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In This Issue

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BLIND APPROACH INDICATORS

As the design of heavier-than-air craft progressed from the memorable flights at Kitty Hawk in 1909 to the present state of 600 miles per hour aircraft, the advancement of aircraft accessories, particularly instrumentation, has shown a less spectacular but remarkable progress. The early aircraft had few instruments and point-to-point flying was generally done by following convenient landmarks such as railroads and rivers. With increased range of flight and the adoption of aircraft for commercial transportation, the need for instrumentation, particularly navigational equipment, provided an incentive for the development of new and more accurate position and direction establishing equipment until at the present time we find such navigational aids as the gyro compass, radio range beacons, Loran and many similar devices or systems.

While each of these devices is capable of directing the flight of aircraft from the origin to destination with remarkable accuracy, none is capable of pin-pointing the runway of the distant airport with sufficient precision to permit landings under low ceiling or poor visibility conditions where the runway is obscured from the pilot's vision.

Radio Instrument Landing Successful in 1931

Preliminary studies in the radio frequency transmission of runway and landing path data by Messrs. Diamond and Dunmore of the Bureau of Standards in 1929 resulted in the first successful radio instrument landing at College Park, Maryland in September 1931. Trial installations were completed and tested at Newark, New Jersey and Oakland, California in 1933 and 1934.

Subsequent tests of this system utilized a Weston Model 635 Crossed Pointer Indicator which had been developed for this particular requirement. See Figure 1. The crossed pointers of the indicator, one operated from the localizer signal and the other by the landing beam or glide path signal, presented a visual interpretation of the position of the aircraft relative to the location of the fixed directional radio beams transmitted by the associated ground equipment.

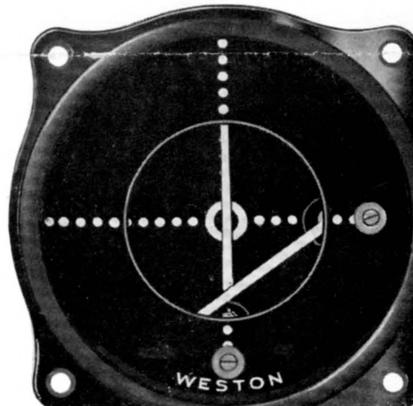


Figure 1—An early Weston blind landing indicator developed in 1933.

Fundamentally, the blind landing system designed by Messrs. Diamond and Dunmore projected a radio frequency space pattern from highly directional antennae, providing a path which could be used to direct a successful landing without visual reference to landmarks or other navigational aids. The system consisted of three elements, a runway localizer beam providing a means of orienting the aircraft with respect to the runway, a glide path to direct the rate of descent and marker beacons to provide distance information. The literature covering these methods is probably familiar to all those interested; the Bureau of Standards papers are classical references.

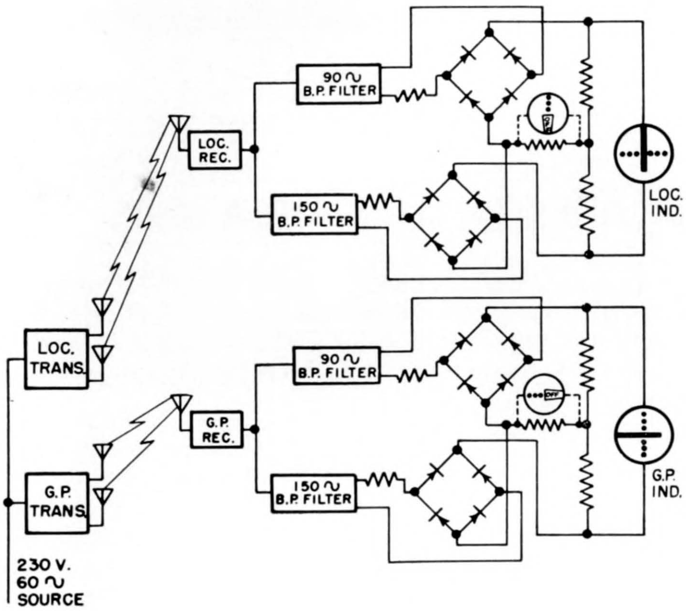


Figure 2—Simplified block diagram of the blind landing transmitting and receiving equipment.

