Hotter than the surface of the Sun, 'plasma arcs' work like lightning to destroy hazardous wastes safely

Quick, complete waste destruction

Ralph Judd

CSIRO laboratory technician Mr Alan Mundy prepares material for pyrolysis by Plascon.

Alchemists once sought the secrets of the universe through the transformation of the impure into the heavenly. They looked on the transmutation of base metal into gold as a symbol of that transformation — and, incidentally, as a convenient way of rewarding their patrons.

Since science has revealed the structure of the universe (and the regrettable impossibility of the transmutation of elements), alchemy has become a symbol of magic rather than reason.

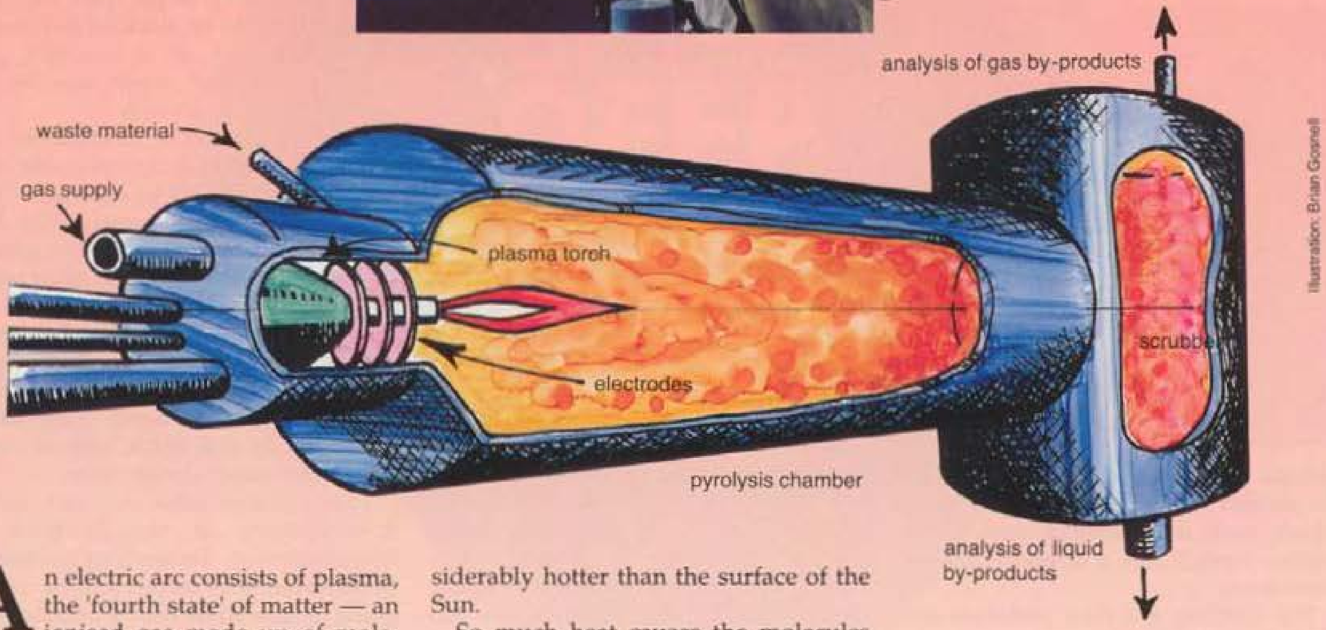
Yet science can itself verge on the magical. Imagine the satisfaction an alchemist would feel if he were to be told of an arc of pure energy, hotter than the surface of the Sun, safely contained and available at the flick of a switch to blast the most horrific poisons ever devised into benign atoms.

Plascon, the plasma converter (also known as a plasma arc furnace) developed by a research group led by Dr Subramania Ramakrishnan, of the CSIRO Division of Manufacturing Technology, may be based on the same principles as lightning or the arc welder, but it has a magical potential to destroy hazardous toxic wastes by breaking them down into their constituent elements and, because its high temperature prevents the formation of large molecules characteristic of hazardous chemicals, virtually eliminating the risk of 'leakage' of hazardous substances.

Best of all, it is so efficient in design that the whole apparatus, including scrubbers and cooling systems, takes up less space than a shipping container and can be built into production lines.

It could become an integral part of industries that need to dispose of dangerous wastes and, at a unit cost of less than $2 million, represents an economical solution to a problem of increasing environmental, social and political concern.

