THE SCR 296A RADAR

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This article is the third on World war II Coast Artillery Radar(see Vol 5 number 5, Nov '89 and Vol 4 number 2 May '90) and represents an detailed look at the most widely installed of the surface gunfire control radars. In previous writings the set was referred to as the SCR 296 while further research has shown production sets to have been designated SCR 296A. This article will cover the elements of and operation of the set.

As stated the SCR 296A was the standard World War II fire control radar utilized by the U.S. Coast Artillery for engaging surface targets. It was authorized for issue to all modern batteries of 6" and larger on a basis of one set per battery. This set was basically identical to the navy Mark III, or FC, set utilized on ships. The function of the Radar was, during periods of poor visibility, to provide the range and azimuth of the target vessel to the plotting room of the battery. In addition it could be used to provide such data to additional batteries as required or to give spotting corrections to other batteries if advantageously sited. The set was normally installed with: a prefabricated metal lattice tower containing the antenna: an operating room containing transmitter/receiver, indicating panels, power panels, and communication devices, and two 25 kw gasoline generators. Normally the operating room was in a prefabricated metal building (HO-2-A and the generators(Fig 1b)in 2 other prefabricated metal buildings(HO-1-A).(Fig 1a). The components weighed 18,943 lbs(operating building), 31,777 lbs(antenna), 9,580lbs(antenna housing), 6,420 lbs(radar components), 16,225lbs(accessories), and 13,450 lbs(2 generators and houses). This resulted in a total weight ,in action, of 96,388 lbs not including the IFF equipment. Variations were possible and in high risk areas the operating room could be bombproof locations such as the battery plotting room bunker(Battery Hatch TH), or located within the metal or concrete multi-story fire control towers. In these instances of tower locations the antenna was located on the roof.(fig 11b)

The first limitation on the system was the necessity for the proper location of the antenna. As Radar at this time was believed limited to line of sight it followed that generally the higher the antenna location the greater the range.(fig 2) As the antenna was not capable of elevation or depression during operation it was possible to site the antenna at too high a location which resulted in an excessive non-scanned, or "dead" area close in to the set(fig 3). Experience with the set showed that the antenna became less effective, due to decreased maximum range, at heights below 100 feet above sea level and created too much "dead zone" at heights above 500 feet.

To provide for this height requirement the obvious answer was to utilize natural heights such as hills, bluffs etc. However, at many sites on the Atlantic and Caribbean U.S. coasts, no such sites were available. For these low-lying sites a prefabricated steel tower(fig 1 and fig 11a)was issued with the set. This tower was supplied in 25, 50,75, and in 100 foot heights to accommodate the needs of each particular site. This allowed for a minimum of 100 feet to be reached however contemporary texts stated that a minimum of 150 feet above sea level was necessary to achieve the minimum effective range necessary to control heavy caliber gunfire. The absolute minimum was necessary to prevent nearby ground interference (clutter)with the radar transmissions.

As mentioned many expedients were utilized to gain the necessary height. The antennas were mounted on the tops of existing steel or concrete fire control towers(fig 11b), with a short(25 feet)lattice tower on top of the hill formed by the Battery Plotting/Switchboard room(Battery Hatch TH), or directly on the Battery Commander's Station(Battery 302 TH, itself at a considerable height above sea level).

While these higher sites gave longer range the arrangement of the Radar was further restricted by the maximum length of the transmission cable between the antenna and the transmitter/ receiver which was 175 feet. This restriction was due to the technology of the period which was unable to prevent signal (electronic power)loss at greater distances. The ideal solution was, when possible to make the distance even shorter which would minimize this loss, make the signal stronger, and result in better performance. This was the reason that some transmitter/receivers were mounted in the towers and on BC and Plotting room locations.

Along with the height requirements for antenna site selection it was necessary to locate the site in such a position that no obstructions such as hills, towers or buildings were located within 8-10 degrees of the flanks of the sweep area and within 8 to 10 degrees below the antenna sweep area. Any obstructions could cause reflection of the side lobes of the transmissions and cause the Radar to falsely show the target to be located midway between the actual target and obstruction

