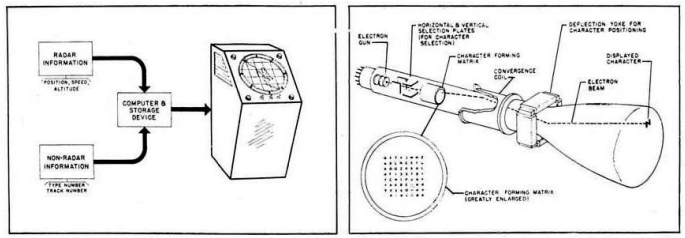


WRITING COMES EASY to Charactron. Left panel shows how radar and operator data are combined; tube operation is shown at right.

'Educated' Tube Will Aid Air Defense

By Philip Klass

San Diego—Convair's Charactron, the "educated cathode ray tube" which can print out up to 25,000 letters and numerals per second on its face, has taken on an important new military job: Used in air defense equipment, it identifies targets on radar scopes by displaying coded information as to aircraft type, friend or foe, speed, altitude, and track number.

Charactrons are being built for Air Force and Navy. In addition, the Charactron should have similar important applications to civil air traffic control.

First unveiled nearly three years ago at the National Institute of Radio Engineers convention by Joseph T. McNaney, its inventor, Charactron created quite a stir (AVIATION WEEK Mar. 24, 1952, p. 35). Some publishers viewed it as the key to a new rapid printing process. Then it dropped from public sight.

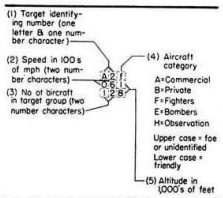
In the intervening period, Convair has been quietly perfecting and setting up to produce the new tube. Troubles which the electronics industry first encountered in setting up to make conventional TV-type cathode ray tubes were multiplied many fold at Convair because of the Charactron's added precision and complexity. The company's lack of experience in this field also made the learning process more painful. However, Convair expects to be turning out four 19-inch-diameter tubes per day in the near future.

▶**How Charactron Operates**—In the Charactron, a small matrix with 64 (or more) different letters, numerals, and symbols cut in it (stencil fashion) is located between a conventional electron gun and fluorescent tube face. By applying appropriate voltages to a set of vertical and horizontal deflection plates, located between the gun and matrix, the electron beam can be squirted through any of the matrix characters. In passing through, the beam's cross section is formed into a corresponding shape. The beam is then centered by a convergence coil.

By applying another pair of appropriate voltages to a second deflection system, located between the matrix and screen, the character-shaped beam can be deflected to position the letter, numeral, or symbol at any desired spot on the screen (see sketch, above, right).

By proper selection and sequencing of the two pairs of deflection voltages, any required intelligence can be written on the Charactron screen. The tube's rapid scan rate, and the persistence of its fluorescent screen, make it appear to the human eye that all characters are printed simultaneously.

▶**Radar Display Problem**—The Charactron may solve one of the most pressing problems of air defense and civil traffic control radar operators: how to keep track of a variety of targets on their scopes. Present PPIs show only target azimuth and distance, plus, in military radars, whether the target is friend or foe. (When civil aircraft are equipped with radar transponder beacons, civil controllers will also be able to identify targets.)



NINE-CHARACTER display completely describes target on air defense scope.

But there is other important information, particularly for military radar operators, such as airplane altitude, speed and track number. Military heightfinder radars and tracking computers can determine this information, but displaying it on a conventional PPI is the problem.

In the past, the ground controller has had to assimilate information from several scopes simultaneously, or else resort to plotting boards to which the data is manually transferred and combined.

▶**Charactron Solution**—The Charactron, and its associated electronic converters, can automatically combine and display information from surveillance and heightfinder radars, from tracking computers, plus manual inputs such as the number of aircraft in a flight, on a single PPI. Several hundred aircraft can be displayed in this manner, Convair reports.

This explains why the AF's air defense (Lincoln Lab) group, the Navy, and the Army reportedly are keen on the new tube.

In one typical arrangement, five different bits of information about the target can be displayed in a nine-character group, three characters wide and high.

The center of this three-by-three character group will appear on a PPI in a position corresponding to the target's azimuth and range (see sketch, top, right).

The two top left-hand characters identify the target by track number. The two middle left-hand characters show its speed in hundreds of miles per hour. The bottom two left-hand characters show the number of aircraft in the target group.

