Emissions Tests on De Montfort Medical Waste Incinerators

Report by DJ Picken

Background

The original (**Mark 1**) incinerator had been tested by CSIR, in South Africa, in December 1999. Representative samples of waste from a typical primary health care centre were prepared by the South African Department of Health at the CSIR testing facilities. Emissions and destruction efficiencies were measured, and the principal findings were:

"The medical waste tested in the trial was rendered non-infectious, the syringes were destroyed and the needles were rendered unsuitable for use.

The emission of particulates, metals and chlorides comply with South African regulations for primary health care clinical waste used in the South African trials on small scale incinerators and the fuel to waste feed conditions for the tests. The combustion efficiency does not comply and the organic emissions are higher by a factor of at least 20 times."

It was noted that the test had been carried out at temperatures below 600°C, and that an undue quantity of wood was burned during the tests, which contributed to the high organic emissions.

The next test was of a **Mark 2** incinerator (same size primary combustion chamber, larger secondary combustion chamber) at the De Montfort University and was reported by DJ Picken in January 2001. The load consisted of mixed medical waste, supplied by ECHO Health Care Ltd, but containing very few hypodermics. The principal findings were:

1. *"The combustion chamber temperature was above 800°C for most of the test;*
2. *For most of the running time there was no visible smoke emission. Only rarely did the smoke level exceed that which is considered acceptable in a diesel engined road vehicle;*
3. *Such smoke as was collected proved to contain only carbon. No metallic elements were present;*
4. *The flue gas was found to contain virtually no dioxins or furans.*
5. *Oxygen level in the flue gas varied between 4% and 16%*
6. *Carbon monoxide level was mostly in the region of 100 ppm, with levels above 400 ppm occurring only rarely."*

A third test was carried out on the **Mark 3** incinerator (larger primary and secondary combustion chambers) in the presence of observers from *Médecins Sans Frontières* in December 2000. Again the results were reported by DJ Picken. This test was carried out to test the efficacy of the incinerator to burn wet textiles as well as general clinical and household waste. Some diesel fuel was added to maintain temperatures. The principal results were:

"In all cases, at least one of the temperature zones through which the flue gas had to pass exceeded 800°C. CO could not be measured precisely at this low value.

O_2 levels fluctuated depending on how recently the load door had been opened, and the type of load.

Rate of burning was very high, in the region of 50kg/h, again depending on load material. This meant that loading had to be very frequent, in the region of every 5 minutes."

Origins of the present test

The test was proposed by Richard Carr of WHO Geneva, and was to investigate emissions caused when the incinerator was used to burn sharps boxes containing hypodermic syringes and needles in conjunction with a mass immunization campaign. The test was originally planned for August 2002, but due to delays in producing the contracts, the test actually took place on 20th May 2003.

Preparations for Test

A site was hired at a farm outside Foxton, Leicestershire, UK, and a **Mark 8a** incinerator built for the tests. This incinerator is of the same thermodynamic design as the original Mark 1, but incorporating a number of modifications to improve the durability and decrease the cost as a result of extensive operating experience in many developing countries. Because of the perceived urgency at the time of building, the chimney was erected from a four metre length of stainless steel flue liner, which it was estimated would last four the month or so till the test took place. In the event it lasted over eight months although it was bent by the gales of an English winter. Casella CRE of Cheltenham UK were located and contracted to sample and measure the emissions, while the author and a technician provided a petrol generator set, loaded the incinerator, and took readings of temperature and smoke level. 7’200 hypodermics and 72 sharps boxes were supplied by WHO from Germany and the USA. Great Glen WI made up the sharps boxes and loaded them with either 100 or 200 hypodermics according to size. Some hypodermics surplus to the 7’200 were supplied loose (dangerously so) and these were burned in initial trials.

Instrumentation

Five thermocouples were used during the test, three in the primary combustion chamber, one in the secondary combustion chamber and one in the chimney. The positions of the thermocouples are shown diagrammatically in Fig 1. Four of the thermocouples were connected to a portable computer with regular data logging, and the fifth was connected to a hand held temperature meter.

A Bosche Smokemeter, of the type used to measure diesel exhaust smoke, was connected to the chimney 300 mm from the base.

