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2 December 1954

FIELD TEST AGENDA

P-101B, Communication System, Infrared

I. Test Objectives

A. Range Tests

The primary objective of the tests is to determine the performance of the equipment as a function of the range and to fix the approximate maximum ACW ranges for day and night operations.

B. General Equipment Performance Tests

The secondary objective of the test is to determine the general equipment performance under typical operating conditions. Particular note will be made of these points:

1. Mechanical Features

a. Apparent quality of mechanical construction overall

b. Waterproofing of equipment closed and open

c. Apparent resistance to shock and vibration

d. Ruggedness and stability of tripod table

e. Yoke mount performance and limitations

(1) Maximum angular swing of equipment in azimuth and elevation

(2) Presence of wobble, backlash, stickiness, etc. in the yoke mounting

(3) Accuracy of horizontal and vertical circles and the ease with which they may be read

(4) Mechanical sweep mechanism performance

f. Mechanical construction of the optical systems.

(1) Quality of glass objective mirror mounting

(2) Ruggedness and stability of mount for the optical sight

(3) Ruggedness and reliability of the bellows system

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(4) Stability of the galvanometer system of modulation

(5) Protection for and mounting of the glass IR filter

2. Optical Features

a. I. R. viewer

(1) Sensitivity (night and day ranges)

(2) Field of view

(3) Quality of reticle and ease of sighting

(4) Optical quality of image

(5) Alignment of viewer with main optical system

~~b. Optical sight~~

~~(1) Field of view~~

~~(2) Quality of reticle and ease of sighting~~

~~(3) Alignment of sight with main optical system~~

3. Electrical Features

a. Amplifier noise level

b. Signal intelligibility

c. Possibilities of voice recognition

d. Battery performance

C. Operational Feasibility Tests

The third objective of the test is to determine the feasibility of using the equipment under various operational conditions. Particular attention will be paid to the following items:

1. The ease of opening the gear and assembling it, e.g., the time required to put the equipment into operation

2. The value of the controls provided and the ease with which they may be used

3. The suitability of the two foot high tripod for operations in varying terrain

4. The suitability of the angular swings in azimuth and elevation, relative to the tripod base, made possible by the present equipment design

5. The operational procedures used and the time required to accomplish the search-find operation using each procedure

D. Complete Photographic Coverage of the Equipment in Operation
The fourth objective of the test is to obtain pictures of the equipment in operation. It is felt that photographs of the terminal areas, both close ups and telescopic views from the other terminal, would be of interest to readers of a test report, since such photographs would give an excellent idea of field conditions, etc.

II. Test Procedures

A. Selection of Field Test Locations

1. Using the 1:62,500 USGS maps of the area, select 2 or 3 locations for line-of-sight ranges of 1,2,4,6,8 miles approximately

2. Make elevation plots of each of these ranges to check for line-of-sight.

3. Select, if possible, probable night and day landmarks from the map to facilitate the location of the terminal stations

4. Note the respective bearings of each station from the other in azimuth ~~and elevation~~ as obtained from the map. Also note the bearings of the landmarks.

B. Field Test Procedures

1. Form two teams of two men each; one team for each station of the range in question. Each team will have following equipment:

a. 2 flashlights
b. 1 compass - Army, 2" diam
c. Data book
d. 35 mm camera, light meter, filters & film, tripod, lenses - 50, 200 or 400, and 35 mm.
e. watch
f. binoculars

2. Make up signal plans for the ranges selected in IIA including:

a. Map overlay of both stations } or map marked with station locations

b. Map

~~c. Elevation plots~~

d. Compass Bearing of each station from the other

e. List of day and night landmarks and their bearings, if any.

f. Time to initiate search-find procedure

g. Time to discontinue search-find procedure failing contact

3. Select a 4 mile range from those of II.A

   a. Send one team to each station by daylight

   b. On this first visit to each station by daylight

      (1) Locate an operating area and set up gear. Record time required

      (2) Locate position of other station by landmarks, compass bearing

      (3) Using optical sight and mechanical sweep execute search-find procedure until contact is established. Record time required.

      (4) Note the horizontal and vertical circle readings for various landmarks

      (5) Take photos of

         (a) The gear in operation and its surroundings

         (b) The other station with 50 and 400 mm lenses

      (6) Review the General Equipment Performance Tests and make pertinent comments

      (7) Record weather conditions, visibility, temperature, etc.

      (8) Record total operating time (battery life)

   c. On the second visit to each station by night

      (1) Set up the gear in the previously located area. Record the time required

      (2) Locate position of other station from bearings of landmarks previously noted

      (3) Using infrared viewer and mechanical sweep execute sweep-find procedure. Establish contact. Record time required.

      (4) Review General Equipment Performance Tests and make pertinent comments

      (5) Record weather conditions

      (6) Record total operating time (battery life)

4. Report the procedure outlined under B, 3 for other ranges, shorter or longer as required under different terrain conditions

5. Repeat B,3,c for a previously unsurveyed site

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III. <u>Test Results</u>

A. A list of the ranges obtained with the signal quality and weather conditions noted

B. Descriptions of the operational situations involved, the search-find methods used for each situation, and the time required to establish contact in each case

C. A description of the overall equipment performance with suggested improvements

25X1

TSS/APD

Distribution:
Orig. - P-101B
3 - AST
1 - Chrono

AST/bb

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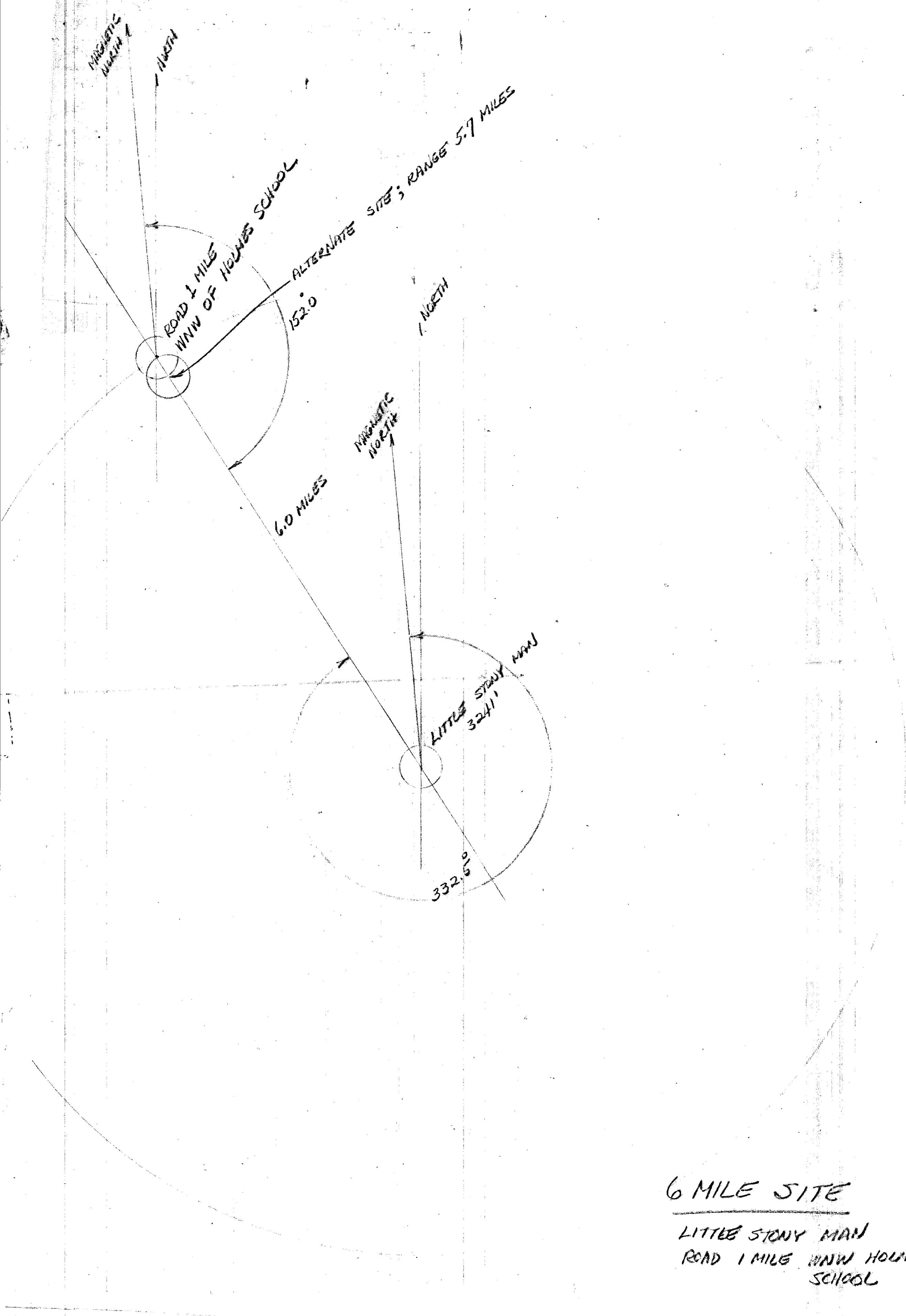
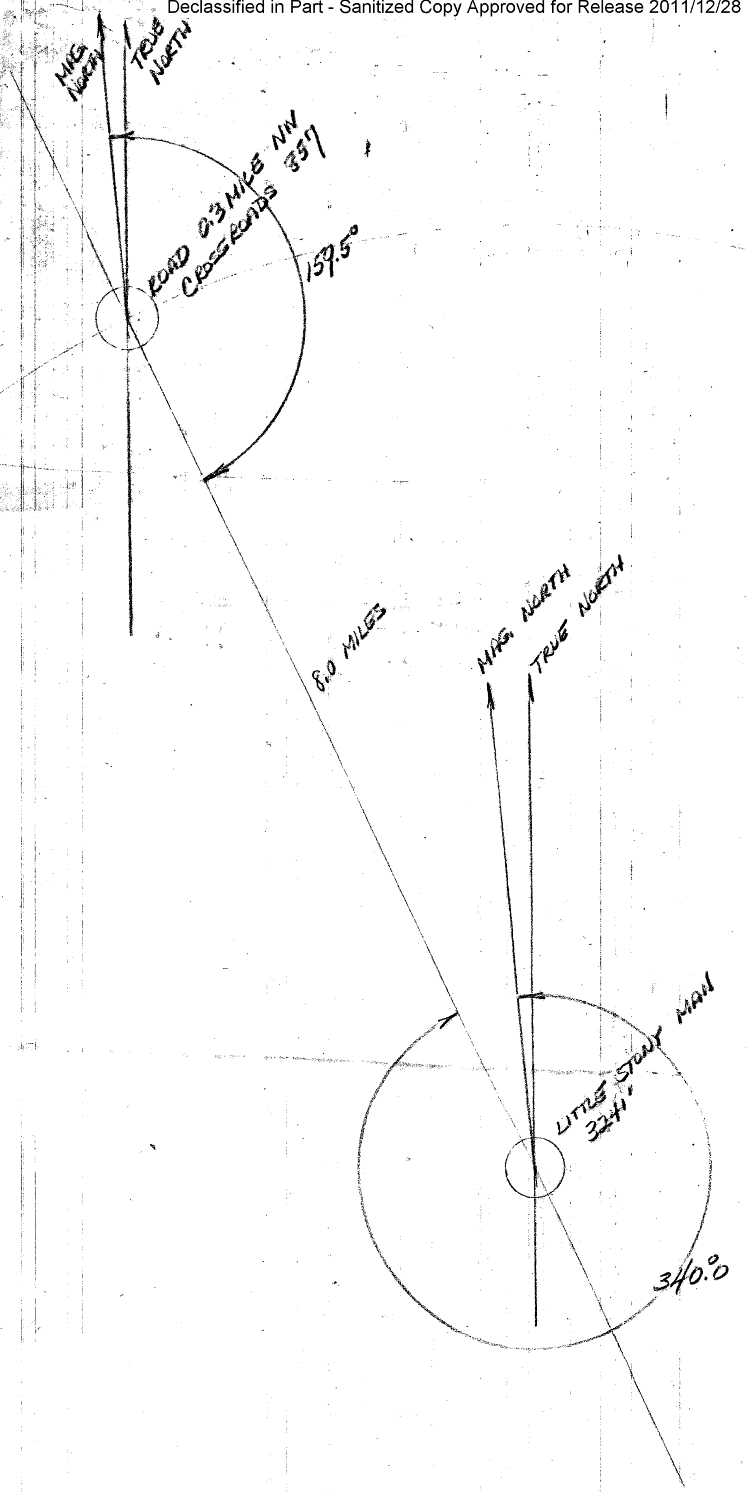
Papers re Spring
Tests, P-10/B



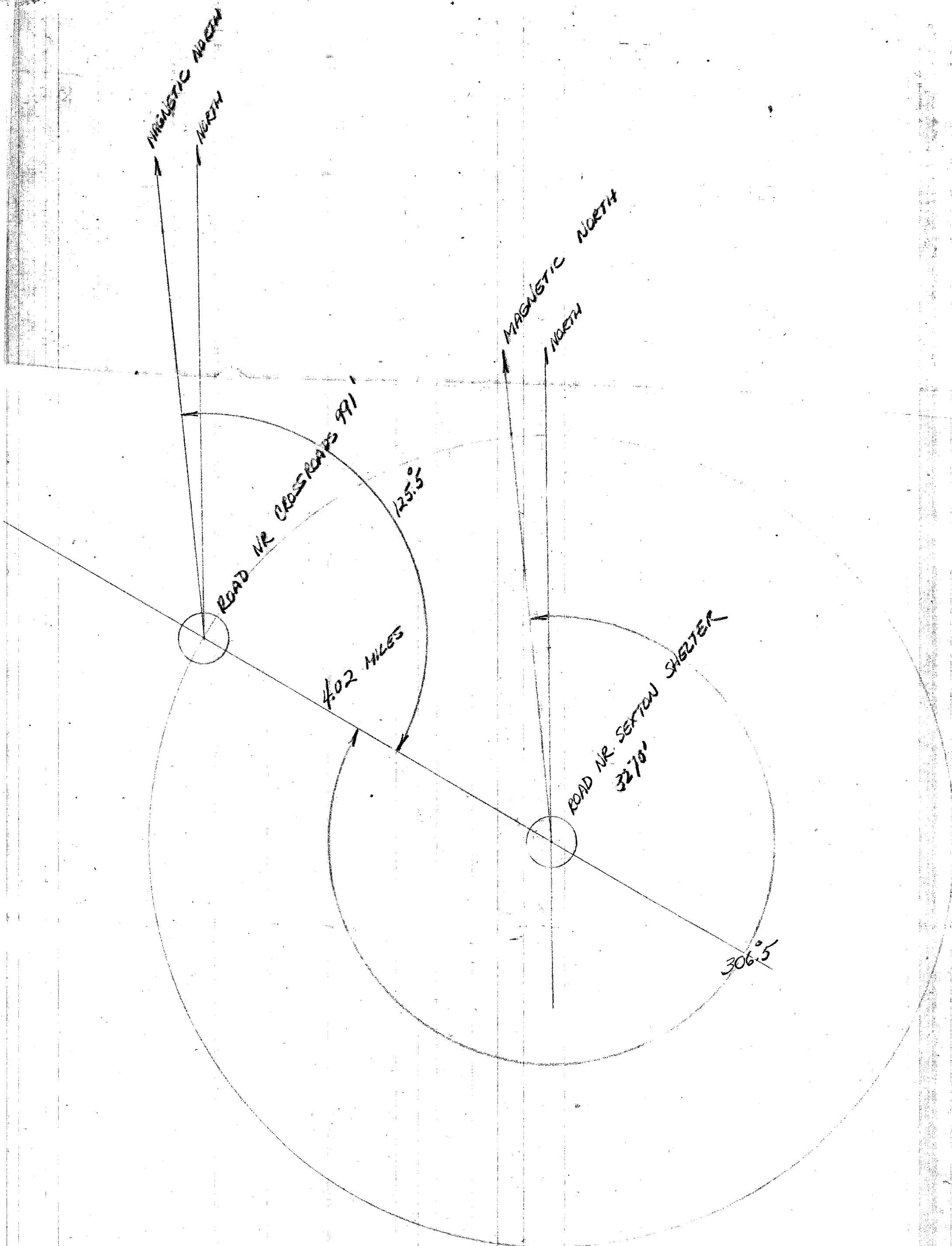
6 MILE SITE

LITTLE STONY MAN
ROAD 1 MILE WNW HOLMES SCHOOL



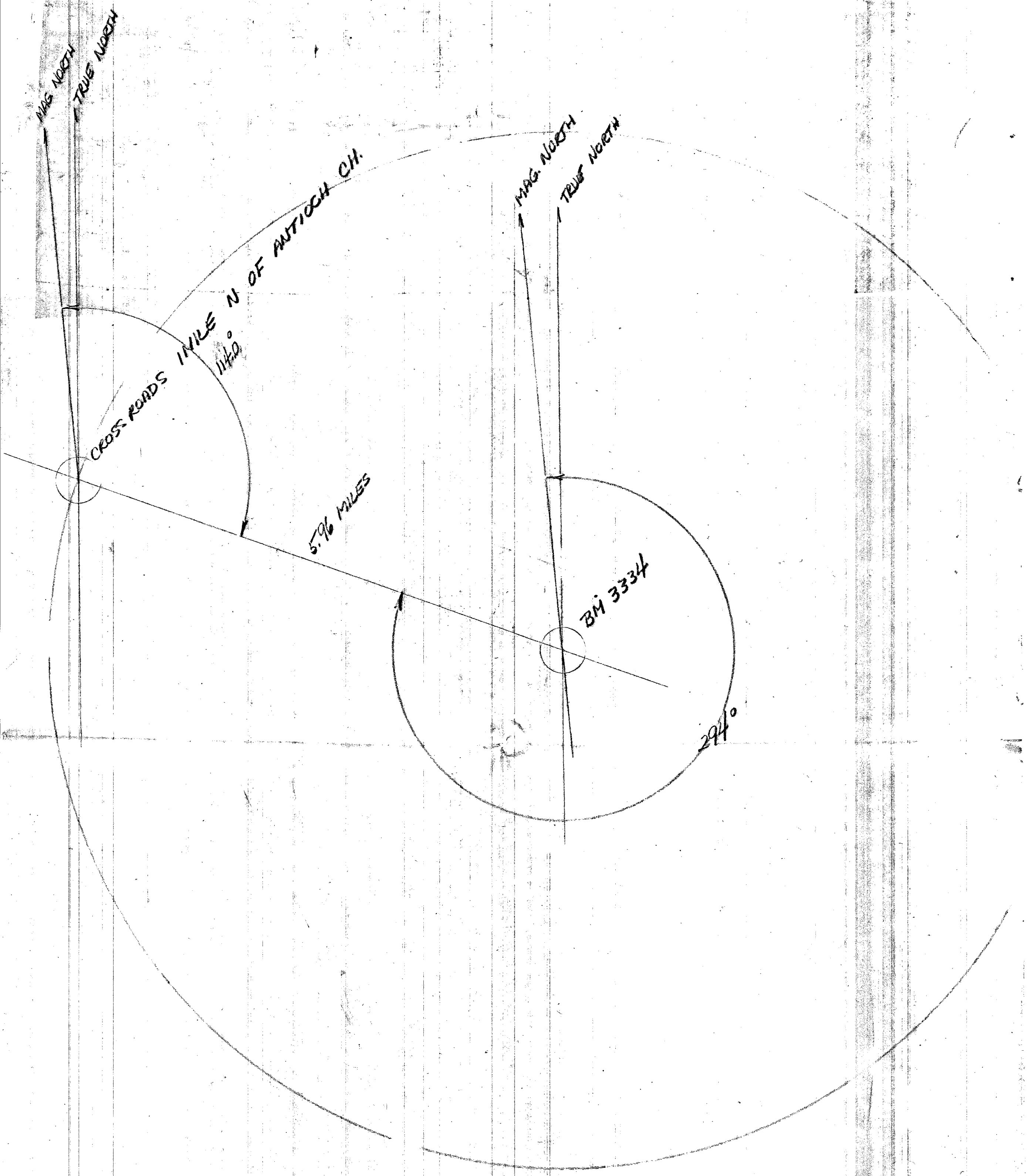
8 MILE SITE

LITTLE STONY MAN
ROAD 0.3 MILE NW X-ROADS 857'



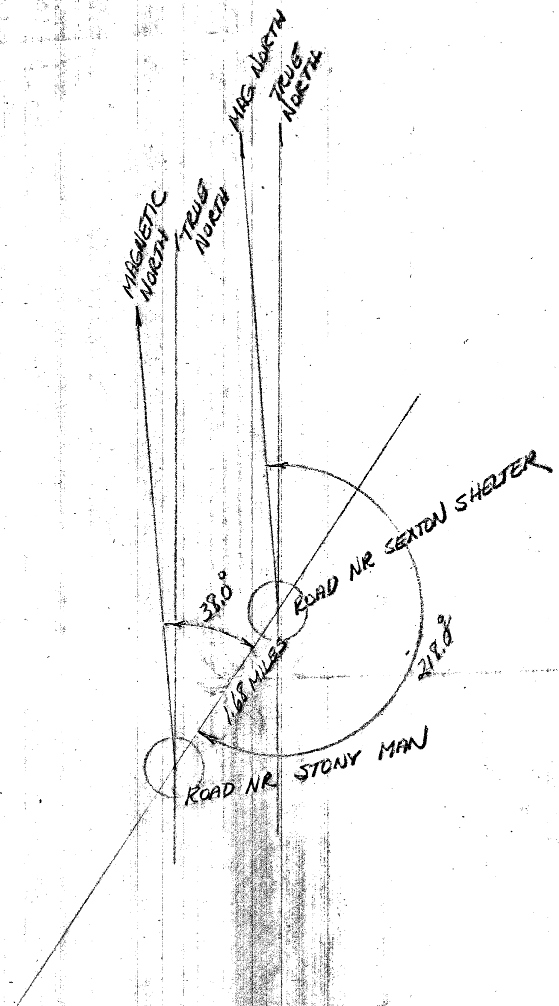
4 MILE SITE

ROAD NR SEXTON SHELTER 3270'
ROAD NR CROSSROADS 991'



6 MILE SITE

BM 3334
CROSSROADS 1 MILE N. ANTIOCH CH.



2 MILE SITE

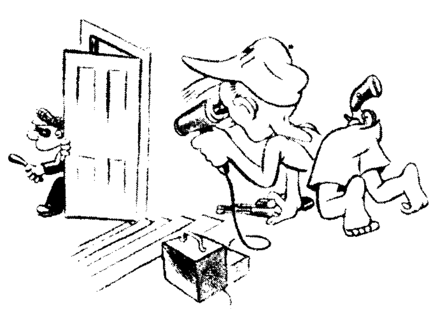
ROAD NR STONY MAN
ROAD NR SEXTON SHELTER

Friend or foe? In pitch blackness the snooperscope will tell whether stray noises are caused by a late-returning husband or a midnight prowler.

Photos by G. Towk

make this SNOOPERSCOPE and see in total darkness

By Harold Pallatz



PICTURED above is only one of the possible applications of the modified wartime sniperscope. This unit, called a snooperscope, is an enlarged version of the instrument used by GI riflemen to enable accurate fire power in total darkness. When the infrared light source is turned on, the user, by employing the special eyepiece, can see in the area covered by the light, although to the naked eye total darkness still prevails.

A number of more practical applications have been developed with the snooperscope because of its ability to peer through any opaque material that passes infrared rays. Crime detection laboratories are now using similar equipment for reading through certain types of material. Since the infrared reflection of pigments in paints and inks is different from that of white light, it is possible to detect forged paintings and checks by the way the colors appear. You can demonstrate this by writing a message with India ink and then painting over it with a coat of ordinary fountain pen ink. Your eye will only see the blackened spot but the snooperscope will peer through the top

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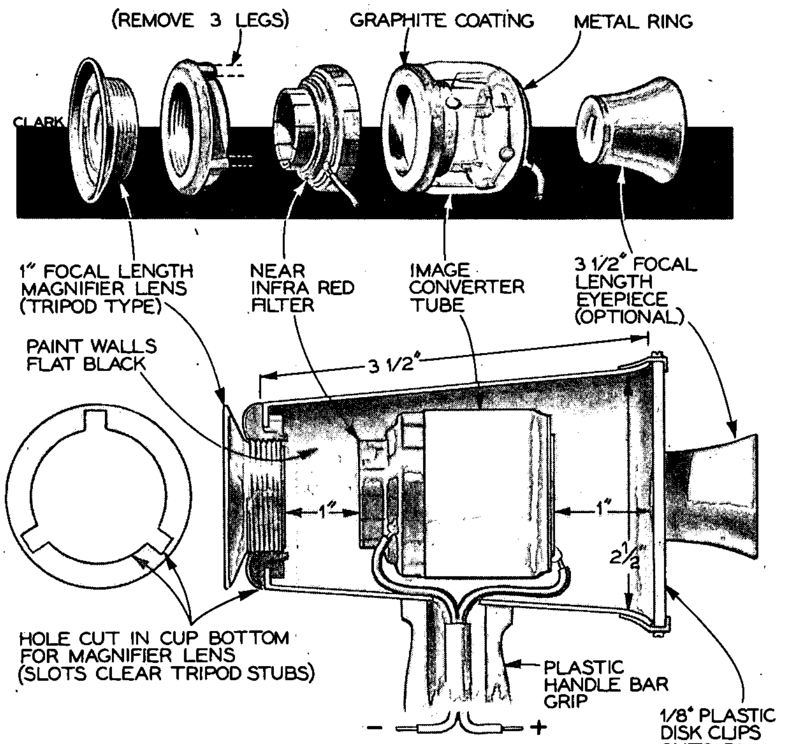


ARRANGEMENT OF UNITS INTO PLASTIC DRINKING CUP

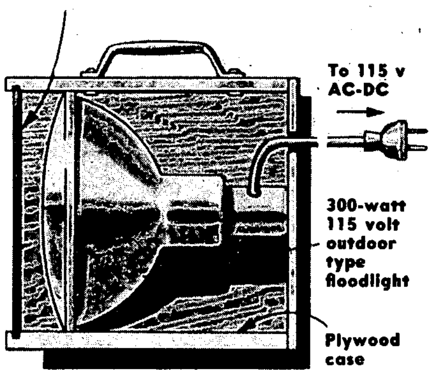
layer of ink and reveal the writing just as clearly as if there were no top coating. This type of inspection can be made photographically if infrared film is used in the camera. The electronic method permits instantaneous examination which often is a great convenience.

As you might have thought, there are several photographic applications. Using this device, you can take photographs with no visible light source. (For instructions on this type of work, see Shoot 'Em In The Dark, January, 1951, MI, pgs. 148-149.) One of the handiest uses is using the snooperscope as a darkroom viewer. Difficult operations that have to be carried out in total darkness can now be viewed clearly throughout the process. If you run into trouble loading film tanks you will appreciate a viewer when the film becomes snarled. A test for fogging should be made before the viewer is used. Within the next few years every modern darkroom may be equipped with infrared viewers.

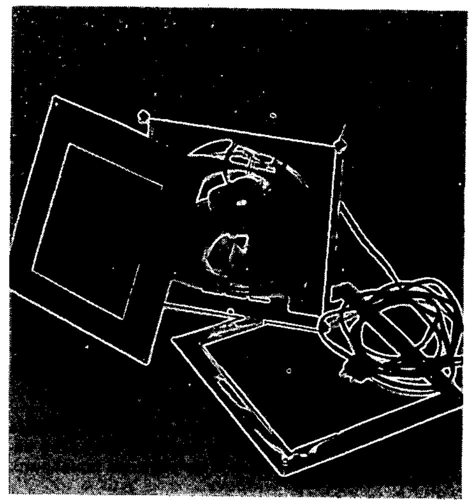
In scientific laboratories a modified unit such as this is used to study the behaviour of small nocturnal animals in total darkness. A converter tube has been used with a microscope to study bacteriological and botanical specimens under infrared rays. Certain large molecules may now be examined in a different way, since they become transparent under infrared light.

