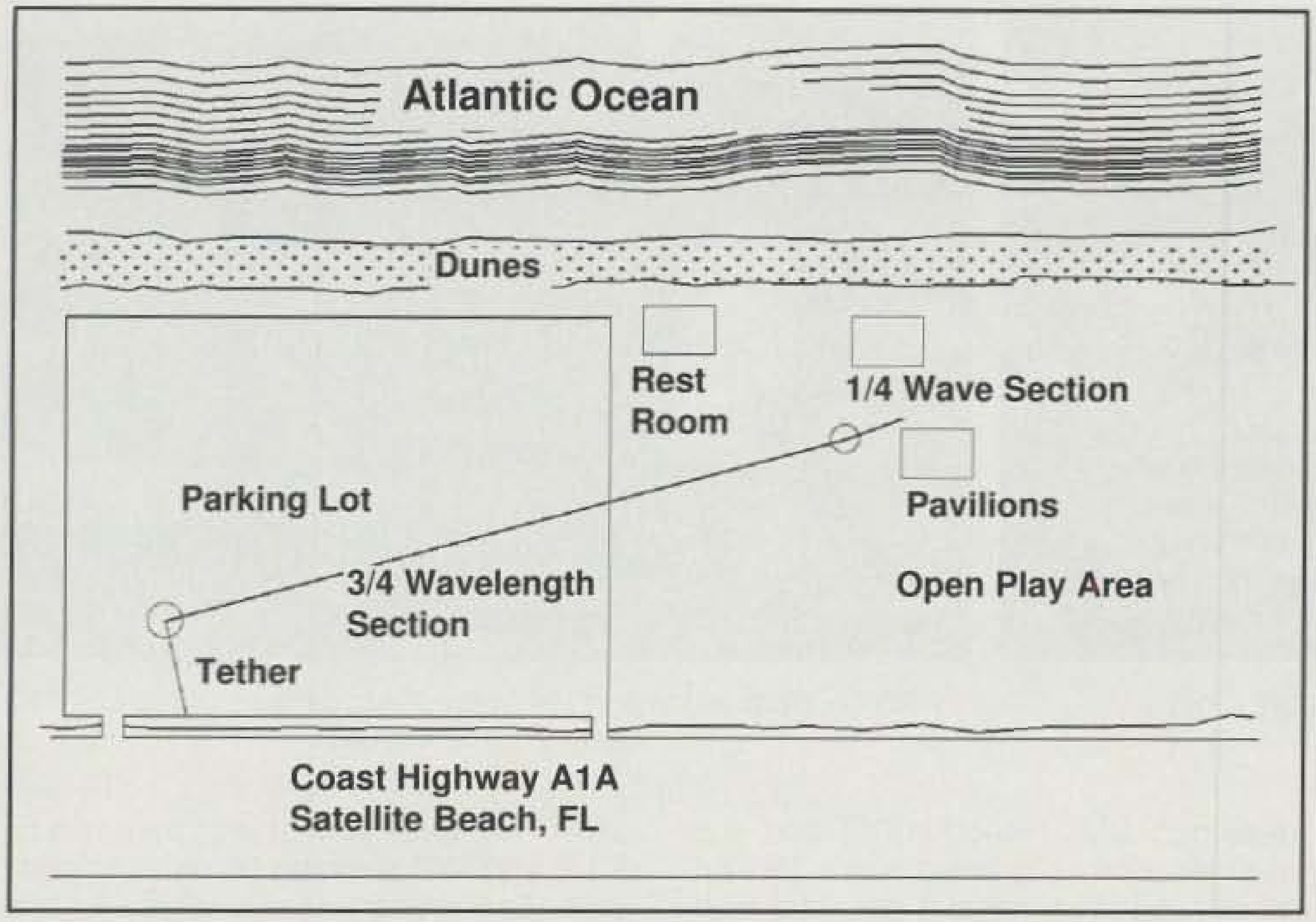

Fig. 7– Site location of the antenna at Pelican Beach Park.

tions, holding the maximum altitude of moored balloons to under 500 feet, or at least 500 feet from the nearest cloud, should the cloud level be below 1000 feet. The balloon cannot be flown from any area where ground visibility is less than 3 miles, or the QTH is within 5 miles of an airport. However, if you are fortunate to be near a tower, you can operate to an altitude below the top of the structure, and within 250 feet of that structure.

