

DESTROYING LLW AND HAZARDOUS WASTE ON-SITE WITH THE SYNTHETICA STEAM DETOXIFIER

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ABSTRACT

The amount of hazardous waste and low level waste generated in the country is growing at a steady rate, yet the options for effectively dealing with these waste streams are becoming fewer and fewer. In this paper we discuss a new technology that holds considerable promise for dealing with LLW and hazardous waste. The Synthetica[®] Detoxifier (STD) does not use air combustion and has no flame – quite different from incineration. It carries out hazardous waste destruction by very high temperature steam reforming (i.e., 2000 to 2700°F), and is only 4 ft x 6 ft x 7.5 ft in size. Vent gases are carbon dioxide and water. Destruction and removal efficiencies (DREs) exceed 99.99% for even the most refractory organics. The capacity is from 2 to 5 drums per day, or a ton per day, depending on the type of waste being processed. The STD combined with a Heated Shredder Evaporator feed system has shown considerable success reducing the mass and volume of low level waste (up to 50 fold reduction). A list of some of the many waste streams that have been processed with the STD are presented.

The STD, with its low-risk operation, small size and the fact that it is not an incinerator greatly simplifies siting and permitting in today's environment. User advantages are that it eliminates risky transportation of hazardous and low-level wastes and terminates their liability with their generated waste for a fixed cost. Costs are less than half that for incineration or landfilling.

INTRODUCTION

The low level radioactive waste (LLW) problem in the United States is serious. When combined with the problems associated with hazardous waste, it is almost overwhelming. The ever-increasing quantity of LLW and hazardous waste combined with the fact that landfilling is fast becoming economically unviable and the fact that incineration is fast becoming politically unviable means that alternative methods for reducing the volume of waste must be found. The Synthetica Detoxifier[®] (STD) addresses the economic and political concerns and presents a serious option to those organizations and locations dealing with LLW and/or hazardous waste.

The Synthetica steam-reforming technology was developed in response to the need for low-risk, on-site destruction of hazardous waste. It is this area where incineration and landfilling, both once very popular, are becoming unviable. Further investigative work showed that the STD combined with the right feed system could also handle LLW very well. It should be apparent that this technology, developed to handle hazardous waste, would be ideal for mixed waste; i.e. LLW waste mixed with hazardous waste.

Before getting into the details of the Synthetica technology, it would be instructive to examine the main alternative technologies for waste destruction.

INCINERATION

Conventional incinerators are usually of the rotary kiln type, where natural gas or fuel-oil-fired flame combustion is generated at one end of the rotating, brick-lined cylinder. Liquid waste is normally introduced at the location of the flame and is subjected to a variety of effects -- mixing, convection, vaporization, radiation, aerosol and solid particulate formation, products of incomplete combustion (PIC) formation, etc. (9-11). The residence time for which the waste is actually in the flame region may be much less than one second -- in fact, the residence time may be as short as 10 milliseconds. In other words, the majority of valuable residence time for the waste is consumed in getting the liquid waste heated and

vaporized to the high-temperature vapor state, at which point the actual destruction chemistry can just begin. The destruction processes cannot begin until the waste components are in the vapor state and up to temperature.

Once the waste has reached the high-temperature vapor state, there is an induction time before the destruction combustion chemistry actually takes place -- further consuming valuable residence time. Then, as part of this destruction combustion chemistry, PIC's are formed, sometimes on the particulate material that is formed in the original combustion chemistry process. These PICs are formed after the combustion chemistry has occurred and therefore takes place, in sequence, later in time after even more valuable residence time is consumed. Finally, these PICs need to undergo combustion destruction, but usually there is very little remaining high-temperature residence time. And PIC destruction kinetics are slow, especially when halogenated aromatic hydrocarbons are involved. To partially correct this serious problem, incinerators are now usually retrofitted with a secondary combustion chamber which is forced to operate at unreasonably high temperatures and long residence times, consuming costly fuel and creating high NOx.

This above scenario of the incinerator destruction combustion process helps one understand why it is so difficult to get PIC destruction to occur satisfactorily before the combustion gases carry the unconverted waste out of the hot flame region into the much colder (i.e. 1000°F) stack gas region downstream. In these colder and cooling spent combustion gases, any further waste destruction chemistry is quickly quenched and the unfavorable thermodynamic equilibria are frozen by slowed kinetics.

