What are the defense possibilities normally at the disposal of a home air defense system: the aircraft reporting service, the fighter aircraft, and antiaircraft artillery or rocket units.

The aircraft reporting service can accomplish its mission most easily if it is provided with appropriate radar equipment. In this lies a chance for success, because even the fastest remote-controlled rockets will never reach the velocity of light, on which radar operations are based. The greater the range and altitude of the guided missiles, the greater is the time available for plotting their position. An adequate aircraft reporting organization can assure time in which to give a preliminary warning to the population. Assuming an altitude of 400 kilometers and a striking velocity of 2,700 meters per second, there is a time span of approximately 140 seconds between the moment when the rockets begin their vertical descent and the moment they strike the ground. With an adequately developed alarm system, there would be just time enough to warn the population.

Warning the population is possible only if the aircraft reporting service is equipped with a radar which has a range of at least 1,200 kilometers and an altitude measuring scale capable of ranging to altitudes as high as those attained by the guided missiles.

The use of fighter aircraft in defense against guided missiles is out of the question, unless, of course, the enemy is still working with rockets of the V-1 type used during the last war. Since these are already far inferior in speed and altitude to the

performance of combat planes, it is quite possible to utilize against them the defence system which has to be developed in any case for use against enemy aircraft.

There is no longer any point in committing fighter aircraft against guided missiles. Apart from the fact that it will be impossible from the standpoint of technical control to bring about contact with the enemy target, the physical limitations of the human beings involved will hardly permit such a performance. Although this physical limit may be raised quite high in horizontal flight, it is relatively very low in climbing, diving, and other combat maneuvers.

The only chance of active defence against guided missiles lies in the development of counter-rockets. This is a top priority defense problem.

At the present time there is no information available regarding the development of the counter-rocket. Tactical and technical requirements for them could, of course, easily be set up, but this would be tantamount to groping in the dark until the scientist, the researcher, has determined what technological possibilities exist for a successful construction. Only after research has discovered the methods, can the military man enter the picture in order to examine these methods in respect to their tactical usefulness. Then, through a mutual pooling of ideas, the first steps can be taken towards production.

The all-important question of what to do now arises. There seems to exist the possibility of issuing a preliminary warning,

so that the population will not have to be helplessly abandoned to the effects of this weapon. If it is possible to get them into previously prepared air-raid shelters in time, a great deal will have been gained so far as the passive aspect of defense is concerned.

However, to the author's knowledge, no effective countermeasure is forthcoming in the near future on the active side of defense. It must be expected that an enemy will definitely make use of guided missiles in ever-increasing number, with ever-greater ceiling and range, which will soon extend even across an ocean. The possibility that these missiles will be in reality independently flying atomic bombs grows steadily greater. As long as the situation for active home air defense is negative, there is only one really effective means of defense, the destruction of these weapons in enemy territory. The situation here is no different than the one pointed out in the discussion of long-range night interception; wasps can best be rendered harmless through a destruction of their nest.

Because rocket launcher stations require extensive expenditure for technical apparatus and because remote-controlled guided missiles are guided from them by means of radio, the first step is to determine either through the radio intercept service or through reports by friendly agents the location of enemy stations. The second step is to destroy them, perhaps most effectively by the capture of the entire installation by paratroopers specially trained for this purpose. Also effective would be simultaneous bomber attacks on production plants and stock depots devoted to

guided missiles and perhaps destruction of these, also by means of paratroop or units working in the manner of commando troops on a large scale.

That is the only foreseeable way of meeting this deadly weapon effectively, and thereby carrying out real home air defense operations and protecting the civilian population from a weapon as justly feared as this one. This form of defense may be termed offensive home air defense to distinguish it from active home air defense through aircraft and antiaircraft artillery, rockets and counter-rockets and from passive home air defense, which is exemplified chiefly by the air-raid warning service.

Today the problem of guided missiles affects all nations equally, because even an ocean can no longer offer protection against them. There is nothing to prevent guided missiles being fired from submarines, whose positions would probably be extremely difficult to detect, as long as they travel under water, with engines of the Walter[1] type or of the newly developed nuclear reaction type. For this reason the extensive coastlines of the continents lie directly in the danger zone. In order to solve this most important of all problems in home air defense, a concerted effort must be made by all the civilized nations of the world.

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[1] Code name for a propulsion unit.

II. ELECTRONIC WARFARE

Electronic warfare is also a product of World War II. By the end of the war electronics had developed to such an extent that this field of physics was fast becoming the most important of all. Yet there are many people who are completely unaware of the capabilities or even the existence of electronic weapons, either because they refuse to face the fact or because it exceeds their powers of comprehension, rooted as they are in traditional concepts. Nonetheless, electronic weapons exist, and they cannot be banished from a future war by wishful thinking. Without exaggeration it can be stated soberly and objectively that Germany suffered its decisive military defeat because of electronically conducted combat. The submarine campaign was lost because of it; home air defense was paralyzed by it. It resulted in the ruins of German cities, in the loss of the war. No weapon can be expected to accomplish more.

It may be concluded that a high-level officer can no longer afford to regard electronic warfare as the specialized field of a few experts, and that every commander in a responsible position should be oriented regarding its basic features and be fully familiar with its essential principles.

The fundamentals of electronic warfare are extremely simple. Perhaps the temptation to disregard them is based on just the fact that they seem too simple and too naive. They can be formulated as follows:

a. To interfere with all enemy electronic activity.

b. To protect oneself against all enemy attempts at interference.

As simple as this idea appears to be, its realisation is difficult because the concept is primarily a subject for argument among the electronic experts themselves. And inasmuch as this battle takes place in the military domain, the soldier is the one to suffer first. An extremely close and understanding spirit of cooperation among science, industry, and the military is necessary. The military should not and must not assume an attitude of indifference towards science and technology, nor can the military be permitted to demand that science and technology take over their work and even do their military thinking for them. The contribution of the military consists in recognising the possibilities presented to it by science and to translate these into tactical and technical requirements to be fulfilled by weapons and equipment. In this way, a kind of teamwork is developed.

A perfect example of this ideal teamwork among science and technology, industry and the military, is the England of Churchill during World War II. Here, from the acting head of the government to the furthermost units at the front, all efforts were directed in unison towards the goal of winning the electronic war--with final victory the result.

A warning example of complete disregard for the importance of electronic warfare, with defeat the result, is provided by the Germany of Adolf Hitler during World War II. This is all the more tragic in view of the fact that German science and technology would certainly have been capable of accomplishing the same feats as the enemy. The pioneering work of German scientific thought is well enough known

to the world that this point needs no proof. But an understanding of the importance and value of electronic technology as a weapon was totally lacking--and not alone in the minds of the top-level command of the German Wehrmacht.

But perhaps we learn the most from the bitter experience in life. Every officer in a responsible position should keep the significance of modern electronic warfare clearly in mind while making decisions which involve the organization of day and night home air defense.

Of just what does electronic aerial warfare--collective term used for all activities connected with radio techniques--consist in actual practice?

Its active aspect consists in attempting, in every way conceivable, to determine what technical equipment, both ground and airborne, is being used by the enemy. This includes radio equipment, radar, radio telephones, airborne radar wave lengths and frequencies, and many other things. Reconnaissance can be undertaken by means of ground and airborne equipment, military intelligence, or reconnaissance in force (commando troops). Sometimes, with luck, very important equipment can be found in downed enemy aircraft, as the discovery of *Rotterdam* and *Rodde*[1] illustrates. A knowledge of the enemy's activity in the field of electronics is of such decisive importance that it must be obtained at all costs. No pains or efforts may be spared in this respect, no price may be considered too high, no expedients may be left untried. It is precisely this knowledge that serves as

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[1] Code name for British 10-cm airborne radar set. No further information available. See footnote 13, page 25 for *Rotterdam*.

the basis for all active interference with the enemy's electronic equipment.

Once it has been clearly determined what electronic equipment the enemy is using, the work of developing methods of interference to render its use impossible or at least extremely difficult begins.

Interference can be accomplished by such means as:

a. Jamming transmitters on the ground,

b. Jamming transmitters in the air,

c. Window jamming--tinfoil strips dropped from aircraft, their length corresponding to half the wave length of the equipment to be jammed,

d. Interference in the enemy's radio, telephone communications--static caused by jamming transmitters and disturbance talk on the enemy's own voice frequency,

e. Interference in key communication.

Two examples of completely successful interference operations during the last war will serve to emphasize the significance of this type of activity. The first, the breakout of the German battleships *Scharnhorst* and *Gneisenau* in the English Channel on 12 February 1942, was made possible only by the fact that the British radar stations had been completely incapacitated by jamming transmitters. The second was the total paralysis by the British of German air defense during the attack on Hamburg on 25 July 1943 by the use of tinfoil strips, accompanied at the same time by jamming activity from ground and airborne transmitters.

The passive aspect of electronic warfare consists in having a

countermeasure for any enemy jamming. To have countermeasures ready is a simple principle, but putting them into practice is often hindered by the limitations of the possible. The production of equipment completely invulnerable to enemy interference cannot be expected. It must always be taken for granted that anyone using the indivisible air for radio communication can also be heard by the enemy, and that the enemy can always obtain information as to the existence and the method of operation of electronic equipment. What can be expected and in fact what must be required is that, whenever new equipment is produced, research and development must be begun on a method by which enemy countermeasures can be met most quickly and effectively.

The problem of making friendly aircraft invulnerable to enemy radar without sacrificing aerodynamical characteristics must be solved in order that their positions can no longer be located. This might conceivably be accomplished by covering the surface of the plane with some non-reflecting material such as synthetic resins or a coating containing glass fibers. Modification of the defender's radar equipment must be considered in case the enemy does the same thing and coats his aircraft with the same material, or one equally unsusceptible to discovery by radar.

In all of this the important thing is which side can come out first with something new and gain a head start. This brings us again to the old tactical principle that two things are necessary for the success of an operation, the element of surprise and the formation of a point of main effort. Here, the element of surprise is of primary importance. The use of an instrument as a weapon with which,

for a while anyway, the enemy is not yet familiar gives the using side the advantage of surprise. As soon as the functioning of this instrument is known and a defense set up against it, it has lost its value, and the search must be resumed for a new surprise with which to obtain another time advantage.

By window jamming all German radar equipment in World War II the Allies succeeded in gaining an advantage in time which was sufficient to enable them to win the air war. The problem of countermeasures against these metal strips is now largely solved and would gain no advantage today, but at that time countermeasures had not yet been devised. Mention has already been made of the catastrophic error committed by the top-level command of the German Wehrmacht in restricting scientific research in electronic countermeasures. In their complete misunderstanding of the significance of electronic warfare, they actually forbade research men to occupy themselves with the problem of counteracting the effects of the window jamming.

That a countermeasure must be immediately ready for use against any enemy interference has still another implication, one which affects the basic structure of a nation and thus goes beyond the limits of the military domain. Not only must science find, through research and development, the ways and means of counteracting enemy interference effectively, but also the electronic engineering industry must be capable of filling production orders rapidly. This latter is something which can be accomplished today only by leading world powers, and not even by these without tremendous work and sacrifice.

If an electronic instrument, as for example an airborne radar,

10,000 of which are being employed at the front, is suddenly jammed by the enemy so that it no longer serves its purpose, research must first of all determine what effective countermeasures can be utilized. If scientific research has done its part, this countermeasure is at hand and can be immediately procured. Procurement in advance is not feasible, since the enemy may happen to take quite different interference measures, which would make necessary a completely different countermeasure. Successful countermeasures depend upon industry's providing them quickly and in the required amounts. Since the enemy action cannot be immediately countered, the interference will continue for a time working for the enemy, and it is precisely this period which may decide the outcome of the war--as was the case during World War II.

Interference operations also include the deceptive measures taken by the enemy for the purpose of enticing friendly fighter aircraft out of their stand-by areas prematurely and directing them to non-existent targets. During the last war, the English employed the well-known Bomber Group 100 for this purpose. Their flying radio laboratories were able to create the illusion that they were entire formations and thus they completely confused the picture of air operations.

The most effective countermeasure for all deception interference maneuvers is a highly efficient radio intercept service. Without it, home air defense commanders would often be completely powerless. The cases in which the radio intercept service produced brilliant reconnaissance results are sufficient to fill an entire book. The

most spectacular successes in electronic aerial warfare were in the reconnaissance field.

The problems of electronic aerial warfare will require the concentrated study of the best and most capable people of any nation. A satisfactory solution of these problems is a <u>sine qua non</u> for successful home air defense. The entire organization of the aircraft reporting service, the control organization for day, night, and all-weather combat as well as for antiaircraft artillery and rocket units, and the organization of headquarters and communication systems--all these are more or less decisively affected by electronics. Electronics have become an all-encompassing technical field, to which a great deal of attention must be devoted.

CHAPTER 10

DEFENSIVE AERIAL WARFARE IN THE FUTURE

I. WHERE SHOULD THE MAIN EMPHASIS BE PLACED?

The attempt to summarize the material which has been discussed in the foregoing pages is guided by the following trains of thought:

Study of Enemy. The first step in solving the problems of a home defense against enemy aircraft is a thorough study of the enemy. The final outcome depends upon having a certain advantage over the enemy in equipment, stage of technological development, and tactics. It must not be assumed that this advantage, once established, can also be maintained. The margin grows relatively smaller from day to day, if a continuous effort to maintain and increase it is not made.

