# Section 15.0: Optical Examination of Steady-State Plasma Jet

Optical analysis of the plasma jet using digital and standard film cameras was conducted to provide a better understanding of how the plasma torch operates. The plasma jet emanating from the torch is both too bright to observe out without welding shields and is also fluctuating throughout time. Looking through welding shields prevents the operator from looking at the flame plume downstream of the torch and also cuts out much of the plasma jet itself because welding shields are designed to remove all but the brightest light. Fluctuations of the plasma jet may be too quick to see with the human eye, especially through a welding shield. For these reasons, a digital and standard camera were used to take pictures of the plasma jet.

Digital and standard cameras were used to take pictures of the plasma torch while operating on methane. Filters removed some of the glaring light, allowing a more refined analysis of the plasma jet. The first objective of this study was simply to discover what the entire plasma jet looked like under normal operating conditions, without looking through a welding shield. Luminosity strata provided a gauge of how temperature varies within the plasma jet. Electrode emission, plasma jet fluctuations and the effects of electrode alignment were also investigated.

## 15.1: Test Procedure

Photos of the plasma jet were taken using an Olympus 200-DL digital camera and a Minolta XG7 film camera, with a Quantaray zoom lens. Pictures taken with the Minolta XG7 were taken coplanar to the plasma torch face at a range of about 2 ½ meters. The zoom lens made it appear as if these pictures were taken 0.4 meters from the torch. Digital photos were taken at a much closer range since the Olympus did not have a zoom feature, nor could be mounted with a zoom lens. The Olympus was mounted 30° off the plane of the plasma torch face and about half a meter away.

Four tests were conducted to take pictures. Two tests were used to take digital photos and two for standard photos. Each test lasted between one to three minutes. For all tests, the plasma torch operated with a 27% current setting and about 25 SLPM of methane.

## 15.2: Results and Discussion

Approximately 50 pictures were taken using both the digital and standard camera during the testing sequence. One of the more informative photos is shown in Fig. 15.1. Beforehand, it was simply assumed that the arc attached on the downstream side of the anode nozzle, indicating that the torch was operating in the high-voltage mode discussed in Section 3. Figure 15.1 proves that the arc is attached downstream of the anode constrictor by the angle that one of the electrode pieces was ejected from the torch. Recall from Section 4 that the anode has a 45° half-angle divergent section downstream of the anode constrictor. In Fig. 15.1 it is clear that the electrode streak identified by the white arrow is definitely leaving the torch at an angle greater than 45°. In order for this to occur, the electrode particle must have originated downstream of the anode constrictor, indicating that the arc is indeed operating in the high-voltage mode.

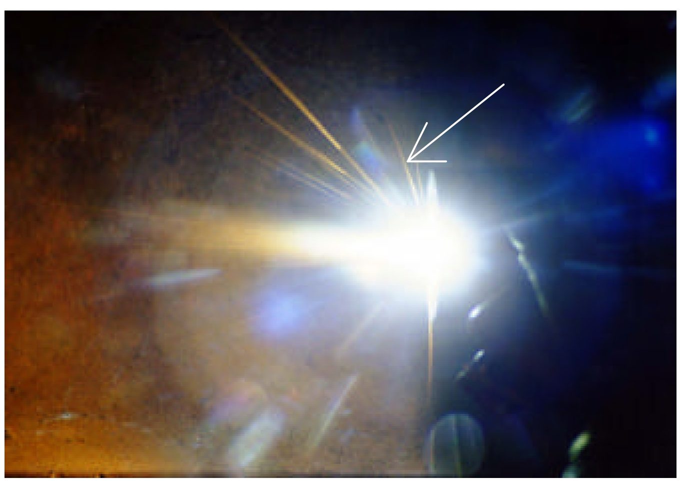

Figure 15.1: Electrode Emission with Methane Operation

Another phenomenon observed through the optical analysis was off-center jets. Electrode misalignment is generally the cause for this, but deformities in the anode nozzle could also create the same effect. A comparison between an off-center jet and a centered jet is shown in Fig. 15.2. The off center jet (shown on the left) is characterized by a plasma jet emanating from the torch at an angle other than axial. This type of effect could be so mild as to not be noticed by casual observation, or so severe that the plasma jet attempts to cut through part of the anode as it exits the torch. The case shown in Fig. 15.2 is considered mild. A centered plasma jet (shown on the right) produces steady, stable operation. Torch life is maximized when operating under these conditions.

