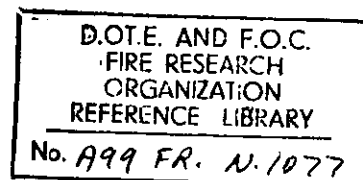


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## Fire Research Note No 1077



INHALATION TOXICITY OF PYROLYSIS PRODUCTS  
FROM POLYURETHANE FOAMS

by

J A G Edginton and R D Lynch

October 1977

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# FIRE RESEARCH STATION

56613

Fire Research Station  
BOREHAMWOOD  
Hertfordshire WD6 2BL  
Tel: 01 953 6177

INHALATION TOXICITY OF PYROLYSIS PRODUCTS  
FROM POLYURETHANE FOAMS

by

J A G Edginton\* and R D Lynch\*

SUMMARY

Rats and guinea pigs were exposed for 30 minutes to the smoke and gases evolved during the pyrolysis of certain types of polyurethane foam. Under the conditions of the experiments, carbon monoxide was the major toxic material produced, and accounted for about two-thirds of the lethal effect. The remainder appears due to the presence of hydrogen cyanide, which was not produced to the extent expected.

\* Chemical Defence Establishment  
Porton Down  
Salisbury  
Wilts

## FOREWORD

This note reports part of a study of the toxicity of the combustion products of wood and plastics carried out at the Chemical Defence Establishment, Porton Down, under contract to the Fire Research Station.

A complete account of the work under the contract and discussion of its implications, is to be published elsewhere. All enquiries concerning the work described in this note should be directed to the Fire Research Station.

The object of this study was to determine whether the inhalation toxicity of the pyrolysis/combustion products of flexible polyurethane foams could be accounted for in terms of the major known toxic gases present, namely, carbon monoxide and hydrogen cyanide.

In amplification of the 'Methods and Materials' section of the text, it may be noted that large-scale fire studies with large loads of flexible polyurethane foam cushions by Kirk and Stark<sup>1</sup> had shown that the total amount of carbon monoxide and hydrogen cyanide in the fire gases from a given load of foam could commonly be in the ratio of about 10 : 1. In an attempt to achieve a ratio similar to this in the toxicity trials, the apparatus used was designed to pyrolyse the foam relatively slowly at temperatures of 500-600°C and then to pyrolyse the gas-borne products further at 800-900°C, following the observations of Woolley<sup>2</sup> that this second stage was the main source of the hydrogen cyanide. However, the desired ratio was not obtained and time did permit the necessary further development of the equipment to achieve it.

It must be emphasised that the results obtained here, for relatively high ratios of CO to HCN, refer to the total production of these gases from the pyrolysis/combustion. In the course of an actual fire involving polyurethane foam, the ratio of these two gases varies widely with time; in the early stages, eg after 2½ minutes, the hydrogen cyanide can be the major toxic gas present (Woolley and Fardell<sup>3</sup>).

#### REFERENCES

1. KIRK P G and STARK G W V. 'Flexible polyurethane foam, large-scale fires of industrial loads of seating cushions, Department of Employment and Department of the Environment, HMSO 1975.
2. WOOLLEY W D. Br. Polym. J, 1972, 4, 27.
3. WOOLLEY W D and FARDELL P J. Fire Research 1977, 1, 11.

## INHALATION TOXICITY OF PYROLYSIS PRODUCTS FROM POLYURETHANE FOAMS

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### INTRODUCTION

Because there have been reports<sup>1</sup> that the evolution of hydrogen cyanide may play a major, if not dominant, role in the hazards from burning polyurethane (PU), experiments have been carried out to measure the inhalation toxicity of the smoke and gases evolved during the pyrolysis of certain polyurethane foams. A previous report was concerned with the pyrolysis products of polyvinyl chloride<sup>2</sup>.

### METHODS AND MATERIALS

The pyrolysis furnace (Fig.1) was designed by P C Bowes of the Fire Research Station (FRS) and fabricated at CDE. It consisted essentially of three compartments, each approximately 640 x 330 x 150 mm. The three parts were joined together by bolted flanges which were sealed with asbestos washers, and the upper section was insulated with approximately 25 mm of asbestos sheet. Stainless steel construction was used throughout.

The lowest compartment contained a drawer into which the PU was loaded for pyrolysis. The middle section was used as a gas expansion chamber, and was separated from the top compartment by a steel plate with a hole at one end 75 x 300 mm. In the top section were mounted six 1 KW fire bars providing the pyrolysis energy. At the end of the top section, distal to the hole in the separating plate, was the chimney 660 long x 280 x 130 mm. Chromel Alumel thermo-couples were used to monitor the various temperatures within the furnace. FRS also carried out a check on the temperature in the upper compartment by optical pyrometry.

Insulation between the 230 V AC supply to the fire bars and the stainless steel case, which was run at red heat, was initially achieved by using heavy duty spark plug bodies, but eventually these were changed for machined asbestos

insulators. The usable life of the fire bars under the extreme conditions met in the experiments was about 2 to 3 trials.

Polyurethane foams were supplied by FRS in bulk and are referred to by the following code letters:-

1. Foam 'D', a non-rigid yellow foam (Polyether foam Ed.)
2. Foam 'F', a non-rigid black foam (containing flame retardant Ed.)
3. Foam 'H', a high density green material (high resilience foam Ed.)

As well as these materials, non-pedigree foam cushions were used in developmental work.

The methods of sampling, biological procedures and atmosphere analysis have been described previously<sup>3</sup>.

## RESULTS

The experimental results fall into the following groups.

1. Initial calibration and development
2. The results from three types of foams using animals
3. Some trials performed to optimise the ratio of CO/HCN.

### Development Work

When the furnace had been constructed at CDE it was sent to FRS for testing. The informal test report from FRS pointed out several faults in the design, all of which were rectified. More importantly, attention was drawn to the possibility of flaming within the equipment rather than slow pyrolysis, and to the high ratio of CO to HCN. Neither of these two difficulties were successfully overcome in any of the CDE trials. However the temperature at the fire bars was measured as being approximately 965°C, with walls of the upper section at 600°C. This was acceptable.

### Trial Runs

Four experiments were carried out, all using 400 g of 'non-pedigree' PU cushion material; the full protocols are given in Appendix A.

### Experiment 1

The equipment was loaded with PU foam at room temperature. To prevent flaming, metal gauze was placed between the chimney and the furnace.

After one hour of heating the analysis of the atmosphere in chamber was as follows:-

CO (%)	O <sub>2</sub> (%)	Plate Temp (°C)*	Chamber Temp (°C)	Smoke (mg/l)	HCN (µg/l)
0.6	17.9	580	54	0.41	116

\*The plate temperature was measured by a calibrated Chromel/Alumel thermocouple in contact with the lower side of the plate in Fig.1.

The residue of unburnt material weighed 50 g.

### Experiment 2

The first run was repeated using a slightly shorter chimney, giving the following chamber analysis after 70 minutes burning:-

CO (%)	O <sub>2</sub> (%)	Plate (°C)	Chamber (°C)	Smoke conc (mg/l)	HCN conc (µg/l)
.09	-	556	-	.09	31

After the equipment had cooled, the wire gauze between the chimney and furnace was found to be almost totally blocked with a tarry deposit, and although the residual ash was only 60 g, the inside of the furnace was covered with large amounts of black tar.

### Experiment 3

A repeat of experiment 2, without the wire gauze, gave the following analysis at 65 minutes:-

CO (%)	Plate (°C)	Chamber (°C)	Smoke conc (mg/l)	HCN conc (µg/l)
.425	601	54	.37	122

After allowing the chamber to cool for 50 minutes the HCN concentration had decreased to 71 µg/l.



