Training of Radar Operators

By Lieutenant Colonel Leonard M. Orman, Coast Artillery Corps

The amount of reliable data that can be obtained from any radar is dependent to a great extent on the proficiency of the operator. It is admittedly difficult to operate a radar with a high degree of effectiveness under all conditions. Therefore, the operators must combine high native intelligence, good visual acuity, manual dexterity and great concentration with an intense interest in the work if radar is to be used to maximum benefit. To become proficient, the operator must practice continually.

The more the operator is able to understand about his radar equipment and about the tactical situation in which it is used, the more useful will be his performance. Many peculiar results have been obtained with radar that have been humorously attributed to phantoms, pixies, gremlins, and the like for want of a reasonable explanation. If the operator understands fully the limitations of his radar he will often be able to recognize the false character of many types of phantom contacts.

Long experience in observing a radar indicator enables the operator to notice many minute variations in the echo that are not apparent to a less skilled man. By noting these small variations, the operator is often able to estimate the size and type of the target. In one case, a very alert operator was often able to tell not only the approximate number of planes in a group, but the type of plane, by observation of only the radar indicator. Such a performance is extraordinary, but it illustrates the excellent results that can be obtained by close observation coupled with wide experience. An unskilled operator can see only range and azimuth, and that perhaps erratically; a skilled man sees in each pip much information beyond the normal range and azimuth measurements.

In general, a skilled operator can detect a target at a greater range than an unskilled operator. This ability results from very close observation of the scope and a "feeling" for the appearance of echoes that are lost in the "grass" to

The British Waafs shown here illustrate the fact that Great Britain trained and used thousands from the Women's Auxiliary Forces to be operators of radar equipment. In many instances women make better operators than men since they seem to bear up better on work which tends to be monotonous.

the untrained eye.

All operators should be schooled in:

1. Theory of radar.
2. Capabilities and limitations of radar to include the effect of weather on the particular set or sets with which they are to work.
3. IFF.
4. Operational techniques.
5. Pipology.
6. Countermeasures, and defense against countermeasures.

No attempt should be made to have operators understand all of the electrical circuits that exist within a radar. This is the function of the repairman and repairs to a set are his responsibility. Operators should be taught to keep hands off if the set needs repairs.

The balance of this article will be confined to operational techniques since pipology and defense against countermeasures are considered broad enough to deserve separate treatment and the other subjects have been covered previously in this series.

When the general instruction has been concluded, the operator should be introduced to the set which he is to operate. Correct step-by-step procedure in turning on and off, calibrating, tuning and operating each set should be demonstrated. The various uses of the set should be explained. Ways to recognize improper operation and inferior performance should be described, along with suggestions for correcting these faults. Finally, results to be expected from his set should be given so that the efficiency of similar radars may be compared, and steps taken to correct performance when it is not up to standard.

Operational Techniques

Various radars differ in physical appearance. Each has its special knobs, types of presentation, and gadgets, depending on the primary function of the individual set. Regardless of this physical variance, there is much that can be said, in a general sense about good operational techniques for all radar sets.

In order to gain the maximum tactical advantage from radar at all times, the radar operational techniques must change as the situation changes. Methods of operation must be flexible. Common sense and a thorough knowledge of the other elements of the battery with which the radar is working must determine which of these techniques should be used in any given situation.

A brief outline of the various basic controls and indicators will form a foundation for a more detailed discussion of these techniques.

1. Range scale. What scale should be used under what conditions?

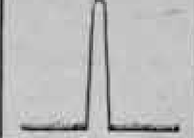
2. Gain control. This corresponds to the volume control of a broadcast receiver. Should it be set high, low, or medium?

3. Antenna rotation. Should the antenna be rotated continuously? How fast should it turn? Should it always search an area of 360°? If stopped, for how long.

4. Range. How should ranges be read? Should the range step and associated dials be used when provided? Should estimated ranges be used with the assistance of improvised scales?