Innumerable Problems Encountered

The innumerable problems of stability of transmitting equipment, the ultimate design of the directional antennae, elimination of course-bends and interference by equipment and buildings adjacent to the airport, and the determination of the best glide path angle, required intensive investigation of the phenomena and the advancement of the art of blind flying has been the result of valuable contributions from many sources. The use of higher frequencies as the art progressed has made for better definition of the optimum space pattern. The search for the least ambiguous arrangement of indications has led to considerable psychological research and a wide expression of ideas. Many of the improvements in design reflect the pilot's viewpoint since the system must necessarily meet the critical appraisal of the man depending on the equipment for safe landings. The receiving equipment likewise presented many problems from the standpoints of circuit details, stability and durability of circuit elements. These problems have now been largely resolved and the resulting simplified block diagram of the receiving equipment is approximately as shown in Figure 2.

In one system resulting from these efforts the localizer transmitter generates a carrier frequency, a portion of which, radiated by one antenna is modulated by a 90 cycle per second signal and another portion, modulated at 150 cycles per second is fed to a second antenna. The modulated carrier frequencies are radiated from a highly directional antennae array in such fashion that the radiation pattern on one side of the runway is predominantly modulated by the 90 cycle per second signal and on the other side of the runway by the 150 cycle per second signal. Both signals, being on the same carrier frequency, are received simultaneously by the localizer receiver in the aircraft. The output signals are separated by frequency discriminators or filters, individually rectified, and recombined by differential connection of the rectifier output to actuate the vertical pointer of the indicator. The glide path section of this system operates similarly, likewise employing a 90 and 150 cycle modulation on a different carrier frequency. As a matter of convenience and to prevent jamming at airports which are in close proximity, a number of broadcast frequencies are reserved for both localizer and glide path beams and a simple switching procedure prepares the pilot for a landing at the desired airport.

Locating the Aircraft Longitudinally

The equipment discussed to this point locates the aircraft with respect to the landing path. However, some means must be provided to locate the aircraft longitudinally. In other words, how far is the craft from the airport and approximately how high from the ground? This intelligence may be imparted to the pilot through the standard head phones in the form of radio beacons keyed as indicated in Table 1 or visually indicated on the beacon lamp or both. Information presented in the table should be considered only as representative inasmuch as the actual details should be obtained from up-to-date airport maps.

Within a matter of seconds after the boundary marker is observed, an aircraft flying on the correct landing path will be in visual or actual contact with the runway for a perfect landing.

Table 1 Marker Beacon Location and Identification Signals

Marker Name	*Distance to Airport*	*Approximate Elevation above Level Ground*	*Signal*
Outer Marker	4.5 Miles	1000 Ft.	2 dashes per second
Middle Marker	1 Mile	200 Ft.	6 dots per second
Boundary Marker	200 Feet	50 Ft.	Unkeyed dash

Early Instruments Prove Undesirable

Rather recently, the Weston Electrical Instrument Corporation was approached with three problems in connection with the indicating instrument, this instrument being the prime source of pilot information. Instruments in use so far had certain undesirable features as listed below in the order of importance:

1. The null type indicator did not provide a means of determining the inoperation or malfunctioning of either ground or airborne equipment since the on-course indication would also be evident in the event of equipment failure.
2. The instrument required shunting by a 1250 microfarad electrolytic condenser to improve the damping characteristics and response time so that minor transient variations in signal would not interfere with the smoothness of operation of the aircraft. These condensers, for size and weight reasons, were necessarily electrolytic and had a high temperature coefficient.
3. The beacon lamp associated with the system could not be located in close proximity to the instrument so that simultaneous observations of instrument and lamp signals were hindered.

The use of warning lights to indicate circuit failures was considered but they could not be operated directly from the output of the final rectified signal. This prevented the warning lights from being connected sufficiently close to the instrument circuit to provide positive indication of failure of any part of the system up to the instrument.