#### Experiment 4

As the primary objective of the pyrolyses was to maximise the HCN concentrations, a further run using less PU was carried out. The rationale was that this might allow a longer residence time of the primary pyrolysis products in the very high temperature region. However, with a PU load of 105g, the analysis at 70 min was as follows:-

CO (%)	O <sub>2</sub> (%)	Plate (°C)	Chamber (°C)	Smoke conc (mg/l)	HCN conc (µg/l)
.055	19.8	532	54.3	.032	16.7

The residual unburnt material weighed 16g.

#### Animal exposures

In brief, the tests called for the pyrolysis of 400 g of PU foam, loading the furnace at room temperature. The pyrolysis phase lasted about 1½ hrs (for specific details see the appendices B1-14). The chamber was ventilated with laboratory air until the carbon-monoxide concentration was at the chosen working level, and the animals were then exposed for 30 minutes.

Details of the results are given in Tables 1-14. The mortality data may be summarized as follows:

For foam 'H':

Run No	Ct (mg min/m <sup>3</sup> )		24 hr mortality (/15)	
	CO	HCN	Rats	Guinea pigs
1	111,000	1860	10	0
2	99,000	1020	4	0
3	121,000	1710	9	0
4	85,000	1040	0	0

For foam 'D'

For foam 'D'

Run No	Ct (mg min/m <sup>3</sup> )		24 hr mortalities (/15)	
	CO	HCN	Rats	Guinea pigs
1	74,000	790	4	0
2	99,000	1340	13	6
3	88,000	1320	2	0
4	97,000	2640	4	0
5	121,000	2730	15	1
6	104,000	1740	9	0

For foam 'F'

Run No	Ct (mg min/m <sup>3</sup> )		24 hr mortality (/15)	
	CO	HCN	Rats	Guinea pigs
1	82,000	620	0	0
2	100,000	1560	2	0
3	117,000	2220	10	0
4	107,000	1560	4	0

Although these results are valid in themselves, they were misleading to the extent that the desired CO/HCN ratio of 10:1 was never achieved. Some runs without animals were carried out to see if the gas ratio could be improved, and the results are as follows:

Trials to optimize the CO/HCN ratio

Full details of the protocol are given in Appendices C1-7

Run 1:

On the basis that the HCN might be oxidised by the furnace by over long pyrolysis times, two short runs were tried. The first, in which the power to the furnace was switched off after 30 minutes gave, with foam 'D'—

	CO conc (mg/l)	CO/HCN ratio
Time from zero		
25'	1.43	
Power off at 30'		
35'	2.6	19
45'	2.76	19
55'	2.79	20
65'	2.81	21

There is some indication that the CO level is rising faster than the HCN, but as the CO levels were only marginally high enough a similar run was attempted using a different PU.

Run 2:

Using foam 'F', with power off at 45 minutes.

	CO conc (mg/l)	CO/HCN ratio
Time from zero		
40'	2.17	18
Power off at 45'		
50'	7.06	42
60'	9.69	49
70'	9.81	49

In this case the ratio was much worse, due to a high CO level.

Run 3:

The furnace was preheated before inserting the cold drawer with its load of 'D' PU foam. The final concentrations of gases at 110 minutes were:

CO = 5.3 mg/l and CO/HCN = 18

Run 4:

An attempt was made to improve this ratio by throttling the chimney cross-section down to about 5 cm<sup>2</sup>, thus prolonging the residence time of the gases in the furnace, using foam 'D', after zero, this gave:

CO mgm/m	CO/HCN
1.65	17

This was a reasonable result vis-a-vis the HCN, but again the CO was unsatisfactory. In fact, when the furnace was examined after cooling 60-70% of the foam remained not pyrolysed.

Run 5:

The throttling plate was removed from the chimney and foam 'H' pyrolysed in a pre-heated furnace, this gave the following results.

Time after insertion of plastic	CO (mg/l)	CO/HCN ratio
10'	.22	17
20'	.70	17
30'	6.26	53
40'	6.34	48
50'	6.56	43
After exhausting chamber to adjust CO conc		
80'	4.22	48

Run 6:

In an attempt to slow down the pyrolysis even further, the dividing plate between the furnace and the middle section was insulated by a mask of two 6 mm thick asbestos sheets. Both the CO and HCN outputs were negligible

Run 7:

In this final run, the centre section of the equipment was removed, the apparatus preheated to 500°C, and 400 grams of foam 'H' inserted. The final measurements, after 1 hr of pyrolysis were:-

$$\text{CO} = 8.61 \text{ mg/l} : \text{CO/HCN ratio} = 43$$

## DISCUSSION

The toxicity data for rats have been analysed to obtain L.Ct50 values. These results have been compared with the carbon monoxide data presented in CDE Special Report No.11<sup>3</sup>. The results are as follows:

Group	L.Ct50 (mg min/m <sup>3</sup> )	Limits
10 Toxicity Data in SR 11 (3)	163,000	148,000 - 178,000
CO Toxicity Data from pyrolysis of PU	106,000	95,000 - 128,000

$$t = 10.1 \text{ for } 31 \text{ degrees of freedom}$$

The full analysis is given in Appendix D.

Further analysis of the two sets of results show that the difference in the L.Ct50 is very highly significant ( $p = 10^{-6}$ ). This is not unexpected in view of the fact that the polyurethane results owe at least some of their toxicity to the presence of HCN; moreover, because the SR 11 results include both pure CO and wood pyrolysis CO results at least some difference due to excitation and minor toxic constituents may be discounted. It is therefore reasonable to consider that the significant difference in the L.Ct50 values between the two groups is due, at least in part, to the HCN content.

The ratio of the L.Ct50's is approximately 1.5, and this is associated with a mean HCN Ct over all the PU exposures of 1050 mg min/m<sup>3</sup>. The arithmetic difference in the two CO Cts is approximately 57,000 mg min/m<sup>3</sup>, and it is tempting to equate this with the effect of the HCN. Further, the toxicity ratio of HCN/CO previously quoted is 45 to 1; the ratio in the present series is 54 to 1. Thus, if the L.Ct50 for CO for PU were adjusted by an amount equivalent to the overall HCN Ct means we have:

$$\begin{aligned}
 \text{CO, L.Ct50} &= 163,000 \text{ mg min/m}^3 \\
 \text{PU-CO, L.Ct50} &= 106,000 \text{ mg min/m}^3 \\
 \text{Mean HCN Ct} &= 1050 \text{ mg min/m}^3 \\
 (\text{PU-CO, L.Ct50}) + (45 \times \text{mean HCN Ct}) &= 153,000 \text{ mg min/m}^3
 \end{aligned}$$

Unfortunately, the inhalation toxicity of HCN is extremely time dependent; ie the absolute toxicity appears to decrease with time. Thus, although the relationship between the PU foam pyrolysis toxicities and the known toxicity ratios for pure gases is temptingly close, what the relationships would be if much higher HCN concentrations had been achieved is not known because the animals would have died very much sooner at a lower total dose of HCN. Woolley<sup>1</sup> has stated that 3 to 4% of the plastic foam weight may be given off in air as HCN under some pyrolysis condition. This would be equivalent in our experiments to 14 grams of HCN; ie 1400 mg/m<sup>3</sup> or 42,000 mg min/m<sup>3</sup>, as against 1050 mg min/m<sup>3</sup> achieved.

If the carboxyhaemoglobin results are examined, they support the argument that CO was not the only intoxicant. Thus, in the previous experiments the burning wood<sup>3</sup> the lowest COHb in dying rats was 86%. the highest in surviving animals, 69%. The equivalent figures for PU CO were; highest figure in a surviving animals 54%, lowest figure associated with death 39%. This low COHb was associated with a Ct of 1344 mg min/m<sup>3</sup> of HCN.