In the extreme right-hand column, the top character shows the type of aircraft, i.e., commercial, fighter, bomber, private, or other, with capital letters used if it is a foe, lower case if friendly. The middle and bottom right-hand characters show target altitude in hundreds of feet.

▶**Conventional Display Possible**—If the radar controller so desires, he can instantly switch the Charactron to a conventional display in which targets appear as single blips, but with certain advantages over even a conventional PPI. For instance, the Charactron and its associated equipment can be designed to place a circle (or other symbol) around unfriendly or unidentified target blips, as shown on sketch, alongside.

Or the brightness of the target dots may be set to produce visible "trailing" on the scope face, as shown below, right, to indicate past movements.

The target display format, three-by-three in the example cited, can be made any size and shape, within practical operating limits. The display format described is one used on a position display equipment which Convair built for the Navy.

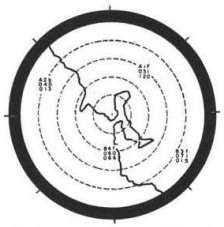
▶**Airborne "Private Line" Display**—Another important use for the Charactron is in the long-awaited "private line" type ground-to-air communications.

Instructions from ground controllers could be transmitted to individual aircraft by radio data link, then displayed in the cockpit on a small storage-tube version of the Charactron (Hughes Aircraft has developed a small airborne storage-tube version of the Charactron).

Instructions for each plane could be transmitted in a fraction of a second, using a relatively narrow bandwidth.

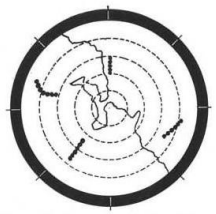
▶**How It Started**—The keen military and civil interest in the Charactron is in marked contrast to the situation in 1941-42 when McNaney patented the basic idea. Convair's first interest in the device occurred in 1949, three years after McNaney had joined its staff. The company was submitting a proposal for the AF's advanced interceptor fire control system competition and the Charactron seemed like a useful device in such a system.

Although Convair lost out to Hughes in the competition, its proposal brought the Charactron to the attention of G. T. Gerlach, Convair's patent counsel. Gerlach had been recommending that the company set up separate projects to exploit patentable ideas outside the airframe business conceived by its engineers.



FOUR TARGETS are shown on PPI in one arrangement used with Convair Charactron.

CIRCLE AROUND BLIP (lower left) indicates foe or unidentified target.



TARGET'S COURSE may be shown by producing visible trail of blips on scope.

Using the Charactron as an example, Gerlach made his pitch again. This time, Floyd Odlum, then Convair's chief, gave the approval to set up a separate Charactron project and named Gerlach to head it.

▶**Enthusiastic Reception**—When Convair first publicly disclosed the Charactron in March 1952, it played up the tube's potentialities as a rapid read-out device for electronic computers and its rapid printing process possibilities. At the time the company had considerably more optimism than actual experience in converting Charactron output to permanent printed form.

However, the company was deluged with inquiries from business machine firms and publishers, Gerlach says. A market survey by two research organizations confirmed that there was an excellent market, "if and when" a suitable dry-printing process for reproducing Charactron output was developed. Investigation indicated that this was a fairly long-term development.

▶**Military Interest Develops**—Meanwhile Convair learned that Navy BuShips was working on a semi-automatic aircraft identification system to provide information such as friend or foe, airplane type, altitude, airspeed, and track number. Further investigation showed that the Air Force and Army had similar problems. The Charactron seemed like a natural for displaying such information.

Deferring its commercial market aspirations, Convair farmed out the development of a dry, highspeed printing process to Horizons, Inc., Cleveland, in order to concentrate on the military market.

▶**Learning the Hard Way**—The art of building CRTs, a closely guarded competitive secret in the electronics industry, was something Convair had to learn the hard way. In fact, Lincoln Labs people actually urged the company to avoid "contamination" with techniques employed in producing low-cost TV picture tubes, Gerlach says. The reason was the much higher order of reliability which the military services required.

For example, a TV picture tube is guaranteed against failure for one year, which means about 700 operating hours in the average set. However, Lincoln Labs wanted the Charactron to operate for a minimum of 4,000 hours without failure, and for 10,000 hours if possible.