Military uses are obvious. The sniperscope has already been mentioned. The Germans used infrared-equipped tanks and trucks for driving during blackouts. Under these conditions they could travel almost as fast as during the day. Cars equipped with a snooperscope would have the advantage during fog. Certain types of fog are transparent to infrared (depending on the particle sizes) and during such weather increased safety of the road could be obtained. The experimenter is cautioned about building a unit for this purpose, as very good lenses are required as well as powerful headlights. Such specialized construction is likely to prove difficult and driving with makeshift equipment would be dangerous.

In the actual construction of your snooperscope, your b[illegible] [illegible]e would be one of several British m[illegible], which are available



UNIT FOR SUPPLYING LIGHT SOURCE



Elements of the light source. Bulb employed is a standard 100 to 300-watt lamp. Although this case is of metal, you may use plywood if so desired.

on the surplus market. Two of these are type CRI 143 and CV 147. For operation at the highest voltages, the tubes should be carefully selected. Other electronic parts required are a 4,000 to 6,000-volt low current power supply (less than one milliampere), a light source and two filters.

For indoor operation a 4,000 to 5,000 volt neon sign transformer operates the tube satisfactorily. Two 1-megohm resistors are used, one in series with each lead, to limit the current. Rectification is not necessary unless the objects are in motion (objects in motion cause a stroboscopic effect when AC is employed.

For portable use either indoors or outdoors a handy-sized power supply may be constructed that operates off three standard flashlight cells. For continuous operation leave the power supply on as long as required. Very long battery life can be obtained by switching on the power supply only momentarily to charge the condenser. The condenser will then store this energy and continue to operate the tube for some time after the unit is turned off. Place a small piece of rubber tubing over toggle switch handle to help eliminate charge pickup.

The high voltage is supplied by a model airplane ignition transformer with a vibrator to interrupt the primary current. These transformers are available on the market with the vibrator already built in. Only two wires need be attached for operation. You can make up your own vibrator coil arrangement by using the parts of an old buzzer or bell. Some types of buzzers can simply be connected in series with the primary of the transformer. Try yours to see if this is possible (1½ volt buzzers). Caution: Avoid contact; these voltages are high and while not dangerous, can give you a rather uncomfortable shock.

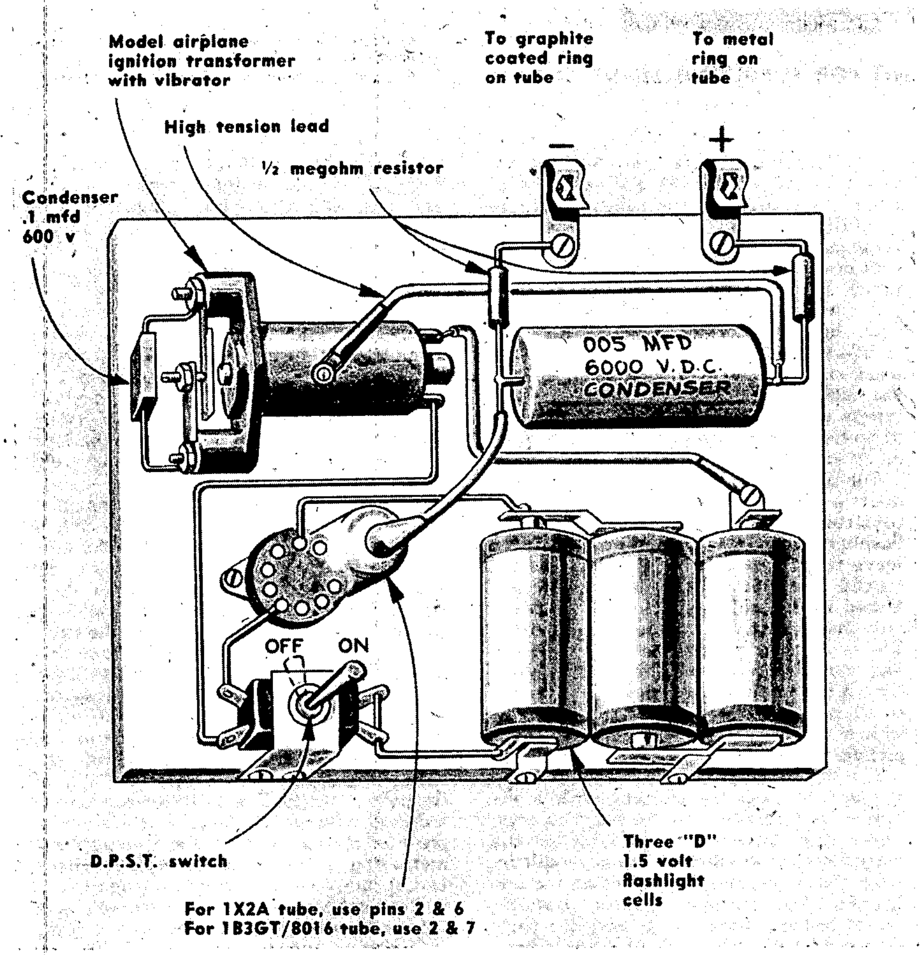
Construction of the snooperscope: The image converter tube is mounted in a plastic drinking cup 3½ in. high by 2½ in. in diameter. The optical system required depends upon your intended use. We used a small tripod type magnifier lens of 10 power (1 in. focal length) for the front lens and objects from three inches to one and a half feet can be focused. There is no reason why a greater range cannot be had with this lens by moving it closer or farther away from the tube.

After selecting the lens system mount it in a hole cut into the bottom of the cup. A jeweler's saw or coping saw is ideal for cutting the hole. Paint the *inside* of the cup with black paint. Black airplane dope works fine. No light other than that from the lens must be permitted to hit the tube. Place an infrared filter between tube and lens to reduce effects of stray white light.

The image converter tube is inserted with the graphite side toward the front lens and the metal ring toward the mouth of the cup. A thin flexible lead from the metal ring connects to the positive side of the power supply. Some tubes were manufactured without this lead, in which case a piece of spring metal pressed against the metal ring will work just as well. The front end of the tube has a graphite ring around it. This is the end where the infrared image is to be focused. The graphite coating is the cathode or negative lead. Connect this lead to the B minus side of the power supply. A piece of spring

Top view of simplified power supply for portable use. Cells are the ordinary flashlight type. The entire unit is mounted on a ¾-in. plywood baseboard.

The snooperscope itself. For indoor use a small neon sign transformer (right) may be used to power the infrared tube within the plastic cup.



PORTABLE POWER SUPPLY UNITS ON WOOD PANEL

brass or even the flat sheet metal carefully removed from a tin can should be formed with the fingers so it fits snugly around the cathode terminal.

The rear viewing lens is optional as it is only required if you wish to view the images closely with the eye. It should have about three power and a focal length between 2½ and 4 in. This lens is mounted and cemented to a piece of plastic or wood. The material should be opaque and have good insulating qualities. The handle is a plastic bicycle handlebar grip which is cemented over a hole drilled into the side of the drinking cup for the high voltage leads. The lead wire can be the plastic type of zip cord, over which is placed plastic insulating tubing.

Light source: The main limit to the viewing distance is the power and type of light source. Greater intensity means greater distance. For the direct viewing of glowing objects this imposes little difficulty. Such objects as the moon and extra bright stars may be viewed directly. A small flashlight with a plastic filter may be detected at quite a distance. Reflected light from objects requires the use of heat lamps, photofloods or standard 100 to 300-watt lamps to illuminate them. Of course these lights are filtered so that no visible light is seen. The light source shown on page 100 consists of a 300 watt sealed beam outdoor type floodlight (115 volt), a glass type infrared filter and a 10x10 in. recessed lighting box.

Outdoor applications involving greater distances require a bulb with a sharply focused reflector. Gold-plated reflectors give very good results. The sniperscope used a 30 watt, 6 volt bulb similar to the type used in auto headlights. This was operated on a small rechargeable storage battery. Good substitutes are auto spotlights of the sealed beam type such as Westinghouse type 4535 or the General Electric 4524. Standard type flashlights with small dry cells *will not* provide ample infrared for viewing by reflection. Never point your snooperscope at extremely bright light sources like the sun. Damage to the tube may result.

Infrared filters: Experimental filters can be made by sandwiching several layers of dark red and blue cellophane between two sheets of clear plastic. Both plastic and glass types are available from photographic and scientific supply houses. The latter type is to be used whenever heat is involved. Infrared filters cut out all or most of the visible radiation and allow the heat rays to pass through unobstructed. Since a tungsten lamp produces much more infrared than it does visible light, the action of a filter reduces its strength only slightly, while to our eyes it now becomes total black. Don't forget that it is possible to overheat even glass filters, so light sources should not be left on longer than necessary. •

SNOOPERSCOPE PARTS LIST

Light Source:
- Sealed beam light or standard 100 to 300-watt lamp and reflector
- Metal housing for above items
- Infrared filter

Snooperscope (Eyepiece unit):
- Image converter tube
- Plastic drinking cup
- Plastic handlebar grip
- Jeweler's eye loupe (approximately 2 to 4-in. focal length)
- Tripod magnifier, approximately 10x, 1-in. focal length
- Five ft. plastic-insulated cord (do not use cord with rubber or cloth insulation)
- Near infrared filter
- Black paint or airplane dope

Power Supply, AC:
- Neon sign transformer, 4 to 5 kilovolts at under 10 mills current rating
- Two ½-megohm resistors (may be as high as 5 meg.)

Power Supply, Portable:
- Three flashlight cells
- Model airplane ignition coil
- Small buzzer
- .005 mfd. condenser, 6,000 volts
- .1 mfd. condenser, 600 volts (if not built into vibrator coil)
- Two ½-megohm resistors
- 1x2A or 1B3GT/8016 tube
- Socket for above tube
- Wooden baseboard
- D.P.S.T. switch
- Grid cap
- Two fahnestock clips

Note: These parts may be obtained from the Precise Measurements Co., 942 Kings Highway, Brooklyn 23, N. Y.

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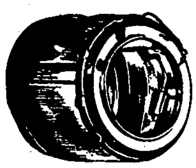
PRECISE MEASUREMENTS COMPANY

SNOOPERSCOPE SUPPLIES

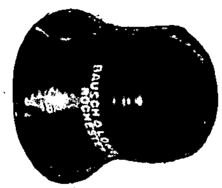
We have a limited quantity of the following supplies for the construction of snooperscope outfits. All material is in new condition and carries our warranty to be free of defects in material or workmanship.

SNOOPERSCOPE TUBE



SEE IN THE DARK

SUPPLY LIMITED—These are government released British snooperscope tubes which employ the special simplified design, making construction of experimental models possible with simple hand tools. Highly sensitive, they provide a bright clear image of invisible infra red rays. Also useful as infra red (invisible) photocells. With complete hookup instructions. Special Price $14.95.



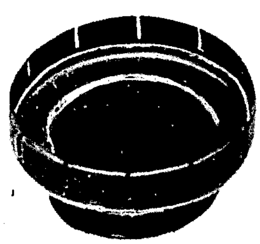
ENGRAVERS GLASS—Has a ground lens for clear sharp images. Focal length three inches. Perfect as either a front or rear view lens. Plastic housing prevents electric shock. **Price 1.25**

SNOOPERSCOPE BOOK

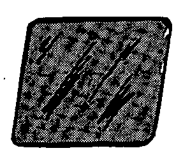
Shows in detail Army and Navy snooperscopes, sniperscopes and infra red telescopes. One of the few books of its kind. Circuit hookups for practical instruments are given.

Special Price $1.50.

IGNITION COIL—This miniature high voltage coil provides high output for snooperscope operation. Has built in condenser for extra power. **Special $2.25**



NEAR INFRA RED FILTER—An efficient filter that fits directly on the front of the image converter tube. High quality glass type with metal mounting clasp. Clasp also serves as the graphite contactor (—lead). **Your Price 1.50**



FILTERS—Infra red filter glass. Manufactured by a famous glass house to exacting specifications. Transmitts over 80% of the infra red rays but appears as a total black for visible light.

3 x 3 inch square	**Price $2.55**
6 x 6 inch square	**Price $4.00**
5⅜" Round	$3.75

PLASTIC FILTERS

Infra red plastic filters are also available at 15¢ each for small test square and 75¢ each for 6 x 6 inch squares. Permits passage of heat rays but appears black to visible light. Buy several at this price while the supply lasts.

942 Kings Highway, Brooklyn 23, New York

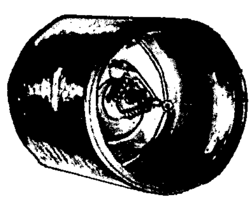
ADDITIONAL INFRA RED SNOOPERSCOPE SUPPLIES

The following additional supplies were made available due to many requests for materials with which to construct experimental infra red instruments and snooperscopes. Sales of any item is limited to stock now on hand. **New materials arriving daily.**

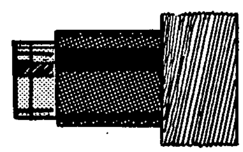
POWER SUPPLY KIT—Provides the proper voltages for image converter tubes. Operates off three ordinary flashlight cells. Completely portable. Every part including case, rectifier tube and batteries is supplied.

Your price $14.95

LENSES—These lenses are of top quality materials and intended for use where the best possible results are required. We make these lenses available only to our customers which have purchased our snooperscope tubes and send us there written assurance that they have been successful with the circuits and the simple lenses and now feel prepared to construct the finer models.



SNOOPERSCOPE LENS — Original Navy Snooperscope lens. Schmidt optical system type Government cost $134.00. Very fast speed F 1.0 **Our Price $12.50**



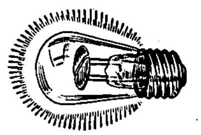
Mounted Optical Lens. High quality lens of fast speed. Excellent for image tubes. Priced at a fraction of their original cost. **Price $8.50**

HOW TO ORDER
IMPORTANT NOTICE

Sales are subject to the following conditions; all prices in this catalogue is subject to change without notice. Most material is shipped postpaid unless otherwise noted. Test instruments are not postpaid and postage fees should be included with your order. We will insure all material unless instructed otherwise. In the event of damage in transit, write us immediately giving details o f the damage and insurance numbers on package. If for any reason you wish to return material write us first giving all details and we will send you ship ping instructions. **POSITIVELY NO MATERIAL ACCEPTED FOR RETURN UNTIL WE HAVE BEEN NOTIFIED AND YOU HAVE OUR SHIPPING INSTRUCTIONS.** Merchandise made to customers own specifications cannot be returned. Foreign orders should add 10% to cover costs of additional packing, postage and con sular expenses. No C.O.D. orders accepted unless accompanied by a deposit of 25%, balance wil be shipped C.O.D.

This catalogue covers only a few of the items that we carry. We carry hundreds of items not listed on these pages write us on your requirements. Prompt efficient service is rendered on all orders regardless of size. Our lab oratory is engaged in the construction of scientific instruments of every de scription. We are always very happy to send our free quotations on equipm ent built to order.

PRECISE MEASUREMENTS COMPANY
942 Kings Highway, Brooklyn 23, New York

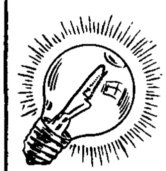


BLACKLIGHT LAMP

Special Argon filled bulb provides a good source of violet and ultraviolet light for blackout experiments and fluorescent materials. Very convenient as it screws into any standard lamp socket.

Clearance Price 45c
10 for $4.00

GE OZONE LAMP



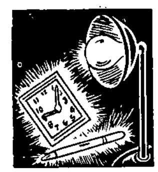
Generates short ultraviolet radiation (1849A & 2537A) which produces ozone by converting the oxygen of the air (O^2) into ozone (O^3). Useful for fluorescent & phosphorescent materials. Uses only 4 watts of power. Lamp supplied with socket and instructions.

Your Price $1.95

FLUORESCENT PIGMENTS

Brightest glowing, concentrated phosphors, available in many colors. Red, White, Blue, Green, Yellow and Orange. Mix with clear lacquer for painting.

SAMPLE SIZE (specify color) . . . . . . 35c each
COMPLETE SAMPLE KIT (6 colors) . . $1.75 ea.
One Ounce Bottles (specify color) . . . 50c each



AMAZING BLACK LIGHTS

Powerful 250 watt Ultra Violet Bulb is very convenient to use as it screws into any standard lamp socket. Provides black light which causes many things to glow. Excellent for experimenting with fluorescent and phosphorescent pigments. Lamp is designed for intermittent duty only.

Price $1.95

PHOSPHORESCENT PIGMENTS. Expose these pigments to sunlight or ultra violet light or ordinary light bulbs. Pigments wil then remain glowing for sometime afterward in total darkness. Comes in powder form mix with clear lacquer for painting. Available in three colors: yellow-orange, green and blue. **One ounce bottle 60¢ ½ pound bottle $2.75**
SAMPLE KIT. Consists of one of each of the above coolrs (three bottles).
Price 98 cents.

SPECIAL PHOSPHORS

ULTRA VIOLET

Energize this phosphor with short wave ultra violet light (approx. 2500 A) and it will convert it to the near ultra violet of approx. 4000 A. This phosphor when used with many types of black lights will increase the ultra violet output considerably. Use as a coating on the outside of photocells to change their response.

Sample 50¢ 1 oz. Bottle $1 $12.50 lb.

TWO COLOR

The beautiful colors that these concentrated phosphors will glow depend upon the wavelength. Different types of blacklights will make it change color. Red and green or yellow and green are available.

Sample 50¢ $12.50 lb. 1 oz. Bottle $1

INFRA RED RESPONSIVE

A specially prepared material with rare earth activators. Charge with ultra violet light or alpha particles, phosphor then stores this energy and releases it in the form of light when infra red radiation is present. Also useful as temperature indicators.

Price $4 oz.

SHORT WAVE

Responds to wavelength of 2500 A or shorter. Will detect alpha particles, electron beams, etc. Lights up a bright green.

Sample 50¢ $12.50 lb. 1 oz. Bottle $1

INFRA RED EMITTING

This unusual material has the property of emitting far red and infra red radiation when excited with ultra violet light. Useful as infra red light sources, experimental fluorescent lights, etc.

Price $4 oz.

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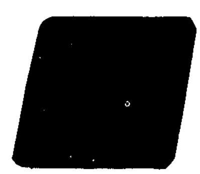

Glass type. Filters out most of the visible light while allowing free passage of ultra violet. Very handy for experimenting with fluorescent phosphors.

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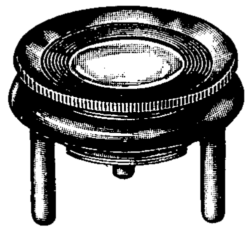

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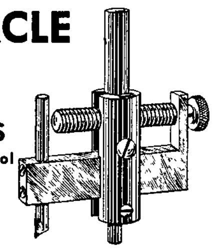

- Micrometer type size control
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At all Dealers

Model	Type	Size	Price
1	Round shank	4 inch	$5.00
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VAN DE GRAAF MACHINE

Produces voltages between 10 KV and 100 KV. Well designed for long life and efficient operation. Under favorable weather conditions sparks up to three inches can be obtained. Many interesting high voltage experiments can be performed with this miniature generator.

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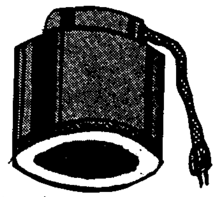

2537 Angstrom units

Consists of a miniature mercury vapor lamp in beautiful plastic housing. Lamp constructed of special glasses for the efficient production of ultra violet radiation. Built in ballasts for long life and good operation. Wavelength changer filter instantly changes the output wavelengths

Your Price $9.95

WAVELENGTH CHANGER FILTERS

available in blue, green, yellow, orange and red. Price $1 each

INFRA RED WAVELENGTH CHANGER FILTERS

Converts your ultra violet generator to an infra red generator. Price $1.50 each

NIGHT VISION GOGGLES.—These goggles were used by the Army for nighttime vision purposes. All are new and in individual cloth case. **Price $1.00 each**

INFRARED FILM. A fortunate purchase of infrared film allows us to offer this material at an almost unbelievable low price. Film is surplus aerial camera stock which is outdated. We have tested this film and find that good results can still be obtained. Speed rating is 50 with red filter. Comes in vacuum sealed can in rolls 5½ inches wide by 26 feet long.

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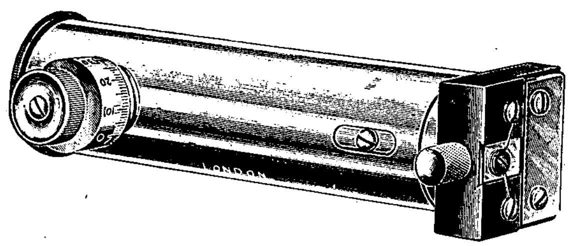
No. 2425 READING DIFFRACTION SPECTROSCOPE.



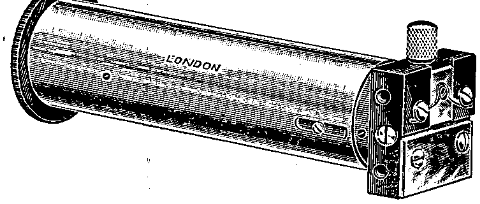
This spectroscope is suitable for medical research, analytical work and general purposes in physical laboratories.

The dispersion is 34° and the slit is provided with an adjustment for varying the width. A graduated drum by which the spectrum can be moved across the field, used in conjunction with an indicator enables readings to be taken. This drum is divided into 100 divisions, which are arbitrary, but which can be calibrated if desired by the user. An adjustment is fitted for accurately focussing the spectrum.

A table stand to carry the spectroscope can be supplied. Provision is afforded for the attachment of a test tube holder and also a cylindrical lens attachment. This latter is a very useful accessory, especially when working with a small or weak source of light, as it concentrates an image of the light source on the slit.

No. 2425. Reading spectroscope, in case **$69.50**

Nos. 2458 and 2459 PRISM SPECTROSCOPES.



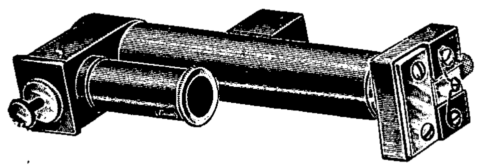
For certain purposes the prismatic type of spectroscope is advantageous, as it passes very much more light than the diffraction type. The dispersion, however, is less, and as explained in the opening description (page 1), gives a smaller relative dispersion at the red end of the spectrum compared with that at the blue end. This model employs a train of five prisms giving a dispersion of 10°. An adjustment is provided to the slit for varying the width; there is also an adjustment for accurately focussing the spectrum. The instrument can be attached to a table stand, and provision is made for the attachment of a test tube holder, etc.

No. 2459 has the addition of a comparison prism. This enables the spectra from two sources to be examined simultaneously.

No. 2458. Prism spectroscope, in case **49.50**

No. 2459. Prism spectroscope, in case **52.95**

Nos. 2522 and 2523 WAVELENGTH PRISM SPECTROSCOPES.



For taking direct readings in wavelengths where extreme accuracy is not required, this instrument will be found extremely satisfactory. The dispersion given is 10°. The scale giving readings in wavelengths is viewed in the same field as the spectrum, each division of the scale representing 100 A. The slit is adjustable and the necessary focussing adjustments are provided. There is also an adjustment to the scale so that it can be set accurately in relation to the spectrum.

Provision for attaching to a table stand is provided and such accessories as test tube holder and cylindrical lens attachment can be employed.

No. 2523 has the addition of a comparison prism. This enables the spectrum being examined to be compared with a standard or other source.

No. 2522. Prism spectroscope, in case **$89.50**

No. 2523. Prism spectroscope, in case **$94.50**

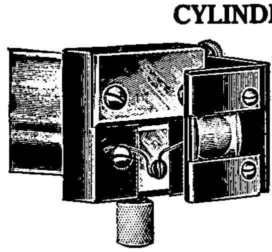
ACCESSORIES

TABLE STAND.

This stand is strongly made, the spread of the feet is arranged to ensure that the stand is rigid. The fitting carrying the spectroscope has adjustments for raising and lowering, also for tilting, both adjustments being provided with clamps. It is suitable for spectroscopes Nos. 2447, 2449, 2425, 2426, 3500, 2458, 2459, 2522, 2523. 2435 and 2438.

No. 2437. Table stand **$9.95**

CYLINDRICAL LENS ATTACHMENT.



When small or weak sources of light are being examined, this attachment is found extremely useful, as it produces an extended image of the light source on the slit. It can be used in conjunction with Nos. 2447, 2449, 2425, 2426, 3500, 2458, 2459, 2522 and 2523.

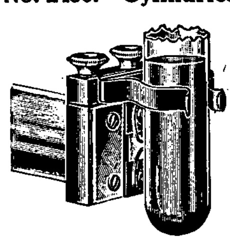
No. 2496. Cylindrical lens attachment .. **$9.50**

CYLINDRICAL LENS ATTACHMENT.

This attachment is on the same principle as No. 2496, but is made in quartz so that it can be used in conjunction with spectroscopes Nos. 2435 and 2438.

No. 2436. Cylindrical lens attachment **$10.95**

TEST TUBE HOLDER.



This holder is a secure method of supporting a test tube and enables a number of tubes to be easily and quickly changed. It is attached to the spectroscope by two clamping screws and can be used on models Nos. 2447, 2449, 2425, 2426, 2458, 2459, 2522 and 2523.

No. 2697. Test tube holder **$2.95**

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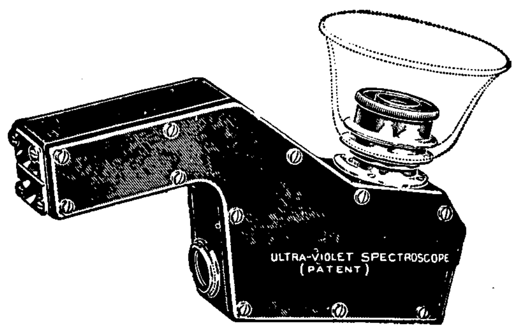
Nos. 2435 and 2438 ULTRA VIOLET SPECTROSCOPES.

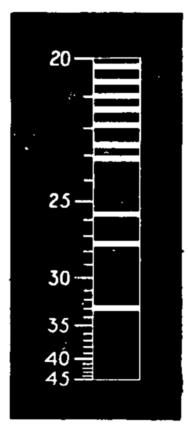


This is a compact spectroscope for the examination of the ultra violet spectrum Its general design can be seen by the illustration. It has an accurately made slit, fixed or adjustable, through which the light passes on to a quartz prism, forming a spectrum upon a fluorescent screen. The spectrum thus formed is examined by an eyepiece, giving a magnified image. The eyepiece is provided with a focussing motion and an eye cup to exclude extraneous light.

Beside the spectrum in the field of view is an illuminated scale, divided in Angström units, so that the wavelength of any portion of the spectrum under observation can be determined. The scale appears with illuminated lines and figures upon a black background, the illumination being obtained through a window in the instrument by means of the visible light in the light source under examination, so that no additional source of light for illuminating the scale is necessary. The spectrum included in the field of view is from 2,000 A. to 4,500 A., which includes a small portion of the visible light.

The instrument can be conveniently used in the hand, table stand can be supplied if required

This spectroscope has been designed with a view to giving a particularly brilliant spectrum, thus rendering it easily used in daylight and with the same ease as a spectroscope for visual light. It is, therefore, specially useful for rapid determinations in electromedical and similar establishments and for industrial workshop use, when a more complicated apparatus is inconvenient to use.



Spark spectrum of zinc and cadmium as seen in eyepiece of spectroscope.

When a small source of light is being examined, the brilliancy of the spectrum can be increased by using a cylindrical lens attachment (page 12), thus making it unnecessary to hold the spectroscope close to the source of light.

No. 2435. **ultra violet spectroscope,** in case **109.50**

No. 2438. **ultra violet spectroscope** with adjustable slit, in case **114.50**

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What's Ahead?

by LLOYD E. VARDEN

With the coming of high-speed pan films, and later, color materials for home processing, photographers were compelled to struggle through most of their darkroom chores in absolute darkness. The once useful dark-green safelight provided enough light—after the eye became adapted—to give one confidence in carrying out the most intricate of darkroom manipulations with slower or less color sensitive materials. Today, though, when a high-speed pan or color film jams, for example, while loading it into a developing reel, about all that can be done is to start from scratch and hope for the best. To turn on a safelight is inviting disaster.