#### CONCLUSIONS

It was not possible to obtain the very high predicted HCN concentrations. This pre-empted any observations on animals exposed to an HCN/CO ratio of 1 to 10. However, it was shown under the conditions of the pyrolysis experiments reported, a toxicity over and above that due to carbon monoxide was present, that this was statistically significant, and was consistent with the HCN produced. The increase, in these experiments, of the hazard by a factor of only 1.5 is marginal.

#### REFERENCES

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2. BOWES P C, EDGINTON J A G and LYNCH R D. Fire Research Note No 1048 1976.
3. CDE (1975) The acute inhalation toxicity of carbon monoxide from burning wood. Special Report No.11.
4. CDE (1975). On the non-existence of synergism between inhaled hydrogen cyanide and carbon monoxide. Special Report No.9.

TABLE 1

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'H' - RUN 1

CO concentration = 3.69 mg/l

Ct = 111,000 mg min/m<sup>3</sup>

HCN concentration = 61.9 µg/l

Ct = 1,860 mg min/m<sup>3</sup>

Ratio CO/HCN = 60

Animal Mortalities:

	c/w	+24 hrs	+ 48 hrs
Rats	10/15	10/15	11/15
Guinea Pigs	0/15	0/15	0/15

Carboxyhaemoglobin levels in preselected animals:

	COHb%	
<u>Rats</u>		
1	66	D*
2	76	D
3	37	S*
4	39	S
5	35	S
<u>Guinea Pigs</u>		
1	35	S
2	31	S
3	26	S
4	35	S
5	31	S

\*D = Dead

"S = Survived

TABLE 2

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'H' - RUN 2

CO concentration = 3.29 mg/l

Ct = 99,000 mg min/m<sup>3</sup>

HCN concentration = 34.1 µg/l

Ct = 1.020 mg min/m<sup>3</sup>

CO/HCN ratio = 96.5

Animal mortalities:

	c/w	24 hrs
Rats	4/5	4/15
Guinea Pigs	0/15	0/15

COHb results:

	COHb%	
<u>Rats</u>		
1	77	D
2	47	S
3	41	S
4	53	S
5	41	S
<u>Guinea Pigs</u>		
1	33	S
2	34	S
3	29	S
4	41	S
5	38	S



TABLE 3

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'H' - RUN 3

CO concentration 4.04 mg/l  
 HCN concentration 56.9 µg/l

Ct = 121,000 mg min/m<sup>3</sup>  
 Ct = 1,710 mg min/m<sup>3</sup>

CO/HCN ratio - 71

Animal mortalities:

	c/w	24 hrs	6 days	8 days
Rats	9/15	9/15	9/15	11/15
Guinea Pigs	0/15	0/15	1/15	1/15

COHb results:

Rats	COHb%		Guinea Pigs	COHb%	
1	78	D	1	29	S
2	54	S	2	23	S
3	51	S	3	30	S
4	39	S	4	26	S
5	55	S	5	30	S

TABLE 4

TOXICITY DATA FOR ANIMALS EXPOSE TO FOAM 'H' - RUN 4

CO concentration = 2.82 mg/l

Ct = 85,000 mg min/m<sup>3</sup>

HCN concentration = 34.5 µg/l

Ct = 1,040 mg min/m<sup>3</sup>

CO/HCN ratio = 82

Animal mortalities:

	o/w	24 hrs
Rats	0/15	0/15
Guinea pigs	0/15	0/15

COHb results:

Rats	COHb%		Guinea pigs	COHb%	
1	70	D	1	30	S
2	73	D	2	30	S
3	50	S	3	32	S
4	46	S	4	30	S
5	43	S	5	24	S

TABLE 5

TOXICITY DATA FOR ANIMALS EXPOSED FOR FOAM 'D' - RUN 1

CO concentration = 2.46 mg/l

Ct = 74,000 mg min/m<sup>3</sup>

HCN concentration = 26.3 µg/l

Ct = 790 mg min/m<sup>3</sup>

CO/HCN ratio = 94

Animal mortalities:

	o/w	24 hrs	7 days
Rats	4/15	4/15	4/15
Guinea pigs	0/15	0/15	0/15

COHb results:

Rats	COHb%		Guinea Pigs	COHb%	
1	18	S	1	25	S
2	21	S	2	17	S
3	15	S	3	19	S
4	5	S	4	25	S
5	20	S	5	26	S

TABLE 6

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'D' - RUN 2

CO concentration = 3.3 mg/l

Ct = 99,000 mg min/m<sup>3</sup>

HCN concentration = 44.8 ug/l

Ct = 1,340 mg min/m<sup>3</sup>

CO/HCN ratio = 74

Animal Mortalities:

	o/w	24 hrs	7 days
Rats	13/15	13/15	13/15
Guinea Pigs	3/15	6/15	6/15

COHb results:

Rats	COHb%		Guinea Pigs	COHb%	
1	39	D	1	5	S
2	45	D	2	5	S
3	42	D	3	5	S
4	39	D	4	5	S
5	40	D	5	5	S

TABLE 7

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'D' - RUN 3

CO concentration = 2.95 mg/l

Ct = 88,000 mg min/m<sup>3</sup>

HCN concentration = 44  $\mu$ g/l

Ct = 1,320 mg min/m<sup>3</sup>

CO/HCN ratio = 67

Animal Mortalities:

	o/w	24 hrs	7 days
Rats	2/15	2/15	2/15
Guinea Pigs	0/15	0/15	0/15

COHb results:

Rats	COHb%		Guinea Pigs	COHb%	
1	44	S	1	29	S
2	45	S	2	41	S
3	33	S	3	28	S
4	33	S	4	38	S
5	33	S	5	34	S

TABLE 8

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'D' - RUN 4

CO concentration = 3.23 mg/l

Ct = 97,000 mg min/m<sup>3</sup>

HCN concentration = 88 µg/l

Ct = 2,640 mg min/m<sup>3</sup>

CO/HCN ratio = 37

Animal Mortalities:

	o/w	24 hrs	7 days
Rats	4/15	4/15	5/15
Guinea Pigs	0/15	0/15	0/15

COHb results:

Rats	COHb%		Guinea Pigs	COHb%	
1	50	S	1	37	S
2	40	S	2	25	S
3	42	S	3	36	S
4	38	S	4	35	S
5	39	S	5	37	S

TABLE 9

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'D' - RUN 5

CO concentration = 4.05 mg/l

Ct = 121,000 mg min/m<sup>3</sup>

HCN concentration = 91 µg/l

Ct = 2,730 mg min/m<sup>3</sup>

CO/HCN ratio = 45

Animal Mortalities:

	o/w	24 hrs	7 days
Rats	15/15	-	-
Guinea Pigs	1/15	1/15	1/15

COHb results:

Rats	COHb%		Guinea Pigs	COHb%	
1	73	D	1	59	D
2	69	D	2	26	S
3	69	D	3	21	S
4	70	D	4	30	S
5	71	D	5	22	S

TABLE 10

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'D' - RUN 6

CO concentration = 3.46 mg/l  
HCN concentration = 58  $\mu$ g/l

Ct = 104,000 mg min/m<sup>3</sup>  
Ct = 1,740 mg/ min/m<sup>3</sup>

CO/HCN ratio = 60

Animal Mortalities:

	o/w	24 hrs	7 days
Rats	9/15	9/15	9/15
Guinea Pigs	0/15	0/15	0/15

COHb results:

Rats	COHb%		Guinea Pigs	COHb	
1	68	D	1	29	S
2	60	D	2	33	S
3	63	D	3	35	S
4	38	S	4	26	S
5	44	S	5	22	S