Mounted on top of the tower was a platform on which was mounted the antenna.(fig 4) This antenna was used for both transmission and reception. It was a directional antenna formed of five curved ribs on which was mounted a metal screen reflector which served as the receiving antenna. Located in the center running horizontally across the antenna was a rod which functioned as the transmitting antenna. The whole apparatus was approximately 6 feet long by 6 feet wide. This antenna was capable of being remotely controlled in azimuth and had an electronic data transmission device which indicated its position on indicators located in the operating room. This action was accomplished by a selsyn motor which operated much like a modern TV antenna rotator. The antenna did not continuously rotate as modern radars do but was directed at the target and in receiving functioned as a modern radio direction finder. It was preset in elevation and adjustment of this was not possible during operation. These restrictions resulted in an ability to search only a narrow sector(the beam had only a 9 degree width in azimuth and 11 degrees height in elevation) and limited its effectiveness when used as an early warning set. The antenna was housed in a round wooden housing shaped much like a contemporary water tower. A ladder was provided for personnel access and an electric winch was available for hoisting major components to and from the ground. Because of the danger presented by the powerful concentrated radio waves of the antenna(much like the modern microwave oven)safety interlock switches were positioned on the platform access trapdoor which shut down the power on its opening. Frequently this resemblance to a water tower was exploited by disguising the antenna housing, as was done at Battery 301 TH by including a dummy water measuring device on the outside.

The radar system normally operated on Post (commercial) AC power requiring 20kw for efficient operation. In isolated locations and as emergency back-up each set was provide with two PE 84C portable gasoline powered generators(Fig 1b)each capable of producing 25 kw of 120 volt 60 cycle AC current. A standard location such as at Charleston had these components located in prefabricated metal buildings designated HO 1-a(fig 1a). Each set weighed 5000 pounds, and was supplied with gasoline by a 1000 gallon underground gasoline tank which was located some distance from the building. As each generator was capable of suppling more than the required 15 KW necessary for operation of the Radar and its auxiliary systems, this resulted in a primary and two alternate emergency operating system each capable of independently operating the Radar.

The power requirement resulted in the third limitation on SCR 296 location, that each of the two 25 Kw gasoline generators could be located no further than 150 feet from the operating room of the Radar. This restriction was a result of the fact that any further cable length would result in excessive power loss to the transmitter/receiver. This fact, coupled with the transmission cable length restriction resulted in a compact system which was concentrated in an area no larger than 300 feet. Such compactness resulted in making the system more vulnerable to enemy shelling and bombing and as a result many stations were placed in bunkers or tunnels to reduce vulnerability.

The most important components of the Radar were located in the operating room. In this area was located the main unit which contained the: Radar transmitter; receiver; power control panel; high voltage rectifier; and operating controls(fig 10) . This area represented the "heart" of the system. The most important area of the operating room contained the operating equipment. This consisted of a table on which were located a bank of six instrument boxes which allowed the system to acquire and determine the range and azimuth of the target(fig 5). These consisted of, from left to right: a Rectifier; azimuth indicator; azimuth oscilloscope; azimuth control unit; range oscilloscope; and range measuring unit.

The standard manning crew for the SCR 296 Operating Room consisted of five personnel. The first was an NCO who functioned as Chief of the Section. The others consisted of a range operator, an azimuth operator, a range reader, and an azimuth reader. The Operating room required a minimum of nine cable pairs for telephonic communication. It was equipped with 4 telephones. It had a command telephone, to communicate with the battery commander; an azimuth reader's phone; a range reader's phone; all connected through the fire control switchboard. In addition a Time-Interval signal and, if equipped, an electronic data transmission system. The fourth telephone the post line, went through the post switchboard and was intended for non-tactical messages.

In operation the range and azimuth(rough bearings)were transmitted telephonically from the HDCP SCR 582/682 radar to the range and azimuth readers in the SCR 296 operating room. This coaching was necessary due to the poor target discrimination of the radar and its narrow beam which meant that the antenna had to be pointed almost exactly at the target.

At this time both the Azimuth and Range Readers readers repeated the data and directed their respective operators to traverse left or right(azimuth) or to increase or decrease the range until the indicated settings appeared on the indicators. At this time the readers gave the command "steady". At this time the target would have been within the scan of the radar beam and appeared as a peak in the line representing the radar sweep signal in the range oscilloscope(fig 6b).

The Range Operator, seated at the table, then observed the target signal on this range oscilloscope and adjusted the signal. When the set was operating the 5 inch wide screen of the oscilloscope electrically generated a horizontal line which represented the radar waves path. This line was 4 inches in length and had a noticeable "u" shaped dip in the center, which represented a 600 yard area. The total length of the complete line represented a 100,000 yard sweep line (Fig 6a). The center "u" notch could be, by use of the "image spread" knob be expanded to a width of 4 inches to represent a 5000 yard search area, while the center notch expanded to represent an expanded presentation of the same 600 yard area. After adjusting the signal strength dial to bring the target echo to a height of between 3/4 to 1 inch in height, the Range Operator rotated the range handwheel, located on the Range Unit(fig 6 item 6), to move the target echo into the notch. Once adjusted he continued to rotate the handweel to the left or right to keep the target in the notch. At this time he called "On Target".