Flexible Long-Range Planning. The top-level command of home air defense operations must be able, in its long-range planning, to predict all technical and tactical eventualities and establish the requirements to be met by scientific research and technological development.

The top-level command must be able to evaluate logically and objectively what is within the realm of possibility today, what is

technically immediately attainable, and what can be accomplished at the moment in terms of personnel and materiel. On the answers to these questions an estimation of the situation and decisions can be made. The concepts of "present" and "future" must not be confused by top-level commanders, for this confusion is fatal. It will lead to countless wrong decisions and finally result in the loss of the war, as the events of World War II proved well enough for Germany.

Since it must be clearly understood that the factors which will decide victory or defeat in aerial warfare are determined during peacetime, the main emphasis in home air defense must be placed on that phase in which a technological and tactical advantage is held over the enemy.

No preconceived idea can be allowed to dictate the placement of the main emphasis. The doctrine of building a point of main effort must not be confined too rigidly, but must remain flexible, to fit itself to the requirements of the moment.

Expressed in more specific terms, the primary problem of defense is the warding off of guided missiles, which may or may not be equipped with atomic warheads. Since at the moment there exists no effective active means of defense against them, the main emphasis is placed on the offensive phase of defense, in other words on the capture and destruction of production plants, launching bases, and stock depots used for guided missiles. If, however, an active means of defense should be found--effective counter-rockets, for example--the main emphasis quite likely would be shifted. The technical developments during the next few years on the guided missiles and

its counter-weapons will determine which type of defense will be used.

Threat of Atomic Attack. The most dangerous planes that the enemy will have will be those equipped to carry atomic bombs. The reasons for this statement require no elucidation. In any case the main effort of each air defense will doubtless be directed toward overcoming this particular danger. No efforts should be spared to determine which of the enemy planes are functioning as atomic bomb carriers. This alone constitutes a difficult technical problem.

If a method should be found by means of which planes carrying atomic bombs could be identified, defense against them would take precedence over everything else. All available defense forces would be concentrated in preventing a carrier from reaching its target. No consideration would be had for the safety of the fighter aircraft, and as many planes as possible would be committed. Antiaircraft rockets would also be launched against the enemy plane, in order to be sure of downing it one way or another.

If the aircraft carrying atom bombs is flying inside clouds or is accompanied by such a strong fighter escort that a direct approach is impossible, antiaircraft rockets are probably the more effective weapon.

Role of Fighter Aircraft. If a rocket-driven fighter plane is available, however, or an interceptor plane like the Lippisch Me 163 or Bachem Natter models, the fighter pilot's chances for success are increased. Although these projects apparently have not yet gone beyond the research and development stage and cannot yet be included

in any concrete planning, very careful attention will have to be given them. If technology should succeed in producing a satisfactory interceptor plane, many problems of defense can be much more easily solved. A piloted, rocket-driven plane is far superior to a jet-propelled bomber in respect to both altitude and speed. The Lippisch Me 163 model was capable of climbing to altitudes above 10,000 meters in two minutes. This plane will create an entirely new set of tactical possibilities.

It is probably wise to place as much emphasis as possible on the development of interceptor fighter aircraft. Development must aim at adequate flight endurance and extremely strong armament (the Bachem-Natter model for example, was to be equipped around the nose with a circle of thirty-six 73-mm rockets), without sacrificing the maximum rate of climb, altitude, and speed.

However, atomic bomb carriers will not comprise the majority of enemy aircraft. Although defense against them is of tremendous importance, it must not be forgotten that there are other enemy planes as well against which a defense must be prepared, and for some time to come these other planes may constitute the enemy's main air strength.

Within this general grouping of planes special attention must be given to a new category of extremely fast planes such as the supersonic fighter, bomber, and transport aircraft. It is highly improbable that the main emphasis will be shifted to this category within the foreseeable future. As has already been brought out in the section on organization and training, the future alone can tell

as whether average pilots will be able to meet the unusually high physical and mental requirements for their operation. These pilots will probably always be an elite group of particularly well-trained and gifted young men—and any "elite group" implies limitations.

__Main Emphasis.__ Where, then, should the main effort in home air defense be made?

As far as the aircraft reporting service, the antiaircraft artillery and rocket units and the air-raid warning service are concerned, there can be no such thing as a point of main effort. These branches must be established systematically and organically within the framework of home air defense in such a way that a complete and unbroken defense network is guaranteed. All the branches have to be uniformly prepared for all eventualities. The same principle applies to the organization and equipment of the higher-level command headquarters.

The situation is different in the case of the fighter aircraft branch. Here opinions may, and probably will, differ greatly, according to the experience, judgment, and temperament of the top command.

Certain points, however, must be considered. For the reasons which have been brought out in detail in this study the main effort in home air defense must lie with the fighter aircraft. Within the fighter aircraft branch, the main emphasis will remain for some time on the conventional fighter aircraft, and here day and night combat aircraft ought to be treated uniformly. The average quality of fighter aircraft personnel must be raised to the highest point

possible. In this way from the very beginning a qualitative superiority over the enemy can be achieved and with it the all-important slight edge.

The all-weather and supersonic interceptor aircraft pilots, who are the specialists of the fighter aircraft branch, limited in number but all the higher in quality to make up for it, tower above all other personnel. It is their responsibility to do combat against whatever enemy specialist planes may appear, be they supersonic bombers and fighter escorts, atomic bomb carriers, or others.

The enemy, too, has his limitations. The difficulties which he encounters are no different than those encountered by anyone else. This is one world, and the men who exploit its forces are all limited by the same factors. Victory belongs to the one who succeeds in achieving and maintaining the advantage in the exploitation of these world forces.

II. CONCLUDING REMARKS

The problems inherent in the conduct of day and night defensive air war have been touched in this study--though by no means exhaustively--, but one final factor should be mentioned, the opening of hostilities. This problem, which goes far beyond the limitations of this study and can therefore only be touched upon here, may be of the most vital significance for home air defense.

In a future war an attacking power, which is unrestricted by political considerations, will be able to launch an offensive from the air with planes and guided missiles without having revealed its preparations. If this initial attack takes the form

of mass penetration flights with atomic bombs and guided missiles against important military targets or area targets in the form of large cities, then it is possible that the outcome of the war may be decided at the moment of its beginning.

An important inference for home air defense can be drawn from the above. The home air defense system must be so constructed that even in peacetime the command organization is ready for commitment in its entirety, and the remaining elements capable of being brought up to strength and, consequently, to full efficiency in a very short time.

This necessitates the presence of a very high percent of active, permanent staff members; specialist personnel should be one hundred percent permanent; and a militia system of the sort used in Switzerland should be worked out for the mobilization of other personnel as they are needed.

The fate of a nation may depend on a home air defense organization of this type--as is proved by the history of World War II.

APPENDIX A

THE FREYA RADAR EQUIPMENT (WITH AND WITHOUT SUPPLEMENTARY EQUIPMENT FOR COMPARISON DIRECTION FINDING)

The Freya was a portable, single cabinet radar[1] which included both distance measurement and adjustment controls. The transmitter had an average high frequency capacity of forty kilowatts and a pulse capacity of eighty kilowatts, with a wave length of two and four-tenths meters. The Huth-Kuehn push-pull apparatus with grid keying was used as a transmitter circuit. Pressure on the key was accompanied by plus two kilovolts, and the time out period during pauses in keying by minus two kilovolts. The anode voltage created by special rectifier tubes amounted to eight kilovolts and the pulse frequency corresponding to a distance range of 300 kilometers was 500 cycles per second, with a pulse breadth of one-millionth of a second.

The Tannenbaum flat-top antenna was used. It consisted of one dipole array (with six vertically polarized dipoles of half-wave-length antenna) for transmitting, and one for receiving. The two arrays, installed one above the other and fastened to a wire mesh screen, could be turned and swiveled about by hand or by means of a motor. The accuracy of direction finding, using the maximum method, was within two or three degrees.

The actual observation and measuring components (circuit diagram, see Sketch 1) consisted of two general view tubes, one coarse and the

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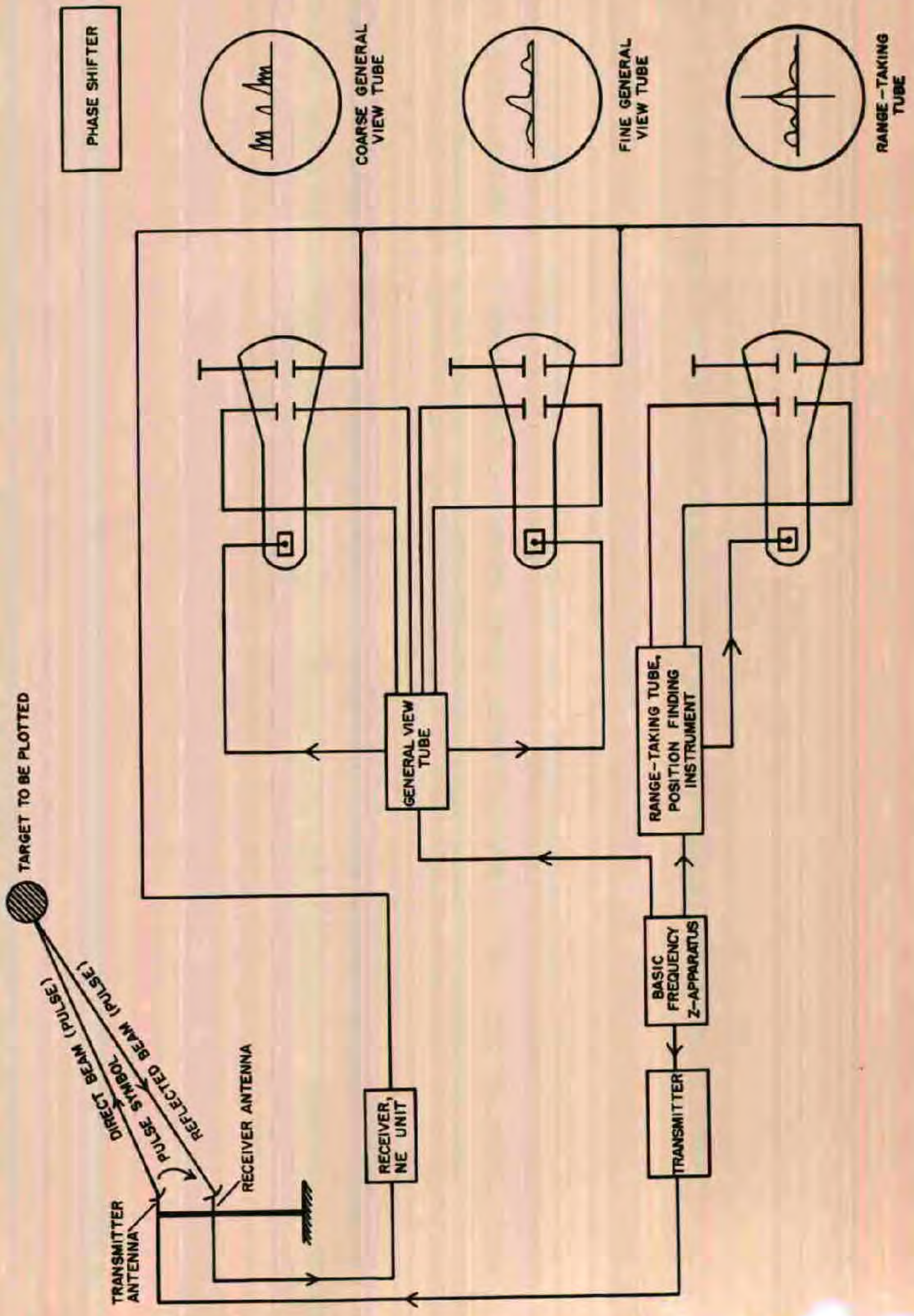
[1] The Freya (Limber Type) weighed 6.82 tons. For similar data see War Dept. TME 11-219, "Directory of German Radar Equipment," April 1945.

