June 25, 1957 R. H. GEORGE 2,797,329

MERCURY CONTACT SWITCH IMPULSE GENERATOR

Filed Nov. 4, 1954

3 Sheets-Sheet 1

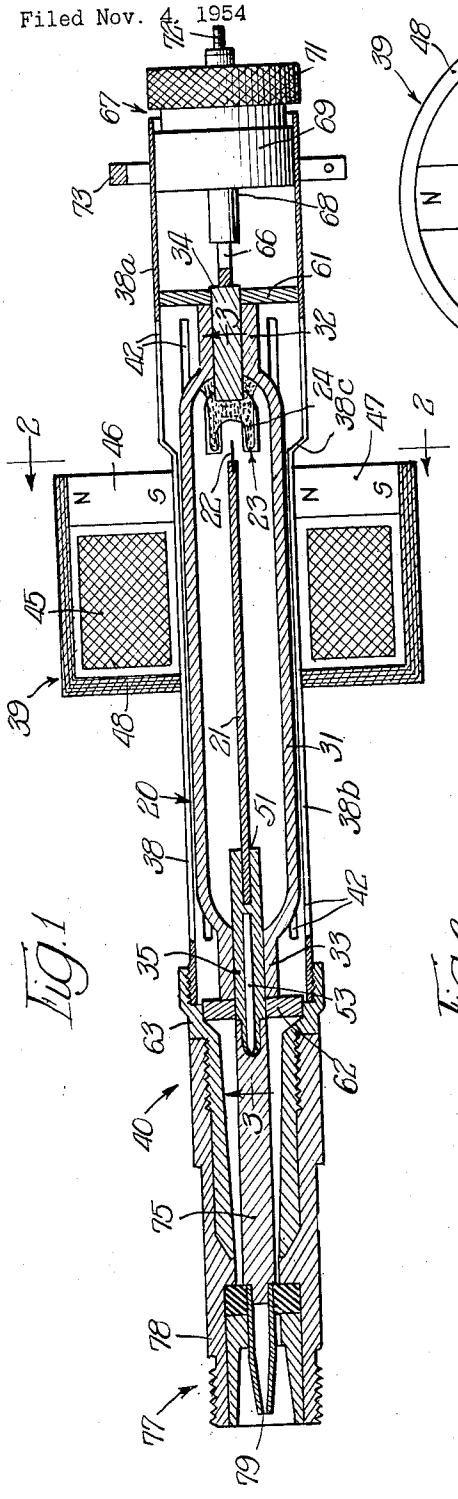


Fig. 1

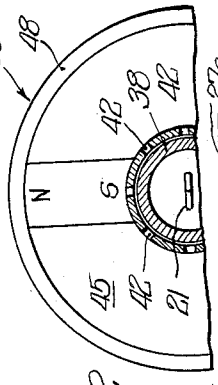


Fig. 2

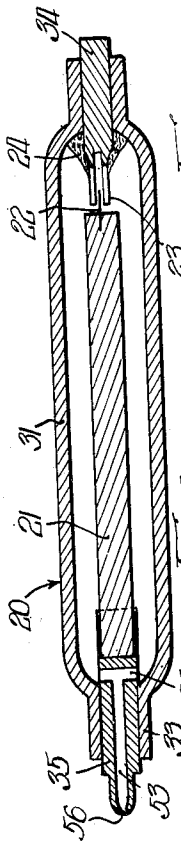


Fig. 3

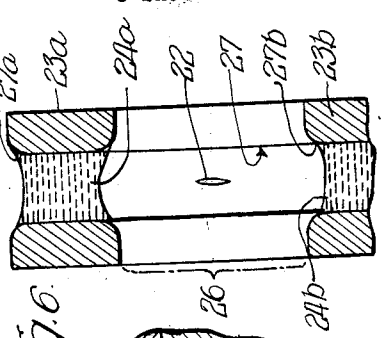


Fig. 6

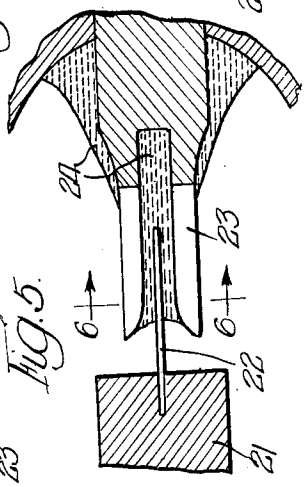


Fig. 5

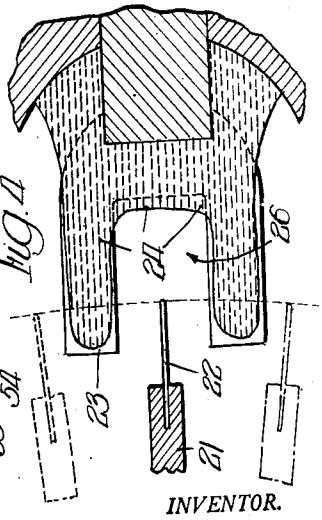


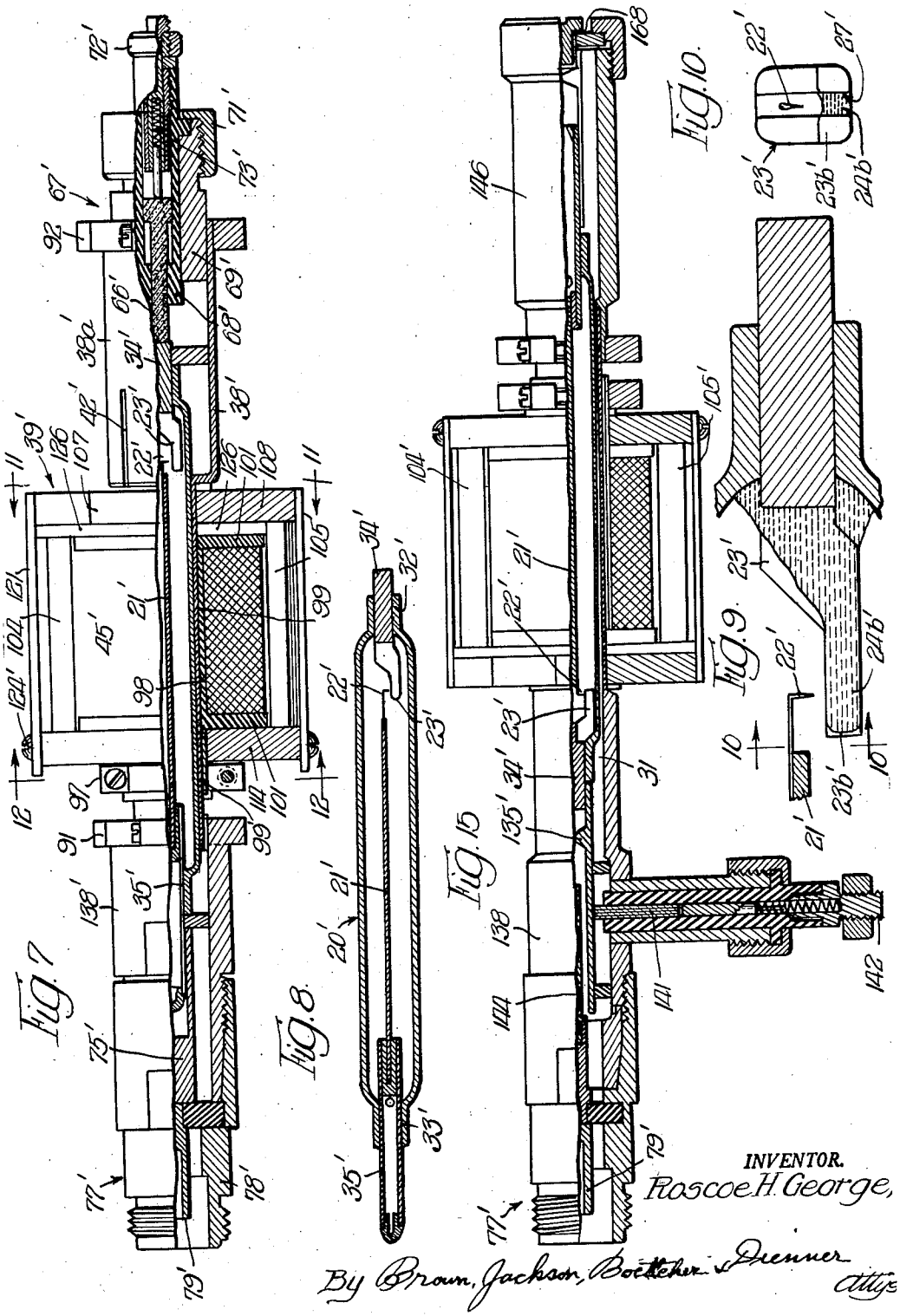
Fig. 4

INVENTOR.
Roscoe H. George,
BY Brown, Jackson,
Boettcher & Dienner
Attys.

June 25, 1957 R. H. GEORGE 2,797,329