Section 101.15 lists the requirements for information to give to the FAA before you launch the balloon (such as names and addresses of operators, size of balloon, location of the balloon launch in terms of azimuth and statute distance from an FAA object that is found on a sectional map, height above the surface of the planned operation, and date and time of the operation).

Section 101.17 deals with lighting and marking of both the tether and balloon. Requirements for flags on the tether and visibility issues are mentioned.

Section 101.19 deals with rapid deflation devices. This means automatic deflation equipment mounted on the balloon and activated once the balloon breaks away from the tether and mooring. Should the deflation not occur properly, the FAA must be notified as to the estimated flight path of the free balloon.

A word to the wise! Keep the balloon

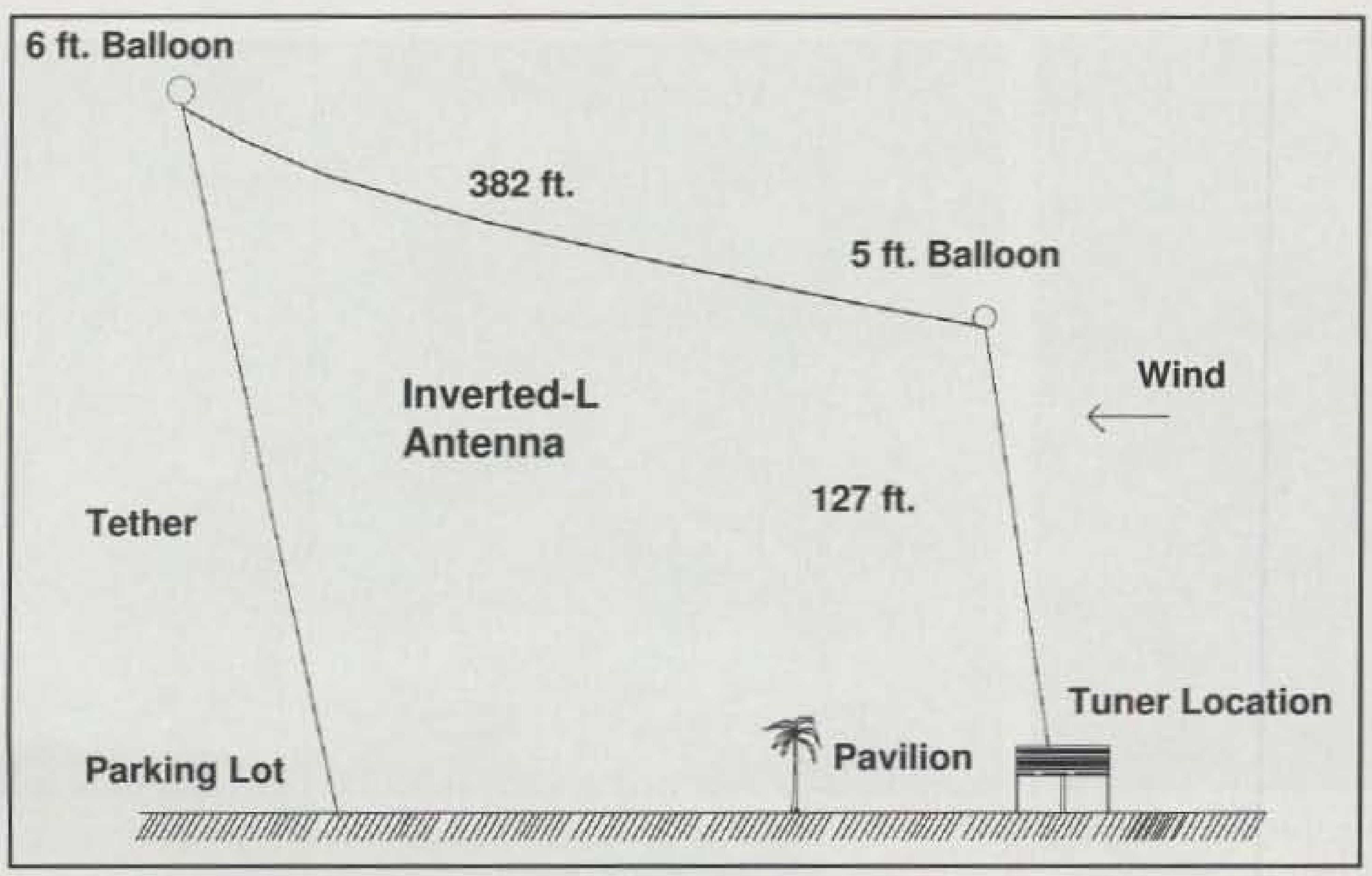

Fig. 8– The 160 meter inverted-L setup.