LANDFILLING

The disadvantages of landfilling are obvious. The number of landfills is being reduced as they are filled, with new ones slow to open due to the obvious political considerations (the Not-In-My-Backyard syndrome). Furthermore, the number of different wastes allowed to be landfilled has been greatly limited by legislation over the last few years. Finally, the

cradle-to-grave liability issue makes landfilling a distasteful option; few, if any, generators enjoy the ongoing uncertainty.

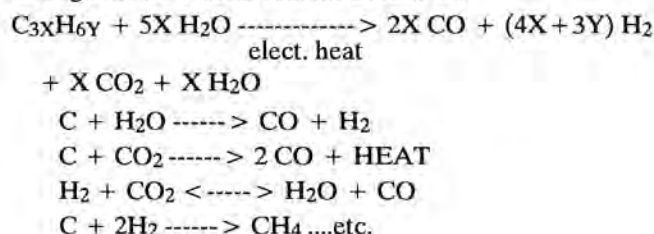
THE SYNTHETICA TECHNOLOGY: A STEAM-REFORMING APPROACH

The Synthetica Detoxifier[®] (hereafter STD) consists of a two-step process (4,5). The hydrocarbons of the waste are first evaporated in a first-stage and separate "waste feed evaporator" process unit (hereafter WFE), that can have a variety of forms depending on the type and form of the waste. Within the WFE, the hydrocarbon vapors are first exposed to superheated steam. In the WFE, steam reforming chemistry starts to occur at temperatures from 600 to 1100°F. The steam reforming of the hydrocarbon forms CO, CO₂, H₂O, H₂, and a small amount of CH₄. These gases generated in the WFE are heated to higher temperature and mixed with excess superheated steam as they are pulled into the main reactor, where the reactions below proceed further to completion.

Figure 1 shows a schematic of the important operational features, where the process is illustrated with the WFE being a simple "Drum Feed Evaporator", a feed system most suitable for liquid hazardous waste. Shown at the left, the vapor stream from one or more 55-gallon drums within the evaporator is pulled into the STD under a slight vacuum. The vaporization of the hazardous waste occurs in the drum(s), shown at the left in Fig. 1. After the STD removes the toxic organics, hot steam-reformed gas is generated and recirculated out to the evaporator to pick up more hazardous wastes. A small vent stream of clean gas is slowly released to maintain pressure balance. The system is fully automatic, so that the waste handler simply places the waste in the WFE, selects the waste type, WFE type, and presses the "on" button.

CHEMISTRY

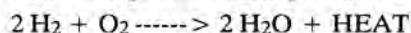
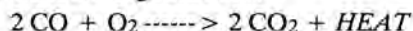
The new detoxification chemistry used in the STD does not involve combustion, as is commonly practiced in incineration. The idealized main chemical reactions, which can be considered to be chemical reduction, occur from the WFE through the STD main reactor as follows:



Although the steam-reforming chemistry is just started in the WFE, it continues to very-near completion as the gas temperature increases along its path through the system, into the main reactor and more reaction occurs with superheated steam. The residence time of 1 second in the nearly isothermal main reactor is entirely at elevated temperature; there is not the only brief exposure to high temperatures as in the incinerator flame region.

Our steam-reforming approach (covered by several issued United States patents) avoids the problems in incineration where valuable residence time is used up in getting the waste to vaporize, going through induction delay, through slow combustion kinetics, PIC formation delays, and finally PIC destruction before this gas is cooled following the flame region. Also the STD main chemical reactor is heated electrically, so that the gases are free of the fuel combustion-produced particulates – so typical of incinerators that adsorb the PICs onto fly-ash and carry them out of the incinerator.

After the CO, CO₂, H₂O, & H₂ gases are formed in the main Synthetica reactor, a small portion are split off the main flow and are either fed to the Catalytic CO Converter, Fuel Cell, Synthesizer, or the Reclaimer. In the CO Converter, excess air is added to convert these gases to CO₂ & H₂O, as per the following reactions:



The heat of reaction released in the CO converter is recovered and reused in the process. The CO Converter catalyst also destroys further any residual toxics that might be present. The Fuel Cell can make electric power, the Synthesizer can produce valuable organic products, and the H₂-Reclaimer can recover H₂ fuel.

Consequently, the STD achieves high destruction levels over 99.99%. Table I illustrates this for a wide range of organic tracer compounds. More details are available (6) from Appendix A of the California State Department of Health Services Grant Program Final Report.