5. If the radar set is equipped with two or more types of cathode-ray indicators, which should be used, and under what conditions is one preferable to the other?

6. Azimuths and Elevations. Is it possible to match pips and still be off target?

SIGNAL TO NOISE RATIO	TYPICAL PATTERN	ECHO STRENGH
1 to 1 or less		Intermittent echo barely perceptible
2 to 1		Weak echo
4 to 1		Good echo
8 to 1		Strong
16 to 1 or greater		Very strong or Saturating echo

The above sketch shows the variation in pattern in relation to the ratio between the signal and "noise."

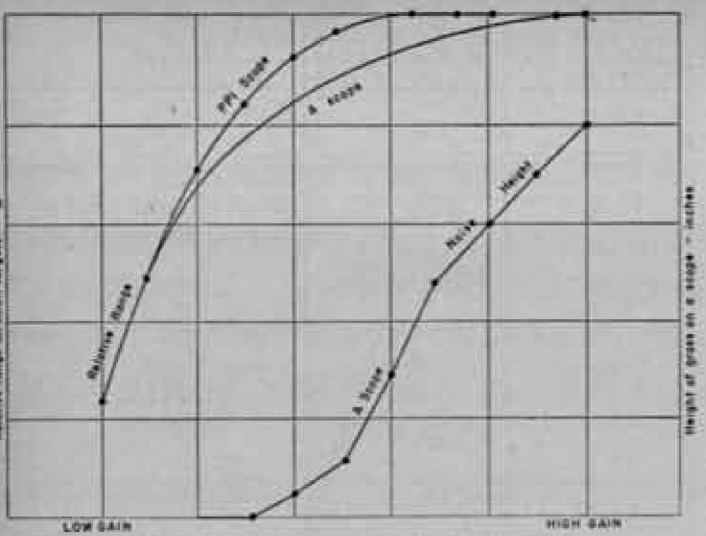
The answers to these questions, for different types of radar sets operating in various tactical situations, will provide the operator with the foundation of operational techniques. From this foundation, each special circumstance will require variations which can only be determined by radar operating experience and common sense.

Each type of radar has been designed for one specific field of application and there is nothing that the operator can do to modify these purposes. An air-search radar is a poor surface-search radar, and vice versa. Each of these types may serve in an emergency as a fire-control radar but they cannot be expected to furnish ranges and azimuths with the same degree of accuracy as a fire-control radar specifically designed for that purpose. In case of failure of either the air- or surface-search radars, the fire-control radar may act as a search set.

Surface-Search Radar

Long-range search for large targets.

It is essential that large surface targets be detected at the maximum possible range of the radar so that an effective defense can be employed. The range scale used should be



Variation in maximum range as function of receiver gain

These curves illustrate the decrease in performance of a radar on a small target as the gain is reduced. Compare the curves showing the range on the A scope and the PPI with the curve that shows the grass height on the A scope. When the gain is reduced sufficiently to make the grass only one-eighth inch high, the radar is approximately 95% effective. If further reduction in gain is made, the performance falls off very sharply.

longer than the expected maximum range on ships. The gain control should be set for maximum readability of an echo at 30,000 to 60,000 yards. This setting must be previously established for each particular radar set. The antenna should be rotated at the slowest available speed; an occasional sweep should be made using the manual control, if one is provided. Radars which have both A and PPI scopes will usually show the initial contact on the A scope before it appears on the PPI. If a contact is established, stop the antenna only long enough to obtain an initial azimuth and the A scope range. Attempt to classify the contact specifically by utilizing previous knowledge of the capabilities of your particular radar. Data concerning previously observed maximum ranges on different types of ships, size of pip, and composition of pips will be useful in making this decision.