Seeing in the dark

During the war, reports leaked out that soldiers had been given devices enabling accurate rifle fire in complete darkness. The secrecy was not entirely warranted, because as early as 1934 disclosures had been made in the scientific literature on converting invisible infrared radiation to visible light. The now well-known *snooper scope* and *sniperscope* employed this principle. An infrared searchlight, which the enemy could not see, "illuminated" the field of observation. The scope contained a lens system that projected an infrared image of the scene onto the photo-cathode of an electrostatic image tube. Electrons emitted from the infrared sensitive surface were then focused by the tube onto a small fluorescent screen, producing a visible image that was observed through a magnifying eyepiece. The principle involved is made clearer in Figure 1.

It is obvious that an instrument of such novelty should find peace-time applications. Immediately after the war, for example, Pavelle Color Inc. purchased a surplus military infrared telescope in the hope that it could be adapted for "seeing" in the pitch black darkness of color processing darkrooms. The instrument was relatively small, and was easily refocused for close-up viewing. It operated from an ordinary 115 volt electric line, and provided an amazingly brilliant image when the area under observation was illuminated by a 150 watt tungsten filament lamp, housed to emit radiation only through a Wratten No. 87 infrared filter. Sufficiently fine detail could be observed to carry out nearly any darkroom operation. (Written instructions on a sheet of paper could be read with ease.) It appeared as though the difficulties that arise from working in complete darkness would soon be a thing of the past.

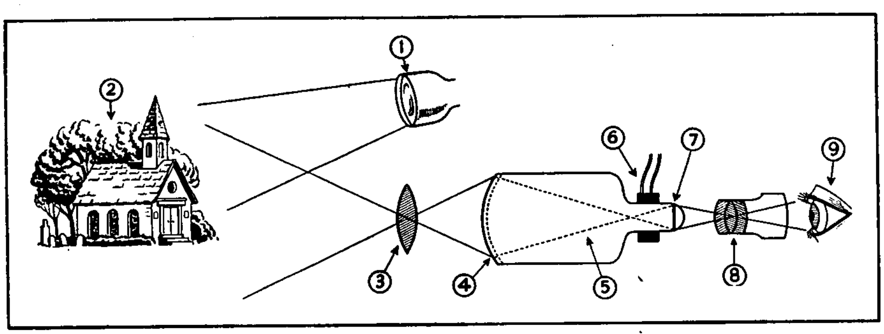
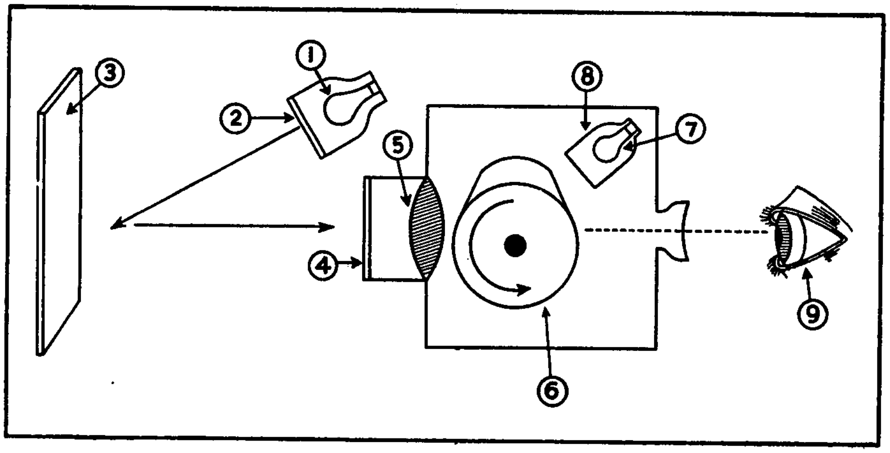


Fig. 1, above: Invisible radiation is projected by infrared searchlight (1) onto scene (2), reflected to lens (3) and onto infrared sensitive photo-cathode (4). Electron beam is focused electrostatically by image tube (5) which gets its power from (6). Fluorescent screen (7) shows image, seen through viewing lens (8) by human eye (9).

Fig. 2, below: Infrared source (1) projects beam through infrared filter (2) onto sheet of film to be observed (3). Rays are reflected through infrared filter (4), lens (5), and onto phosphor-coated surface of rotating cylinder (6) which has previously been exposed to rays from ultra-violet source (7) in reflector (8). Image thus becomes visible to human eye (9). This is principle of Tuttle's device.



Fundamental problems involved

The application of the infrared image tube for general photographic purposes is restricted by at least two fundamental problems. First, many photographic emulsions, after exposure in the camera, exhibit an image reversal when exposed to infrared radiation. This is known as the Herschel effect.

The first of these problems could no doubt be overcome by limiting the viewing times in the darkroom to a minimum, or by reducing in other ways the amount of infrared radiation reaching the film.

A different approach

Another approach to seeing in the dark was recently described by C. M. Tuttle of the Eastman Kodak Co. in U. S. Patent 2,521,953. Tuttle makes use of an infrared source and phosphorescent substances, but the visible image is formed in a manner different from the image tube. He takes advantage of the fact that infrared radiation can be employed to stimulate the fluorescence of a previously excited phosphor, i.e., one that has been exposed to ultraviolet radiation, for example, so that the brightness of the fluorescence increases with the amount of infrared the phosphor receives. Or, by proper choice of the phosphor, the infrared can be used to quench, or "put out" the fluorescence previously produced by an ultraviolet source. Now, by means of a rotating phosphor-coated surface enclosed in a box with an ultraviolet source, and with a lens on one side and a viewing hole on the opposite side, it is possible to illuminate a light sensitive material with infrared and view its visible fluorescent image. One such device described by Tuttle for inspecting film during manufacture is shown in Figure 2. The rotating phosphor-coated surface passes the ultraviolet source where it is excited. It then passes the infrared image formed by the lens where, depending upon the phosphor used, the fluorescence of the rotating surface is stimulated or quenched according to the amount of infrared radiation striking any particular point. The image produced remains on the surface long enough to be viewed through the peephole before reaching the ultraviolet source again. With one type of phosphor a negative image is produced, and with the other, a positive image. A device based on this principle could be made fairly compact and at much less cost than one incorporating an electronic image tube. Whichever approach is taken, there is no reason why photographers cannot expect to "see in the dark" in the darkroom of the future.—THE END.

Reprinted from

MODERN PHOTOGRAPHY

ARMY PLANS TO BUY 6,918 'SNIPERSCOPES'

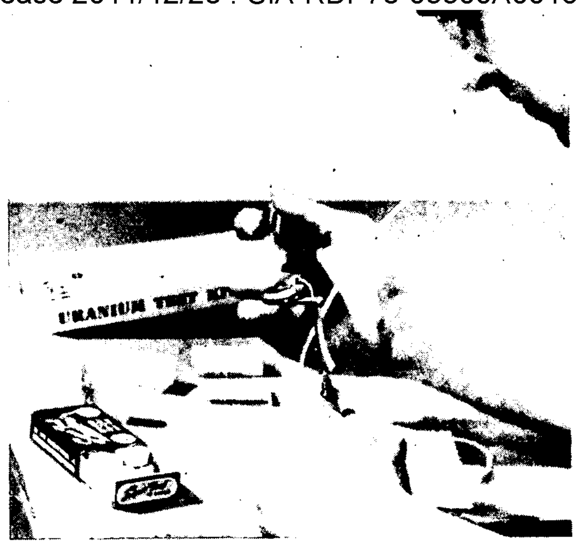
WASHINGTON, —The "night eyes" of the rifleman, the electronic "sniperscope" that is credited with causing 30 per cent of all enemy casualties in the Okinawa campaign, is being made a standard item of Army equipment.

Army sources disclosed today that the field forces were so impressed with the efficacy of the auxiliary weapon that enables the infantryman to "see" the enemy through darkness that units in all the Army's ten divisions would be equipped with the device.

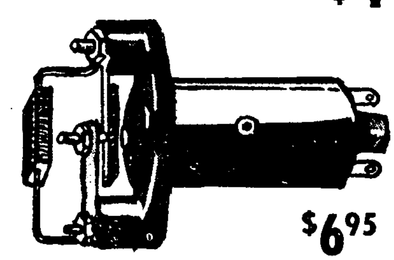
Included in the Army's budget requests now before Congress is an $8,654,418 item for the purchase of 6,918 "sniperscopes" at a cost of $1,251 each. How many of the devices are already in use is considered secret information.

The "sniperscope" consists of an electronic telescope that is mounted on the standard Army .30-calibre carbine. Wiring runs from a portable power pack carried in a harnessed knapsack on the soldier's back.

Operating under cover of darkness, the rifleman points the "sniperscope" and his gun sights toward a spot whence a sound has come. By switching on an infrared spotlight, he makes rays scan the territory. These are reflected from the target, picked up by the telescope and transformed into an image across the sights of the rifleman.



Uranium Test Kit designed to fit in your pocket, will make a positive identification in five minutes. Chemical bead is formed on wire, fused with crushed ore, then examined for lemon-yellow fluorescence under ultra-violet light. **$4.95**



$6.95

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IGNITION COIL—This miniature high voltage coil provides high output for snooperscope operation.

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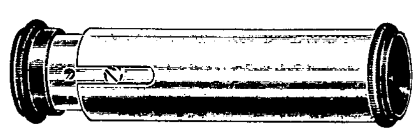

This is a very convenient pocket spectroscope for general purposes and students, use, having a dispersion of 20°. The slit is of a fixed width, protected by a glass cover to prevent dust from entering. An adjustment for accurately focussing the spectrum is provided.

No. 2444. Pocket spectroscope, in case **Our Price $12.50**

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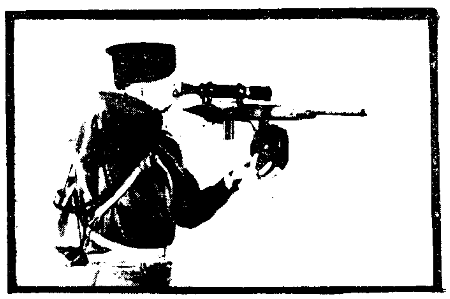

Ingenious infra-red viewing device lets you see in the dark

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An Infrared Image Tube and its Military Applications

by

G. A. Morton and L. E. Flory

Reprinted from RCA REVIEW
September 1946, Vol. VII, No. 3

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AN INFRARED IMAGE TUBE AND ITS MILITARY APPLICATIONS*†#

By

G. A. MORTON AND L. E. FLORY

Research Department, RCA Laboratories Division,
Princeton, N. J.

Summary—The military value of the security obtained by the use of infrared for nocturnal vision was recognized even before the entry of the United States into World War II. A program for the development of infrared viewing devices employing electron image tubes was consequently set up by the National Defense Research Committee. Before the close of the war a number of types of infrared telescopes had been manufactured in quantity and had seen service in fairly large numbers.

The 1P25 image tube is the essential element in the infrared electron telescope, and serves to convert the invisible infrared image into a visible image. The tube contains a semi-transparent photocathode which is processed to be sensitive to infrared radiation, and an electron lens for imaging the electrons from the photocathode onto a fluorescent screen which becomes luminous upon bombardment by electrons. When an infrared image is focused on the photocathode, a visible reproduction of this image is formed on the fluorescent screen.

Basically, the infrared telescope consists of the image tube, an objective for forming the infrared image on the photocathode and an ocular for viewing the reproduced image. Associated with the telescope is a battery operated vibrator power supply which furnishes the 4000 to 5000 volts and the several intermediate voltages required by the image tube.

A variety of types of telescopes was developed and produced for a number of different applications. These included a signalling telescope employing a large aperture reflective optical system as objective, the Sniperscope which is a carbine-mounted telescope and infrared source permitting aiming and shooting in complete darkness and the Snooperscope composed of the same infrared units mounted on a handle for short range reconnaissance work. Binocular telescopes, helmet-mounted driving and flying instruments, long-range reconnaissance units and other special night-seeing devices were also developed in the course of this project.

EVEN before the entry of the United States into World War II, it was recognized that many military operations would require the secrecy afforded by complete visual darkness. Therefore, the National Defense Research Committee, under Army and Navy directives, undertook the development of infrared viewing devices employing electron image tubes and an investigation of the applications

*Decimal Classification: R138.31 × R800(621.375).

† This paper is based in whole or in part on work done for the National Defense Research Committee under Contracts OEMsr-169 and OEMsr-440 with Radio Corporation of America.

Reprinted from *RCA Review*, September, 1946.

of such devices. This work was carried out by these laboratories.

A variety of infrared telescopes was developed suitable for different tasks and a number of types saw considerable service during the war. Among the most widely used were the Navy infrared signalling equipment and the Sniperscope and Snooperscope procured by the Army. Figure 1 illustrates an infrared telescope, while Figure 2 shows the laboratory prototype of the Sniperscope.

Basically, all of these telescopes consist of an objective for forming an infrared image of the scene being viewed upon the photosensitive cathode of the image tube, the image tube itself, and an ocular for viewing the reproduced image. The general form of the electron tele-

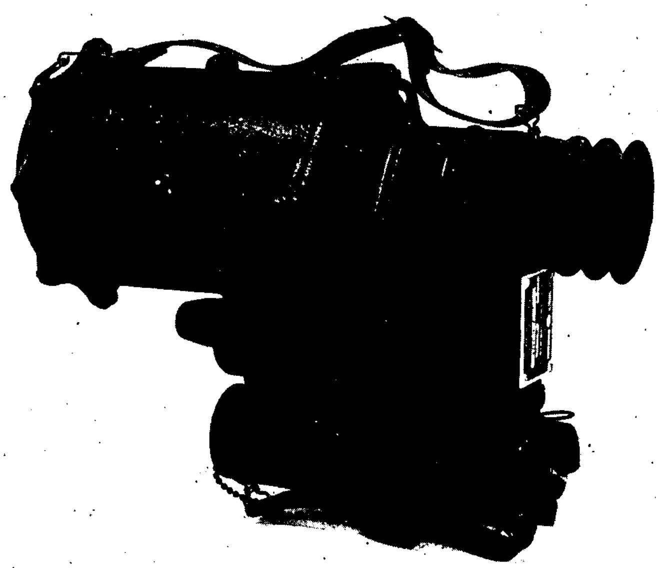

Fig. 1—Infrared telescope.

scopes using refractive and reflective optics is shown schematically in Figure 3.

The fundamental component of these infrared telescopes is the electron image tube. This tube consists of a semi-transparent photocathode processed so that it has high sensitivity in the infrared portions of the spectrum, a fluorescent screen and an electron optical arrangement for focusing the electrons onto the screen.

In undertaking the design of these instruments and tubes, the requirements of mass production as well as those relating to the particular application, were taken into consideration. As a result, the U. S.

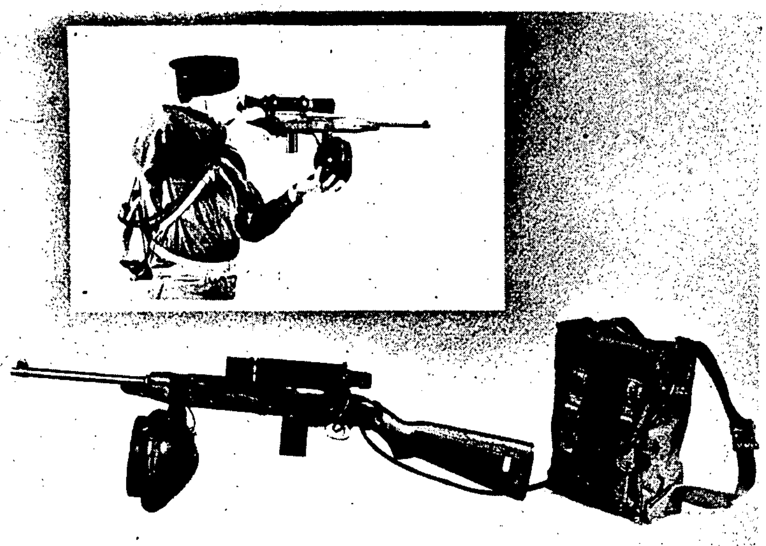

Fig. 2—Laboratory prototype sniperscope.

Armed Forces were able to obtain these instruments in far larger quantities than could either the Germans or the Japanese whose instruments were not suitable for quantity production.

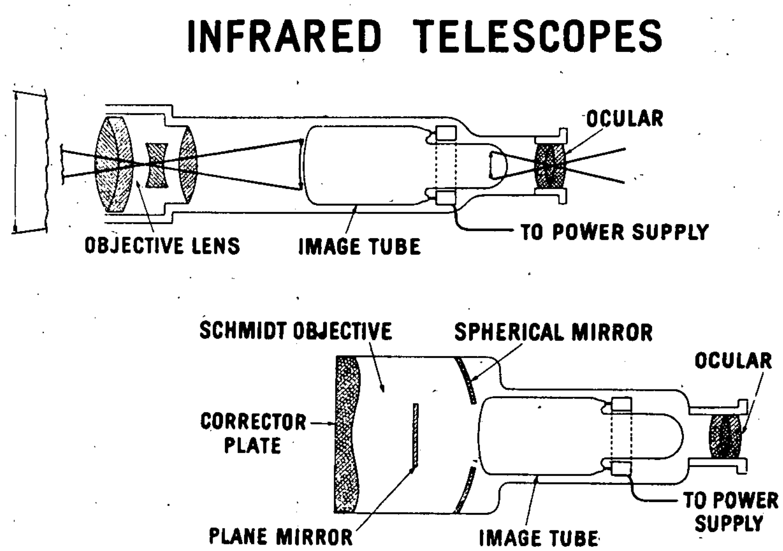

Fig. 3—Schematic diagram of two types of infrared telescopes.

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THE IMAGE TUBE

An investigation of electron imaging dating back to the early 1930's had resulted in successful image tubes.[1,2] However, the requirements placed on an image tube for military applications were so very different from any heretofore encountered that it was necessary to re-examine the entire subject again.

The most important considerations were, of course, sensitivity of the tube and perfection of the image. These are properties of the activation, phosphor efficiency and electron optics, and will be discussed in greater detail. A second very important consideration was that the tube be of such a form that it could be produced quickly in fairly large numbers. Finally, it should be so designed that a single type of tube could be used for all of the various applications envisaged.

Tube dimensions selected as being the best compromise between the very small size which would be desirable for portable instruments, and the larger tube suitable for fixed units, were 4½ inches length and 1⅞ inches maximum diameter. This size was found convenient from the production standpoint, and useful in a wide variety of instruments. Consideration of power supply design, cable insulation and tube stability dictated an overall voltage range of 4000 to 6000 volts.

The first decision which had to be made concerned the most practical way of imaging the electrons from the cathode onto the fluorescent screen. There are essentially three systems which may be used, namely:

(1) uniform field between cathode and screen;
(2) magnetic lens; and
(3) electrostatic lens.

The first was rejected because of the close spacing between cathode and screen and high field strength necessary in the vicinity of the cathode. This makes the activation difficult and the tube prone to cold discharge. Also, the image produced in this way is erect where preferably it should be inverted. Magnetic focusing was also rejected from the standpoint of weight and complexity, and because of the difficulty of obtaining an inverted image.

An electrostatic lens system is capable of a sharp, clear image over a wide range of magnifications. The image is inverted making it unnecessary to use an inverting ocular for viewing the reproduced image. It is necessary to curve the photo cathode in order to produce an undistorted image over a large angular field. Where a reflective optical system is used as objective, the curvature of the cathode can be made

[1] V. K. Zworykin and G. A. Morton, "Applied Electron Optics", *Jour. Opt. Soc. Amer.*, Vol. 26, No. 4, pp. 181-189, April, 1936.

[2] G. A. Morton and E. G. Ramberg, "Electron Optics of an Image Tube" *Physics*, Vol. 7, No. 12, pp. 451-459, Dec., 1936.

to match that inherently present in the image surface of these optics. It is, however, sometimes necessary to use an optical field corrector lens when an ordinary refractive objective is employed, if the field of view is to be flat. However, since the electrostatic lens is also free from the objections mentioned in connection with the magnetic and uniform field systems, it was selected as the most satisfactory for the purpose.

The magnification of the image tube has an important bearing on its performance. This is because the brightness of the reproduced image varies inversely with the square of the magnification. Thus, if a telescope with a given overall magnification employing an image tube

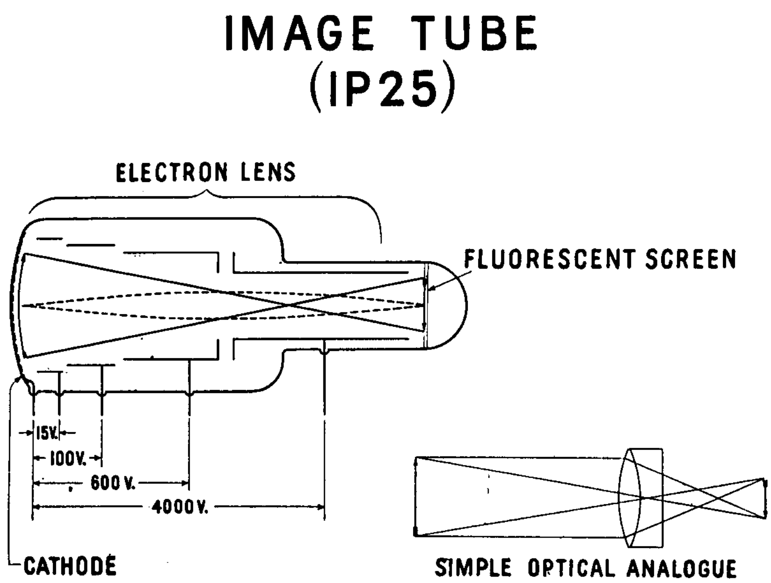

Fig. 4—Schematic diagram of 1P25 Image Tube.

with unity magnification and an X5 ocular is compared with one using an image tube with magnification ½ and an X10 ocular, the image in the latter will be four times brighter. However, for a given size of image tube and angular field of view, the magnification cannot be decreased indefinitely because as the power of the ocular increases the size of the exit pupil decreases until a point is reached where the pupil of the dark adapted eye is not filled. Beyond this point, the brightness of the retinal image does not increase with decreasing magnification of the image tube. For many applications, it is also essential that the exit pupil be much larger than the pupil of the eye, so that the observer's eye does not have to be located too exactly with respect to the instrument. Experiment showed that for a tube the size of the image tube under discussion, the magnification should not be less than one-half. Figure 4 illustrates schematically the construction and action of the image tube adopted.

Electron Optical Considerations

The electron optical system of the image tube consists essentially of a strong main lens as the principal imaging means and a series of relatively weaker correcting lenses between the cathode and main lens. The potential distribution along the axis of the tube is shown in the upper portion of Figure 5. Two electron paths, one of an electron

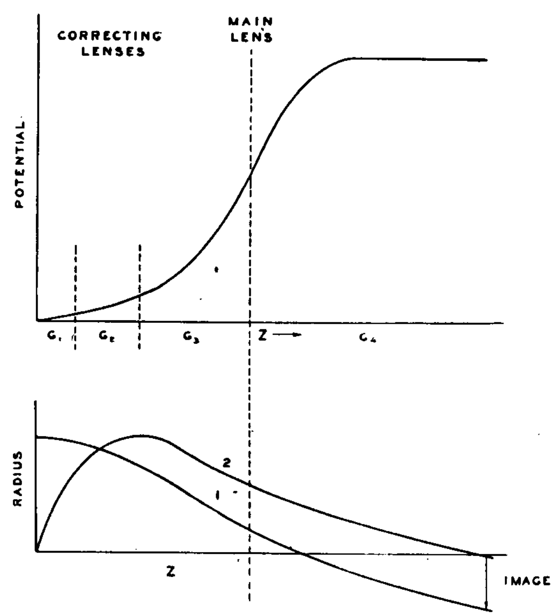

Fig. 5—Potential distribution and electron paths in the Image Tube.

originating from the cathode on the axis of symmetry with radial initial velocity, the other originating off the axis with no initial velocity, are illustrated in the lower part of the figure. These two paths are sufficient to determine the first order imaging properties of the system.

A detailed theoretical study of this type of system leads to the following conclusions:

(1) Curvature of the image field and pincushion distortion can only be eliminated by the use of a curved cathode (or a radial potential gradient on the cathode).

(2) Curvature of the image surface and astigmatism limit the off-axis definition.

(3) Chromatic aberration due to the spread of initial velocities of the photoelectrons establishes the limit of resolution at the center of the image.

(4) Spherical aberration and coma play a negligible role in limiting the definition.

The radius of curvature of 2.38 inches selected for the cathode was a compromise between that required for a flat electron image surface and optical considerations of the objective. With this curvature very little pincushion distortion remained, and a definition of 350 lines (television nomenclature) or better could be obtained near the margins of the picture.

At the center, the diameter ($\triangle$) of the circle of confusion due to chromatic aberration is given approximately by:

$$\triangle \cong 2m\, V/E \qquad (1)$$

where E is the gradient near the cathode and V the initial electron energies in electron volts. Evaluating this from the gradient known to exist in the tube and from the initial velocities expected near the infrared threshold, the limiting definition at the center is 2000 or more lines. Definitions of 1000 lines were realized in laboratory tubes, and of 450 lines or better in production tubes. In general, the difference in definition between the theoretical estimated definition and that achieved in practical tubes is due to misalignment of the electrodes, inhomogenities in the photo-cathode and granularity of the fluorescent screen.

Photo-Electric Cathode

The photo-sensitization of the cathode is one of the critical steps in the preparation of the image tube. Research to date has lead to the conclusion that a complex surface involving caesium, oxygen and silver yields the highest infrared response of any of the surfaces yet studied. This surface is formed by evaporating a thin layer of silver on the cathode disk, oxidizing it completely, then adding alternately silver, caesium and silver while subjecting it to an appropriate thermal treatment. The completed surface is semi-transparent so that, when illuminated from the outside, electrons are emitted from the inner surface. The photoemission from a well activated surface of this type will be 30 to 50 microamperes per lumen for whole light (visible + infrared) from a tungsten source at a color temperature of 2870 degrees Kelvin.

Figure 6 illustrates the spectral response of this type of emitter.

FLUORESCENT SCREEN

The requirements of the fluorescent screen are the following:

(1) It must have a high efficiency of conversion of electron energy into visible light of a color suitable for scotopic vision.
(2) It should have a fine grain structure capable of giving high definition.
(3) Its time constant must be short so that moving images do not blur.
(4) It should be inert to the chemical action of caesium.

Synthetic willemite was found to satisfy these requirements fairly well, although its phosphorescent decay time is somewhat longer than

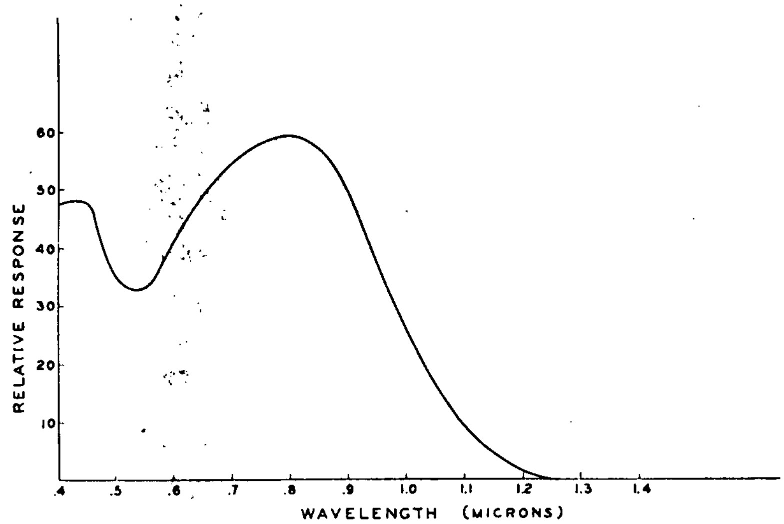

Fig. 6—Spectral response of 1P25 Image Tube.

might be desired. In spite of its shortcoming as far as persistence is concerned, it was selected as the phosphor most suitable for the 1P25 because of its availability and ease of handling together with its chemical stability.