MERCURY CONTACT SWITCH IMPULSE GENERATOR

Filed Nov. 4, 1954 3 Sheets-Sheet 2



June 25, 1957 R. H. GEORGE 2,797,329

MERCURY CONTACT SWITCH IMPULSE GENERATOR

Filed Nov. 4, 1954 3 Sheets-Sheet 3

Fig. 10

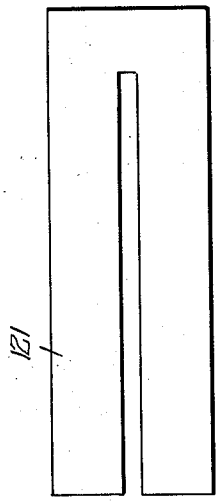


Fig. 13

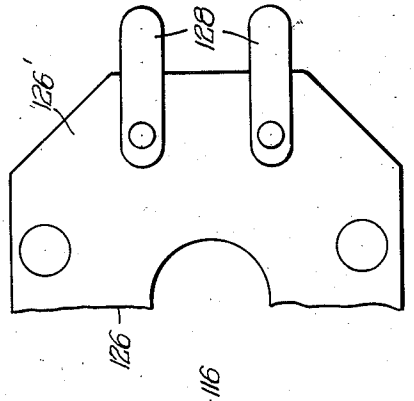


Fig. 12

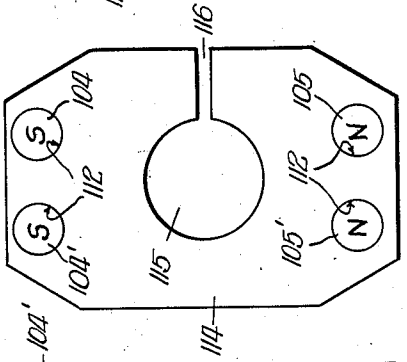


Fig. 11

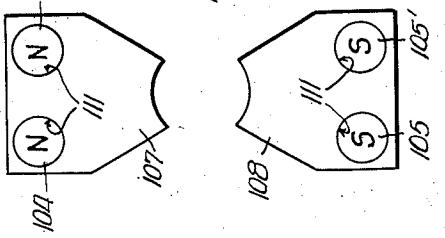


Fig. 16

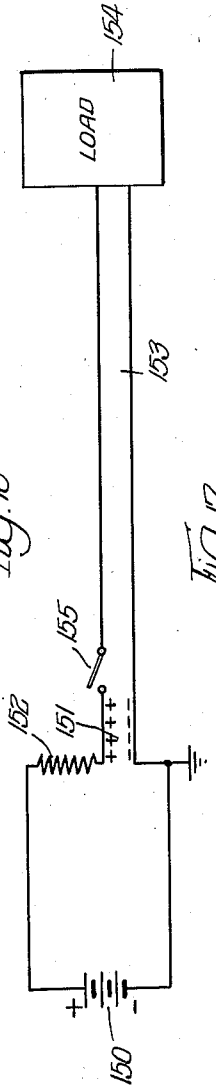
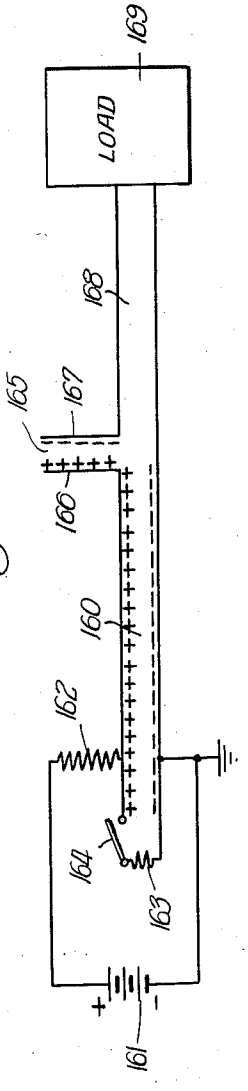


Fig. 17



INVENTOR.
Roscoe H. George,
BY Brown, Jackson,
Boettcher & Dienner
attys.