Assume for this discussion that you are not interested in firing on the new contact. However, you might desire to keep a rough track thereof. Your procedure, then, would be to continue a long-range search, reading azimuths and ranges of the contact "on-the-fly," without stopping the antenna. With practice, sufficiently accurate data may thus be obtained to maintain a reasonably exact track. The important consideration of the on-the-fly operating technique is that you are continuing to search for other contacts without sacrificing the search efficiency of the radar by stopping its antenna on a contact that may not be of primary interest.

Ranges read on-the-fly may be more nearly accurate and easier to obtain if the A range scope is equipped with a scotch-tape scale, and if the PPI is marked with thinly inked range circles. Azimuths can be estimated directly from the PPI.

Short-range search for small targets.

This might be called the submarine or PT-boat search. The range scale used for small-target search should usually be the shortest available scale, although on some sets it may be found that the mid-range scale can be used to better advantage. The receiver gain should be varied during the entire search, its setting depending on the amount of sea return present and other tactical considerations. Look for periscopes close, increase the gain a little, and search near the outer limits of the sea-return area for surfaced submarines and small patrol craft. Remember that sea return is basically the same as an echo from a target, and that it must be present if a small target echo is to be detected.

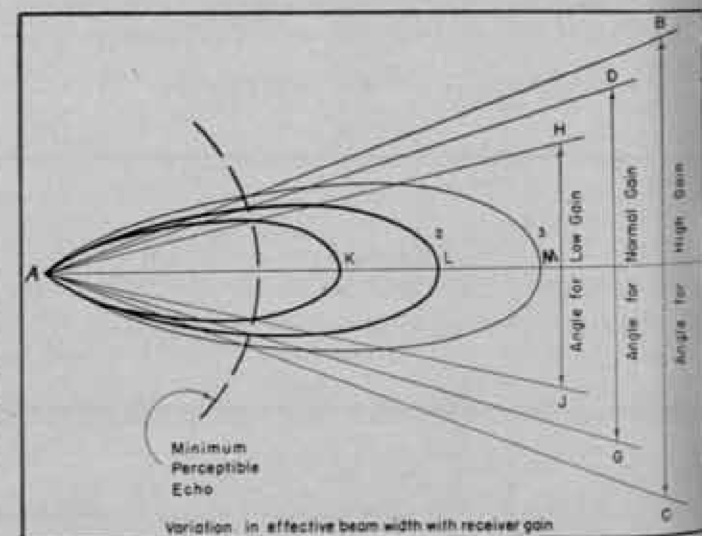
Operating experience will determine the correct gain setting for different amounts of sea return. Antenna rotation should be as slow as possible; again, make occasional manual searches. New targets should appear on either the A scope or the PPI almost simultaneously, provided the gain is set high enough for PPI operation. These indicators should be alternately observed for equal periods of time to reduce eye strain and monotony. If a contact is made, follow the procedures listed for long-range search. If the target is to be fired upon, coach the fire-control radar on to the contact and resume the search immediately.

Auxiliary fire control.

If your battery has no fire-control radar, or if such equipment has failed, you may have to depend completely on surface-search radar for the control of gunfire.

The radar operator must furnish more accurate ranges and azimuths than those provided by obtaining them on the fly. The antenna must be stopped to obtain accurate ranges from the A scope and azimuths from the azimuth scale. If no A scope is available, the most accurate method of obtaining this data must be selected, depending upon the particular radars in use.

For radar spotting, the antenna must be fixed on the target while the shells are in flight so that splashes may be noted on the radar indicator. In spite of the high degree



If a target lies on the lobe axis, and the receiver gain is varied the size of the received echo will also vary. For high gain, the echo will be proportional to the line AM, for medium gain to AL, and for low gain the echo will be proportional to AK. Thus, at high gain, the radar can see the target if it is within the angle BAC since all echoes received in lobe 3 within this angle are larger than the minimum that can be detected. When the gain is reduced to normal, angle DAG applies and for low gain, angle HAJ is the limit.

of accuracy necessary to the satisfactory solution of fire-control, the safest procedure is to make one or two complete antenna rotations every minute or so to make sure that bigger game is not approaching from a different direction.

