FIELD OPERATIONS WITH CESIUM CLOCKS IN HF NAVIGATION SYSTEMS

E. H. Christy and D. A. Clayton

OFFSHORE NAVIGATION, INC.
P. O. BOX 23504
HARAHAN, LOUISIANA 70123

ABSTRACT

For over 10 years, Offshore Navigation, Inc. (ONI) has operated and maintained networks of HF phase comparison marine navigation stations employing cesium clocks. The largest permanent network is in the Gulf of Mexico where some fourteen base stations are continuously active and others are activated as needed. As these HF phase comparison systems, which operate on a single transmission path, require a clock on the mobile unit as well, the ONI inventory consists of upwards of 70 clocks from two different manufacturers.

The maintenance of this network as an operating system requires a coordinated effort involving clock preparation, clock environment control, station performance monitoring and field service.

EQUIPMENT CONFIGURATIONS

The ONI ACS (Atomic Clock Systems) network is comprised of the base stations shown in Figure 1. In addition, other networks may be established temporarily in various coastal areas of the U. S. and elsewhere around the world as required by the on-going search for energy. Each of these base stations is comprised typically of a CW transmitter driven by a synthesized signal generator locked to a cesium standard. As shown in Figure 2 provision is included for automatic transmitter switchover should that unit fail, and battery backup to keep the CS standard alive during power failure. These base stations are situated in locations that have all degrees of access, from easy to difficult, including offshore platforms.

The mobile station configuration, also shown in Figure 2, is comprised of a Cs clock and synthesizer providing local phase reference to a narrow band receiver. The mobile equipment also has battery backup provisions for the clock. The oven is not generally necessary as the equipment is frequently in the conditioned equipment room of the vessel.

The clock environmental chamber (oven) is actually an insulated plywood box fabricated at ONI. Equipped with a thermostatic heater the temperature of the clock inside is maintained at about $38 \pm 3\,^{\circ}C$ ($100 \pm 5\,^{\circ}F$), somewhat above ambient. Early base station huts were uninsulated and the higher temperature was what could be maintained easily. Figure 3 shows a picture of the oven and Figure 4 is a typical base station hut.

Sixteen roving technicians, seven on call at all times, are strategically located from Florida to Mexico to perform normal maintenance and emergency repairs. Additionally, a helicopter is continually available for service calls to offshore platforms.

CLOCK TYPES AND PREPARATION

ONI employs clocks manufactured by both HP and FTS. The model type and age distribution of these is broken down according to the following table:

TYPE	DATE PURCHASED	QTY	
HP 5061A	1970	1	
	1971	7	
	1972	7	
	1973	3	
	1974	18	
	1975	6	
	1978	3	
	1979	4	
			49
FTS 4000	1979	2	
			2
FTS 5000	1980	12	
			12
FTS 4050	1980	6	
	1981	8	
			14
	TOTAL COMPLEMENT		77

Prior to their deployment, clocks are rated in-house for a minimum of 24 hours and, frequently, 48 hours to observe their general stability and suitability for field use. Any clock whose last service record is 3 months or more old is subjected to a routine series of electronic checks at various test points. These readings are written down and kept as part of that unit's record.

At installation time on board ship, the clock is rated by the navigation operator against the navigation net. Final adjustments to the C-field are made at that time and the clock is left undisturbed throughout the voyage, usually 14 days. A typical seismic operation may last from one, to many such voyages.

BASE STATION PERFORMANCE MONITORING

Base station performance is monitored by two land-based "mobile" stations equipped with strip chart recorders, each station looking at a different section of the net. Note that absolute accuracy is not important; it is only necessary that the net maintain zero relative drift of one station with respect to another. The transmission monitoring here is basically across land at 1700 kHz so one can expect to see substantial short term variations in recording during the course of a day. These may be due to skywaves, weather fronts, etc.

Efforts are made to observe these recordings at regular times every day and thereby ascertain relative drift, if any. It is believed that the 24 hour observations can reliably detect errors of .05 lane (25 nanoseconds) of one station with respect to the "master". At present, when this amount is reached, a technician is dispatched to the station to make a C-field adjustment.

