# THE MOBILE PCF 2

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## ABSTRACT

Designing a successful remediation program requires substantial preparatory work. The task is made more formidable by the lack of satisfactory characterization tools. This paper provides a brief description of the PCF 2, a new tool for pilot scale waste remediation studies. Basic theory of operation and the equipment configuration is discussed.

## INTRODUCTION

For years U.S. government, industry and individuals have operated as if the environment was an infinite resource. The assumption was "The world is sufficiently large to provide an inexhaustible capacity for the assimilation of our culture's harmful by-products". The past decade however has resulted in the ever growing awareness that our global ecosystem is in fact a closed system. As population pressures continue to rise, humanity is faced with the threat that unless responsible action is taken to deal with the residues of a technically advanced society, we may all soon be swimming in the effluvium of our civilization.

The "Dump" is one of mankind's oldest institutions. Archaeologists regularly utilize ancient dump sites as a window into the daily activities of civilizations that have passed from the contemporary world. It should be noted that although the culture under investigation may have been extinct for thousands of years, the garbage has survived. A big difference between those ancient peoples and our culture of today is in the type of material cast-off as the remnants of every day life. In an ancient culture the material that was thrown out was no longer useful, whereas today the material may have the added caveat of being dangerous as well. Unfortunately, for many years the dumping of such materials continued in the traditional fashion. The recognition was slow in coming that some types of waste products could have significant, harmful and lasting effects if improperly disposed of.

## THE TOXIC WASTE PROBLEM

The realization that we have reached the level of technology where we are capable of inflicting irreparable damage within our ecosystem has pierced the awareness of the public at large. Safe handling and disposal methods for hazardous materials are being mandated and previously unrecognized hazards are being identified. As a result we are now beginning to recognize, and take responsibility for the impact and damage our waste streams may have on our daily lives. An offshoot of this increasing awareness is the acknowledgment that a significant number of our previous waste handling practices have left a toxic legacy that is either a real or potential danger to the population at large.

Waste dumps with the potential for having a harmful effect on the environment are being identified. The ultimate goal of such activities is to insure that the materials contained therein are unable to significantly damage any aspect of the biosphere. To accomplish this worthy goal many materials which are currently residing in such dumps will need re-processing. Unfortunately, in far too many cases the integrity of the initial storage containers has been sufficiently compromised to allow the uncontrolled egress of hazardous materials into the surrounding soils. We now have areas where municipal water supplies are being threatened by the neglected residuals of yesterdays' technological base.

## THE NEED FOR PILOT SCALE PROCESSING

Cleaning up such a contaminated area is a problem of significant proportions. The material to be processed may consist of a mix of soils, metals and organics. Heavy metals in solution may reside in a soil matrix along with volatile organic constituents. The remains of drums and materials such as toxic slags or sludges may also be present. It is difficult to develop an effective remediation program since much of the material in older dump sites is uncataloged and many processing techniques are not sufficiently omnivorous to handle the unexpected effectively . The result is that designing an effective cleanup program entails substantial financial risk and significant preparatory characterization expenses. In order to accelerate cleanup efforts, equipment which may be moved on site and used to design the cleanup regime is necessary. Until such time as effective pilot scale equipment is available to provide actual on site evaluations, material progress towards the treatment of these leaching time bombs will be slow at best.

## THE PCF 2

The PCF 2 is a piece of equipment specifically designed for the on site evaluation of the processability of hazardous waste problems. The modular equipment is constructed in drop side containers which are easily transported from site to site. When connected these modules form a complete portable pilot scale waste remediation facility. Alternatively the equipment could be transported from hospital to hospital as a cost effective means of disposing of medical wastes. The omnivorous character of the PCF is well suited in the role of providing feasibility insights into many waste problems.

P.C.F. stands for Plasma Centrifugal Furnace. It is a high temperature thermal processing device which uses a Retech plasma torch as its primary heat source. Figure 1 is a plan view of the configuration of the mobile PCF 2.

Container A holds the auxiliary equipment and the operator control station. This particular design requires 480 volt power and some cooling water. Container B encompasses the PCF, lid trolley system and off-gas treatment system. The PCF hardware consists of a refractory lined vessel containing a rotating refractory lined processing crucible with a central opening through which processed slag may be poured. When the processing crucible is rotating, centrifugal force drives the slag away from the center thus inhibiting pouring of the material. After processing an amount of material determined by the characteristics of the feed stock, the rotation is slowed and the processed material in the form of a homogeneous slag is allowed to slump and pour through the center hole.