United States Patent Office 2,797,329 Patented June 25, 1957

2,797,329

MERCURY CONTACT SWITCH IMPULSE GENERATOR

Roscoe H. George, West Lafayette, Ind., assignor, by mesne assignments, to Research Corporation, New York, N. Y., a corporation of New York

Application November 4, 1954, Serial No. 466,731

12 Claims. (Cl. 250—37)

The present invention relates to an improved mercury contact switch and impulse generator, and is related generally to the types of impulse generators disclosed in copending application, Serial No. 221,394, filed April 16, 1951, by Roscoe H. George and George R. Cooper, now issued as Patent 2,722,608, and in copending application, Serial No. 221,395, filed April 17, 1951, by Roscoe H. George.

The general object of the invention is to provide improved methods and apparatus for generating stable pulses of extremely short duration, such as of the order of 10^{-10} seconds, or in that approximate range.

A more specific object in this regard is to provide an improved impulse generator having a frequency spectrum which is substantially flat from approximately 20 to approximately 3,000 megacycles for use in calibrating impulse noise measuring equipment, for general laboratory testing, as a signal source for radar equipment and the like, etc.

Another object of the invention is to provide an improved mercury contact switch of the electromagnetically actuated type, which is particularly adapted to use in these impulse generators, although it is also capable of advantageous use in other situations. A more specific object of the invention in this regard is to provide an electromagnetically vibrated mercury contact switch for use in such impulse generators which is capable of producing a wide range of controlled pulse repetition rates extending up to a relatively high value, as for example from approximately 20 pulses per second up to approximately 1,000 pulses per second.

Another object of the invention is to provide a mercury contact switch and pulse generator which will require only a relatively low driving power, which is of particular advantage in portable test equipment. For example, portable test equipment embodying the present invention has been constructed and operated successfully wherein the driving power was less than 5 milliwatts.

Another object of the invention is to provide a construction of the above apparatus which will be of relatively small size and weight, which is also of particular advantage in portable test equipment.

Another object of the invention is to provide an improved vibrating reed mercury contact switch which is capable of making either single or double contact in each vibratory cycle, depending upon the amplitude of vibration imparted to the reed.

Another object of the invention is to provide a mercury contact switch in which the relatively high surface tension inherent in mercury is uniquely utilized to maintain a body of mercury in operative position as one of the circuit making and breaking elements of the switch. This unique arrangement avoids the necessity of providing a supporting or backing surface for the mercury lying in the plane of relative motion of the circuit making and breaking parts. By thus avoiding the necessity of a mercury supporting surface in the plane of relative motion

of the switch parts, this relative motion may be made of any desired amplitude without any possibility of non-yielding physical striking contact occurring between the switch parts. This feature is of particular importance in connection with the previously described feature of being able to obtain a wide range of pulse repetition rates, over which range there may be substantial changes in the amplitude of vibration.

Another object of the invention is to provide a mercury contact switch in which one of the switch contacts, preferably the stationary contact, is of forked or slotted construction, with a body or film of mercury held in spanning or covering relation with respect to such fork arms by surface tension, so that the other switch contact can vibrate with varying amplitudes of movement through the fork slot in the circuit making and breaking operation.

Another object of the invention is to provide improved adjusting means for adjusting the magnetic response of the vibratory reed to the electromagnetic driving means.

Another object of the invention is to provide an impulse generator in which the vibratory reed of the switch or contactor forms the center conductor of the output line of the impulse generator.

Other objects, features and advantages of the invention will appear from the following detail description of three preferred embodiments of the invention. In the accompanying drawings illustrating such embodiments:

Figure 1 is an axial sectional view of a coaxial line type of impulse generator embodying a double contact form of vibrating reed mercury contactor;

Figure 2 is a fragmentary transverse sectional view taken approximately on the plane of the line **2—2** of Figure 1;

Figure 3 is a longitudinal sectional view of the double contact form of mercury contact switch alone, corresponding to a section taken approximately on the plane of the line **3—3** of Figure 1;

Figure 4 is a detail sectional view of the switch contacts on a highly magnified scale, taken in the plane of Figure 1 and showing the double contact make and break between the vibrating reed contact and the stationary mercury contact when the reed is given sufficient amplitude of vibration to pass through and beyond both legs of the double mercury contact;

Figure 5 is a sectional view on the same scale as Figure 4, but taken at right angles thereto, such as in the plane of Figure 3;

Figure 6 is a detail sectional view taken on the plane of the line **6—6** of Figure 5, but on a still larger scale of magnification;

Figure 7 is a lengthwise or axial view, partly in elevation and partly in section, showing a modified construction of impulse generator employing a modified form of vibrating reed mercury contactor adapted to make only a single contact on each vibratory swing or excursion of the reed;

Figure 8 is a fragmentary sectional view of this modified single contact mercury contactor removed from the impulse generator;

Figure 9 is a fragmentary sectional view, on a magnified scale, showing the coaction between the contacts of this single contact vibrating reed mercury contactor employed in Figure 7;

Figure 10 is a transverse view taken on the plane of the line **10—10** of Figure 9;

Figure 11 is a transverse section taken on the plane of the line **11—11** of Figure 7, showing the spaced pole pieces at one end of the energizing coil;

Figure 12 is a transverse section taken on the plane of the line **12—12** of Figure 7, showing the magnetic end plate at the other end of the energizing coil;

Figure 13 illustrates an insulating plate which carries the coil terminals;

Figure 14 is an elevational view of one of the magnetic shunting plates which may be employed for adjusting purposes;

Figure 15 is a view similar to Figure 7, but showing the invention embodied in a series stub line type of impulse generator; and

Figures 16 and 17 are schematic diagrams useful in explaining the operation of the embodiments of Figures 1 and 15.

Referring first to the embodiment illustrated in Figures 1 to 6 inclusive, the mercury contact switch, designated **20** in its entirety, comprises as its main elements the vibrating reed **21**, the movable contact **22** carried at its vibrating end, the stationary contact **23**, and the body of mercury **24** carried by the stationary contact **23**. This mercury contact switch **20** is enclosed within a sealed glass tube **31** having reduced neck portions **32** and **33** at its right hand and left hand ends respectively. A conductor **34** which is joined to the stationary contact **24** extends out through the neck **32** and is sealed therein. Similarly, a conductor **35** to which the stationary end of the reed **21** is anchored extends out through the neck **33**, and is sealed therein.

