THE GENERAL RADIO

EXPERIMENTER

VOLUME 37 No. 11 NOVEMBER, 1963

PRECISION COAXIAL EQUIPMENT

the 900 SERIES

A SLOTTED LINE OF HIGH ACCURACY AND PRECISION

TERMINATIONS

AIR LINES

ADAPTORS

THE GENERAL RADIO

EXPERIMENTER

Published Monthly by the General Radio Company

VOLUME 37 • NUMBER 11 NOVEMBER, 1963

CONTENTS

The General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in electronic techniques in measurement. When sending requests for subscriptions and address-change notices, please supply the following information: name, company address, type of business company is engaged in, and title or position of individual.

GENERAL RADIO COMPANY

West Concord, Massachusetts*, 01781

Telephone: (Concord) 369-4400; (Boston) 646-7400
Area Code Number: 617

METROPOLITAN NEW YORK:*	**Broad Avenue at Linden, Ridgefield, N. J., 07657** *Telephone — N. Y., 212 964-2722* *N. J., 201 943-3140*
SYRACUSE:	**Pickard Building, East Molloy Road, Syracuse, N. Y., 13211** *Telephone — 315 454-9323*
PHILADELPHIA:	**1150 York Road, Abington, Pa., 19001** *Telephone — Phila., 215 424-7419* *Abington, 215 887-8486*
WASHINGTON* and BALTIMORE:	**Rockville Pike at Wall Lane, Rockville, Md., 20852** *Telephone — 301 946-1600*
ORLANDO:	**113 East Colonial Drive, Orlando, Florida, 32801** *Telephone — 305 425-4671*
CHICAGO:*	**6605 West North Avenue, Oak Park, Illinois, 60302** *Telephone — 312 848-9400*
CLEVELAND:	**5579 Pearl Road, Cleveland, Ohio, 44129** *Telephone — 216 886-0150*
DALLAS:	**2501-A West Mockingbird Lane, Dallas, Texas, 75235** *Telephone — 214 FLeetwood 7-4031*
LOS ANGELES:*	**1000 North Seward St., Los Angeles 38, Cal., 90038** *Telephone — 213 469-6201*
SAN FRANCISCO:	**1186 Los Altos Ave., Los Altos, Cal., 94002** *Telephone — 415 948-8233*
TORONTO:*	**99 Floral Parkway, Toronto 15, Ontario** *Telephone — 416 247-2171*
MONTREAL:	**Office 395 1225 Laird Blvd., Town of Mount Royal, Quebec** *Telephone — 514 737-3673, -3674*

*Repair services are available at these offices.

GENERAL RADIO COMPANY (OVERSEAS), ZURICH, SWITZERLAND
REPRESENTATIVES IN PRINCIPAL OVERSEAS COUNTRIES

PRECISION COAXIAL EQUIPMENT

the 900 series

• A SLOTTED LINE OF HIGH ACCURACY • TERMINATIONS • AIR LINES • ADAPTORS

The recent introduction of the TYPE 900-BT Precision Coaxial Connector[1,2] marks the beginning of a new era in coaxial precision measurement. Prior to the development of this connector, precise impedance-measuring instruments and standards were not commercially available for the microwave region.* Using this new connector, General Radio has developed a line of precision coaxial equipment with performance commensurate with that of the connector. Prominent features of the basic connector are low VSWR, and superior stability, life, convenience, and repeatability. Of these,

[1] A. E. Sanderson, "A Radically New Coaxial Connector," *General Radio Experimenter*, 37, 2 & 3, February-March, 1963.

[2] A. P. Lagon, "A New Precision Coaxial Connector (Type 900)," *NBS Report, No. 7277*, June 29, 1962, pp 54–82.

* In fact, even at low frequencies, for instance in the audio range, the accuracy of two-terminal measurements has been limited by the repeatability and reproducibility of coaxial connectors.

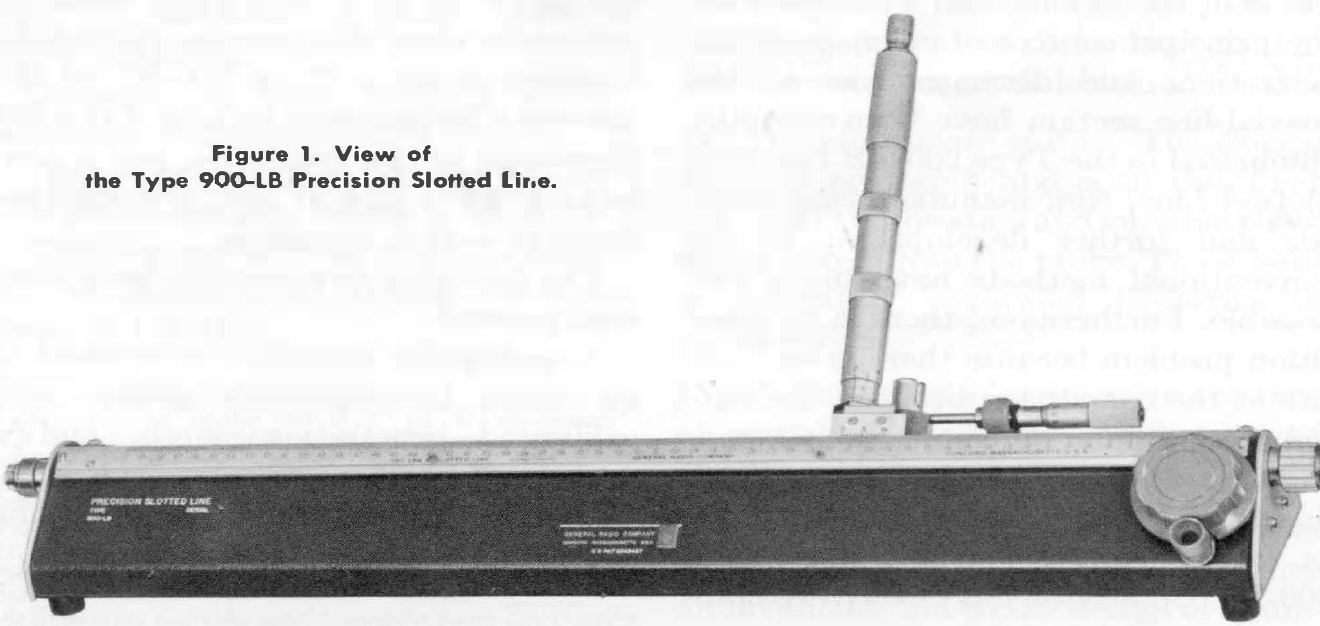


Figure 1. View of the Type 900-LB Precision Slotted Line.

low VSWR and repeatability at uhf and shf were the most difficult to achieve. Once assured, these characteristics led quickly to the development of new uhf-shf instruments and components, including a precision slotted line, air lines, terminations, and adaptors, as well as precisely fabricated tubing and rod stock for coaxial lines.