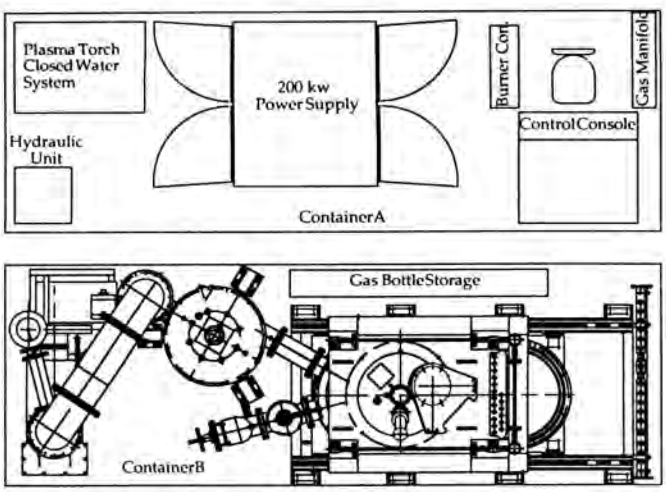


**Fig. 1. Plan view of piggyback containers.**

The slag pour is captured in a pig mold and allowed to cool. The resultant product is a homogeneous glassy material that resembles obsidian. It has been shown to be non-leaching. As a demonstration, a tropical fish tank has been set up where PCF slag is the predominant furnishing material. Fish tanks have a tendency to become acidic and the PH of this tank is in the 6.2 range. The fish, plants and algae all are quite healthy. Several generations of fish have successfully reproduced.

## GENERAL ASSEMBLY

Figures 2 & 3 are elevations of the PCF hardware. The main chamber houses the processing crucible and the slag mold. As it is intended for pilot studies, the equipment is a batch processing apparatus which necessitates a cooling off period before the slag can be removed from the chamber. The slag mold rotates with the processing crucible and is mounted directly below it. The mold is removed through an opening in the crucible support framework. Removal of the mold is accomplished via the chamber's full opening front door.

The entire processing area is gas tight and kept at a negative pressure. This design is based on similar metallurgical designs where isolation of the molten metal from the