Surrounding the glass sealing tube **31** of the mercury contact switch is a thin walled metallic tube **38** composed of a non-magnetic metal, such as brass, which supports the driving coil assembly **39** and which also constitutes part of the impulse generator **40**, as will be later described. This tube **38** which is turned from a single piece of brass rod is preferably formed to have a large diameter right hand portion **38***a* and a smaller diameter left hand portion **38***b*, joined by a reducing portion **38***c*. Extending most of the length of the tube are longitudinally extending slits **42** located at six or eight angularly spaced points around its periphery, these slits serving to minimize eddy currents tending to arise in the tube as a result of the pulsing magnetic field transmitted through the tube to the reed **21**. This pulsing magnetic field is created by the aforementioned driving coil assembly indicated in its entirety at **39**, such assembly comprising a winding **45** surrounding the smaller portion **38***b* of the tube, and also comprising a pair of permanent magnets **46** and **47** mounted in opposed polar relation substantially in the plane of flexure of the reed **21**, these permanent magnets creating a polarizing field acting in such plane of flexure substantially at the flexing end of the reed. The winding **45** and permanent magnets **46** and **47** are enclosed within a magnetic shell or casing **48** having one end open to receive the permanent magnets **46** and **47**, and having its other end closed to complete the flux path, at least across the end of the coil **45**. The driving coil assembly **39** can be shifted to different positions of adjustment along the mounting tube section **38***b*, for adjusting the frequency response, amplitude, etc. of the reed **21**.

Referring more particularly to the vibrator reed **21** and its mounting, this reed is preferably in the form of a single strip of magnetic metal, although a two-ply or laminated construction may be employed if desired. The most satisfactory reeds have been composed of Allegheny Electric Metal #4750 (47% nickel and 53% iron), but the reed may be composed of Allegheny Mu Metal (75% nickel, 16% iron, 5% copper and 4% molybdenum), Permalloy A (78.5% nickel and 21.5% iron), silicon transformer steel, clock spring steel, or other suitable metal. The stationary end of the reed is brazed in a transverse slot **51** cut out in the end of the stationary mounting conductor **35**. This brazing operation is best performed by first clamping or lightly spot welding the reed in the slot **51**, following which the joint is coated with a thin paste of Nicrobraz powder and water. After the paste has dried, the conductor **35** and the reed are held between carbon electrodes. This assembly is immersed in an atmosphere of dry hydrogen, and a heavy current passed through the carbon electrodes and joint until the heat from the carbon electrodes causes the Nicrobraz to flow into the joint **51** and form a smooth fillet. "Nicrobraz" is a heat and corrosion resistant alloy for brazing stainless steels, manufactured by Wall Colmonoy Corporation of Detroit, Michigan.

A molecularly fused glass to metal seal should be provided at each reduced neck **32** and **33** of the glass tube **31**. A very effective glass to metal seal can be obtained at each end of the sealing tube by having those portions of the conductors **34** and **35** which pass through the glass necks **32** and **33** composed of Kovar (29% nickel, 17% cobalt, 0.3% manganese and 53.7% iron) for molecular sealing with the glass. As shown in Figure 3, it will be seen that an axial bore **53** extends from the outer end of the conductor **35** and has its inner end communicating through a transverse passageway **54** with the interior of the glass envelope **31**. The glass envelope or tube is exhausted through this passageway **53—54** by connection to a vacuum pump, the tube being baked out while on the pump. Thereafter, the tube is filled with hydrogen and then exhausted, this exhausting and hydrogen refilling operation being performed several times to insure a complete evacuation of objectionable gases. The mercury **24** is then inserted through this passageway **53—54** by boiling it over into the tube, following which the tube is again filled with hydrogen to atmospheric pressure, and thereafter the outer end of the passageway **53** is sealed off at **56**, which may be either a Kovar or a glass tip-off. The stationary contact element **23** has previously been properly amalgamated, so that the mercury **24** will be held thereto by surface tension. As the result of an annealing process, the reed **21** has been previously covered with a brown oxide to prevent it from becoming amalgamated with the introduced mercury, and thus having its resonance frequency changed.

The stationary contact element **23**, when designed for double contact operation, is of forked construction, as viewed from the side (Figures 1 and 4). This results in vertically spaced upper and lower fork arms **23***a* and **23***b* respectively, separated by a transverse clearance space **26**. When the contactor coil **45** is not energized and the movable contact **22** is inert, it normally stands substantially centrally in this clearance space **26**, approximately midway between the upper and lower fork arms **23***a*—**23***b*, as shown in Figures 4 and 6, or slightly upwardly or downwardly therefrom, depending upon any bias exerted by the permanent magnets **46—47**. Cut down vertically through the central plane of the stationary contact element **23** is a slot **27** which establishes vertical clearance channels **27***a*—**27***b* through the upper and lower fork arms **23***a*—**23***b* respectively for permitting the movable contact **22** to have an amplitude of movement entirely through and beyond the upper and lower fork arms, as illustrated in dotted lines in Figure 4. While Figure 4 illustrates an embodiment in which the amplitude of movement of contact **22** is such that four contacts per cycle of operation are made, the more normal use of the mercury switch contemplates its operation with only two contacts per cycle of operation. This is achieved by simply reducing the amplitude of movement of contact **22** so that it is driven into the mercury, but not through it.

The vibratory movement of the reed **21** swings the movable contact **22** substantially centrally of the vertical slot, out of physical contact with each fork arm. The proportions of the fork arms **23***a*—**23***b* and slot **27** are such that the inherently high surface tension of the mercury **24** will retain it in position spanning the slot or clearance channels **27***a*—**27***b*. As illustrative of some typical proportions, the transverse or clearance width of the clearance channels **27***a*—**27***b* may be in the order of $\frac{1}{16}$" to $\frac{1}{32}$" wide, from which it will be seen that the surface tension of the upper and lower films of mercury

24*a*—24*b* will hold them in suspension in the vertically disposed clearance channels 27*a*—27*b* (Figure 6), notwithstanding the high speed motion of the vibratory contact 22 therethrough. The transverse width of the vibratory contact 22 is considerably less than the clearance width of the channels 27*a*—27*b*, which reduces the possibility of the vibratory contact 22 physically displacing any appreciable quantity of mercury entirely out of either clearance channel 27*a*—27*b*. This possibility is still further minimized by the vibratory contact 22, such as by forming it to have relatively sharp top and bottom edges, as shown by the exaggerated scale illustration of the vibratory contact 21 appearing in Figure 6.