The gaseous emissions instrumentation is described in the report from CRE.

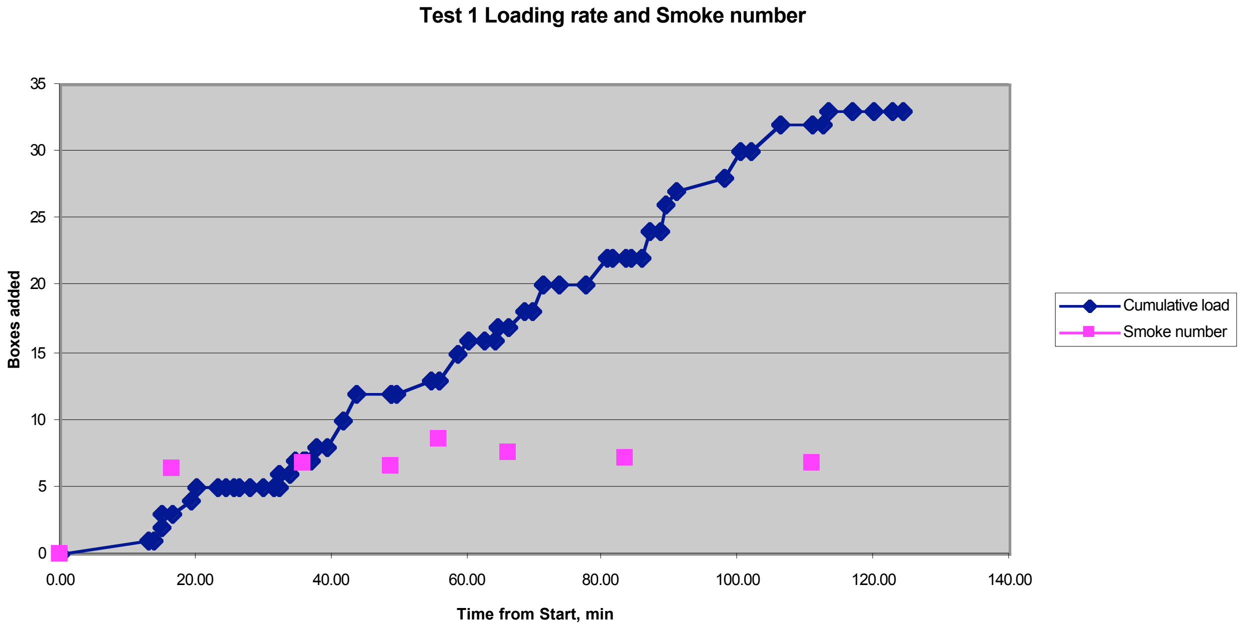
Test Procedure

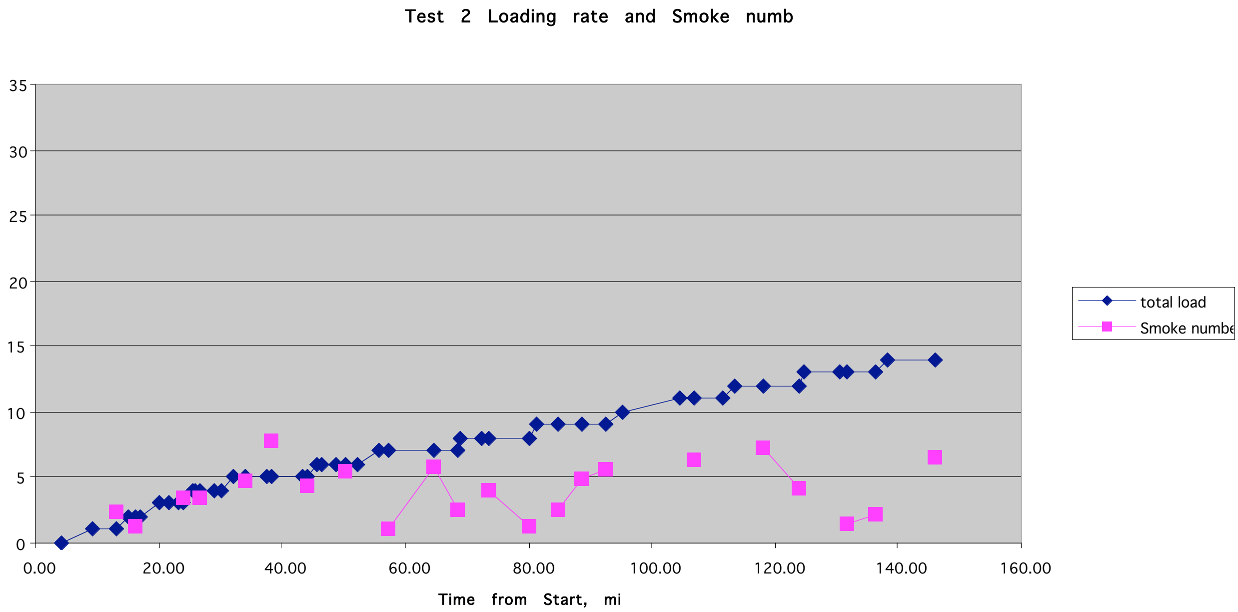
Two tests were carried out, each of just over two hours’ duration. In Test 1, the loading regime was the same as that used for burning mixed medical waste, i.e. the primary combustion chamber was kept more than half full throughout the test. As can be seen from the smoke test results, this resulted in an unacceptably high level of smoke and the need for some recycling of the solid residue beneath the grate. It also made the emissions sampling very difficult because of clogging of the filter.

