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COPY No. 5

THE ASSOCIATED OCTEL COMPANY LIMITED

PRODUCTION DEPARTMENT

**REPORT ON INCIDENT AT
PASIR PANJANG, SINGAPORE —
28th. AUGUST TO 21st. SEPTEMBER, 1965**

AUTHOR:

E. R. HARDING

**ELLESMERE PORT
OCTOBER 1965**

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AUTHOR: E. R. HARDING

APPROVED: C. S. REES

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CIRCULATION:

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Associate Director
- 2 - 5. Sales Manager
- 6 - 7. Manager - Production Department
8. Manager - Research & Engineering Department
9. Chief Medical Officer
10. Mr. E. R. Harding
11. - 15. Information Department

ELLESMERE PORT
OCTOBER 1965

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1. INTRODUCTION

At a date unknown but before January 30th, 1947 two 55 (US) gallon drums of antiknock compound were buried at a Shell oil installation at Pasir Panjang on the south-west coast of Singapore. (Appendix (1) report by M.A. Pryke).

In 1958 the 17 acre site was sold by Shell and is understood to have changed ownership several times since that year.

Early in 1965 Garden Estates Ltd. (Nassim Company) Singapore Ltd. 4/4-1 Collyer Quay, Singapore 1, commenced development of the site as a low cost housing development of approximately 226 homes.

Malay labour engaged on a casual daily basis at 5 "Straits" dollars (10s) per day was allowed to "camp out" in partly finished dwellings and to go to their homes up country once each week.

The site lies some 800 yards from the sea with the west coast road between the site and the sea. The water table at Pasir Panjang is between 6' to 8' and all excavation work requires extensive timber shoring and continued pumping to enable work to be done below these depths.

Examination of Appendix (2) will show the sewage drainage system of the site and the terraced block system used for housing layout.

A 6" sewage pipe running off to a septic tank was being installed and an excavation (manhole No. 6 marked in orange on Appendix (2) required excavation to about 26' to 28'.

The manhole excavation was 8' square and 14' deep at the time the incident occurred. (See photograph No. 1).

The stages of construction of nearby houses (which proved a serious limiting factor in dealing with the incident) can be seen in photograph Nos. 2 and 3.

Following excavation of No. 6 manhole at 14' depth between 16th July, 1965 and 25th July, 1965 by a work team of 27 men (listed in Appendix (3)) two men;

[REDACTED]

died, following exposure to lead alkyl compound.

It is understood that this information was later confirmed by post mortem conducted (in the case of [REDACTED]) by Dr. Sugai at the General Hospital, Singapore and that [REDACTED] died at Layang-Layang Tampoi Hospital, Malaya.

It should be noted from Appendix (3) that three workers could not be traced.

Dr. M.C. Bain, medical consultant to The Associated Octel Company Limited and Mr. R.W. Lerrigo, General Manager, Shell (Eastern) were informed by Mr. W. Watson, senior partner (Messrs. Swan and MacLaren) architect for the development, during the early stages of the occurrence.

At the request of the Public Health authorities, Singapore, Shell (Eastern) Ltd. conducted analytical work at the site (see Appendix (4)) which indicated that samples of a blue dye taken at the base of the excavation at manhole No. 6 contained high concentrations of an organic lead compound.

In addition to advice on the significance of the analytical data, Shell (Eastern) Ltd. informed Mr. W. Watson that the material in manhole No. 6 was highly toxic and that expert advice should be taken on decontamination and certification for future safe working.

On 25th July, the Public Health authorities stopped all excavation work and restricted access to a wide area surrounding manhole No. 6.

Following consultation between Shell (Eastern) Ltd. the Public Health authorities and Messrs. Swan and MacLaren and The Associated Octel Company Limited, Mr. E.R. Harding (acting as consultant to Messrs. Swan and MacLaren) arrived in Singapore on Saturday 28th September, 1965. See cables Nos. 1 and 2 Appendix (5).

Upon arrival, Mr. E.R. Harding was met by Mr. W. Watson and given a copy of a statement by Dr. C.M. Bain, (Appendix (6)).

Mr. Harding spoke to both Dr. C.M. Bain and Mr. R.W. Lerrigo, later the same evening.

2. CHRONOLOGICAL ACTIVITIES

Sunday 29th August, 1965

Arrangement for transport to site, some 8½ miles from Singapore city, was made by Mr. W. Watson. On site at 08.00 hours, obtained general information concerning depth of water table, excavation and availability of pumps, air blowers, etc. Manhole No. 6 excavated at 14' depth and full with running water from water table. Water pumped away from No. 6 manhole and associated trenches to permit visual examination and sampling.

