LARGE THERMAL PLASMA DEVICES SOME ASPECTS OF THEIR DESIGN AND OPERATION

A.L. HARE, B.Sc (ENG), A.C.G.I.
Tioxide International Limited

ABSTRACT

It is twenty years since the Tioxide Group became actively interested in the application of thermal plasmas to the oxidation of titanium tetrachloride. Within ten years Tioxide had moved from laboratory to commercial operation of a plasma powered titanium dioxide pigment manufacturing process. To complete that development programme it was necessary to utilise and adapt information from a wide variety of sources. Today there exists a mountain of information on various aspects of the design of large scale plasma devices and the problem now is one of deciding which is relevant to the process being considered.

In the development of a plasma process the major problem is of assessing its economic viability. In general the capital cost of the plasma equipment is only a small fraction of the total plant. The use of plasma processing frequently results in a more simple plant with a consequent saving in capital expenditure. However these economic benefits can soon be lost if the plasma system is unreliable. Therefore in the design of commercial plasma equipment considerable effort has to be directed towards ensuring reliable safe operation.

Unreliable operation can occur because of random failures of the electrical and ancillary equipment, arc instabilities and undesirable arc/electrode interactions. The dynamic arc characteristics are the common factors between these different failure modes. The relative importance of these failure modes will tend to be process dependent. At low powers ($\approx$1 MW) and where short term interruptions to the process are acceptable then several alternative solutions are available. But if the benefits of a large single stream unit operating continuously for several weeks are to be obtained then the limitations of these solutions soon become apparent.

Three broad categories of plasma reactor can be defined, a gas phase reactor, a solids processor and a gas/solids contactor. For each category, to minimise energy costs, an estimate can be made of the preferred operating arc voltage and current ranges. The dominant arc characteristic is dI/dt which when combined with the Kaufmann criteria allows the outline specification of the power supply to be drawn-up. Other factors which have to be taken into account before the complete specification can be drawn include:-

1. Power supply authority requirements

2. Legal safety requirements

3. Reliability and maintainability

4. Efficiency

The arc/electrode interface is probably the least well-understood sub-system in any plasma operation. Over the last few years considerable progress has been made in understanding the basic physical processes occurring in this region such that for the first time reasonable estimates of the micro and macro processes can be made. In gas heater applications it is usually desirable to minimise the energy density at the electrodes to lower the rate of electrode wear. In solids processors the energy density at the arc roots will be increased to the maximum level to heat the solids and inject them into the plasma column. However there is plenty of evidence to show that apparently minor process changes can have dramatic effects on the arc/electrode interactions. This shows the need for relatively large scale trials before a decision is made to build a large multi-megawatt plasma process.

Finally the design must take into account the environment within which the unit will be used. The equipment will be operated and maintained by people generally less skilled than those responsible for the development and in an environment less suitable for the maintenance of the very high standard of electrical and mechanical integrity required for high powered plasma devices. Any fall-off in the maintenance of these standards will soon cause unreliable and erratic operation with a consequent loss in production and increased risk to personnel.