Newly installed clocks require close attention for about two weeks. Thereafter the average clock will remain within plus or minus 2 one hundredths of a lane (10 nanoseconds) without requiring a C-field correction for 6 to 12 months. Adjustments to the beam current, second harmonic content, and control voltage are performed once every 3 to 6 months.

Plans are being made to implement a semi-automatic clock adjustment scheme. This scheme employs "phase microsteppers" such as the Austron 2055A which can be remotely controlled over telephone or radio linkages to implement step/drift corrections as small as 10^{-5} nanoseconds.

FIELD PERFORMANCE SUMMARY

Of the 49 active standards 12 have thus far undergone tube replacement at ONI. Additionally there have been 5 warranty repairs effected at HP. Figure 5 lists the dates of purchase and replacement together with the approximate months of tube life realized (non-warranty). Over one-half of the clocks dating from 1974 or earlier are still performing with original tubes. Thus our avarage realized tube life is significantly greater than the 74.6 mos avarage service life of the failed tubes.

By way of comparison we find the HP standard easier to service and more universally understood by our field operators. The FTS standards are more difficult to repair but they come with a 5 year warranty and appear more temperature-stable. We have no quantitative data to present in that regard, however.

In our experience the parts which fail most often in the HP unit are listed below in order:

1. 5 mHz oscillators
2. operational amplifier A9
3. synthesizer A1
4. multiplier A3
5. oven controller

Troubles with the FTS units appear primarily power supply related. Since all FTS units are in warranty, no failure records are on hand.

Several aspects of clock operation and maintenance are perhaps peculiar to our operating environment and will be described here briefly.

Recently HP has recommended higher C-field levels attendant to operating with the higher Zeeman frequency of 53 kHz as opposed to the older 42 kHz. Though there may be some improvement in stability with this modification the C-field adjustment resolution is decreased to $8\text{-}10^{-14}$ from its present 5×10^{-14}. ONI thus would run the risk of having field operators make improper C-field adjustments depending upon whether or not their particular clock had been modified. This we have chosen not to do as there were plenty of mistakes made some years ago when the C-field resolution was again changed by HP.

A common occurrence in shipboard operations is the switching of ship's generators on-line. This action frequently results in severe power surges of the AC line. As the 5061A oven control operates from the unregulated supply voltage it is a frequent casualty in the mobile systems.