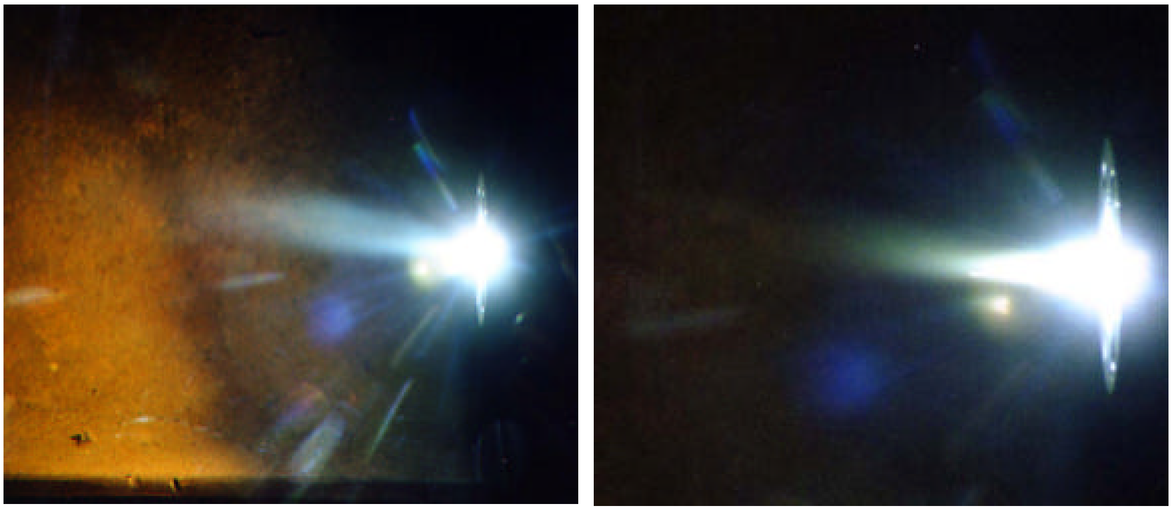

Figure 15.2: A Comparison Between Off-Center and Centered Plasma Jets (Methane)

Luminosity gradients in the plasma jet yield some qualitative temperature data on how temperature varies within the plasma jet. Although luminosity is assumed to provide a gauge as to how the temperature varies in the plasma jet, it does not provide the actual temperatures. Figure 15.3 shows a plasma jet with high luminosity in the center and decreasing luminosity farther from the centerline of the jet. As expected, the plasma temperature decreases the farther the plasma is from the torch nozzle. The plasma is bright around the centerline of the jet and tapers off in brightness both axially and radially. These luminosity strata could be caused, in part, by the plasma jet oscillations described in Section 13 as well as actual temperature gradients within the plasma jet itself.