<u>After</u> the Range Operator had "locked onto" the target the Azimuth Operator turned the handwheel located on the Azimuth Control Unit(Fig 6 item 4) to match the height of the two "V" shaped pips (Fig 7a)which appeared in the Azimuth Oscilloscope. These pips <u>only</u> appeared <u>after</u> the range operator had centered the target in the notch and represented this target. These two "V"s were one of the operating secrets of the 296 and were a function of the "lobe switching" mode. If the antenna transmitted from the center it functioned as a simple direction finder. The "lobe switching" allowed the antenna to alternately transmit a number of radar pulses slightly off center. This allowed the target reflection to be received at slightly different angles(fig 7b)and this increased the accuracy of the azimuth measuring.

The operator then adjusted the handwheel on the Azimuth Control Unit to the left or right, which rotated the antenna, and caused the target to be centered between the two lobes (fig 7b). The correct adjustment was indicated when the two "v"s visible on the azimuth oscilloscope assumed an equal height (fig 7a). As an aid to proper adjustment a meter(fig 7c) was provided on the Azimuth Indicator which indicated the target position. When the operator had the needle centered the target was properly located. While this method was more reliable than utilization of the Azimuth oscilloscope, its use was limited. This meter could not be utilized if another 296 was operational within its sweep area or if natural interference(land mass, towers etc were on the edges of the beam as the meter would indicate a false target location midway between the actual target location and interference.

Once the target was positioned both operators continued to utilize their respective handwheels to track.it. Late in the war some sets were equipped with Aided Tracking. This was a system which, when the range and azimuth change rate had been established, automatically accomplished the tracking. During this operation the operators had to use their adjustment wheel only for minor adjustments and greatly increased the accuracy of the range and azimuth determination.

After stabilizing the tracking the Range Reader then observed the Range Measuring Unit(fig 6 item 6)and read the dials(Fig 8 item 3). Proceeding from left to right the first square window two dials with a with a common indicator line running through the center. The left hand dial made a 360 degree revolution for every 100,000 yards, the maximum range of the set. It was numbered from 1 to 10 and each number represented 10,000 yards. The dial on the right of the indicator window made a revolution for each 10,000 yards and was marked 0000 to 10,000. Each number represented 1000 yards and each was further subdivided into 100 yard increments indicated by 10 short lines. Moving on, the next knob upper(fig 8 item 2)was utilized for "zeroing" the range knobs with the Range Tracking wheel(Fig 8 item 1)located below it. Attached to the extreme right side of the unit was a square box. This contained the final range indicator, and consisted of a dial which rotated once for each 1000 yards. It was marked with numbers from 1 to 10. Each number represented a 100 yard increment and each was further subdivided by 5 small lines which represented 20 yard intervals. This enabled the Reader to interpret the range to the nearest 5 yards.

For azimuth determination the Azimuth Reader observed the Azimuth indicator(Fig 6 item 4). It contained two round dials located in a common face(Fig 9). The index lines consisted of two "Y" shaped pointers. The stem indicated the reading point. The dial on the left one rotation for each 360 degrees of antenna rotation and was numbered at each 10 degree mark. Each 10 degrees was subdivided by 5 short lines into 2 degree increments. The right dial turned one complete revolution for each 10 degrees and was marked with numbers from 1 to 10. Each degree was subdivided by 20 short lines which allowed the azimuth to be interpreted to the nearest .05 degree.

In operation the both operator ceased tracking the target as the Time-Interval bell signal from the Battery plotting room rang. The Readers then reported the dial reading, interpolated to the nearest 5 yards(range)or .05 degrees (azimuth)telephonically to the Plotting room. If the set was equipped with the Aided Tracking Equipment, it was not possible to stop the tracking and the Reader's job was made more difficult by having to read the dials while they were in motion. As they became available some sets were equipped with an electrical data transmission which gave continuous range and azimuth information to dial s in the plotting room. In those batteries equipped with the Gun Data Computers M-1 or M-8 the data transmission was connected directly to the computer. This eliminated both the "dead time" delay and probability of human error associated with the telephonic procedure as well as freeing the plotting room from the delay necessary in waiting for the next time interval bell. In modern terms the Plotting Room was supplied with "real time" data. Despite these advantages the telephonic and Time-Interval method were retained and practiced for emergency use.