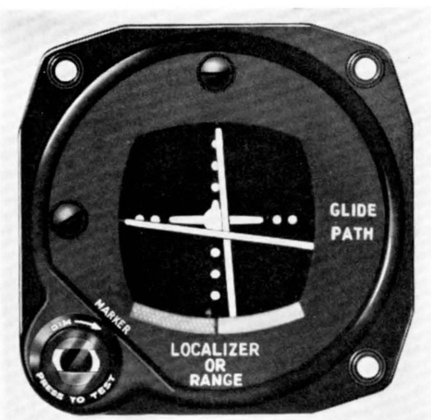


Figure 3—The Weston Model 888 showing operative conditions: ship is slightly above the glide path and slightly left of the localizer course.

Warning Flag Mechanism Installed

Sensitive electrical mechanisms, however, were capable of being operated in the output circuit of the receiver and an instrument was designed not only to include the localizer and glide path pointers but also a warning flag mechanism for each main pointer. The dotted circuit of Figure 2 shows the connections of the flag mechanisms in the output circuit of the receivers. Note that the warning flags operate from the summation of the rectifier output while the main pointers operate from the differential of this output, thus providing positive failure signals by virtue of the fact that the sum and difference is provided by the same output. Figure 3 shows the resulting instrument, designated as the Weston Model 888 Blind Landing Indicator, with an off-course but operating indication and Figure 4 shows the completely inoperative condition. Note that in the inoperative condition the warning flags provide a very definite "OFF" indication and that they also cover about one quarter of the indicating pointers. Positive "OFF" indication is attained by suppressing the zero, on the warning mechanisms so that the warning flags are held in the position of Figure 4 by the mechanism springs when the operating current is below a predetermined value.

The problem of incorporating the beacon lamp assembly in the instrument case was purely mechanical and subject only to those limitations imposed by restricted space. The lamp assembly was finally located in the lower left corner of the case flange as shown in Figures 3 and 4.

Probably the most interesting of the new requirements from the design standpoint was the matching of the dynamic characteristics of the localizer and glide path pointers with those of the preceding design which were shunted by

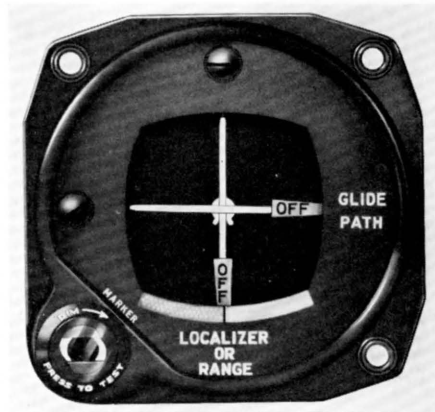


Figure 4—The Weston Model 888 showing inoperative condition of ground or airborne equipment.

the condensers. The characteristics of pointer motion are important because under damped mechanisms exaggerate minor field strength and course changes which is highly undesirable. Carried to the opposite extreme, very heavy damping is equally undesirable because the instrument response is delayed resulting in delayed pilot action and hunting of the aircraft as the pilot continues to make course changes.

The response time established by A.A.F. specifications is such that the full-scale instrument indication must be substantially attained within the period of 1.4 to 1.8 seconds and the mechanisms are required to be overdamped. These narrow limitations on response time and damping require precise control of such factors as flux density, spring torque, moment of inertia and specific damping coefficient, all of which have a substantial bearing on the ultimate result.

Disassembly a Simple Operation

Another problem, imposed not only from the manufacturing but also from the service and overhaul standpoints was the necessity for simplicity of assembly, disassembly and adjustment. The internal design is such that any one of the four mechanisms may be removed from the assembly after removal of the case, by simply unsoldering two connecting leads and removing two screws. All electrical adjustments are accomplished by means of wire-wound resistance spools, accessible upon removal of the back-plate. These resistance spools may be adjusted and inserted with the instrument case in place, thus eliminating danger of damage to the mechanisms. Color coding of all wiring simplifies the tracing and isolation of circuits. Completely assembled external connections are made through a 10-pin AN receptacle to the indicator and warning flag circuits and through a 3-pin AN receptacle to the beacon lamp circuit.