Plascon's 'heart' is surprisingly compact, and its protective sheathing means little can be seen of the arc itself, although it is hotter than the surface of the Sun.



Waste is fed under pressure into the core of the incandescent arc, and converted into simple, harmless molecules.

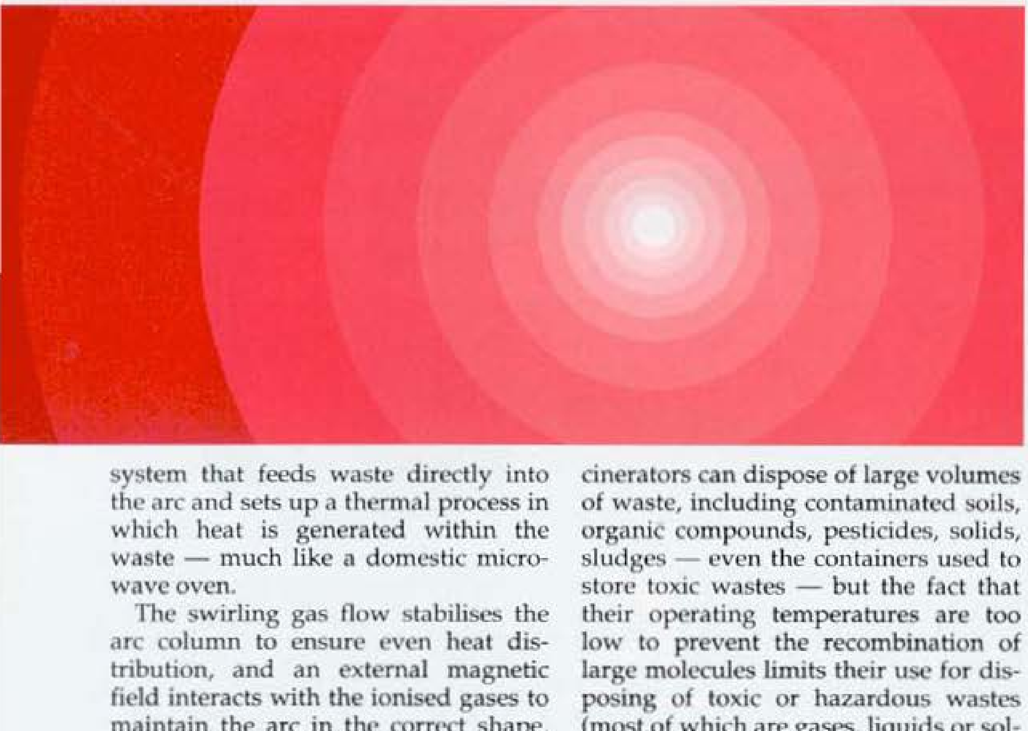
An electric arc consists of plasma, the 'fourth state' of matter — an ionised gas made up of molecules, atoms, ions and electrons that is electrically neutral. If plasma is not to discharge itself quickly (as plasma in the form of lightning does), the supply of free electrons must be maintained by adding energy — at a temperature of at least 5000°C.

This is best achieved by adding an electric current, which means the plasma need not depend on oxygen; in principle, any gas can be used, so that plasma for waste destruction works by pyrolysis (degradation by heat) rather than incineration (degradation by oxidation).

Toxic waste, in the form of gases, liquids or even finely ground solids mixed into a liquid, is fed under pressure into the core of an incandescent arc between two copper electrodes, using the same principle as the arc welder but working at stupendous temperatures — 10 000° to 15 000°, considerably hotter than the surface of the Sun.

So much heat causes the molecules of the material for disposal to dissociate into atoms that recombine as safe, non-toxic compounds. In the case of polychlorinated biphenyls (PCBs), the hydrogen and chlorine recombine to form hydrochloric acid that can be used in industrial applications, while 99·9999999% of the toxic chemical is destroyed. Further, when combustion takes place without oxygen, the constituents of the PCBs cannot recombine to form dioxins.

Plascon had its beginnings in a collaborative research venture, between the Division and Siddons Ramset Ltd, to investigate industrial applications for electric arcs. That venture has already resulted in the commercial release of the Synchropulse CDT pulsed-arc welding machine (an international success that has led to other commercially significant de-



velopments), a number of innovative flux cored welding wires, new arc welding processes and the plasma torch for bonding metallic and ceramic coatings.