In addition to the >99.99% destruction of the waste feed tracer compounds (POHCs under EPA's RCRA law), the measured air emissions have low risk levels (7-8). Since the STD operates at high temperatures, in the range of 2000°F up to 2700°F and it does not use fuel-air, or flame, or combustion of the hydrocarbon liquid hazardous waste, it avoids the troublesome particulate, SO_x, NO_x emissions, and incinerator products of incomplete combustion (PIC's) (3).

THERMODYNAMICALLY REFORMED COMPOUNDS (TRC'S)

Thermodynamic equilibrium is approached in any high temperature organic destruction process, whether it is incineration by combustion or by steam-reforming. Incineration tends to form very toxic chlorinated dibenzo-*p*-dioxins or dibenzofurans, whereas the Synthetica steam-reforming-type chemistry tends to form light olefins and aromatics. Using high resolution GC/MS for aromatics, we typically find low levels of benzene, toluene, xylenes, naphthalene, styrene, acenaphthenes, etc. near the detection limits.

In addition to the above, the STD was run on high-level chlorinated organic feeds and work has been done with XAD2 sorbent tube traps to look for dioxins and furans. Results have shown that Dioxin (specifically 2,3,7,8-TCDD) was not detected below the level of detection at 3.7 picograms. Environ

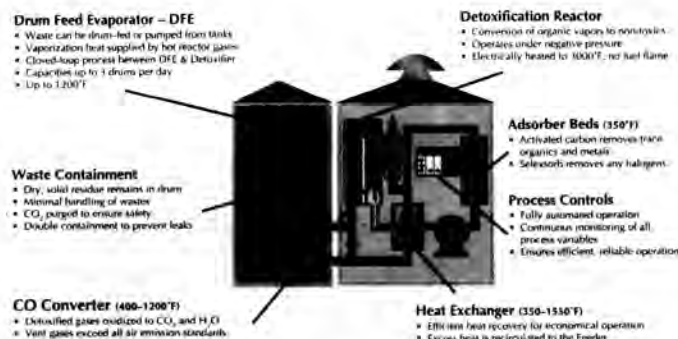


Fig. 1. Schematic of operational features.

TABLE I
Summary of Typical Test Results

| COMPONENT (POHC) | STD CORE °F | SYNFEED % | STD EXIT ppb org. | STD EXIT ppm CO | DRE LEVEL,% |
|------------------------|----------------|--------------|----------------------|--------------------|----------------|
| Acetone | 2170 | 66 | -- | - | 99.9995 |
| Carbon Tetrachloride | 2100 | 33 | 21 | -- | 99.9952* |
| Chloroform | 2100 | 33 | 7.8 | -- | 99.9992* |
| Dichlorobenzene | 2050 | 5 | -- | 2930 | 99.9904§ |
| Isopropanol | 2100 | 19 | 6 | 4500 | > 99.9994 |
| Methanol | 2100 | 35 | -- | 11500 | > 99.9996 |
| Methylene Chloride | 2100 | 33 | 16 | -- | 99.9978* |
| Methyl Isobutyl Ketone | 1800 | 25 | < 10 | -- | > 99.99* |
| 1,1,1-Trichloroethane | 2000 | 1 | - | 163 | 99.9916§ |
| Xylene | 2024 | 1 | -- | -- | 99.9926 |

NOTE: All results were obtained from tests conducted on STD #2001, unless noted by (*) for STD #1001, a prototype unit that was operated at Hercules, CA, or noted by (§) for STD #2002, the latter having large condensate corrections. Note that the > symbol is used for the DRE when the analytical results are at the limit of instrument detection and only a lower bound can be determined. So that in the case of isopropanol, the DRE is over 99.9994% but the exact DRE can only be determined with either higher isopropanol concentrations in the feed or a longer sampling on the adsorption tube or a smaller amount of sorbent inside the sorbent tube (not available commercially).

(8) has used the actual halocarbon feed concentrations together with these TCDD data to calculate a risk level of 1.6×10^{-8} , some 60 times lower than the EPA and BAAQMD "de-minimis risk" level set at 1×10^{-6} .

Table II is a summary of STD main high temperature reactor emissions. These results were obtained for the typical halocarbon solvent mixtures (66% acetone, 32% xylene, 1% 1,1,1 TCA, & 1,2 DCB) under the Grant Program testing with the STD operating without any air emission abatement devices.