TABLE 11

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'F' - RUN 1

CO concentration = 2.72 mg/l

Ct = 82,000 mg min/m<sup>3</sup>

HCN concentration = 20.5 mg/l

Ct = 620 mg min/m<sup>3</sup>

CO/HCN ratio = 133

Animal Mortalities:

	o/w	24 hrs	7 days
Rats	0/15	0/15	0/15
Guinea pigs	0/15	0/15	0/15

COHb results:

Rats	COHb%		Guinea Pigs	COHb%	
1	14	S	1	28	S
2	20	S	2	27	S
3	19	S	3	5	S
4	20	S	4	21	S
5	17	S	5	25	S

TABLE 12

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'F' - RUN 2

CO concentration = 3.32 mg min/l

Ct = 100,000 mg min/m<sup>3</sup>

HCN concentration = 52 µg/l

Ct = 1,560 mg min/m<sup>3</sup>

CO/HCN ratio = 64

Animal Mortalities:

	o/w	24 hrs	7 days
Rats	2/15	2/15	2/15
Guinea pigs	0/15	0/15	0/15

COHb results:

Rats	COHb%		Guinea Pigs	COHb%	
1	29	S	1	70	D
2	37	S	2	35	S
3	27	S	3	23	S
4	35	S	4	29	S
5	33	S	5	31	S

TABLE 13

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'F' -- RUN 3

CO concentration = 3.89 mg/l

Ct = 117,000 mg min/m<sup>3</sup>

HCN concentration = 74 µg/l

Ct = 2,220 mg min/m<sup>3</sup>

CO/HCN ratio = 53

Animal Mortalities:

	o/w	24 hrs	7 days
Rats	10/15	10/15	10/15
Guinea Pigs	0/15	0/15	1/15

COHb results:

Rats	COHb%		Guinea Pigs	COHb%	
1	17	S	1	63	D
2	15	S	2	30	S
3	9	S	3	23	S
4	14	S	4	22	S
5	13	S	5	21	S

TABLE 14

TOXICITY DATA FOR ANIMALS EXPOSED TO FOAM 'F' - RUN 4

CO concentration = 3.55 mg/l

Ct = 107,000 mg min/m<sup>3</sup>

HCN concentration = 52 µg/l

Ct = 1,560 mg min/m<sup>3</sup>

CO/HCN Ratio = 68

Animal Mortalities:

	o/w	24 hrs	7 days
Rats	4/15	4/15	5/15
Guinea pigs	0/15	0/15	0/15

COHb results:

Rats	COHb%		Guinea pigs	COHb%	
1	43	S	1	79	D
2	34	S	2	49	S
3	38	S	3	57	S
4	33	S	4	50	S
5	36	S	5	46	S

400g OF POLYURETHANE FOAM CUSHION PYROLYSED

Time	CO%	O <sub>2</sub> %	Plate Temp OC	Chamber Temp C	Smoke (conc) mg/l	HCN (conc) µg/l
0'		20.93	40	30.5		
5'			294	31.0		
10'			385	34.0		
15'			439	37.0	Smoke from chimney	
20'	0.05	20.70	523	40		
25'	0.19	20.30	547	44		
30'	0.27		559	46		108
35'	0.32		579	48.5		
40'	0.39		575	50.5	0.44	
45'	0.46	18.90	557	52.0		
50'	0.51	18.50	579	53.0		
55'	0.55	18.20	583	54.5		
60'	0.60	17.90	581	54.5	0.41	116
Power off						
65'	0.63		460	54.0		
Chamber Exhausted						
70'		20.80	276	34.0		

Residual ash 50g

400g OF POLYURETHANE FOAM CUSHION PYROLYSED

Time	CO%	Plate temp °C	Smoke conc mg/l	HCN conc µg/l
0'				
5'		263		
10'		380		
15'	0.01			
20'	0.02	492		
25'	0.02			
30'	0.03	530	0.05	
35'	0.035			
40'	0.05	541		
50'	0.06	547		
60'	0.085	546		
70'	0.090	556	0.09	31.1
80'	0.125	560		
90'	0.150	563		

Residual ash 60g, inside of box covered with thick tarry distilled low smoke, CO and HCN concentrations due to blocked gauzes in chimney.

400g POLYURETHANE FOAM CUSHION PYROLYSED

Time	CO%	Plate temp °C	Chamber temp °C	Smoke mg/l	HCN ug/l
0'		23	23		
5'		256	24.5		
10'					
15'		427	29.3		
20'	0.05				
25'	0.11	550	38.0	0.16	
30'	0.14				80.0
35'	0.16	581	44.2		
40'	0.25	590	49.0		
50'	0.35			0.26	133.3
55'	0.40	600	52.5		
60'	0.425				
65'	0.425	601	54.0		122.2
70'	0.400			0.37	
Power Off					
75'	0.400	435	52.0		
85'	0.400	303	46.0		
95'	0.400	231	40.4		
105'	0.400	185	36.0		
115'	0.380	151	33.1		
120'	0.380			0.45	81.1
135'	0.370	108	29.3		
150'	0.360			0.48	71.1
155'	0.360	82	27.7		

Residual ash 35g

105g POLYURETHANE FOAM CUSHION PYROLYSED

Time	CO%	O <sub>2</sub> %	Plate temp °C	Chamber temp	Smoke mg/l	HCN µg/l
0'		20.93	25	25.5		
5'		20.93	235	26.4		
10'		20.93	360	30.7		
15'		20.93				
20'		20.93	447	36.6		
25'	0.015	20.93				
30'	0.025	20.60	527	41.8	0.044	26.0
35'	0.030	20.35				
40'	0.032	20.10	541	47.1		
45'	0.035	20.00				
50'	0.040	20.00	537	50.5	0.036	16.7
55'	0.045	19.90				
60'	0.050	19.80	535	52.9		
65'	0.053	19.80				
70'	0.055	19.80	532	54.3	0.032	16.7
Power off						
75'	0.060	19.80	251	47.1		
80'	0.060	19.75	200	42.8		
120'	0.058	19.75	164	39.9		

Residual ash 14g



400g OF POLYURETHANE FOAM H (GREEN HIGH DENSITY) PYROLYSED  
(CONDITIONS AS BEFORE)

Time	CO%	CO2%	O2%	Plate temp	Chimney temp	Chamber temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	21	21	22.4		
10'	-	-	20.93	239	158	25.8		
20'	-	-	20.93	343	215	30.6		
30'	0.04	-	20.93	399	261	35.0		
40'	0.10	-	20.80	425	256	37.9	0.244	84.0
50'	0.16	0.20	20.55	444	279	40.8		
60'	0.185	0.45	20.30	465	292	43.2		
70'	0.20	0.80	19.90	474	287	45.2		
80'	0.22	1.10	19.60	484	296	47.1		
90'	0.54	1.75	18.35	568	298	51.0		
100'	0.76	2.75	17.35	637	298	52.9		
110'	0.76	3.00	17.15	525	295	52.9	0.377	205.0
+18' smoke from the chimney, 40' smoke sample brown in colour +85' Smoke from chimney followed by rapid rise in CO, and fall in O2 level +100' Power off. +110' Smoke sample black in colour. +110' chamber exhausted to correct levels of CO, CO2 and HCN.								
140'	0.34	1.70	19.20			28.2		

Time	CO%	CO2%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber temp
0'	0.32	1.70	19.20	0.087		24.3
5'	0.32	1.70	19.20	0.087		
10'	0.32	1.70	19.20		68.0	22.0
15'	0.32	1.70	19.20			
20'	0.32	1.70	19.20	0.067	61.1	20.0
25'	0.32	1.70	19.20			
30'	0.32	1.70	19.20	0.060	56.7	18.5