The incinerator was shut down, the chambers cleaned out, and the incinerator restarted for Test 2. In this test, the primary combustion chamber was loaded with one sharps box (100 hypodermics) and the smoke leaving the chimney observed. When the smoke cleared, a second sharps box was added and the procedure repeated throughout the test.

Test results

1. Loading rate and smoke levels

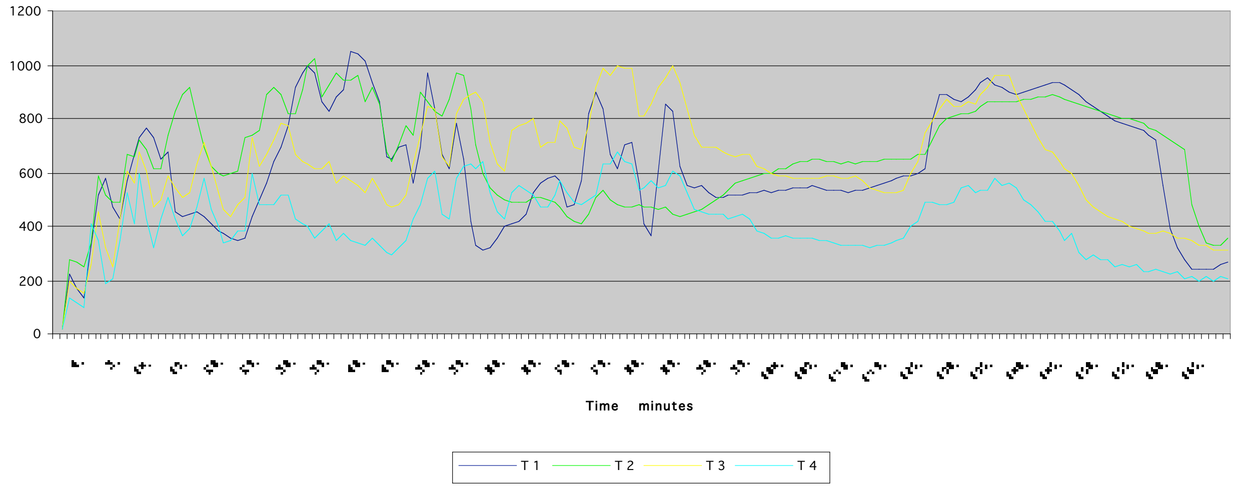




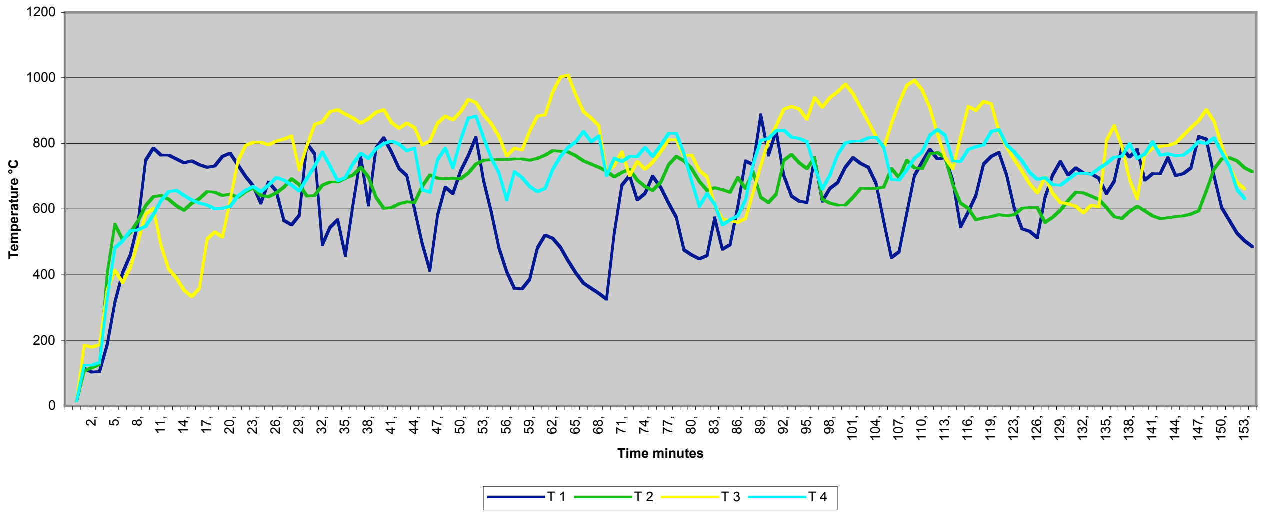
The first two graphs show loading rate and smoke number against a time base for tests 1 and 2. Test 1 gives a load of 3’300 hypodermics in 2 hours, a loading rate of 27.5 hypodermics per minute, or one standard sharps box every 3.6 minutes. The average smoke number for this rate of loading was 7.1, which represents a very dark smoke. Test 2 gives a load of 1’400 hypodermics in 150 minutes, a loading rate of 9.3 hypodermics per minute, or one standard sharps box every 10.7 minutes. The average smoke number for this rate of loading was 4.0, which is much more acceptable.

2. Temperatures

Incinerator Mk 8a Test No.1 DE192203 Temperature °C v's Time mi



Incinerator Mk 8a Test No.2 DE200113 Temperature °C v's Time minutes



Both tests show a variation in temperature both with time and position of probe. However in both cases one of the temperatures, usually in the secondary combustion zone, was over 800°C for most of the test duration, showing that sterilization would take place in the incinerator. The temperature readings in positions 1 and two were almost certainly lower than reality because of the insulating effect of ash, plastic and other debris resting temporarily on the probes.