Two types of abatement devices have been tested -- the CO catalytic converter (removing >97% of the organics), activated carbon beds (removing >95% of the organics and volatile inorganics, and a halogen adsorber (removing 95%). These standard devices on the STD typically reduce the organic emissions by a factor of 500 to the point where only benzene can be detected at very low levels.

THERMODYNAMIC EQUILIBRIUM PREDICTIONS

In support of the experimental program and related discussion of results outlined above, Synthetica's global Gibbs free energy minimization modeling effort (9-10) is now summarized. The code was run for a wide variety of synfeed mixtures tested in the STD. Concentration of all reactor prod-

uct species were calculated down to levels of 1 ppb, covering the temperature range from 0 to 1800°K or 2800°F. The output tabulates and plots all of the species (with solid carbon kinetically frozen out) considered simultaneously in this equilibrium, free energy minimization calculation.

The concentrations of each of the STD reactor product species as a function of temperature were calculated down to the 1 ppb level. We have run many hundreds of calculations, but illustrate with a few here. At typical reactor core temperatures of 1800 to 2000°F, the dominate species within the hot reactor are H₂, CO, H₂O, and CO₂, varying from 57.9%, 25.5%, 12.9%, and 3.6%, respectively. In Figs. 2 & 3, the feed mixture of 68% acetone, 19% IPA, 9% methanol, 1% xylene, 1% butanol, 1% TCA, 1% DCB, and 30 & 50% excess water was calculated. The results are very typical of most waste mixtures. Benzene and naphthalene levels are dropped 25 times lower and then only increased as the temperature exceeded 2000°F.

A NEW DIRECTION

The STD provides a unique approach for the destruction of hazardous waste in the electronics, petrochemical, petroleum, and general manufacturing industries and the destruction

TABLE II
STD Main High Temperature Reactor Emissions

| | | | |
|------------------------|--------------|--------------------|-----------|
| Carbon dioxide | 80% | Water | 15% |
| Hydrogen | 1.4% | Light hydrocarbons | 3.3 % |
| Carbon monoxide | 2,000 ppm | NOx | 0.3 ppm |
| Particulate Mat., PM10 | < background | Hydrogen chloride | 4 ppm |
| 1,2 Dichlorobenzene | 4 ppm | 1,1,1 TCA | 3 ppm |
| 2,3,7,8 TCDD | < 0.3 ppt | 1,1,2 TCA | < 0.3 ppm |
| Acetone | 30 ppm | Xylene | 30 ppm |
| Benzene | 9870 ppm | Toluene | 300 ppm |
| Ethylbenzene | < 40 ppm | Styrene | 40 ppm |
| Benzyl Chloride | 40 ppm | Naphthalene | 40 ppm |