Use of this system of instruments, however, is not restricted to calibrations or measurement on devices equipped with the TYPE 900 Precision Connector. Precision adaptors permit a tie-in with popular connectors, such as the type N and the TYPE 874. When a TYPE 900 adaptor to another type of connector is used, the accuracy is limited only by the performance of the other connector. For example, the residual VSWR of the TYPE 900-LB Slotted Line, which is 1.002 at 1 Gc, is still only 1.01 when a type-N adaptor is installed.

TYPE 900-LB PRECISION SLOTTED LINE

The slotted line is the basic immittance- and VSWR-measuring instrument for the uhf and shf ranges. It has yet to be surpassed in absolute accuracy, versatility, and bandwidth. Its accuracy is absolute because its built-in impedance standard is the characteristic impedance of its coaxial line, which is directly dependent upon mechanical dimensions.

Imperfections in the slotted coaxial-line system and the discontinuities at slot end, transitions, and connectors are the principal sources of error. Such imperfections and discontinuities in the coaxial-line section have been virtually eliminated in the Type 900-LB Precision Slotted Line. New manufacturing methods and further development in the conventional methods have made this possible. Furthermore, there is no transition problem because there is no transition; the connection between the slotted section and the connector is a continuous, uniform, coaxial transmission line with very close control of diameters, as in the slotted section. And TYPE 900-BT Connector has effectively eliminated connector errors.

The new precision slotted line is similar in general construction to the TYPE 874-LBA, which has in recent years been constantly improved and ruggedized, and whose accuracy is comparable with that of other commercially available types. Many of its design features have been embodied in the 900 model, along with a number of refinements and improvements.*

The precision slotted line uses an air-dielectric coaxial line, with an outer conductor ID of 0.5625 inch, made to extremely close dimensional tolerances. Connectors are a TYPE 900-BT at the unknown terminals, a locking TYPE 874 Connector at the input side, and a non-locking TYPE 874 at the demodulated detector output terminals.

The following new features have been incorporated:

A new probe assembly, comprised of an externally adjustable probe, with calibrated penetration depth, and a probe tuner with micrometer-type drive, calibrated in centimeters, and having excellent tuning stability.

* The Type 900-LB Slotted Line does not supersede the Type 874-LBA, which is still available.

A vernier scale and, in addition, a micrometer drive for fine resolution.

Provision for direct rf connection to the probe; the tuner is replaced with an rf probe assembly.

A protective cover, which can be closed to prevent dust accumulation and damage. The cover reinforces the basic assembly and adds very little extra weight.

Quick conversion into a precision type N or TYPE 874 Slotted Line by means of low-VSWR adaptors (adaptors to TNC, C, and other types are under development).

The slotted line can be calibrated absolutely with the TYPE 900-BT Connectors to a much higher degree of accuracy than with other connector types. The TYPES 900-L10, 900-L15, 900-L30 Air Lines, and the TYPE 900-W50 Termination are excellent calibration devices for this purpose.

The most important feature, however, is performance:

Residual VSWR is extremely small (Figure 2), $1.001 + 0.001 \times f_{Gc}$. With a TYPE 900-QNJ or -QNP Adaptor to type N installed, over-all VSWR is $1.005 + 0.005 f_{Gc}$.

Constancy of probe coupling, a most important characteristic, is ±0.5%.

Frequency range is 300 Mc to 9000 Mc; probe carriage travel is 50 cm.

With the precision air lines the length can be extended to permit operation down to 150 Mc.

[3] A. E. Sanderson, "A New High-Precision Method for the Measurement of the VSWR of Coaxial Connectors," *IRE Transactions on Microwave Theory and Techniques*, Vol MTT-9, No. 6, November 1961, pp 524–528.

[4] A. E. Sanderson, "An Accurate Substitution Method of Measuring the VSWR of Coaxial Connectors," *The Microwave Journal*, Vol 5, No. 1, January 1962, pp 69–73.

[5] G. A. Deschamps, "A Simple Graphical Analysis of a Two-Port Waveguide Junction," *Proceedings of the IRE*, 42, 859, May 1954.

[6] J. E. Storer, L. S. Sheingold, and S. Stein, "A Simple Graphical Analysis of a Two-Port Waveguide Junction," *Proceedings of the IRE*, 41, No. 8, 1004, August 1953.

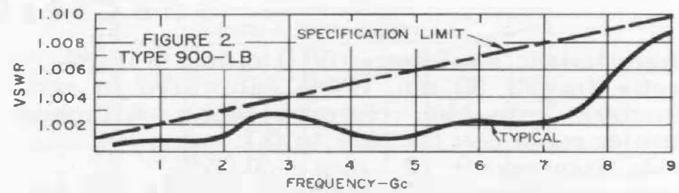


FIGURE 2. TYPE 900-LB

Applications

The TYPE 900-LB Slotted Line is well suited to all the well-known slotted line measurements, such as immittance, VSWR, and reflection coefficients of distributed and lumped elements and antennas. More importantly, it is recommended for the absolute calibration of standards.

Additional applications include:

(1) Measurement of connectors and elements by the substitution method.[3,4]

(2) Determination of small-signal characteristics of diodes and transistors. For these measurements, the slotted line is driven through the probe with the special connector provided, and the detector then connects to what is normally the generator end of the line. By this means, adequate sensitivity is maintained at low voltage levels.

(3) Measurement of dielectric constant and loss tangent of dielectric materials.

(4) Precision phase shifter. The slotted line can be terminated with the TYPE 900-W50 Termination and variable phase signal taken from the probe. Phase shift is accurately calibrated in terms of probe travel.

(5) Sliding short-circuit measurements of scattering coefficients of distributed and lumped elements.[5,6]

Those engaged in the development of coaxial devices will find this slotted line an invaluable aid to the design of equipment with truly low standing-wave ratio.

