

SECTION A — Discussion: Flash Light Sources

Note: A participant's full name and address are given with his first contribution to the Discussion. Authors' full names and addresses are given with the title of each paper. For subsequent entries the addresses are omitted.

Paper A-1: Holdover in Xenon Flashlamps, Harold E. Edgerton and David A. Cahlander, Dept. of Electrical Engineering, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.

E. J. G. Beeson (Associated Electrical Industries Lamp and Lighting Co. Ltd., Melton Rd., Leicester, England): The use of mixed gases — other than pure xenon on which the paper is based — could provide an extension to the frequency at which a tube can be operated. I would like to ask Dr. Edgerton whether he has obtained similar curves at the point of inflection where there are changes from a positive to a negative resistance condition.

Dr. H. E. Edgerton: Some experiments have been made with mixtures of hydrogen with rare gases but I have no curves showing the results. Although deionization time is decreased with hydrogen inclusion, the resulting tube becomes more difficult to start than before.

D. P. C. Thackeray (Vickers Research Ltd., Sunninghill, Berks, England): Have you tried any arrangement for recharging the capacitor, in which the dynamic parameters of the power source are varied continuously to a predetermined program; the intention being to keep the source impedance greater and/or the voltage lower than the instantaneous values for recondensation of the tube?

Dr. H. E. Edgerton: Yes, a series switch or a variable series circuit element in the charging circuit such as a thyatron or tube has been used to decrease the instantaneous charging current. You can gain a great deal that way.

Paper A-2: The Control of High-Power Xenon Flashes by Magnetic Switching, E. J. G. Beeson, Associated Electrical Industries Lamp and Lighting Company, Ltd., Melton Rd., Leicester, England.

J. S. McVeagh (Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent, England): Could this magnetic switching be used for times of 1 to 2 msec? A sufficiently rapid rise of field might be produced by the discharge of a condenser by a spark gap.

E. J. G. Beeson: To achieve flash durations of about 1 msec we are dependent upon the magnetic rise-time of the circuit. In addition we must maintain some persistence of the magnetic flux to prevent arc re-establishment due to the deionization time of the excited xenon atoms and the thermal state and cathode condition promoting arc reignition. We have not extended our studies below a 10 msec flash duration.

Dr. W. G. Braun (USAF Research Division, Wright Field, Ohio): Does the magnetic switching of the tube reduce its useful life?

E. J. G. Beeson: When a xenon lamp is subjected to these high pulse currents lamp life is affected. For the lighthouse application where the lamp is flashed at 2 kw on a $\frac{1}{10}$ duty cycle, lamp lives of 1200 to 1500 hours are being achieved and we are confident this can be extended to 2000 to 3000 hours. Where much higher currents are passed, 500 to 1000 amps, no extended life tests have been carried out but we would consider that several hundred flashes would easily be achieved. Bulb blackening generally occurs on the cooler part of the lamp envelope but no serious tungsten deposition occurs providing the lamp current and its duration are controlled to prevent local fusion of the anode tip. The principle of magnetic arc extinction does not appear to affect the general lamp performance.

Paper A-3: High-Intensity, Fractional Microsecond Light Sources, Philip Nolan, Farrand Optical Company, 4401 Bronx Blvd., New York 70, N. Y.

Dr. Frank Früngel (Dr.-Ing. Frank Früngel, GmbH., Hamburg-Rissen (24a), Germany): For several years our firm has been manufacturing pulsed optical "ceiometers" for measuring cloud height, using spark light sources. We drive these lamps with a pressure of 5 atm of argon, at 5 flashes per second, and 20-joule stored energy per flash. The spark chamber is demountable. The light from the sparks has a rise time of less than 10^{-7} sec even at this high energy level. The peak luminous intensity on the axis of the mirror is 2×10^{11} candlepower; and the specific brightness (luminance) of the source is 1 or 2×10^8 candles/cm². Therefore we would expect that, with the lower energy used by the author, a shorter rise time would be available. Similar sparks, but triggered at rates up to

50,000/sec, are produced by our "Strobokin" high-frequency flash unit. (This spark chamber technique is described in the *Proceedings of the Second International Congress on High-Speed Photography*, Dunod, 92 rue Bonaparte, Paris 6, 1956, pp. 19-30.)

Paper A-4: Millimicrosecond Light Source, Heinz Fischer, Air Force Research Division, Hanscom Field, Bedford, Massachusetts.

George H. Lunn (Atomic Weapons Research Establishment, Aldermaston, Berkshire, England): I note the reciprocity failure factor of about 0.64 quoted in this paper for an exposure time of 10^{-6} sec. We, at AWRE, from work done by Dr. A. H. Gabriel, have reason to believe that this factor is incorrect. Gabriel suggests that this factor reduces from unity as exposures decrease towards 10^{-5} sec; but at shorter exposures still it then begins to improve, giving better film response than has often been assumed. Has the author any reason to believe that this is true? (*J. Sci. Instr.* 37:50 (1960))

Dr. H. Fischer: Well, we got our reciprocity factor from data published by Eastman Kodak for Tri-X film; and they claim that the reciprocity factor stays roughly constant in the submicrosecond exposure range.