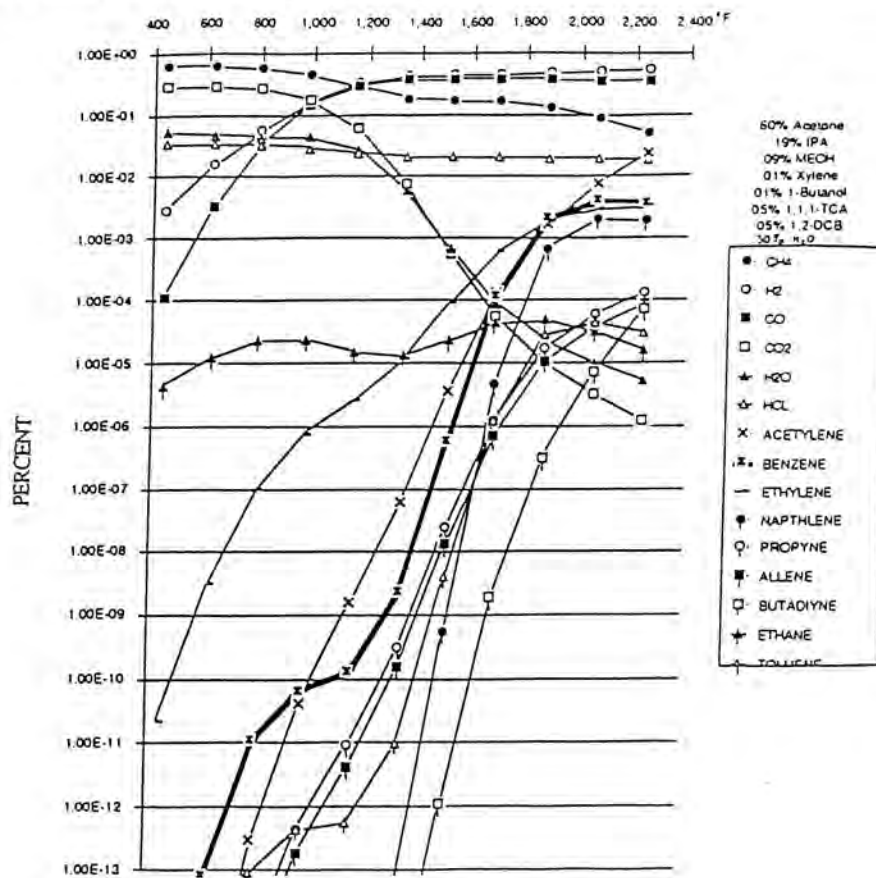


Fig. 2. Effect of 30% excess water on Acetone-IPA-MeOH-C4OH-C4OH-Xylene mixture spiked with 5% TCA and 1% DCB.

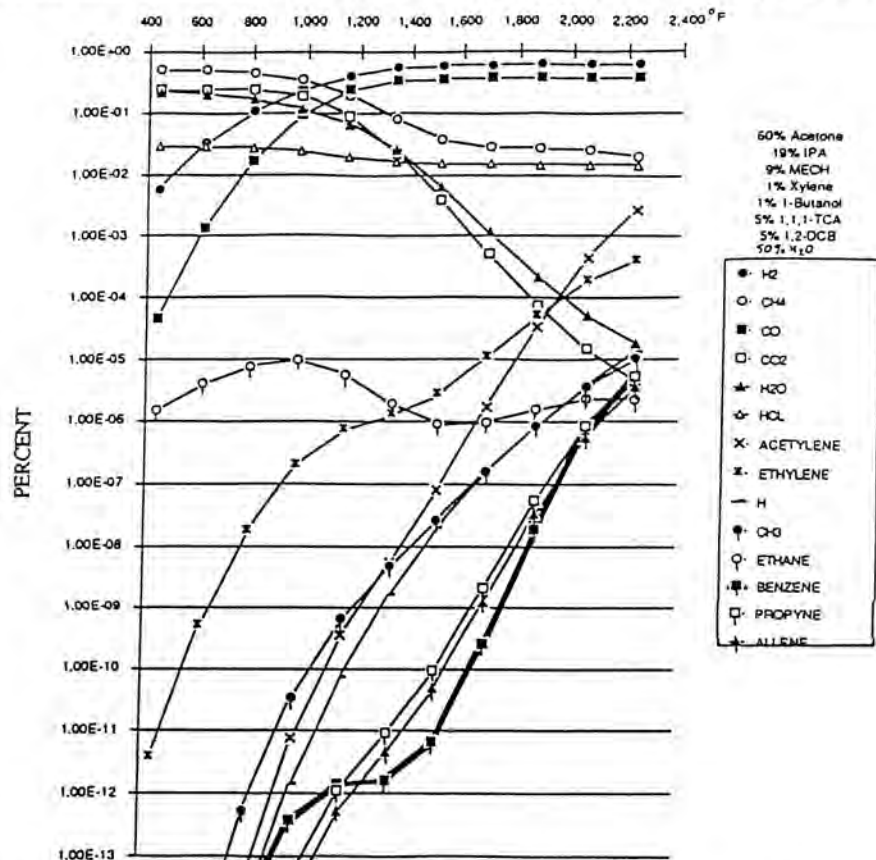


Fig. 3. Effect of 50% excess water on Acetone-IPA-MeOH-C4OH-Xylene mixture spiked with 5% TCA & 1% DCB.

of LLW for utilities and other generators of LLW (see Fig. 4). The STD's operating characteristics are:

- Achieves destruction levels of 99.99% or more.
- Is small enough to fit into a building's mechanical area.
- Provides acceptable installation costs.
- Destroys liquid solvents and their contaminants.
- Destroys organic contaminants adsorbed on activated carbon
- Destroys organics in the vapor state.
- Processes continuous liquid feed streams.
- Processes drummed wastes without removal from drums.
- Operates high-temperature waste feed evaporator for solid organics.
- Serves as part of a process to purify ground water.



Fig. 4. Synthetica detoxifier coupled to drum feed evaporator.