Choice of luminescent markings, dictated by government specifications, is such that the instrument can be used satisfactorily under all lighting conditions likely to be encountered in operation. These conditions include daylight, ultra-violet, and red lighting, and for the condition of total darkness the localizer and glide path pointers and the instrument dial proper are finished with radioactive luminous material which has an intensity under its own activation sufficient to be visible but not interfere with vision under the most trying circumstances.

The new instrument bids fair to be standard equipment for blind approach systems to be used on all scheduled and most non-scheduled commercial aircraft, both national and international. The C.A.A. Blind Approach System is being installed at many first class airports as rapidly as equipment becomes available and it is expected that this navigational aid will provide significant relief from air traffic congestion with the resultant costly delays and flight cancellations now occurring during low visibility and low ceiling conditions.

E. N.—No. 18 —*W. H. Skidmore* —*E. W. Hoyer*

MECHANICAL EROSION OF THERMOWELLS AND THERMOMETER STEMS

IT has been our observation that each type of industry solves the majority of its problems satisfactorily and with a reasonable approach to standardization as to methods and practices. This is particularly apparent with respect to instrumentation. A relatively small percentage of the problems met in the industry, however, remain more or less unsolved in a practical sense throughout that entire industry. Some plants suffer in silence, others discuss their problems increasingly, still others go to great length to correct the trouble within their own resources and sometimes succeed. The solution, however, is purely local and does not benefit the industry as a whole.

Dozens of such problems come to mind quite readily but this article is concerned with only one, a simple one to be sure, but one which causes no end of trouble, expense, and a certain amount of danger.

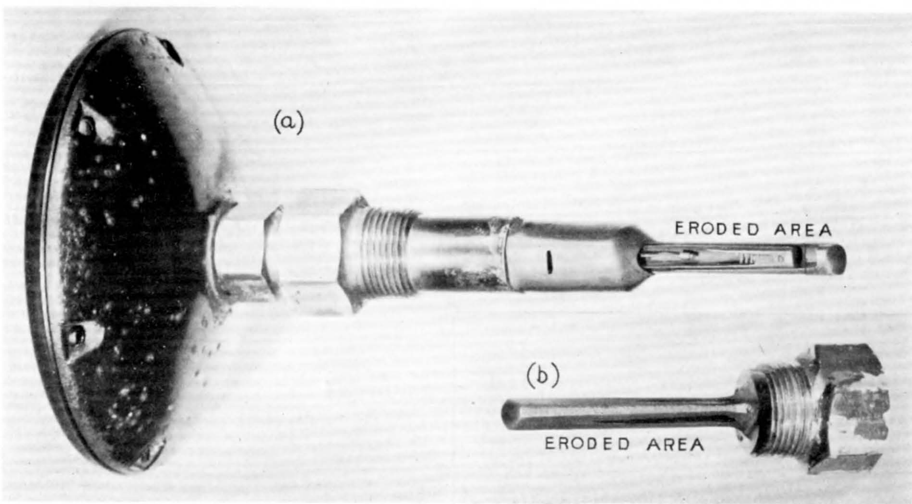


Figure 1—Actual photograph illustrating the effects of improper installation of the Weston Model 222D Industrial Thermometer (a) and a smaller socket similarly eroded (b).

Mechanical Erosion Overcome by Simple Means

The mechanical erosion of thermometer stems, thermowells and protective sockets by the impact of solid particles conveyed by air blast or suction is a particularly troublesome problem but one which is readily overcome by fairly simple means. When one considers the similarity between air blast conveying systems and the familiar sand or grit blasting where the intention is to provide a controlled abrasion to clean surfaces or otherwise prepare them for subsequent operations, it becomes apparent that the same type of erosion can be anticipated. Erosion caused by particles in the air blast conveying system is continuous and uncontrolled and may cause considerable damage before detection. While ducts of such systems are generally designed with this problem in mind, the accessories such as thermometers are necessarily designed for the primary function, temperature measurement, and must be protected against mechanical erosion by some means of installation designed to minimize the effect of such abrasion. Figure 1-a shows the badly eroded protective socket and stem of a thermometer removed from an air-pulverized-coal conveying system. Figure 1-b shows the effects of the improper installation of a protective socket in a similar system.