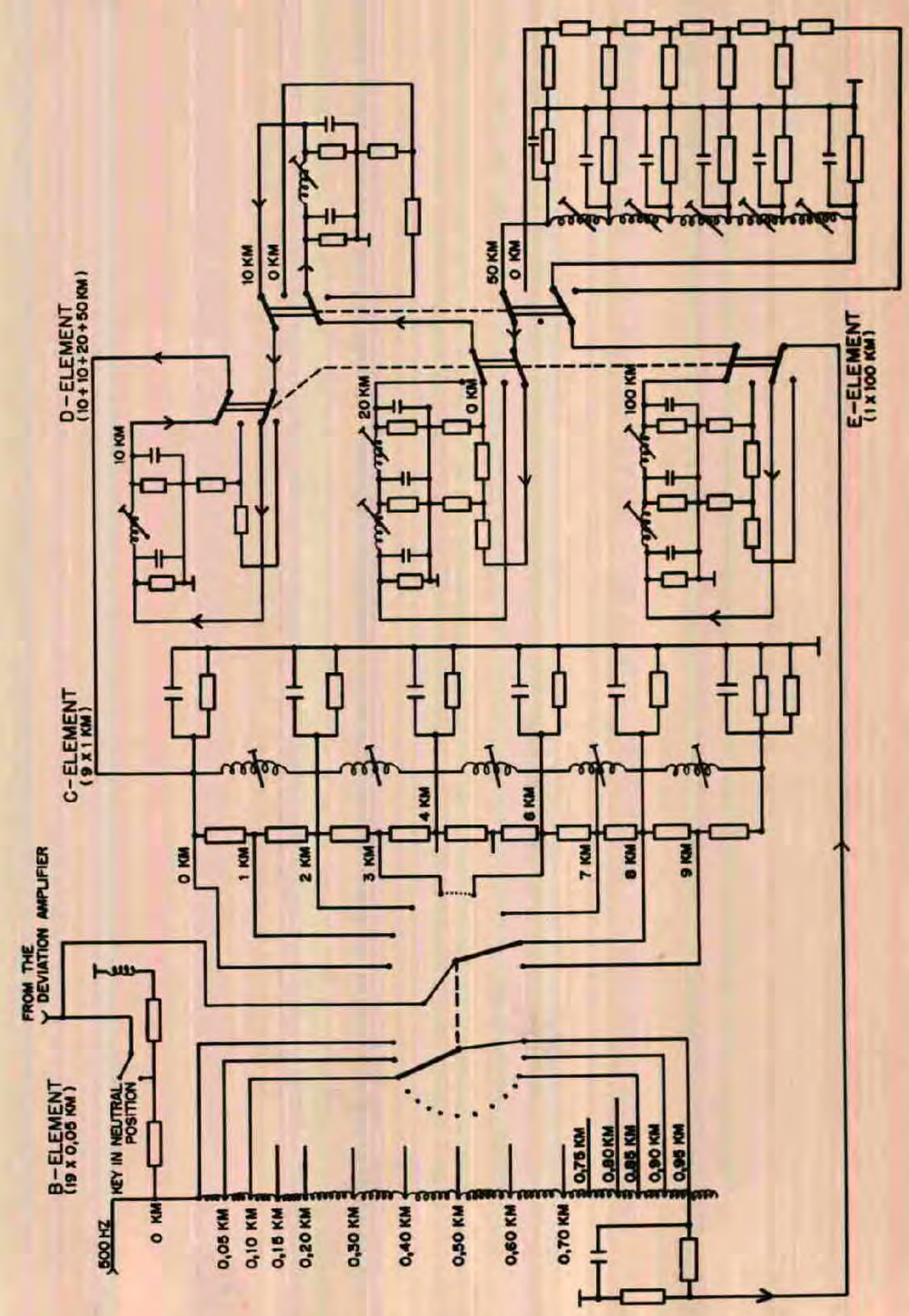
SKETCH I


PHASE SHIFTER
COARSE GENERAL VIEW TUBE
FINE GENERAL VIEW TUBE
RANGE-TAKING TUBE
TARGET TO BE PLOTTED
DIRECT BEAM (PULSE)
PULSE SYMBOL
REFLECTED BEAM (PULSE)
RECEIVER ANTENNA
TRANSMITTER ANTENNA
RECEIVER, NE UNIT
GENERAL VIEW TUBE
RANGE-TAKING TUBE, POSITION FINDING INSTRUMENT
BASIC FREQUENCY Z-APPARATUS
TRANSMITTER

other fine, and a range-taking tube. On the fluorescent screen of the coarse general-view tube, behind a calibrated range scale of the entire 300 kilometers, a section representing up to 200 kilometers of the whole could be seen. A section, which could be chosen at will, representing twenty kilometers of the total range could be seen on the fine general presentation unit. The section in question was adjusted on the screen by means of a corrector, which could in turn be adjusted to the instrument distance scale. The corrector controlled the armature of a goniometer, and the goniometer in turn produced a sinusoidal voltage whose phase could be shifted, and which could thus be utilized for chronography. On the screen of the range-taking tube, a section corresponding to sixty kilometers of the total range could be seen. The center of this section could be moved up and down by a hand crank in graduated progressions of fifty meters each with a phase advancer or calibrated phase changer which adjusted the indications. For purposes of distance measurement the base points of the blips were adjusted to coincide with a point of light projected onto the surface of the observation screen. When the advancer changer was in neutral position, and the pulse originated by the transmitter coincided at its moment of release with the light point, the length of time needed for the pulse to be reflected could be measured in terms of distance by means of a counting mechanism attached to the phase changer or shifter, after moving the corresponding pulse symbol to the neutral position. By careful adjustment of the circuit elements, the phase shifter could be made accurate to one-tenth of one percent.

The phase shifter consisted of four elements, B, C, D and E (see Sketch 2). The B element, which was composed of inductances arranged behind one another, each of which caused a delay of one-tenth kilometer, was supplied with a voltage of 500 cycles per second produced by the generator. By center tapping of the inductances, partial delays of even one-twentieth of a kilometer could be obtained. In order to reduce attenuation, the condenser C was located at the end of the element. In the neutral position, the entire B element was short-circuited first by one arm of the main switch, and then, in nineteen switch-stages, a delay of one-twentieth kilometer for each step was switched on, whereby the counting mechanism also advanced one-twentieth kilometer. Thus the total distance range of the B element was from zero to ninety-five hundredths of a kilometer. The B element had been switched on in its entirety when the counting mechanism had reached the indication "ninety-five hundredths of one kilometer." In the next position of the main switch, the entire B element was again short-circuited, and the slider of another switch arm moved to the first switch position of the C element. This consisted of five individual units, each capable of producing a delay of two kilometers, which terminated at the resistance R. This element was continually supplied with voltage. The delay could be reduced by half by means of potentiometers which covered each individual unit. As soon as the counter had reached the position "one" and the one slider of the main switch had moved to the first tapping point of the C element, additional delays of one-twentieth kilometer each could be switched on by continued operation of the slider in the B

SKETCH 2


B-ELEMENT
(19 x 0,05 KM)
KEY IN NEUTRAL POSITION
FROM THE DEVIATION AMPLIFIER
500 HZ
0 KM
0,05 KM
0,10 KM
0,15 KM
0,20 KM
0,30 KM
0,40 KM
0,50 KM
0,60 KM
0,70 KM
0,75 KM
0,80 KM
0,85 KM
0,90 KM
0,95 KM
C-ELEMENT
(9 x 1 KM)
0 KM
1 KM
2 KM
3 KM
4 KM
6 KM
7 KM
8 KM
9 KM
D-ELEMENT
(10+10+20+50 KM)
10 KM
10 KM
0 KM
20 KM
0 KM
50 KM
0 KM
100 KM
E-ELEMENT
(1 x 100 KM)

element. In this way, the distance range from one to one and ninety-five hundredths kilometers was covered. The slider of the C element now moved forward to the position "two kilometers," and the B element was tuned in again.

The B and C elements together could measure a distance range of from one kilometer to nine and ninety-five hundredths kilometers. When the counter had reached the position "nine and ninety-five hundredths kilometers," both step-switch sliders of the phase shifter transferred the full delaying capacity of both elements into the current flowing to the range-taking tube.

If the operator key of the phase shifter was turned forward, both sliders returned to the neutral position, and the step switch of the phase shifter switched on the first circuit element of the D element. At the same time, the counting mechanism moved forward to "ten kilometers." The D element was composed of nine uniformly constructed units, each consisting of a circuit element for ten kilometers and an attenuating pad to go with it. By means of a step switch, they were supplied with voltage one at a time in turn. Two of the nine circuit elements were combined into one element capable of producing a delay of twenty kilometers, and five of them into one capable of producing a delay of fifty kilometers.

When the first element for ten kilometers' delay was switched on, the two step-switches began to work again, so that now a distance range of from ten kilometers to nineteen and ninety-five hundredths kilometers could be covered. After the second ten kilometer delay circuit had been switched on, the range from twenty

kilometers to twenty-nine and ninety-five hundredths kilometers was covered. When the limit of twenty-nine and ninety-five hundredths kilometers had been reached, one of the ten kilometer circuit elements was switched out by means of a snap switch, and its attenuating pad switched on in its place. At the same time the attenuating pads of the twenty kilometer element were switched off and its circuit elements switched on, so that the range-taking key could measure the range from thirty kilometers to thirty-nine and ninety-five hundredths kilometers.

By switching on the free ten kilometer element again, the range from forty kilometers to forty-nine and ninety-five hundredths kilometers could be covered; and by switching on the fifty kilometer element, the range from fifty kilometers to ninety-nine and ninety-five hundredths kilometers was covered. When the counting mechanism indicated "ninety-nine and ninety-five hundredths kilometers," the delay elements of the B, C and D elements had been fully switched on. If the operator key of the phase shifter was turned forward, all the delay elements were switched off again, and the circuit elements of the E element switched on.

The E element was composed of two complete chain elements of fifty kilometers' capacity each, which were replaced by their attenuating pads when not in use. When the E element was switched on, the counting mechanism moved forward to the indication "100 kilometers." Then the switching procedure already described began again from the beginning, so that the distance range of 100 kilometers to 199.95 kilometers was reached, and with it the range limit.

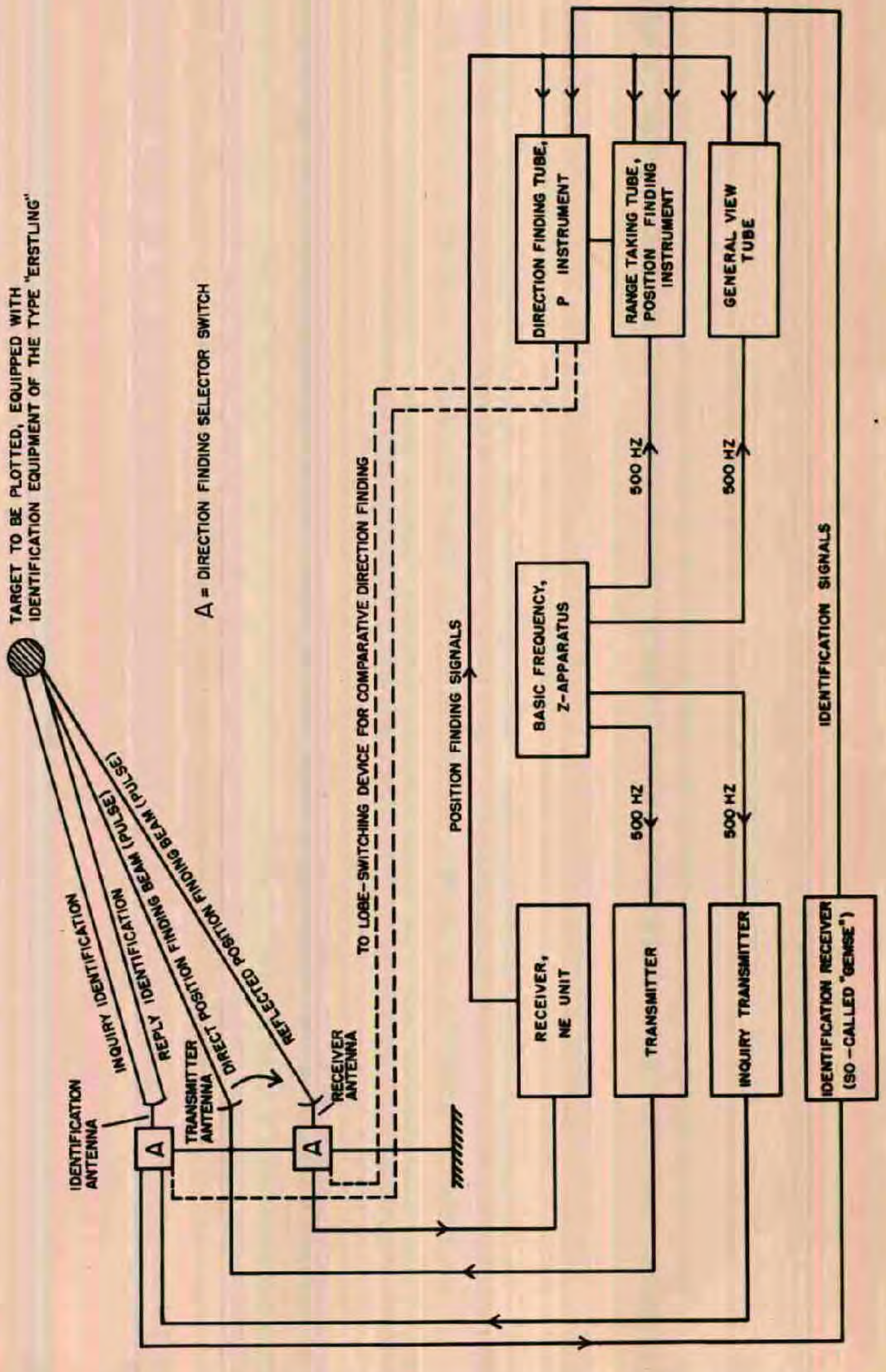
It should be mentioned that, by alternating attenuating pads and circuit elements within the phase shifter, the voltage of 500 cycles per second present at the end of the shifter could be maintained without any change in amplitude, thus avoiding any alteration in the length of the pulse symbol as it appeared on the light screen of the range-taking tube. Without attenuating pads, the voltage of 500 cycles per second would diminish in amplitude as the distance capability increased, so that either the degree of deflection of the electron stream would become smaller and the picture on the screen more compressed, or the amplification would have to be continually regulated.