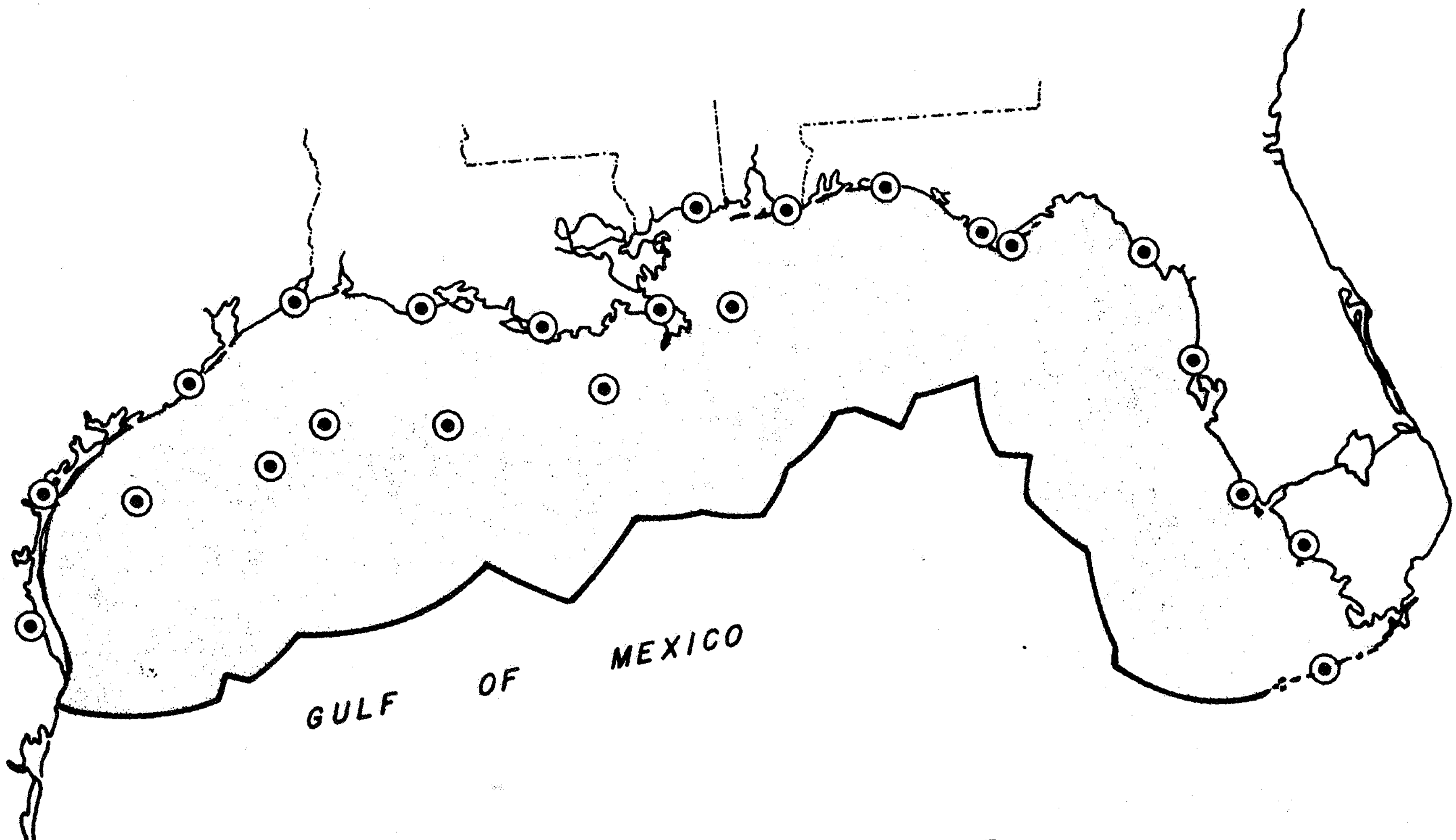
All clocks have been equipped with Sonalert audible alarms indicating power or logic failure. This will alert the mobile operator immediately, even if he is in a noisy environment, as he cannot always observe the clock itself.

We have had several instances wherein the standard was stored without power for extended periods. In these cases, with the ion pump inoperative, tube leakage can become so great that subsequent operation is impossible. In two cases of roughly six-months inadvertent storage, the tubes were unrecoverable.

In a third case the standard was a casualty of a severe fire aboard ship, the insides and outsides of the instrument becoming charred and fire blackened. The unit was subsequently dismantled and left in pieces around the shop for over a year while the technicians worked to refurbish it in spare time. The Cesium tube was reinstalled in the refurbished unit and rejuvenated with a high voltage power supply. That unit is now fully functional and serves as our in-house standard.