SPECIFICATIONS

Characteristic Impedance: 50.0 ohms ± 0.1%.
Probe Travel: 50 cm. Scale calibrated in centimeters from the reference plane. Attached vernier scale can be read to 0.1 mm.
Scale Accuracy: ± (0.1 mm + 0.05%).
Frequency Range: 300 Mc to 9 Gc. At 300 Mc, covers a half wavelength. Operates below 300 Mc with Type 900 Precision Air Line.
Constancy of Probe Pickup: ±0.5%.
Residual VSWR: Less than 1.001 + 0.001 × f_{Gc} (e.g., 1.002 at 1 Gc).
Accessories Supplied: Type 874-R22A Patch Cord; Type 900-WN Precision Short-Circuit; Type 900-WO Precision Open-Circuit; tuning stub-probe assembly (including 1N21C and 1N23C diodes); rf probe assembly (with Type 874-BL Connector); micrometer carriage drive (accurate to 0.01 mm); spare drive cable; storage box; Smith charts.
Accessories Required: Generator and detector.
Dimensions: Width 27½, height 10, depth 4¾ inches (700 by 255 by 125 mm).
Net Weight: 10¾ pounds (4.9 kg).
Shipping Weight: 27 pounds (12.5 kg).

Type		*Code Number*	*Price*
900-LB	**Precision Slotted Line**	0900-9651	**$575.00**

TERMINATIONS

TYPE 900-W50 PRECISION 50-OHM TERMINATION

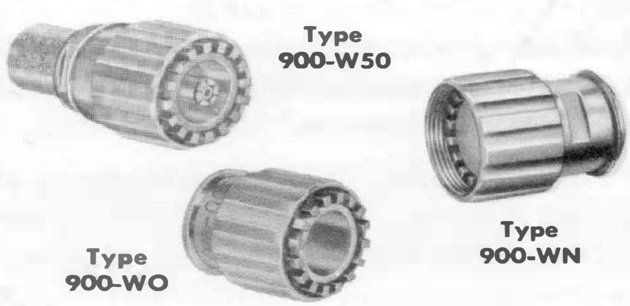
The Type 900-W50 Termination is a broadband device with extremely low vswr, useful from dc to 9 Gc. It comprises an accurately derived, continuous transition and a precision cylindrical resistor. The connector is a Type 900-BT. Typical vswr characteristics are given in Figure 3. The change of resistance and vswr *vs* heating due to incident power is negligible up to 1-watt incident power.

Applications

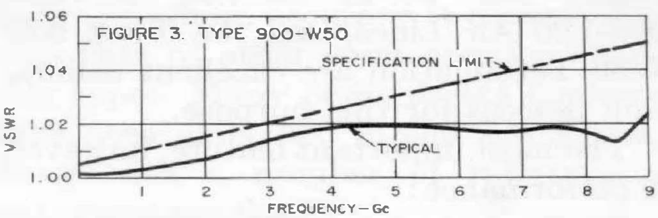
As a 50-ohm standard for the calibration of bridges, slotted lines, impedance plotters, reflectometers, etc.

As a termination in measurements of networks with more than one port.

As a precision dummy load.



As a precision type N or Type 874 Termination when used with a Type 900-QNJ, 900-QNP, or 900-Q874 low-vswr adaptor.



SPECIFICATIONS

VSWR: Less than 1.005 + 0.005 × f_{Gc}, up to 9 Gc.
DC Resistance: 50 ohms ± 0.3%.
Maximum Power: 1 watt with negligible change; 5 watts without damage.
Temperature Coefficient: < 150 ppm/°C.
Over-all Length: 2 inches (51 mm).
Net Weight: 3½ ounces (100 grams).

TYPES 900-WN AND 900-WO SHORT-CIRCUIT AND OPEN-CIRCUIT TERMINATIONS

The Type 900-WN Short-Circuit Termination and Type 900-WO Open-Circuit Termination are low-loss devices, which effectively short circuit or open circuit a coaxial line.

Type 900-WN Short-Circuit Termination

The reference plane of this termination is conveniently located at the mating plane of the TYPE 900-BT Connector. Ohmic losses are extremely small, as demonstrated by a reflection coefficient of 0.999 or greater at 9 Gc. The termination is a silver-plated brass slug with the necessary TYPE 900 external hardware, gold-plated for protection against tarnishing. The excellent performance cited is inherent in the TYPE 900 Connector. The inner conductor shorting contact is achieved by the flat surface of the slug pressing against the TYPE 900-BT contact.

Type 900-WO Open-Circuit Termination

A TYPE 900-WO Open-Circuit Termination presents an effective open circuit 0.26 cm from the mating plane of a TYPE 900-BT Connector. It is a closed-end, standard-size outer conductor with TYPE 900 external mounting hardware. The open-circuit reference plane cannot be made identical in position to the short-circuit reference plane because of end effect. This end effect can be represented closely by an additional length of line, in this case 0.26 cm, or a capacitance of 0.173 pf shunting the end of the line. The effective length, however, is frequency dependent. Measured data are shown in Figure 4.

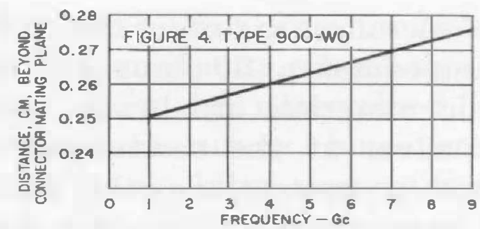


FIGURE 4. TYPE 900-WO

Applications

The TYPES 900-WN and 900-WO Terminations are useful in the following applications:

Establishing reference planes in direct or substitution coaxial-line measurements.

As low-loss terminations for measurement of networks with more than one port (including loss measurements).

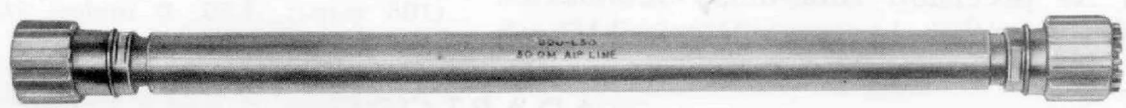
As coaxial-line reactance standards in combination with TYPE 900-L10, 900-L15, or 900-L30 Air Lines.

SPECIFICATIONS

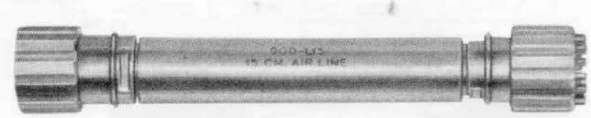
Reflection Coefficient: > 0.999.
Net Weight: TYPE 900-WN, 2½ ounces (75 grams); TYPE 900-WO, 2 ounces (60 grams).
Over-all Length: 1$\frac{1}{16}$ inches (27 mm).