400g OF POLYURETHANE FOAM H (GREEN, HIGH DENSITY) PYROLYSED

Time	CO%	CO2%	O2%	Plate temp	Chimney temp	Chamber temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	20	20	21		
10'	-	-	20.93	272	162	26.3		
20'	0.005	-	20.93	375	229	31.6		
30'	0.07	-	20.65	424	474	36.4		
40'	0.15	0.10	20.50	447	268	39.4	0.242	76.0
50'	0.175	0.40	20.10	474	289	42.7		
60'	0.175	0.75	19.80	540	299	45.6		
70'	0.75	1.50	18.40	613	304	51.0		
80'	1.00	2.35	17.30	533	293	52.4		
90'	0.95	2.85	17.00	484	272	51.5	0.276	190.0
100'	0.95	2.85	17.00	315	201	47.1		
+18' Smoke from chimney +30' Smoke stopped, 40' Smoke sample brown in colour. +64' Black smoke from chimney, followed by rapid rise in CO, CO2 levels and fall in O2 level. +90' Power switched off. +100' Chamber exhausted to correct levels of CO, CO2 and HCN								
+150'	0.33	0.90	19.60					

20 Guinea pigs (nos 496-515) and 20 rats (nos 528-547) exposed in chamber for 30'

Time	CO%	CO2%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber temp
0'	0.285	0.70	19.70			22.4
5'	0.285	0.70	19.70			
10'	0.285	0.70	19.70	0.029	39.0	22.4
15'	0.285	0.70	19.70			
20'	0.285	0.70	19.70	0.025	32.2	22.4
25'	0.285	0.70	19.70			
30'	0.285	0.70	19.70	0.021	31.1	22.4

400g OF POLYURETHANE FOAM H (GREEN HIGH DENSITY) PYROLYSED

Time	CO%	CO2%	O2%	Plate temp	Chimney temp	Chamber temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	20	20	22.2		
10'	-	-	20.93	350	157	25.8		
20'	0.005	-	20.93	432	214	31.0		
30'	0.07	-	20.70	480	261	35.4		
40'	0.125	0.10	20.60	501	255	38.8	0.150	53.5
50'	0.135	0.40	20.30	553	276	42.2		
60'	0.70	1.10	18.90	610	297	47.6		
70'	1.20	1.95	17.70	609	295	51.0		
80'	1.14	2.55	17.25	561	275	51.5		
90'	1.10	2.85	17.00	357	208	48.0		
+17' Smoke from chimney, 40' Smoke sample brown in colour.								
+54' Black smoke from chimney. +58' Sheet of flame from chimney								
+80' Power off. +90' Chamber exhausted to correct levels of CO, CO2 and HCN								
+130'	0.35	1.05	19.50					

20 Guinea pigs (Nos 516-545) and 20 Rats (Nos 548-567)  
exposed in chamber for 30'

Time	CO%	CO2%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber temp
0'	0.35	1.05	19.50			24.6
5'	0.35	1.05	19.50			
10'	0.35	1.05	19.50	0.046	68.0	23.6
15'	0.35	1.05	19.50			
20'	0.35	1.05	19.50	0.046	55.5	23.6
25'	0.35	1.05	19.50			
30'	0.35	1.05	19.50	0.042	47.1	23.1

Residual ash 63g

400g of POLYURETHANE FOAM H(GREEN HIGH DENSITY)PYROLYSED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	24	24	25.3		
10'	-	-	20.93	338	162	29.2		
20'	0.005	-	20.93	430	215	34.0		
30'	0.06	-	20.70	473	249	38.4		
40'	0.12	0.15	20.55	494	262	41.3	0.170	77.0
50'	0.13	0.35	20.20	550	257	45.2		
60'	0.45	1.15	18.95	610	299	50.5		
70'	1.20	2.15	17.40	616	314	54.4		
80'	1.15	2.80	17.00	562	275	54.4	0.265	235.0
90'	1.12	3.00	16.80	357	207	50.5		
+17' Smoke from chimney 40' Smoke sample brown in colour. +54' Black smoke from chimney, followed by muffled bangs within apparatus, 59' several sheets of flame from chimney. +80' Power Off +90' Chamber exhausted								
150'	0.245	0.60	19.0			28.7		

20 Guinea Pigs (Nos 536-555) and 20 Rats (Nos 568-587) exposed in chamber for 30'

Time	CO%	CO2%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber Temp
0'	0.245	0.60	19.90			26.8
5'	0.245	0.60	19.90			
10'	0.245	0.60	19.90	0.042	37.0	24.3
15'	0.245	0.60	19.90			
20'	0.245	0.60	19.90	0.040	34.4	22.9
25'	0.245	0.60	19.90			
30'	0.245	0.60	19.90	0.040	32.2	21.9

407g OF POLYURETHANE FOAM D PYROLYSED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/L
0'	-	-	20.93	31	47	22.9		
10'	-	-	20.93	336	216	27.3		
20'	0.05	-	20.80	490	248	32.1		
30'	0.14	0.10	20.20	519	287	36.0		
40'	0.30	-	19.65	564	292	42.3		
50'	0.40	1.40	18.70	574	313	46.6	0.54	
60'	0.60	2.00	18.00	584	314	49.0		122.2

Power switched off at +60' chamber exhausted to correct concentrations, allowed to cool.

20 Guinea Pigs and 20 Rats exposed in chamber for 30'  
(Nos 226-245) Nost 288-307

Time	CO%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber Temp
0'	0.22	19.50			35.5
5'	0.22	19.50	0.06		
10'	0.22	19.50		30.0	32.1
15'	0.22	19.50	0.046		
20'	0.22	19.50		25.6	30.2
25'	0.22	19.50	0.04		
30'	0.22	19.50		23.3	28.8

## 403g OF POLYURETHANE FOAM D TYROLISED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	28	28	28		
10'	-	-	20.93	353	198	32.6		
15'	-	-	20.93					
20'	0.025	-	20.93	458	292	37.9		
25'	0.20	-	20.25					
30'	0.22	0.70	19.80	546	280	42.7		
35'	0.30	1.40	18.90	574	315	47.1		
45'	0.44		18.30					
50'	0.54	2.00	17.60	586	315	51.0	0.59	
60'	0.57	2.60	16.80	625	306	53.4		166.6

Power switched off +60' Chamber exhausted to correct concentrations and allowed to cool. (Guinea pigs Nos 246-265, Rats Nos 308-327)

20 Guinea Pigs and 20 Rats exposed in chamber for 30'

Time	CO%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber Temp
0'	0.295	18.85			34.6
5'	0.295	18.85	0.114		
10'	0.295	18.85		45.6	33.1
15'	0.295	18.85	0.109		
20'	0.295	18.85		44.7	32.0
25'	0.295	18.85	0.104		
30'	0.295	18.85		44.0	31.2

Residual ash 43.0g

400g OF POLYURETHANE FOAM D PYROLYSED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	22	23	23.4		
10'	-	-	20.93	265	154	25.8		
20'	0.11	-	20.60	529	252	33.5		
30'	0.35	0.10	18.10	597	262	40.8		
40'	0.55	1.10	16.90	563	265	46.1	0.994	255
50'	0.95	2.90	16.90	551	292	49.5		
60'	0.95	3.80	16.90	510	270	50.5		
70'	0.95	3.80	16.90	327	205	44.2	0.77	255
80'	0.95	3.90	16.90	240	157	37.4		
+13' Smoke from chimney. +20' Flames from chimney, followed by several muffled blow outs. Power off +60'. + 180' chamber exhausted for correct levels of CO, CO2, O2 and HCN								
+120'	0.290	1.30	19.80					