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Samples taken were:-

Lead in air

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air mgPb/10m³</u>
29th Aug	1100	1	Surf side soil heap of manhole pit	Dark sub-clay	0.75
29th Aug	1130	2	6 yards west in 2' excavation	Dark sub-clay dry	1.05
29th Aug	1300	3	At seepage north west corner base of pit	Wet sandy sub-soil	>10.6

Soil samples

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Organic lead ppm</u>
29th Aug	1600	4	North west side corner of excavation pit		375
29th Aug	1630	5	South west corner near house 113		345
29th Aug	1645	6	North east corner near house 113		438

Three light blue rivulet appeared between shoring planks at about 8 to 10' depth. The blue liquid appeared to be floating on water and there was additional evidence of an oil substance floating on the water surface. The frequency of lead-in-air determination at surface soil level at this stage was governed by the necessity to "husband" chemical reagents.

At the end of the day's work it was clear;

- 2.1 Visible signs and lead in air tests showed that serious concentrations of organic lead vapour were present in the manhole excavation. The lead-in-air level was estimated (under wet conditions and following three dilutions with dithizone) at between 60-80 mgPb/10m³.
- 2.2 The soil contamination at ground level was indiscriminately placed through haphazard dumping of excavated soil and provided little physical disturbance took place did not at this time present a serious vapour risk.

Instruction was given to;

- 2.3 Flood and maintain a constant head of water level on the manhole

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and trenches.

- 2.4 Erect a physical barrier of corrugated iron sheet with locked entry to prevent unrestricted access.
- 2.5 Permit normal work to continue outside the restricted area.

In addition, it was obvious that the proximity of already constructed houses, pile driven foundations and the nature of the soil and sand strata above the water table would be serious inhibiting factors on removal of contaminated soil.

The use of heavy mechanical excavation equipment was not feasible, photographs Nos. 3, 4 and 5 and drawing Appendix (2) will illustrate this point. Mr. W. Watson was informed that a plan to deal with the situation would be formulated and presented by the late afternoon of Monday 30th August.

Monday 30th August

Arrangements made for physical site supervision with Mr. Albrecht (Clerk of Works, Swan and MacLaren staff). At 9.30 a.m. with a 6' water level the lead in air level 2' above the water in the centre of the excavation pit was 7.5 mgPb/10m³.

A junior official arrived from the Public Health authority. In response to detailed questioning on the action of the authority and data on any sampling carried out by them, it was ascertained the authority had undertaken no sampling other than analysis of the piped drinking water supply.

It had been previously determined there were no artesian wells in the vicinity and that all piped water came from Johore (Malaya) to storage reservoirs located near the principal golf course some miles away.

Visit arranged to Mr. R.W. Lerrigo, at 11.15 a.m., Shell House, Collyer Quay.

Arrangements on solid sampling agreed and information obtained on previous sampling activities carried out by Shell (Eastern) Ltd. (See Appendix (4)).

It should be noted that a 36 hour delay occurred initially for receipt of the stock solutions from Pulau Bukom Refinery following the taking of solid samples. Within a week this 36 hour period has been reduced to a same day service.

Enquiries on the location of the two buried drums proved abortive but Shell provided a copy of a report by M.A. Pryke (Appendix (1)). Further investigation involved interviews with retired staff, and exhaustive checks on the filing system and drawings, which provided no information of value.

Mr. Lerrigo outlined the Shell position in the incident stating that the 17 acre old oil installation site had been sold in 1958; that ownership had changed several times since, and that whilst Shell took the view there was no legal liability upon them, they were extremely anxious to see the situation safely resolved with minimum delay.

Arrangements were made for limited supply of safety equipment and Uni-jet chemical reagents to be sent to Pasir Panjang from Shell refinery at Pulau Bukum.

On site p.m., arrangements made to bore a series of 6" auger holes (see auger device photograph Nos. 6 and 7) at 6', 8' and 10' depths, in an attempt to locate the main contaminated soil strata.

Lead in air

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10m³</u>
30th Aug	0920	7	Centre No. 6 manhole dry conditions	Unit suspended 2' over centre	> 7.5
30th Aug	1800	8	Hole No. 9 on surface soil		3.5

In addition, Mr. W. Watson was requested to organise the use of a mine detector from British Army sources. (photograph No. 8).

It was agreed that a meeting take place on Tuesday 31st August, to advise the Health authority on the current activities and the plan to resolve the situation.

Tuesday 31st August

A visit from Mr. Chattagee, Chief Inspector, Health authorities. The visit confirmed the earlier view that the authorities had been unable to determine by any analytical means the true nature and extent of the incident, and had confined their activities to stopping work and tracing the whereabouts of the persons exposed. Lead in air tests taken at the base of 6" auger holes indicated heavy organic lead contamination.