Composition.

Continuous practice is needed by all radar personnel before they become proficient in analyzing the pip on a radar screen. Every opportunity in analyzing should be utilized when friendly ships are near in order to make notes on the composition of an echo.

Familiar double-peaked echoes are often noted from large ships, such as battleships and carriers at medium or close ranges. Fluctuations of the pip are different when the reflecting object is a rolling destroyer or a more stable cargo vessel. These are among the tricks of the trade that must be mastered by an operator before he can be considered an accomplished operator.

Air-Search Radar

The continually changing tactics of the enemy relating to air attacks makes it difficult to outline the best operating techniques for this type of radar.

For long-range, early warning, air-search radar, the problem involved is that we want to make initial radar contact with the enemy attack groups at the maximum radar range.

The range scale should be set to provide the longest available range in accordance with the observed maximum ranges of the particular radar. The PPI and the A scopes should be watched alternately with the antenna rotating slowly. Receiver gain should be set for maximum readability of the indicator under observation. This means that the gain control will be at a different position for A and PPI operation.

Under radar contact, the antenna should be stopped and the echo scrutinized to determine the composition of the pip. The target should be challenged and the A scope should show the IFF response if the target is friendly.

The slow antenna rotation should be resumed immediately, and the all-around search continued to detect other possible targets. The procedure to follow at this time will vary, depending on factors too numerous to present here.

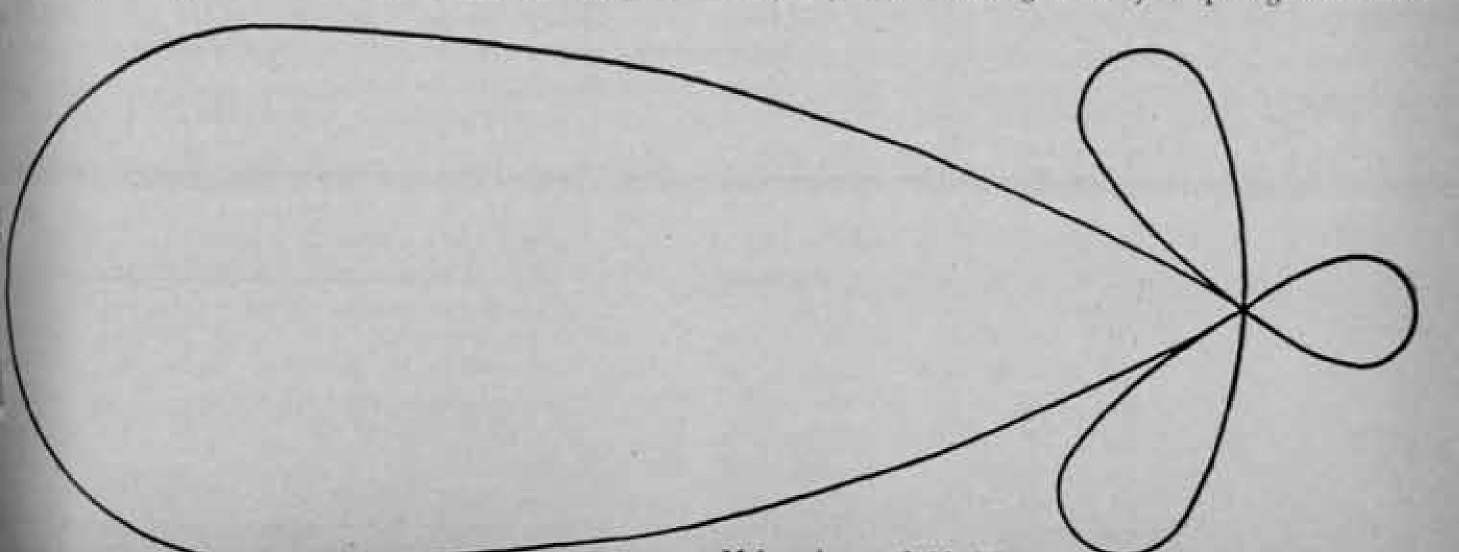
Azimuths should be obtained from the PPI and ranges should be estimated directly from the PPI.

