A HIGH INTENSITY NON-REVERSED SODIUM ARC

By Carl J. Christensen and G. K. Rollefson
Chemical Laboratory, University of California, Berkeley

(Received September 3, 1929)

Abstract

An improved high intensity sodium arc using the principle of the Cario, Holtgreven arc is described. This has sufficient of the second resonance radiation of sodium (3303A) so that quite brilliant fluorescence is produced in sodium vapor when this radiation is used for excitation.

AN INVESTIGATION of the fluorescence radiation of sodium vapor excited by the 3303A resonance radiation has recently been undertaken by the authors.[1] The exciting source of resonance radiation was one of the outstanding initial problems. This has been solved in a very satisfactory manner by construction of a sodium arc, the design of which can undoubtedly be employed to produce arcs of other alkali metals. The principle is that of the Cario[2] lamp; and the lamp is in some respects similar to the modifications of the original Cario lamp introduced by Holtgreven[3] and Hupfeld.[4]

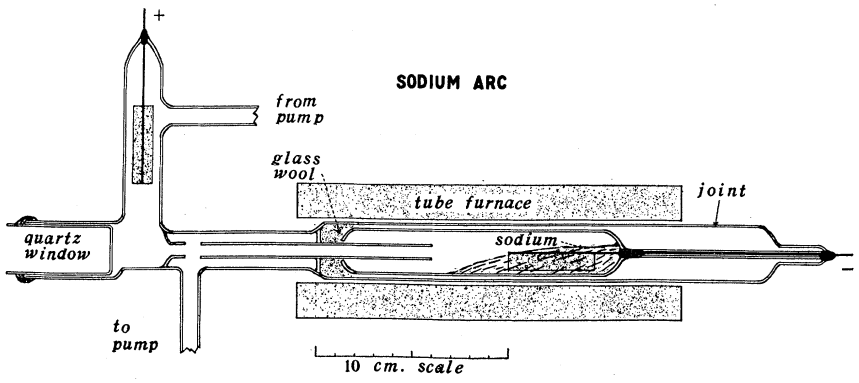

Fig. 1. Design of sodium arc lamp.

Figure 1, drawn to scale, gives the design of the lamp. The glass is of hard Pyrex throughout. The quartz window is sealed in with ordinary Dennison sealing wax. If cooling of the wax is necessary while the arc is operating at high currents this can be easily done with a wet cotton pad. The electrical leads through the glass are of tungsten and the electrodes are of sheet nickel rolled into a cylinder. The sheet from which they are rolled is wide enough so that the joint overlaps by half a turn or so. The tungsten

[1] To be published in the Physical Review.
[2] Cario and Holtgreven, Zeits. f. Physik **42**, 22 (1927).
[3] Holtgreven, Zeits. f. Physik **47**, 362 (1928).
[4] Hupfeld, Zeits. f. Physik **54**, 484 (1929).

is pushed between these overlapping layers and electrically spot-welded only at the lower end. This is an important feature, particularly for the electrode that lies in the sodium, since the action of this metal when hot is such as to cause any welded joint between the tungsten and the nickel to break. If this joint is broken the sodium quickly distills away from the tungsten lead and the arc becomes useless. In making the electrode as described, the tungsten wire always gives mechanical support to the nickel cylinder and the pressure on the tungsten due to the natural elasticity of the overlapping nickel layers is enough to give electrical contact.

The cathode is of metallic sodium. In the original Cario lamp, sodium is also the cathode; but here trouble is always encountered at high current densities (0.1 ampere) due to the fact that the arc always seems to strike just at the margin where the sodium pool is in contact with the glass. Here the sodium layer is thin and the heat conductivity from the point is poor. Hence, invariably the glass becomes heated sufficiently at these points to soften and suck through, or cause strains which very soon develop into cracks. In the Holtgreven modification a large nickel cylinder becomes the cathode, this is surrounded by sodium vapor. It is well known that the current in low voltage arcs is largely determined by the thermionic emission of the cathode. Hence the limit of the Holtgreven modification is soon reached. In the models the author constructed, a current of greater than 0.3 amperes was never attained, unless a globule of sodium of sufficient size became the cathode by making contact with the nickel cylinder, whereupon the current through the lamp immediately increased; but now the difficulty of the original Cario lamp was manifest. A particular advantage with the Holtgreven modification, however, is the ease with which a steady discharge can be obtained. When the sodium acts as cathode, there is a tendency for the intensity to fluctuate when the "active point" shifts on the cathode, although after the lamp here described has been operating for an hour or so it becomes as steady as the Holtgreven modification.