20 Guinea Pigs (Nos 436-455) and 20 Rats (Nos 468-487) exposed in chamber for 30'

Time	CO%	CO2%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber Temp
0'	0.255	1.10	20.05			22.4
5'	0.255	1.10	20.05			
10'	0.255	1.10	20.05	0.062	51.0	22.4
15'	0.255	1.10	20.05			
20'	0.255	1.10	20.05	0.057	42.0	22.0
25'	0.255	1.10	20.05			
30'	0.255	1.10	20.05	0.050	39.0	22.0

400g OF POLYURETHANE FOAM D PYROLYSED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	21	22	23.9		
10'	-	-	20.93	147	104	24.3		
20'	-	-	20.93	228	155	26.8		
30'	0.25	-	20.30	493	252	32.6		
40'	0.34	0.50	19.20	559	268	40.3	0.825	365
50'	0.64	2.20	17.70	597	286	46.1		
60'	0.74	3.65	16.50	543	286	50.0		
70'	0.74	4.10	16.50	352	227	47.1		
80'	0.74	4.10	16.50	253	163	41.8	0.444	325
140'	0.68	3.80	16.65	-	-	23.4		
+21' Smoke from chimney. +60' Power off. +140' Chamber exhausted to correct levels CO, CO2, O2 and HCN								
170'	0.28	1.30	19.25			23.4		

20 Guinea Pigs (Nos 456-475) and 20 Rats (Nos 488-507) exposed in chamber for 30'

Time	CO%	CO2%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber Temp
0'	0.28	1.30	19.25			23.4
5'	0.28	1.30	19.25			
10'	0.28	1.30	19.25	0.055	94.0	22.9
15'	0.28	1.30	19.25			
20'	0.28	1.30	19.25	0.055	85.0	22.9
25'	0.28	1.30	19.25			
30'	0.28	1.30	19.25	0.047	85.0	22.9



400g OF POLYURETHANE FOAM D PYROLYSED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	21	21	23.4		
10'	-	-	20.93	385	157	25.8		
20'	0.25	0.05	20.25	537	268	33.5		
30'	0.525	0.90	18.50	617	284	42.3		
40'	0.910	2.10	16.90	624	285	48.1	0.765	310
50'	0.850	3.30	16.40	540	284	49.0		
60'	0.800	4.20	16.40	524	271	49.5		
70'	0.760	4.20	16.40	337	211	46.1	0.419	240
+10' Smoke from chimney. +60' Power Off. +70' Chamber exhausted to correct levels of CO, CO2 and HCN								
120'	0.35	1.20	18.65			22.7		

20 Guinea Pigs (Nos 556-575) and 20 Rats (Nos 588-607) exposed for 30'.

Time	CO%	CO2%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber Temp
0'	0.35	1.20	18.65			22.7
5'	0.35	1.20	18.65			
10'	0.35	1.20	18.65	0.094	106	21.9
15'	0.35	1.20	18.65			
20'	0.35	1.20	18.65	0.082	84	21.9
25'	0.35	1.20	18.65			
30'	0.35	1.20	18.65	0.074	83	21.9

400g POLYURETHANE FOAM D PYROLYSED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	22	22	22.9		
10'	-	-	20.93	325	154	26.3		
15'	-	-	20.93	-	-	-		
20'	0.09	-	20.55	504	232	33.1		
25'	0.28	0.25	19.75	-	-	-		
30'	0.30	1.25	19.20	577	270	40.3		
35'	0.42	2.10	18.40	-	-	-	0.487	
40'	0.60	2.75	17.70	591	288	46.6		250
45'	0.77	3.30	17.10	-	-	-	0.448	
50'	0.90	4.00	16.40	606	296	50.5		360
55'	0.92	4.50	16.20	-	-	-		
60'	0.92	4.60	16.00	371	224	48.1		
65'	0.92	4.60	16.00	-	-	-	0.385	
70'	0.90	4.60	16.00	269	171	42.7		360
+12' Smoke from chimney. +50' Power off. +70' Chamber exhausted To correct levels of CO, CO2, O2 and HCN								
110	0.30	1.30	19.10			25.3		

20 Guinea Pigs (Nos 576-595) and 20 Rats (Nos 608-627) exposed for 30'

Time	CO%	CO2%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber Temp
0'	0.30	1.30	19.10			22.9
5'	0.30	1.30	19.10			
10'	0.30	1.30	19.10	0.047	61.0	22.9
15'	0.30	1.30	19.10			
20'	0.30	1.30	19.10	0.043	59.0	22.9
25'	0.30	1.30	19.10			
30'	0.30	1.30	19.10	0.043	54.0	22.9

## 402g OF POLYURETHANE FOAM F PYROLYSED

Time	CO%	O <sub>2</sub> %	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	20.93	26	26	26		
10'	-	20.93	307	177	29.2		
20'	0.02	20.75	440	235	34.0		
30'	0.145	20.60	479	282	37.9		
40'	0.22	20.45	491	284	40.3		
50'	0.28	20.30	510	290	43.2		
60'	0.56	19.40	599	296	49.0	1.12	
Power off +60							
65'	1.00	18.70					
70'	1.35	18.20	403	243	47.6		
80'	1.35	18.20	285	194	43.2	1.01	235
85'	1.30	18.20					
105'	1.20	18.20					

Smoke from chimney at +15', dense black smoke +52' with rapid rise in CO level.

Chamber exhausted to correct level of CO etc +110'

20 Guinea Pigs (Nos 266-285) and 20 Rats (Nos 328-347) exposed in chamber for 30'

Time	CO%	O <sub>2</sub> %	Smoke mg/l	HCN $\mu$ g/l	Chamber Temp
0'	0.24	20.25			29.2
5'	0.24	20.25	0.053		
10'	0.24	20.27		23.5	29.2
15'	0.24	20.25	0.044		
20'	0.24	20.25		20.0	26.8
25'	0.235	20.25	0.036		
30'	0.235	20.25		18.0	23.9

400g OF POLYURETHANE FOAM F PYROLYSED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	22	22	25.2		
5'	-	-	20.93	115	87	25.2		
10'	-	-	20.93	264	161	27.1		
20'	-	-	20.93	381	235	31.5		
25'	0.05	-	20.93	-	-	-		
30'	0.12	-	20.93	436	284	35.9		
40'	0.19	-	20.93	459	289	38.8	0.69	105
50'	0.28	0.15	20.93	479	314	41.2		
60'	0.44	0.35	20.20	590	309	45.1		
65'	0.80	1.20	19.10	-	-	-		
Power off +65'. Smoke from chimney +15'. Dense black smoke from chimney +57' followed by rapid rise in CO and CO2 levels.								
70'	0.90	1.40	18.65	515	271	48.5		
80'	0.94	1.75	18.40	327	204	43.2	1.97	269
90'	0.90	1.75	18.40	245	158	38.5		

Chamber exhausted to correct levels CO, CO2, O2 and CN by +120'

20 Guinea Pigs (Nos 356-375) and 20 Rats (Nos 368-387) exposed to chamber for 30'

Time	CO%	CO2%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber Temp
0'	0.29	0.40	20.45			26.6
5'	0.29	0.40	20.45			
10'	0.29	0.40	20.45	0.139	59.0	25.2
15'	0.29	0.40	20.45			
20'	0.29	0.40	20.45	0.122	50.0	24.2
25'	0.29	0.40	20.45			
30'	0.29	0.40	20.45	0.085	46.0	23.2

## 400g OF POLYURETHANE FOAM F PYROLYSED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	23.4	23.9	24.9		
10'	-	-	20.93	306	166	28.2		
20'	0.03	-	20.93	403	233	32.6		
30'	0.18	-	20.80	449	260	36.4		
35'	0.21	0.05	20.70	-	-	-		
40'	0.25	0.15	20.55	471	277	39.4	0.50	110
50'	0.32	0.25	20.40	492	296	41.8		
60'	0.77	0.95	18.90	605	289	47.6		
65'	1.03	1.45	18.25	616	307	50.0		
70'	1.05	1.90	17.80	471	272	49.5	1.78	
80'	1.05	2.10	17.70	313	203	43.7	1.57	200
Power off at +65'. Smoke from chimney at +15'. Dense black smoke from chimney +53' followed by rapid rise in CO, CO2, +80' exhaust.								
90'	0.43	0.80	19.45	234	158	38.4		
100'	0.38	0.65	19.60	185	123	32.6		