Lead in air

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10m³</u>
31st Aug	0930	9	No. 3 auger hole 1' water level	Excess to scale of sampling unit	> 21.0
31st Aug	1030	10	No. 5 auger hole 1' water level	Excess to scale of sampling unit	> 20.5
31st Aug	1630	11	No. 7 auger hole 4' depth		> 1.2

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It became necessary to prepare a detailed scale chart of the area (Drawing Appendix (7)) to make proper deductions from lead-in-air tests and solid sampling results.

Fluorceine dye was put into test holes in an attempt to trace the water table flow surrounding the manhole excavation. This proved unsuccessful, (later attempts with potassium permanganate solution in differently located holes proved successful). At 12.30 p.m. a meeting took place at the offices of the Public Health authority with the Deputy Director Dr. A Kanagarathnam in the Chair; Dr. S.K. Nath (Health Officer for Pasir Panjang area) and six other Health authority officials. Mr. W. Watson, Mr. E.R. Harding and Dr. C.M. Bain, also attended.

The following points were made:-

- 2.6 Serious organic lead vapour contamination existed in the excavation pit and at certain locations in the concealed levels of the soil strata.
- 2.7 Attempt would be made to find and eliminate the source (i.e. buried leaking drums) of contamination.
- 2.8 Action would be taken to remove contaminated soil under controlled conditions for final disposal at sea in sealed drums.
- 2.9 Arrangements would be made for adequate control of the water flow from the excavation pit.

Dr. C.M. Bain had been previously advised of the action contemplated and had fully endorsed the proposals.

On site p.m., Dr. N.W. Ashworth, Medical Officer Shell Refinery - Pulau Bukum, visited the site. Safety equipment and 60 drums from Pulau Bukum arrived during the afternoon. All arrangements were made concerning emergency lighting, water supply, decontamination facilities, polythene buckets, protective clothing, etc., for the removal of contaminated soil from the excavation pit and also for the soil coming from 6" auger holes.

Written instructions were drafted and issued following a full explanation to Mr. E.R. Albrecht on the control conditions required for the safe removal of the contaminated soil from the excavation pit (see Appendix (8)).

Wednesday 1st September

A cable was sent to London requesting further supplies of safety equipment, chemical reagents and a device known as a "revealer" to assist with the location of the buried drums. A temporary safety centre was established in a nearby house (Drawing Appendix (7)). A plan to remove the most heavily contaminated soil estimated at some 3 to 4 tons at the base and lower sides of manhole No. 6 was discussed and all the physical

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arrangements involved were established. Work to start at 17.00 hours on Thursday 2nd September and to continue until removal was accomplished. A name check on available labour revealed that 16 of the 27 men directly involved with the previous exposure in July again reported for work. Other men on site were rapidly made available.

Three teams of seven men (only six canister respirators were available) with the seventh acting as "dresser" and safety attendant, were briefed and instruction given on the correct methods of wearing respirators, etc. At 92°F, air temperature and humidity at 82%, rubber boots, shorts, respirators and PVC gloves only were worn. Immediate ample supplies of kerosine, running water, soap, towels, etc., were arranged; a system involving the use of coloured rubber bands on the wrists of workmen was instituted with the aim of ensuring that no man worked more than a 2 hour period "in an estimated 8 hour total" at the base of the excavation pit.

Even taking into account Shell supplies, it had become necessary to "ration" the use of Uni-jet reagents until further quantities arrived from the United Kingdom.

Work and treatment of surface contaminated soil (from indiscriminate dumping) went on throughout the day. Soil was treated with both dry and wet solutions of potassium permanganate (a total of 16 cwt of potassium permanganate was eventually to be used during the incident). Lead in air levels on surface soil were:-

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10m³</u>
1st Sept	0830	13	Centre of restricted area	Removing top soil	0.3
1st Sept	0915	14	North east corner restricted area	Near soil pile of sub-soil	1.2
1st Sept	1500	15	Centre restricted area 2' 6" depth	Men digging	1.05
2nd Sept	0830	16	Centre north west side of restricted area	On level pile of excavated soil	0.3

In the temperature conditions experienced 92° to 95°F, it was essential to keep all surface soil constantly wet and to maintain a head of 5' to 6' of water on the excavation pit.

Thursday 2nd September

A visit from four Public Health officials including Dr. S.K. Nath, Health Officer for the district.

An air "blower" system was installed at the base of the excavation pit, and precautionary lead-in-air tests taken in readiness for the night work

of soil removal scheduled at 17.00 hours.