Typical performance tests have shown that the above described construction of mercury contact switch 20 is capable of obtaining controlled pulse repetition rates ranging from as low as 20 pulses per second to as high as 1,000 pulses per second, without objectionable displacement of mercury. It will be understood that when sufficient driving energy is fed through the coil 45 to cause a large amplitude of vibration of the movable contact 21 so that is passes entirely through and beyond each vertically slotted fork arm 23*a*—23*b*, as illustrated in dotted lines in Figure 4, such large amplitude will cause two makes and two breaks on each upward half of the oscillation, or four makes and four breaks on each complete cyclical oscillation. Conversely, when the driving energy is only sufficient to oscillate the movable contact 22 into but not through the upper and lower films or bodies of mercury 24*a* and 24*b*, then only two makes and two breaks are obtained on each complete cylical oscillation of the moving contact 22. By virtue of the fact that in the normal inert condition of the device the moving contact 22 is completely out of engagement with the mercury 24, there is no necessity of having to overcome the inertia of the mercury in the starting of the reed, and hence it requires very little energy to start the reed to vibrating.

Referring now to the mounting and functioning of the mercury contact switch 20 in the impulse generator 40, it will be seen from Figure 1 that the axial conductor 34 of the stationary contact 23 projects outwardly beyond the sealing neck 32 of the glass tube and has mounting in an insulating washer 61, preferably composed of "Teflon" (polymerized tetrofluorethylene) or other like material, which has a snug fit in the enlarged portion 38*a* of the mounting tube. The other end of the mercury contact switch 20 has its opposite axial conductor 35 also projecting outwardly beyond the end of the glass sealing neck 33, and this projecting portion has similar mounting in an insulating washer 62, also preferably composed of "Teflon" or like material. This latter washer 62 is mounted in a tubular metallic shell 63 which screws over a thread 64 on the left hand end of the mounting tube 38.

Referring again to the right hand end of the impulse generator, the axial conductor 34 leading from the stationary switch element 23 has connection through a suitable charging resistor 66 with a charging resistor assembly 67 mounted in the end of the mounting tube portion 38*a*. This comprises a centrally disposed insulating bushing 68 which is carried in a mounting collar 69 and insulates charging resistor 66 from the tube portion 38*a*. A longitudinally compressed spring (not shown) is mounted inside and coaxial with bushing 68 to bias resistor 66 into positive contact with conductor 34. The resistor assembly is provided with a knurled outer head 71, and projecting beyond this knurled head is a terminal post 72 for establishing electrical connection from the control circuit through the charging resistor 66 to the stationary switch element 23. A clamp assembly 73 surrounding this end of the impulse generator serves to establish electrical connection with the mounting tube portion 38*a*; and it may also be utilized as a mounting device if desired.

At the other end of the impulse generator 40, the shell 63 which screws over the threaded end of the mounting tube 38 constitutes the outer conductor of the impedance matching line of the coaxial impulse generator. Extending axially thereof is the center conductor 75 of the output line of the impulse generator. This output end of the impulse generator is provided with a suitable coaxial connector 77 for establishing connection through a coaxial cable, wave guide or the like leading to a point of use of the generated impulses. This coaxial connector comprises the conventional outer and inner coaxial conducting members 78 and 79 electrically insulated from each other. The connector 77 which I have illustrated is conventionally known as type N, UG–23B/U or UG–21B/U (exemplified on page 145 of Catalog #62 of Newark Electric Co., Chicago, Illinois), but obviously other types of coaxial connectors may be employed if desired.

Attention is directed to the fact that the connection to the stationary switch element 23 through the axial conductor 34 becomes the center conductor of the discharge line in the impulse generator; and that the vibratory reed 21, its coaxial supporting conductor 35, and the members 75 and 79 become the center conductor of the output line in the impulse generator. The enlarged section 38*a* of the brass mounting tube 38 forms the outer conductor of the discharge line; and the small section 38*b* of this tube, together with the shell 63 and outer connector element 78 form the outer conductor of the output line. The charging resistor 66 will ordinarily have a resistance ranging between 50 and 100 megohms, but it will be understood that this is merely illustrative. Where the conductor size and the glass envelope permits, the output line is preferably designed for an impedance of approximately 50 ohms. However, the above values may vary considerably for different structures, different operating conditions, different frequencies, etc. For example, under some conditions it may be necessary to make the output line with a higher impedance and use a tapered section to transform the impedance down to 50 ohms. In order to obtain a frequency spectrum that is essentially flat to 3000 mc., the effective length of the discharge line should be a quarter-wavelength at a frequency of 3500 to 4000 mc. This should be a length of between .74 and .84 inch with air insulation. The presence of the glass insulation will reduce this value considerably. The length of the reed 21 will depend on the resonance frequency chosen, the material in the reed, and its thickness. For example, satisfactory results have been obtained with one-piece reeds composed of Allegheny Electric Metal #4750, having a straight width of .125" and a thickness of .018" and various lengths ranging from 2⅜" to ¾", such reeds having resonant frequencies starting at approximaely 70 to 80 cycles for the longer lengths and ranging up to 800 to 900 cycles for the shorter lengths. Tapered width reeds can also be employed, particularly for the higher frequencies, but in other respects the straight width reed is preferable. Sealed off tubes using the one-piece straight width reed have been constructed having a resonance frequency of approximately 500 cycles. At resonance, these tubes can be made to produce noise pulses at repetition rates of 500 and 1000 p. p. s. By using a tapered reed 2$\frac{5}{32}$" long, tapered from .125" at the base to approximately .050 at the tip, having a resonance frequency of 1000 cycles, it was possible to obtain pulse repetition rates of 1000 and 2000 p. p. s. Driving power for operating the reed through the driving coil 45 may be supplied from various sources, such as a multivibrator, or a Boonton type 140A beat frequency oscillator, or a Hewlett-Packard type 200 AB audio oscillator.

In describing the single contact embodiment as illustrated in Figures 7–15 inclusive, I shall use the same reference characters as before, wherever practicable, but shall give them a prime appendix. Referring first to the showing of this single contact mercury switch 20′ in Figures 8–10, it comprises a vibrating reed 21′ carrying a movable contact 22′ at its vibrating end, but this con-

tact 22' is in the form of a downwardly directed contact having a needle-like point. The stationary contact 23' is modified to the extent that it comprises only half of the double contact element 23; i. e. it has only the lower fork arm 23b', which is of the same vertically slotted construction to provide the vertical clearance channel 27b' there-through in which channel the mercury film or body 24b' is held by surface tension. In the normal inert condition of the reed 21', the downwardly directed tip of the movable contact 22' is out of engagement with the mercury. However, when the reed vibrates, the movable contact 22' penetrates the mercury for establishing switch closing contact. The same treatment steps are performed in making the single contact switch 20', as were described above in the case of the double contact switch 20. The switch is mounted in a generally similar mounting tube 38' having an enlarged portion 38a' and a reduced portion 38b', both portions being longitudinally slitted at 42' to reduce eddy currents. In order to get the driving coil 45' as close to this outer conductor tube 38' as possible, this part of the assembly can be made in two parts, as shown in Figure 7. That is to say, the reduced end 38b' of the conducting tube 38' has secured thereto an extension portion 138', the latter being fastened to the conductor tube 38' by the clamp 91. The inside diameter of this outer conductor tube is varied to maintain a 50 ohm impedance in the output line and a 70.7 ohm impedance in the discharge line.