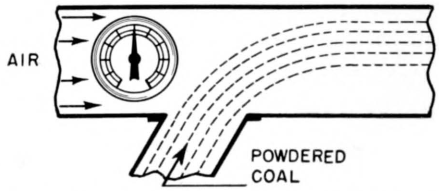


Figure 2—Thermometer can be installed in the heated air stream just before the powdered coal is injected.

Powdered Materials Most Troublesome

Of the various pulverized or powdered materials such as coal, coke, lime, cement, and similar substances handled and moved by suction or blowing and of which temperature determination is of importance, coal and coke are by far the most troublesome. Certain industrials find coal the most convenient and economical fuel and generally purchase "run-of-mine" lots which vary from large lumps to relatively fine grains. This coal is then passed through some type of ball or hammer mill where it is pulverized after which it is moved by air to storage or directly to the combustion chamber.

It is common practice to preheat the air-powdered-coal mixture before its entrance into the combustion chamber by admitting heated air into the conveying ducts. The mixture is maintained at a temperature of 275-300 F or thereabouts, but generally not above 350 F because of the danger of pre-ignition, which might blow out or severely damage part of the equipment or at least shut down the fire.

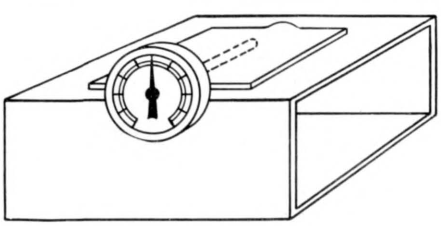
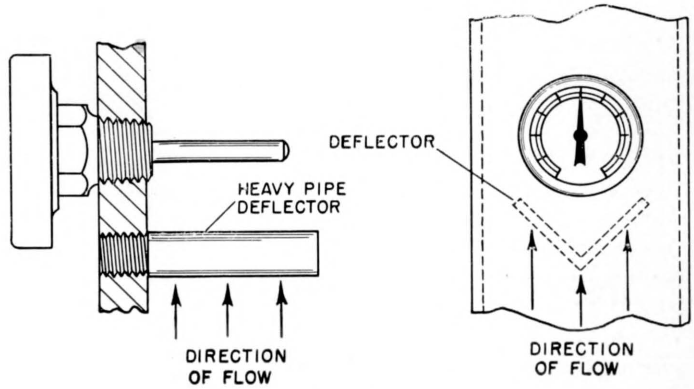


Figure 3—Using the thermometer to indicate surface temperature.

The correct operation of the thermometer is therefore very important, even critical, so that it behooves the operator to see that it is installed properly for permanently accurate temperature indication. The only damaging influence encountered in this type of installation is the eroding action of the powdered coal as it hits the stem or socket. If placed directly in the stream of powdered coal the wall of a stem may wear away completely in a few days, a regular socket in a few weeks, and a heavy duty socket may last six months to a year or two. Since the destruction is one of pure mechanical abrasion and tear and certainly not of thermometry, the solution is one of simple mechanics.

Figure 5—If the thermometer can not be moved it is recommended that deflectors be installed as shown



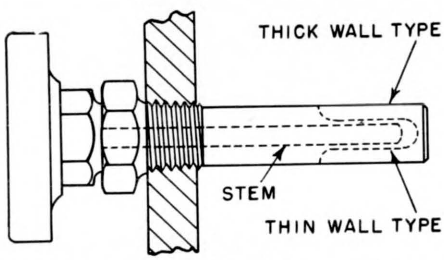


Figure 4—Sketch showing the use of the thermometer with a protective socket.