The STD is 4' x 6' x 7.5' and uses standard industrial power. The DFE involves feeding from the evaporator containing a drum of waste that produces a hot vaporized gas stream of the waste which is blended with carrier gases and then fed into the STD. Alternatively, wastes can be continuously fed from tanks into an evaporator which internally produces a vaporized stream which feeds the STD. Any inorganic residue stays behind in the drum. Several different types of evaporators, such as Moving Bed Evaporator, Heated Shredder Evaporator, and Heated Screw Feed Evaporator are available for feeding waste to the STD.

Liquid organic hazardous waste are fed continuously into the evaporator connected to the STD with little or no preprocessing. The vaporized hazardous components are processed directly. If there are any solids present or heavy organics, the residue is left in a drum in the evaporator for later landfill disposal. The STD can process as low of a concentration of

contaminants in aqueous waste or ground water with organic as the customer wants.

Heavy solid-liquid slurries or thick liquids that are difficult to vaporize directly in a standard drum can be fed into a Moving Bed Evaporator that vaporizes all volatiles and produces a powdered residue at the outlet. The volatile vapor stream exits at the top of the unit and is drawn directly into the STD.

For LLW, a Heated Shredder Evaporator (HSE) (see Fig. 5 above) is used. This unit shreds and grinds up the waste and simultaneously heats and volatilizes the liquids away from the solid residue. Typically, the mass and volume of the LLW is reduced by 25-100 times, producing a small amount of residue for disposal in an appropriate landfill.

Solvent or organic hazardous waste-contaminated building air or ground water can be processed by the STD preprocessing scheme that involves an activated carbon adsorption bed which concentrates the hazardous waste. After this concentration step, the carbon canister can then be reactivated by the STD. This process has the advantage of being able to handle low contamination levels. The activated carbon vessels may either be reactivated in place with hot gas from the STD, or from small canisters, in the Drum Feed Evaporator. The process is also inexpensive to operate, small in size, and can be incorporated into the building's utility system. Operational costs and amortized capital are competitive with present waste hauling and disposal costs.

STD CONTROL SYSTEM

The STD has a unique control system that makes it ideally suited for an on-site treatment application. The operation is highly automated through the application of the latest computer technology -- distributed process controllers, fail-safe circuitry logic, 4-level redundancy, on-line process modeling, error checking, etc.

As the result of the above, the STD achieves consistently and without failure the highest destruction levels available and has such low risk levels that locations in an urban and residential setting are acceptable to the public. The STD has four levels of safety features in the control system design that ensure a very high level of safety that is not found in the industry today (United States patents in process). Since the STD operates at high temperatures, typically from 2000°F up to 2700°F, and does not use air, flame, or combustion, it avoids the troublesome NOx emissions, and the oxygen-radical catalyzed formation of products of incomplete combustion (PIC's) without special downstream emissions controls.

ADVANTAGES OVER CONVENTIONAL INCINERATION

The key features in the STD technology⁹ are the use of the atmospheric pressure, steam-hydrocarbon reforming-type chemistry using non-combustible mixtures in a unique chemical reactor design that provides the right turbulence, temperature, and residence time to get over 99.99% destruction; a process unit operation and piping system that provides the optimal technical requirements for this chemistry, safety features, and energy recovery; and a waste feed evaporator that receives the waste input and provides the right gas chemistry conditions and vapor streams for the steam-hydrocarbon reforming destruction. For more details, the reader is referred to previous publications (1-12).

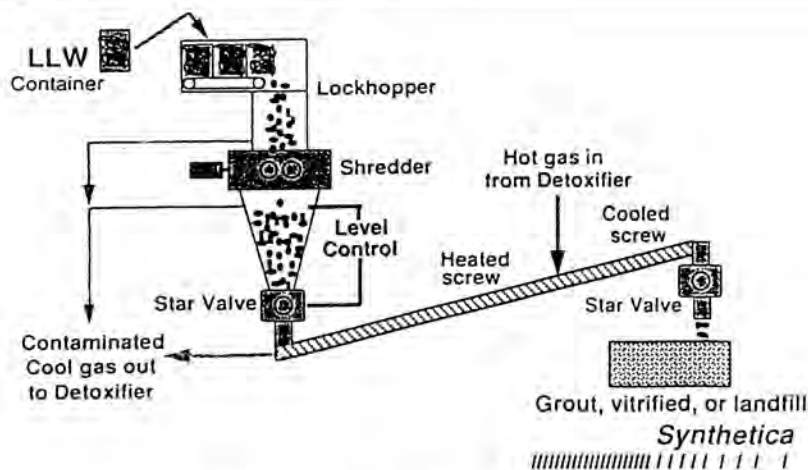


Fig. 5. Heated shredder evaporator for coupling to STD.