The normal practicable range of Freya equipment in tactical employment was 150 kilometers.

The modified Freya equipment which utilized the so-called "AN" platform was a stationary ground set which was used for covering a sky area for purposes of aircraft spotting, and which, at the same time, could also serve as fighter aircraft control equipment. It differed from the original Freya equipment in its outer construction and in that it was provided with a mechanism for comparative direction finding (AN direction finding) and for the identification of friendly and hostile aircraft ([illegible]).

The AN platform was equipped, in addition, with a special direction finding instrument, the so-called [illegible] instrument. Two double illumination tubes were built into the [illegible] instrument to facilitate observation of indicated data. A direction finding selector switch ([illegible]) was built into the receiving aerial. To solve the problem of

SKETCH 3


TARGET TO BE PLOTTED, EQUIPPED WITH IDENTIFICATION EQUIPMENT OF THE TYPE "ERSTLING"
A = DIRECTION FINDING SELECTOR SWITCH
INQUIRY IDENTIFICATION
REPLY IDENTIFICATION BEAM (PULSE)
DIRECT POSITION FINDING BEAM (PULSE)
REFLECTED POSITION FINDING BEAM
IDENTIFICATION ANTENNA
TRANSMITTER ANTENNA
RECEIVER ANTENNA
A
A
TO LOBE-SWITCHING DEVICE FOR COMPARATIVE DIRECTION FINDING
POSITION FINDING SIGNALS
IDENTIFICATION SIGNALS
DIRECTION FINDING TUBE, P INSTRUMENT
RANGE TAKING TUBE, POSITION FINDING INSTRUMENT
GENERAL VIEW TUBE
BASIC FREQUENCY, Z-APPARATUS
500 HZ
500 HZ
500 HZ
500 HZ
RECEIVER, NE UNIT
TRANSMITTER
INQUIRY TRANSMITTER
IDENTIFICATION RECEIVER (SO-CALLED "GEMSE")

identification of aircraft, the LW platform was equipped with a supplementary question-and-answer-identification set, which had its own transmitter, receiver and antenna, as well as identification tubes, which were combined with the position finding tubes to form double illumination tubes. The antenna itself consisted of three parts, the transmitter antenna for identification and the two groups of receiver dipoles. By means of a direction finding selector switch, it was possible, in the receiver system, either to switch one of these groups directly, or the other one indirectly via a slight detour to the feedlines, so that the maximum of the antenna characteristic, which no longer coincided with the normal standard but deviated from it by several degrees, was deflected towards the right or left (AN direction finding).

The general view and range-finding tube, which served the same purpose as in the ordinary Freya set, was supplemented by the indicator of the position finder. The control apparatus of the position finder and direction finding tubes as well as of the identification tubes, which will be described subsequently, was supplied by the basic frequency of 500 pulses per second.

The purpose of "identification" is to be able to distinguish between the pulses reflected by friendly aircraft and those reflected by hostile aircraft. The wave length of the identification transmitter, called also inquiry transmitter, was different from the position finding wave length and lay within the range of meter waves. This wave length was uniformly established by the directing agency for all installations located within a particular sky survey area. The

friendly aircraft stationed in this area were equipped with a special receiver-transmitter set, the *FuG* 25 A (*Erstling*) type. When the pulses originated by the identification transmitter reached the friendly plane, the receiver of the *FuG* 25 A set reacted to them, releasing its transmitter which, on another "reply frequency" differing from the "inquiry frequency" but uniform for the whole area, sent forth amplitude-keyed reply pulses which followed one another, in a certain, specially selected rhythm, with the same frequency as the inquiry pulses.

If it was necessary to distinguish among various formations of friendly aircraft, it could be accomplished by selecting different keying rhythms. While the enemy could not be prevented entirely by frequent changes in the keying rhythms from breaking the identification code and making use of it for purposes of deception, this at least made it difficult for him. The amplitude-keyed reply pulses originated by the *FuG* 25 A were received by an identification receiving set, the so-called *Gemse*, which was adjusted to the wave length of the *FuG* 25 A transmitter by means of an identification aerial. The pulses were amplified, modulated, and conducted to the identification tubes, where they appeared on the light screens of the general view and range-taking tubes as mirror images in comparison to the ordinary position finding pulses. The identification antenna served for both transmission and reception, the two channels being separated by an electric switch. Like the actual position finding antenna, the identification antenna, too, was equipped with a direction finding selector switch, which made comparative direction

finding possible, in accordance with the same principle as in position finding. The direction finding selector switches for position finding and identification were combined in the P instrument.

In identification procedure, the pulses picked up by the receiver were not reflected ones but original pulses emitted by the active airborne transmitter. Therefore, the picture produced by them on the screens of the observation tubes was usually clearer than the pattern of the blip in the case of actual position finding. If distance and position measurements were made on the basis of this picture, the circuit through the airborne identification equipment had to be taken into consideration.

In connection with the direction finding operation, the following observation tubes were used:

1. The *coarse direction finding tube* for position location, on which, out of the entire distance range covered by the set, there appeared only the small section needed for comparative direction finding. This was the section surrounding the point of light on the range-taking tube, and it was selected with the help of the phase shifter switch. In this way, misunderstandings among the operators as to which spotting target has been picked up were avoided.

2. The *fine direction finding tube* for position location, on which both comparison pulses of the coarse tube appeared next to each other. One of the two pulses was then deflected to the side by temporarily altering the basic potential of the deflector plate by means of a contact governed by the direction finding selector switch. The entire electron stream of the tube was supplementarily

made visible, after having been blocked during the intervening pause, thus causing the section of the blip pattern appearing on the screen to coincide exactly with the two comparison pulses.

3. The <u>coarse direction finding tube for identification</u>, on which appeared the identification pulses in exactly the same way as the reflected pulses appeared on the coarse tube for position finding. Both coarse direction finding tubes were combined into a single double illumination tube. For the actual recording of data, there was always only one stream available at a time, the other was blocked. During operation, a switch could be made from coarse direction finding for position finding to coarse direction finding for identification by means of a simple change-over switch. The direction finding data were accurate to approximately one-half of one degree.

4. The <u>direction finding general view tube</u>, on whose screen the same picture appeared as on the range-taking tube, in approximately the same size. In this way the direction finding operators were kept informed of changes in the screen picture. The direction finding general view tube and the fine direction finding tube, too, were combined into one double illumination tube.

The production of the basic frequency of 500 cycles per second, which was required for measuring pulse timing and which served as a measurement of the length of the total range of the equipment, was accomplished in the so-called Z apparatus by a master-tone generator with amplifier, working on the principle of the Hartley inductive oscillator. Since the accuracy of the distance measurement was

dependent upon the constancy of this basic frequency, the necessary stabilising equipment for the operating voltages was also included in this apparatus. With the help of a built-in change-over switch, which bore the designation Frequenz-[illegible]generator, frequencies of 494, 497, 500, 503 and 506 cycles per second could be switched on at will. At the same time, provision was made to connect an outside generator in place of the built-in master-tone generator by means of a change-over switch. From the tapping point of a synchronised oscillator circuit located in the amplifier of the master-tone generator, the basic frequency was conducted further by means of a collector bar as follows:

a. To the range-taking tube and the fine general view tube for the purpose of recording the time axis,

b. To the oscillator of the coarse general view tube for the purpose of synchronisation, and

c. Via a separator stage to the transmitter for the purpose of producing a keying impulse which was synchronised with the chronography.

The keying impulse could be shifted to make its own symbol coincide with the point of light on the range-taking tube by means of a coarse phase shifter with six stages of four and two-tenths kilometers each and a fine phase shifter for continuous coverage of a range of five and one-half kilometers, both built into the separator stage.

As further special modifications of the Freya equipment, particularly in regard to the arrangement of the antenna, mention should be made here of the extensive stationary installations along the coasts,

such as the so-called *Elephant*, using a wave length of seven and one-half meters, and the so-called *Mammoth* on a wave length of two and four-tenths meters, both of which had a range of more than 300 kilometers, and of the revolving *Wassermann* set, utilizing a wave length of two and four-tenths meters. For the most part these sets were equipped with supplementary instruments for use in comparative direction finding and in determining altitude. They were produced in very limited quantity, however, and were used chiefly in aircraft reporting and early warning operations.

The *Freya* equipment, with the supplementary instrument for comparative direction finding, was also used successfully in the control of night fighter aircraft, until the *Wuerzburg-Seeburg* method was fully worked out. It required, however, great technological and tactical know-how on the part of the fighter aircraft control officer, who had to guide the aircraft directly from his position on the LZ platform where the *Freya* equipment was set up. For this reason there were only a very few particularly good fighter aircraft control officers who possessed mastery over this method. This was also the reason why the *Wassermann* sets, which were also provided with equipment for comparative direction finding, could not be utilized for purposes of fighter aircraft control.

APPENDIX B

WUERZBURG RADAR EQUIPMENT

(WUERZBURG A, C, D, AND WUERZBURG RIESE)

Four stages in the development of the *Wuerzburg* equipment must be distinguished: A, C, D, and *Wuerzburg Riese*.

The transmitter of the Wuerzburg radar functioned on the principle of the Hartley oscillator with grid keying, on a wave length of fifty-four centimeters, and was provided with an air-cooled sender tube (type LS 180). The keying capacity was eight to ten kilowatts, the anode voltage eight kilovolts; the negative grid polarization voltage during pauses in keying was two kilovolts, and the positive grid polarization voltage while keying, two and three-tenths kilovolts. The keying pulse had a breadth of two-millionths of a second, while the keying frequency corresponding to a distance range of forty kilometers amounted to 3,750 cycles per second.

In contrast to the *Freya* equipment, the *Wuerzburg* A, C, and D types were not equipped with an unwieldy flat-top antenna, but rather with a parabolic reflector antenna of approximately three meters in diameter and with an aperture angle of twelve degrees. This antenna could be moved up and down and from side to side, and could be folded together for transport. The antenna could be used for both transmission and reception. The first *Wuerzburg* sets of the A, C, and D types were not set up in inclosed shelters, and the operating crews were exposed to the weather.

The *Wuerzburg* A set was equipped with a stationary dipole of

half-wavelength located at the electrical focusing point of the antenna mirror, and supplied with current. The antenna could be operated by one person, and was suited only to maximum direction finding of azimuth and altitude angles with a degree of accuracy of from plus or minus twenty-four-sixteenths to plus or minus thirty-two-sixteenths of one degree. The degree of accuracy attained in distance measurement was from plus or minus eighty to plus or minus 120 meters. As a general view and range-taking tube, an electrode tube of the Orion type was used. On its screen the accuracy of direction finding data was confirmed when the pulse symbol coming from the target being plotted reached a maximum. The distance of the pulse symbol from a marker in zero position, to which the symbol of the pulse originating from the transmitter was adjusted, then indicated the distance away on a distance scale located around an illuminated circle.

The small degree of accuracy attainable with the Wuerzburg A made necessary further development, and the C and D types came into being. In contrast to the Wuerzburg A, which had only maximum direction finding facilities, these instruments were equipped with mechanisms for comparative direction finding, also called AN direction finding. A dipole array of half-wavelength, which was located eccentrically to the axis of the antenna mirror, was rotated by a synchronous motor at a speed of fifty revolutions per second. The radiation maximum of the characteristic was deflected seven degrees from the optical axis. With this comparative direction finding, a degree of accuracy of from plus or minus five-sixteenths to plus

or minus eight-sixteenths of one degree for azimuth could be attained, and from plus or minus seven-sixteenths to plus or minus nine-sixteenths of one degree for altitude. With the help of a special supplementary distance measuring instrument (the so-called Emil), which represented the only difference between the Wuerzburg C and D type sets, the degree of distance accuracy attainable by the Wuerzburg D equipment could be increased by plus or minus thirty meters. The observation part consisted of a general view tube with a distance range of up to forty kilometers. The distance could be read on a permanent distance scale surrounding the illuminated circle produced by a rotating field. The pulse symbols were represented by jagged deflections of this illuminated circle. By shifting a blackout marker located on the illuminated circle, the position which was to appear as sectional pictures on the other tubes--the azimuth and altitude direction finding tube as well as the range-taking tube--could be adjusted on the distance scale. In other words, the section selected by means of adjusting the blackout marker appeared on all the tubes, and in this way the possibility of the operating crew's mistaking the plotting target could be eliminated.