Lead levels were:--

Lead-in-air

<u>Date</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10cm³</u>
2nd Sept	17	Base of pit	Water drained away	> 7.5
2nd Sept	18	Base of pit	Water drained away Air blower on	3.5
2nd Sept	19	Base of pit	2 Air blowers Wet soil digging in progress	7.5
2nd Sept	20	South of pit by 5 yards		> 7.5
2nd Sept	21	East of pit by 5 yards in 6' trench	Near sealed drums	2.8

At 09.30 hours C.S.M. Black, Royal Engineers, commenced searching the restricted area with a mine detector. The range of the detector was between 3' to 4' 6" and the concrete pile foundations (with $\frac{3}{8}$ " steel reinforcement rods) seriously affected the efficiency of the device.

A great deal of odd "tramp" metal was discovered but no drums or likely disintegrated residues.

Boring with the 6" auger continued in a further attempt to locate the contamination source and to delineate the affected area.

At 17.00 hours work began on removal of soil from the base of the excavation pit. The method involved physically lifting buckets of soil from 14' depth of the pit and dumping into 50 gallon drums; treatment with potassium permanganate solution and clamping down drum lids. Temperature and humidity conditions made this work most arduous.

At 23.30 hours nearly 3 tons had been removed.

During the early stages of the work a second air blower (the open-ended delivery pipe of an air compressor) was put into the pit. Before closing down one cwt of dry potassium permanganate crystals was spread over the 8" square base of the pit and the two related trenches blocked off to restrict the water flow.

A copy cable (addressed to Dr. C.M. Bain) received from Dr. P.S.I. Barry (No. 8 Appendix (5)) advising that, if considered necessary, urine analysis facilities could be provided for persons previously exposed. Consultation with Dr. C.M. Bain indicated he did not wish to take advantage of the proposal.

Friday 3rd September

As a general policy both Mr. R.W. Lerrigo and Dr. C.M. Bain were informed by telephone at night of the changing pattern and work done during each day. The use of the mine detector continued until early afternoon and was then abandoned as unlikely to be of further assistance.

Lead in air levels following disturbance of the soil base in the excavation pit were greatly in excess of previous levels.

Lead in air

<u>Date</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10m³</u>
3rd Sept	23	2' 6" from base of pit	Water drying No ventilation	21.0
5th Sept	28	South west corner No. 6 pit	Men working dis- turbing sand etc. Ventilation off	21.0

Notwithstanding the use of air blowers such lead levels in the excavation pit clearly prohibited the use of canister respirators and it was decided to review the total position, reconsider resources, other limiting factors and all known information effectively to maintain adequate control of the developing pattern of events.

In addition it was clear at this stage that the demands of the situation required the services of two members of Company staff. The control of extensive site work, heavy sampling needs, preservation of confidence of the Public Health authorities, and Shell (Eastern) Ltd.; together with the organisation and supply of equipment and facilities exacted their physical toll.

The unique circumstances of the assignment, however, where the Company accepted no liability and all costs were payable by Swan and MacLaren weighed heavily with the writer and it was decided to await further developments during the next three or four days.

The foregoing paragraphs should not in any way be interpreted as a reflection upon the practical help and assistance received from the interested parties. Their efficiency and commitment were beyond praise.

After examination of all factors a meeting with the principals of Swan and MacLaren was arranged for 13.00 hours.

At this meeting the following points were made.

- 2.10 The current lead in air levels in the excavation, in relation to availability of safety equipment demanded that over-riding priority be given to the prevention of further fatalities.
- 2.11 That preliminary consideration be given to re-location and re-design of the sewage drainage system to avoid the existing manhole No. 6.
- 2.12 That whilst a prime objective was now to attempt to decontaminate in situ, it might be necessary, taking all factors into account, to consider sealing off the area by PVC membrane and concrete if the objective could not be achieved. (It should be remembered at this stage that the safe limit on soil contamination was still maintained at 20 ppm).
- 2.13 That continued attempts would be made by use of the "revealer" and boring by auger, to locate the buried drums.
- 2.14 Finally, that following activity on Saturday and Sunday formal advice would be given on Monday 6th September.

Dr. C.M. Bain and Mr. R.W. Lerrigo were informed later in the day and a brief provisional report prepared to be sent airmail to London on Saturday 4th September. Cable No. 9 (Appendix (5)) sent to London and a cable received stating all safety equipment requested would arrive air freight 19.00 hours Saturday 4th September.

Saturday 4th September

Provisional report (Appendix (9)) dictated and despatched to London. Arrangements made with Mr. W. Watson for immediate customs clearance for equipment and reagents arriving at 19.00 hours.

