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Project Summary

Minipilot Solar System: Design/Operation of System and Results of Non-Solar Testing at MRI

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A Minipilot Solar Reactor System (MSRS) with liquid organic feed was designed, constructed, and tested without solar input (the solar tests were to be done later at DOE's National Renewable Energy Laboratory). The non-solar tests were done to determine whether use of EPA's sampling and analysis methods would allow quantitation of the expected significantly lower organic emissions when the MSRS is operated with solar input.

Results of the 10 tests showed that it should be possible to determine if there is a significant reduction in emissions (>3X) when operating with solar input. Such reduction in the emissions should be determinable for two of the principal constituents contained in the synthetic feed liquid (CCl_4 and dichlorobenzene), for both the volatile and semivolatile products of incomplete combustion (PICs), and for dioxins and furans. But reductions are probably not determinable for the other two feed constituents (toluene and naphthalene). Results also showed that a three-fold reduction in volatile PICs occurred in both single-chamber tests when an artificial UV light was utilized.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

A Tri-Agency effort was initiated in 1991 to develop solar technology for the destruction of hazardous wastes. The three Agencies are EPA (RREL, the Risk Reduction Engineering Laboratory), DOE (NREL, the National Renewable Energy Laboratory), and DOD (USAEC, the U.S. Army Environmental Center). As part of the Tri-Agency effort, EPA's RREL set out to design, construct, and test an MSRS with liquid organic feed. The system was designed to enable the study of the destruction of organic compounds and the emission of PICs when combustion of the liquid organic feed was augmented with concentrated solar input.

This project did not involve use of solar energy for desorption of organics from soil. Rather, it was directed to the use of solar energy for destruction of organics that would be desorbed from soil by conventional low-temperature thermal desorption, with recovery of the desorbed organics in liquid form prior to their solar destruction. Advantages of this concept are that it utilizes conventional desorption equipment and enables soil desorption operations to be continuous (that is, independent of solar availability). Also, this concept enables the solar destructor to be relatively small since it needs to process only the amount of organics recovered as liquid from the soil desorption operations.

Testing of the MSRS was intended to include the determination of the degree of destruction of principal organic hazardous constituents (POHCs) and the emission of PICs, when operating with concentrated solar input using facilities at DOE's National Renewable Energy Laboratory. It was first necessary, however, to conduct tests without solar input to determine if it would be possible to quantify significantly lower levels of emissions that might be provided by solar input.

The system has not yet been tested with solar input, but testing without solar input has been completed. Those "non-solar" results are summarized here, along with results from tests done with the input of artificial ultraviolet (UV) light.

Methodology

The MSRS was designed to operate in either of two modes: single or duel chamber. In the single-chamber mode, the liquid feed is combusted in one chamber that is equipped with a quartz window for the concentrated solar rays to enter. In the dual-chamber mode, the liquid is combusted in one chamber and the gases then enter the second chamber which is equipped with the quartz window.

The entire system consisted of many components including the feed and control of liquid organic and combustion air, and effluent gas monitoring and cleanup (see Figure 1). It was fully equipped with process monitoring instruments, flame detectors and other safety shutdown interlocks, continuous emission monitoring of CO, 0_2, and THC, and computerized data logging and control.

The design of the system was based on a liquid organic feed rate of 11 g/min. and an air feed rate of 10 ft^3/min. Each reactor chamber was 10.5 in. inner diameter by 36 in. long with approximately 4-in.-thick internal insulation and 4-in.-thick external insulation (see Figure 2). Operating temperatures could be varied over a range of 1400° to 2000°F.

The composition of the synthetic liquid organic feed to be used in most of the non-solar and solar testing was selected by the Tri-Agency group. Its composition was:

POHC/Fuel Oil Blend	
• No. 2 fuel oil	40%
• o-Dichlorobenzene (DCB)	40%
• Carbon tetrachloride (CCl_4)	10%
• Naphthalene	5%
• Toluene	5%
	100%

After initial operation of the system and preliminary testing with an on-line gas chromatograph/electron capture detector, tests were conducted using EPA Methods 0030 and 0010 (volatile organic sampling train [VOST] and modified Method 5 [MM5]) to quantify the emissions of the POHCs listed above and the emission of PICs. As noted previously, the primary purpose of these tests was to measure emissions in the non-solar mode in order to determine if significantly lower emissions could be quantified when operating with solar input. This was determined by comparing the measured emissions with the detection limits of the methods and blank levels.