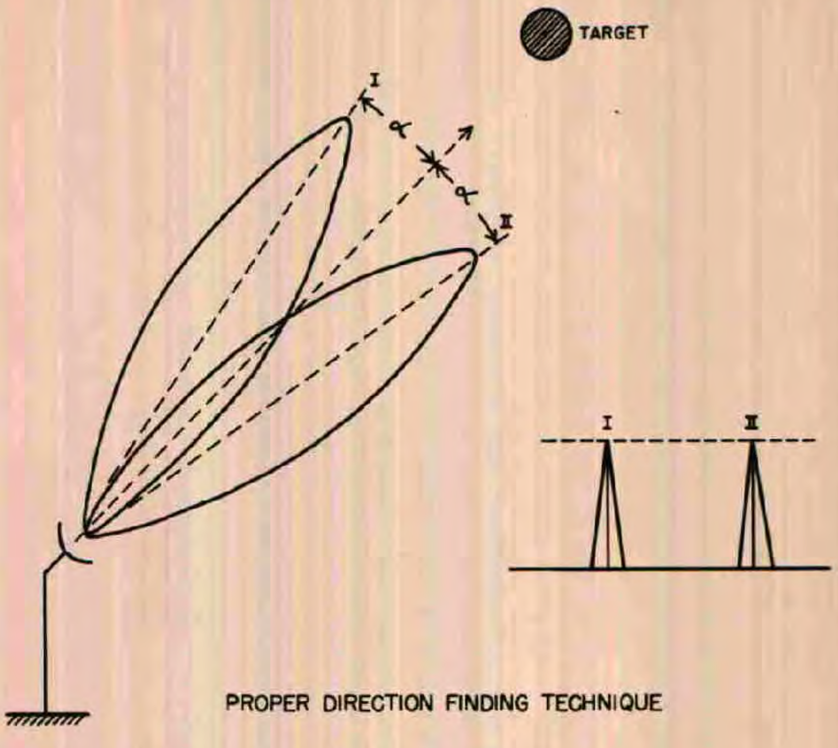
By adjusting the blackout marker, two pulse symbols corresponding to the section selected on the general view tube appeared on the azimuth and altitude direction finding tubes for comparison purposes. On the azimuth tube these comparative symbols appeared horizontally against a vertical base line, and on the altitude tube, vertically against a horizontal base line. The deflections from the base lines were governed by a pole-changer, the so-called Grille

unit, which was connected to the rotating dipole. In the two horizontal positions of the dipole, the voltage on the deflector plates of the azimuth direction finding tube was affected, and in the two vertical positions, that of the deflector plates of the altitude direction finding tube. The moment contact was made by the direction finding selector switch, the cathodes of the corresponding direction finding tube received a positive impulse which freed the blocked cathode beam in the tube. The number of pulses for each direction finding position was approximately six. In the case of proper direction finding, the two pulse symbols were of equal size on the azimuth and also on the altitude direction finding tube; in the case of wrong direction finding, they were different in size (Sketch 4).

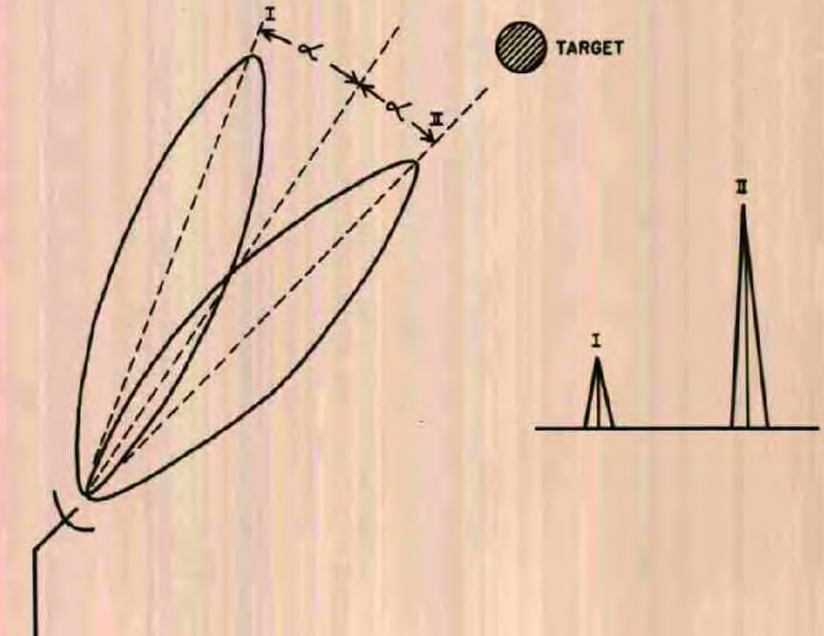
In altitude direction finding, the accuracy of the operation depended upon the angle of elevation of the target being plotted. Inside the ground clearance range, that is if the altitude bearing angle was too low, the angle of elevation may have been distorted by ground reflections. For this reason, it was found better to get along without a blast wall directly surrounding the instrument or, if one was absolutely necessary, to keep it as low as possible.

Of the entire range of the general view tube, a section of six kilometers was reflected on the screen of the range-taking tube, and the location of this section in relation to the whole range could be selected by means of a goniometer. A blackout marker also appearing on the illuminated screen was adjusted to the point of the pulse symbol to be measured, and the distance could be read directly on a distance scale.

Sketch 4



PROPER DIRECTION FINDING TECHNIQUE



WRONG DIRECTION FINDING TECHNIQUE

The product of the fourth stage of development, the Wuerzburg Riese set, was identical to the Wuerzburg D type in respect to electrical equipment, and differed essentially only in that it had a larger antenna mirror, which was approximately seven meters in diameter rather than three meters. With its range of eighty kilometers, its distance accuracy was from plus or minus thirty to plus or minus forty meters. As a result of the sharper focusing, its direction finding accuracy was from plus or minus eight-sixteenths to plus or minus ten-sixteenths of one degree for azimuth, and from plus or minus six-sixteenths to plus or minus eight-sixteenths of one degree for altitude.

The Wuerzburg Riese type set became the standard radar equipment of German day and night fighter aircraft stations.

The distance ranges actually attained in tactical commitment were as follows:

the Wuerzburg A type equipment: thirty-six kilometers,
the Wuerzburg D type equipment: twenty-five kilometers, and
the Wuerzburg Riese type equipment: eighty kilometers.

APPENDIX C

SEEBURG PLOTTING TABLE

(INCLUDING FULLY AUTOMATIC ANTENNA CONTROL)

The radar data from two Wuerzburg Riese radars, one of which was used to plot the friendly plane and the other the enemy plane, were fed into a mechanical calculating instrument, the so-called Seeburg table, by means of teletransmission systems, to be described later. These data consisted of the slant range "oe" (the distance from the radar position to the plane), the vertical visual angle "γ" and the azimuth angle "δ" (in relation to north-south direction). The feeding of these data into the Seeburg table was done in the beginning by hand, later automatically. The Seeburg table was a mechanical calculating instrument by which the data mentioned above, slant range "oe" and vertical visual angle "γ" (the azimuth angle "δ" remained unchanged) were converted into the horizontal range "oh," according to the following formula:

$$oh = oe \times \cos \gamma.$$

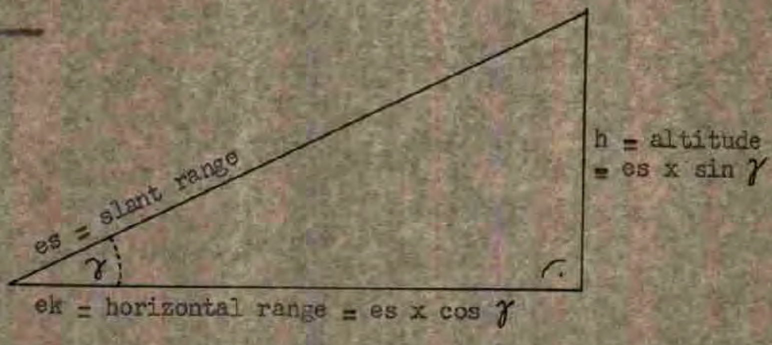
One light indicator for the friendly plane and one for the enemy plane were directed by means of hand cranks. Through the lens of these light indicators, the calculated position finding data were projected from below as varied colored lights onto a horizontal, transparent glass plate, resembling somewhat the surface of a table. On the glass plate, which was oriented towards the north, a 1:25,000 scale map of the area surrounding the two radar sets was reproduced, and the positions of the radar sets indicated. The points of light

changed their positions on the glass plate in accordance with the movements of the aircraft and thus gave the positions of the planes being plotted, provided, of course, that the map and the calculation and the transmission processes were accurate.

In the case of fully automatic control of the light points, the position finding data were converted by means of a special transmission process (to be described later) developed by the Askania Company into the corresponding voltage values, which were used to drive the motors which, in turn, brought the light points into the correct positions. With fully automatic control of the Seeburg table, control of an altitude chart was effected at the same time, based on the altitude data calculated from the slant range "es" and the vertical visual angle "γ" for both friend and enemy in the following formula (see Sketch 5):

$$h \text{ (altitude)} = es \times \sin\gamma.$$

Sketch 5



The altitude chart was set up in such a way that, out of a series of incandescent lamps located behind two opaque glass screens, the two lamps indicating the actual altitude data for friend and enemy flashed on behind the appropriate figures superimposed on the front of the screens. These two opaque glass screens with altitude figures were arranged next to one another on a board, so that the differences in altitude of the two planes were graphically presented. This altitude chart was set up in such a way that it could be seen from the Seeburg table.

With the Seeburg-Wuerzburg Riese method, the friendly fighter pilot received altitude data by radio, as well as appropriate orders directing him to the enemy target. During proper guidance of the fighter plane to the enemy target, the distance between the two light points would decrease, and when contact had been made the two light points would coincide. In the method described, this guidance procedure was accurate to plus or minus 400 meters, assuming efficient operating crews.

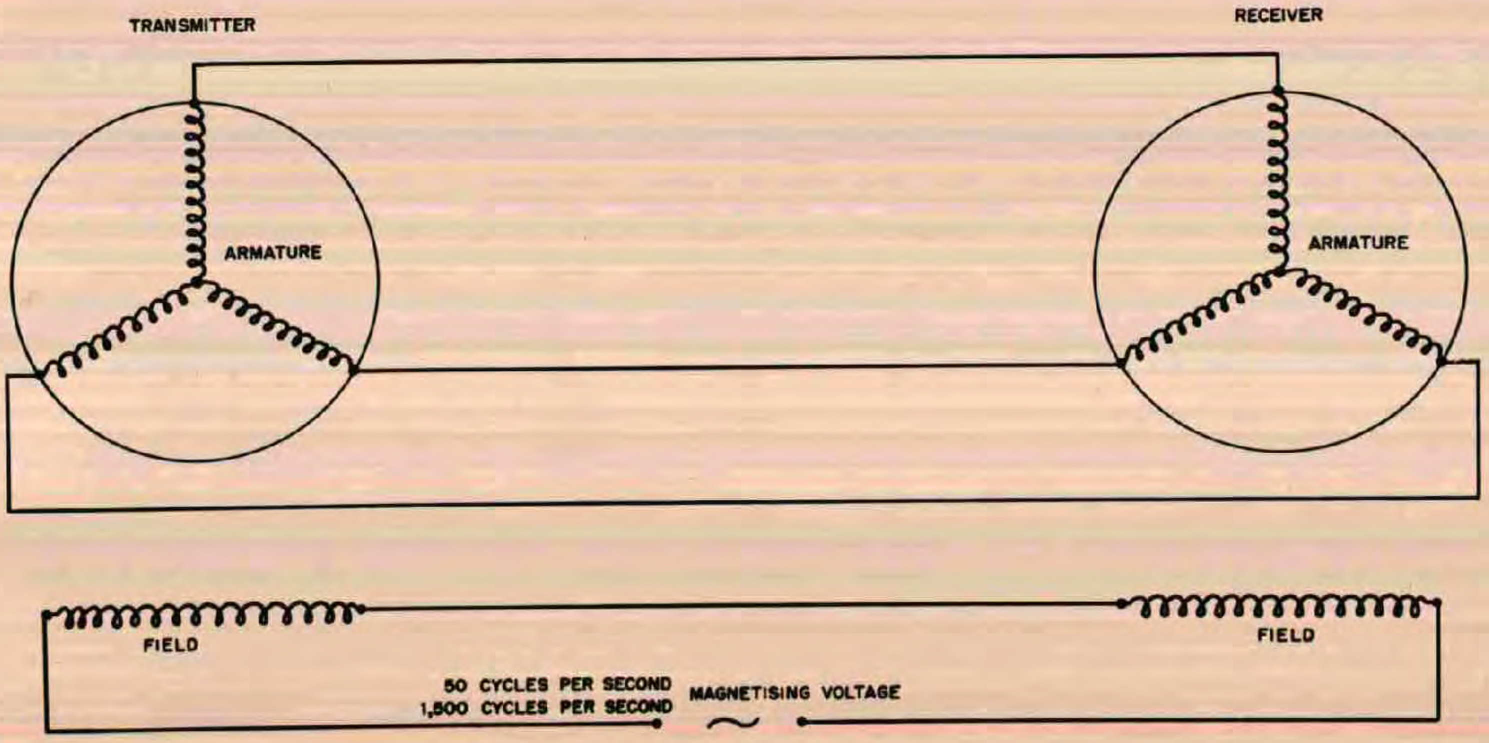
The transmission of data from the radar equipment to the Seeburg table was accomplished either by telephone or by means of the electromagnetic rotary field systems developed by Siemens and Askania. These are composed of senders and receivers. An altitude transmitter, for plotting the vertical visual angle "γ" of the antenna mirror, an azimuth transmitter, for plotting the azimuth angle "δ" of the antenna mirror, and a distance transmitter, for plotting the slant range on the range finder, were attached to the radar set. In the manual operation of the Seeburg table, the corresponding receiver

systems for slant range, azimuth angle, and vertical visual angle were set up near the table in the form of a control desk. Operating crews assigned to the transmission apparatus read the figures from the scales of the receiver systems, and called them out to the crews at the <u>Seeburg</u> table, who in turn fed the data into the table. The functioning of the rotary field systems is graphically presented in Sketch 5.