Plasma arc furnaces for disposal of hazardous wastes have been mooted for more than a decade, but attempts to design commercial-scale apparatus have in the past been frustrated by the fact that the waste stream must be directed accurately at the core of the arc if complex toxic molecules are to be destroyed completely. The stream of cold waste also tends to cool the arc, displacing the zone of maximum temperature away from the core and resulting in incomplete pyrolysis.

Dr Ramakrishnan's group has overcome those problems with a patented system that feeds waste directly into the arc and sets up a thermal process in which heat is generated within the waste — much like a domestic microwave oven.

The swirling gas flow stabilises the arc column to ensure even heat distribution, and an external magnetic field interacts with the ionised gases to maintain the arc in the correct shape, maximising its effectiveness.

Dr Ramakrishnan and his research group initially developed a 150-kW experimental laboratory plasma torch, testing it with safe chemicals such as alcohol and isopropynol. They then built a 50-kW protoype converter to dispose of chlorophenols to simulate industrial applications.

Plans are well advanced for a 200-kW unit that will be able to dispose of 50 litres of waste per hour. They estimate that, running 24 hours a day (with a shutdown every 100 hours to replace the electrodes), the 200-kW unit will be able to dispose of a dozen 100-litre drums of toxic waste every 24 hours for no more than a dollar a litre — and that most of that cost will be for electricity and for the gas used to carry the waste into the arc.

Although the commercial-scale Plascon unit uses 200 kW of power, smaller units — using as little as 20 kW — could be constructed for industries that produce less waste. The maximum practicable limit is unknown, but according to Dr Ramakrishnan it would be more efficient and economical to link a number of 200-kW furnaces in parallel rather than construct a single, much larger, unit.

He also stresses that Plascon is not intended as an alternative to conventional high-temperature incinerators (which operate at a fraction of plasma's temperature). Instead, it represents an invaluable addition to them.

Conventional high-temperature incinerators can dispose of large volumes of waste, including contaminated soils, organic compounds, pesticides, solids, sludges — even the containers used to store toxic wastes — but the fact that their operating temperatures are too low to prevent the recombination of large molecules limits their use for disposing of toxic or hazardous wastes (most of which are gases, liquids or solids that can be ground and mixed with liquids for treatment by Plascon).

Rotary-kiln incinerators, for example, operate at temperatures of 650° to 1200°C, with a 'residence time' — the time taken to destroy waste within the incinerator — up to several hours. Fluidised-bed incinerators work more quickly, but at similar temperatures (750°–1000°); two-stage infrared incinerators, designed primarily for PCBs, dioxins and contaminated soils, have a total residence time of 10 to 180 minutes and operate at 1250°C.

The major disadvantages of all conventional incinerators are the relatively low temperatures at which they work, allowing the possibility of producing dioxins or other toxic chemicals even after incineration, and long residence times. The 'high-temperature' incinerator under investigation for Australia, for example, operates at 1200°C and needs about 20 minutes' residence — which also means the incinerator takes 20 minutes to come to a complete stop after it has been shut down.

In contrast, Plascon has a residence time measured in milliseconds... and if it has to be shut down, it will take only milliseconds more to destroy the material (less than 1 cubic centimetre) already in the system.

One of the most compelling advantages of Plascon, for industry and the environment alike, is its small size; a 200-kW unit, including power supply, scrubber and gas supply, is no larger than the average office. It can be installed in-line and on-site, as part of a factory's production line, and waste can be destroyed as it is produced.

Some conventional incinerators can be constructed at a transportable size, but they have such low capacity and such high energy requirements that mobile systems are only marginally economic. It is easier to transport waste to a central incinerator and store it before disposal, but this involves high costs and hazards during both transport and storage. Full-sized Plascon units, on the other hand, could easily be moved by rail, truck, ship or air to hazardous-waste storage sites.

The commercial-scale unit under development at the Division of Manufacturing Technology's Preston, Melbourne, laboratories will be undergoing on-line trials with a leading Australian chemical manufacturer within 12 months and will serve as a demonstration model for the European, Scandinavian and United States firms that have already approached Dr Ramakrishnan.

One company has expressed interest in using Plascon to dispose of American chemical weapons on Johnston Atoll — a task for which it is well suited, not only because of its efficiency in destroying hazardous substances but also because of its ease of transportation. Dr Ramakrishnan, however, says he would prefer 'to demonstrate the technology working in Australian industry and use that as a launching pad for exports.

'It is an excellent opportunity for us to prove to the world that we can win the race to instal on-site waste-elimination systems in our factories.'

Carson Creagh