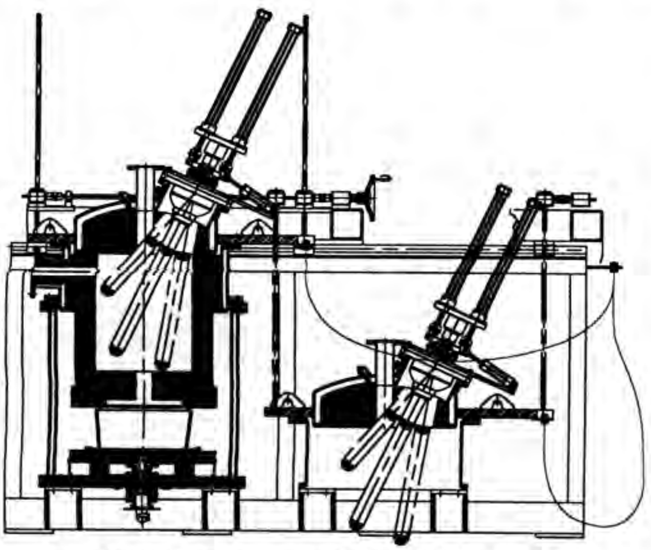

**Fig. 2. Side elevation of the Mobile PCF 2.**

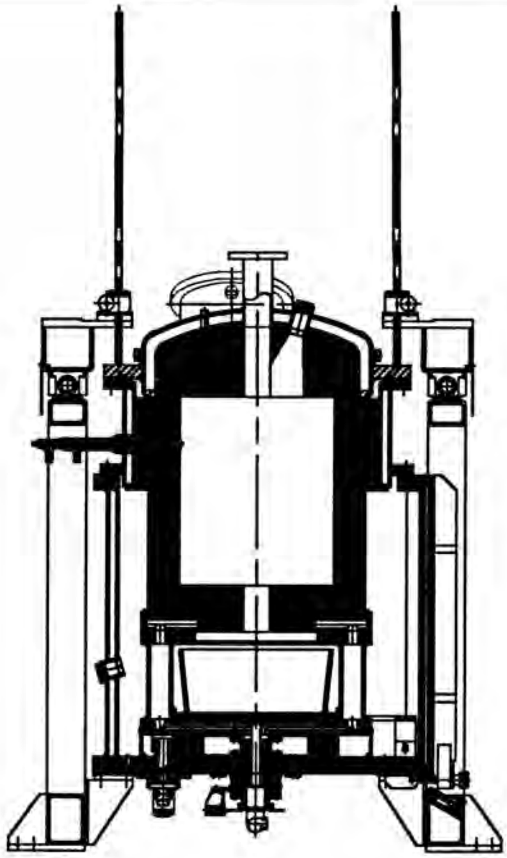

**Fig. 3. End elevation of the Mobile PCF 2.**

outside world is of paramount importance. The metallurgical heritage of the equipment allows the use of proven designs which insure that, from the moment it enters the PCF until processing is complete, the material being processed is completely isolated from the environment. In addition the mixture of gasses in the chamber is under full operator control. The amount of oxidant either from pure $O_2$ or air and the amount of inert or other gasses can be tailored to the needs of the waste treatment process.

The processing hearth rotates at speeds from 20 to 70 rpm. Modification of the rotational velocity provides a mechanism for the control of the molten slag. Increasing the velocity causes the slag to be spun out closer to the crucible walls thereby preventing the escape of molten material through the center hole. Decreasing the rotational velocity allows the material to slump and pour from the center of the crucible into the slag mold below. Since both crucible and slag mold are rotating at the same speed splashing is minimized and the pour is well controlled.

The chamber lid mechanism is designed to lift and slide sideways into a maintenance / shipping position. When the lid is in the maintenance position there is complete access to the interior of the crucible as well as to the plasma torch which is mounted within the lid. This configuration provides a straightforward way of monitoring the interior of the crucible in order to gather data on issues such as slag mixing, effects of the processed material on the interior, et cetera. The maintenance position is additionally designed to facilitate plasma torch inspection and maintenance. This configuration allows the operator to inspect and maintain the torch while minimizing the potential exposure to residual hazardous materials that may be present.

Once the lid mechanism has been moved over into the maintenance position, it may then be lowered into the shipping position. This feature significantly reduces the overall height of the equipment and enables placement in a standard container.

## PLASMA TORCH

The plasma torch that is used as the primary heat source is a Retech model RP-75T specifically modified for waste applications. This torch is based upon a similar device that is used in the aerospace metals industry for small scale metal melting.

As shown in Fig. 4, the torch consists of a hollow rear electrode, a gas injection ring and a nozzle. Once an arc has been established, gas enters the interior of the torch on a continuous basis through the gas injection ring. This gas enters tangentially and is swirling around the plasma column. Radiant energy from the plasma column heats up this gas. Some of the gas is pulled down the through the nozzle and out whereas the rest continues to heat up and rise around the periphery of the plasma column. Ultimately the gas becomes hot enough to be ionized into a plasma whereupon it changes direction and is ejected from the torch. As the gas is an ionized plasma, it is conducting current. This current must pass from the torch and through the slag bath on its way to ground. (The processing crucible is grounded with contact shoes to facilitate this.) While the unprocessed material and slag receive heat from Joule heating of the slag, radiation from the arc and from the recombination energy released as the current carriers return to the ground state, the predominant mode of heat transfer is due to the conduction and convection of the hot gas.

The heat from a plasma torch such as this is sufficient to melt virtually anything exposed to it. As a result any complex organics introduced into the system are quickly broken down into more basic constituents. The selection of plasma gasses is quite varied and can be such things as air, argon and oxygen or nearly anything else. This allows the added dimension of tailoring the plasma gas for desired processing results. As an example with a methane plasma gas the organics could be broken down and then the still combustible exhaust stream could be utilized for power generation. Alternatively, an oxidizing plasma gas could be utilized to allow most of the heat to be released while the material is still in the processing crucible.