AIR LINES

Type 900-L30



Type 900-L15



Type 900-L10

TYPES 900-L10, 900-L15, AND 900-L30 AIR LINES

The TYPES 900-L10, 900-L15, and 900-L30 Air Lines are precision coaxial air-line sections fitted with standard TYPE 900-BT Connectors. The air-line sections are held to extremely close dimensional tolerances. The inner conductor tolerance is ±65 microinches, and variations are restricted to ±25 microinches along a given rod. The outer conductor diameter is held to ±140 microinches.

These tolerances maintain the characteristic impedance at 50 ohms ± 0.65%. The basic materials are brass, with a layer of silver at the conducting surfaces, and a protective gold plating. Typical VSWR characteristics are shown in Figure 5. The low-frequency, skin-effect correction is shown in Figure 9.

Applications

(1) As 50-ohm quarter-wave reference standards. When the lines are used at frequencies where length is an odd multiple of $\lambda/4$, any immittance-measuring instrument, Smith-Chart plotter, etc., can be calibrated with respect to 50 ohms and the termination error isolated. The following table lists $(2n - 1)\ \lambda/4$ frequencies for the three air-line sections.

Quarter-Wave Frequencies of Type 900-L Air Lines

900-L10 Frequency, Gc	*900-L15 Frequency, Gc*	*900-L30 Frequency, Gc*	
0.75	0.5	0.25	4.75
2.25	1.5	0.75	5.25
3.75	2.5	1.25	5.75
5.25	3.5	1.75	6.25
6.75	4.5	2.25	6.75
8.25	5.5	2.75	7.25
	6.5	3.25	7.75
	7.5	3.75	8.25
	8.5	4.25	8.75

(2) As precision time-delay standards. The lines are held to an electrical length

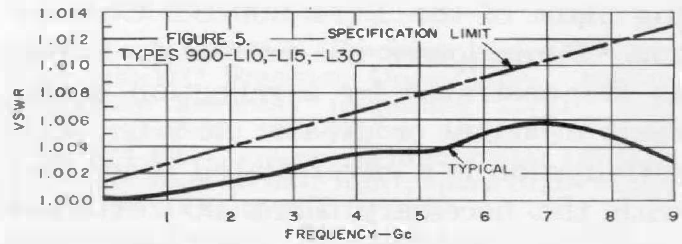


FIGURE 5. TYPES 900-L10,-L15,-L30

of ±0.012 cm, which is equivalent to ±0.4 picosecond.

(3) As reactance standards, with the TYPE 900-WN Short-Circuit Termination or the TYPE 900-WO Open-Circuit Termination.

(4) As extension lines. The lines may be used to extend the lower frequency limit of the TYPE 900-LB Slotted Line below 300 Mc. With a sufficient length of air line, this limit can be reduced to 150 Mc.

SPECIFICATIONS

VSWR: Less than 1.0013 + 0.0013 × f_{Gc}, up to 9 Gc.

Characteristic Impedance: 50 ohms ± 0.1%.

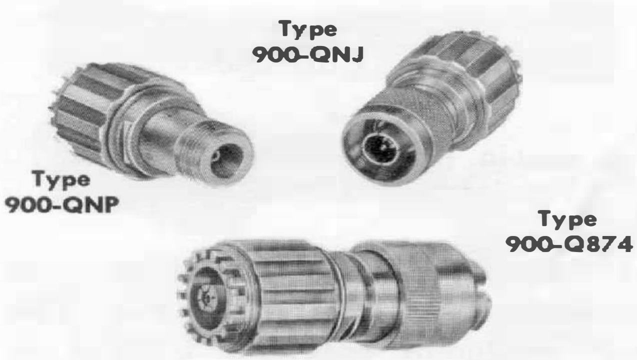
Electrical Length: TYPE 900-L10 — 10.00 ± 0.02 cm; TYPE 900-L15 — 15.00 ± 0.02 cm; TYPE 900-L30 — 30.00 ± 0.02 cm.

Time Delay: TYPE 900-L10, 0.333 nsec; -L15, 0.5 nsec; -L30, 1.0 nsec; all ± 0.4 psec.

Net Weight: TYPE 900-L10, 6½ ounces (185 grams); -L15, 10 ounces (285 grams); -L30, 15 ounces (425 grams).

Over-all Length: TYPE 900-L10, 4 inches (105 mm); -L15, 6 inches (155 mm); -L30, 12 inches (305 mm).

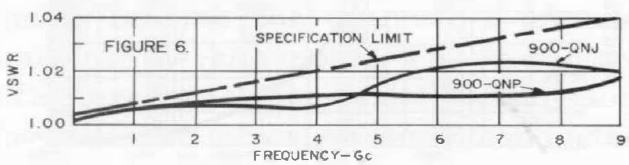
ADAPTORS



TYPES 900-QNJ AND 900-QNP ADAPTORS

Type N Adaptors

There are two type N adaptors: the TYPE 900-QNJ, which consists of a type N jack and a TYPE 900-BT Connector, and the TYPE 900-QNP, which contains a type N plug and a TYPE 900-BT Connector. These adaptors have specially designed, continuous transitions between the two line sizes. The absence of any discrete discontinuities in the transition is a unique feature of these adaptors. The type N jacks and plugs in these adaptors are of a special, low-VSWR design. Although they are compatible with standard military type N connectors, they should be used with special type N connectors for lowest VSWR. The instruction sheets provided with these adaptors show the electrical length and reference-plane as well as other optimum configuration details for the mating plug or jack. VSWR characteristics are shown in Figure 6.



SPECIFICATIONS

VSWR: Less than $1.004 + 0.004 \times f_{Gc}$, up to 9 Gc, either unit.

Electrical Length: TYPE 900-QNP — 5.50 ± 0.03 cm to end of male outer conductor. TYPE 900-QNJ — 5.00 ± 0.03 cm to end of female inner conductor.

Net Weight: TYPE 900-QNP, 3½ ounces (100 grams); -QNJ, 4 ounces (115 grams).

Over-all Length: TYPE 900-QNP, 2-5/16 inches (59 mm); TYPE 900-QNJ, 2¼ inches (58 mm).