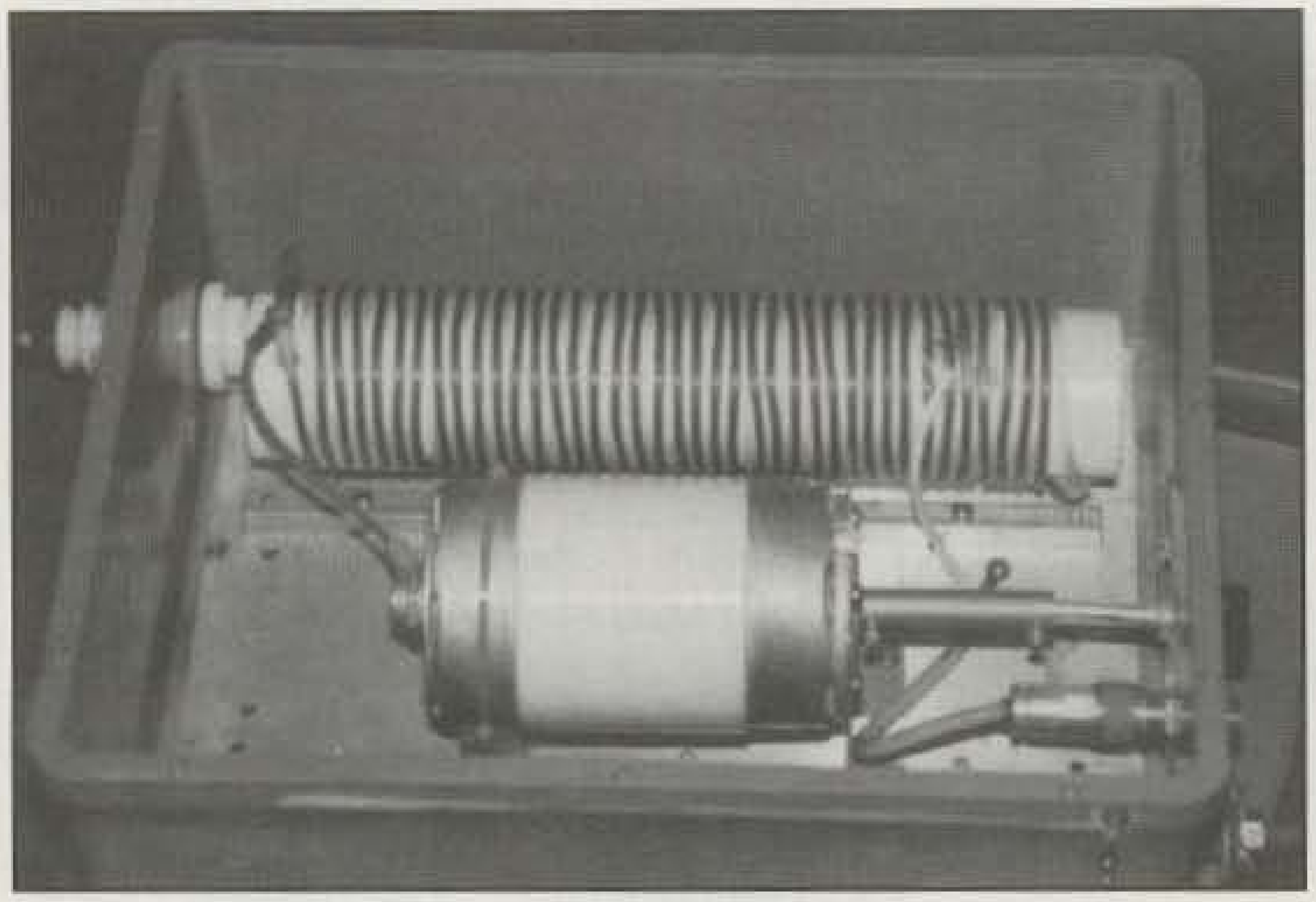

Photo B– The homebrew heavy-duty tuner.

Photo C– Help unloading the truck of equipment for the CQ 160 Meter Phone Contest.

under 6 feet in diameter, and always notify the FAA to issue a Notice to Airman (NOTAM) so that low-flying aircraft do not suddenly suck up your balloon in the middle of the night! Also, never operate a balloon-lifted antenna when lightning is in the area (probably keep it at least 5 miles away), and never operate where the antenna could come down and cross a high-tension line.

Antenna Matching

The full-wave antenna will change impedance as the antenna moves off the vertical plane due to wind shift. This meant that the design goal of the tuner was to match an antenna fed with 50 ohms and having a feed point between 1000 and 5000 ohms (fig. 6). By modeling this requirement on the computer, I came up with a tank circuit tuner that contained a vacuum variable capacitor which had a value of between 50 pFd and 4000 pFd (Jennings CMV1-4000-0005) and was rated for 5000 volts breakdown. This rating allowed me to wind a coil, 11.5 inches long and 2.5 inches in diameter, from #8 AWG Solid Copper Wire (same material used for the corona ring), spaced for four turns per inch.