Chamber exhausted to correct levels of CO, CO2, O2 and HCN by +120'  
20 Guinea Pigs (Nos 376-395) and 20 Rats (Nos 388-407) exposed in chamber for 30'-

Time	CO%	CO2%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber Temp
0'	0.34	0.65	19.80			25.8
5'	0.34	0.65	19.80			
10'	0.34	0.65	19.80	0.166	90.0	24.8
15'	0.34	0.65	19.80			
20'	0.34	0.65	19.80	0.137	67.0	24.8
25'	0.34	0.65	19.80			
30'	0.34	0.65	19.80	0.126	64.0	24.3

400g OF POLYURETHANE FOAM F PYROLYSED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	24.0	25.0	25.3		
10'	-	-	20.93	173	99	26.8		
20'	0.05	-	20.93	370	196	31.6		
30'	0.19	0.05	20.60	454	260	36.4		
40'	0.28	0.10	20.30	492	274	39.8	0.76	105
50'	0.37	0.25	20.00	575	277	43.7		
60'	1.10	1.10	18.50	616	282	48.5		
65'	1.25	1.55	17.70	-	-	-		
70'	1.25	1.60	17.70	472	268	49.5		
80'	1.25	1.60	17.70	318	191	44.7	1.45	280
Power off +65' Smoke from chimney +15'. Dense black smoke from chimney +50' rapid rise in CO, CO2 and smoke levels. +80' exhausted to correct levels of CO, CO2 and smoke levels +80' exhausted to correct levels of CO, CO2, O2 and HCN by +120'.								

20 Guinea Pigs (Nos 396-415) and 20 Rats (Nos 408-427) exposed in chamber for 30'

Time	CO%	CO2%	O2%	Smoke mg/l	HCN $\mu$ g/l	Chamber Temp
0'	0.31	0.38	19.60			27.3
5'	0.31	0.38	19.60			
10'	0.31	0.38	19.60	0.102	60.0	25.3
15'	0.31	0.38	19.60			
20'	0.31	0.38	19.60	0.100	49.0	23.9
25'	0.31	0.38	19.60	0.098	47.0	22.9

370g OF POLYURETHANE FOAM D PYROLYSED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	23	23	23.4		
5'	-	-	20.93	224	110	25.8		
10'	-	-	20.93	323	162	28.2		1.0
15'	-	-	20.93	396	196	30.6		
20'	0.02	-	20.80	435	233	33.5		3.8
25'	0.13	-	20.30	537	270	37.9	0.292	NB
30'	0.23	0.20	19.50	575	271	41.3		85.0
35'	0.24	0.70	19.10	435	226	42.3	0.544	
40'	0.25	1.30	18.80	373	211	42.3		140.0
45'	0.255	1.65	18.60	329	182	41.8	0.377	
50'	0.255	2.00	18.50	279	169	40.1		147.5
55'	0.255	2.00	18.50	234	150	38.9	0.342	
60'	0.255	2.00	18.50	211	136	27.9		139.0
65'	0.255	2.00	18.50	191	127	36.4	0.308	
70'	0.255	2.00	18.50	167	109	35.0		135.0

+14 Smoke from chimney. +30' Power switched off

Residual Ash 93g included some tarry distillate

RATIO	CO/HCN
25'	18.3
35'	20.5
45'	20.7
55'	22.0
65'	22.6

## 435g POLYURETHANE FOAM F PYROLYSED

Time	CO%	CO2%	O2%	Plate Temp	Chimney Temp	Chamber Temp	Smoke mg/l	HCN $\mu$ g/l
0'	-	-	20.93	22	22	23.9		
5'	-	-	20.93	228	113	24.8		
10'	-	-	20.93	326	166	27.3		
15'	-	-	20.80	400	194	30.4		
20'	0.035	-	20.80	438	227	33.1	0.162	16.3
25'	0.140	-	20.70	463	259	36.0		
30'	0.225	0.05	20.55	473	258	38.4	0.486	73.0
35'	0.280	0.15	20.45	481	267	39.8		
40'	0.320	0.20	20.20	497	284	41.3	0.594	122.8
45'	0.430	0.25	18.40	573	267	42.7		
50'	0.660	0.45	17.55	471	244	46.1	1.340	169.5
55'	0.900	0.80	17.55	415	218	45.6		
60'	0.900	1.10	17.55	326	191	44.2	1.741	198.8
65'	0.900	1.20	17.55	275	170	41.8		
70'	0.900	1.20	17.55	210	134	38.4		

+10' Smoke from chimney. +43' Black smoke from chimney +45' Power off  
Residual Ash 76g

TIME	RATIO CO/HCN	
20'	25.0	
30'	36.9	
40'	31.4	} Useful range
50'	46.8	
60'	54.2	
70'	53.9	



375g OF POLYURETHANE FOAM D PYROLYSED IN APPARATUS PREHEATED TO  
500°C CHIMNEY THROTTLED BY PLATE. POWER SWITCHED OFF AT +5' AFTER  
FOAM INSERTED

Time	Plate Temp	Chimney Temp	Chamber Temp
0'	18	19	19
10'	308	161	22.9
20'	421	215	28.7
30'	457	231	35.5
40'	479	242	35.5
50'	488	245	37.4
60'	493	256	40.3
70'	493	259	41.8

Foam inserted

Time	CO%	O2%	Smoke	HCN μg/l	Plate Temp	Chimney Temp	Chamber Temp
0'	0.00	20.93					
5'	0.25	20.35		180	500	261	43.2
10'	0.48	19.65	0.665				
15'	0.52	19.10		310	374	196	40.8
20'	0.52	18.85	0.581				
25'	0.52	18.70		297	294	154	37.4
30'	0.52	18.50	0.482				
35'	0.50	18.50		294	220	129	34.0
40'	0.48	18.50	0.438				

Residual Ash 119g

380g OF POLYURETHANE FOAM D PYROLYSED IN APPARATUS PREHEATED  
TO 490°C CHIMNEY THROTTLED BY PLATE

Time	Plate Temp	Chimney Temp
0'	19	19
10'	311	167
20'	412	213
30'	450	244
40'	471	255
50'	481	248
60'	486	262
70'	490	267

Foam Inserted

Time	CO%	O <sub>2</sub> %	Smoke mg/l	HCN μg/l	Plate Temp	Chimney Temp
0'	0.00	20.93			490	267
2'	0.01	20.93			484	268
4'	0.06	20.70			446	244
5'	0.09	20.50		41.0		
6'	0.105	20.40			408	226
8'	0.115	20.35			371	216
10'	0.125	20.35	0.783	101.0	345	207
12'	0.130	20.35			323	198
14'	0.135	20.30			304	188
15'	0.140	20.30		101.0		
16'	0.140	20.30			287	179
18'	0.145	20.30			271	171
20'	0.145	20.30	0.901	98.0	257	162

410g OF POLYURETHANE FOAM H GREEN PYROLYSED PREHEATED TO 490°

Time	Plate Temp	Chimney Temp
0'	19.0	19.0
10'	305	164
20'	413	211
30'	450	237
40'	468	247
50'	478	250
60'	479	252
70'	480	258
80'	486	260
90'	488	260
100'	490	267