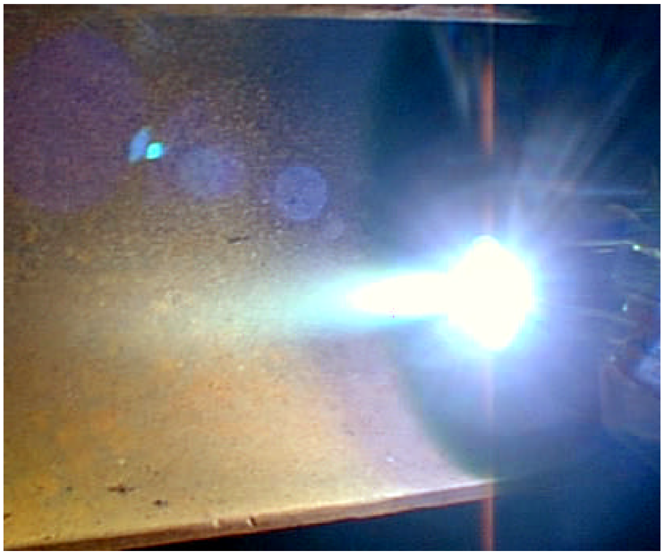

Figure 15.3: Luminosity Strata in a Methane Plasma Jet

Another effect observed during the optical analysis was jet fluctuation. This fluctuation is not to be confused with the jet oscillation detailed in Section 13. This type of fluctuation was completely random and unpredictable, unlike the jet oscillation, which occurred at 180 Hz. During some tests, the plasma jet would burst into a brighter, much larger plasma jet, seemingly for no apparent reason. These fluctuations were slow enough to be recognized by the human eye. Pictures detailing these fluctuations are shown in Fig. 15.4.

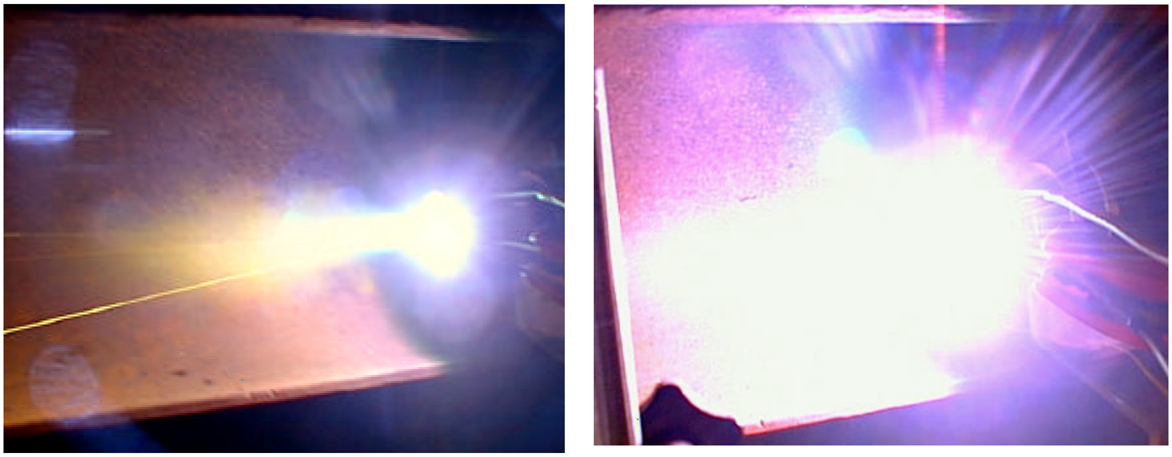

Figure 15.4: An Example of Plasma Jet Fluctuations

The photo on the left is of a normal-sized, centered methane plasma jet. It also has a small flame plume at the tip of the jet. The torch operates in this mode about 95%

of the time. The photo on the right is of a plasma jet, which has just burst into a much brighter, larger jet. This type of operating mode lasts generally no more than a few seconds. These fluctuations are most likely caused by electrode deposition on the anode and an increase in torch chamber pressure. The torch attempts to return to a stable operating mode by dislodging the electrode buildup inside the anode constrictor. If successful, this lowers the torch pressure and the torch returns to stable operating conditions, otherwise buildup continues and eventually causes the torch to extinguish.

## 15.3: Recommendations and Final Remarks

Optical analysis of the plasma jet provided useful information on how the plasma torch operates under various conditions. Pictures of electrode emission proved that the arc attaches on the downstream side of the anode nozzle. Electrode misalignment and anode deformation were shown to produce off-center plasma jets by altering the flow dynamics of the feedstock as they passed through the torch. Luminosity strata in a methane plasma jet demonstrated qualitatively how the temperature varies both radially and axially in the jet. Finally, optical examination of the plasma jet revealed that the jet fluctuates between normal-sized, average luminosity jets and much brighter, larger jets. These fluctuations are thought to have been caused by electrode deposition on the anode and an effort by the torch to expel the constriction. Optical examination of the plasma jet is a very important tool for understanding how the torch operates and for predicting how it might behave under future conditions.