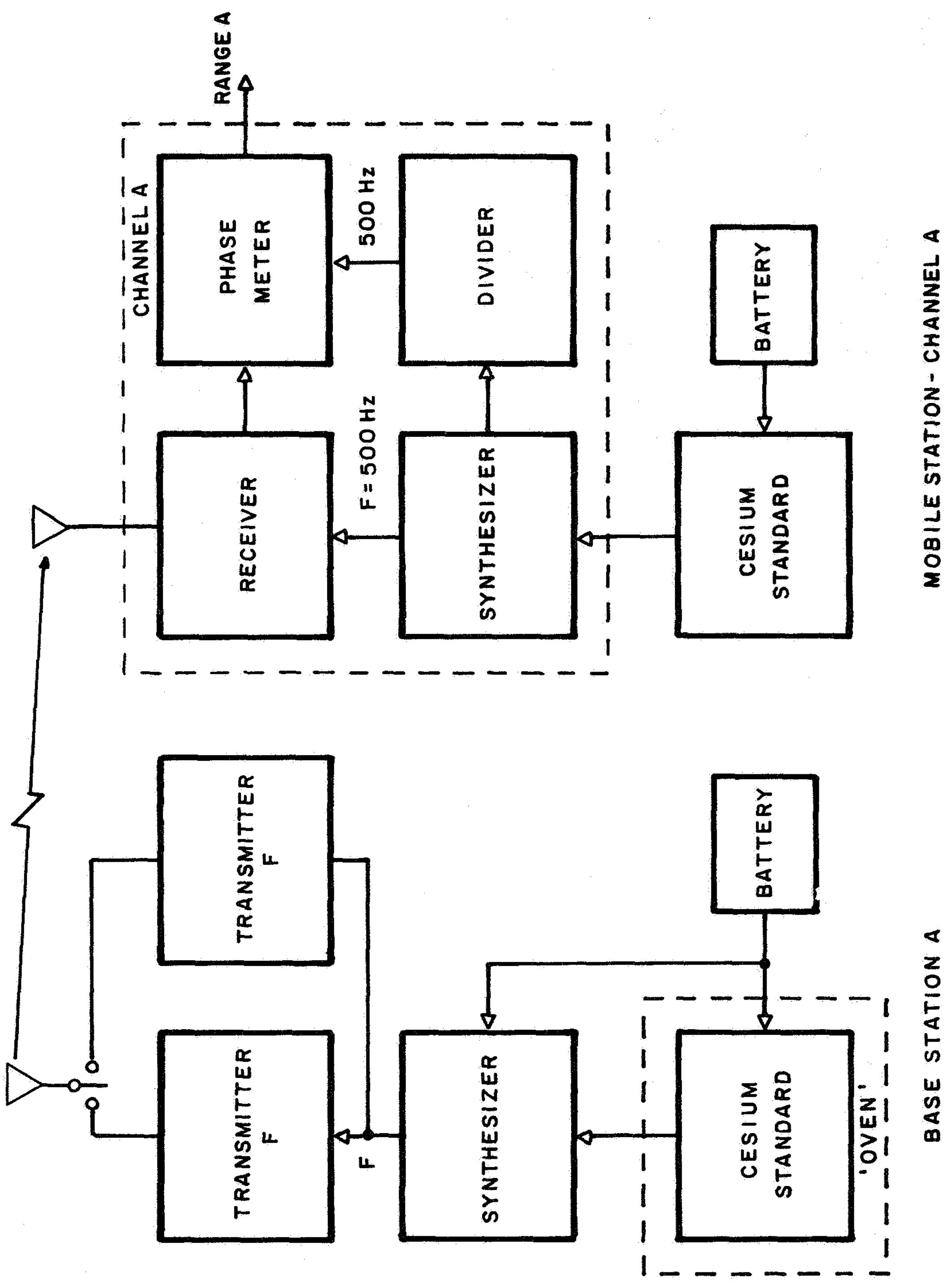
<u>Summary</u>

The Cesium standard has proven to be a reliable component in providing a system of navigation not achievable by other means to date. Whether or not GPS receivers can perform as reliably and economically remains to be determined. With it's complete in-house service capability, ONI will be maintaining it's clocks for years.