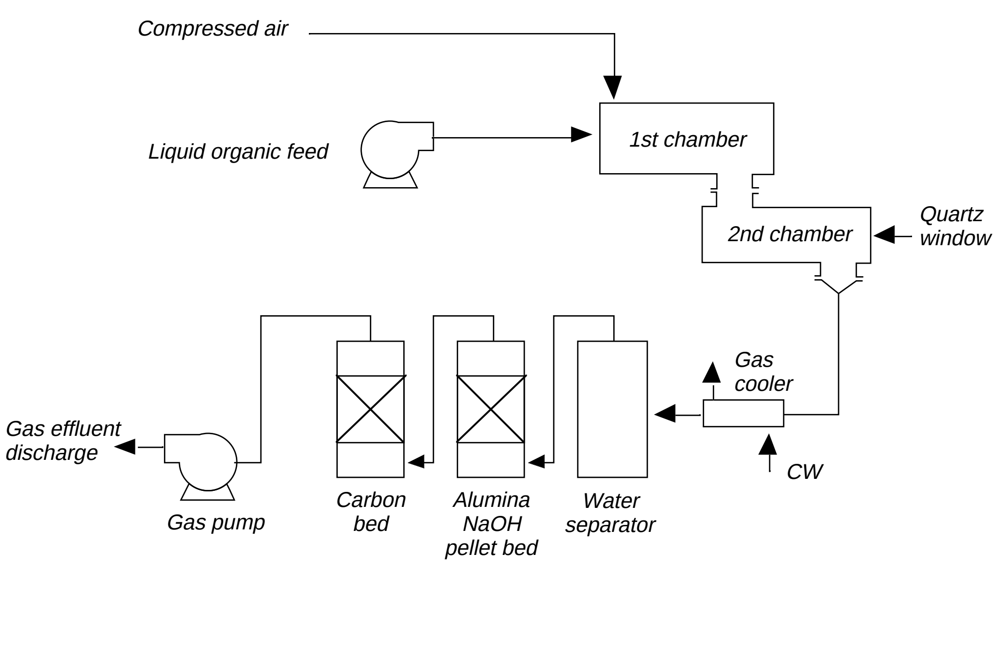

Figure 1. *Simplified schematic diagram of Minipilot Solar Reactor System.*

Results

A series of 10 tests, without solar input, was carried out using the EPA methods (VOST and MM5). This series included tests in both the single- and dual-chamber modes at two waste feed and air input flow rates (referred to as "low flow" and "high flow"). Four of these tests were done with the input of UV light to simulate the solar tests that were to follow at DOE/NREL's "High-Flux Solar Facility" located in Golden, CO. All tests involved analysis of samples for POHCs and PICs, and some tests also included the analysis of dioxins/furans.

Results from the 10 tests are summarized in Table 1. Runs 35, 36, 39, and 40 of Table 1 show the four UV-light tests. These can readily be compared with the six "conventional incineration" tests also shown in the table.

Conclusions

Major conclusions drawn from the test results were:

- Destruction/removal efficiency for the four POHCs were all above 99.999% in these non-solar tests.
- Based mainly on the comparison of measured emissions with blank levels, it will be possible to quantify a significant decrease in emissions of volatile and semivolatile PICs and two of the POHCs (CCl_4 and DCB) when the solar ("on-sun") tests are done at NREL. It will not be possible, however, to quantify any significant decrease in emissions of the other two POHCs (toluene and naphthalene).
- Tests with artificial UV light indicated a significant decrease in emissions of volatile PICs when operating in the single-chamber mode; however, these tests did not show a significant decrease for semivolatile PICs, nor for any of the four POHCs tested.

The full report was submitted in fulfillment of Work Assignment No. 18 of EPA Contract No. 68-DO-0137 by the Midwest Research Institute (MRI) of Kansas City, MO under the sponsorship of the U.S. Environmental Protection Agency.