The added design and manufacturing care are reflected in the difference in price between a TV picture tube and the Charactron. A 19-inch TV tube sells for around $30-40, whereas it will be some time before Convair gets the price of the 19-inch Charactron below $2,000.

▶**More Money for Less Air**—One factor which affects tube life (and cost) is the degree of bulb evacuation. Gas left in the tube ionizes and bombards the cathode, eventually destroying it. Whereas TV picture tubes are evacuated for a mere 45 minutes, the Charactron goes through a 24-hour cycle of heating and evacuation that brings bulb vacuum down to 2 x 10^{-5} microns, Gerlach says (a micron is 1/1000th of a millimeter of mercury).

Following Lincoln Lab's advice, Convair has tried to learn the CRT art rather than hire people with know-how in this field. For instance, of its 10 tube makers, only two have had previous CRT experience. On the engineering side, all were newcomers to the picture tube field. Convair has called upon outside consultants and Gerlach credits Massachusetts Institute of Technology scientists for their help in electron optics design and fabrication techniques.

▶**Doubting Thomases**—Some segments of the electronics industry were skeptical as to whether an airframe manufacturer could bootstrap itself into this ultra-precision business, Gerlach says.

When an air defense system contractor had a requirement for more than 100 radar display tubes, Convair was given only 60 days to produce three prototype Charactrons to qualify for the business. This came at a time when the company had not yet set up its manufacturing operations and lacked many of the necessary machines.

However, fortunately for Convair, a small Eastern TV tube manufacturer had recently gone out of business and all of his machinery was up for auction. When the opening gavel sounded, Convair representatives were in there bidding. Before it was over, they had the machinery they needed.

▶**Brute Strength Approach**—Working days, nights, and weekends, Convair people were able to meet their 60-day deadline. The big production order then followed. Gerlach admits that the brute-strength approach has been necessary but costly, with a high number of tube rejects at the start. Out of one batch of 50 "bottles" received from the glass tube manufacturer, Convair rejected 22 even before it started to make them into Charactrons, Gerlach says.

Fabrication of the Charactron's complex electron optical system, with its double set of deflection plates, electromagnetic lens system for converging the beam, and deflection yoke assemblies, coupled with a stringent display linearity requirement, has posed many difficult problems.

In some cases, Convair reports it has had to pioneer new techniques, then design the machine to employ them. For example, the helical accelerating winding (used to increase display brightness) is "inked on" the sloping throat of the tube, using a Convair-developed machine.

By keeping the size of the character matrix small, tube design problems are simplified, but this introduces manufacturing problems. In a typical matrix, the characters are only 0.012 in. high, yet must be clean-shaped. This requirement forced Convair to develop an improved photo-etch process for making the matrix.

▶**A Separate Operation**—The Charactron project has been set up as a separate entity, with its own 13,000-sq. ft. building located several miles from the main Convair plants. The project maintains its own set of financial books, establishes its own overhead rates.

The present staff numbers around 70, of whom approximately 45 are electronic and mechanical engineers, physicists, chemists, and technicians.

Many of the electronics people developed the associated equipment which is required to convert input analog or digital signals into correct deflection voltages for the Charactron. One novel experimental converter accepts Morse code and automatically translates it into corresponding letters and words on a Charactron.

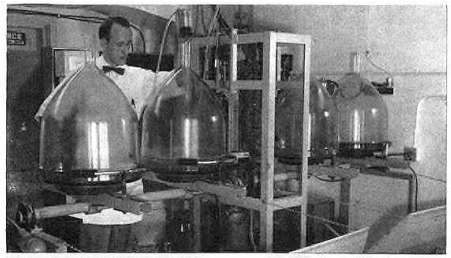
▶**Over the Hump**—Although Convair may not yet be out of the production woods on its Charactron project, Gerlach believes the clearing is in sight.

If this appraisal is correct, the company justifiably can be proud of having made a place for itself in one of the toughest phases of electronics.

Precision Steps in Charactron Production

CHARACTER-FORMING MATRIX, smaller than a dime, is checked for sharpness.

ELECTRONIC GUN is assembled under glass hood by technician wearing lint-free gloves.



CHARACTRON CATHODE RAY TUBE has vacuum of 2x10^{-7} microns. That is one reason the 19-in. tube costs so many more times than a TV tube of the same size.