Time	CO%	CO2%	O2%	Smoke mg/l	HCN µg/l	Plate Temp	Chamber Temp	Chimney Temp
0'	-	-	20.93			464	39.3	260
5'	0.01	-	20.93			500	41.3	276
10'	0.02	-	20.70		13.0	520	41.8	259
15'	0.035	-	20.30			572	43.2	270
20'	0.065	-	19.90		42.0	579	43.7	264
25'	0.33	0.25	19.40			597	44.7	267
30'	0.58	0.45	18.80	0.339	117.5	431	43.1	
35'	0.58	0.90	18.70			352	41.3	209
40'	0.58	1.15	18.70	0.301	132.5	290	38.9	183
45'	0.56	1.20	18.70			179	20.5	116
50'	0.56	1.20	18.70	0.278	155.0	145	17.6	96
Power off at 25'. Residual Ash 63g included some tarry distillate								
+50'	Chamber cooled and exhausted.							
80'	0.36	0.85	19.55	0.127	87.5	121	17.6	

TIME

RATIO CO/HCN

10'	18.0	
20'	18.6	
30'	59	)
40'	53	)
50'	43	)
80'	49	)

Useful range

400g OF POLYURETHANE FOAM H PYROLYSED IN MODIFIED FIREBOX. (PLATE  
INSULATED FROM TOP SECTION BY 2 PIECES  $\frac{1}{4}$  INCH THICK ASBESTOS SHEET)

Time	Plate Temp	Chimney Temp	Chamber Temp	CO%	O <sub>2</sub> %	CO <sub>2</sub> %
0'	28	28	27.5		10.93	
10'	59	101	28.0			
20'	111	129	30.9			
30'	149	147	35.8			
40'	153	147	37.3			
50'	164	153	37.7			
60'	169	156	29.7			
90'	176	160	47.5			
100'	187	167	48	0.06	20.30	1.0
110'	188	166	50	0.06	20.10	1.3
120'	190	164	50	0.06	19.85	1.5
130'	190	164	51	0.06	19.70	1.75
140'	188	160	51	0.06	19.60	2.00
150'	187	165	52	0.06	19.45	2.20
160'	187	165	52	0.06	19.40	2.30
170'	186	162	51	0.06	19.20	2.50
180'	185	160	51	0.06	19.20	2.60

HCN Samples	Time	-mv	$\mu\text{gm/ml}$	Total	$\mu\text{gm/l}$
1	100' - 120'	118	0.20	20	1.0
2	120' - 140'	177	2.3	230	11.5
3	140' - 160'	179	2.5	250	12.5
4	160' - 180'	180	2.6	260	13.0

400g OF FOAM H PYROLYSED IN MODIFIED FIRE BOX (CENTRE SECTION  
REMOVED) APPARATUS PREHEATED TO 500°C

Time	Plate Temp	Chimney Temp
0'	26	26
10'	328	164
20'	418	226
30'	468	244
40'	493	267
50'	502	264
60'	506	268

Foam inserted

Time	CO%	CO2%	O2%	Smoke mg/l	HCN µg/l	Plate Temp	Chimney Temp	Chamber Temp
0'	-	-	20.93			483	269	42.0
5'	-	-	20.93			523	248	43.0
10'	0.08	0.30	20.40			564	247	43.7
15'	0.25	0.60	20.00			593	239	45.1
20'	0.45	0.80	19.70	1.54	185	613	252	46.6
25'	0.74	0.95	19.35			524	240	47.1
30'	0.80	1.05	19.15	1.21	250	436	215	45.9
35'	0.81	1.15	19.00			374	184	44.1
40'	0.81	1.15	19.00	0.81	260	326	178	42.2
45'	0.81	1.15	19.00			289	157	41.1
50'	0.78	1.15	19.00	0.50	260	258	143	39.0
55'	0.78	1.15	19.00			233	132	37.7
60'	0.78	1.15	19.00	0.40	200	211	120	35.8

Power switched off at +25' Residual wt 50g

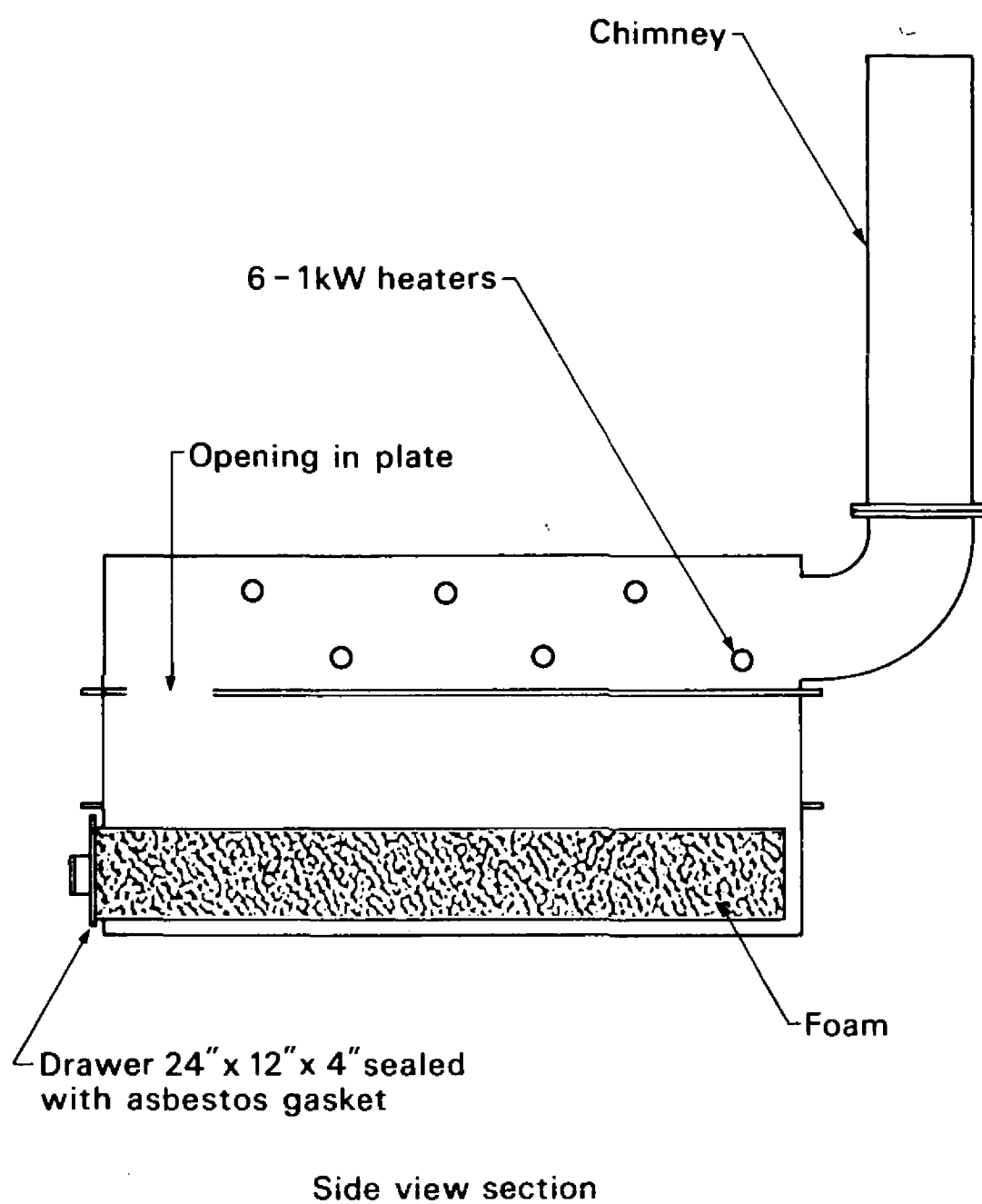


Figure 1 Pyrolysis unit for polyurethane foams