When a plane attack is imminent and when raids are approaching from different directions, short-range search will be in order. Here, continuous antenna rotation is a necessity. The range scale should be set at its medium position, and the gain adjusted for maximum readability of the PPI. Ranges and azimuths are obtained in the same manner as discussed for long-range search. The speed of antenna rotation should be increased as the attack closes and the operator must be prepared to shift to the short-range scale as soon as the targets have reached the outer range limits of this scale.

Tracking targets over land masses is not as difficult as it may seem at first, although it is an art which requires considerable practice. Whenever planes fly over land masses, their contacts can not always be seen on the PPI. When this is the case, use the A scope and the shortest range scale on which the plane can be seen. With the antenna in manual rotation, train slowly through the land mass, watching for a bouncing pip among the steady ones. This will indicate the presence of a plane over land, and the operator may then read its range almost as accurately as if the land were not there. To find its azimuth, adjust the antenna carefully for maximum activity of the bouncing pip. When practicing this technique on friendly planes, IFF affords an excellent method of checking from time to time to be sure that you are on the plane.

When attacking groups of planes have closed within 20 miles, it is essential that close cooperation be maintained between the air-search radar and the fire-control radars. The guns must often be talked on directly from the air-search radar, or by electrical target designation systems connected to that radar. The antenna should be rotated as fast as possible, and the range scales used should be the shortest available on the radar. While this measurably decreases the air-search efficiency, primary consideration must be given to fire-control when planes have closed to attacking ranges.

Side lobes are especially troublesome in this type of operation and the operator must be quick to distinguish the extraneous echoes involved. It will help to reduce the gain as far as practicable, in order to minimize these echoes. They may often be distinguished by comparing their width



Main, minor and side lobes

(in degrees) with the echo received due to main echo radiation.

Composition.

The A scope is of the greatest value when the composition of a contact is to be obtained. Constant drill by operating crews in estimating the composition of friendly planes is of inestimable value as a means of obtaining reliable data to be used on enemy raids. Composition of raids should be checked at regular intervals, about every 20 miles of target travel, to make sure that any splitting of attack groups may be noted.

Men assigned to search radars should be rotated every thirty minutes. Periods of continuous observance of PPI scopes longer than this are injurious to the eyes.

Fire-Control Radars Employing Pip Matching Scopes. (K-Indicator)

A handy rule to remember when operating a pip matching type of scope is to train toward the smaller of the two pips. The pointer elevates if the left pip is lower. A rule to follow is the THREE L RULE. For the trainer: left, low, left; meaning if the *left* pip is *low*, train to the *left*. For the pointer: left, low, lift; meaning if the *left* pip is *low*, *lift* or elevate the antenna.

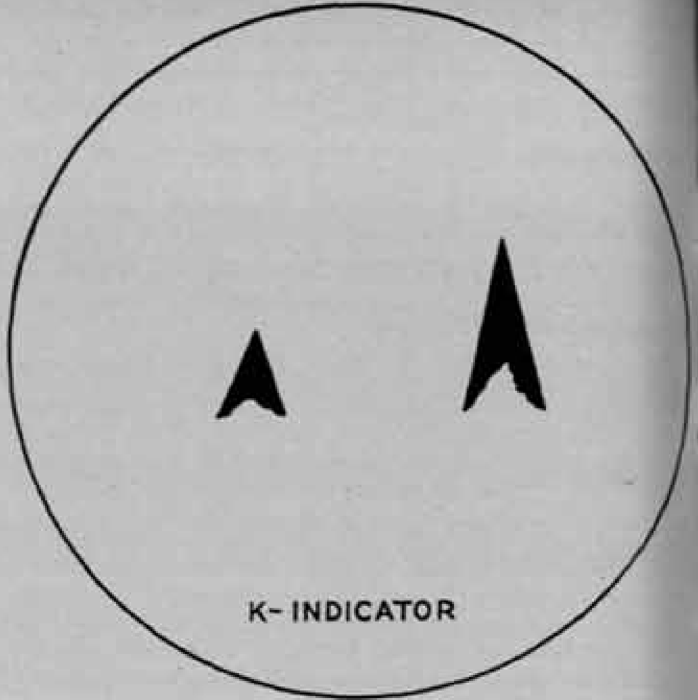
Some pointers think of the left pip on their scope as an indication of the position angle of the antenna. If the left pip is low in relation to the right pip, the antenna is pointed below the target. If the left pip is high, the antenna is pointed above the target.