Paper A-6: Submicrosecond Flash Sources, Harold E. Edgerton, John Tredwell and Kenneth W. Cooper, Jr., Massachusetts Institute of Technology, Cambridge, Massachusetts.

Winston O. S. Johnson (E. I. du Pont de Nemours and Company, Mechanical Research Laboratory, Wilmington, Delaware): We consider that the vapor visible on breakage of an inflated balloon is due to condensation on sudden release of pressure.

J. Tredwell: This is a possibility. We didn't know what it was. We were curious about it. I'm glad that somebody had some information about the phenomenon.

W. O. S. Johnson: Have the authors studied other flashtube configurations that might result in a more condensed source?

J. Tredwell: One other configuration for the guided spark involved bending a glass tube so that there was a loop in it, and placing the discharge electrodes inside the glass tube with the trigger wire outside. The gap length was the same as in the straight tube — one inch. The light output of this tube was the same as that of the straight tube; the latter design was chosen because it was easier to make, and fitted better into our equipment design.

Martin R. Dachs (Farrand Optical Company, 4401 Bronx Blvd., New York 70, N. Y.): What is the spark length of the "guided spark" at 18 kv — 0.05 μ f?

Dr. H. E. Edgerton: The spark length in the 8 watt-second lamp is one inch.

M. R. Dachs: What is the spectral distribution of light output for the guided spark?

Dr. H. E. Edgerton: The spectral distribution of light is a continuous one with a few strong lines. The color slides shown in the presentation were taken on daylight Super Ektachrome, using a CC20Y yellow filter to cut down the excess blue light.

Paper A-8: Investigation of the Brightness of Spark-Discharge Channels in Various Gases, M. P. Vanyukov and A. A. Mak, U.S.S.R.

Kenneth R. Coleman (Atomic Weapons Research Establishment, Aldermaston, Berkshire, England): Were the measurements mentioned in the second of the papers, with bandwidth 1 to 40 Angstrom, made with filters?

Dr. I. A. Tchernyi (Ulitsa Tchaikinoy 4, Apt. 5, Leningrad 3, U.S.S.R.): The measurements were sometimes made with interference filters, and on other occasions with spectral instruments.

Paper A-10: A High-Intensity Rectangular-Pulse Light Source for High-Speed Photography, Theodore Marshall, B. J. Crapo and Lemuel I. Hill, U.S. Naval Ordnance Laboratory, Silver Spring, Maryland.

D. P. C. Thackeray: Could I ask why your line has so many sections? Guillemin, in his theoretical work, optimizes pulse shape and losses at 6 to 8 sections; and W. C. Griffin, in his very

similar piece of work at NOTS about five years ago, used as few as three sections to give very acceptable pictures. In Cambridge, England, I built an 8-section line with trimming inductors, all inductors being wound from power cable, and with mutual inductance between them. This gave a good 1-msec current pulse; but with the very small flashtubes I had available the light output did not follow the current waveform. The same line, with change of coils, could equally well have been tailored for 100 μ sec or 10 msec, had we desired it. (Griffin, *Jour. SMPTE* 66: 127 (1957); Thackeray, *Proc. 3rd Int. Congress on High-Speed Photography*, pp. 21, 42 et seq. (1957)).

T. Marshall: The number of sections of the line is dictated by the resistance of the lamp, time duration of the flash, total energy to be stored, and the cost of commercially available capacitors.

Kaye Weedon (J. L. Nerlien A/S, Nedre Slottsgate 13, Oslo, Norway): Some of us have had the advantage of reading the preprints, and I made a study of this paper. I have a criticism in that the mutual inductance between the various sections of the line was not taken into consideration. It is well known in line theory that the particular line used here has a very poor phase characteristic, so that the time will be different for the various frequencies in the range passed by what is, in effect, a low pass circuit. This is evident in one of the slides shown, because you can see the high-frequency ripples at the end of the pulse. A study of the literature on lines would allow the authors to produce a much better light source.

L. I. Hill: Your previous letter was taken very much to heart. We did look up the reference and we'd like to thank you for referring it to us, because it does look as though we may be able to make use of some of those techniques.

Winston O. S. Johnson: Some time ago, I designed a pulsed line source. The problem was put on to an analog computer to optimize the design, taking into account mutual inductance, self-inductance, lamp impedance and other parameters.

L. I. Hill: I have just started some work putting almost exactly that problem on an analog computer. I haven't had much success at the moment, but am still working on it.

Paper A-11: Use of High-Explosive Flash for Photography by the Schardin System, Louis Deffet and Rene Vanden Berghe, Centre de Recherches Scientifiques et Techniques Pour l'Industrie des Produits Explosifs, Val du Bois, Sterrebeek, (Brabant), Belgium.

Anonymous: May I ask why the authors used explosive cord for providing known delays and for synchronizing? I was impressed with the extraordinary precision of the results; but why did they not use modern electronic devices?

R. Vanden Berghe: I will try to give you the answer in English. There are many advantages. The present method has a very high resolution. Electronic devices, unless very complex, do not give comparable resolution.