Solutions to the Eroding Problem

The best solution, where applicable, is to place the thermometer stem or socket where it will not contact the coal particles, in the heated air stream just before the powdered coal is injected. See Figure 2. Next best from the accuracy standpoint is to use the thermometer as a surface thermometer outside of the housing as shown in Figure 3. By attaching the thermometer in such a manner that the stem rests against the outside metal surface, and covering with a patch of insulation (lagging) the thermometer will indicate skin or surface temperature which in most cases will be within a few degrees of actual powdered coal temperature. If for some physical reason the thermometer must be placed where the stem will be in direct contact with the powdered coal, certain minor variations in adapting the thermometer may alleviate the erosion. A heavy duty, thick-walled socket may be used or a suitable baffle or deflector can be installed. See Figures 4 and 5. The socket or thermowell need be used only if it is desired to be able to remove the thermometer without leaving the resulting opening, Figure 6. In some installations the use of a short stem thermometer has given very good results in retarding erosion by keeping the stem out of the

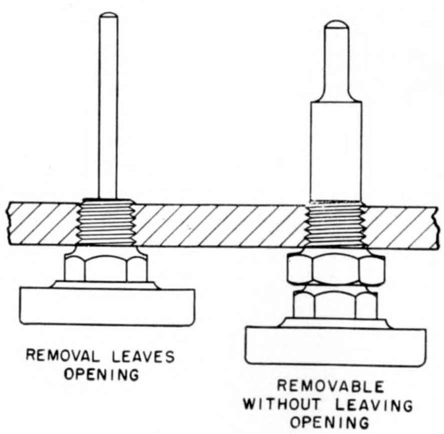


Figure 6—The above sketch illustrates the use of the thermometer with and without its protective socket.

direct flow of coal. Figure 7 shows the installation of a short stem thermometer.

One or more of the above schemes should afford adequate protection for the thermometer against erosion and also against larger stray pieces of coal, slate, iron, etc., and in the long run, maintenance costs will be reduced, but more important the thermometer will be permitted to perform its intended function; to measure temperature correctly and accurately and to protect life, property, and profits.

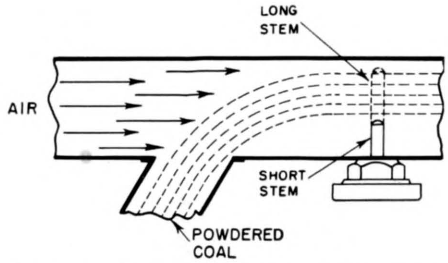


Figure 7—The use of the short stem thermometer is another solution to the erosion problem.

E. N.—No. 19 —*Anthony H. Lamb*

INSTRUMENTS FOR FREQUENCY MODULATION MONITORS

As of January 10, 1946, the Federal Communications Commission circulated the latest revised specifications with regard to modulation monitors for frequency modulation broadcast stations along with the requirements for type approval. This document carries the reference "Public Notice 88280" and essentially is the newly adopted Section 15.

In the application of instruments to these monitors there have been a number of questions raised which can, perhaps, be clarified for those concerned. No reference is made here to the associated network which is specified in terms of its constants.

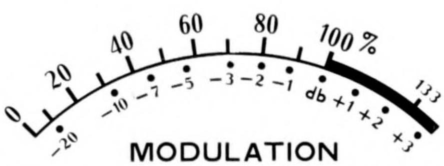


Figure 1—The scale used on FM monitor instruments.

The specification states, "The meter scale shall be similar in appearance to that of a standard VU meter. The scale length between 0 and 100% modulation markings should be at least 2.3 inches. In addition to the other markings, a small mark for 133% modulation and designated as such should be included for the purpose of testing transmitters for 100 kc swing.

The characteristics of the indicating meter are also rather definitely covered and it is stated that these characteristics shall be as follows: "Speed—The time for one complete oscillation of the pointer shall be 290 to 350 milliseconds. The damping factor shall be between 16 and 200."