The efficiency of this phosphor in the vicinity of 5000 volts is between 1 and 3 candles per watt. Its color is green or yellow-green which is quite satisfactory from the standpoint of scotopic vision. With a little care, the grain and aggregate size can be made small enough so that the screen does not limit the definition of the image. The decay characteristic of the material cannot be expressed by a single time constant. However, for the brightness involved in such applications of the tube as night driving, reconnaissance, and sniperscopes, the relation:

$$B = B_0 \varepsilon^{-60t} \qquad (2)$$

where t is the time in seconds after excitation ceases and B_0 is the brightness at $t = o$ is entirely adequate. The expression for phosphorescent decay indicates that the image brightness falls to 10 per cent of its initial value in 0.04 secs. While rapid enough for most purposes, it causes some loss in definition for rapidly moving objects. At very low brightness levels, the decay becomes less rapid than is indicated by this expression. This long low-level afterglow is of consequence in the detection of an infrared marker and signal light near the visual threshold.

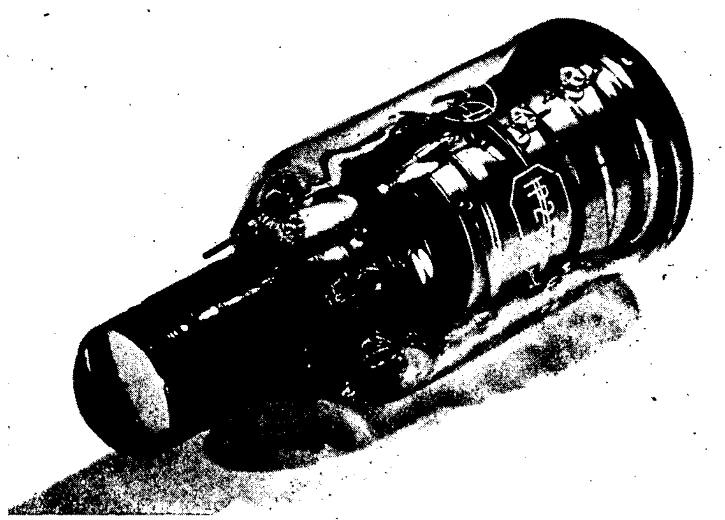

Fig. 7—1P25 Image Tube.

Image Tube Performance

The performance of the 1P25 image tube may be summarized as follows: The light output per lumen of light incident on the photocathode, or conversion, is in the neighborhood of 0.5 to 1 lumen. In conjunction with an infrared filter, the conversion is reduced by the corresponding filter factor. It has been customary to express this filter factor in terms of the ratio of the image-tube response for whole light from a given incandescent source at color temperature 2870 degrees Kelvin to the response from the same source when filtered.

The central definition of the image is 450 lines or more and the peripheral definition 300 lines. This definition is such that for most brightness levels encountered in practice, the eye rather than the instrument is the limiting element.

A photograph of the finished tube is shown in Figure 7.

During the later stages of the research program, a number of new types of tubes were developed to meet special problems. One of these was a single-voltage tube, contained in an envelope identical to that of the 1P25, but requiring no intermediate or focusing voltages. This tube is interesting in that it employed an electron optical system with an unconventional departure from circular symmetry. A second tube operated at an overall-voltage of 16 kilovolts employing a multiple lens anode.

Instruments Employing The 1P25

During the course of the investigation, many different types of infrared instruments were developed employing the image tube. The number is so large that only a small fraction of them can be described in this paper. Therefore, a few representative instruments have been selected which will be described and their performance indicated.

Signalling Telescopes

One of the widest and at the same time most exacting use of the electron telescope is for the observing of infrared signal and marker lights. Here, since the object observed is an unresolved luminous point, the considerations involved in determining the sensitivity of the instrument are quite different from the case of an extended image. The two primary optical factors are the area of the objective and the magnification, while for the image tube the conversion and background only are involved. It will be noticed that the f-number of the objective and magnification of the image tube do not affect the sensitivity. However, if a lens with a large f-number or an image tube with high magnification is used, the angular field of view will be small which is undesirable for a marine signalling or search instruments. For these reasons the signalling telescope was designed with an objective having a short focal length and large aperture. The only practical way of achieving such a system is by the use of reflective optics, as illustrated in the lower part of Figure 3. The corrector plate and spherical mirror were of transparent plastic, assembled as a unit in a plastic barrel. The system was arranged so that the image was folded back by means of a plane mirror onto the cathode of the image tube. The focal length of this objective was 2.4 inches and its effective f-number was about 0.9. The image on the fluorescent screen was viewed through an X11 ocular. A hemisphere, which was an integral part of the image tube bulb, was a component of the ocular system. The telescope and power supply were assembled in a light, weatherproof and hermetically sealed magnesium casting. A discussion of power supplies for this type of instrument will be postponed until a later section.

A much larger reflection-type telescope was also developed having a 7-inch focal length and approximately the same effective numerical aperture. This instrument was very much more sensitive as a signalling telescope but had a much smaller angle of view. Because this instrument was also designed for reconnaissance, its optical focus was made variable through an adjustment which moved the plane mirror in and out.

Reconnaissance Telescope

With the exception of the large reflective-type telescope mentioned in the preceding paragraph, the reconnaissance instruments were in general of the small portable variety. In order to give them greater depth of focus than could be obtained with a reflective optical system, these telescopes employed refractive optics with f-numbers down to about 2.0. With an f/2.0 lens and an image tube having a conversion of 1.0 the ratio of brightness of the image of an object illuminated with whole light as seen through the telescope to brightness as seen directly is about 0.10. This ratio is reduced by the appropriate filter factor when a filtered source is employed.

In their simplest form, these instruments consist of a barrel (usually of mu-metal or other high permeability alloy for a shield) containing the image tube, to which are affixed the objective and ocular, both in focusing mounts. Tests indicated that objective focal lengths in the range 2½ to 3½ inches and ocular magnification of X8 to X12 were most satisfactory. For example, when used as the basis of a driving telescope, as will be discussed below, an instrument with a 2½-inch objective and an X8 ocular giving an overall magnification of unity and a 24-degree field of view gave best results, while for devices such as the Sniperscope and Snooperscope a 3½-inch focal length objective and a X8 or X12 ocular were to be preferred.

Power for the image tube was supplied through a three wire, insulated cable providing ground, the overall voltage and the variable focusing voltage. A resistance voltage divider at the image tube socket provided the other voltage steps for the 1P25.

Other instruments were designed with the power supply an integral part of the telescope. One unit employs a 2½″ focal length f/2.0 plastic objective and an X12 ocular. A model is illustrated in Figure 8. Its size and weight is only about one third that of the telescope shown in Figure 1.

For general purpose observation, these simple in-line monocular telescopes served as very useful tools. For example, this type of instrument was frequently carried by an observer during night driving. Also, it was used to supplement the large reflective-type telescopes as general orientation instruments, and for many other supporting operations. Under these circumstances, the illuminator providing the infrared radiation was a separate unit over which the user of the telescope had little or no direct control.

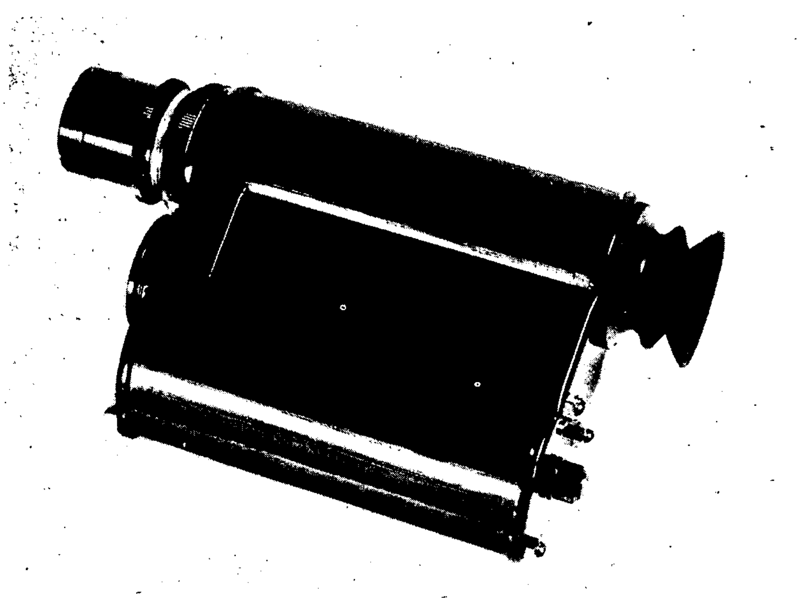

Fig. 8—Experimental telescope.

Frequently it is advantageous to have a portable light source to use in conjunction with the telescope. Therefore, a study was made of instruments involving source-telescope combinations. In particular, two instruments of this class were developed, namely, a monocular telescope and a light source mounted on a handle for relatively short range reconnaissance (see Figure 9) and a similar telescope and source mounted on a carbine in such a way that the telescope could be used for aiming in complete visual darkness. These instruments were christened Snooperscope and Sniperscope respectively and were later named Molly and Milly by members of the Armed Forces.

The telescopes used in the laboratory prototypes of these units were essentially the same as the monocular telescope described in earlier paragraphs. The objectives were 3½-inch focal length f/2.0 lenses while an X8 ocular was used for viewing the screen. A chevron was placed on the surface of the field-corrector lens to serve as the aiming index for the Sniperscope. This chevron was accurately aligned with the direction of fire of the piece. By placing the aiming index at the objective, distortion or deflection of the electron image had no effect on the accuracy of aiming.

Tests were made to determine whether the telescope, including the image tube, was sufficiently rugged to withstand the rough usage involved in this application. No particular difficulties were encountered

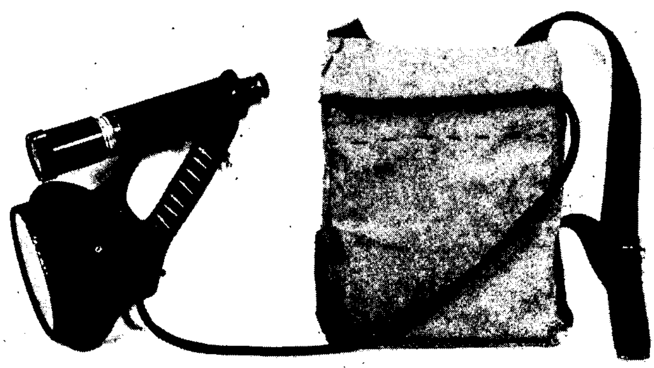

Fig. 9—Laboratory prototype Snooperscope.

in the case of the Snooperscope. In the Sniperscope, a certain percentage of tubes were found to fail as a result of the shock of firing, due to minute particles of the phosphor becoming dislodged from the fluorescent screen and settling on the lens electrodes and causing flashing in the tube because of cold discharge. This made it necessary to shock-test production tubes before employing them for this purpose.

The selection of the size and form of light source was a result of compromises in a number of directions. These included angular field, range, operating life for the allowable battery weight, and considerations of security. The source chosen for the laboratory models was a special General Electric sealed beam lamp with a 12 to 15 degree spread and a maximum beam candle power of 80,000. Various infrared filters were used including Corning 2540 heat transmitting glass and the Polaroid XRX series.

The high voltage power supply and storage batteries were carried in a knapsack with a cable from it to the instrument carrying both the image tube voltages and the current for the infrared source. The design of the power supply is discussed in a later section.

The weight of the telescope and source was about 5 pounds while the power supply and batteries weighed approximately 13 pounds. The unit was capable of 3 to 4 hours continuous operation before it was necessary to recharge the batteries. The Snooperscope and Sniperscope were manufactured on a fairly large scale, the production design being carried out by the Engineer Board of the Army for the Corps of Engineers.

Driving Instruments

In some applications, particularly vehicle driving, it is advantageous to have binocular vision. It is interesting to note that while the observer feels a very definite need of being able to use both eyes it makes very little difference whether or not he has stereovision.

The first experimental driving instruments were in the form of a single large barrel carrying the objective and eyepiece, and enclosing an image tube which was much larger than the 1P25. The eyepiece was so arranged that the virtual image of the fluorescent screen was at infinity and the observer saw this image with both eyes.

This type of driving telescope was found to be generally quite satisfactory, but suffered from two serious drawbacks. It was quite large and occupied considerable space in the vehicle and it was difficult to use on short turns.

To overcome these difficulties, a small binocular instrument was developed using two 1P25's. This instrument, illustrated in Figure 10 gave the observer true stereovision. The binocular consisted of a pair of in-line telescopes mounted parallel to one another by means of hinges so that the interpupillary distance could be adjusted to fit the user. In order to obtain satisfactory register of the images seen by the two eyes, it was necessary to provide means for moving the two images relative to one another. This was accomplished by mounting the ocular lenses in such a way that their axes were slightly displaced with respect to the axes about which the ocular fittings could be rotated. When the eyepiece fittings were turned the two virtual images seen by the observer moved in circles about two different centers. The points of intersection of these circles are the points of register of the images.

Separate focus of the two objectives and two oculars was provided. The power supply was designed so that the electrical focus of the two image tubes was also independent.

These binoculars, with a suitable head rest, served as excellent driving telescopes, when supported on a pivoted arm in front of the driver. As designed the instrument not only gave the operator use of both eyes but also permitted true stereovision.

Some experiments were undertaken in helmet mounting the in-line binoculars. However, even when counterbalanced to neutralize the forward torque of the instrument, the moment of inertia was rather high which made it awkward to handle.

To overcome this, an investigation was made on a series of helmet-

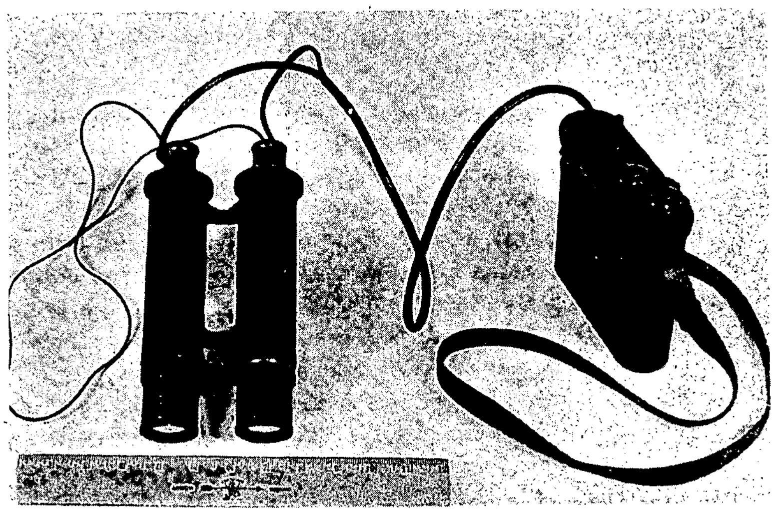

Fig. 10—Infrared In-line Binocular.

mounted instruments. Figure 11 illustrates an early right-angle periscopic unit. The results of these tests were so encouraging that the development of a light-weight, Z-shaped binocular suitable for night flying and driving, was undertaken in collaboration with the Johnson Foundation of the University of Pennsylvania. The completed instrument is illustrate in Figure 12. The unit was made of aluminum, and plastic optics were used throughout (except for the ocular lenses) to reduce the weight to a minimum. The folding was accomplished by means of plastic prisms. Again, independent optical and electrical focusing adjustments were provided for the two sides, the electrical focus being controlled by means of potentiometers mounted at the bases of the telescope barrels. Register of the image was effected by means of a pair of rotatable ring magnets mounted on each barrel just below an inner mu-metal shield which surrounded the image tube from cathode to main lens. The resultant field of these ring magnets, which could be varied in intensity and direction by rotating the rings, made it possible to deflect the electron images into exact alignment.

These helmet telescopes appeared to be a very adequate solution to the problem of infrared night driving, and were on the verge of going into production when the war ended.

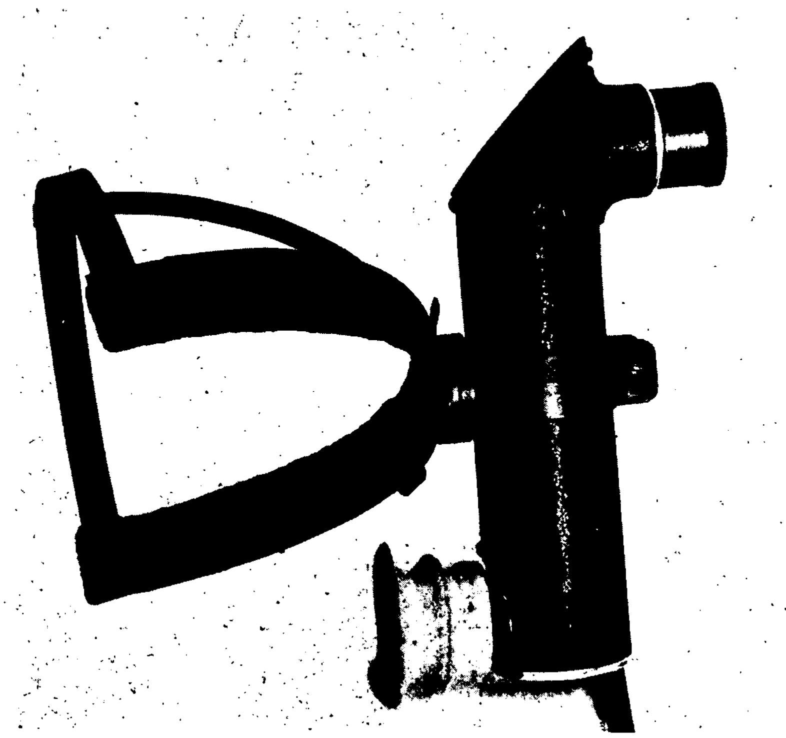

Fig. 11—Periscopic Helmet Monocular.

High Voltage Power Supplies

The 1P25 image tube requires a rather high voltage for its operation. Since portability was one of the aims of the development, it was essential that the power supplies be small and operate from a small primary battery source. At the same time, the battery life had to be above a certain minimum if the instrument was to be practical.

The design of a power supply meeting these requirements is possible only because of the fact that while a 4000 to 6000-volt output is

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required, the actual power needed is very small. The tube itself requires only a fraction of a microampere of current even under bright light conditions. The total power output required to supply the tube and the voltage divider necessary for the various focusing electrode voltages of the 1P25 is on the order of a tenth of a watt.

The only practical available means of converting the low voltage

Fig. 12—Type Z Helmet Binocular.

from the batteries to the high potential necessary to actuate the image tube is a vibrator-transformer-rectifier combination. A typical vibrator power supply is shown in Figure 13. It differs from the conventional vibrator power units used in battery operated radios, in that, due to the low power requirement, use can be made of the relatively high voltage peaks appearing across the primary of the transformer when the magnetic field collapses as the primary circuit is broken by the vibrator. In addition the primary is tuned to resonate with the natural period of the secondary to obtain maximum transfer of energy. By this method an effective primary voltage of ten to twenty times the battery voltage is realized. This makes possible a great reduction in the size of the transformer required.

A standard automobile type vibrator was used because of ease of procurement. The frequency was of the order of one hundred interruptions per second and the power consumed was about 0.2 watt. A conventional rectifier circuit and capacity filter was used employing the special rectifier described later.

The design of the transformer was necessarily a compromise between light weight and efficiency. A light-weight transformer with

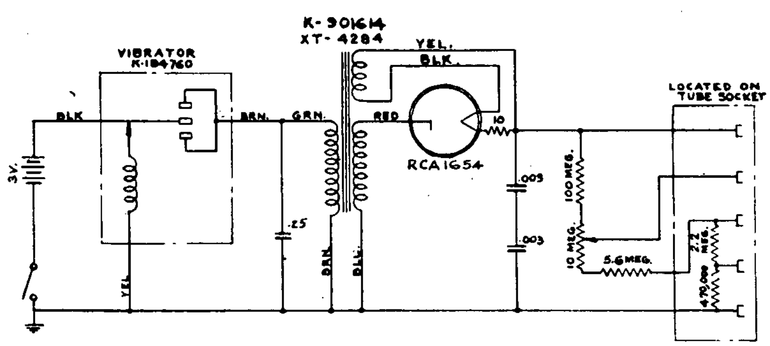

Fig. 13—Basic circuit of vibrator power supply.

somewhat lower efficiency means a larger battery or shorter battery life, while a heavier transformer will give a higher efficiency due to lower core losses. As a result, the optimum transformer is usually a design unique to the particular application. For an overall efficiency of 10 per cent, including vibrator power and rectifier filament, at an output of 4000 volts, the weight of the transformer is on the order of 20 ounces per watt of output. This means that in order to supply one-tenth watt at 4000 volts a two-ounce transformer would be required at an input of one watt. At somewhat higher power ouputs the efficiency may run as high as 20 per cent, since the power taken by the vibrator and rectifier will be constant.

A typical transformer design may be approximated by making the following assumptions:

Vibrator frequency—100 per second
Time of contact—.005 second
Battery voltage—3 volts
Maximum battery current (peak)—3 amperes
Peak output voltage—4000 volts.

Under the type of operation required, the secondary current is small and most of the power dissipated in losses. Therefore, as a first approximation the effect of the secondary circuit on the primary may be neglected except as it affects the resonant frequency.

If the time constant of the primary is made equal to the contact time, then

$$\frac{L}{R} = .005$$

Since the maximum current is to be 3 amperes and the voltage is 3 volts, the primary resistance is 1 ohm. Consequently,

$$L = .005 \text{ Henries.}$$

If the decay time of the primary current is now assumed to be one-tenth of the contact time as determined by the resonant frequency of the secondary to which frequency the primary is tuned, then

$$e = L\frac{\Delta i}{\Delta t}$$

$$= .005\frac{3}{.0005} = 30 \text{ volts.} \qquad (3)$$

Since the peak output is to be 4000 volts, the turns ratio of the transformer becomes

$$\frac{4000}{30} = 133$$

To obtain the necessary primary inductance requires about 100 turns. Thus 13,300 turns will be required for the secondary.

The direct current from the 3-volt battery under these conditions is about 0.5 amperes with the secondary delivering about 50 microamperes. A core cross section of 0.25 square inch ordinary silicon steel with a 0.010 air gap was found sufficient.

Since no rectifier of small size and low filament power consumption was available, a special tube was developed. This tube, shown in Figure

14, is now in production as the 1654 and in the special circuit shown will deliver 100 microamperes at 5000 volts.

A typical example of this form of power supply is shown in Figure 15. This supply delivers 0.15 watts at 4000 volts with an input of one watt. The total weight including the battery, which will operate the instrument for 2½ hours, is 2½ pounds.

A high degree of stability of the overall voltage is not essential but the ratio of voltages on the various electrodes must be maintained to

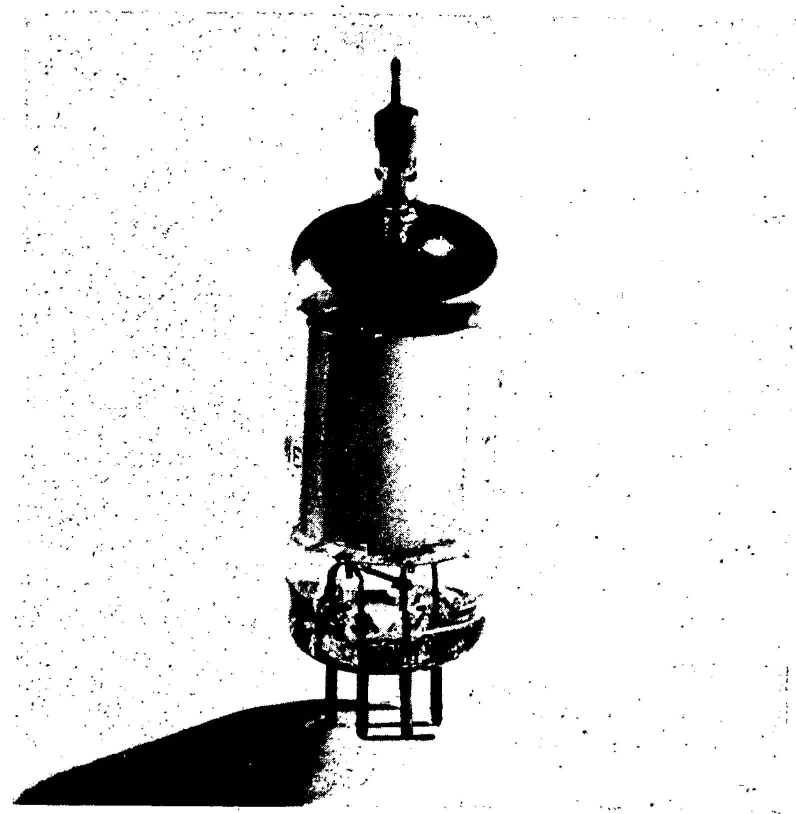

Fig. 14—1654 Rectifier Tube.

keep the image in good focus. The regulation of the power supply is not important since the load is essentially constant. As a matter of interest the equivalent resistance of the power supply shown in Figure 15 is approximately 40 megohms.

Since the overall voltage varies considerably as the batteries discharge and since the instruments may be subjected to wide ranges of temperature, behavior of the components of the voltage divider as regards temperature and voltage was a matter of considerable concern. It would be highly desirable to be able to maintain the proper voltage ratios over the range of temperatures and voltage encountered in the field. However, this is not always possible and occasional refocusing may be necessary although the variations can be greatly reduced by proper choice of components in order to balance their characteristics.

All of the available high value resistors (50 megohms or more) show considerable change of resistance with voltage. The voltage characteristics of a few of the best-known resistors are shown in Figure 16. Using dry cells as a source of power, a 2 to 1 change in overall voltage may be encountered from start to end point. Under these conditions, it is impossible to maintain focus without adjustment since a 50 per cent change in voltage represents a change of about 5 per cent in

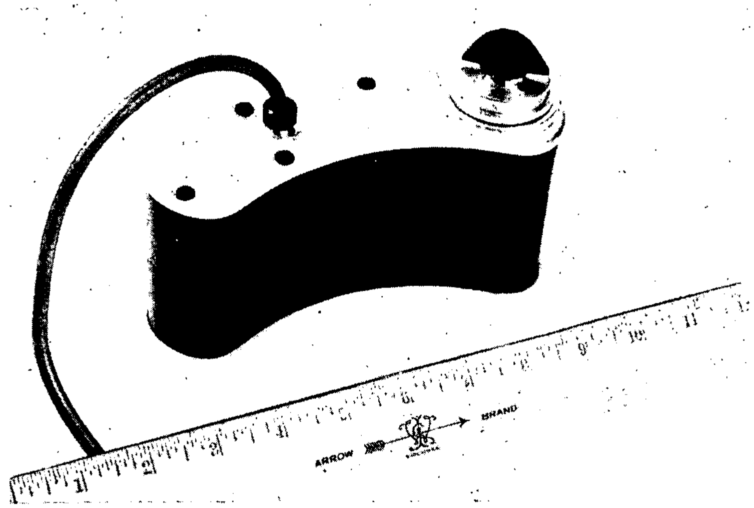

Fig. 15—5-kilovolt vibrator power supply.

resistance of the best resistor. Therefore, unless compensation can be provided, it is necessary to refocus as the batteries deteriorate. In the case of storage batteries, about 10 per cent change in voltage may be expected over the operating life. This produces a negligible change in resistance of the No. 5 resistor and no refocusing is necessary.

Most resistors have a high temperature coefficient and in order to design a voltage divider which will maintain the tube focus independently of temperature, it is necessary to select components which either have the same coefficient, so that the ratio remains the same over the temperature range, or which have coefficients which tend to compensate

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for each other. Variation of resistance with temperature for a variety of resistors is shown in Figure 17.