When you train or point toward the lower pip, and it gets lower rather than higher, it indicates that you have a minor lobe contact. The target actually is 15° or 20° to the left or right of this.

Sometimes the trainer will be able to match up two pips, but no pips will show on the elevation scope. This can also be caused by minor lobes, and the trainer should train back and forth until the pointer and the trainer both can see two pips.

In order to realize the full accuracy possible with fire-control radar, the operators must practice making precise measurements of range, and elevation azimuth. Since azimuth and elevation accuracy often depend on matching pip heights, extensive practice in this operation is necessary to develop the operator's judgement to the point where reliable azimuths and elevations can be determined within the rated accuracy of the equipment. Accurate pip matching is difficult and cannot be done well by inexperienced personnel.

The two greatest responsibilities of the range operator are: (1) to keep the pip in the notch, and never let it saturate (flatten on top due to too much receiver sensitivity). The pip must be kept in the center of the notch so that the pip appears even on the pointer's and trainer's scopes. If the pip saturates on the range scope, it will saturate on the trainer's and pointer's scopes, thus preventing them from knowing which way to train or elevate. (2) He must know the position of all controls so well that he can make adjustments to the scope without groping for the knob or taking his eyes from the scope.



Spotting Shell Splashes

It is possible to follow projectiles in flight and to observe the splash thrown up when they hit the water. You can also see shells from the enemy coming toward you on the screen. Since the splash lasts for only three to five seconds considerable training is required before the operator can range accurately on the point of impact. Large shells throw more water up in the air than small shells. Therefore, the splashes produced by heavy guns can be detected at a greater range than those from light guns. In general, the maximum range at which splashes can be detected compares well with the maximum effective range of the guns producing the splashes. High-explosive shells give better splashes than armor piercing or sand loaded shells.

Projectiles that fall very close to the target may appear to be a hit because of the limitations in resolution inherent in radar. Therefore, the absence of splash echoes is not an absolute indication of a hit although the shells are followed toward the target on the radar. In general, projectiles that fall short are easier to detect than those that fall beyond the target, because the range resolution of the radar coupled with the extent of the target in range combine to produce a dead space beyond the target.

Rapid fire may produce a sort of enlarged grass in the area of the splashes because of the continuous fall of projectiles. With salvo fire, however, each projectile produces a single fuzzy echo of short duration. Therefore, salvo fire is much easier to spot by radar than rapid fire.

Because the separation in range between targets required for range resolution is usually much less than that required for azimuth resolution, spotting in range by radar is more effective than spotting by deflection. Unless the azimuth resolution of the radar is very good, the operator will not be able to detect shell splashes that are at the correct range but off in deflection.

Antiaircraft bursts produce radar echoes much less effectively than splashes in the water. The echo is returned partly from the metal fragments scattered through the burst and partly from the hot ionized gases that are the product of the explosion. As the gases expand, they cool; when the gases cool, they lose their ionization. Since the explosion very quickly scatters the metal fragments over a wide area, and because the gases expand very quickly, an antiaircraft burst does not reflect radar pulses for more than a second or two.