The Hupfeld modification is very similar to that of Holtgreven. It owes its advantage only to the fact that it is constructed entirely of quartz and so allows a very high operating temperature. From Hupfeld's description it would seem that a current of 1 ampere is hardly attainable.

The modification here described allows a current of 1.5 amperes without any difficulty and it seems possible to increase the current to a limit much beyond this. The lamp has been run continuously at this current for as long periods as 10 hours. The total life of any of these lamps so far constructed has been at least 50 burning hours. The advantage of this modification lies in the fact that sodium is the cathode, which gives high thermionic emission. The inner chamber holding the sodium, being evacuated on both sides, does not readily break as it would if there were a difference of pressure on the two sides. All of these inner chambers have been very badly corroded and cracked when the life of the lamp has been spent, but still they have confined the sodium.

To introduce the sodium into the lamp, the outer chamber is cut with a hot wire at the point marked "joint." The cathode and inner chamber then

easily slide away from the rest of the lamp. Purified or freshly cut sodium is introduced into the inner chamber, the lamp reassembled and the "joint" sealed. Commercial sodium contains large quantities of occluded gases. Purified sodium for the purpose of this arc is produced by heating commercial sodium in a vacuum to dispel the occluded gases, and then pouring through a capillary. If freshly cut commercial sodium is used some difficulty in starting the lamp is encountered due to the occluded gases being dispelled. If, however, the lamp is alternately struck and pumped the occluded gases are finally dispelled and the final operation is as good as the operation when the purified sodium is used. The circulating pump for argon gas is an ordinary mercury vapor pump which is operated just rapidly enough to keep the yellow beyond the break in the discharge column when the arc is operating. The gas must be sent through at least two liquid air traps filled with glass beads, or the equivalent, before it reaches the arc, otherwise a large amount of mercury is carried into the discharge. Argon is initially introduced with a pressure of 1 or 2 millimeters.

The tube furnace is brought to a temperature of from 200°C to 250°C. This has been found to be the best operating temperature. For operation of the arc, 220 volts direct current has been found adequate. A higher potential than this is advantageous however to age the arc and bring it to the stable operating condition. When "burning" at 1.5 amperes the potential across the lamp is somewhat less than 100 volts, hence a ballast resistance must be used. A choke coil in the circuit is advantageous since it has a marked stabilizing effect. The "breakdown voltage" is high, but when a high frequency spark[5] is applied anywhere the arc immediately starts. If the arc has a tendency to go out when the "active point" on the cathode surface changes position, it is found good practice to coil loosely a wire from the high frequency spark about the tube conducting the gas from the lamp to the pump.

After the arc has "burned" a short time and any residual gas in the sodium has been dispelled, by pumping if necessary, the pressure of the argon is increased to as high a value as possible, still allowing the stability of the arc to be maintained. This is important for the life of the lamp, since if the mean free path of the gas molecules is large the sodium distills away from the nickel electrode and chokes the discharge column. When this happens, the lamp must be cleaned and fresh sodium introduced. The "*D*" radiation from this lamp is very intense and causes brilliant fluorescence in sodium vapor at pressures corresponding to temperatures as low as 150°C. The 3303A fluorescence excited by radiation from this lamp is intense enough to give very black photographs through a Hilger quartz spectograph in 15 minutes when the sodium vapor is at 190° C. The "*D*" fluorescence from the 3303A excitation is intense enough to be observed easily when the fluorescing vapor is at 170°C. The authors' experience in attempting to use a number of the sodium arcs described heretofore in the literature is convincing that the arc here described is much superior to any before described.

[5] The authors use an ordinary "Eisler Vacuum Tester" which is designed for finding leaks in vacuum lines.