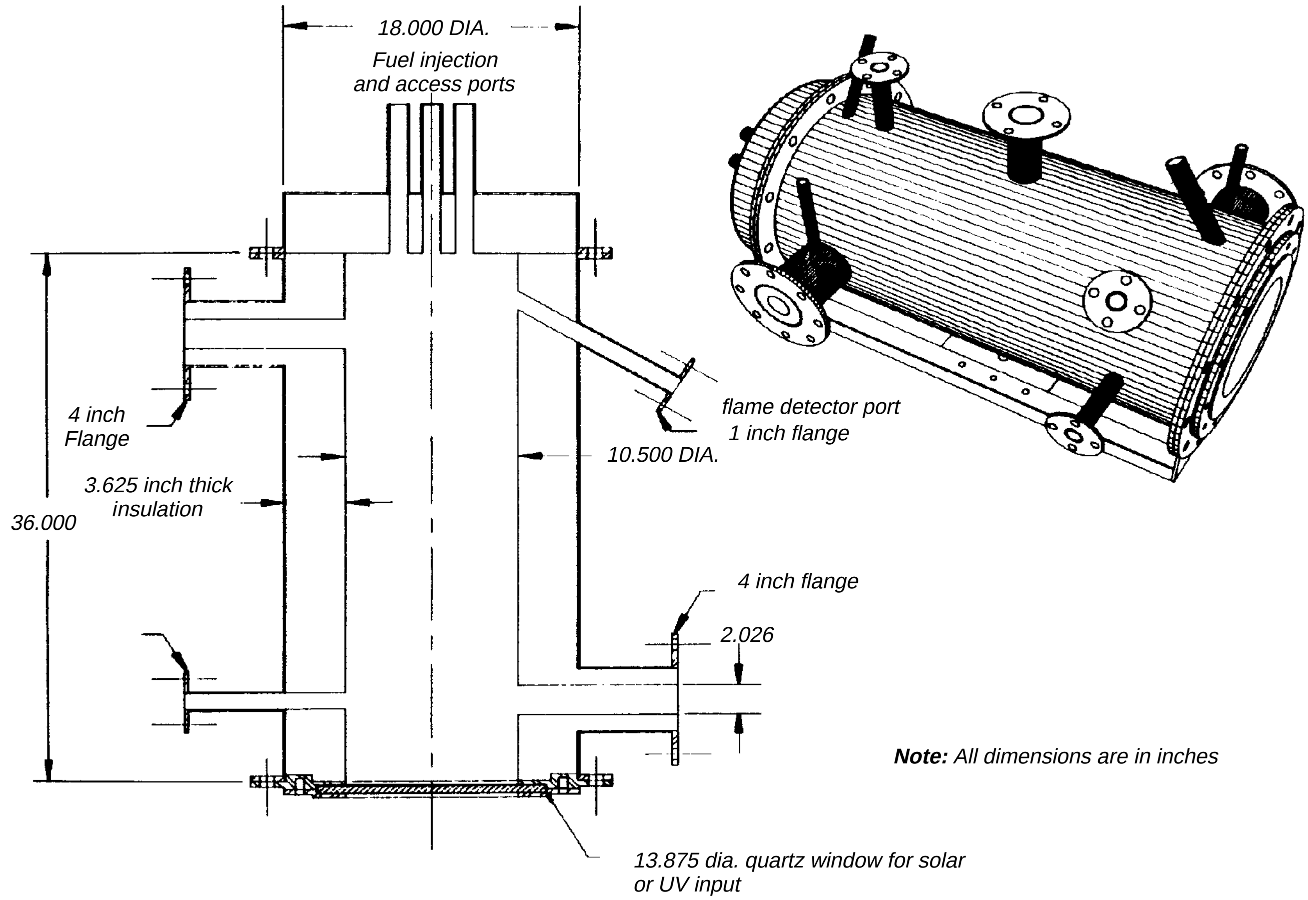

Figure 2. *Solar detoxification reactor - section view.*

Table 1. *Summary of Results from Minipilot Solar Reactor Runs 31 through 40*

		Single chamber						Dual chamber			
	Units	Run 31	Run 34	Run 36*	Run 32	Run 33	Run 35*	Run 38†	Run 37†	Run 39†	Run 40
Operating Conditions		Low flow	Low flow	Low flow	High flow	High flow	High flow	Low flow	High flow	High flow	High flow
Secondary airflow	dscf/min	4.14	4.23	4.29	7.84	7.44	7.62	4.38	7.64	7.77	7.88
Liquid organic flow rate	mL/min	4.10	4.62	4.22	7.85	7.45	8.17	4.10	7.77	7.69	7.21
UV light	Yes or No	No	No	Yes	No	No	Yes	No	No	Yes	Yes
O_2 level	%	9.3	9.0	3.2	12.3	11.9	7.9	4.2	8.7	6.7	11.8
Residence time	sec	7.1	7.0	6.8	4.0	4.2	4.0	13.3	7.8	7.8	8.9
DREs											
Carbon tetrachloride	%	99.999968	99.999963	99.999970	99.999811	99.999910	99.999829	99.999981	99.999949	99.999914	99.999546
Toluene	%	99.999951	99.999926	99.999950	99.999905	99.999938	99.999966	99.999965	99.999935	99.999941	99.999952
Dichlorobenzene	%	99.9999975	99.9999965	99.9999950	99.9999924	99.9999944	99.9999977	99.9999976	99.9999960	99.9999988	99.999991
Naphthalene	%	99.99966	99.99940	99.99926	99.99943	99.99949	99.99952	99.99949	99.99935	99.99962	99.99961
Volatiles (amount of one trap pair)											
Carbon tetrachloride	ng	21.9	37.2	25.2	124.9	46.9	158.7	13.6	40.9	125.8	230.0
Toluene	ng	5.6	61.2	25.4	23.5	41.6	19.2	15.1	22.0	27.6	14.7
Total PICs	ng	4,685	6,862	1,376	4,824	5,827	1,823	779	895	1,079	1,069
Volume sampled	L	18.12	18.80	18.64	20.87	18.76	18.94	19.20	19.29	19.16	19.45
POHC and PIC concentration‡	µg/dscm	260	370	76	238	315	106	42	50	64	68
Semivolatiles											
Dichlorobenzene	µg	0.22	0.36	0.36	0.86	0.68	0.30	0.21	0.45	0.15	1.04
Naphthalene	µg	3.70	7.72	6.75	8.00	7.72	7.89	5.55	9.09	5.91	5.75