ONI 24 HOUR MICROPHASE COVERAGE
Figure 1

BASE STATION



ONI ACS EQUIPMENT CONFIGURATION
Figure 2

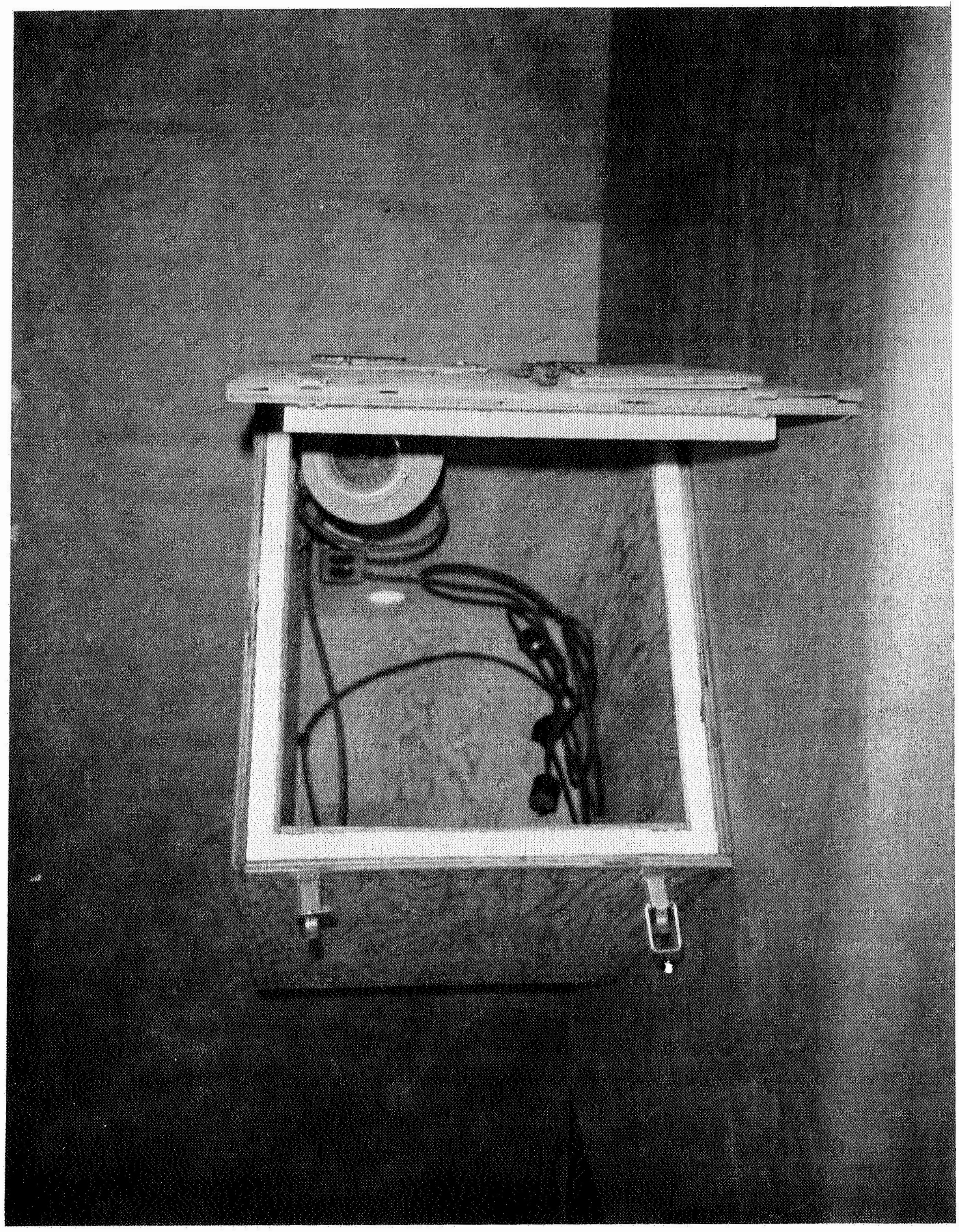


FIGURE 3

THERMOSTATICALLY-CONTOLLED OVEN FOR Cs STD.