TYPE 900-Q874 ADAPTOR

(Connects with either locking or nonlocking Type 874 Connector)

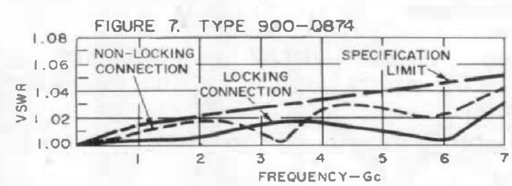
The TYPE 900-Q874 Adaptor comprises a TYPE 874-BL Locking Connector and a TYPE 900-BT Connector, mounted on a short section of precision air line. This adaptor contains a newly designed, fully compensated TYPE 874 support bead. Although the adaptor mates with both locking and nonlocking TYPE 874 Connectors, a mechanically stable, low-leakage connection requires a TYPE 874-BL Connector. For coaxial-line measurements where the reference plane must be determined with the maximum accuracy, however, a TYPE 874-B (nonlocking) connector should be used. The reason for this is that the locking-type connector is intentionally disengaged a slight amount by the locking system, so as to prevent mechanical jamming. This disengagement can vary from 0.006 to 0.042 inch from connector to connector because of tolerance limits. However, it is generally close to a nominal 0.020 inch. The nonlocking connector, on the other hand, mates automatically within much closer limits because the connectors are always fully engaged. The electrical length and reference-plane data are given in the instruction sheet that accompanies the adaptor. VSWR characteristics are shown in Figure 7.

Applications

Extends usefulness of TYPE 900-LB Slotted Line, permitting precision measurements of type N and TYPE 874 components.

As a precision type N or TYPE 874 50-Ohm Termination, when used with TYPE 900-W50.

Converts instruments with type N or TYPE 874 connectors to TYPE 900.



SPECIFICATIONS

VSWR: Less than $1.00 + 0.015 \times f_{Gc}$; $1.01 + 0.005 \times f_{Gc}$ from 1 to 7 Gc.

Electrical Length: 6.50 ± 0.04 cm to front face of mated nonlocking TYPE 874 connector bead.

Over-all Length: 2-9/16 inches (65 mm).

Net Weight: 3½ ounces (100 grams).

TYPE 0900-9782 ADAPTOR FLANGE

This flange is a general-purpose device which converts any Type 900 component connector to a flange connector, making use of the fact that the inner contact of the Type 900-BT works suitably against any flat surface with no special additional contacting device or bullet required. The configuration is shown in Figure 8.

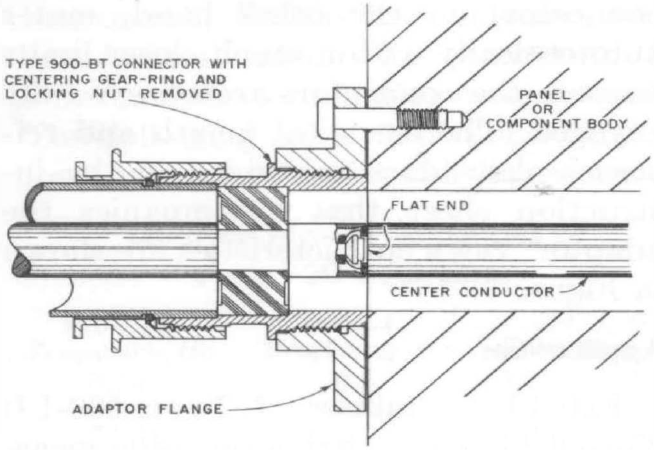


Figure 8.
Flange adaptation on Type 900-BT Connector.

Applications

For connecting to a coaxial system ending in flat, flush surfaces, typically in special bridges.

Specifications

Mounting Holes: 0.157 ± 0.005-inch dia, 120° ± 0.5° apart on a radius of 0.812 ± 0.003 inch.
Net Weight: 3 ounces (85 grams).

PRECISION ROD AND TUBING

For those who wish to assemble coaxial systems using the Type 900 Connector, coaxial air-line rod and tubing having extremely tight diameter tolerances are now offered by General Radio Company. The rod is brass with a layer of silver approximately 0.0005-inch thick and a finished diameter of 0.24425 inch ±65 microinches. The tube has a layer of silver approximately 0.0005-inch thick and a finished inner diameter of 0.5625 inch ±140 microinches. Both tubing and rod are stress-relieved to minimize diameter changes due to machining and

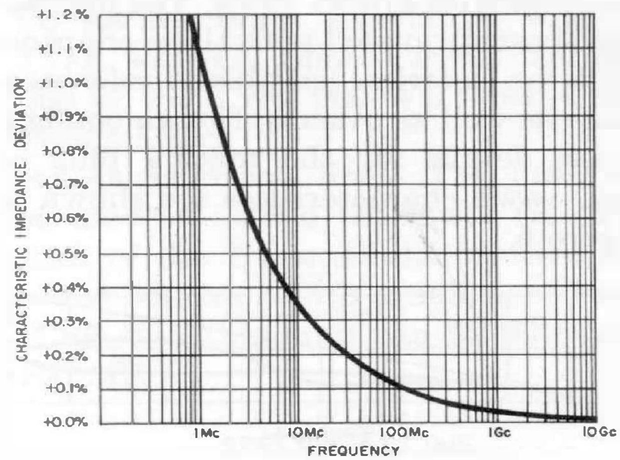
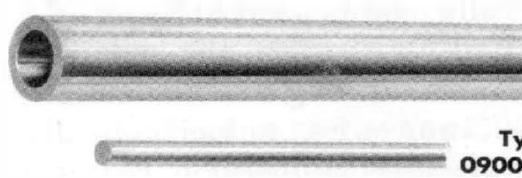


Figure 9. Skin-effect characteristic-impedance error as a function of frequency.

are straightened. The instruction sheet provides directions for machining the material for use with the Type 900-BT Connector, including procedures for minimizing dimensional changes. At frequencies where skin depth is negligible, the characteristic impedance of a transmission line made from this material is 50 ±0.0013 ohms, or ±0.065%. The skin-depth deviation as a function of frequency is shown in Figure 9.