The tuner was built in a surplus fiberglass case, which housed a Coast Guard tuner and was water-tight. The coil was mounted on one side, and the vacuum variable was mounted near the center (photo B). Using the MFJ-259 analyzer and connecting a 4000 ohm resistor from the top of the tank circuit to ground, the correct point to tap the coil was found. This point was then connected to a piece of RG-213 center, and the braid was connected to the nearest ground point. The other end was connected through an N-type bulkhead female connector. Measurements were made at frequencies from 1800 kHz through 2000 kHz, and with load values from 1000 ohms to 5000 ohms. The tuner was able to resonate to a 1.0:1 VSWR showing 50 ohms impedance. Everything was now ready for the 160 contest.

Selection of Location

Chuck and I wanted to be far from power lines and industrial noise sources. We wanted to be near the ocean or the Indian River. We also wanted to have a place with commercial power. All three criteria were met when we selected the Satellite Beach park called Pelican Beach Park (fig. 7).

We had use of picnic pavilions for shelter, and the Atlantic Ocean was 40 feet to our east. We were located on flat ground, with minimal trees, and with no overhead power. Because January's CQ 160 Meter CW Contest proved to be a chilling experience (temperatures near 35 degrees with winds up to 20 MPH), we knew that tarps had to be used to block winds from freezing us. The weekend of the phone

Photo D– Shown here are AD4ES (third from the left) filling the balloon, KF4RYE (next to right) holding it, and K9ES (left) attaching the tether.