The charging resistance assembly 67' is held in place by a clamp 92, and can be adjusted along the axis of the conducting tube 38' to take care of slight differences in the length of the mercury contact switching tubes 20'. This charging resistance assembly comprises a mounting bushing 69', a spring 73', a knurled cap 71' screwing over the outer end thereof, and a threaded terminal post connection 72'. The knurled cap 71' serves to hold an insulating mounting sleeve 68' within the bushing 69', and disposed within this insulating mounting sleeve is a charging resistor 66' which spring 73 urges into electrical connection against the end of the axial conductor 34', which mounts the stationary switch element 23'. The resistor 66' has a resistance ranging between 50 and 100 megohms.

The driving coil assembly 39' is held in place on the conductor tube 38' by a clamp 97. The coil 45' is wound upon an insulating spool 98 comprising a tubular shank portion 99 and radially extending end flanges 101. At one end of this insulating spool the tubular shank portion is extended beyond the adjacent end disk, as indicated at 99', this extended portion being axially slitted so that it can be compressed into clamping engagement at any adjusted point on the mounting tube 38' by the clamp 97.

In this modified embodiment illustrated in Figures 7–15, a different arrangement of permanent magnets and magnetic circuit is employed, particularly characterized by the use of four permanent magnets 104, 104' and 105, 105', preferably of cylindrical bar type, and composed of Alnico V or comparable magnetic material. These bar magnets extend longitudinally of the mercury switch and impulse generator assembly, two of the magnets being disposed above the vibratory reed 21' and two below the reed. The polarizing field established by these permanent magnets is made to act on the vibrating end of the reed 21' through upper and lower pole pieces 107 and 108 respectively (Figure 11), which have inwardly facing arcuate pole pieces engaging directly over the brass conducting tube 38'. The adjacent ends of the pairs of bar magnets seat in circular apertures 111 in these pole pieces.

The other ends of the bar magnets have similar mounting in circular holes 112 formed in a steel end plate 114. This end plate has a circular central aperture 115 which fits over the shank extension 99' of the insulating spool 98. Extending outwardly from this central aperture 115 to one of the side edges of the steel plate is a slot 116 to reduce eddy currents in plate 114. The four permanent magnets 104, 104' and 105, 105' are in a parallel-series arrangement to produce quite a strong field between the pole pieces 107 and 108 without saturating the reed 21'. When the coil 45' is energized and the reed magnetized, the flux flows across the air gap to the steel end plate 114 at one end of the coil, through the aiding permanent magnets, through one of the pole pieces 107 or 108, through the air gap and then back through the reed 21'. The end of the reed is attracted to one of the pole pieces and repelled from the other, producing a very strong force on the reed. When the coil current is reversed, the reed is deflected in the opposite direction.

In cases where the reed is not perfectly centered, or the gap at the contacts is too wide or not wide enough, the operation of the reed can be improved by the use of one or more magnetic shunting strips 121 on one side of the magnet or the other. When putting the impulse generator into operation, driving power is applied to the coil 45', and the driving coil and magnet assembly 39' is rotated with respect to the vibratory reed to give best operation with a minimum amount of driving power. Thereupon, the clamp 97 is tightened to hold the driver assembly 39' in place, following which the driving voltage is reduced until the reed 21' stops making contact between 22' and 23'. Thereupon, one of the magnetic shunting strips 121 is brought up to first one side of the magnet and then the other to see if the generator will operate at the lower driving power. If the shunt improves the operation, it is adjusted by sliding it until no further reduction in driving power can be made, and is then clamped to the steel end plate 114 by the screw 124.

Interposed between the right hand of the coil spool and the pole pieces 107, 108 is an insulating plate composed of Bakelite or the like, designated 126. This insulating plate has apertures therein through which are passed the permanent magnets 104, 104' and 105, 105' for their mounting in the pole pieces 107 and 108. The insulating plate 126 has a laterally projecting portion 126' (Figure 13) adapted to carry terminal clips 128 for establishing electrical connection with the winding 45'.

The output end of the impulse generator is provided with a suitable coaxial connector 77', this connector having substantially the same relation of outer conducting element 78' and inner connecting element 79', as previously described, the outer element having electrical connection with the outer conductor of the output line and the inner element having connection with the inner conductor 75' of the output line. In order to minimize reflections on the output line of the impulse generator, the section where the reed 21' forms the center conductor of the output line should have the same impedance as where the switching tube end terminal 35' or the member 75' form the center conductor. The design of this impulse generator is based on the assumption that the effective diameter of the reed 21' is the same as the cylindrical conductor 35', which is 0.125 inch.

In Figure 15, I have illustrated a series stub line type of impulse generator using this same single contact mercury switch 20', this type of impulse generator providing more flexibility for adjusting the peaking frequency. The coaxial line through the mercury contact switch is designed for a constant impedance of 50 ohms, and is terminated in the 50 ohm disk resistance 168. The section of the line comprising stationary switching contact 23', axial conductor 34' and the conducting element 135' is charged up through the resistor 141 when potential is applied between terminal 142 and the grounded outer conductor 138 and 146.

The conductor 135' is hollow at one end and forms the outer conductor for the series stub line. The diameter of the center conductor 144 of the series stub is adjusted for an impedance of 70.7 ohms where it extends into conductor 135'. The part 144 screws into the part 79', which forms the center conductor of the 50 ohm output line. By making a series of parts 144 of different lengths, the peaking frequency and the output of the impulse generator can

be varied over a considerable range by the simple operation of changing the part **144**. This change can be made very quickly by unscrewing the coaxial connector **77'**, replacing the part **144**, and then replacing the coaxial connector **77'**. With the construction and proportions illustrated in Figure **15**, and with the dimensions of the part **144** unchanged, it should be possible to change the peaking frequency from 3.6 to at least 10 kmc. by using a part **144** of appropriate length i. e. ¼ wavelength long at the desired peaking frequency. By lengthening the parts **135'**, **138** and **144**, much lower peaking frequencies and a higher output can be obtained.