A continued "build-up" of information from lead-in-air and solid samples made on drawing of contaminated area (see Appendix (7)). Prepared draft certificate for disposal of "decontaminated" soil in drums removed from No. 6 excavation pit. Obtained advice from Mr. Cottrell, Shipping Manager, Shell (Eastern) Ltd. that the area Sultan Shoal near the port limits was an area in which port authorities might consider disposal.

In addition that the port authorities would require an endorsement of the disposal certificate by the Public Health authorities of Singapore on the nature of the material being dumped.

In view of further drums coming forward for disposal the arrangements were left subject to confirmation. All equipment from the United Kingdom collected and released by Customs at 20.00 hours and an acknowledgement cable sent to London.

Sunday 5th September

The "revealer" was used throughout the day in attempts to locate the drums. No success. Check lead-in-air levels taken at ground level on treated decontaminated soil were;

Lead in air

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10m³</u>
5th Sept	1200	24	In room used as Safety Centre		0.7
5th Sept	1240	25	Near heavily contaminated soil	Hole No. 2	0.7

In the excavation pit;

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10m³</u>
5th Sept	1430	26	South west corner excavation pit	5' from base of pit. Water running Ventilation off	1.2
5th Sept	1505	27	South west corner excavation pit at bottom	Wet running water surface Ventilation off	3.5
5th Sept	1615	28	South west corner No. 6 pit	Men working disturbing sand etc. Ventilation off	> 21.0
5th Sept	1645	29	South west corner No. 6 pit	Men working. Ventilation on blowing across sampling unit	3.5

It should be noted that Test No. 29 was subject to the air flow of the "blower" immediately across the sampling unit.

Following pumping of the excavation pit to enable lead-in-air tests to be taken a further one cwt of potassium permanganate was spread over the pit base. In addition, all 6" auger holes (now numbering over 50) were packed two-thirds depth (varying depth of holes 5 - 9') with dry potassium permanganate crystals. All soil extracted by the auger was treated by layering with potassium permanganate solution before placing into sealed drums for disposal.

At this stage there were indications that the main strata of contaminated soil lay some 5' below the surface running to a depth of 10' possibly 12' and lying roughly north east of the excavation pit.

Further, that the pit was acting as a "collecting" centre or seepage point of liquid through the soil and that the water table flow (through which potassium permanganate colour evidence existed) was flowing from north east to roughly south west. This was consistent with the flow of the water table towards the sea.

Monday 6th September

In view of the relatively low solubility of decomposition products in water no sampling had been done on water flow from the excavation pit to open water culvert from the site to a small river running finally into tidal prawn and fish beds some 800 yards away. Tests for organic lead (ppm in the water running from the excavation) were;

Liquid sample

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Organic lead</u> <u>ppm</u>
6th Sept	0830	30	No. 1 liquid sample	Water from site office culvert	1.0
6th Sept	0900	31	No. 2-near pump suction south of excavation pit		1.5
6th Sept	0935	32	No. 3-water from excavation pit	Top of water level with pit full	2.5

In response to a request from an excavation gang working near the site office on the most southerly aspect of the site a precautionary lead in air test was taken following a complaint about a "bad smell". The result was;

Lead in air

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10m³</u>
6th Sept	1000	33	South of site near excavation 25 yds. from Site Office	Bad smell	0.3

Examination of all analytical data indicated that apart from surface contamination by indiscriminate dumping of soil when originally excavating the pit a top layer of some 3' 6" of clean uncontaminated soil lay over the restricted area. It was decided to remove this layer over the whole 30' x 30' area which meant physical removal by hand of approximately 140 tons of soil. The removal of this layer of soil would:

2.15 Permit more accurate depth searching for the buried drums.

2.16 Possibly expose the contaminated soil strata which might then be more easily removed into drums in open air circumstances.

It was now necessary for labour, material and other costs, to maintain accurate records of expenditure and commitments being made. A final estimated statement of costs including labour, materials, etc., is given in Appendix (10)).

It was agreed that a meeting to inform the Health authorities of the latest developments should take place on Tuesday 7th September.

Tuesday 7th September

Extended use of "revealer" continued in the areas where 3' to 4' of clean top soil was being removed. A routine inspection of the excavation pit indicated that the water table flow was passing decontaminant through the soil strata. There were no signs of blue dye at the base of the pit and the pronounced "decomposition" smell was no longer present. A check lead in air test at excavating ground level was;

Lead in air

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10m³</u>
7th Sept	0930	34	At ground level excavation	4' in area	0.7

Tests at the base of 5' auger holes (without decontamination treatment) were;

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10m³</u>
7th Sept	1000	35	At No. 10 auger hole	5' depth (outside restricted area)	> 21.0
7th Sept	1050	36	At No. 11 auger hole	5' depth	2.8

Both these "test" borings were outside the restricted area and north east of the excavation pit by almost 30-40' (Drawing Appendix (7)).