In making up a divider, many combinations of resistors tending to compensate are possible. From the curves in Figure 17, two combinations were selected and the characteristics of the dividers plotted in Figure 18. In both cases, the G_3 voltage remained essentially constant over the entire temperature range, the small variations being in such a direction as to compensate for the variation in G_2. With divider No. 1 adjusted for focus at 20 degrees Centigrade, the voltage on G_2 remains in the region of good focus over the range from −10 degrees Centigrade to + 60 degrees Centigrade. Divider No. 2 remains in focus

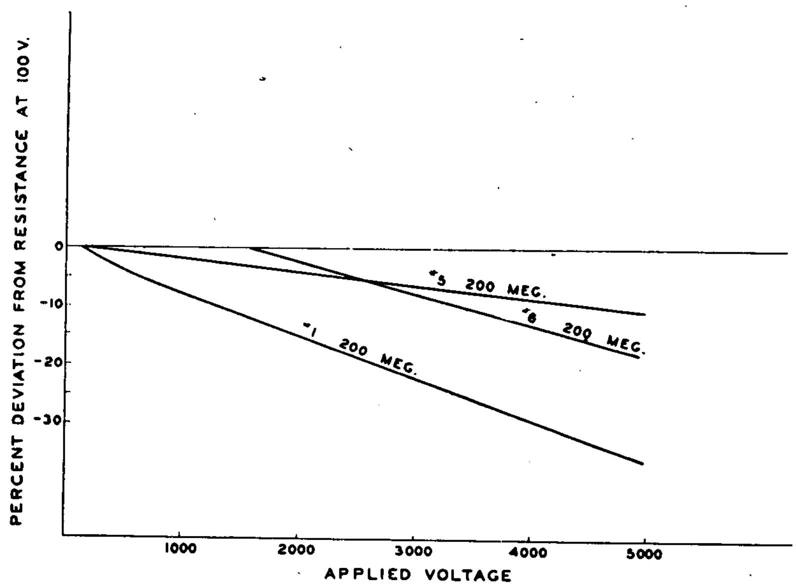


Fig. 16—Voltage characteristics of resistors.

from −40 degrees Centigrade to +75 degrees Centigrade. Therefore, using storage battery supply and selected components for the voltage divider, it is possible to build an instrument which will not require electrical focusing in the field under the range of conditions usually encountered.

The Type S_2 supply shown in Figure 19 is an interesting modification of the vibrator power supply. This arrangement is similar to the conventional voltage doubler circuit except that the two halves of the doubler are brought out separately. In this way, it is possible to place a voltage divider across one side without disturbing the other. In these vibrator supplies, the alternating-current wave is non-symmetri-

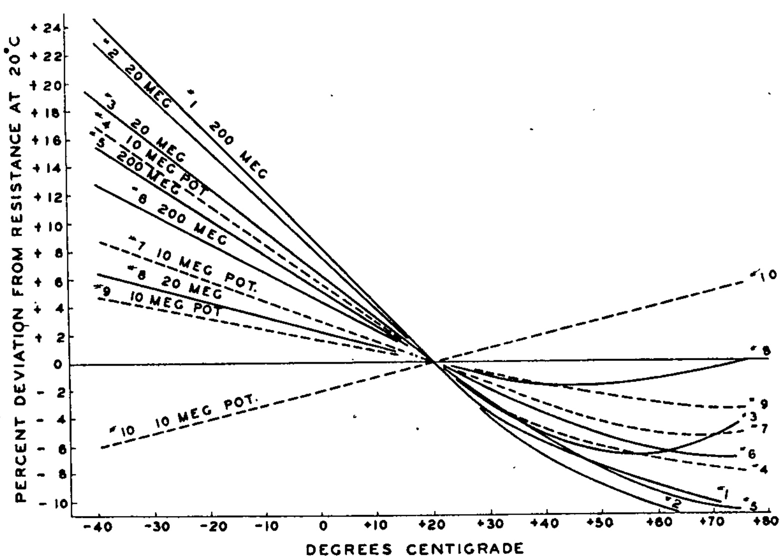


Fig. 17—Temperature characteristics of high-valued resistors.

cal, being in the nature of a damped oscillation, so that in the circuit shown, the voltage across the high voltage section, which is determined by the first loop of the wave, is about 4000 volts while the voltage in the opposite section, determined by the second or negative loop, is about 1000 volts. Therefore, by putting the voltage divider across

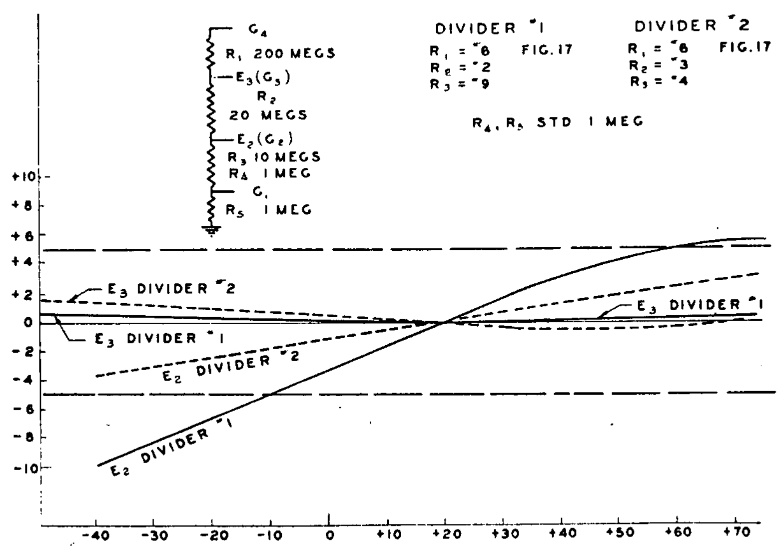


Fig. 18—Temperature characteristics of composite voltage divider.

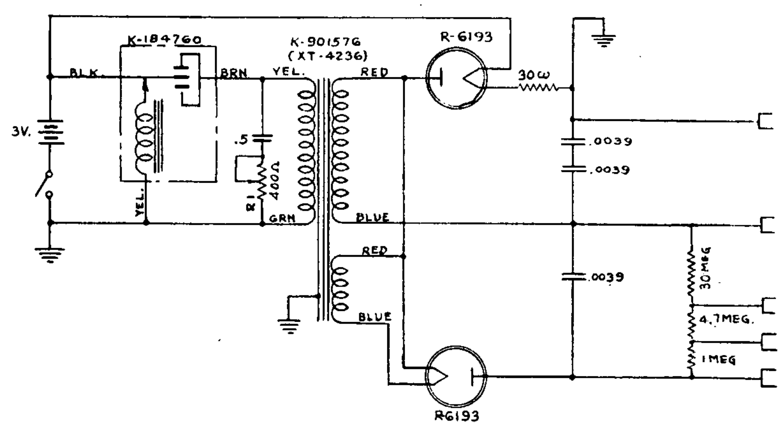


Fig. 19—Voltage doubler power supply (Type S-2).

only the low voltage section, the desired low voltages may be obtained without loading down the high voltage section. Another very interesting feature of this circuit is the fact that by introducing resistance in the tuned primary circuit, the damping of the circuit is increased which tends to decrease the second or negative loops and thus the low voltage without appreciably affecting the high voltage. This action is shown in the curves on Figure 20. This affords a means of varying the

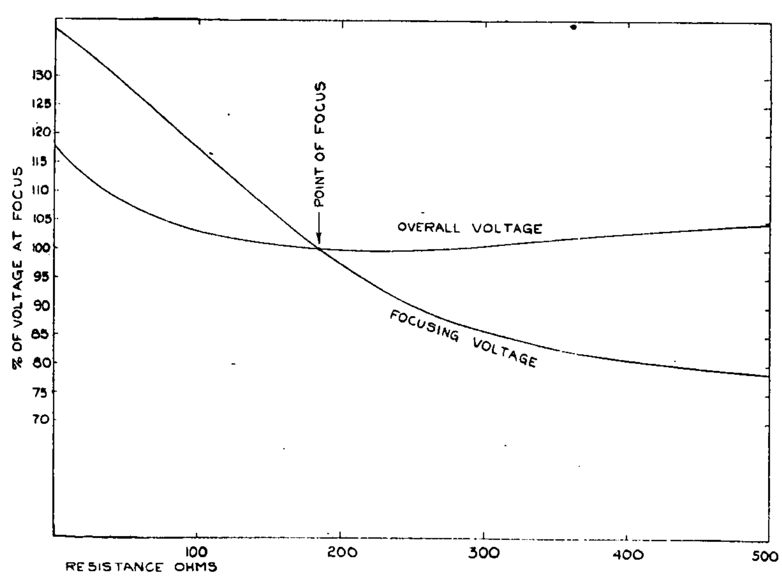


Fig. 20—Voltage control of type S-2 Power Supply.

focusing voltage by an element in the primary circuit which is a great advantage from the standpoint of electrical design.

Another power supply of interest was developed for use with the single voltage tube. With this tube the only load on the power supply is the actual photocurrent and leakage. By careful design, the entire load resistance can be made as high as 10^{10} ohms. Using a relatively large capacity in the output, the time constant of the circuit can be made to equal several seconds so that a quite infrequent charging of the circuit is required. For this purpose, an interrupter was designed consisting of an electrically-driven balance wheel having a period of

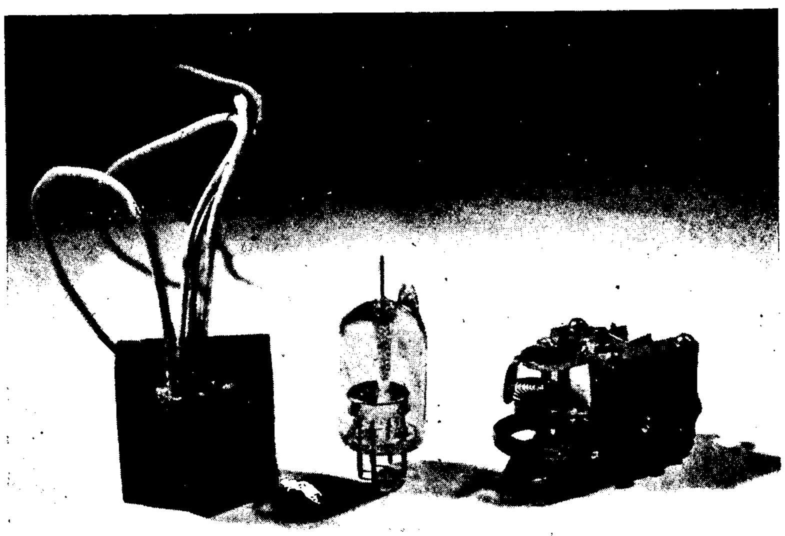


Fig. 21—Electrical components of pulsed power supply.

about ¼ second. The design was such that the transformer primary is open most of the time and is closed for a short time, to allow the current to build up, and immediately opened. In this way the drain on the battery is extremely small, the supply operating for as long as 50 hours on a single size D flashlight cell. A photograph of the interrupter, the 1-ounce transformer designed for the purpose and the special rectifier described below are shown in Figure 21.

Since the primary power required by this supply is so small, the power taken by the usual rectifier filament becomes very large in comparison. Consequently, a new type "filamentless" rectifier was developed, known experimentally as the KR-31.

This rectifier depends for its action upon a gas discharge in Helium, Neon, or other inert gas at about 0.5 millimeters pressure. The cathode is an aluminum cup, mounted so that its closed side faces the anode. The anode is a nickel rod or tube, over which is fitted a woven fibreglass sleeve. The entire anode is covered with the fibreglass; the sleeve fits down over the glass seal at one end and is closed by fusing the glass at the free end.

The peak inverse voltage of the KR31 is 6000 volts and the forward breakdown voltage is 300-600 volts. The peak current may be several milliamperes but the allowable average current is low. In the applications for which the tube was designed the average current is under 10 microamperes. An average current of 50 microamperes may not be exceeded except for very short periods due to sputtering and clean-up of the gas.

This tube has not been put into production and is not available commercially.

The power pack for the Snooperscope and Sniperscope involved some special considerations. A 6-volt, 25-ampere-hour storage battery was used to operate the infrared source so the power required to operate the high-voltage power supply was a negligible drain on the battery. It was necessary to silence the vibrator to a surprisingly high degree since the most obvious uses of the instruments were under conditions of extreme quiet and where the utmost in secrecy was essential. The usual rubber-mounted automobile radio-type mounting is effective for damping out the high frequencies, but the fundamental vibrator frequency (100 cycles) is not sufficiently suppressed. One method used in experimental models was to suspend the mounted vibrator by two flat spiral springs of at least one turn, coiled around the vibrator can, the inner ends being fastened to the vibrator can and the outer ends to the power supply chassis or box. By proper choice of spring thickness, a period of only a few cycles per second can be obtained with sufficient stiffness to support the vibrator adequately. By this means it was possible to silence the vibrator so that the user himself could not detect the vibration. Another method used, with some increase in bulk, was the addition of one or more stages of sponge-rubber cushioning around the usual vibrator can.

The type MA4, high-voltage image tube raised some special problems in power supply design. The overall voltage required is on the order of 15 to 20 kilovolts and in addition, a number of intermediate voltages are required. These intermediate voltages, particularly those over 4000 volts are difficult to obtain efficiently by conventional means because of the relatively large power which would be wasted in a voltage divider of sufficiently low resistance to be stable. Also, it is possible to obtain higher voltages from the previously described power supplies only by increasing the flux in the transformer. This in turn can be accomplished only by increasing the primary power, necessitating larger transformer and batteries. Lastly, if a conventional power supply is used, a rectifier tube capable of withstanding 20 to 30 kilovolts inverse voltage would be necessary. This type of rectifier is not available in small size and low filament power. Consequently, a cascade type (voltage-adding) power supply was designed which overcame most of the objections and automatically provided the necessary four steps of high voltage without a voltage divider.

A schematic diagram of the S-5 power supply making use of this circuit is shown in Figure 22. As can be seen, this supply is made up of four rectifiers which are essentially in parallel for alternating cur-

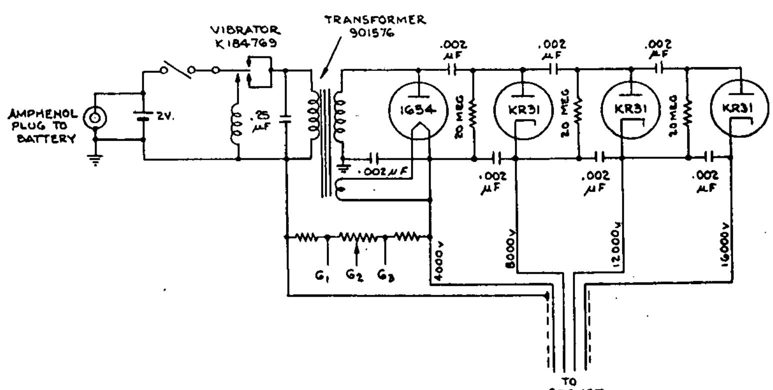


Fig. 22—Circuit of voltage quadrupler power supply (Type S-5).

rent. The direct-current voltages developed across the rectifiers, however, are added by means of the resistors which connect the anode of one rectifier to the plate of the next and thus place all the rectifiers in series for direct current. These resistors offer much higher impedance to the alternating current than do the capacitors so they do not affect the parallel alternating-current connection. Any number of stages may be cascaded in this manner, provided, of course, that the transformer will deliver the proper voltage to all the rectifiers in parallel. Four stages were chosen in this case because four steps of voltage are necessary for operation of the MA4 tube. The lower voltages required for the tube are obtained in the usual way by a voltage divider across the first section of the power supply. A thermionic rectifier (1654) is used in this stage in order to supply the divider current but the following stages make use of KR31 gas rectifiers, thus eliminating the need for filament supply circuits, with a high degree of voltage insulation. The current drain at the high voltages is very low so that the voltages shown are obtained with a total battery current of only 0.4 ampere at 2 volts. A photograph of the power supply is shown in Figure 23.

The chief problems in connection with this supply are leakage and corona. These must both be kept to a minimum since the internal resistance of the power supply is quite high (approximately 10^9 ohms at the 16-kilovolt tap). Leakage can be minimized by use of high-quality insulation and protection from humidity. Hermetical sealing, or other provisions for drying, are essential with this type of voltage supply.

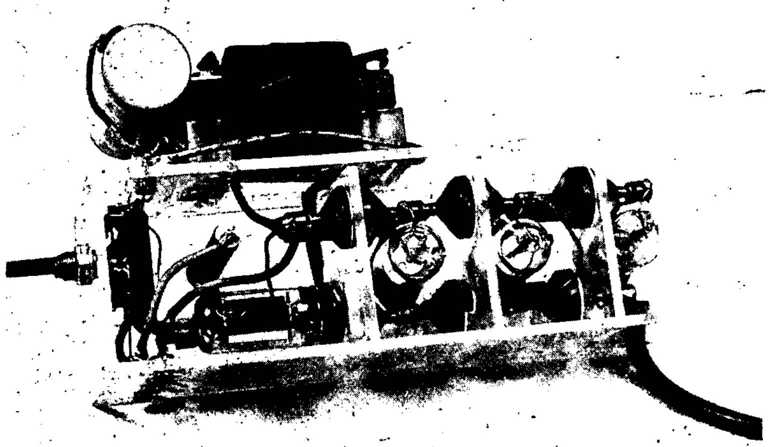


Fig. 23—16-kilovolt voltage quadrupler power supply.

Corona can be prevented by eliminating all sharp edges at the high voltage connections or by coating with a closely-adhering insulating material such as wax.

Conclusion

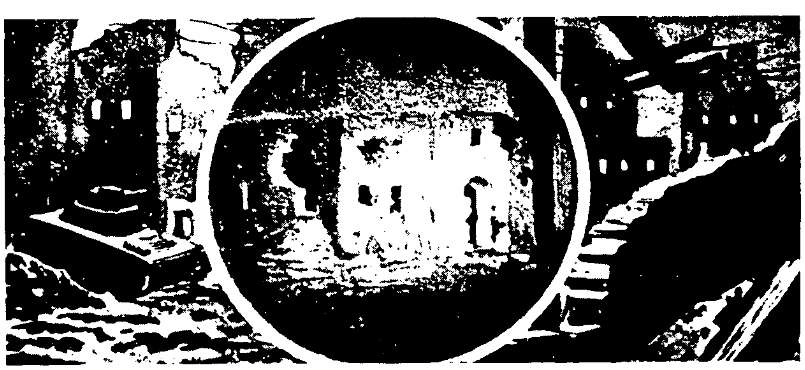
The above discussion stresses only the military application of infrared imaging equipment. There are, however, a number of peacetime uses for these instruments. Among these applications are their possible value in police work, their use in the field of medicine, the viewing of the usual types of photographic film during processing and production and for the inspection and control of a number of other industrial and scientific processes where visible light is undesirable.

In closing, the authors wish to express their appreciation to Dr.

V. K. Zworykin, Director of Electronic Research, for his advice and encouragement during the course of this development and also their recognition of the contribution made by Dr. J. E. Ruedy, G. L. Krieger and Dr. P. Rudnick to this project. Credit should go to Dr. L. B. Headrick, Miss H. C. Moodey and Dr. R. B. James of the Lancaster plant for work on the production design of the image tube.

As an interesting example of the effectiveness of the infrared devices described in this paper, two illustrations of a war street scene at night are included below. The upper picture shows the scene as viewed by the unaided eye. The lower picture shows, in the circle, the details of the scene when viewed by the infrared devices.

The Manager, RCA REVIEW



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Home-Built Snooperscope

Ingenious infra-red viewing device lets you see in the dark

By HAROLD PALLATZ

DURING wartime, man's inability to see in the dark can often mean the difference between life and death. This is particularly true of scouts, patrols, night drivers, and flyers. Since visible light makes an excellent target for the enemy, military forces began experimenting with infra-red rays as aids to nocturnal vision when visible light is not permitted for reasons of security. Many types of infra-red telescopes were developed as the direct result of this need for invisible illumination.

The sniperscope (an infra-red light source and telescope mounted on a carbine to permit the soldier to locate and shoot the enemy while both are in total darkness) and the snooperscope (an infra-red light source and telescope used for short-range observations) are perhaps the most well known of these developments. Other infra-red instruments include helmet-mounted driving and flying binoculars, and blackout signaling devices.

The infra-red telescope is designed around an infra-red image converter tube which transforms invisible infra-red rays to visible light. Several types of image converters were developed. The American forces used equipment built around the RCA 1P25 infra-red image tube. This tube has a cathode which emits electrons in proportion to the amount of infra-red light falling on it. Additional electrodes within the tube focus the electrons on a fluorescent screen. Thus the image falling on the cathode is focused on the screen without scanning devices. This tube, described in detail in the September, 1946, issue of *RCA Review*, requires voltages of 15, 100, 600, and 4,000 for proper operation.

The British developed a simplified infra-red image converter tube requiring a single source of 4,000 to 6,000 volts for its operation. This tube, type CRI 143 or CV 147, is currently available on the surplus market and is used in this experimental snooperscope.

The parts for this snooperscope—a CRI 143 or CV 147 infra-red image converter tube, a 4,000-volt, low-current power supply, two infra-red filters, and a light source—are easy to obtain.

The power supply

For indoor operation, a 4,000- to 6,000-volt neon-sign transformer operates the tube satisfactorily. Rectification is not necessary unless the objects under observation are in motion. (Application of the image tube as a stroboscope is the subject of a patent application made by the author.)

A portable 4,000-volt power supply designed for use with this snooperscope is shown in the photograph and in Fig. 1. This efficient supply needs to be turned on only momentarily to charge the 0.1-μf, 6,000-volt capacitor. The snooperscope works for several minutes on the charge, and thus it can be operated for long periods without noticeable battery drain.

The high voltage is supplied by a model-airplane ignition transformer with a vibrator to interrupt the primary current. The vibrator, not visible in the photograph, was removed from a small buzzer and mounted just above the core at one end of the transformer. A small buzzer can be inserted in series

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former if desired.

The rectifier tube is a 1B3-GT/8016. When the power supply is turned on, the current drain drops the voltage of each cell to approximately 1 volt; therefore the 1B3 was connected in series with a 1-ohm resistor across two cells. (A 3Q5, with its plate and screen grid tied together and control grid floating, might do the job just as well and would use less filament current. See the battery-operated, high-voltage supply described in the article "Build This Geiger Counter," in the September issue of Radio-Electronics.—*Editor*)

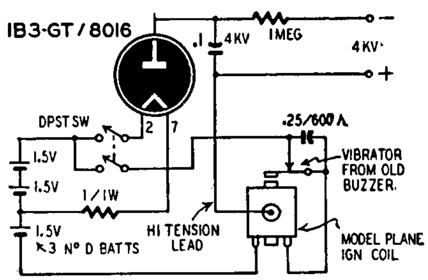


Fig. 1—Miniature high-voltage power supply.

The power supply was constructed in a plastic ice-box dish and fitted with insulated binding posts. Avoid contact with the output of this power supply or a rather uncomfortable shock may result. The capacitor remains charged for some time after the supply is turned off, so be careful. (It might be wise to shunt the output terminals with two or three 47,000-ohm resistors in series when the supply is not being used.—*Editor*)

Assembling the snooperscope

The snooperscope is constructed as shown in Fig. 2. The image converter is mounted in a plastic drinking cup 3½ inches high and 2¼ inches in diameter. The optical system depends on the requirements for the snooperscope. We used a double-lens, fixed-focus jeweler's loupe (engraver's glass). It has a focal length of approximately 3 inches and objects a foot away from the observer's position are focused sharply.

After selecting the optical system, mount it in a hole cut into the bottom of the cup. A jeweler's saw or coping saw is ideal for cutting the hole. A few drops of household cement will hold the loupe in place. Paint the inside of the cup with a jet black paint phone black. This will prevent stray reflections.

Place an infra-red filter between the tube and lens to reduce the effects of stray illumination on the tube. No light should be allowed to enter the unit except through the lens. The light source must of course be filtered if it is to be invisible. Near infra-red filters will cut out most of the visible light. Far infra-red filters, while of somewhat lower efficiency, will cancel out visible light completely. They must be used with comparatively powerful light source.

Infra-red filters can be purchased from a number of scientific and photographic supply houses. Experimental infra-red filters can be made by sandwiching several layers of red and blue cellophane between two sheets of clear plastic.

The image-converter tube is inserted with the metal end toward the mouth of the cup. The thin flexible lead connects to the positive side of the power supply. The other end of the tube has a ring of graphite around the outside. This is the cathode terminal. This makes contact with the B-minus lead through a strip of spring brass or a thin coil spring formed to fit snugly around the cathode terminal. A piece of rubber tubing holds the tube in place. It is protected by a window cut from clear plastic and held in place with three brass clips as shown in the photograph.

The handle is a plastic bicycle handlebar grip cemented over a hole drilled in the side of the drinking cup for the high-voltage leads.

The light source

The required intensity of the light source is determined by the distance from the target to the lens. Heat lamps, flashlights, and ordinary bulbs will work well for most indoor applications. Our model is equipped with automobile parking light housings on both sides. These supply a limited amount of illumination. The intensity of the parking lights is insufficient for many applications and a heat lamp is used. Outdoor applications involving greater distances require a bulb with a sharply focused reflector. The sniperscope used a 30-watt, 6-volt bulb operated on a small rechargeable storage battery. Good substitutes are auto headlamps, the sealed-beam type being preferable for this purpose. The heat lamps mentioned are of course those sold for infra-red treatment.

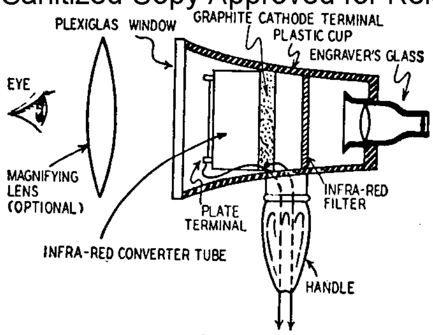
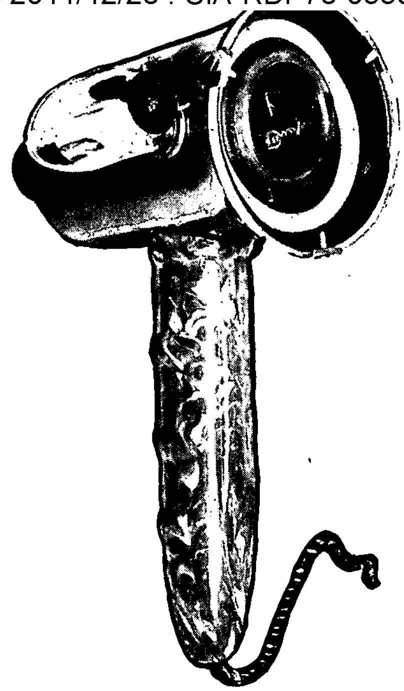


Fig. 2—The construction of the snooperscope.



Snooperscope experiments

A number of interesting and entertaining stunts can be devised around the snooperscope's ability to look through any opaque material which passes infra-red rays. Crime-detection laboratories use parallel equipment for reading through certain types of material. Since the infra-red reflection of pigments in paints and inks is different for white light, it is possible to detect forged paintings and checks by the way the colors appear. Demonstrate this by writing a message with India ink and then painting it over with a coat of ordinary fountain-pen ink. The eye will only see the blackened spot but the snooperscope will peer through the top layer of ink and reveal the writing just as clearly as if there were no top coating. This type of inspection can be made photographically if infra-red film is used in a camera. The electronic method permits instantaneous examination, which is often a great convenience as well as an interesting experiment.

Driving in fog has always been a great hazard. An infra-red beam will display the road with 30% more clarity. This increase may be the difference between a safe situation and a very dangerous one. Snooperscopes for this purpose require very good lenses and powerful headlights. It would probably be difficult for an experimenter to construct one and dangerous to use it.

The image-converter tube can be used as an infra-red phototube. Reduce the voltage to 250 or 300, and insert a 470,000-ohm to 1-megohm resistor in the B-plus lead. Connect a two-tube amplifier and relay across this resistor. The relay operates when infra-red rays strike the converter tube, changing the voltage across the resistors.

A modified snooperscope has been used in biological laboratories to study the behavior of rats and other small nocturnal animals in total darkness. The converter tube has been used with a microscope to study bacteriological and botanical specimens under infra-red rays. They have also been used in measuring temperatures of materials below visible red heat.

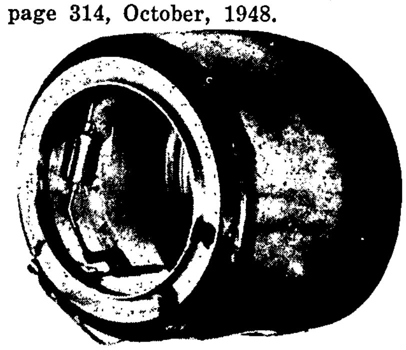
For additional reading on this subject, see:

Forsythe, William E., *Fluorescent and Other Gaseous Discharge Lamps.*

Pratt, T. H., *Journal of Scientific Instruments*, Vol. 24, No. 12, December, 1947.