The transmitters and receivers used in the rotary field systems were similar in both their outward appearance and their internal structure to small motors. Like these, they were composed of a stationary field coil, also called magnetizer coil, and a rotating armature coil. The magnetizer coil took the form of a simple alternating current coil, and the armature coil that of a rotary field coil, that is, it was composed of three alternating current coils arranged in such a way that they formed three angles of 120° at the center of the armature coil, as is shown in Sketch 6. The magnetizer coils of the transmitter and receiver were in serial connection and were activated by alternating current. The rotary field coils in the armatures of the transmitter and the receiver were also in serial connection. If, for example, the armature of the transmitter was brought into any position in relation to the field and was anchored there, voltages were induced in the three alternating current coils of the armature, which together comprised the rotary current coil. The intensity of these voltages depended upon the position assumed by the individual coils, arranged at intervals of 120 degrees from one another, in the alternating field of the

SKETCH 6

TRANSMISSION EQUIPMENT FOR USE WITH THE SEEBURG METHOD
(DEVELOPED BY SIEMENS AND ASKANIA)



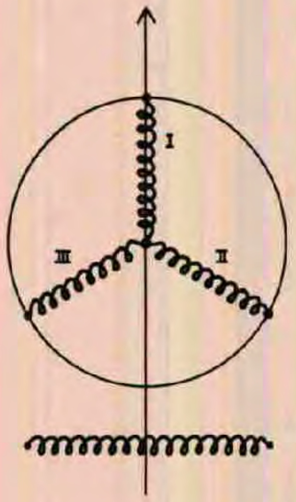
magnetizer coil. These voltages might assume completely different intensities in the three alternating current coils of the armature (see Sketch 7).

Because of the mutual connection of the transmitter armature coil and the receiver armature coil, the distribution of current in the armature coil of the receiver was the same as that in the transmitter coil, in other words, a field vector was created in the armature coil of the receiver which corresponded to whatever position the field vector in the transmitter armature had assumed. Due to the fact that the field vector in the receiver armature attempted to assume a position coinciding with that of the stationary field vector of the magnetizer coil, the freely moving receiver armature was rotated into a position corresponding to that of the transmitter armature. In other words, if the armature axes of both transmitter and receiver were equipped with indicator needles, both these needles would assume the same position. If the transmitter and the receiver were equipped with needles and scales, after adjusting both systems to a stationary point of reference, the position of the transmitter armature in relation to this established point of reference could be read from the receiver scale.

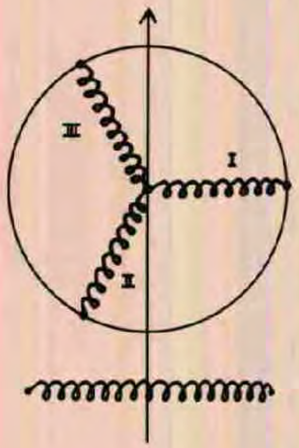
In the case under discussion--the <u>Seeburg</u> technique--the axes of the transmitter armatures were linked up with the altitude, azimuth, and distance axes of the radar set; thus the values of the vertical visual angle and the azimuth angle and of the slant range "es" could be read on the receiver scales.

The frequency of the activating voltages used by these transmission systems was fifty cycles per second. (For other purposes,

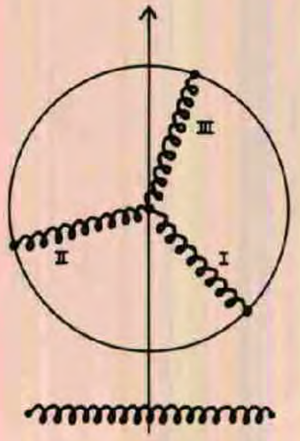
Sketch 7



COIL I — MAXIMUM VOLTAGE
COILS II AND III —
UNIFORM VOLTAGE DISTRIBUTION



COIL I — MINIMUM VOLTAGE
COILS II AND III —
UNIFORM VOLTAGE DISTRIBUTION



ALL 3 COILS —
VOLTAGES OF VARYING INTENSITY

there existed transmission systems which utilized an activating voltage of 500 cycles per second, but these required the use of an audio-frequency generator, which of course meant additional expenditures.)

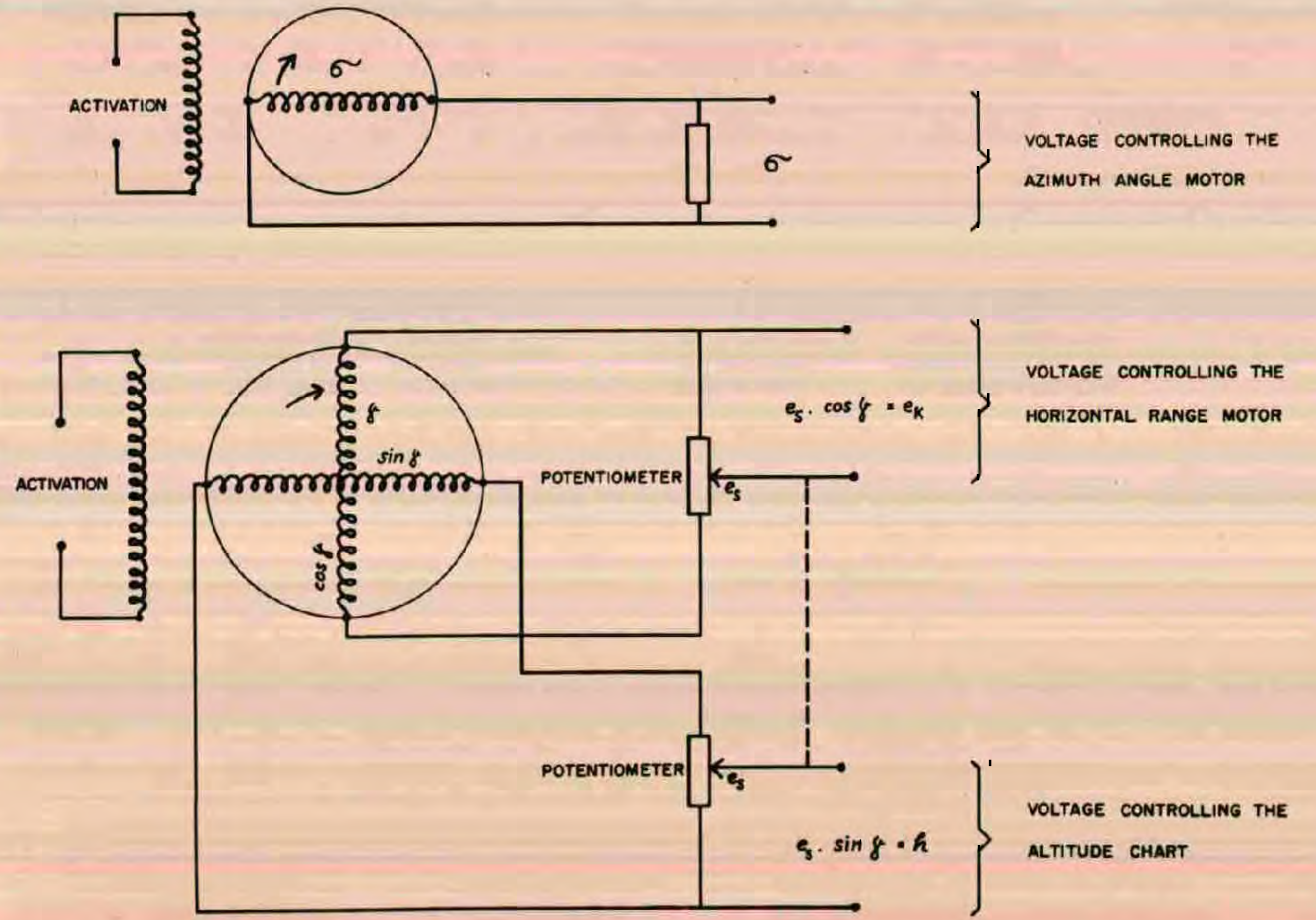
The transmission system described required five cables for transmission. The use of this system permitted coverage of distances of approximately six kilometers with a degree of accuracy of plus or minus one-sixteenth of one degree.

In order to eliminate the factors of time lag and inadequacy on the part of operational crews in this transmission technique, the Askania Company of Berlin developed a completely automatic *Seeburg* table. By means of a transmission system developed especially for the *Seeburg* method, the conversion of slant range "oe" into horizontal range "oh" (oh = oe x cos γ) and of slant range "oe" and vertical visual angle "δ" into altitude "h" (h = oe x sin γ) could be accomplished directly by the transmission system, and the final values of horizontal range and altitude, as well as the azimuth angle " ", could be utilized in the form of voltage to drive motors which in turn controlled the movement of the points of light. In addition, the altitude "h" could be entered directly on the altitude chart. In other words, the calculation process itself was no longer accomplished inside the *Seeburg* table. The principle of this transmission system will be described in the following discussion (Sketch 8).

An armature with two coils crossing each other at right angles at the center rotated in the field of the magnetizer coil corresponding to the vertical visual angle "γ". In the horizontal coil,

Sketch 8

TRANSMISSION SYSTEM DEVELOPED BY THE ASKANIA CO. FOR CONTROL OF THE AUTOMATIC SEEBURG TABLE



a sine voltage was induced, and in the vertical coil, a cosine voltage. By means of potentiometers (indicated by "P" in Sketch 5) a resistance coefficient—and thus a voltage coefficient—corresponding to the slant range "es" value indicated on the range finder of the radar set, was switched on. In this way the values "es x cosγ = ek" and "es x sinγ = h" could be read directly as voltage at the output terminals of the transmission system.

The value of the azimuth angle "δ" (as indicated in Sketch 5) was also transmitted as a voltage value, and with it the azimuth motor directing the movement of the points of light was activated.

The transmission system developed by the Askania Company was characterized by a high degree of accuracy, approximately plus or minus one-sixteenth of one degree at a range of four kilometers, and simplified to a considerable extent the construction of the Seeburg table.

APPENDIX B

THE LICHTENSTEIN AIRBORNE SEARCH INSTRUMENT

In 1941 the first airborne search instrument (radar) was developed in the form of the experimental *Lichtenstein B/C*. This instrument had a range of from two to four kilometers and was equipped for altitude and azimuth direction finding on the principle of comparative direction finding. The latter was accomplished by the use of a rotating phase shifter which switched on the various antennas in sequence. The angle of aperture was sixteen degrees to either side, and the wave length was fifty centimeters.

The first equipment of this type which was suitable for series production appeared in 1942, as the *Lichtenstein C* instrument, which, however, could be used only in aircraft of the Ju 88 type. Its technical data were the same as those of the *Lichtenstein B/C*.

Technology was not yet in a position to fulfill the requirement, set by the men in charge of night aerial combat, of an instrument with a range of at least six to eight kilometers with a near resolving power of up to approximately 200 meters, and with an angle of aperture of sixty degrees to either side, and thirty degrees to the rear.

As a temporary stop-gap there appeared in the spring of 1943 a wide-angle airborne search instrument, which did possess the required angle of aperture of sixty degrees to either side, but whose range was only one kilometer. This instrument, of course, was completely useless.

It was not until August 1943 that six instruments of the *Lichtenstein SN 2* type were put into operational employment. This airborne search instrument functioned on the *Freya* wave length, with a broad-band wave length of between two and three meters. For this reason, it was subject like the *Freya* equipment to window jamming, which had begun in July 1943. This interference did not make itself nearly so seriously felt, however, as in the case of the *Lichtenstein B/C* instrument, for the majority of the metal strips dropped by the enemy corresponded to half the wave length of the *Wuerzburg* equipment, and thus of the *Lichtenstein B/C* instrument. The range of the *Lichtenstein SN 2* was up to eight kilometers, the angle of aperture sixty degrees to either side, and the near resolving power up to 200 meters. Thus it fulfilled approximately the requirements set by the night aerial combat command elements in the year 1942. Owing to the increasing destruction of industrial installations, however, from autumn 1943 on, few instruments could be delivered.

The further development of airborne search instruments aimed at replacing the *Lichtenstein SN 2* at a later date with the so-called *Berlin N*, an airborne search instrument functioning on centimeter wave length. This had a considerably longer range, for an antenna it used a concave mirror with a diameter of eight meters which was remote-controlled. The searching activity required by this arrangement had to be accepted as part of the bargain, but this was not felt to be too disadvantageous, since it permitted particularly clear observation of the enemy, in case he should divert his course to

the side. This instrument was also invulnerable to jamming by means of metal strips. Only ten instruments of this model, however, could be put into employment in night combat operations before April 1945; but with these ten, several additional successes were achieved in terms of enemy aircraft downed.

Automatic search antennas, which were to make column control superfluous, were in the process of development at the end of the war; however, they never reached the stage of employment in operations.