There is a practical limit to the length of the precision air line that can be made from this material because of inner conductor sag. An expression for the sag is given below. This expression is pessi-



Type 0900-9509

Type 0900-9508

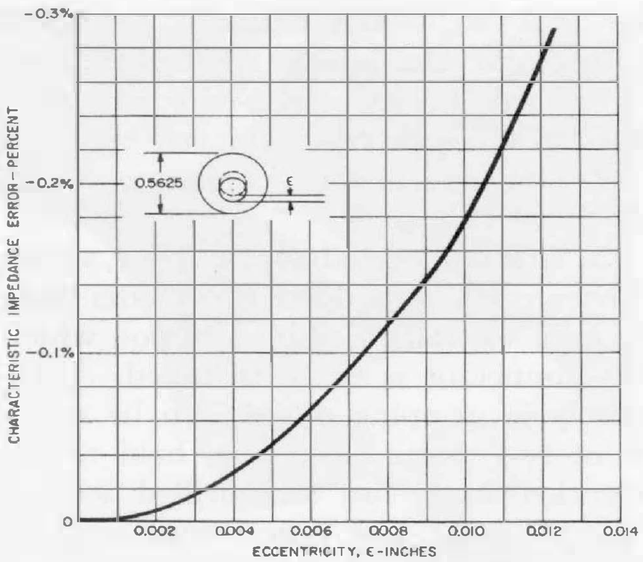


Figure 10. Characteristic-impedance error vs sag in inner conductor.

mistic because the connectors provide some cantilever support. The characteristic impedance of a coaxial transmission line with an eccentric inner conductor is given by

$$Z_o = A \cosh^{-1} \left[\frac{b}{2a} \left(1 - 4 \frac{\epsilon^2}{b^2}\right) + \frac{a}{2b} \right]$$

where

$A = 59.9368$

b = coaxial line outer conductor ID

a = coaxial line inner conductor OD

ϵ = amount by which conductor is off center

The sag, ϵ, at the center is given approximately by,

$$\epsilon \cong \frac{l^4}{15 \times 10^6} \text{ inches}$$

where l is the length of the inner conductor in inches.

For a 16½-inch length, the sag, ϵ, is 0.005 inch at the center.

The characteristic impedance error calculated from the above formula along an incremental length of line at the center is −0.046% for this amount of sag (see Figure 10). Therefore, 16½ inches may be considered the longest permissible air-line section for precision work. With Type 900-BT Connectors at each end, the corresponding air line is 45.5 cm long, electrically.

When maximum accuracy is desired for the longer line sections, the line should be mounted vertically.

Applications

Precision sliding loads and shorts, air lines.

Precision 50-ohm air-line impedance and time-delay standards.

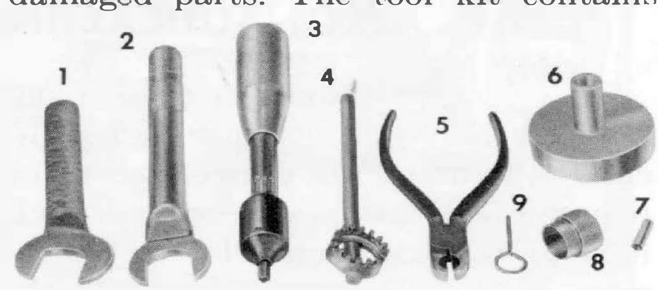
General component use.

Specifications

Net Weight: Rod, 7 ounces (0.2 kg); tube, 2½ pounds (1.2 kg).
Over-all Length: 27 inches (690 mm).

TYPE 900-TOK KIT

The Type 900-BT Precision Coaxial Connector should be assembled on components with the Type 900-TOK Tool Kit, both for the best precision and for avoidance of damage to connector. The tool kit, designed for this purpose, includes all the tools required to assemble the Type 900-BT Connector on a component and the devices needed to reassemble a connector that has been inadvertently disassembled or to replace damaged parts. The tool kit contains



1. Open-End Wrench
2. Coupling-Nut Torque Wrench
3. Inner-Conductor Torque Wrench
4. Gear Wrench
5. Inner-Conductor Plier
6. Bead Pusher
7. Inner-Conductor Injector
8. Bead Compression Sleeve
9. Spring-Contact Wrench

an open-end wrench, a coupling-nut torque wrench, an inner-conductor gripping plier, and a contact Allen wrench. In addition, for connector reassembly, it contains an inner conductor injector, a bead compressor sleeve, and a bead pusher.

For some users, purchase of the complete tool kit may not be wholly justifiable. It is possible to install the connectors on components with ordinary tools, listed below. It is not possible, however, to reassemble a connector that has been completely disassembled because the parts are press-fitted together with the assembly tools furnished in the Type 900-TOK Tool Kit.

The following tools may be employed to install connectors. Extreme care must be used, so as not to apply excessive torque and thus damage connector parts.

1. Two 11/16″ open-end wrenches with 3/32″-wide blade (bicycle type).

2. One, and in some cases two, 5/32″ Allen wrenches.

3. One inner-conductor gripper, a plier device with a padded 0.244″-dia hole to hold the inner conductor upon which the connector is to be installed. Alternately, a gripping device can be made from two strips of plastic, held firmly together in a vise and drilled with a 15/64″ drill. The inner conductor is installed in the hole and gripped in the vise.

4. One 1/16″ Allen wrench.

— John Zorzy

Type		*Code Number*	*Price*
900-L10	Precision Air Line (10 cm)	0900-9605	$ 85.00
900-L15	Precision Air Line (15 cm)	0900-9607	90.00
900-L30	Precision Air Line (30 cm)	0900-9613	100.00
900-Q874	Adaptor to Type 874	0900-9883	45.00
900-QNJ	Adaptor (contains type-N jack)	0900-9711	50.00
900-QNP	Adaptor (contains type-N plug)	0900-9811	50.00
900-TOK	Tool Kit	0900-9902	95.00
900-WN	Short-Circuit Termination	0900-9971	9.00
900-WO	Open-Circuit Termination	0900-9981	9.00
900-W50	50-Ohm Termination	0900-9953	60.00
0900-9508	Precision Inner-Conductor Rod	0900-9508	25.00
0900-9509	Precision Outer-Conductor Tube	0900-9509	35.00
0900-9782	Adaptor Flange	0900-9782	3.50

OF FUEL GAGES AND THE AERONAUTICAL INSTRUMENTS LABORATORY

To a pilot, it is a matter of some importance that the fuel gage in his aircraft be accurate. The degree of accuracy required and the various types of fuels used by modern aircraft led to the demise of the float-type gage and to the development of a fuel-quantity gage that operates by sensing the electrical capacitance of the fuel-tank probes. This parameter is directly proportional to mass, which in turn is closely related to the energy content of the fuel. To check the accuracy of such a gage, a special capacitance standard ("fuel-gage tester"), connected to the gage in place of the tank, simulates full- and empty-tank conditions.