Within the short time that the echo is visible it is very difficult to determine the range, azimuth and altitude of an antiaircraft burst relative to the plane at which the shell was fired. A range spot can sometimes be determined satisfactorily; however, the time is so short that it is unlikely that reliable azimuth and altitude spots can be obtained unless the operators are exceptionally alert and well trained.

Manipulation of Controls

For detection of targets at maximum range, the grass must show on the A scope and the "snow" on the PPI. However, the tendency of many operators is to cut receiver gain to a low level in order to obtain an indicator presentation which is sharp, and which shows strong contrast between signals and background noise. This is a dangerous practice. Large signals may continue to show up well on indicators, but the ability of the operator to detect small signals can be greatly reduced. It is necessary that small targets, such as periscopes, and airplanes, be detected at the greatest possible range.

There is no way to eliminate receiver noise entirely. It is always present in sets which are operating properly, but it may not show if the receiver gain is too low. Signals smaller than the noise add to the noise to make the grass higher or the snow brighter. By noting the small change in the appearance of the trace caused by this addition, a good operator is enabled to discern very weak echoes. However, these echoes, which are equal to or less than the noise voltage, cannot be seen if the noise itself does not show.

A properly trained operator will measure ranges always in exactly the same way so that his personal error is small and constant. As a result, the range and azimuth data obtained by a good operator will be more consistent and more reliable than that obtained by an unskilled operator. The skill and dexterity developed by constant practice enable a good operator to measure a range and azimuth quickly. Not only is it desirable that each operator be trained to measure ranges in precisely the same manner on each target, but it is also very desirable that all radar operators be trained in exactly the same operating procedures.

Conclusion

No equipment is better than the man who operates it. Without an operator, a radar set is merely a large box of radio tubes. With a well-trained, alert, interested operator a radar set can become the most important equipment for determining information, in the hands of troops.

Obviously, the techniques presented here will change as equipment and tactics change. In some instances it may be not only practical but advisable to follow another course of action. Resourcefulness based on knowledge and sound judgment should always be the goal and will invariably pay dividends.

Non-Divisional Ground Units to Lose Distinctive Insignia

In a move toward standardization of shoulder sleeve insignia of units other than those of the Divisions, Corps, or Armies, the varied shoulder sleeve insignia which were worn by the small, non-divisional units during wartime soon will disappear. In their place will be seen a predominance of the familiar circular insignia, horizontally divided into equal segments of blue, white, and red, worn by the Army Ground Forces.

General Jacob L. Devers, Commanding General, Ground Forces, has announced several changes in the shoulder sleeve insignia pertaining to units under his command and the War Department has made similar changes in insignia worn by units of the National Guard, and Organized Reserve.

The changes are the result of an effort to decrease individual arm or service consciousness and foster an increased Ground Forces "esprit de corps." To this end, distinctive insignia worn by non-divisional units such as armored, amphibian, airborne, and *antiaircraft artillery*, and the distinctive arc tabs above the shoulder sleeve insignia heretofore worn by members of airborne and mountain units, have been discontinued. Instead these non-divisional units will wear the insignia of the Corps or Army to which assigned. If not assigned to a Corps or Army, these units will wear the insignia of the Army Ground Forces.

Personnel except trainees of each Replacement Training Center are to wear the shoulder sleeve insignia of the Army under whose control the Center is operating.

Personnel at Ground service schools including students under the assignment jurisdiction of the Army Ground Forces, with the exception of those on temporary duty, will wear the present Army Ground Forces insignia.

National Guard and Organized Reserve Corps divisions will continue to wear their respective shoulder sleeve insignia, but the non-divisional ground units of these components will wear the shoulder sleeve insignia of the Army Ground Forces. National Guard personnel will wear a strip with the name of the state or territory below the normal shoulder sleeve insignia when their units are not in the active Federal military service. This will be removed when in active Federal Service. National Guard State headquarters and detachments will wear only the State strip.