Total PICs	µg	1,560	3,248	2,334	4,018	2,014	3,714	2,148	3,579	2,331	14,271
MM5 sample volume	dscm	0.617	0.612	0.494	0.751	0.815	0.824	0.604	0.726	0.801	0.802
POHC and PIC concentration§	µg/dscm	2,535	5,320	4,739	5,362	2,481	4,517	3,566	4,943	2,918	17,803
Dioxins and Furans											
Dioxins	µg	--	0.00161	--	--	0.00316	--	--	0.00655	0.01082	0.00825
Furans	µg	--	0.00871	--	--	0.02102	--	--	0.04470	0.07802	0.04134
Total	µg	--	0.01032	--	--	0.02508	--	--	0.05125	0.08884	0.04759
Blanks											
Carbon tetrachloride	ng	<4.0	<4.0	6.5	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Toluene	ng	<4.0	<5.2	5.8	<4.0	<4.0	<4.4	7.6	<4.0	7.7	<6.0
Volatile PICs	ng	85									
Dichlorobenzene	µg	0.06									
Naphthalene	µg	4.32									
Semivolatile PICs	µg	225									
Dioxin	µg	0.000618									
Furan	µg	0.0000776									

* Auxiliary fuel (fuel oil) was fired in Runs 35 and 36 to maintain operating temperature during these tests with UV light in the single chamber mode.
† Propane was fired in the second chamber in Runs 37, 38, and 39 to maintain the operating temperature in the second chamber.
‡ Volatile POHC/PIC concentrations range from 42 to 370 µg/dscm, which is equivalent to 0.010 to 0.088 ppm, (assuming an approximate average MW of 100).
§ Semivolatile POHC/PIC concentrations range from 2,481 to 17,803 µg/dscm, which is equivalent to 0.40 to 2.88 ppm, (assuming an approximate average MW of 150).

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The complete report, entitled "Minipilot Solar System: Design/Operation of System and Results of Non-Solar Testing at MRI," (Order No. PB94-152238AS; Cost: $27.00, subject to change) will be available only from:
National Technical Information Service
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