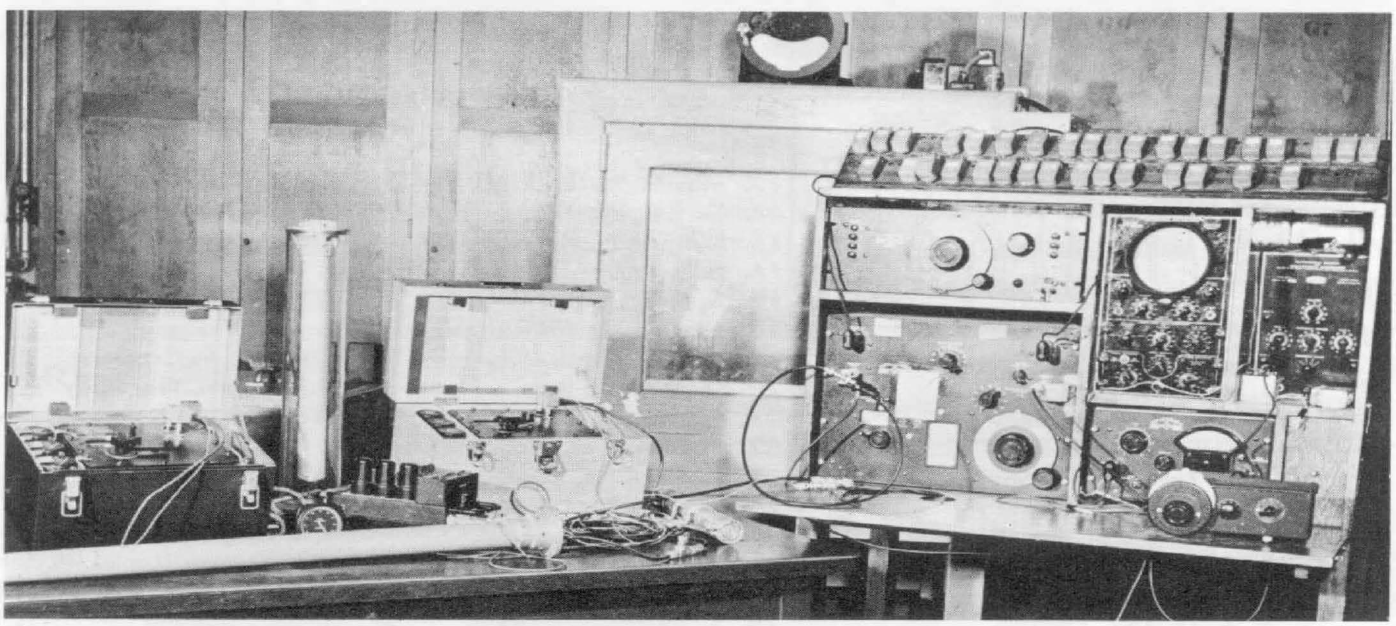
General Radio, an old hand at designing capacitance standards and bridges, contributed importantly from the outset

Technician calibrates fuel gage of modern jet aircraft by means of a GR Type 1429-A Fuel-Gage Tester.

to the development and subsequent refinement of fuel-gage testers. At the Aeronautical Instruments Laboratory of the U. S. Naval Air Development Center at Johnsville, Pennsylvania, GR bridges were used to evaluate differences in dielectric characteristics between aviation gasoline and jet fuel and among fuels refined in different parts of the world. From such measurements came a circuit element to compensate for variations in the density of the fuel.

The General Radio MD-1 Tester was the first to meet military requirements; our current Type 1429-A Fuel-Gage Tester, a slimmed-down version of the MD-1, is widely used to calibrate gages on both reciprocating- and jet-engine aircraft.

In the development of fuel-gage testers, GR has worked in close co-operation with two military agencies: the Aeronautical Instruments Laboratory at Johnsville and the Wright Aeronautical Development Center at Dayton. The Aeronautical Instruments Laboratory is now celebrating its silver anniversary. Inasmuch as our association with this laboratory covers most of those 25 years, we are especially pleased to note the event and to congratulate AIL on its quarter-century of service to the nation.

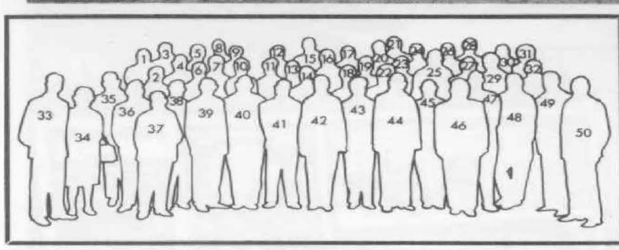


Equipment used in early fuel-gage tester development, shown in this 1951 photo taken at Aeronautical Instruments Laboratory, includes capacitance bridge, generator, and detector. (Official Photograph U. S. Navy)

OVERSEAS SEMINAR IN MILAN

The third biennial sales and engineering seminar for GR overseas representatives was held in Milan during the last week of May, 1963, with nearly forty sales engineers and export sales representatives from fifteen countries attending, plus several from General Radio Company and General Radio Company (Overseas). Technical and sales sessions in the forenoon and laboratory workshops in the afternoon were held to acquaint the participants with latest General Radio equipment.

Much of the credit for the success of the seminar goes to our hosts, the firm of Ing. S and Dr. Guido Belotti, who have represented General Radio Company in Italy for over thirty years. The accompanying photograph shows most of those attending.



1. A. P. G. Peterson, GR
2. Mrs. Molac, France
3. Dov Peleg, Israel
4. A. Lara Saenz, Spain
5. R. Danziger, Israel
6. G. F. Molac, France
7. Mrs. Carla Lupi, Italy
8. I. G. Easton, GR
9. K. G. Teir, Finland
10. Miss M. E. Aeschbacher, GRO
11. Miss A. M. Minoja, Italy
12. C. Binetti, Italy
13. Miss S. Fiore, Italy
14. G. Belotti, Italy
15. I. Myrseth, Norway
16. N. J. Kuster, GRO
17. S. Maio, Italy
18. Miss A. Agnisetta, Italy
19. Mrs. O. Curti, Italy
20. G. Venturi, Italy
21. G. Malfassi, Italy
22. P. Fabricant, France
23. R. Peel, Belgium
24. L. Marcomini, Italy
25. A. R. Buys, Holland
26. T. Imoto, Japan
27. M. Berlin, France
28. K. Kyriokos, Greece
29. V. Helmisalo, Sweden
30. C. E. Worthen, GR
31. A. Rasmussen, Denmark
32. M. Meriaux, France
33. P. J. Macalka, GRO
34. Miss C. Naichouler, France
35. K. Lindenmann, Switzerland
36. R. Natarajan, France
37. M. Ky, France
38. J. Keller, Switzerland
39. G. Nüsslein, Germany
40. W. P. McLean, New Zealand
41. L. Picasso, Italy
42. A. E. Thiessen, GR
43. A. R. Mouriaux, France
44. U. Clementz, Sweden
45. A. R. O. van Lierop, Holland
46. H. A. Molinari, Switzerland
47. H. Klip, Holland
48. J. Beyerholm, Denmark
49. S. W. DeBlois, GR
50. D. B. Sinclair, GR