On several occasions there have been requests for instruments with VU scales for this purpose but it must be pointed out that the VU meter is basically different in dynamic characteristics. It is covered in detail in the pamphlet entitled "American Recommended Practice for Volume Measurements of Electrical Speech and Program Waves," C16.5-1942, published by the American Standards Association and sponsored by the Institute of Radio Engineers. The VU meter must have such characteristics that the instrument pointer will reach 99% of reference deflection in 0.3 second, ±10% and its damping factor shall be between 66 and 100. These characteristics actually result in a time for a complete oscillation of approximately 500 milliseconds. Therefore, the VU meter, as specified and manufactured, does not meet the requirements for the FM monitor, being more tightly limited in damping factor and somewhat slower in operation.

By the same token, it is not correct to mark the faster meter required for the monitor in terms of VU because the instrument would then not measure VU in the specified terms.

Characteristics of the Scale

Accordingly, the instruments which have been supplied for these monitors and which have passed through final approval in certain instances with the associated vacuum tube network have been supplied with scales as shown in Figure 1; Figure 2 shows the VU meter scale for comparison. It will be noted that the letters "VU" have been replaced by the letters "db". A line at 133% has been added. The caption, "Modulation", has been furnished on some instruments. These modulation monitor scales have been furnished in black on white as well as on the standard buff paper of the VU meter. The db values have been made in red on some and in black on others; in one instance the db marks below the arc were deleted entirely.

All of these modifications are deemed to come within the requirement that the scale be *similar* in appearance to that of the VU meter to a sufficient degree and yet without purporting to measure VU in any sense. Actually the instrument can be considered as measuring decibels from 1 milliwatt if associated with a suitable attenuator.

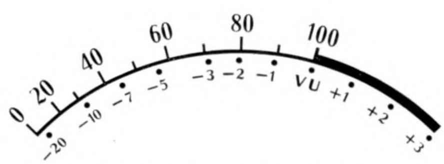


Figure 2—Standard scale for VU Meters.

Considerable Energy Required to Drive Pointer

The damping and speed characteristics specified are readily maintained, although it must be pointed out that the instrument is essentially the high speed variation of the db meter as furnished for some years although, again, the instrument, per se, is not a rectifier type instrument but rather a direct current instrument used with the associated vacuum tube network. The high speed requirement does pose one restriction and that is simply that the most sensitive instruments ordinarily made are just not possible at this speed. Considerable energy is required to drive the pointer up scale in the limited time allowed and, as an example, an instrument coming within these requirements for the modulation monitor, if made 1 ma full scale, would have a resistance of some 400 ohms. Also, as an example, 50 microampere instruments with this speed are not possible with pointers of the size needed for the specified scale length.

This matter of speed of action is an important criterion of instrument design. As an example, it can be shown mathematically that, for a given moving element, to double the speed of an instrument with everything else remaining the same, the torque must be quadrupled. If the torque is quadrupled, four times as much current is required for a given amount of deflection and, maintaining the same resistance, the net power in microwatts taken by the instrument with doubled speed is 16 times as great as in the first instance. In other words, doubling the speed of the instrument requires 16 times as much power and this fourth power requirement effectively blocks high sensitivity if high speed is wanted at the same time.

The scale length requirement effectively eliminates the use of 3½″ panel instruments for this purpose so that the nominal 4″ meter seems to be the most generally accepted type. Great care is taken in the manufacture of these instruments and they are individually timed and carefully inspected to come within the requirement.

There are some other requirements as to accuracy and frequency characteristics but, in general, these have to do with the associated network since the instrument itself is a direct current type and the accuracy of 2% of full scale deflection will allow for an approximately equal tolerance in the associated vacuum tube system.

E. N.—No. 20 —*A. G. Smith*

A BRIDGE FOR HIGH RESISTANCE, HIGH VOLTAGE MEASUREMENTS

THERE are occasions when a requirement is presented for the measurement of high resistances, of the order of a few megohms, measured in terms of resistance while, at the same time, a relatively high voltage is applied. As an example, series resistors for high voltage plate supply voltmeters specified in Joint Army-Navy Specification JAN-R-29 must be checked either by a voltmeter-ammeter or a bridge method with the rated voltage impressed on the resistor.

In general, the voltmeter-ammeter method is hardly accurate enough for precision testing because the possible errors in the two instruments may be additive. On the other hand, there appears to be no commercially available bridge where several thousand volts can be applied to the resistance under test.