Both Dr. K.S. Nath and the Public Health Analyst visited the site.

Further removal of clean top soil (to be re-used for back filling) and continued packing of 6" auger holes with potassium permanganate crystals of over 100 holes throughout the restricted area was carried on throughout the day.

A meeting attended by Dr. A. Kanagarathnam, Dr. K.S. Nath, Mr. Watson and E.R. Harding took place at noon at the Public Health Department offices.

The current situation was fully outlined and the Health authority requested a written statement on the views expressed. A statement was sent to the authorities at 17.00 hours on the same day.

A summary of the statement follows;

- 2.17 There was, following removal of contaminated top soil (through indiscriminate dumping) no contamination of the soil strata above a depth of about 5'.
- 2.18 That whilst every attempt would continue to be made to locate the drums and to achieve decontamination in situ it would be prudent to consider the implications of:-
- (a) Re-design and re-location of the sewage system to completely avoid Manhole No. 6.
 - (b) The as yet unknown effect of continued application of decontaminant to the area through packing auger holes and the excavation pit including 10' of related trenches with potassium permanganate crystals.
 - (c) The placing over the defined area of an overlapping PVC membrane with a 3" layer of concrete followed by a further PVC membrane and an additional final 3" concrete screed to give a total depth of concrete of not less than 6".

The Public Health authority officers asked for time to consider the implications assuming that decontamination in situ might not be possible and promised a decision by Friday 10th September.

Dr. C.M. Bain had been consulted and gave his assent before the above proposals were put to the authorities. Mr. R.W. Lerrigo was informed later. In addition, a summary of the statement was cabled to London. Cable No. 11 Appendix (5).

Wednesday 8th September

A cable was received from London (No. 10 Appendix (5)) at 08.00 hours advising the dispensation that only soil above 50 ppm organic lead be regarded as contaminated.

A check lead in air test when the 3 to 4' of clean top soil was being removed was;

Lead in air

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-a</u> <u>mgPb/10m³</u>
8th Sept	0900	37	Check test digging back top soil	3 to 4' men excavating	0.7

Soil samples were taken indicating that the potassium permanganate treatment to the general area was proceeding satisfactorily.

Solid samples

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Organic lead ppm</u>
8th Sept	1030	38	5' depth centre of restricted area		16
8th Sept	1030	39	Solid sample 8' north west corner auger hole		24
8th Sept	1030	40	11' deep No. 3 auger hole		80

Further check tests during the day were;

Lead in air

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air mgPb/10m³</u>
8th Sept	1100	41	North west corner restricted area	3 to 4' digging level	1.2
8th Sept	1430	42	North east side restricted area	Decontaminant in holes	0.7

Solid sample

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Organic lead ppm</u>
8th Sept	1630	43	At base of auger hole south west of restricted area		40

A visit to Shell House, Collyer Quay indicated that the disposal of "decontaminated" soil was beset with problems ranging from naval escort to possible confrontation headaches with Indonesia. Shell were advised that efforts would be directed at arranging disposal from an ocean going vessel.

A p.m. visit to site showed that it was necessary to excavate 3 to 4' beneath the foundations of the N.E. house to ensure that no contaminated strata was missed. (See photograph Nos. 9 and 10).

Using the "revealer" further attempts were made to find the drums. The excavated area 3' to 4' gave rise to hopes that the closer proximity might provide success. All efforts proved fruitless. Further supplies of decontaminant and kerosine stocks were obtained.

KE 0004949

Thursday 9th September

Torrential rain all day. Excellent flooding at depth of the whole area with potassium permanganate solution from the packed auger holes.

60 tons of top soil moved under abject miserable working conditions.

Lead in air tests (knowingly under wet conditions) were;

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/lCm³</u>
9th Sept	1100	44	North east near excavation pit	Torrential rain Men digging	0.4
9th Sept	1530	45	In excavation pit 6' down	Water drained away No ventilation	2.8

Detailed inspection of the excavation pit base gave no further signs of blue dye. Notwithstanding the appalling working conditions a heavily stained potassium permanganate permeated base and sides of the pit gave the first signs that decontamination in situ might be effective.