Monahan, A. C., *Science News Letter*, Vol. 50, page 26-28, July 13, 1946.

Pratt, T. H., *Electronic Engineering* (London), Vol. 20, No. 247, page 278, September, 1948; and Vol. 20, No. 248, page 314, October, 1948.



SNOOPERSCOPE TUBE

The Infra-Red Image Converter Tube

Based on a Lecture delivered before the Electronics Group of The Institute of Physics

By T. H. PRATT*

THE principle of the infra-red image converter tube is not new but it has only been with the development of equipment for Service applications that any particular interest has been shown in such devices. In principle the image converter is a system for rendering visible radiation of wavelengths lying outside the range of spectral sensitivity of the human eye. Several tubes have been described in the scientific journals, and the wartime work has consisted of the development of operationally serviceable equipment based on the principles given in the published accounts. In particular, equipment has been produced for Service use that transforms an image in the near infra-red spectral region into an image visible to the eye.

It is, perhaps, appropriate first to make a brief reference to this near infra-red region of the electromagnetic spectrum which lies between about 8,000 and 13,000 Angstroms (0.8 and 1.3 microns). The lower wavelength represents the approximate long wave limit of the response of the eye,[1] while the upper figure is the long-wave limit of sensitivity of most of the photodetectors available for use in this region.

Transmission of near infra-red radiation through the atmosphere is virtually the same as that of visible light. In particular it should be noted that at wavelengths so slightly removed from the visible, no useful advantage is obtained in conditions of mist or fog. The tungsten filament lamp running at normal colour temperatures (say 2,800° K.) is, of course, an extremely efficient source of radiation in the region of one micron, and was used in all Service applications.

The main phenomena used for detection in the region are photography, photoconductivity, phosphorescence and photoemission. In the case of the first of these, the sensitivity of the photographic plate can be extended to about 1.3 microns by the use of a suitable dyestuff such as pentacarbocyanine[2] to absorb radiation and transfer the energy to the main silver bromide lattice. Results obtained in long range aerial photography using infra-red plates have led to the widespread impression that near infra-red radiation will penetrate mist, but it must be stressed that the increased atmospheric penetration is only obtained through the small particle haze that is present even under conditions of the best visibility. Photoconductivity and phosphorescence rely, as does the photographic plate, on an internal photoelectric effect. In the former, absorption of radiation raises electrons to the conduction level from impurity centres in a semi-conductor lattice, with a corresponding variation in resistance, while in the case of phosphorescence, electrons that have been raised into trapping centres by some activation process, are removed from these centres by the infra-red radiation and return to the ground level with the emission of visible radiation. The best known photo-conductor in this region is thallium sulphide,[3] while typical of an infra-red sensitive phosphor is strontium sulphide sensitised with samarium and europium.[4] In the case of photo-emission, we have the external photo-effect, the absorption of radiation completely removing electrons from a layer. The main infra-red sensitive layer consists of a silver

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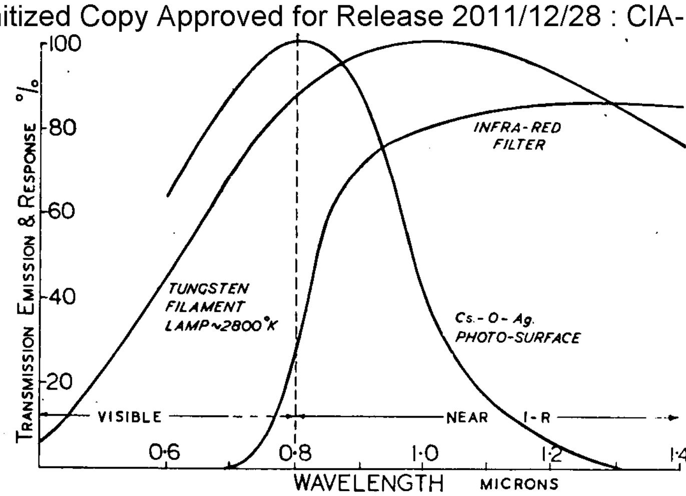


Fig. 1. The near infra-red region of the spectrum

caesium oxide compound surface.[5] It is, of course, this latter effect that is used in the infra-red image converter tube. Image converter tubes relying on an internal photo-electric effect and an electron mirror system[6] will not be considered here, nor will devices such as the image orthicon in which the visible image is not formed in the tube itself.

Principle of the Image Converter Tube

In the infra-red image converter tube, an image formed with radiation of about 1 micron wavelength is transformed into a visible image. The infra-red image is focused on to a Ag-O-Cs photo-cathode and the electrons emitted caused to impinge on an anode in the form of a fluorescent screen. The converter may thus be divided into three main components, the photo-emissive surface, the electron optical system, and the screen, with each of which it is intended to deal briefly here.

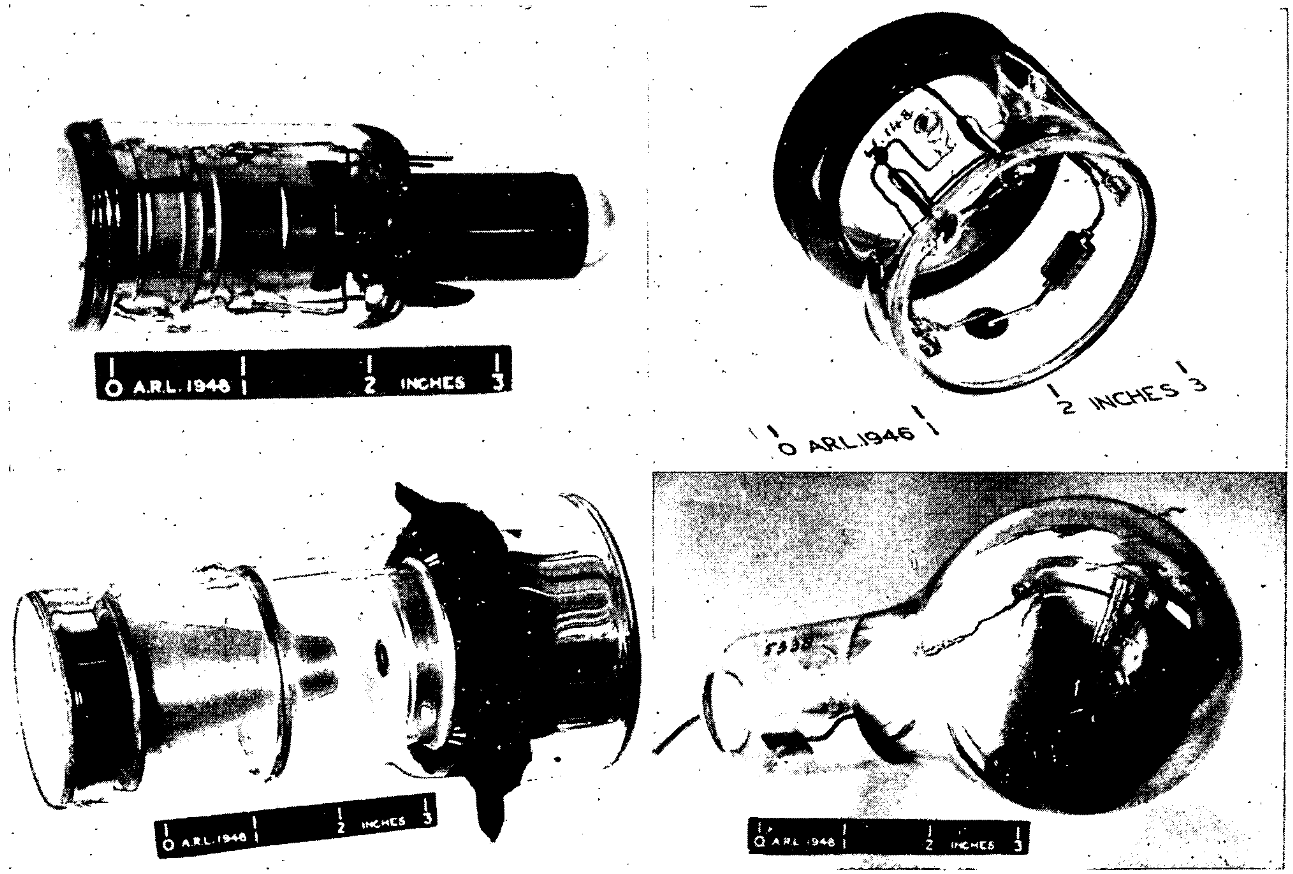
The photo-emissive effect in an Ag-O-Cs layer results from the removal of electrons from the outermost orbits of the caesium atoms by absorption of infra-red radiation. The energy transferred to an electron by a photon is sufficient not only to enable it to leave the field of influence of the parent atom but also, under favourable conditions, to overcome the forces of surface attraction and so leave the layer and pass into the evacuated space outside. The magnitude of the effect is dependent upon the wavelength of the incident radiation, and in the case of the composite caesium surface, peak response occurs at about 8,000 Angstroms with a long wave cut-off at 13,000 Angstroms. The number of photo-electrons is proportional to the intensity of radiation, although at room temperature there is always a number of electrons leaving the surface as a result of thermal agitation. There is some spread in velocity among the photo-electrons corresponding to the different wavelengths (energy) of the exciting radiation and to the varying depths in the layer at which the electrons are released. The high accelerating voltages employed render this spread of velocity unimportant. Since the number of electrons leaving a point of the photo-sensitive surface will be proportional to the intensity of radiation at that point (ignoring the background of thermal electrons), it can be seen that the electron density immediately outside the surface will vary from point to point according to the corresponding variation in the intensity of the infra-red image focused onto the surface. The infra-red image has thus been replaced by an electron image.

The electrons forming this image are accelerated towards the fluorescent screen anode by an applied field of several thousand volts, and, except in the simplest forms of image converter, pass through some form of electron optical system in the process. The high voltage both limits the electron spread during the passage from cathode to anode and also gives a fluorescent

Fig. 3. Types of infra-red image converter

R.C A. (American)
A E G. (German)

E.M.I. Ltd. (British)
Philips (Dutch)



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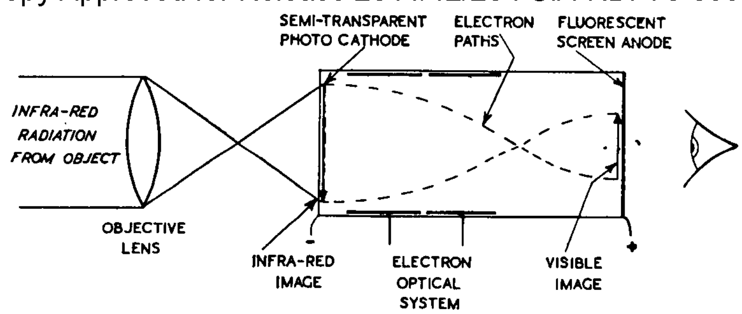


Fig. 2. Principle of the image converter tube

image of high brightness. The tendency of electrons to follow helical paths about magnetic lines of force may be utilised to bring all the electrons leaving a point of the cathode to a point focus on the screen irrespective of the original angle of emission of the electrons. Alternatively an electrostatic focusing system may be employed when the inverted infra-red image formed by a normal glass lens on the photocathode may be reproduced as an erect image on the screen, and further the size of the latter image may to some extent be varied. It is an advantage to reduce the size of the fluorescent image and so, by increasing the electron concentration, obtain a brighter image on the screen. An electron optical reduction to about one-half is the optimum. The principles of electron optics and the analogy to normal optics are well known, applications being widespread in both the field of electronics and, for example, electron microscopy. Use is made of the fact that electrons are deflected by an electrostatic field, tending to follow a path at right angles to the equipotential lines. Thus the electron lens formed by the field between two adjacent co-axial cylinders of different potential has a similar focusing effect on a parallel beam of electrons as does a convex glass lens on a parallel beam of light. In the image converter tubes use is made, for the most part, of either cylindrical or aperture electrostatic lenses. Little use has been made of electromagnetic lenses owing to the greater weight of such systems.

After passing through the electron optical system the electrons impinge on the fluorescent screen. Various compounds are available for use as screen material, for example, zinc sulphide and willemite (zinc orthosilicate). The comparative inertness of the latter to caesium contamination makes it particularly suitable, as does the colour (green) which corresponds roughly to the maximum sensitivity of the eye. Bombardment by high velocity electrons will, of course, cause the screen to glow. The intensity of the light emitted by the fluorescent material is proportional to the number of electrons striking it, and thus the variations in brightness from point to point of the fluorescent image will correspond to the variations in electron density in the electron image which, in turn, is directly related to the variations in intensity of the original infra-red-image. The latter has thus been transformed into an image visible to the eye.

Historical Development

The development of the image converter tube may be traced back to the modification of the electron microscope employed, for example, by Brüche[7] in an investigation of metallic surfaces. The state of a surface is, to some extent, reflected in the electron emission under ultra-violet irradiation. Brüche formed an image of a zinc surface in an electron microscope using the electrons emitted by the zinc when illuminated with a mercury arc. Other workers used similar systems and it was a logical development to arrive at a device in which the electrons imaged on the fluorescent screen originated from an infra-red image focussed on a caesium photosurface. In 1934 the first description was published of a normal of which had earlier been advanced in the form of a patent (B.P. 326200) by Holst and his co-workers[8] of Messrs. Philips of Eindhoven. Their arrangement is of particular interest since it was chosen by the Admiralty in 1940 as the basis of the British Service image converter tube. The cylindrical glass envelope of the tube is fitted with two plane parallel windows, on one of which is deposited the photo-cathode, on the other the fluorescent screen. An accelerating potential of a few thousand volts is applied between anode and cathode which are separated by a distance of 2 cm. The photo-electrons emitted are accelerated along a straight path by the homogeneous electrostatic field and impinge on the fluorescent screen giving rise to a visible image bearing a one-to-one correspondence to the original infra-red image falling on the cathode. The definition attainable with such a simple device is limited by the varying angles of emission of the photo-electrons and by the spread due to mutual repulsion during passage to the screen. Coeterier and Teves later introduced improvements to the simple system, and experimented with alternative focusing devices.

Also in 1934, Farnsworth published in America details of a so-called image dissector tube for television purposes.[9] In his tube a plane cathode was used with a uniform electrostatic field, together with a uniform magnetic field produced by a solenoid wound around the outside of the tube. Since electrons travel in helical paths about the magnetic lines of force, all electrons leaving a point of the cathode, whether in a normal direction or not, can be brought to a point focus in the final image plane by means of the magnetic field. It can be shown that the position of this focus is independent of the transverse velocity of the electrons on emission. In the image dissector tube, the whole electron image was deflected by means of additional magnetic coils, so that it fell point by point on the collecting anode after passing through an 0.015 in. aperture. This aperture using a 4 in. cathode Farnsworth achieved a 240 line picture. Although developed as the basis of a television camera, in which application an electron multiplier was added to the anode, in order to examine the quality of the electron image the collecting anode may be replaced by a fluorescent screen, when the system corresponds to that of Holst with the addition of a long magnetic lens.

The focusing effect of the long magnetic lens and the consequent improvement of definition led Coeterier and Teves to modify the Philips tube to include a uniform magnetic field.[10] They also constructed tubes in which use was made of a converging field that permitted an electron optical reduction in image size. The improvement in definition resulting from the employment of focusing systems was calculated by Henneberg and Recknagel of A.E.G.[11] Three systems were considered, the uniform electrostatic field, the electrostatic field with uniform magnetic field added, and a short lens. Calculated circles of confusion in the three cases were:

$$4l\sqrt{\frac{E}{U}}\,;\quad \frac{2lE}{U}\,;\quad 2L\frac{V}{(2V+1)}\frac{E}{U},$$

where l is the anode-cathode spacing, E, the velocity of emission of the photo-electrons, and U, the final velocity of the electrons. In the third formula V is the magnification, and L the cathode-lens centre spacing. With a factor E/U of the order of 10^{-4} a resolution of 250 lines per in. (black plus white) might be expected from the simple electrostatic arrangement with a gain of about 100 times with the magnetic field. In practice E.M.I., Ltd., achieved a better figure and Coeterier and Teves with the long magnetic lens reported a resolving power many times better than with the simple system. In general, the theoretical gains with lens systems have not been obtained.

Tubes employing more complex electron optical arrangements were soon investigated. Pohl[12] first described the use of a short lens between cathode and anode. Heimann[13] of the German Post Office

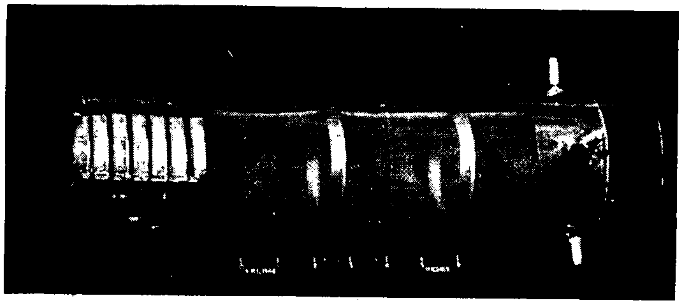


Fig. 4. Early R.C.A. tube with electostatic focusing.

Laboratory developed a tube employing both magnetic and electrostatic focusing, the latter being carried out by two metal cylinders at different potentials. The electrostatic lens inverted and reversed the fluorescent image relative to the infra-red image on the photocathode so that the orientation of the final image corresponds to that of the object. Schaffernicht[14] also produced a tube with combined electrostatic and magnetic lenses resulting in an electron optical reduction in image size, whereas Heimann's tube gave a magnified fluorescent image. The opaque cathode was deposited on a concave surface and the shape on the anode cylinder was such that a suitable focusing effect was produced with a single applied voltage. Movement of the magnetic lens enabled the magnification to be varied. Cathode-anode spacing was 40 cm. and accelerating potentials up to 20,000 volts were applied. The original tube was not, in fact, an infra-red image converter, but employed an ultra-violet sensitive potassium photo-surface. Von Ardenne[15] describes a similar arrangement in which the cylindrical electrostatic lens incorporated a resistance element in the form of a fine nickel spiral. It was claimed that the system resulted in reduced field emission owing to the lower potential gradient in the vicinity of the cathode.

Early RCA Tubes

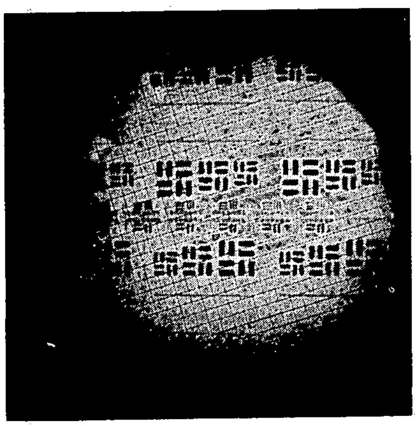
In America, Zworykin and Morton,[16] of R.C.A., reported on optical systems for image converter tubes using only electrostatic focusing. A curved cathode was used in conjunction with a series of focusing rings giving a compromise between the resistance lens and the single element (Fig. 4). Introduction of an aperture between lens system and anode enabled the magnification to be varied. Morton and Ramberg[17] extended the investigations of this type of system using moveable anode and cathode. The R.C.A. team also described a tube employing a uniform electrostatic field and a long magnetic lens.[15]

Continuing their work on image converters, Coeterier and Teves[10] developed a tube that could be used conveniently with an opaque photocathode and fluorescent screen. Use was made of a magnetic field to deflect the electrons through a right-angle. The radiation passed through the wall of a spherical glass bulb before falling on the cathode on the back wall of the bulb. The anode was mounted in the neck of the bulb at right angles to the cathode, both anode and cathode having a cylindrical magnet behind them. An accelerating potential up to 10,000 volts was applied. An alternative arrangement was also used in which the positions of anode and cathode were reversed and a third electrode added in the form of a ring spaced a short distance from the cathode. The accelerating voltage was applied between ring and cathode so that the deflecting and focusing action took place in a region free from any disturbing electrostatic field. A further development consisted of a double system in which the first anode consisted of a caesium treated plate, the secondary electrons from which were in turn focused on a fluorescent screen.

In 1938, E.M.I., Ltd., produced a system employing a plane parallel cathode and anode with a long magnetic lens, either in the form of a solenoid or a permanent magnet.

caesium-coated grids were introduced between cathode and anode. This resulted in a substantial improvement in sensitivity at the expense of resolution. It thus came about that, at the outbreak of war, some form of image converter tube was available in this country, in America, in Holland, and in Germany.

based on the original Holst design. When the complexity of the Super-Emitron television camera is compared with the simplicity of the image converter, it is perhaps not surprising that within a month or two Dr. J. D. McGee, of E.M.I., was able to demonstrate a successful tube of the simple type.



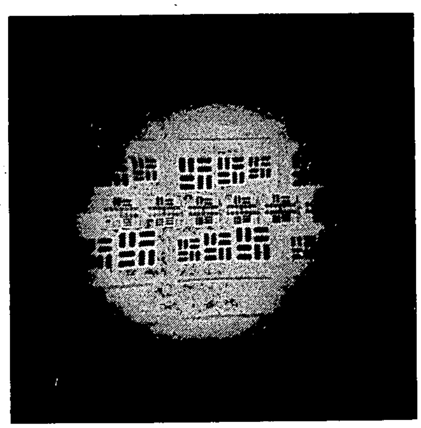


Fig. 5. Comparison of definition of E.M.I. (left) and (right) A.E.G. tubes

War-Time Development

Consideration of the military applications of infra-red image converter tubes was commenced by the Admiralty in 1938. It soon became apparent that the devices already available were too cumbersome for many of the possible Service uses, although technically the performance was promising. In addition, production techniques were difficult. After comparative tests of the available British, American and Dutch gear in 1940, it was decided that if useful quantities of equipment were to be available for Service use in an acceptable time, the original system of Holst offered the best possibilities. The Philips team had given a number of reasons why the simple arrangement was undesirable—for example, the difficulty of working at high voltages with a small cathode-anode spacing, optical retroaction between fluorescent anode and the cathode, and the relatively low sensitivity of semi-transparent photo-surfaces, but it was considered that simplicity justified a fuller investigation. Accordingly E.M.I. were asked to under-

E.M.I. Tube

The final arrangement of the tube is shown in the photograph of Fig. 3. The cylindrical Pyrex envelope, 5 cm. in diameter and 4 cm. in length, is fitted with plane end windows 2 mm. in thickness. On the inside surface of one of these is deposited the semi-transparent Ag-O-Cs layer, while the screen is mounted at a distance of 5 mm. from the photo-surface. The willemite is deposited on a thin glass disk on which a platinum graticule has been sputtered to reduce screen resistance. The screen mounting is carried on tungsten wire supports sealed into the second window through which the fluorescent image is viewed. Cathode contact is made by a platinum paste seal at the edge of the window. To prevent caesium contamination of the willemite and to facilitate the deposition of a uniform photo-surface, during the activation processes the screen lies with willemite surface downwards on the back window of the tube. Evaporation of both silver and caesium is carried out by electrical the tube itself. Otherwise the processes employed are similar to those normally used in the preparation of this type of layer. Care in design and manufacture resulted in a high level of insulation being maintained and potentials of between 3,000 and 7,000 volts can be applied to the tube without failure. The deposition of the cathode on a plane glass surface without any associated metal parts helps in this respect by reducing cold emission. The final sensitivity of the semi-transparent photo-cathodes was comparable with the values normally obtained for opaque surfaces of the same material.

RCA Tube

Both the American and German tubes developed for military applications employed electrostatic focusing. The R.C.A. tube has been described by Morton and Flory.[20] Use is made of a four-component cylindrical lens in conjunction with a curved cathode, the actual curvature of the latter being a compromise between light and electron optical considerations. The introduction of low potential components between cathode and main lens enables a sufficiently flat image plane to be obtained. The electron optical magnification is ½, which represents the best compromise between the brightness of the fluorescent image and the power and exit pupil of the viewing lens required. Accelerating potential is 4,000-5,000 volts. The overall dimensions of the tube are 11 cm. length and 4 cm. diameter.

AEG Tube

The production version of the A.E.G. tube manufactured for the German forces used an aperture lens requiring a single intermediate potential. Again image distortion was reduced by using a curved cathode and electron optical magnification was about ½. A high-voltage was applied to the tube (up to 17,000 volts) and the image brightness was further enhanced by the application of an aluminium layer to the back of the screen. Overall dimensions were 8 cm. by 16 cm., although a smaller version was commencing production at the end of the war. The photographs of Fig. 3 show the development of the various tubes ments and the relative sizes can be judged from the scales. The simplicity of the British tube resulted in it being the first to become available in production quantities, whereas in the case of the A.E.G. tube, in spite of very much greater development effort, Service equipment had only reached the training stage in the German army at the end of the war.

Although the E.M.I. tube represents the best compromise between performance and complexity in the applications for which it was originally intended, namely the detection of sources such as infra-red homing beacons, the more complex focusing systems are an advantage where extended images are involved. Some gain in resolving power is possible, using a lens system, but operationally the more important advantage is the higher brightness level of the fluorescent image. The electron optical reduction combined with a high power viewing lens is partly responsible for this gain. In addition, the larger cathode-anode separation enables higher accelerating voltages to be used as in the case of the A.E.G. tube. Comparative resolving powers of the British and German tubes are shown in Fig. 5. The uniform resolution over the whole screen of the former is apparent as is the high resolution at the centre of the screen in the case of the latter. Exposure time in photographing the screen of the British tube was several times that required for the A.E.G. tube.

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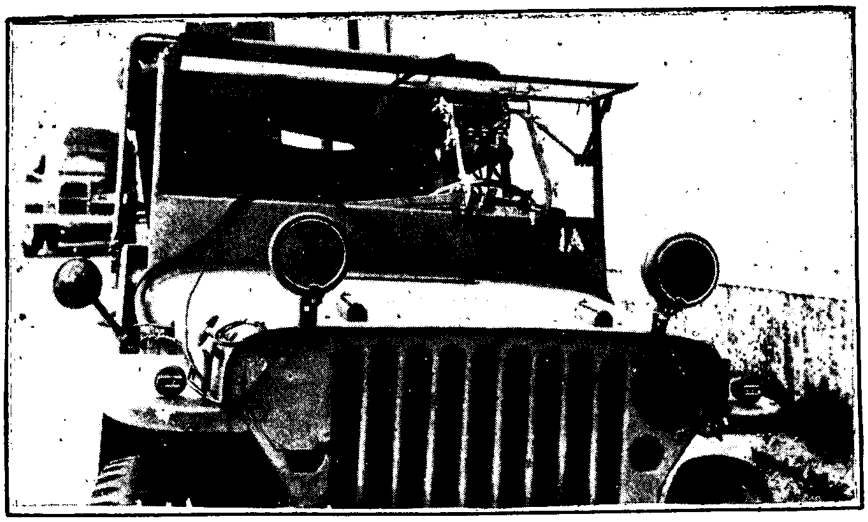
The Infra-Red Image Converter Tube

By

T. H. PRATT



Infra-Red driving equipment mounted on a jeep

Service Equipment

A TYPICAL complete Naval receiver of the type used for beacon detection is shown in the diagram of Fig. 6. An aspheric plastic objective lens, used in conjunction with a plastic field flattening component focuses infra-red radiation from a distant beacon on to the photocathode. An infra-red filter is included in the optical system to reduce the effect of stray illumination such as moonlight. The field of view is 25°. The screen is viewed through a simple plano-convex eye lens set at a fixed focus of 1 dioptre. Presentation is, of course, inverted and reversed.

In all applications it is necessary to have a source of infra-red radiation, and in this respect the high efficiency in the one micron region of the tungsten filament lamp running at normal colour temperature is convenient. The lamp must be screened with some material that absorbs visible light while transmitting infra-red radiation. Several filters were developed by the Admiralty and produced by firms such as Erinoids and B.I.P. Most filters consisted of a plastic base in which was incorporated a dyestuff with the required transmission characteristics. Polyvinyl alcohol, melamine, viscose and cellulose acetate are typical bases, while a polyazo direct dye such as napthalene leather carbon is a suitable dye. Typical transmission characteristics given in terms of Kodak Wratten 87 are:

Visual Transmission	Infra-red Transmission (to a Ag-O-Cs photosurface)
25%	75%
2%	50%
—	20%

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In most applications the transmission of some visible red light through the filter was permissible particularly in view of the low sensitivity of the retina (except for the fovea) to red light. Data has been published on similar infra-red filters developed in America.[22,23] Where high power transmitters were concerned and plastic-based filters unsuitable, use was made of a Chance-Pilkington pigmented glass.