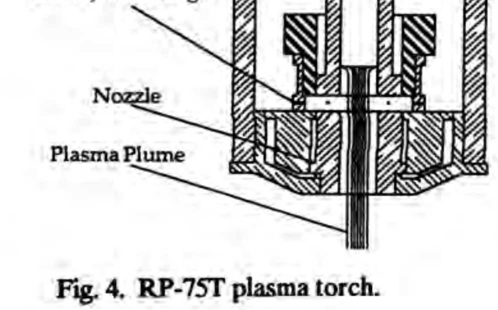


Fig. 4. RP-75T plasma torch.

## SCC

The Secondary Combustion Chamber is a vertical cylindrical vessel which is sized for a two second residence time at 140 normal cubic meters per hour gas flow and a maximum expected gas temperature of 1500°C. The SCC is water jacketed to prevent danger to the operators, as is especially appropriate for pilot scale processing equipment. The SCC has a tangential inlet at the top of the vessel, and a radial exit at the bottom of the vessel. We have found this design assures a longer retention of large particulate, and facilitates complete combustion.

The SCC is refractory lined. This assures energy efficient preheat, and minimizes the energy required to maintain minimum destruction temperatures by minimizing losses. To preheat the system and to maintain temperature, a 250 k-Btu/h (75kW) multi-fuel (propane or natural gas) burner is installed at the inlet end of the SCC. The burner uses compressed air to deliver combustion oxygen to the flame, so that in the event the system experiences a burp, or momentary over pressure no leak path back through the burner is present . To assure safe processing of dangerous materials, this pressure tight feature is consistent throughout the hot part of the PCF system. Compressed air jets are used in the SCC to complete combustion, although oxygen could be used for waste streams where the off-gas volume must be further minimized.

## GAS TREATMENT

The off gas system for the PCF-2 needed to be inexpensive, flexible, and compact to allow transport to various sites. It needed to assure acid emission control and particulate removal, and it needed to provide a rugged low maintenance system with the fewest possible secondary waste streams. Taking these considerations into account, Retech chose to utilize a small wet gas scrubbing system, consisting of a venturi quencher with a sump to collect particulate, a shaped packing for demisting, and an induced draft fan with a reflux line for pressure control in the primary chamber.

Other scrubbing systems including dry systems and more elaborate wet scrubbing systems were considered, but none could provide the flexibility in handling a wide range of feeds given the small package requirements of the PCF-2. It should be clear that a variety of off-gas treatment systems could be offered with the PCF-2 to accommodate different process needs and comply with applicable or relevant and appropriate requirements.

The wet part of the system is maintained at a pH between 8 and 9 through the addition of caustic soda. This control neutralizes virtually all of the HCl resulting from processing chlorinated hydrocarbons in the primary chamber. The caustic will also neutralize most of the SOx formed during waste processing. The wet portion of the system also quenches the off-gas from 1200-1400°C to 90°C very quickly, which avoids (minimizes) the formation of dioxins and furans which may form in the 350°C range. Other halogen generating wastes are also treatable, since the salts vaporized are water soluble, and generally will end up in the scrubber water. In general, wet systems offer superior flexibility in their ability to remove entrained particulate, metal fumes, condensed particles, and pollutant gasses from the off-gas stream.

Following the venturi quench, the gas is passed through a de-mister containing a wave form packing which traps the condensed water plus particulate droplets. These are rinsed from the de-mister packing by cool scrubber liquid to prevent fouling of the packing. From this point the gasses enter the induced draft fan, and are discharged to the stack.

The induced draft fan is rated at 7.5 hp, and provides 25" of water vacuum at the fan inlet. This translates into 5-10 " of water vacuum in the primary chamber. A reflux line handles changes in the flow of gas generated in the PCF reaction chamber, as the gas generation can vary, depending on feed, moisture content, and organic content. A damper on the reflux line controls the primary chamber pressure by taking a signal from a pressure transducer to proportionally open and close the reflux line to maintain an operator selected set point, usually 10-15 inches of water vacuum.

The plasma torch in the Retech PCF 2 is expected to produce about 400 g/h of NOx when operated on nitrogen. This 0.9 ton per year (based on 8 hr days, 250 days per year) $NO_x$ production is well below the 40 tons per year limit. The PCF has been shown to do an excellent job of destroying hazardous organic compounds, and to burn completely all organics, so no off gas system provisions have been included for trace hydrocarbons removal from the off-gas. The off-gas system is designed to remove 99% of the particulate produced by processing, which is below the .18 g/Nm$^3$ (.08gr/dcsf) limits.