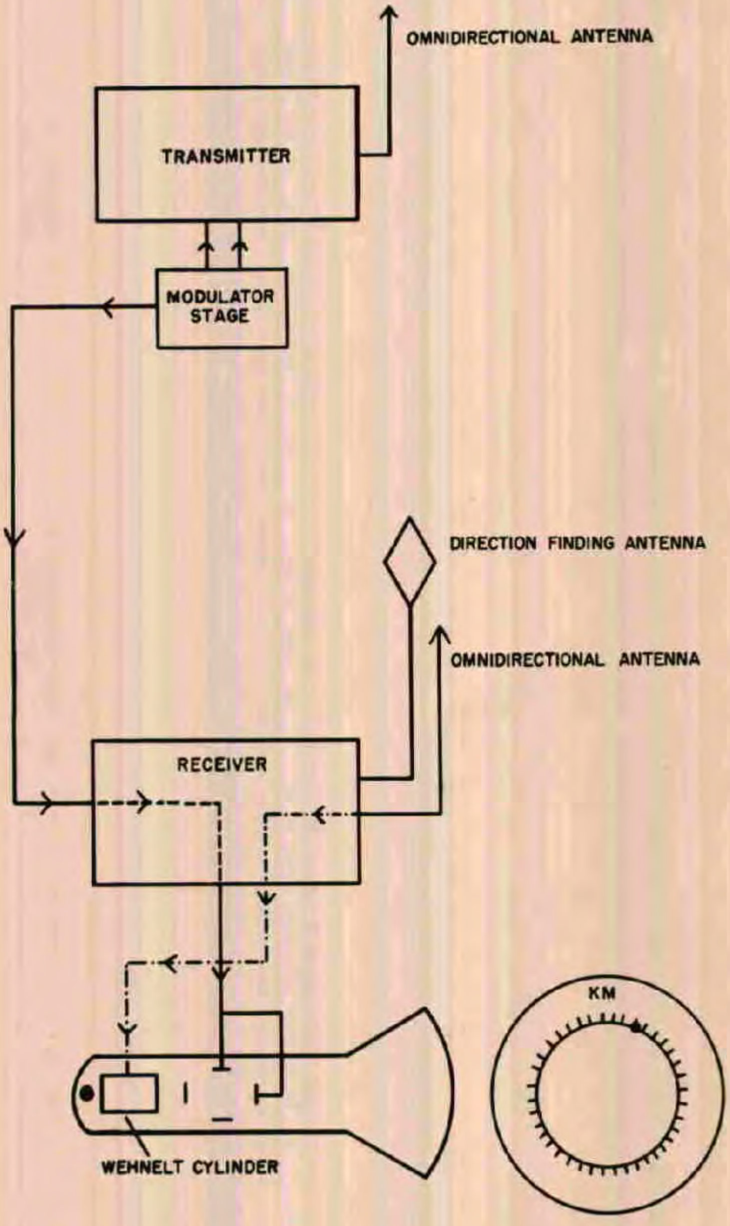
APPENDIX E

THE Y-TECHNIQUE OF FIGHTER AIRCRAFT CONTROL (BENITO CONTROL SYSTEM)

In the Benito control system a radio transmitter and receiver were used not only for the transmission of messages between the ground station and the friendly fighter plane but also for location of the position of the latter. The plane itself had to be equipped with a frequency converter, also called "target transmitter." Unlike the methods described heretofore, this technique did not make use of pulse timing for range position finding, but rather of the measurement of the phase shift resulting from the difference in course time of the carrier modulation wave picked up directly from the transmitter by the receiver, and that same wave picked up by the receiver after it had been sent out from the transmitter and reflected back from the target. Depending upon two differing methods of data reading, there were two different ways of using this technique, resulting in an electrical and a mechanical Benito control system. In both methods, the carrier wave of the transmitter located at the ground station was used alternately for transmission of messages and for position finding.

In the electrical Benito control system for the transmission of orders a vocal modulation which could be picked up by the airborne receiver was impressed by a microphone on the ground transmitter (EBSG) (Sketch 9).

ELECTRICAL BENITO CONTROL SYSTEM



Bearings were taken at intervals of ten or twenty seconds for five seconds at a time. During this time the ground transmitter received a control pulse and emitted the modulation frequency, which was produced in its own modulator stage and which also controlled cophasally the ground receiver (EMSG). By means of an electron beam, which was deflected in the rhythm of the frequency modulation, a circle of light, the so-called range circle, was outlined on the observation screen of a cathode ray tube located in the ground receiver. For purposes of adjustment to a particular distance, this circle could be made to coincide with a calibrated kilometer scale on the observation screen. The ground receiver was equipped not only with a direction finding antenna, but also with an omnidirectional one. Activated by the modulated carrier wave from the ground transmitter, the frequency converter in the aircraft also emitted a modulated carrier wave. With the aid of the direction finding aerial of the ground receiver, the azimuth of the fighter plane could be determined in accordance with the minimum method. The carrier frequency of the frequency converter was picked up by the omnidirectional aerial of the ground receiver and conducted to a modulation amplifier located in the recording unit of the receiver. Here it was amplified, demodulated, differentiated and converted into pulses. The negative pulses were suppressed by rectification. By means of the positive pulses, the intensity of an electron beam was regulated in such a way that a bright point appeared on the range measurement circle. By comparing the position of this point of light to the zero position, the distance

of the fighter plane away from the ground station could be read from the scale in kilometers.

Thus, depending upon the modulation frequency "f", a complete crossing of the point of light on the range measurement circle corresponded to a definite distance between the fighter plane and the ground station, as expressed by the following formula:

$$300{,}000 / 2 \times f = \text{distance in kilometers.}$$

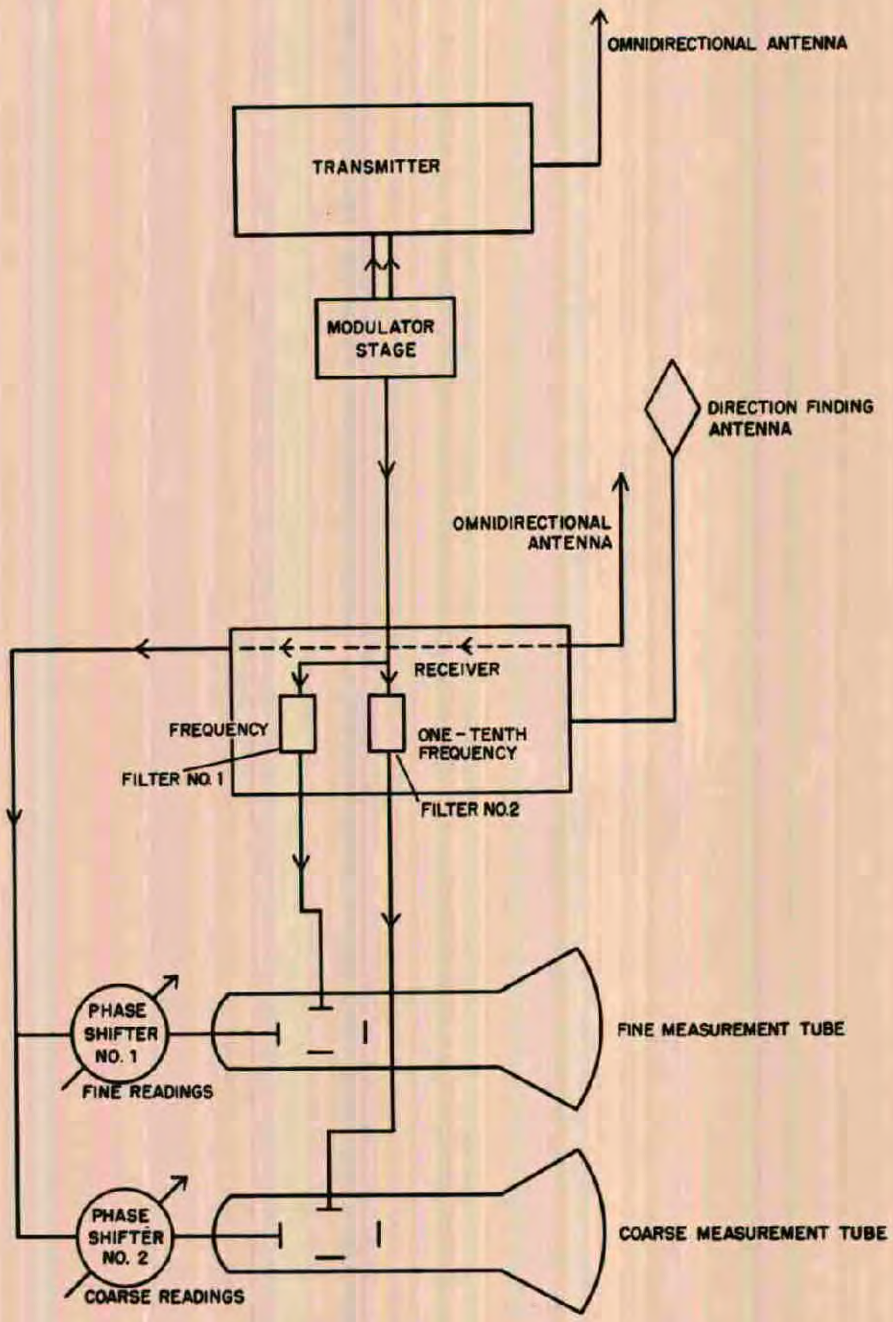
In the case of distances farther than the one established, the point of light would cross the range measurement circle several times, depending upon the distance concerned. In order to determine how many times the point of light had crossed the range measurement circle, and therefore by what the distance represented by one revolution on the circle had to be multiplied, the modulation frequency was increased by a certain percent, causing the point of light to move forward on the circle a corresponding amount in terms of the distance involved. On the basis of the length of this arc, indicating the percentage of increase in distance, the correct distance away could be definitely determined.

The mechanical *Benito* control system differed from the electrical in that, for purposes of coarse and fine determination of distance, it used phase shifters of its own with which the reference phase could be rotated from zero to 360 degrees, and from whose scales, calibrated in kilometers, the distance could be read directly.

In the mechanical *Benito* control system, too (Sketch 10), modulation pulses of five seconds' duration were sent out by the

SKETCH 10

MECHANICAL BENITO CONTROL SYSTEM



ground transmitter at the intervals indicated above for the purpose of taking bearings. In fine measurement, the modulation frequency again had a definite value corresponding to maximum distance, as expressed in the formula below:

(300,000 / 2 x f km).

For coarse measurement, one tenth of this frequency was utilized. In the ground receiver, both frequencies were conducted through filters, amplified, rectified, and conducted to one of the pairs of deflector plates in each one of two built-in cathode ray tubes, one for fine measurement and the other for coarse measurement. Through the unchanged modulation frequency, a streak of light was outlined by the electron stream on each screen of the cathode ray tube concerned. On the second pair of deflector plates in each of the two cathode ray tubes, the modulated carrier frequency picked up from the transmitter aerial of the ground transmitter was given, after demodulation, as the basic degree of phase rotation during the course time. Depending upon the degree of phase shifting between the two modulation frequencies on each cathode ray tube, there appeared on the illuminated screens of the tube a streak, an ellipse, or a circle. By means of one phase shifter each, through which the basic frequencies picked up from the aerial had to pass, the phase angle between these basic frequencies (at one pair of deflector plates) and the actual modulation frequencies (at the other pair of deflector plates) could be shifted in such a way that ellipses and circles were transformed into a streak of light. The adjustment

of the scale values corresponded automatically with the rotation of the phase shifter, so that coarse and fine distance values could be read in kilometers from the appropriate scales. The distance readings were taken at the moment at which ellipse or circle changed into a clearly recognizable streak of light.

In the regulation of scales in the ground installation equipment, ground and air equipment were placed directly next to each other, so that the lag in pulse timing which occurs in the ground instruments as well as in the airborne equipment could be taken into account from the outset; thus the distance values read from the phase shifter scales actually represented true distances and needed no further corrections.

Radio communication between the ground station and the fighter plane, and also azimuth direction finding, were carried out in the same fashion as in the electrical Benito control system.

APPENDIX F

THE UHU-2 METHOD OF FIGHTER AIRCRAFT CONTROL

(A COMPLETELY AUTOMATIC TECHNIQUE)

The UHU 2 represented a method of transmitting orders from ground to air, by which a friendly fighter plane could be guided completely and automatically by a ground station to an enemy target. By making use of this technique, radio communication was reduced to a minimum, almost entirely eliminating the possibility of interference by the enemy.

For purposes of transmission, a pulse modulated Benito control transmitter on ultrashort wave was used. Due to this pulse modulation, a margin of safety from interference of approximately three nepers[1] was attained, in other words, the interference signal could be three nepers greater than the operational signal. Actually though, it never happened that the enemy recognized the code signal and jammed it.

With this set-up, three kinds of information could be transmitted simultaneously from ground to air: azimuth, altitude, and distance.

If a three-dimensional autopilot was used, azimuth and altitude could be transmitted directly to the control elements of the fighter plane.

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[1] Each neper is equivalent to 8.686 decibels.

With the ordinary *Askania* automatic pilot, only the message pulses for azimuth control were transmitted directly to the autopilot.

The cut-off signal modulator for azimuth was located in a small case fitted with a hand crank, which was operated by the fighter aircraft control officer from his position at the *Seeburg* table.