M. Sultanoff (Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland): I would like to make one comment here — I think we have as modern a laboratory at Aberdeen Proving Ground as exists anywhere; but when we have timing problems of this type, we also find it much simpler and much more reliable to use detonating fuse. We use primacord. Usually there are immense difficulties in electronic synchronizing, especially with large numbers of pieces of equipment, as then you get interference between the circuits. If you work in a laboratory with people using x-ray apparatus they are liable to pulse their x-ray unit at a time when you're trying to time a sequence, and this may well give spurious results. It really is much cheaper, and much simpler, if you can tolerate the variation in time that you get with a detonating cord, to use that rather than to use electronics. Moreover, it doesn't take a full-time electrical genius to keep the primacord running; you know just how it's going to behave.

Paper A-12: Explosive Flashlight: A New Development in an Explosive Light Source, Jack Gershon and R. H. Stresau, Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois.

Dr. David C. Oakley (University of California, Lawrence Radiation Laboratory, Livermore, California): What film did you use in the examples?

J. Gershon: The film used in all examples was Tri-X developed in Microdol for 15 minutes at 68 F.

Dr. D. C. Oakley: Have you used reflectors to concentrate the light more?

J. Gershon: The light output of the explosive flashlight is quite adequate as it is presently designed. However, I would not be surprised if some kind of reflector might increase the light output, if it were found to be necessary.

Dr. Louis Zernow, (Aerojet General Corp., 11711 Woodruff Ave., Downey, California): I shudder at the cost of the unit described. We find we can get excellent results with ice-cream cartons, a Saran wrap window and C-4 plastic explosive, all for very low cost.

J. Gershon: For some applications, the ruggedness, resistance to environment and general handiness is worth the cost to us.

L. Zernow: Is there any quantitative data comparing relative intensities with and without the annular explosive charge?

J. Gershon: No, but the time-intensity curve is believed to be more reproducible.

Anonymous: Have you tried using shaped charges as a shock medium?

J. Gershon: We have not.

Lincoln L. Endelman (The Martin Company, Cocoa Beach, Florida): About four years ago Messrs. Sewell and Cosner described a method for producing light from argon gas by means of a dynamite cap (*Journal SMPTE*, January 1957, pp. 21-24). Have you tried this rather than the shaped charge or explosive that you are using?

J. Gershon: Our flashlight was specifically designed for use with the Beckman & Whitley Model 189 camera. This camera has a lighting requirement that varies from about 6 μ sec to a few hundred μ sec. And I don't believe that the shock waves emitted from a dynamite cap will last that long.

M. Sultanoff: The brightness of the flash is a function of the pressure in the shock wave. It's not an ignition of the argon; it's an excitation phenomenon. The discovery of this phenomenon dates back to Muraour and Michel-Levy in France, about 1932 or 1934. It has been "rediscovered" and "reinvented" several times since then. What we need is a strong shock — a high pressure shock — in order to excite the gas to give the luminous output. It's not ignition, and a shaped charge or a dynamite cap would be the wrong way to do it. Actually, in a later paper it is shown that the light at the head of a shaped charge is not a very bright light whatever the surrounding gas — air, argon, propane; though it does depend on the gamma of that gas.

J. S. McVeagh: It is possible that the tubular form of the explosive will cause a reinforcement of pressure at the center of the tube due to interaction of shock waves. I will show a streak record of this phenomenon in my later paper.

J. Gershon: We had this in mind when we designed the flashlight. We have evidence that the effective light source is highly concentrated about the centerline of the tube.

Dr. W. G. Braun: Please comment on the accuracy of the triggering of this light source.

J. Gershon: The accuracy with which such light sources can be triggered is very nearly the reproducibility of the functioning time of the detonator, which varies with type of detonator and the characteristics of the firing pulse. The combination we have used, a U.S. Army M36 detonator fired by means of a one-microfarad condenser, changed to 300 volts, and discharged through a 2D21 thyratron, fires in $20 \pm 1 \mu$ sec. To obtain such reproducibility with a commercial blasting cap would require thousands of volts.

William P. Brooks (Sandia Corporation, Div. 5133, Albuquerque, New Mexico): Is the 15-in. circle of light reduced with a flat piece of Plexiglas over the end of the Lucite tube?

J. Gershon: The circle of light is not reduced by using a flat piece of Plexiglas at the output end of the explosive flashlight. Tests have shown that by using a 48-mm diameter double concave lens affixed to the Plexiglas window, the circle of light can be expanded to 3 feet in diameter.

Paper A-13: High-Intensity Explosive Light Sources, Zev Pressman, Poulter Laboratories, Stanford Research Institute, Menlo Park, California.

Dr. David C. Oakley: The gas mixtures mentioned were studied with 1/16-in. glass partitions. The more useful comparisons would be those of gas mixtures without the partitions. If my memory serves me, without the partition between the high explosive and the gas, 10% xenon in argon gave 20% more light than pure argon; and pure xenon gave twice as much light as pure argon.

Z. Pressman: We don't have time to say anything about this. I have much more data, and would be prepared to discuss this with those who are interested.