3. Solid residue

At the end of Test number 1, there was some molten plastic amongst the ash below the grate, which had to be recycled to achieve complete combustion, confirming that the loading rate was too high for the burning rate of this size of incinerator.

At the end of Test number 2, only grey ash was evident below the grate.The total volume of residue for this test was 3.3 litres.

In both cases needles were still present in the residue, though the ones investigated were denatured and pliable.

4. ***The gas analysis result obtained by Casella CRE Emissions were as shown in the tables below***

The following results were obtained for the required determinants:

Flue Gas Characterisation Information

Test	Date	Time Start	Time End	Moisture Content % v/v	Oxygen Content % v/v, dry	Temp. °C	Velocity m/s	Flow Rate m^3/s
1	20/5/03	0920	0935	26.0	3.7	418	2.2	0.01
2	20/5/03	1310	1320	13.6	5.1	538	7.2	0.03

Dioxin and Furan Emissions

Test	Date	Time Start	Time End	Concentration ng/m^3 (TEQ)			
1	20/5/03	1017	1158	0.0287	±	0.0172	lower
				0.1413	±	0.0848	upper
2	20/5/03	1324	1524	1.582	±	0.949	lower
				1.605	±	0.963	upper

Total dioxin and furan concentrations are expressed on a toxic equivalent basis using the WHO 1997 toxic equivalent factors applicable to humans and mammals. Upper limit values assume non-detected congeners are present at their detection limit, whilst lower limit values assume the concentration of non-detected congeners to be zero.