Thus the control officer had the direction of the fighter plane assigned to his station literally in the palm of his hand. He watched the two points of light on the *Seeburg* table, which represented the data furnished by the *Wuerzburg Riese* set or, in case two fighter planes were being controlled at the same time within the same area, partly by the *Wuerzburg Riese* (red) set, and partly by the *Benito* control ground station. By turning the crank of the cut-off signal modulator for azimuth, he could direct the friendly fighter plane in such a way that it approached the enemy plane from behind in a pursuit course.

The cut-off signal modulator for altitude also consisted of a small case equipped with a hand crank, and by operation of this crank the altitude of the enemy plane, measured by the *Wuerzburg Riese* (red), was transmitted to the friendly plane in the air. In the cockpit of the fighter plane was a corresponding receiver set which controlled an indicator instrument, enabling the pilot to read the altitude of the enemy plane and compare it with his own. For this purpose the indicator unit was arranged on the instrument panel in such a way that the indicator needles assumed the same position when the two planes had reached the same altitude.

The cut-off signal modulator for the distance between the friendly plane and the enemy aircraft, calculated by measuring the two points of light on the *Seeburg* table, transmitted distance data in the same way to the friendly plane in the air, where the pilot could read them from an indicator instrument.

By almost completely eliminating verbal radio communication, which was subject to enemy interference, a method of fighter aircraft control was attained, which was for the most part free from interference and entirely automatic.

APPENDIX 6

THE JAGDSCHLOSS-JAGDHUETTE METHOD OF FIGHTER AIRCRAFT CONTROL

The *Jagdschloss* was an omnidirectional search apparatus, with whose help all the targets within a radius of 150 kilometers could be plotted one after the other. Because of this characteristic, it was used for coverage of a sky area and for aircraft reporting operations. In order to scan the entire area, the antenna, which was composed of a dipole screen twenty-four meters wide, was rotated by means of a seventy-five kilowatt motor at 10 revolutions per minute. The echo principle of the position finding operation was used. The company manufacturing it, Siemens, retained insofar as possible the basic principles of construction used in the *Freya* equipment, and merely made the modifications necessary for omnidirectional search purposes. The construction form was that of a stationary ground set.

It was possible to change the frequency in the *Eibsee* transmitter during operation. The same antenna, the broad band type, was used for both transmitting and receiving (simultaneous operation).

1. The panoramic scanning tube, for position finding, had a distance range of zero to 150 kilometers and covered a ground surface of 70,000 square kilometers. A scale of 1:750,000 was selected for the electron map, with a screen diameter of forty centimeters. Corresponding to a maximum range of 150 kilometers, the basic frequency for the chronography was 1,000 cycles per second. This was

produced in a sweep stage synchronized at 1,000 cycles per second. In order to be able to survey the ground surface, the electron stream was radially deflected by means of an electrode tube through deflecting coils revolving in synchronization with the rotation of the antenna. Wherever there were targets, bright points appeared on the illuminated screen, that is, the electron stream was brightened at that point. The return course was completely blacked out. In this way, a whole electron map came into being on the illuminated screen. This map could be adjusted with the help of a pulse contact oriented towards the north, which, whenever the antenna revolved across the north, caused a bright point of light on the range circle provided the instrument was properly adjusted. The electron map and this point of light could be so adjusted that the point came to rest on the upper rim of the illuminated screen.

2. The range-taking tube, on whose screen any section sixty kilometers long of the total range of 300 kilometers could be shown, could be adjusted with the help of a phase shifter (advancer). The smallest progressions which could be adjusted were one-half kilometer.

3. The identification screen of the panoramic scanning tube presented the entire range from zero to 150 kilometers. As in the *Freya* equipment provision was also made for a separate identification transmitter and receiver antenna, which worked in double function. This was attached above the direction finding antenna and could be rotated with it. The frequency of the series of pulses emitted by

the identification transmitter was 500 cycles per second; the radial deflection of the electron stream was activated by 1,000 cycles per second. For purposes of identification as well as position finding, each second stream was brightened, while the first was blacked out. The switch-over from identification indicator to position finding indicator was accomplished by means of a symmetrical square-wave voltage of 500 cycles per second at the Wehnelt cylinder.

4. One or more supplementary panoramic tubes, for the observation of data appearing on the screens of other omnidirectional search equipment were located at more or less remote distances away. The transmission of the voltages and frequencies necessary for the supplementary panoramic view tubes was carried by circuits, cables, or wireless transmission.

During World War II, with the help of a carrier frequency transmission set, supplementary indicator instruments could be connected to aircraft plotting centers located many kilometers away. The first set of this type transmitted the picture on the illuminated screen of a Jagdschloss instrument in the vicinity of Nauen to the antiaircraft tower located at the Zoo in the center of Berlin.

The identification indicator of the Jagdhütte equipment, manufactured by Siemens, was utilized in fighter aircraft control. At the beginning of 1945, new sets were planned, which were to function with two wave lengths and were to have a range of 300 kilometers. Equipment of the Jagdschloss type achieved a range of only 150 kilometers in tactical employment.

In exploiting the development of airborne equipment of the *Berlin* type, the German counterpart of the *Rotterdam* instrument on centimeter wave length, a sample model of a general view instrument working with centimeter wave length (the *Jagdschloss Z*) had been constructed, but could no longer be employed.

Another general view instrument working on centimeter wave length was the so-called *Forsthaus* instrument, which also made use of the Berlin equipment, with the addition of a so-called split antenna. This, too, could no longer be put into employment.

By April 1945, a total of eighty large general-view sets of the *Jagdschloss* type and five sets of the *Jagdhuette* type had been built by Siemens and Halske. Few of these instruments, however, had reached the stage of tactical employment.

APPENDIX E

AN AIR DEFENSE DIVISION HEADQUARTERS

The center of activity of a division headquarters was the position map. In the night fighter aircraft stations the position map was placed horizontally on the *Seeburg* table (two by two meters in size), but in division headquarters a large vertically placed position map, especially treated to prevent warping, was utilized. This map had a scale of 1:50,000 and its size, never smaller than six by six meters, depended upon the extent of the area to be covered. It was divided into grid squares, with designations such as AA, AB, AC, the so-called fighter aircraft grid network.

The position map with its aircraft grid network can be seen clearly in photos 1, 2, 3, 4, and 5, but especially in photo 2.[1]

The first information which had to be indicated on this large position map was enemy targets. This could be accomplished by various methods. As long as the radar equipment was not jammed or as long as it could still give accurate information as to the positions of enemy targets, the position data of targets plotted by the *Wuerzburg Riese* equipment located at the night fighter stations were transmitted telephonically by the *Seeburg* plotting

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[1] All photographs are of the headquarters installation at Stade, near Hamburg.

crews to the division headquarters. The *Seeburg* plotting technique made use of a transparent map placed on the top of the plotting table. This map was divided into the same grid network as was used on the large position map, so that the position data supplied could be transferred directly to the latter.

This in turn was done by means of special light point projectors (see photos 6, 7, 8, 9, and 10).

There were various models of light point projectors, but basically they all served the same purpose.

The simpler version of the light point projector, the so-called light indicator, consisted of tubes approximately seventy centimeters in length, the lower ends of which were equipped with a lead pencil unit. At the upper end of the tube was a lens, behind it a small incandescent lamp (later quartz lamps were used), and in front of it an adjustable rotary diaphragm. The light indicator tubes were suspended on a gimbal attached above a square table top measuring approximately sixty centimeters on each side. On each table top was located a fighter aircraft grid map which corresponded to a section of the large position map and to the map on the *Seeburg* table of whatever night fighter aircraft station was supplying the operator with grid locations. The data, received through radio head-sets worn by the female operating personnel, were marked by the pencil point on the end of the light indicator tube on the appropriate grid square on the table map, causing a point of light to be projected through the lens of the light indicator onto the corresponding grid square of the large position

map. This method of transmitting data required very careful adjustment of the table tape. The position of the points of light on the large position map represented the actual position at any given time of the target being plotted by radar, since the time lag caused by transmission was taken into account. The identity of the target was accomplished by an appropriately colored filter in front of the lens of the light indicator.

As the target moved from one grid square to another, its flight course was traced and recorded on the table map by the pencil line. The record of the flight course could be retained for a short while on the large position map by brushing it over with a fluorescent substance, causing a sort of after-glow effect.

The necessity for indicating graphically on the map both altitude and course of the aircraft being plotted, led to the introduction of special light point projectors (see photos 9, 10, 11, and 12) in place of the light indicators. In outward appearance, the light point projectors resembled small telescopes; they were set on a base in such a way that they could be turned up and down and from side to side. Because of their larger lens, they had a greater light intensity than the light indicators; due to the greater facility with which diaphragms could be attached, as well as the greater ease in adjusting the latter, the girls operating the projectors were able to indicate simultaneously altitude data and grid square data. The altitude data were projected onto the large position map either below or next to the point of light representing the plane. Altitude data were also telephoned to the

operators. When the light point projector was used, the recording of the flight course with a fluorescent substance was done only on the large position map.

In the beginning, the light indicators or light point projectors were located behind the large position map, and the girls operating the projectors had to be familiar with mirror writing. Later on the light point projectors, too, were accommodated in work areas in a raised gallery in front of the large position map (see photos 6, 7, and 8).

When the enemy began jamming in July 1943, and radar no longer furnished dependable information, the ordinary eye-ear aircraft reporting service was relied upon for a time. Information from this source was graphically presented on the large position map. By this method the data received at the so-called *Klein* plotting table (see photo 13) were projected onto the large position map by means of light point projectors (see photos 9 and 10).

Even if the aircraft reporting service failed to send in any information, the data supplied by the radio intercept service could be projected onto the large position map, either by the tele-reception method or by ordinary movie projection. In this case, the plotting data supplied by the radio intercept service were transmitted from specially equipped plotting tables (see photos 11 and 14) to the projector located in the gallery, whence they were projected onto the large position map.

Thus, by various means the attempt was made to obtain a picture

of enemy air operations and to present this picture on the large position map.

If one aspect of division headquarters activities was devoted to the enemy air situation, the second, no less important, aspect concerned itself with the picture of friendly air operations, in order that tactical control of the friendly fighter aircraft could be attained.

For this purpose, a row of work areas for fighter aircraft control officers, usually ten to fifteen in number, was set up in front of the large position map. (For views of these fighter aircraft control desks, see photos 4, 6, 8 and 15). Each fighter aircraft control desk was equipped with a microphone to maintain radio contact with the fighter plane or fighter formation in the air, and a telephone to maintain contact with the airfields at which the fighter aircraft were stationed.

Verbal radio communication was carried on either in conjunction with the *Benito* control system or, if this was not available, by a voice or key ground to air transmitter.

If the *Benito* control system was used, the position data of friendly fighter aircraft were indicated by the technique described in Appendix E. Their position indications, like those of enemy targets, were projected by light point projectors onto the large position map, except that these light point projectors had been placed from the very outset on a raised gallery in front of the position map (see photos 6, 7 and 8).

If the _Benito_ control system was not available--there were only a few of these systems set up before the autumn of 1943--the positions of friendly fighter aircraft had to be determined by the so-called _Adcock_ direction finding system. The data were entered on special plotting tables (see photos 12, 16 and 17) and projected from these onto the large position map by the usual light point projector system.

The fighter aircraft control officers were able to guide the friendly fighter planes up to enemy targets by observing the movements of the blue and red dots of light. The more accurate the picture on the position map, the better the chances of success. For this reason the chief purpose of the entire division headquarters organization was to attain the greatest possible degree of accuracy in the picture of aerial operations. The entire arrangement of the vast headquarters was guided by this basic principle.

A special work area was assigned to the aircraft reporting service (see photo 12), and a picture of air operations at any given time could be transmitted through established reporting channels to any agencies concerned with the reporting service.

The antiaircraft artillery also occupied a work area (see photo 2), so that the antiaircraft artillery officer on duty could keep subordinate units informed of events and give them orders if need be.

The commanding officer of the headquarters, the commanding

officer of the fighter aircraft division, had his own work area (see photo 1). He, of course, was in a position to choose any place he wanted in front of the large position map. In photo 1, he is sitting at the very front directly before the large position map; in other headquarters, his place was at the very back so that he could better survey the entire room. The most important thing about his place was that it commanded a good view of the large position map and had direct line communications to all the agencies whom it might be necessary to reach. Communications lines could be linked together, and a conference held of all interested parties. The conferences eliminated any time lag in the transmission of orders, and all agencies could be informed simultaneously and given orders.

The work area assigned to the division meteorologist was located in the upper story of the command headquarters. The weather maps were hung along the side walls of the large room, readily visible to the aircraft control officers; these officers could contact the meteorologist on duty at any time by telephone from their desks.

In the upper story there was also an ordinary aircraft reporting station, whose reports were entered on the *Kleta* plotting table (see photo 13), and could be projected onto the large position map if necessary.

All division headquarters were equipped with their own power plants, emergency power units, and special work-shops in order to reduce to a minimum the danger of their being forced to drop out

of action. They also had appropriate lounges and restrooms.

The division headquarters in Doolen had a subterranean emergency exit in case its entrances were destroyed by enemy activities.