In addition to the basic set the SCR 296 was later provided with an RC 136 IFF system. This consisted of a smaller antenna mounted near the main antenna(Fig 11c), as well as a separate transmitter/receiver in the operating room. In action it functioned a a separate transmitter receiver which activated a Mark III transmitter fitted to friendly ships. When activated this transmitter caused a series of coded pips to appear near friendly targets on the main radar, thus allowing the separation of enemy and friendly ships. As with all new devices this worked better in theory than practice and if ships were closer than 1200 yards in range or separated by less than 20 degrees of azimuth the system was incapable of identification. As each battery was assigned its own Radar it was necessary to equip the sets with a selection of 4 different Magnetrons. When installed they varied the transmitting frequency between 680 and 720 MC/sec, and prevented interference between sets operating in close proximity.

According to contemporary manuals the SCR 296 was also given credit for being able to track the shell splashes and thus be used for fire adjustment. Postwar assessment however stated that, due to the poor resolution of the set it was impossible to distinguish between separate shell bursts and such adjustment was impossible. This lack of resolution and azimuth discrimination also meant that the 296 operator was only able to separate targets that were more than 275 yards apart and more than 12 degrees apart in azimuth. With all these failings the SCR 296 was credited with a the ability to track and give warning of surface targets at a range of over 100,000 yards. This figure represents the maximum range. Postwar the 296 was credited with being able to give reliable range on large targets(battleships and cruisers) at 40,000 yards, while smaller vessels(destroyers)could only be tracked at ranges of 20,000 yards. Such a limitation restricted its utility with the 16-inch weapons(44,900 yards). For all these failings the SCR 296 served throughout the war as the standard Coast Artillery Fire control Radar.

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Orman, Lt Col L. M., "Radar, A Survey, Coast Artillery Journal. Vol LXXXIX #2(Mar-Apr, 1946).

Orman, Lt Col L. M., "Identification of Friend or Foe" Coast Artillery Journal. Vol LXXXIX #6(Nov-Dec 1946).

War Department, FM 4-95, "Service Of The Radio Set SCR 296", 15 Sept 1943.

ILLUSTRATIONS

Figures 1a, 1b, 4, 5, 6a, 6b, 7a, 7b, 7c, 8, and 10 from War Department, FM 4-95, "Service Of The Radio Set SCR 296", 15 Sept 1943.

Figure 11b from War Department, FM 4-96, "Service Of The Radio Set SCR 582", 9 Nov 1943.

Figure 11c from Orman, Lt Col L. M., "Radar, A Survey, Coast Artillery Journal. Vol LXXXIX #2(Mar-Apr, 1946).

Figure 11a from Thompson, George R., and Harris, Dixie R, and Data for fig 2 from Oakes, Pauline M., U.S. Army in World War II, "The Signal Corps, The Test.", Office of the Chief of Military History, United States Army, Washington, D.C. 1957.

Figures 2 and 3 by author.