In applications involving the viewing of any extended scene an erect presentation is obtained by the introduction of an erecting viewing system as shown in Fig. 7. This instrument, which is a binocular, employs as objective a 1½ in. focal length f/1.9 projection lens, a cemented doublet erector and a 1 in. Ramsden eyepiece. A resolving power of 350 lines per in. on the cathode is obtained at one foot-candle level of target illumination, at which level the visual acuity of the eye is the limitation. In the case of these picture-forming applications where the best resolution and brightest image are required, a voltage of about 6,500 volts is applied to the tube from a vibrator power unit. The weight of the receiver is about 7 lb. and the dimensions 16 in. by 6¾ in. by 5 in., the power unit with cold cathode rectifier weighing about 5 lb. and being 8 in. by 5¼ in. by 3 in. in size. It is interesting to compare the weights of the various British receivers with the equivalent German instrument, which weighed 27 lb. and was 21 in. long and 6 in. diameter, with a power unit of weight 20 lb. and size 11 in. by 8½ in. by 7 in. The relative sizes of the tubes themselves are shown in Fig. 8.

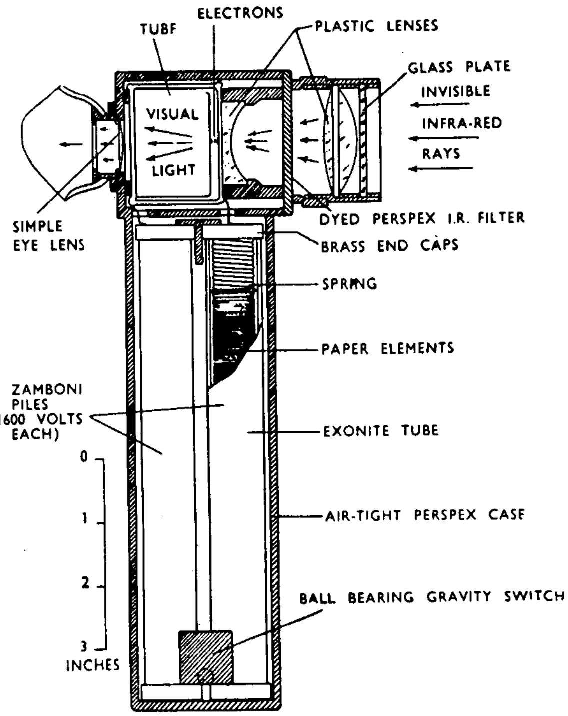

Fig. 6 **Infra-red receiver with enclosed Zamboni pile power unit for beacon detection**

Service Applications

Service applications of image converter tubes fall into two distinct categories. The first is concerned with the detection of distant sources of infra-red radiation such as homing beacons, the second with the observation of a scene illuminated with infra-red radiation. The earliest operational uses were of equipment of the first type in connection with special Naval operations in the Mediterranean in 1941. The Naval applications were almost all concerned with homing aids. Thus, in all the X-craft operations, commencing with the attack on the Tirpitz in Alte Fjord and continuing with the operations in the Far East, the craft returned to parent vessels using an infra-red telescope to home on an infra-red beacon. Again, the small combined operations pre-invasion reconnaissance parties that worked along the coast of France and North Africa and later in Malaya, used similar equipment to enable canoe parties to return to parent craft. Infra-red beacons or corner cube reflec-

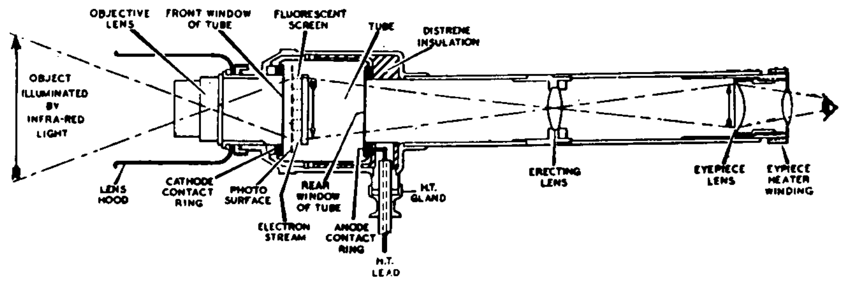

Fig. 7. Infra-red receiver for viewing scene illuminated with infra-red radiation

tors served to mark beach rendezvous for the collection of personnel operating inside enemy territory.

R.A.F. applications were concerned with recognition systems. In 1942, when German intruder aircraft were mixing with our returning night bombers, night fighters were equipped with an infra-red receiver and a coded infra-red beacon was attached to the tails of our bombers. Before carrying out an attack, the fighter pilot glanced in his telescope and if the plane ahead was British the appropriate signal would be seen. Later in 1944, a similar device was fitted to rear turrets of night bombers to enable rear gunners to differentiate between members of the bomber stream and German night fighters, the former being fitted with suitable beacons shining forward.

The main Army application was a night vehicle driving aid, using normal headlamps covered with infra-red filters in conjunction with the binocular receiver for viewing the terrain ahead. This arrangement enabled convoys of armoured or supply vehicles to move at night over roads or open country at speeds about equal to normal daytime convoy speeds without danger from air observation. The equipment was fitted as a navigational aid on amphibious vehicles used in ferrying troops across the Rhine during the main crossing. The Army also possessed quantities of simple receivers for use as countermeasures in the event of enemy use of infra-red.

Research and Commercial Applications

The first image converter tubes were not, of course, developed with a view to military applications. As has already been stated, Brüche was concerned with the examination of the surface of a metal plate using the electrons emitted under ultra-violet illumination to form a fluorescent image of the surface. Similarly Kluge[24] used the form of tube developed by Heimann for an investigation of semi-transparent photo-surfaces. The application to spectroscopy[25] is immediately apparent since the tube can be used for the direct observation of emission or absorption phenomena out to 1.3 microns. During the war an image converter tube attachment was made for the N.P.L. spectrometer to facilitate the direct measurement at one micron of the refractive indices of various materials used in the optical components of infra-red receivers. The R.C.A. workers described the use of their tube in conjunction with a microscope for the observation of biological and botanical specimens in the infra-red.[26]

Useful information can be obtained on animal behaviour in the dark using infra-red viewing equipment. During the war this was applied in connection with an investigation on the sensitisation of the retina to infra-red radiation.

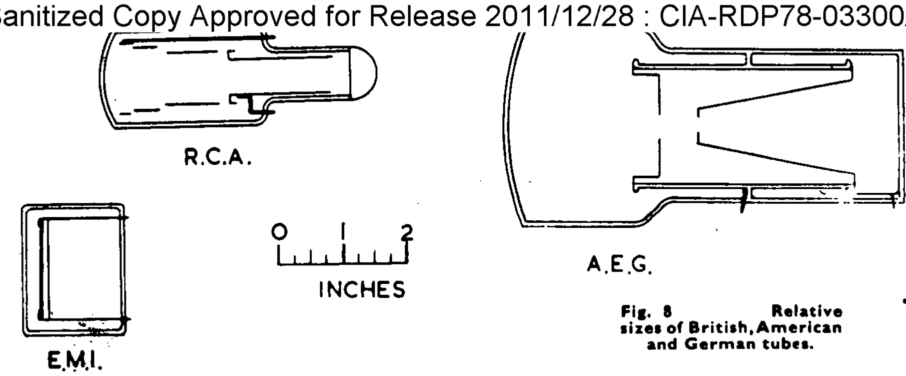

Fig. 8 **Relative sizes of British, American and German tubes.**

More recently Colonial Office field teams have used instruments for observing rats in the dark in the course of an investigation of the spreading of scrub typhus in the Far East, and for observing the behaviour of malaria-carrying mosquitoes in the dark over water. Although the wavelengths to which the image converter tubes are sensitive are too short to be preferentially transmitted through natural scattering media such as fog, where scattering particles are sufficiently small, some advantage can be gained by using an infra-red receiver. Thus descriptions have been given[26,27] of the application of the converter tubes to ophthalmic problems connected with certain types of corneal opacity. Infra-red aids have immediate application to the production of photographic materials. Simple manipulative work, time studies and inspection are all made inestimably easier using the simplest devices. The use of optical pyrometric methods at temperatures below visible red heat is made possible by the use of the image converter tube. Many of these applications are only now being investigated fully, but there is no doubt that the return from the war-time effort will be considerable in the fields of research and industry.

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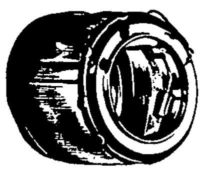

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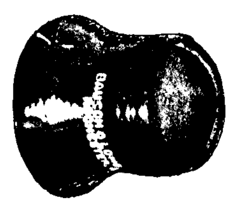

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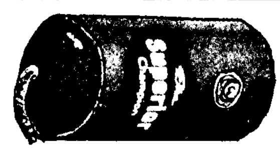

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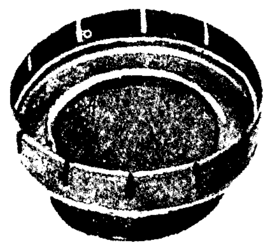

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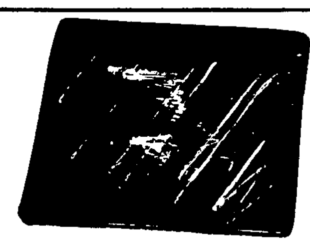

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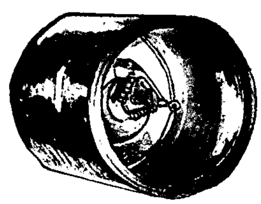

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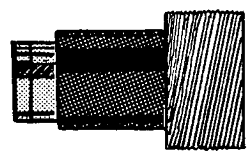

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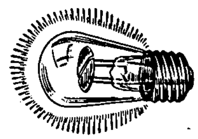

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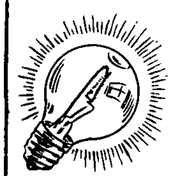

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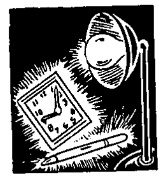

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SPECIAL PHOSPHORS

ULTRA VIOLET

Energize this phosphor with short wave ultra violet light (approx. 2500 A) and it will convert it to the near ultra violet of approx. 4000 A. This phosphor when used with many types of black lights will increase the ultra violet output considerably. Use as a coating on the outside of photocells to change their response.

Sample 50¢ 1 oz. Bottle $1 $12.50 lb.

TWO COLOR

The beautiful colors that these concentrated phosphors will glow depend upon the wavelength. Different types of blacklights will make it change color. Red and green or yellow and green are available.

Sample 50¢ $12.50 lb. 1 oz. Bottle $1

INFRA RED RESPONSIVE

A specially prepared material with rare earth activators. Charge with ultra violet light or alpha particles, phosphor then stores this energy and releases it in the form of light when infra red radiation is present. Also useful as temperature indicators.

Price $4 oz.

SHORT WAVE

Responds to wavelength of 2500 A or shorter. Will detect alpha particles, electron beams, etc. Lights up a bright green.

Sample 50¢ $12.50 lb. 1 oz. Bottle $1

INFRA RED EMITTING

This unusual material has the property of emitting far red and infra red radiation when excited with ultra violet light. Useful as infra red light sources, experimental fluorescent lights, etc.

Price $4 oz.

ULTRA VIOLET FILTERS

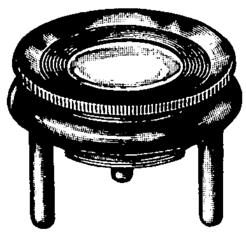
Glass type. Filters out most of the visible light while allowing free passage of ultra violet. Very handy for experimenting with fluorescent phosphors.

3 x 3 inch square Price $2.55
6 x 6 inch square Price $4.00

PRECISE MEASUREMENTS COMPANY

942 Kings Highway, Brooklyn 23, New York

TRIPOD MAGNIFIER



Lenses are ground for better clearity. Has high magnification power and is adjustable by means of a screw thread. Very popular item with experimenters, colleges and research labs.

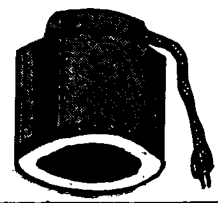
Your Price $1.75

VAN DE GRAAF MACHINE

Produces voltages between 10 KV and 100 KV. Well designed for long life and efficient operation. Under favorable weather conditions sparks up to three inches can be obtained. Many interesting high voltage experiments can be performed with this miniature generator.

Price $15.00

ULTRA VIOLET GENERATOR



2537 Angstrom units

Consists of a miniature mercury vapor lamp in beautiful plastic housing. Lamp constructed of special glasses for the efficient production of ultra violet radiation. Built in ballasts for long life and good operation. Wavelength changer filter instantly changes the output wavelengths to the 3500 A band thus enabling complete coverage of the most important bands.

Your Price $9.95

ADDITIONAL WAVELENGTH CHANGER FILTERS

available in blue, green, yellow, orange and red. Price $1 each

INFRA RED WAVELENGTH CHANGER FILTERS

Converts your ultra violet generator to an infra red generator. Price $1.50 each

NIGHT VISION GOGGLES.—These goggles were used by the Army for nighttime vision purposes. All are new and in individual cloth case. **Price $1.00 each**

INFRARED FILM. A fortunate purchase of infrared film allows us to offer this material at an almost unbelievable low price. Film is surplus aerial cameral stock which is outdated. We have tested this film and find that good results can still be obtained. Speed rating is 50 with red filter. Comes in vacuum sealed can in rolls 5½ inches wide by 26 feet long.

Your Price $1.25

CESIUM VAPOR LAMPS

These lamps produce nearly a pure output of infra red light of 8521 and 8943 Angstrom units. They are the most efficient source of infra red at these wavelengths and are about 700% more efficient than the Tungstem filament lamp. These lamps may be modulated up to 10,000 cycles with voice or code. Only a very limited quantity of these lamps are available as they were used in Navy projects. Lamps are rated at 90 Watts at 5.5 amperes. **Price $30.00 each.**

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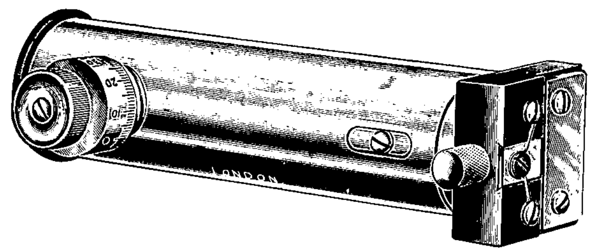


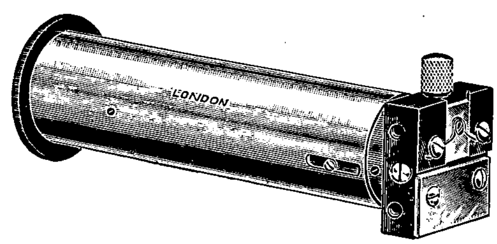
This spectroscope is suitable for medical research, analytical work and general purposes in physical laboratories.

The dispersion is 34° and the slit is provided with an adjustment for varying the width. A graduated drum by which the spectrum can be moved across the field, used in conjunction with an indicator enables readings to be taken. This drum is divided into 100divisions, which are arbitrary, but which can be calibrated if desired by the user. An adjustment is fitted for accurately focussing the spectrum.

A table stand to carry the spectroscope can be supplied. Provision is afforded for the attachment of a test tube holder and also a cylindrical lens attachment. This latter is a very useful accessory, especially when working with a small or weak source of light, as it concentrates an image of the light source on the slit.

No. 2425. Reading spectroscope, in case **$69.50**

Nos. 2458 and 2459 PRISM SPECTROSCOPES.

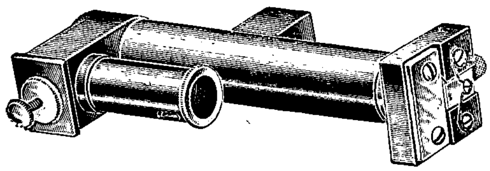


For certain purposes the prismatic type of spectroscope is advantageous, as it passes very much more light than the diffraction type. The dispersion, however, is less, and as explained in the opening description (page 1), gives a smaller relative dispersion at the red end of the spectrum compared with that at the blue end. This model employs a train of five prisms giving a dispersion of 10°. An adjustment is provided to the slit for varying the width; there is also an adjustment for accurately focussing the spectrum. The instrument can be attached to a table stand, and provision is made for the attachment of a test tube holder, etc.

No. 2459 has the addition of a comparison prism. This enables the spectra from two sources to be examined simultaneously.

No. 2458. Prism spectroscope, in case **49.50**

No. 2459. Prism spectroscope, in case **52.95**



For taking direct readings in wavelengths where extreme accuracy is not required, this instrument will be found extremely satisfactory. The dispersion given is 10°. The scale giving readings in wavelengths is viewed in the same field as the spectrum, each division of the scale representing 100 A. The slit is adjustable and the necessary focussing adjustments are provided. There is also an adjustment to the scale so that it can be set accurately in relation to the spectrum.

Provision for attaching to a table stand is provided and such accessories as test tube holder and cylindrical lens attachment can be employed.

No. 2523 has the addition of a comparison prism. This enables the spectrum being examined to be compared with a standard or other source.

No. 2522. Prism spectroscope, in case **$89.50**

No. 2523. Prism spectroscope, in case **$94.50**

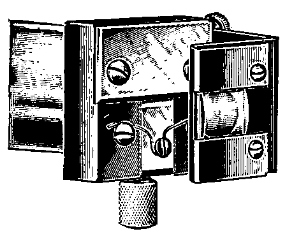
ACCESSORIES

TABLE STAND.

This stand is strongly made, the spread of the feet is arranged to ensure that the stand is rigid. The fitting carrying the spectroscope has adjustments for raising and lowering, also for tilting, both adjustments being provided with clamps. It is suitable for spectroscopes Nos. 2447, 2449, 2425, 2426, 3500, 2458, 2459, 2522, 2523. 2435 and 2438.

No. 2437. Table stand **$9.95**

CYLINDRICAL LENS ATTACHMENT.



When small or weak sources of light are being examined, this attachment is found extremely useful, as it produces an extended image of the light source on the slit. It can be used in conjunction with Nos. 2447, 2449, 2425, 2426, 3500, 2458, 2459, 2522 and 2523.

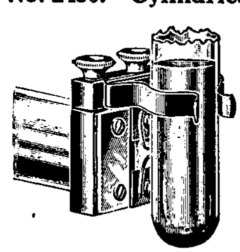
No. 2496. Cylindrical lens attachment .. **$9.50**

CYLINDRICAL LENS ATTACHMENT.

This attachment is on the same principle as No. 2496, but is made in quartz so that it can be used in conjunction with spectroscopes Nos. 2435 and 2438.

No. 2436. Cylindrical lens attachment **$10.95**

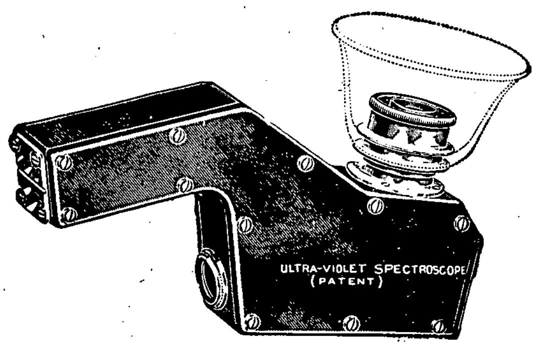
TEST TUBE HOLDER.



This holder is a secure method of supporting a test tube and enables a number of tubes to be easily and quickly changed. It is attached to the spectroscope by two clamping screws and can be used on models Nos. 2447, 2449, 2425, 2426, 2458, 2459, 2522 and 2523.

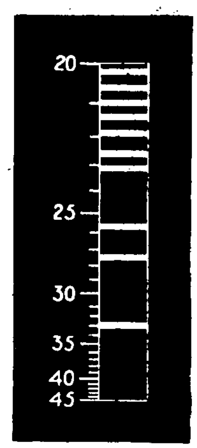
No. 2697. Test tube holder **$2.95**

Nos. 2435 and 2438 ULTRA VIOLET SPECTROSCOPES.



This is a compact spectroscope for the examination of the ultra violet spectrum Its general design can be seen by the illustration. It has an accurately made slit, fixed or adjustable, through which the light passes on to a quartz prism, forming a spectrum upon a fluorescent screen. The spectrum thus formed is examined by an eyepiece, giving a magnified image. The eyepiece is provided with a focussing motion and an eye cup to exclude extraneous light.

Beside the spectrum in the field of view is an illuminated scale, divided in Angström units, so that the wavelength of any portion of the spectrum under observation can be determined. The scale appears with illuminated lines and figures upon a black background, the illumination being obtained through a window in the instrument by means of the visible light in the light source under examination, so that no additional source of light for illuminating the scale is necessary. The spectrum included in the field of view is from 2,000 A. to 4,500 A., which includes a small portion of the visible light.



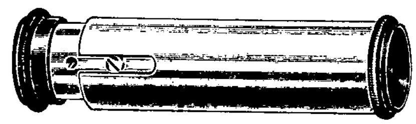
Spark spectrum of zinc and cadmium as seen in eyepiece of spectroscope.

The instrument can be conveniently used in the hand, table stand can be supplied if required

This spectroscope has been designed with a view to giving a particularly brilliant spectrum, thus rendering it easily used in daylight and with the same ease as a spectroscope for visual light. It is, therefore, specially useful for rapid determinations in electromedical and similar establishments and for industrial workshop use, when a more complicated apparatus is inconvenient to use.

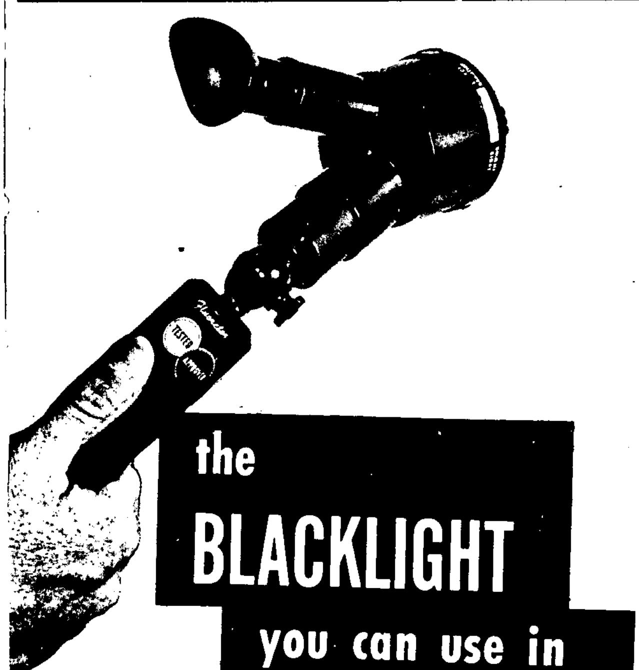
When a small source of light is being examined, the brilliancy of the spectrum can be increased by using a cylindrical lens attachment (page 12), thus making it unnecessary to hold the spectroscope close to the source of light.

No. 2435.	**ultra violet spectroscope,** in case	**109.50**
No. 2438.	**ultra violet spectroscope** with adjustable slit, in case	**114.50**



This is a very convenient pocket spectroscope for general purposes and students, use, having a dispersion of 20°. The slit is of a fixed width, protected by a glass cover to prevent dust from entering. An adjustment for accurately focussing the spectrum is provided.

No. 2444. Pocket spectroscope, in case **Our Price $12.50**

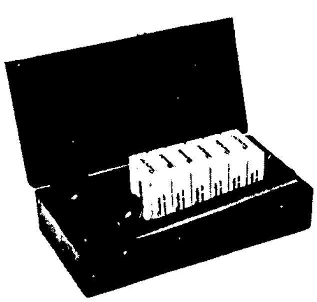


hobbies

The Fluoretor makes many hobbies more enjoyable. Mineral collectors use it in the discovery of fluorescent specimens in the field and to enhance displays of their collections. Philatelists identify papers, cancellations, ink variations, surprints and forgeries.

chemical testing

Both quantitative and qualitative chemical checks are made in or out of the laboratory with light, convenient Fluoretor. Invaluable in smaller laboratories. Long or short wave, choice of battery or electric outlet power.



the menlo *Fluoretor*

battery powered, in this professional instrument case with six different specimen-holding end caps; choice of long or short wave operation — complete: $49.50. Fluoretor for 115-v 60-cycle power: $42.00. Interchangeable lamp for alternate wavelength: $20.00.

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Rush Order Blank

Name ______________________ Date __________

Street Address or Rural Route ______________________ Box No. ____

Town ______________________ Zone ____ State __________

QUANTITY	DESCRIPTION	PRICE	PER	AMOUNT

MINIMUM ORDER 50 CENTS. MATERIAL IS SHIPPED POSTPAID TO ANY POINT IN U. S. A. UNLESS MARKED OTHERWISE. CANADIAN AND FOREIGN ORDERS ADD 10% TO COVER COST OF ADDITIONAL PACKING. REMIT BY MONEY ORDER OR POSTAL NOTES.

PRECISE MEASUREMENTS COMPANY
942 Kings Highway, Brooklyn 23, New York

Rush Order Blank

Name ______________________________ Date ____________

Street Address or Rural Route ____________________ Box No. ____

Town ________________________ Zone _____ State ____________

QUANTITY	DESCRIPTION	PRICE	PER	AMOUNT

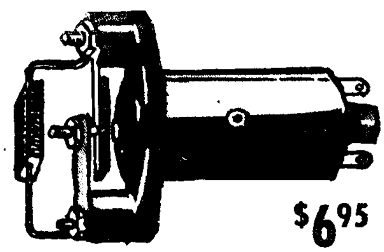
MINIMUM ORDER 50 CENTS. MATERIAL IS SHIPPED POSTPAID TO ANY POINT IN U. S. A. UNLESS MARKED OTHERWISE. CANADIAN AND FOREIGN ORDERS ADD 10% TO COVER COST OF ADDITIONAL PACKING. REMIT BY MONEY ORDER OR POSTAL NOTES.

PRECISE MEASUREMENTS COMPANY

942 Kings Highway, Brooklyn 23, New York

VIBRATOR

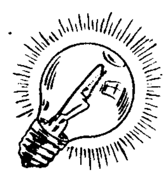
TRANSFORMERS



$6.95

IGNITION COIL—This miniature high voltage coil provides high output for snooperscope operation. Has built in condenser for extra power.

GE OZONE LAMP



Generates short ultraviolet radiation (1849A & 2537A) which produces ozone by converting the oxygen of the air (O_2) into ozone (O_3). Useful for fluorescent & phosphorescent materials. Uses only 4 watts of power. Lamp supplied with socket and instructions.

Your Price $1.95

FLUORESCENT PIGMENTS

Brightest glowing, concentrated phosphors, available in many colors. Red, White, Blue, Green, Yellow and Orange. Mix with clear lacquer for painting.

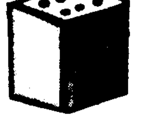
SAMPLE SIZE (specify color) .... **35c each**
COMPLETE SAMPLE KIT (6 colors) ..... **$1.75 each**
One Ounce Bottles (specify color) .... **50c each**

No. 2444 POCKET DIFFRACTION SPECTROSCOPE

This is a very convenient pocket spectroscope for general purposes and students' use, having a dispersion of 20°. The slit is of a fixed width, protected by a glass cover to prevent dust from entering. An adjustment for accurately focussing the spectrum is provided. Not a toy but a scientific instrument. Available for the first time in small size.

No. 2444. Pocket spectroscope, in leather case. **Special $12.50** (while they last)

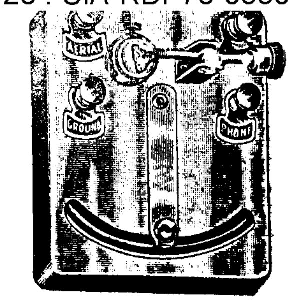
HIGH VOLTAGE TRANSFORMER



Pri. 115 v. 50-60 cy. Sec. **4500V. 2MA** #2: 2.5v @ 5A.