| Present Incinerator Technology | Synthetica Detoxifier |
|---------------------------------------|---|
| Explosive Mixtures | Non-explosive Mixtures |
| Oxygen-Hydrocarbon Combustion | Steam-Hydrocarbon Reforming |
| Exothermic Chemistry | Endothermic Chemistry |
| Positive Feed Pressure | Negative Feed Pressure |
| Waste Handling | No Waste Handling |
| No Leak Detection | On-line Leak Detection |
| Physically Large Units | Physically Small Units |
| Usually Off-site | Compact, On-site Unit |
| Risk Levels Around 5×10^{-5} | Risk Levels Around 1.6×10^{-8} |
| Problematic Toxic PICs & TRCs | Insignificant TRCs |

SOME TYPICAL APPLICATIONS

The Synthetica steam reforming-type chemistry is suitable for a wide variety of waste streams (solid, liquid, or gaseous), such as solvent wastes; water; water with organic toxic contaminants; paint, printing ink, glues, and sealants; medical, infectious, and low level radioactive wastes (including those mixed with RCRA wastes); loaded activated carbon (vapor- or liquid-phase); spent adsorbents and catalysts; organic-contaminated soils; spent filters of all kinds (automotive, diesel, etc.); off-spec or discarded pharmaceuticals, medicines, drugs, etc.; pesticides; chemical weapons, napalm bombs, missiles, etc.; spent classified printed circuit boards and command and control systems; some explosives; and many more. Considerable experimental work has been done evaluating the effectiveness of the Synthetica steam reforming-type chemistry on several waste streams. The following is a list of some of the detailed experimental reports available upon request (summaries of the experimental work with waste solvent-contaminated rags and mixed cellulosic & plastic waste are included with this paper as appendices).

- Reactivation of Granular Activated Carbon
- Results from Cresote Waste Destruction
- Results from Waste Solvent-Contaminated Rags
- Mixed Cellulosic & Plastic Waste
- Destruction of Paint Waste Sludge On-Site
- Results from Waste Paint Cans

COSTS

The cost savings with the Synthetica steam-reforming-type chemistry can be dramatic, as shown in Table III. The data for Medical Waste are shown for comparison purposes; although the Synthetica technology disposal option is more expensive today for generators of medical waste, there is considerable interest in the Synthetica technology because of the obvious upward trend in offsite disposal costs.

TABLE III
Cost Comparisons - Synthetica Vs. Conventional
Disposal Costs \$/ft³

| | Synthetica | Landfill | Incineration |
|-----------------------------|------------|----------|--------------|
| Hazardous Waste | \$10 | ~\$50 | ~\$100 |
| Medical Waste | \$10 | ~\$5 | ~\$5 |
| Low-Level Radioactive Waste | \$10 | ~\$55 | ~\$25 |

The data in the table for Synthetica reflects the total cost of the installed system amortized over eight years, with the system processing 50,000 ft³/yr., and includes all operating, maintenance and residue disposal costs. The costs for landfilling and incineration are July, 1993 estimates; the landfilling cost estimate assumes the generator is part of a sited compact. Non sited compact landfilling costs are currently around \$320/ft³ and this option will probably not even be available after June 30, 1994 when the Barnwell, S.C. site closes to non Southeast compact states.

CONCLUSIONS

The Synthetica steam reforming-type chemistry significantly reduces the toxic air emissions below those of incinerators. Since the STD is electrically heated and no air-fuel combustion is needed, all of the typical combustion-type pollutants such as NO_x, SO_x, particulate, etc. are eliminated. The typical incinerator emissions such as the polychlorinated dioxins, furans, and benzopyrenes are reduced to below analytical levels of detection. The particularly toxic halogenated aromatics found in incinerator emissions are not significant in the STD since this steam reforming-type chemistry cleaves off the halogen from the ring. There is also experimental evidence

of aromatic dealkylation and alkylisomerization reactions. Thus, the mechanism of the destruction chemistry is first cleaving halogens, then aromatic alkyl substituent groups, then alkyl group translocation, then some ring cleavage and ring additions. This can be seen by the relative conversion of feed xylene into toluene, benzene, styrene, naphthalene, dichlorobenzene, benzyl chloride, etc. This is a productive area for more mechanistic incite and computation.