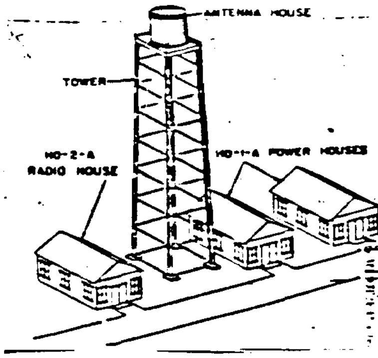


Fig 1 a

HEIGHT	RADAR HORIZON
100 FT	25,000 YDS
150	30,000
200	35,000
250	40,000
300	42,000
350	45,000
400	50,000
450	52,000

Fig 2

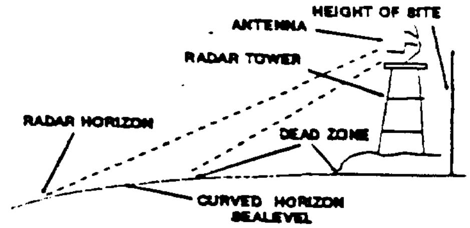


Fig 3

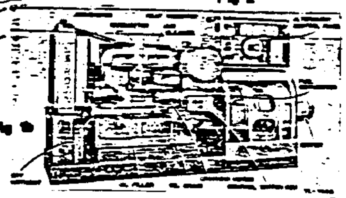


Fig 1b

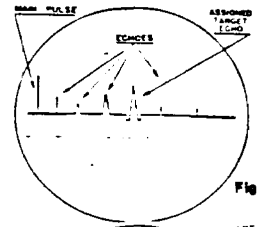


Fig 6b

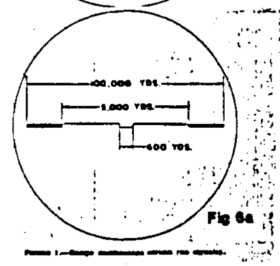
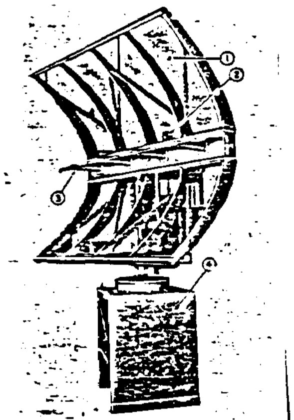


Fig 6a



1. Reflector.
2. Lobe-switching mechanism.

Fig 4

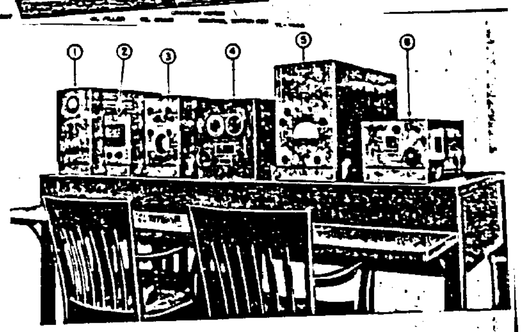


Figure 8.—Indicating equipment.

1. Rectifier RA-40-A.
2. Indicator I-110-A (azimuth tracking motor).
3. Oscilloscope BC-718-A (azimuth).
4. Control Unit RM-38-A.
5. Oscilloscope BC-719-A (range).
6. Range Unit BC-722-A.

fig 6

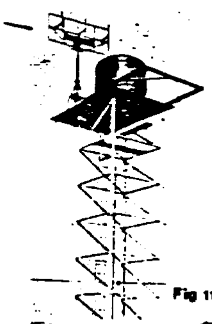


Fig 11c

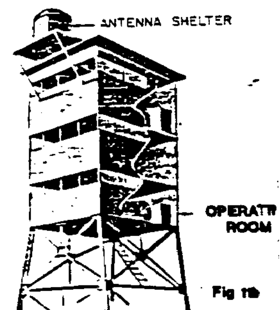


Fig 11b

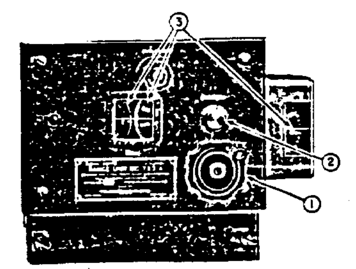
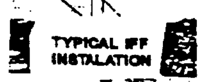


Figure 22.—Range unit (reading 19,620 yards).
1. Range handwheel. 2. ZERO ADJustment. 3. RANGE dials.

Fig 8



TYPICAL IFF INSTALATION

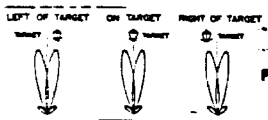


Fig 7b

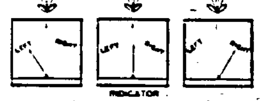


Fig 7C

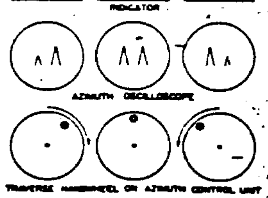


Fig 7a

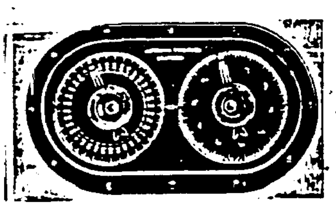


Fig 9

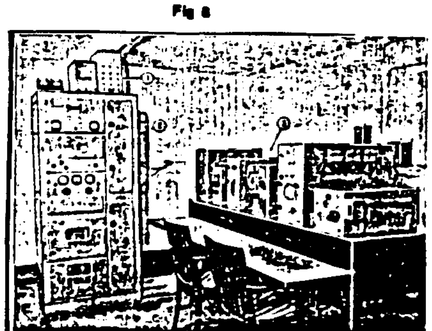


Figure 5.—SCR-296-A operating room.

Fig 10

Fig 11a