DETERMINATION OF CAPTURE PROBABILITIES OF PRECIPITATION PARTICLES WITH THE STROBOLUME

by Dr. Roland List*

One of the major problems of modern cloud physics is the description of the growth of precipitation particles (raindrops, graupels and hailstones). Theoretical computations show that the gas-phase contributes negligibly to the growth of the mass, as long as the growing particles show diameters of more than 2 mm. The determining factor for the growth of precipitation particles is, therefore, the accretion, the capture of cloud particles, either water droplets or ice particles with diameters from 10–100 μ.

If we observe, for instance, the growth of ice particles falling in a cloud of undercooled water droplets (temperature less than 0°C), we can determine the collection efficiency based on the growth of the mass of a test particle in form of icing. This can be done by careful determination of weight. The result, however, does not give us dependable information about the number of impinging particles because we do not know exactly how many of the particles are hurled back into the air stream. To determine this, stroboscopic photographs were taken with the General Radio Company Strobolume during icing tests of the climate-controlled wind tunnel on the Weissfluhjoch, Switzerland. The Strobolume switch was in the high intensity position. Figure 1 shows the icing of a 2-cm steel ball in an air stream of a velocity of 20 m/s, at a temperature of −5°C and an absolute humidity of approximately 4 g/m³. The average size of the water droplets is 50 μ. The photo was taken with an Alpa camera with normal lens and adaptor rings at *f*/11. Agfa, Isopan Record Film, with a sensitivity of 34–40°DIN (2000–8000 ASA) was used. The most important result obtained from this photographic observation is that, under existing icing conditions, no rebounding of impinging water droplets could be observed. Therefore, the number of impinging particles equals the number of captured particles (collision efficiency equals collection efficiency).

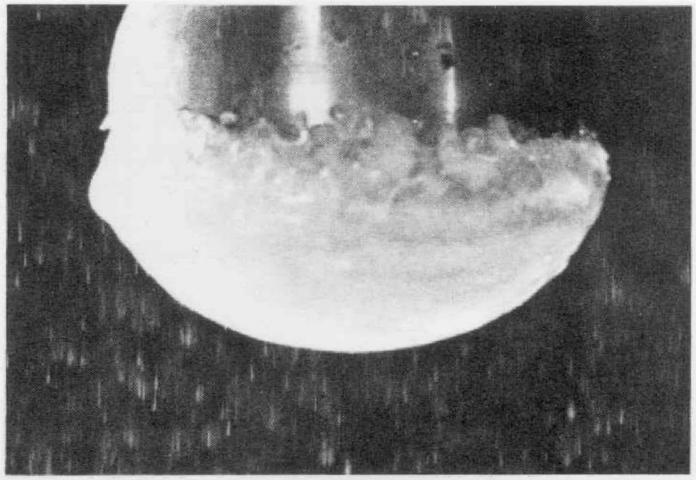


Figure 1. Icing of a 2-cm steel ball in an air stream (temperature −5°C).

The following additional conclusions can be drawn from Figure 1:

a) The direction of movement of droplets can be determined from their appearance in the photograph as streaks of light. Since the electronic flash of the Strobolume shows, directly following trigger, a defined intensity peak followed by a steady decay, the movement vector of a "particle streak" can be seen from

* Federal Institu e for Snow and Avalanche Research, Weissfluhjoch-Davos (now w th the Department of Physics, University of Toronto).

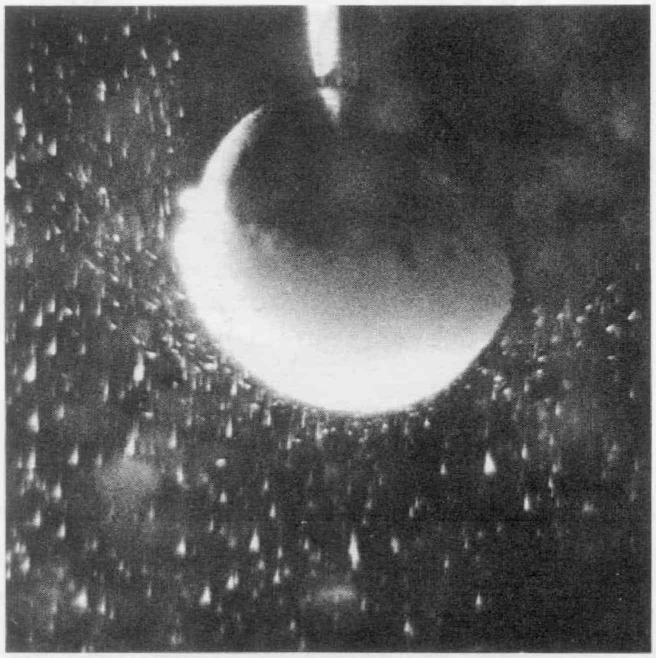


Figure 2. Icing of a 2-cm steel ball in an air stream (temperature −25°C); diameter of the arriving ice particles or subcooled water droplets 50-100 μ. Observe the "boundary layer" of the rebounding particles. For this photograph, a slot illumination (slot opening 2 mm) was used, necessitating a camera opening to $f/1.6$. The visible diffraction pattern (rains) results from reproduction of cloud droplets passing the steel ball at a distance of more than 2 cm in the direction of the camera.

the brightness pattern. For a slot illumination, perpendicular to the camera axis and passing the center of the icing particle, the flow lines of the floating particles can be determined.

b) If the particles arriving at an obstacle are partly iced, the rebounding particles can be observed as such from their "streak direction" (Figure 2).

c) From the direction of the streak image, the velocity of cloud particles can be determined as a function of their location as long as the particles do not differ largely in size.

From these observations, it is apparent that the Strobolume is a useful device for research of the complex capture processes which, in a diversity of manner, play an important role in the formation of precipitation.

The observations described here were made within the framework of the research project No. 2071 of the Swiss National Fonds.

General Radio Company

PRINTED IN U.S.A.