We are very pleased with computational thermodynamic equilibrium results, since they not only tend to confirm our experimental observations, but give us a quick diagnostic and predictive capability for exploring process optimization conditions in operating the STD for a large variety of feed organics.

We have also provided a variety of examples of waste streams or simulated streams that have been detoxified with the Synthetica Detoxifier system to produce either no residue or a non-hazardous residue. The range of waste and waste forms is very broad and they can be gaseous, liquid, or solids. The system is sized for the small generator for their onsite use to meet the environmental regulations of the future world-wide.

Based on considerable experimental data, it is apparent that low level radioactive waste can be successfully handled in the STD. The cost/benefit ratio is dramatic: the STD will reduce the volume of the waste by as much as 100 times and the mass of the waste by as much as 50 times while doing so at a cost that is less than one quarter of the cost for incinerating and/or landfilling the waste. Additionally, Synthetica has successfully developed a program for LLW based on their experience with the State of Washington; this program could easily be adapted for the onsite destruction of LLW anywhere in the world.

ACKNOWLEDGMENTS

We wish to thank the California State Department of Health Services staff for their encourage and support, NASA for the use of their CEC1 rocket combustion code, and Tom Green for his valiant success in converting the CEC1 code from Cray XMP use for efficient use on the Mac-IIfx computer.

APPENDICES

Results From Waste Solvent-Contaminated Rags

A demonstration test was done on a 55-gallon drum about 70% full of 10-inch square, standard shop rags (dyed red in color) mixed with 30% shredded rags, paper, clothes, etc. The rags were tossed into the drum with no attempt to compact or compress the load. The shredded rags were placed in the center of the load and were not distributed with the 10-inch red rags. The total mass of rags was 26 lbs. Table IV gives composition of the organic chemicals, oils, and solvents that were added onto the rags.

The drum was placed into the Drum Feed Evaporator and the temperature ramped up from room temperature to around 1025°F. After 2.5 hours at temperature, the DFE was cooled quickly and opened to inspect the condition of the rags. Unprocessed rags were found in the center of the load. The drum was replaced into the DFE and the temperature held at 1025°F for another 6 hours until no indication of any on-going detoxification chemistry by the CO sensors. The DFE was cooled and the drum removed, and the residue collected for a final weight of 0.5 lbs.

TABLE IV
Composition of Organic Chemicals, Oils, and Solvents
Added onto the Rags

| Organic | Volume Added | % |
|------------------------------|--------------|-------|
| 1. Trichloroethane, TCA | 125 cc | 20.5 |
| 2. Methyleneethylketone, MEK | 125 cc | 20.5 |
| 3. Paint Thinner | 50 cc | 8.2 |
| 4. Brake Oil | 210 cc | 34.4 |
| 5. Sump Oil | 100 cc | 16.4 |
| | | 100.0 |

The volume reduction was from 40 gallons (5.3 cubic feet) to 1/2 quart (0.016 cubic feet) or 1/320 of the original volume. The weight reduction was about 25 lbs to 0.5 lbs, or 1/50 of the original weight. The volatiles had been removed, so that the residue solids can be disposed by Class 3 Landfill. The residual metals are covered below.

Mixed Cellulosic & Plastic Waste

The purpose of these pilot-scale tests was to simulate the steam-reforming chemistry of the STD-Heated Shredder system for mixed cellulosic and plastic wastes destruction to remove all toxic organics from the mixed waste and still leave behind a small volume of residue for final safe disposal. This test was done at 1025°F for a residence time of 1.5 hours with the following mix of materials out of the box sent by the customer to us:

| | |
|-------------------|--------|
| Cotton Gloves | 16.20% |
| Mop cotton | 25.98% |
| Paper Towels | 7.37% |
| Paper Suit | 8.23% |
| Rubber Gloves | 29.07% |
| Clear Plastic Bag | 13.15% |

The residue was very small in mass, only 8.49% of the original mass feed. This is a twelve-fold reduction in mass from the original material. These processing conditions were found to be excellent at 1025°F for a residence time of 1.5 hours.

Samples of the residue were submitted to an EPA-certified laboratory where two analyses were done. The first test was for corrosivity and the results indicated that the pH of the residue was 9.83. This is well below the pH < 12.5 corrosivity trigger level under Washington State Regs.

The second analysis was designed to look for any of the California State CAM 17 metals that would be above the level of detection.

The conclusion from these tests are that the solid residue produced from our steam-reforming tests would be **Non-hazardous** under Washington State regulations.

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