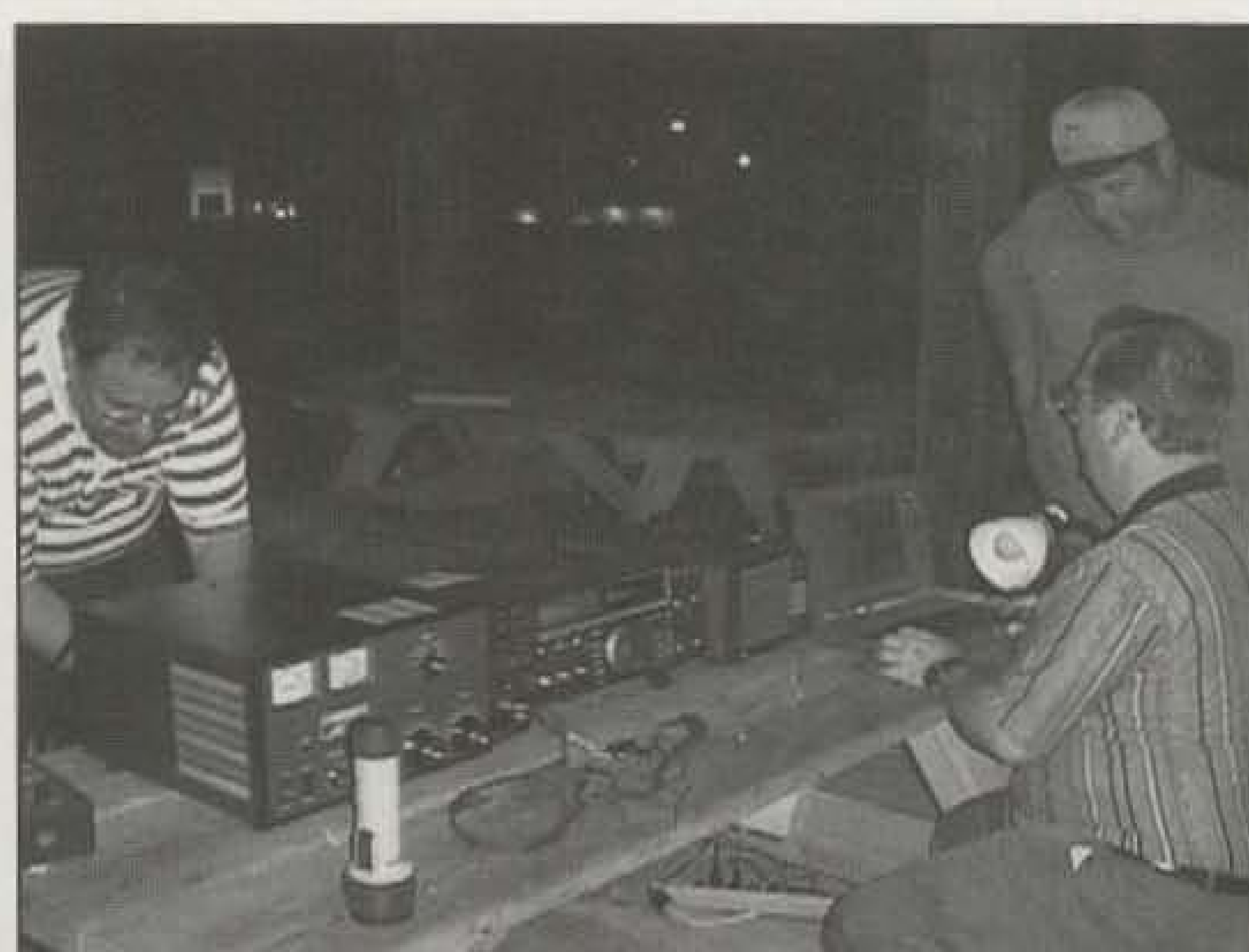

Photo E– K9ES (left), AD4ES (seated) making adjustments, and KF4TQF watching the procedure.

section of the contest was to be a warmer weekend, however, with a possibility of rain storms during Sunday.