Friday 10th September

A cable No. 12 (see Appendix (5)) received from London 07.00 hours endorsing the statement and proposals made to the Health authority on Tuesday 7th September. Lead in air test taken was;

Lead-in-air

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/lCm³</u>
10th Sept	1115	48	At ground level top of pit	North East centre check test	2.8

All 2" x 9" timber planks (28' long) surrounding the excavation pit and certain sections of the trenches, were marked to have 12' lengths cut off and to be burned.

Mr. W. Watson requested information from the Health authority on the proposals put forward on Tuesday 7th September and was advised that the authority wished further time to consult other Departments, and opinion could not be given before Wednesday 15th September.

This delay did not affect the major objective; to endeavour to achieve decontamination in situ.

Late p.m. the whole 30' x 30' restricted area was cleared at 3 to 4' top soil level. At this stage a total of 186 6" auger holes (at 5 to 8' depth) now percolated the whole area.

Saturday 11th September

Visit made to Mr. R.W. Lerrigo and a brief report given on the existing situation. Arrangements made to speed up delivery of stock solutions on solid samples from Pulau Bukum to site.

Dr. C.M. Bain informed of the Health authority delay and cabled advice from Octel London including the dispensation concerning the safe limits of organic lead in soil.

At this stage it was decided to link auger holes together by a draught hole. In addition, to half fill one hole with two to three gallons of kerosine and burn the soil strata. This technique worked magnificently (see photograph Nos. 11, 12 and 13). Further supplies of kerosine were obtained and this method extended to cover all 186 holes.

A police inspector visited the site accompanied by a photographer.

An examination of the results of lead in air and soil samples from the pit evoked consideration of removal of some of the side shoring timbers of the manhole excavation.

The nature of the soil was such that the pit sides would collapse if timbers were removed. In the initial stages of decontamination (including removal of contaminated soil) it was essential to avoid collapse of the pit sides thereby covering contaminated areas.

The examination of analytical data showed that the continued application and flow of potassium permanganate was taking effect. It was agreed to remove selected planks of the shoring timbers on the north side of the excavation pit.

Sunday 12th September

At 08.30 hours removal of three strategically placed planks revealed the most heavy contamination yet encountered. An immediate start was made by cutting out the soil, placing it into drums layered with potassium permanganate. The strata was some 4 to 5' thick over an area of about 12' x 16'. Photograph Nos. 6, 14, 15 and 17 show the auger holes cut partly away during the cutting out of this contamination.

Blue streaks could be clearly seen in the sand soil strata and the "decomposition smell" reappeared.

Notwithstanding further supplies from the United Kingdom it was now necessary to conserve Uni-jet reagents for final authoritative tests. Some 54 tests had been taken and additional use of dithizone and chloroform necessary on the high initial figures experienced. A check test taken at the end of the day was:-

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10m³</u>
12th Sept	1630	55	After clearing soil strata (for disposal) from restricted area		0.7

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0004051

The identification of the most heavily contaminated area was a major breakthrough and its removal meant no further contamination could seep into the excavation pit.

Monday 13th September

Solid samples taken at the base of the excavation pit were:-

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Organic lead</u> ppm
13th Sept	1000	55a	Centre North east ground level in pit		48
13th Sept	1015	56	West corner ground level in pit		64
13th Sept	1030	57	East corner ground level in pit		32
13th Sept	1045	58	North east corner ground level in pit		16

Special facilities were organised to meet the ferry from Pulau Bukom to enable the stock solutions of the solid sample to be received on site the same day. A level of 3" of potassium permanganate crystals were placed into the pit and 10' of related trenches. 4' of hardcore was added with a 6" layer of clean sand. This preparation could not prejudice in any way any action which might be suggested by the Health authorities as it was already clear that the excavation pit was now free from significant hazard to health. Removal of the adjacent and external to the pit contaminated soil strata continued steadily throughout the day. The area was kept constantly wet with water and potassium permanganate solution applied by watering cans.

In addition extended burning of soil with kerosene in selected auger holes took place. In reply to a letter written by Mr. Watson on Friday 10th September, Dr. A. Kanagarathnam, Deputy Director Public Health authority advised that a meeting to discuss statement made on Tuesday 7th September would take place at 11.30 a.m. on Wednesday 15th September at the authority's offices.

Tuesday 14th September

A visit from seven senior officials of the Health Department. The officials were anxious to receive information on immediate developments presumably with the prospect of avoiding complications at Wednesday's meeting. Lead in air tests taken:-

Lead in air

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air mgPb/10m³</u>
13th Sept	1050	59	Ground level near excavation pit	Men working	0.3
14th Sept	1000	60	Near pit at ground level	Men burning	0.3
14th Sept	1600	61	Above excavation pit	Pit filled with hardcore	0.7

Both Dr. C.M. Bain and Mr. R.W. Lerrigo were informed that decontamination in situ and removal of the main contaminated soil strata was proceeding successfully.