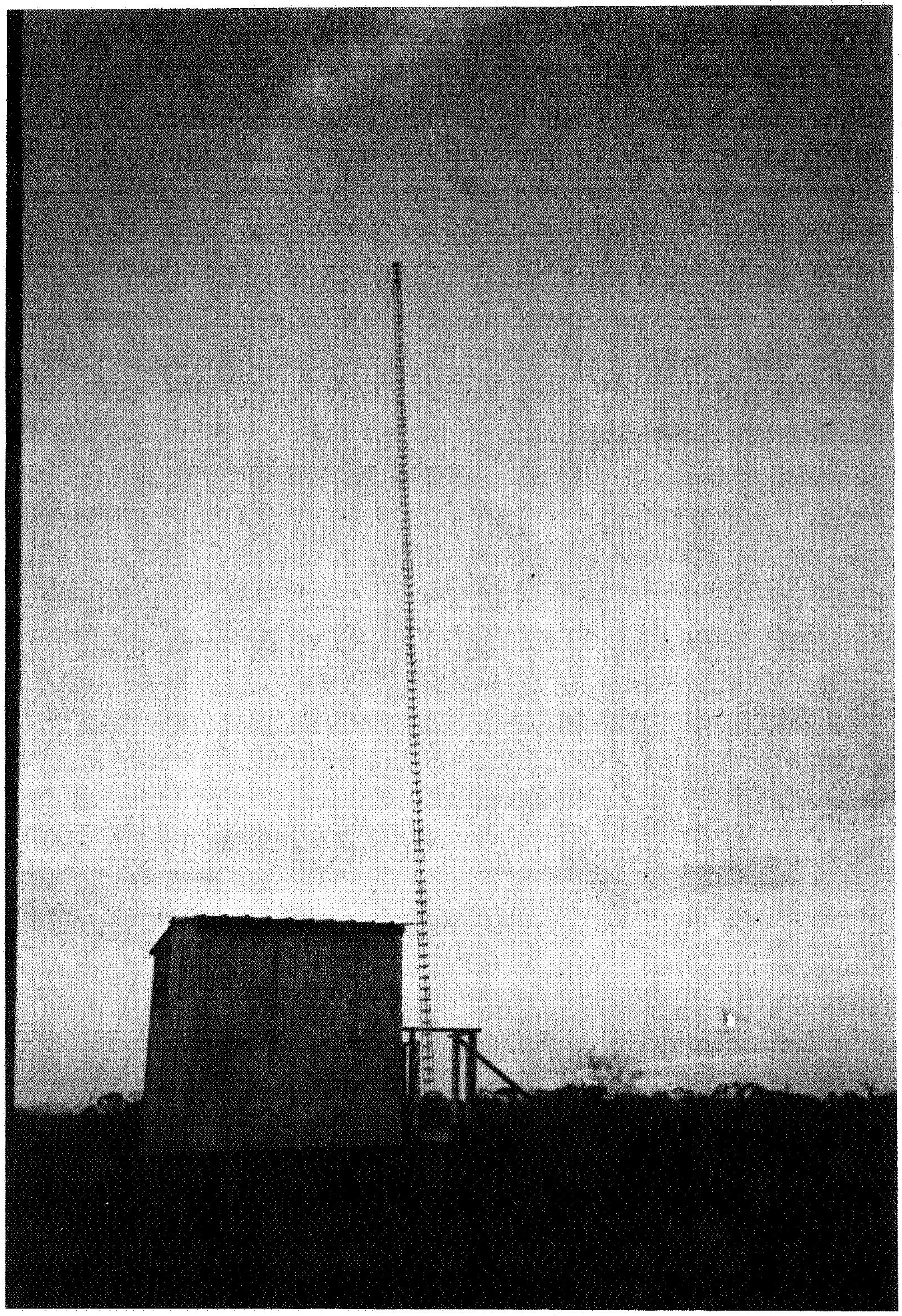


FIGURE 4

TYPICAL REMOTE BASE STATION INSTALLATION

UNIT #	DATE/PURCH	DATE/REPL	NO. MOS.	
007	12/13/71	09/24/81	117	
009	10/01/71	07/28/75	46	
011	04/05/72	06/12/81	110	
014	07/06/72	04/08/80	93	
015	08/03/72	08/16/78	72	
016	11/10/73	09/02/81	94	
017	11/10/73	05/20/76	30	H.P. WARRANTY
020	02/01/74	09/27/79	67	
021	02/01/74	06/25/80	76	
022	02/01/74	10/25/76	32	H.P. WARRANTY
023	02/01/74	06/20/80	76	
024	02/01/74	11/08/77	45	H.P. WARRANTY
025	02/01/74	12/09/76	34	H.P. WARRANTY
025		07/17/79	31	
029	04/30/74	02/16/79	58	
031	05/08/74	02/14/77	33	H.P. WARRANTY
031		11/19/81	55	
		AVERAGE	74.6	

CESIUM BEAM TUBE REPLACEMENT SUMMARY

FIGURE 5