The driving coil and magnet assembly for this series stub line impulse generator shown in Figure 15 is the same as for the coaxial line generator illustrated in Figure 7. However, it should be noted that for best operation of the series stub line generator, the output connection should be at the bottom instead of the top. The procedure for adjusting the driving coil is the same as for the coaxial line impulse generator. Either of the embodiments illustrated in Figures 7 and 15 may be supplied with driving power from either the same sources described above in connection with Figure 1.

It has been noted in the operation of both types of impulse generators that if the contact point **22'** is very sharp, the output is somewhat erratic if a negative charging potential of more than 200 volts is applied. This effect is not present if a positive potential is used. It can be attributed to the effect of polarity on a point to a plane discharge in gases, such as hydrogen, nitrogen or air. For a given gap spacing in these gases, the break-down potential with the point negative may be as much as 2.5 times as much as when the point is positive. In the case of the impulse generators described, the point is at ground potential so the break-down potential across the gap is greatest when the charging potential is positive with respect to ground. Therefore, it is recommended that a positive charging potential be used whenever feasible.

The operation of the coaxial line noise generator of Figure 1 may be most readily understood with reference to Figure 16 which, for convenience, illustrates an electrically equivalent 2-wire line instead of the usual coaxial line. In Figure 16 a charging potential source **150** has its negative terminal coupled to ground and its positive terminal coupled to one wire of a discharge line **151** through a high resistance **152**. The other wire of discharge line **151** is connected to ground and to one side of an output line **153** which is coupled to a load **154**. The non-grounded side of discharging line **151** is connected through the series combination of a switch **155** and the other conductor of line **153** to load **154**. In operation, discharge line **151** is charged up to a pre-determined potential through resistor **152** from potential source **150**. A step voltage is produced on discharge line **151** by discharging it through switch **155** into output line **153** which is chosen so as to have a lower impedance. The length of discharge line **151** determines the natural period of oscillation of the noise transient and also the amount of energy stored in it.

In coaxial line impulse generators designed for exceedingly high noise frequencies, the length of the discharge line becomes very short. In the case of the mercury contact type of impulse generator, it becomes difficult to build impulse generators with short enough discharge sections to generate exceedingly high frequency noise transients. To solve this difficulty the series stub line impulse generator of the type embodied in Figure 15 has been utilized. The operation of this type of impulse generator will be most readily understood by reference to Figure 17 in which a line **160** may be charged from a source of potential **161** through a high resistance **162**. The positive terminal of potential source **161** is connected to resistor **162** while its negative terminal is connected to ground and to one side of line **160**. A resistor **163** which has an impedance equal to the characteristic impedance of line **160** is connected to the grounded side of line **160** and through a switch **154** to the other side of this line. A stub line **165** has a side **166** connected to line **160** and its other side **167** connected to an output line **168**. Output line **168** is connected to a load **169**. In this case, line **160**, since it is to be terminated in its characteristic impedance, may be of any physical length. The frequency of the noise transients are determined by the length of stub **167** which serves as a quarter wave resonant line.

A voltage is generated on line **160** from potential source **161** and on side **166** of stub **165**. This induces an equal but opposite charge on side **167**. When switch **164** is closed, line **160** discharges through an impedance **163** equal to its characteristic impedance. A discharge wave or step voltage flows down line **160** to discharge stub **165** and release the induced charge on side **167** of this stub. By properly adjusting the impedance of the series stub line and the output line, reflections occur on this line and form the noise transients. By varying the length of the stub line, its natural period of reflection will be charged, thus changing the peaking frequency of the noise transients.

While I have illustrated and described what I regard to be the preferred embodiments of my invention, nevertheless it will be understood that such are merely exemplary and that numerous modifications and rearrangements may be made therein without departing from the scope of the invention.

I claim:

1. In a series stub line impulse generator the combination of a charging line having a predetermined characteristic impedance, an output line and a stub line connected in series and intermediate said charging line and said output line, means for supplying a charging potential to said charging line and said series stub line, a terminating impedance equal to said characteristic impedance of said charging line, and means including a mercury contact switch for discharging said charging line through said terminating impedance whereby reflections are generated in said stub and in said output line.

2. In a series stub line impulse generator the combination of a charging line having a predetermined characteristic impedance and comprising coaxial conductors, an output line comprising coaxial conductors, a series stub disposed between said charging line and said output line and having a pair of coaxial conductors, one of said coaxial conductors of said series stub being connected to said charging line, and the other conductor being connected to said output line, means for supplying a charging potential to said charging line and said one conductor of said series stub, whereby a potential is induced on said other conductor of said series stub, a terminating impedance for said charging line equal to said characteristic impedance, means including a mercury contact switch for discharging said charging line through said terminating impedance whereby a noise pulse is generated in said series stub line and in said output line.

3. In a series stub line impulse generator the combination of a charging line having a predetermined characteristic impedance and comprising coaxial conductors, an output line comprising coaxial conductors, a series stub disposed between said charging line and said output line and having a pair of coaxial conductors, one of said coaxial conductors of said series stub being connected to said charging line, and the other conductor being removably connected to said output line, means for supplying a charging potential to said charging line and said one conductor of said series stub, whereby a potential is induced on said other conductor of said series stub, a terminating impedance for said charging line equal to said characteristic impedance, means including a mercury contact switch for discharging said charging line through said terminating impedance whereby a noise pulse, whose peaking frequency may be changed by alternatively substituting conductors of different lengths of said stub line, is

generated in said series stub line and in said output line.

4. In a series stub line impulse generator the combination of a charging line having a predetermined characteristic impedance, an output line and a stub line connected in series and intermediate said charging line and said output line, means for supplying a charging potential to said charging line and said series stub line, a terminating impedance equal to said characteristic impedance of said charging line, and means for discharging said charging line through said terminating impedance whereby reflections are generated in said stub and in said output line.

5. In a series stub line impulse generator the combination of a charging line having a predetermined characteristic impedance, an output line and a stub line connected in series and intermediate said charging line and said output line, means for supplying a charging potential to said charging line and said series stub line, a terminating impedance equal to said characteristic impedance of said charging line, and means including a switch for discharging said charging line through said terminating impedance whereby reflections are generated in said stub and in said output line.