But, if we go back to the fundamental bridge method as described in the first article of Volume 1, No. 1 Engineering Notes, we can see that there is nothing inherent to prevent us from applying whatever voltage is desired.

The simplest way to make a test of this sort is to set up a bridge as shown in Figure 1 where *d* is the unit under test and

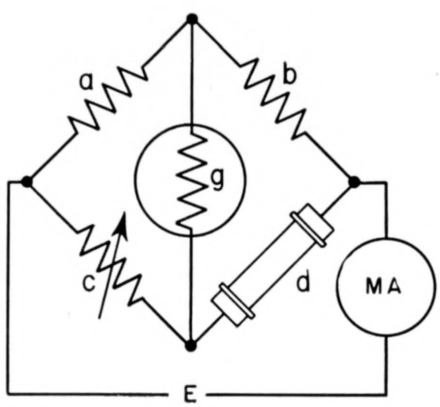


Figure 1—Diagram of Wheatstone Bridge for high resistance measurements at normal operating voltage.

b is a standard wire wound resistor of high accuracy having the same value as the nominal value of the resistance being tested. This may, for example, take the form of a so-called megohm box or a series of such boxes. Let *a* and *c* be a pair of decade boxes and for working in the megohm range these can be the order of 10,000 ohms each. Better yet, let *a* be an accurate 10,000 ohm resistor and *c* consist of a decade box with a top range of something over 10,000 ohms or a fixed resistor of some 8000 ohms and a decade box to go beyond this value. The associated galvanometer should, of course, have an extremely high resistance but in practice galvanometers of as much as 10,000 ohms are not available and one can merely say that the highest resistance galvanometer readily available should be used.

Since the drop across arms *a* and *c* in the example given is less than 1% of the total, the potential, E, can be rated voltage of the unit under test which, in the case of the plate voltmeter resistors is 1000 volts per megohm. Adjustment of the voltage *E* may be in terms of the current measured by the milliammeter shown, considering only the parallel resistance of *b* and *d*. If a voltage of 1000 volts per megohm is required, and *b* and *d* are nominally alike, when a current of 2 milliamperes is indicated the conditions are met.

This voltage supply may well be derived from a small rectifier system and since the current drain is only 2 milliamperes, the supply itself need not be large, nor is it necessary that it be well filtered; 5 or 10% ripple apparently does no harm.

With such an arrangement the bridge is balanced by adjusting arm c and when balance is indicated on the galvanometer, if b is equal to the nominal value of d, the actual value of d in terms of b is obtained from the value of c in in terms of a. For example, if we are testing a nominal 5 megohm resistor and make b accurately 5 megohms, and if a is 10,000 ohms as suggested, and a balance is obtained when c is 9956 ohms, then d is actually 99.56% of its nominal value or 4.978 megohms and is in error by .44% from it nominal value.

By this means we have tested the resistance by the most accurate method, namely, the bridge, and at the same time have applied rated voltage to the resistor so that if there should be some breakdown effects occuring only at full voltage, they would be evident during the test.

The same method with other values of voltage can be used for checking composition resistors for their true value of resistance when specific voltages are applied to determine voltage effect under working conditions. In the case of tubular resistors made in accordance with the cited government specification and sold for high voltage use, tests are also made at 50 to 100% over-voltage, in which case the power supply must be capable of delivering the full current requirement and the standard resistor must in turn be capable of taking the higher current without undue heating or change in its own resistance.

E. N.—No. 21 —*John H. Miller*

IMPORTANT NOTICE

With this issue of WESTON ENGINEERING NOTES we have included a card bearing a few questions. Prompt reply by you will greatly assist us in the revision of our mailing list.

The mailing list revision has been found to be necessary at this time due largely to the inevitable post-war shift of personnel in many organizations as evidenced by the number of change address notices which we have received in recent months.

Please fill in and mail the card today . . . your cooperation will be much appreciated by us.

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Weston Representatives are well qualified as consultants on instrumentation problems and are listed below for the convenience of those readers who may desire information beyond that provided in articles appearing in Weston Engineering Notes.

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