$7.95 Postpaid in U.S.A.

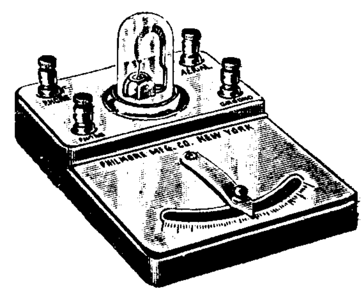
NIGHT VISION GOGGLES.—These goggles were used by the Army for nighttime vision purposes. All are new and in individual cloth case. **Price $1.00 each**



"Little Wonder" RADIO RECEIVING SET

Compact in size but big in results. The open type detector permits adjustments to be made to the finest degree. This set includes the Philmore Supersensitive Crystal which assures quick results when "looking" for a station, because the entire surface of the crystal is sensitive.

Cat. No. 7000 .... **Price $1.75**
Plus Federal Excise Tax



"Supertone" RADIO RECEIVING SET

A remarkable Radio Receiving Set built to give everlasting service.. This set will bring in broadcasting loud and clear without distortion or noises. The Supertone Crystal Set is equipped with a Philmore Supersensitive Crystal which will give excellent results over an indefinite period of time.

Cat. No. 7001 .... **Price $2.25**
Plus Federal Excise Tax

AERIAL KIT

A complete kit of parts for assembly of a professional antenna. Attractively packaged in a multi-colored display box.

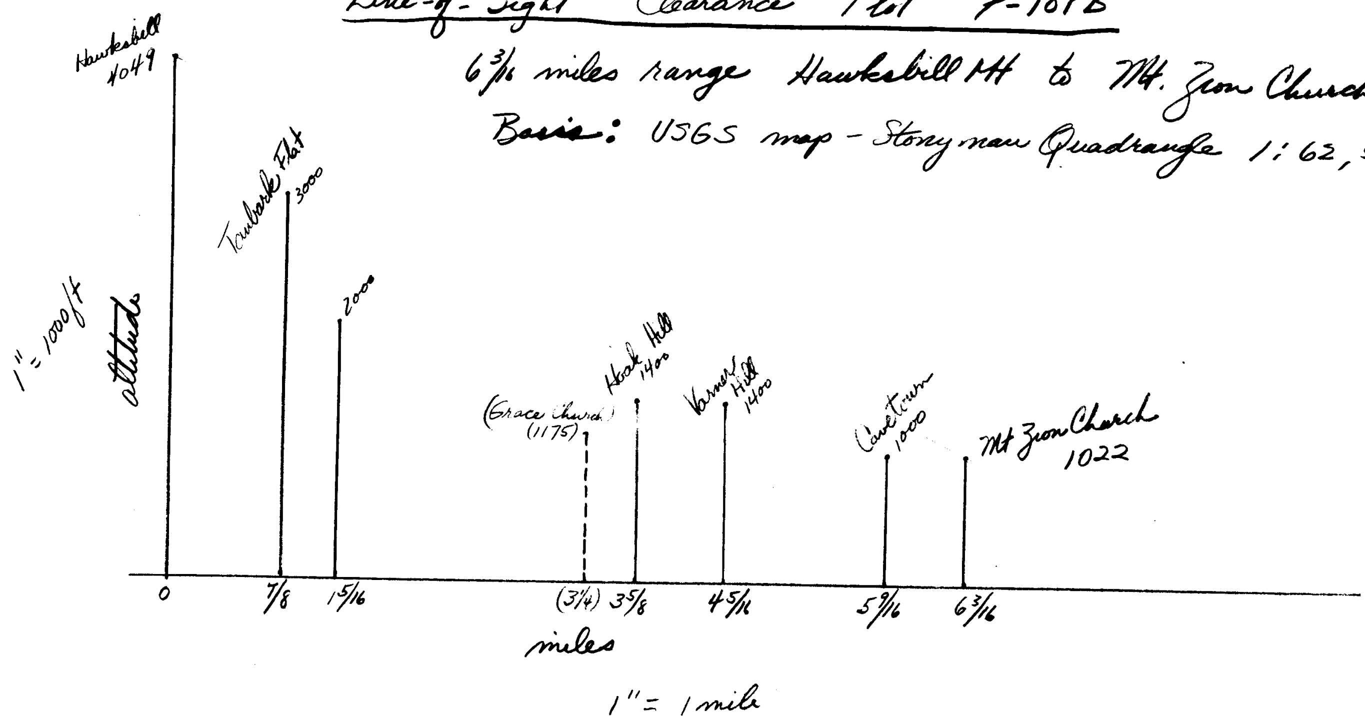
1 coil 7-26-50 ft. stranded copper aerial wire.
1 coil 25 ft. rubber covered lead-in wire.
1 Ground Clamp.
1 Lead-in-strip.
2 Porcelain insulators.
2 Nail-it knobs.
1 Instruction sheet.

Cat. No. 2103 Price $1.50

Line-of-Sight Clearance Plot P-101B

6 3/16 miles range Hawksbill MH to Mt. Zion Church

Basis: USGS map - Stonyman Quadrangle 1:62,500



Assembly of the tripod is straightforward. The longer set of le gs engage the set of holes farthest apart. The legs should be unfolded to form a point at the lower end.

BATTERY CHARGER AND BATTERIES

When a substantial portion of the ampere hour capacity of the batteries has been discharged, the batteries should be recharged. To doso remove the front cover and plug the line cord into a 115 AC line. (A link is provided in case only 230 VAC is available) Turn the function switch to position "C" and depress the charge start switch button which is located near the modulation indicator light. The indicator light will be lit and will remain lit as long as the charger is in operation. It may be necessary to depress the start button for several seconds due to capacity in the relay circuit.of the charger. If the charger fails to remain in operation upon relaease of the start button after several attempts this indicates that the batteries are very close to a fully charged condition. The charger will cut off automatically when the battery potential has risen to a fully charged condition. It requires approximately 12 to 14 hours to charge a set of batteries which are completely discharged. The equipment should be kept in an upright position while the charger is in pperation if this is possible.

As a result of some field testing of the equipment by the manufacturer, the following procedures are recommended for establishing contact between two units.

Since the viewers are not as effective in daylight as they are in darkness, initial familiarization will probably best be done at night at moderate ranges(two or three miles)

It is assumed that the watches of the operators have been synchronized and that some particular time has been designated for the establishment of contact.

NIGHT OPERATION

1. Both units are assembled for operation, the legs are attached to the table and the unit is mounted in the yoke.
2. The scan mechanism is disabled by running through a complete scan (three sweeps to the left alternated with three sweeps to the right) In this condition, the instrument does not change its angle of elevation with further horizontal scanning.
3. The angle of elevation is then set approximately and the wing nuts at the side of the unit are tightened to the yoke. The azimuth setting is adjusted so that sweeping will cover the area in which the other unit is believed to be located.
4. The Function Switch is turned to "F".
5. The R-T Switch is turned to R.
6. The viewer charging switch, located just to the right of the eyepiece is depressed, and held depressed until lights in the vicinity form sharp green points on the viewer screen, or if there are no lights moon , or sometimes even stars will suffice. Keep the switch depressed for 5 to 10 seconds.
7. At the designated time, operator A turns his R-T switch to T and slowly scans the area in which operator B is supposed to be located.

Operator A also watches through his viewer for the appearance of the light of operator B, and continues scanning until this light appears.

8. Operator B watches through his viewer for a flashing light. The duration of the flash will depend on the speed of A's sweeping, and the brightness will depend on the accuracy of alignment as well as range. At the specified initial test range of 2 or 3 miles, the light will probably be brighter than any other light visible.

9. When B sees what he thinks is the light of A, he turns his unit so that the light falls within the reticle of his viewer. (With some tubes, the background brightness is so low that the reticle will be seen only with difficulty. In this case the image is brought to the center of the screen as judged by the operator) The azimuth setting is then carefully adjusted for maximum loudness of the 1000 cycle note that will be heard with each flash. Because of the nature of the source (i.e. not steady) this adjustment will probably not be exact, but will probably be sufficiently close.

10. When the adjustment (9.) has been completed, B turns his R-T Switch to T.

11. When B completes step (10.) A will see the light of B in the viewer of the A unit. When this light apears, he turns his R-T switch to R and adjusts his azimuth setting for maximum loudness of the 1000 cycle tone being transmitted by B. Since the B transmitter is fixed, A can make this adjustment with considerable accuracy. He also will "touch up" the elevation adjustment, again for maximum loudness of B's signal.

12. When A has completed step (11.) he turns his R-T switch to T. He again watches his viewer for the apearance of B's light.

13. B, when he sees A's light according to (12.) turns his R-T switch

to R, and makes final touch-up adjustments to his azimuth and elevation settings. This time B has a steady tone on which to align, and so can do this alignment with accuracy.

14. When B has completed his alignment, he turns his function switch to OP, and his R-T switch to T, and then starts communication.

15. When A sees B's lamp in (14) he turns his R-T switch to R and his Function switch to OP.

After the initial alignment has been completed, the viewers need not be used, however it has been found that if they are used, "Break-in" operation is possible. That is, when the person who is transmitting sees the lamp of the other in his viewer, he knows that he should go into the R condition.

DAYTIME OPERATION

The procedure for the first seven steps are as above, except that because of the high brightness of the landscape, A probably will not be able to see the light of operator B at any time. The viewer is still useful if the collimation of it with the unit is known since the unit can now be quite accurately aimed at any reference landmarks that may be known.

8. During the course of his scanning, operator A must interrupt the transmission to listen for B. It is suggested that after each minute or two of scanning with the R-T Switch in the T position, operator A should make a complete scan with the R-T switch in the R position.

9. Operator B leaves his R*T switch in the R position, and slowly, very much more slowly than A, scans the area in which A is believed to be located. If A completes a horizontal scan in three or four seconds or less, a scan by B should take not less than 30 seconds. Actually the B scan should consist of a series of finite steps, each about 1/3 or less of the diameter of the reticle. Obviously, if B knows the

location of A quite accurately, he will have a smaller range of scan to make.

9a. If B does not hear A's tone after two scans, he should change the elevation by approximately 1/3 the height of the reticle and repeat step 9 until the B unit is aimed for the best loudness of the A tone.

10. B locks his unit and turns his R-T Switch to T. ~~Every~~ At the end of each minute for three minutes he listens, i.e. Turns the R-T switch to R and listens for a steady tone signal (as compared to the pulses of the 1000 cycle tone heard during the A scan)

11. If A hears a tone from B's transmitter on one of his "listening scans", A immediately aligns his instrument for loudest signal. This will involve both azimuth and elevation fine adjustment. When his unit is aligned, A turns his R-T Switch to T. Each minute thereafter A turns the R-T switch to R for 10-15 seconds.

12. When B hears a steady tone from A, he makes fine adjustments on his azimuth and elevation settings for maximum loudness of signal. The signal will be turned off after some period of time which should not exceed 1 minute. When the signal from A ceases, B turns his R-T switch to T and his function switch to OP, and starts communication.

13. When A hears voice modulation from B during his listening period as mentioned in (11) he turns his function switch to OP, and continues communication.

Since the viewers are not able to distinguish the transmitter from the background during daytime operation, Break-in operation is not possible, but each operator must wait until the other has finished his transmission.

REPLACEMENT OF COVERS

Care should be used while replacing the covers to prevent distortion of the draw pull catches. The catches should all be fully extended before any are latched in order to prevent the catch from being wedged underneath the gasket. The catches on opposite sides of the cover should be latched in pairs for best results. Make sure that the locating tabs on the center section do not extend into the gasket groove. The tabs should pass to the inside of the innermost flange. Screw the occular of the viewer inward before replacing the tripod platform. The microphone may be wedged into the compartment against the arms of the bellows mechanism to prevent rattle. The covers are stamped with serial numbers and should be replaced only on the corresponding units.

Suggested List of Equipment

Two-way radio commo - 6 mile range
✓ 1 ~~4~~ cameras, 35 mm, 50 mm and 400 mm lenses
✓ 2 binoculars ~~[illegible]~~
✓ 1 ~~#~~ tripods for camera, ~~[illegible]~~
2 army compass
~~2 [illegible]~~
✓ 1 Drawing gear inc.
~~drawing board~~. (Tsquare + triangle)
~~tracing paper~~
~~protractor~~
~~Compass~~
~~pencils~~ (knife + sandpaper)
~~ruler~~, decimal scale
~~eraser, gum~~
2 maps of area — (Stony Man Va / ~~Stony Man~~ Quadrangle / 15 min. series / Edition of 1933 / Reprint 1944 N3830 - W7815/15)
✓ 4 flashlights with batteries
✓ 2 notebooks for data + remarks
2 thermometers

5101

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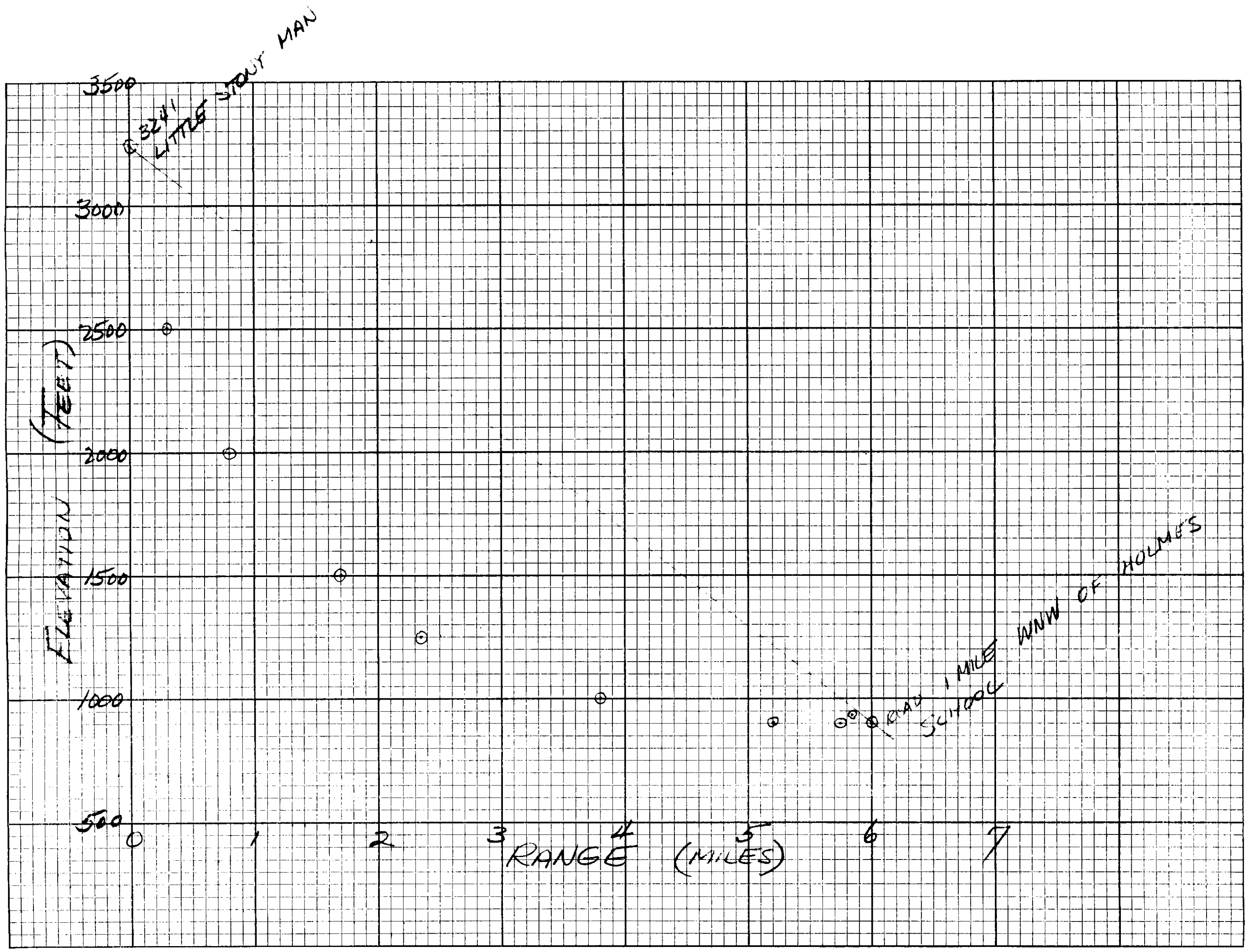

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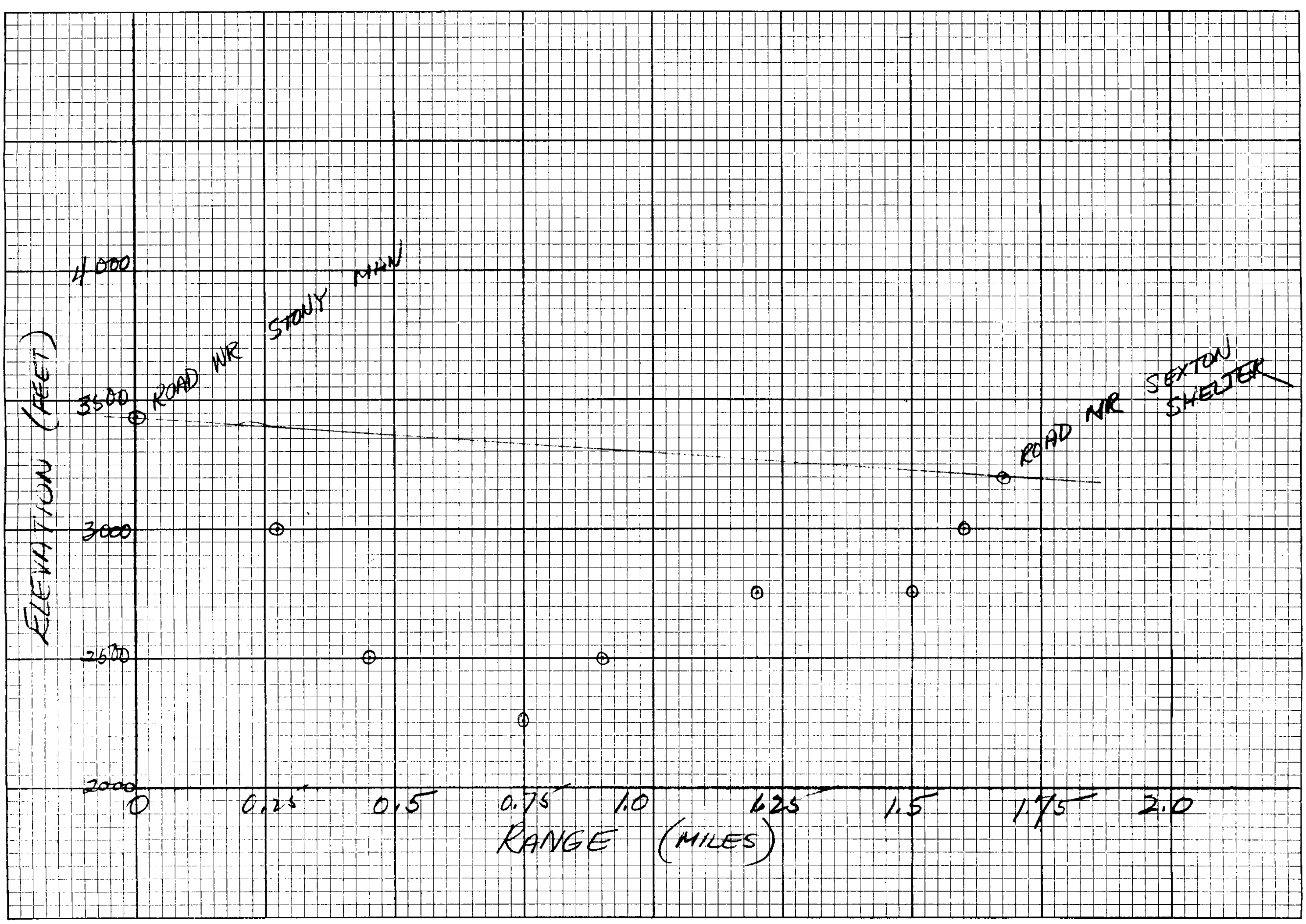
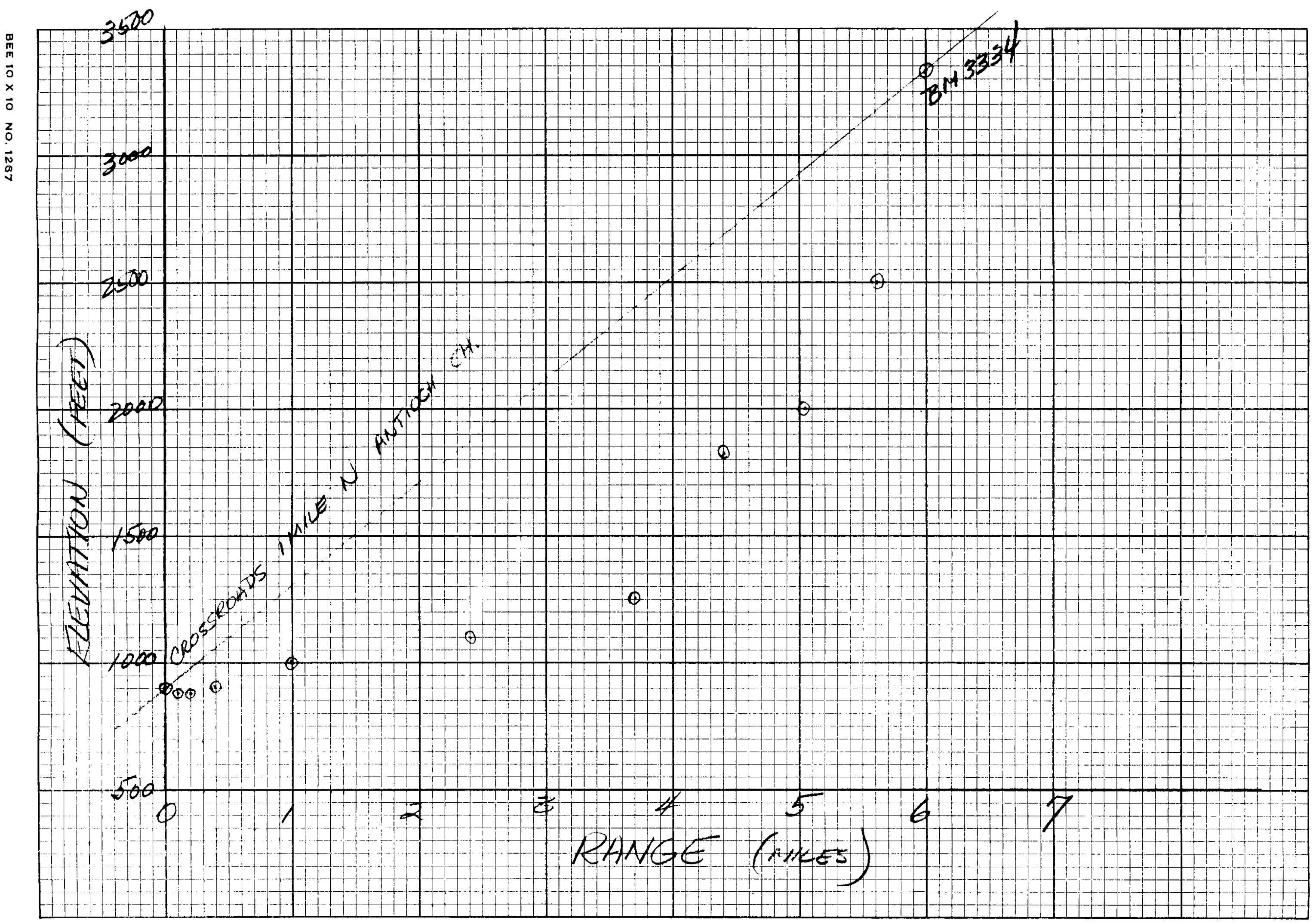
BEE 10 X 10 NO. 1267





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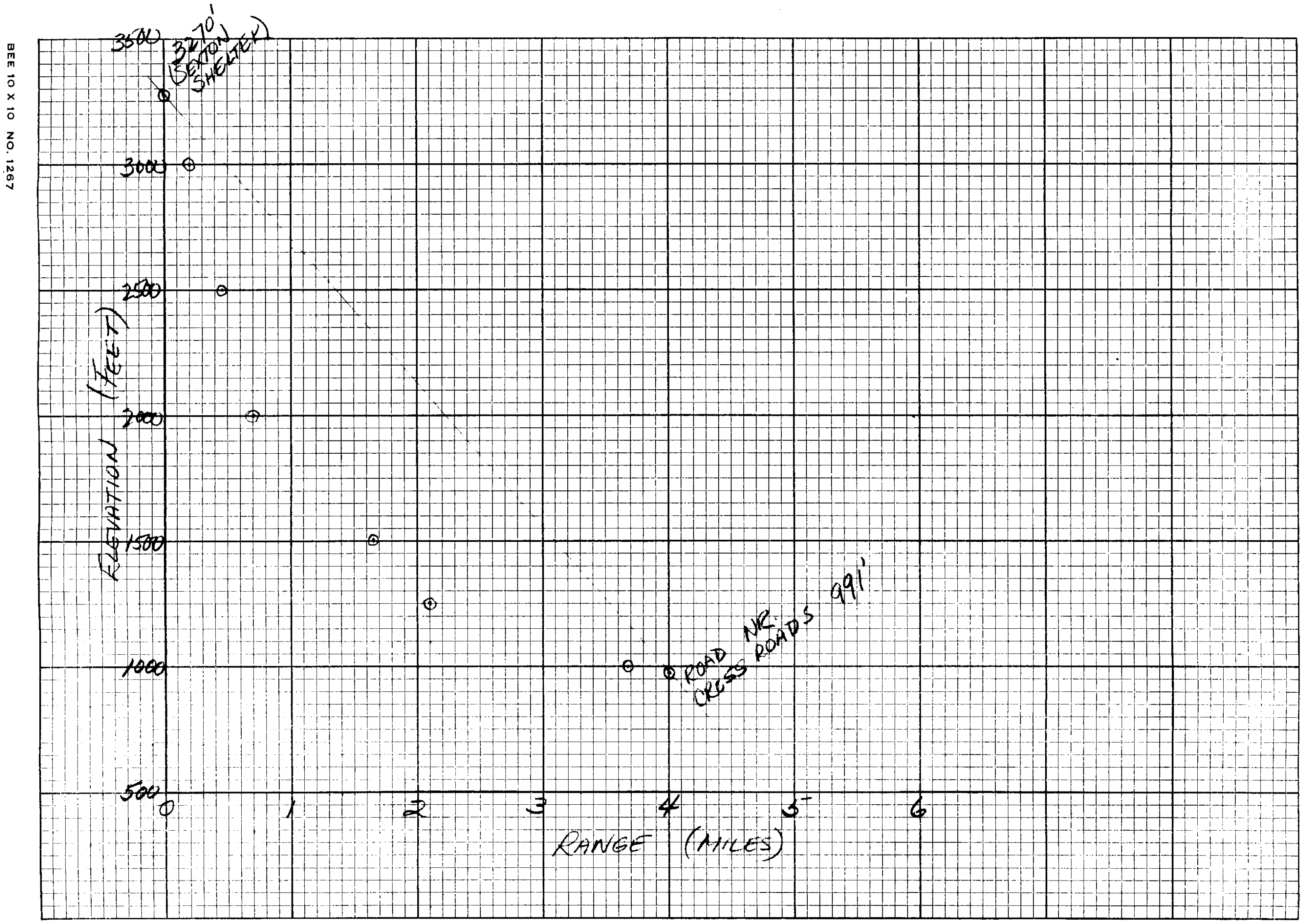
BEE 10 X 10 NO. 1267
3500
3270' (BENTON SHELTER)
3000
2500
2000
1500
1000
500
ELEVATION (FEET)
ROAD NR. CROSS ROADS 991'
0
1
2
3
4
5
6
RANGE (MILES)

BEE 10 X 10 NO. 1267