6. In an impulse generator of the class described, the combination of a charging line comprising coaxial conductors, a charging resistor, means for supplying a charging potential to said charging line through said charging resistor, an output line comprising coaxial conductors, a vibratory magnetic reed contact switch arranged for connecting the inner conductor of said charging line with the inner conductor of said output line, said switch comprising a vibratory reed, a moving contact carried thereby, a stationary contact having a clearance opening therein into which said moving contact is adapted to move without establishing physical engagement with said stationary contact, a film of mercury maintained in said clearance opening by surface tension and adapted to be engaged by said moving contact, a sealing tube enclosing said reed and said contacts, a sleeve-like conductor of non-magnetic material surrounding said sealing tube and electrically connecting the outer coaxial conductor of said charging line with the outer coaxial conductor of said output line, permanent magnet means outside of said sleeve-like conductor for establishing a polarizing field acting on said magnetic reed, and an electromagnetic winding encircling said sleeve-like conductor for creating a pulsing magnetic field operative to vibrate said reed at relatively high frequencies.

7. In a coaxial line type of impulse generator of the class described, the combination of a charging line comprising coaxial conductors, an output line comprising coaxial conductors, a vibratory magnetic reed contact switch arranged for connecting the inner conductor of said charging line with the inner conductor of said output line, said switch comprising a vibratory reed, a moving contact carried thereby, a stationary contact having a clearance opening therein into which said moving contact is adapted to move without establishing physical engagement with said stationary contact, a film of mercury maintained in said clearance opening by surface tension and adapted to be engaged by said moving contact, a sealing tube hermetically enclosing said reed and said contacts, a sleeve-like conductor of non-magnetic material surrounding said sealing tube and electrically connecting the outer coaxial conductor of said charging line with the outer coaxial conductor of said output line, a pair of pole pieces mounted outside of and on opposite sides of said sleeve-like conductor for transmitting a magnetic field through said non-magnetic conductor and through said sealing tube to act on said reed in the plane of its vibratory movement, permanent magnets transmitting a polarizing field through said pole pieces to said vibratory reed, an electromagnetic winding encircling said sleeve-like conductor for creating a pulsing magnetic field operative to vibrate said reed, and a circuit for transmitting pulse frequencies to said electromagnetic winding for vibrating said reed at frequencies capable of obtaining pulse repetition rates ranging from approximately twenty pulses per second to approximately one thousand pulses per second or higher.

8. In a series stub line impulse generator, the combination of a charging line having a predetermined characteristic impedance, an output line, a stub line connected in series and intermediate said charging line and said output line, means for supplying a charging potential to said charging line and said series stub line, a terminating impedance equal to said characteristic impedance of said charging line, means including a mercury contact switch for discharging said charging line through said terminating impedance whereby reflections are generated in said stub line and in said output line, said mercury contact switch comprising a vibratory magnetic reed, a moving contact carried thereby, a stationary contact having a clearance opening therein into which said moving contact is adapted to move without establishing physical engagement with said stationary contact, a film of mercury maintained in said clearance opening by surface tension and adapted to be engaged by said moving contact, and an electromagnetic winding creating a pulsing magnetic field operative to vibrate said reed at relatively high frequencies.

9. In a series stub line impulse generator, the combination of a charging line having a predetermined characteristic impedance and comprising coaxial conductors, an output line comprising coaxial conductors, a series stub disposed between said charging line and said output line and having a pair of coaxial conductors, one of said coaxial conductors of said series stub being connected to said charging line, and the other conductor being connected to said output line, means for supplying a charging potential to said charging line and said one conductor of said series stub, whereby a charge is induced on said other conductor of said series stub, a terminating impedance for said charging line equal to said characteristic impedance, a mercury contact switch for discharging said charging line through said terminating impedance whereby a noise pulse is generated in said series stub line and in said output line, said mercury contact switch comprising a vibratory magnetic reed, a moving contact carried thereby, a stationary contact having a clearance opening therein into which said moving contact is adapted to move without establishing physical engagement with said stationary contact, a film of mercury maintained in said clearance opening by surface tension and adapted to be engaged by said moving contact, permanent magnet means establishing a polarizing field acting on said magnetic reed, and an electromagnetic winding creating a pulsing magnetic field operative to vibrate said magnetic reed.

10. In a series stub line impulse generator, the combination of a charging line comprising coaxial conductors, an output line comprising coaxial conductors, a series stub disposed between said charging line and said output line and having a pair of coaxial conductors, one of said coaxial conductors of said series stub being connected to said charging line, and the other conductor being connected to said output line, means for supplying a charging potential to said charging line and said one conductor of said series stub, whereby a charge is induced on said other conductor of said series stub, and a mercury contact vibrator for discharging said charging line, said mercury contact vibrator comprising a vibratory magnetic reed, a moving contact carried thereby, a stationary contact having a clearance opening therein into which said moving contact is adapted to move, a film of mercury maintained in said clearance opening by surface tension and adapted to be engaged by said moving contact, and electromagnetic means for vibrating said reed.

11. In a series stub line impulse generator, the combination of a charging line having a predetermined characteristic impedance and comprising coaxial conductors, an output line comprising coaxial conductors, a series stub disposed between said charging line and said output line

and having a pair of coaxial conductors, one of said coaxial conductors of said series stub being connected to said charging line, and the other conductor being adjustably connected to said output line, means for supplying a charging potential to said charging line and said one conductor of said series stub, whereby a charge is induced on said other conductor of said series stub, a terminating impedance for said charging line equal to said characteristic impedance, means including a mercury contact switch for discharging said charging line through said terminating impedance whereby a noise pulse, whose peaking frequency may be changed by adjusting the length of said other conductor of said series stub line, is generated in said series stub line and in said output line.

12. In a device of the class described, the combination of a charging line, an output line, a vibratory reed mercury contact switch for creating pulses in one of said lines, said switch comprising a vibratory reed, a moving contact carried thereby, a stationary contact, a film of mercury maintained on said stationary contact and adapted to be engaged by said moving contact, an electromagnetic

coil for vibrating said reed, a pulsating driving circuit connected with said electromagnetic coil for vibrating said reed at a relatively high frequency, and a charging circuit for supplying a direct current charging potential to said charging line, said charging circuit having its positive polarity connected to the movable contact of said mercury contact switch.

References Cited in the file of this patent

UNITED STATES PATENTS

1,289,637	Bruce	Dec. 31, 1918
1,975,762	Behmer	Oct. 9, 1934
2,060,235	Miller	Nov. 10, 1936
2,445,406	Pollard	July 20, 1948
2,448,364	Ganz et al.	Aug. 31, 1948
2,459,306	Burton	Jan. 18, 1949
2,485,024	Vale et al.	Oct. 18, 1949
2,519,463	Harrison	Aug. 22, 1950
2,584,901	Miller et al.	Feb. 5, 1952
2,609,464	Brown et al.	Sept. 2, 1952