Contest Time Arrives

The CQ 160 Meter Phone Contest was scheduled to start on Friday, February 27 at 6 PM local time. We had all the equipment loaded into the vans, and had two K-Tanks of helium also in the back of one van. All the tethers were pre-measured and spooled. The antenna was also spooled, and loaded into the van. Everything was ready to go but the NOTAM, which had been requested for the weekend evening hours between 5 PM and daylight. A call to the St. Petersburg Traffic Control Center gave us some bad news: The NOTAM could not be granted due to regulations. The FAA failed to elaborate, but insisted that the tether be flagged and the balloon carry a strobe and deflation equipment. We had the strobe ready to go, but the deflation equipment and flags on the tether were a crimp in our plans. A quick check with the Internet showed the technicality about balloon size, and Chuck and I agreed to run the contest. Daylight was gone, though, and we had to set up in the dark (photo C).

The tuner was mounted on an upside-down trash can, about 40 feet from the operating position. This was important, since there would be very high RF fields present at the feed point of the antenna. An 8 foot ground rod was driven into the sand, just next to the tuner, and connected to the ground terminal of the tuner. While there was no real need to have a ground plane or counterpoise with this antenna, it was vital to provide a path to discharge any lightning or static which might be induced in this long antenna.

To keep the public clear from the tuner and antenna, yellow police ribbon was placed around the trash can/tuner/antenna. This gave ample warning for people to stay clear.

An Inverted -L

Even with a NOTAM issued a month earlier, while we were deploying the balloon and full-wave delta loop (another article), an MD-80 passenger jet attempted to land and mistook the Patrick Air Force Base runway for Melbourne Airport. When the pilot realized his error, he began a climb and headed south, directly over the beach. Our balloon was at about 250 feet when this huge jet almost ran into it. From the view point of everyone on the ground, it appeared that the jet missed by less than 50 feet, causing the balloon to almost rip from the turbulence.

A full-wave vertical was designed, but that meant having the balloon (now reduced to 6 feet in diameter to avoid FAA restrictions) up to almost 525 feet. Chuck and I worried that even low-flying planes which track nesting turtles and marine mammals along the Brevard County Atlantic Ocean coast might run into the tether or the balloon, destroying both and possibly bringing down an airplane. We came up with an inverted -L design, with the vertical section going up one-quarter wavelength, and the three-quarter wavelength end going north to another balloon. The end balloon was set to hold the end of the antenna approximately 250 feet above a parking lot.

Both balloons were inflated, emptying only one tank of helium (photo D). The second tank was for the second night. To use the city park at Satellite Beach, we had to remove antennas for day activities by the public.

The antenna was attached, the tether was let out, and the antenna flew (fig. 8). I connected the feed end to the tuner, and adjusted the tuner for minimal VSWR. The tuner was then connected to a wattmeter, and the wattmeter was connected through about 40 feet of RG-214 to the linear (AL-572), which was connected to the IC-765. The speaker almost jumped off the table. A quick check verified that both wattmeters measured the same forward power and the same VSWR (photo E). We measured no reflected power with 100 watts forward. The linear was turned on, and we then fed the tuner to 1 KW. There was still no reflected power. I looked at the antenna and noticed no orange spots, indicating heating from the RF current. Everything was working great!

The 2.0:1 VSWR bandwidth was then measured. The antenna was flat at 1845 kHz, and remained under 2:1 from 1800 kHz to 1870 kHz. We were all ready to go!

The contest was going very well with stations being worked from New England out to the Caribbean and out to the West Coast. At the most active period, our run rate was 178 per hour. However, the noise was really bad, and we were not able to hear as well as some other stations who used their arrays of beverages. With only 10 hours of operating the first night and less than 4 hours the second night (due to a severe thunderstorm hitting us at 1 AM Sunday morning, with hail and tornado-like winds), we still made almost 300 QSOs.

The next contest will add receive antennas to this outstanding transmit antenna. I think that reports given said that we were one of the strongest stations from central Florida. All we need now is the ability to hear the many stations that must have been calling us.

Footnotes

1. Greene, R. C., W8PWU. "More on Balloon Supported Antennas," *QST* (Nov. 1940), pp. 38, 39, 82. Newington CT: ARRL.

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3. Fair Radio Supply, 1016 E. Eureka St., Lima OH 45802. Catalog Item SEB-42-ALV.

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