PCB Emissions

Test	Date	Time Start	Time End	Concentration ng/m^3 (TEQ)			
1	20/5/03	1017	1158	0	±	-	lower
				19.9	±	19.9	upper
2	20/5/03	1324	1524	0	±	-	lower
				11.5	±	11.5	upper

Total polychlorinated biphenyls concentrations are expressed on a toxic equivalent basis using the WHO 1997 toxic equivalent factors applicable to humans and mammals. Upper limit values assume non-detected congeners are present at their detection limit, whilst lower limit values assume the concentration of non-detected congeners to be zero.

Full details of the sampling and analysis methods used are given in the Casella CRE Emission report number **G2171/030502**.

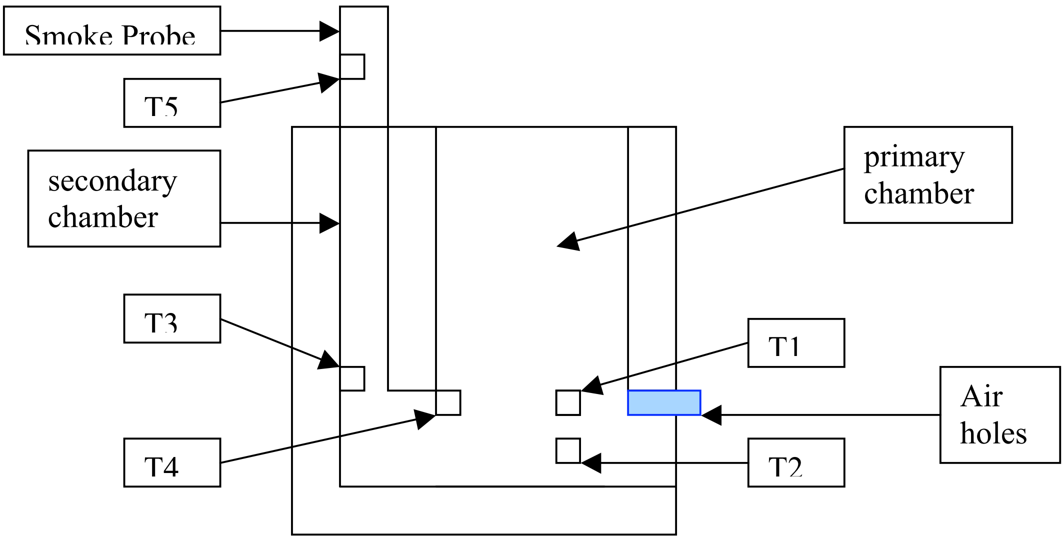


Figure 1: Diagram showing approximate positions of the temperature probes

Conclusions

1. The test loads represented a very heavy concentration of plastic hypodermic syringes. Each sharps box contained exactly 100 syringes, and these varied greatly in size. Virtually no supplementary fuel was used during the tests.
2. As the sharps boxes burned, syringes could and did, drop to the floor of the incinerator. For this reason much of the burning was of molten plastic burning below the grate.
3. Nevertheless, apart from the particulate loss represented by smoke, burning was complete by the end of test 2, and also at the end of test1 after some recycling.
4. As on previous tests with general waste, the incinerator maintained temperatures of over 800°C for most of the burning period, though the distribution of temperatures varied with time.
5. Loading rate was a key factor in reducing smoke level, and 1 full sharps box every 10 minutes seemed to give optimum burning rates, combining high temperatures with relatively low smoke levels. This loading rate cannot be taken too precisely in the field because it is unlikely that sharps boxes will be so tightly packed with syringes during an immunization campaign.
6. Analysis showed that PCB emission rates were lower in test 1 with a higher loading rate than in test 2, despite the higher smoke level. It is suggested that this is due to a greater secondary burning in the former case, but a laboratory-based study would be needed to explain this fully.
7. The operating instructions for the incinerator need to be clarified to explain the differences between burning general medical waste for which it was designed, and for a load consisting of hypodermics only which may be used during an immunization campaign.
8. As an Engineer, I should not comment on the dioxin and furan PCB results, but leave that to the medically or chemically qualified.

DJ Picken, May 2004