Discussion took place during the afternoon with staff of Messrs. Swan and MacLaren on the preparation of a scale drawing of the decontaminated area (Appendix (11)). This was prepared for later submission to the Health authority.

Wednesday 15th September

Analysis of the whole pattern of activity at Pasir Panjang and the developments since 29th August, provided the basis for advice to both Messrs. Swan and MacLaren and the Public Health authorities.

A draft certificate with an accompanying scale drawing was prepared (Appendix 11). Dr. C.M. Bain had been consulted on the draft documents and gave his full endorsement. The critical words in the draft certificate were "the area of ground identified in red on the drawing attached is free from significant health hazard resulting from contamination", etc.

The organic lead levels in soil (see tests 46, 47, 49, 50, 51, 52, 54, 55, 56, 57 and 58 Appendix (12)) even though balanced against the dispensation on the safe limit from 20 ppm to 50 ppm organic lead prohibited any statement that the area "is free from significant traces of", etc.

The Director of Public Health and some eight senior officials with Mr. W. Watson and E.R. Harding attended a meeting at 11.30 a.m. at the authority's offices.

- 2.19 After an outline of the current position, the draft certificate was read over to the authority officials and the document was accepted without reservation.

Mr. W. Watson submitted a drawing of the re-location of the drainage system which received endorsement.

In response to questions Mr. E.R. Harding stated:

- (a) Any decision to install PVC membranes and concrete screeds,

KE 0004353

made by Messrs. Swan and MacLaren in consultation with the Health authorities.

Note:

The parties concerned agreed the re-location of the sewage system was a simple matter; (for which the Sewage Department representative present gave immediate approval). And that such re-location of the sewage system together with the installation of PVC membranes and appropriate concrete screed were useful precautionary measures.

- (b) Reference to the clear wording of the certificate would decide whether there was any necessity to notify (presumably by covenant) purchasers of the houses in the immediate vicinity of the nature of the incident.

Note:

All present accepted that such notification was not required.

- (c) He would carry out 8 trial borings and if necessary lead in air or solid sampling tests at 40 yards and 100 yards along 4 compass points centred from the excavation pit.

Note:

Tests conducted next day, all tests proved negative.

- (d) Whether there were any further sites in Singapore where lead alkyl compound had been buried was a question more properly directed towards the oil companies resident in Singapore.

Note:

Mr. R.W. Lerrigo, Shell (Eastern) Ltd., was fully informed of the authority's question on this matter.

- (e) If the authority wished to obtain a copy of the report by Mr. M.A. Pryke (Appendix (1)) they should communicate with the Company Secretary, The Associated Octel Company Limited.

Thursday 16th September

Five samples (Nos. 63 to 67 inclusive) were collected for later analysis at Ellesmere Port, Cheshire. A level of 3" potassium permanganate was placed into the excavation pit base and 10' of the related trenches. This was covered by some 4' of hardcore and a PVC membrane placed above the hardcore followed by a 4" concrete screed. All shoring timbers were then removed for cutting and subsequent burning. The excavation was then back filled and rammed with clean top soil to the

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9.2 concrete
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level of the adjoining excavated area from which the main contaminated strata had been removed. A PVC membrane was then overlapped throughout the full restricted excavation area including the excavation pit (this method ensured a double PVC membrane and concrete screed over the pit). See photograph No. 18 on completion of the concrete screed.

Final documents were dictated for Messrs. Swan and MacLaren and copies made of accompanying scale drawing. It was agreed between Mr. W. Watson, senior partner Swan and MacLaren, that Mr. E.R. Harding would provide original documents for Swan and MacLaren who would be responsible for issue and circulation to interested parties.

The only exception made to this arrangement was the issue to Dr. C.M. Bain by E.R. Harding of the documents and drawing in Appendix (11).

Friday 17th September

Arrangements including certification of contents (Appendix (11)) were confirmed for the disposal of 26 drums containing approximately 16 tons decontaminated soil.

A vessel owned by the Straits Steamship Co. Ltd., sailing on or about 22nd September from Singapore to Penang would dump the drums into the open sea.

Cleaning and return of all equipment on loan from Shell (Eastern) Ltd., was carried out during the day; several items, notably rubber boots and respirators had received very heavy duty and where possible, replacements were made from Company stocks received from the United Kingdom.

The remaining U.K. items were consigned by sea transport to Ellesmere Port.

A visit was made at 12 noon to Mr. Neville Fakes, Chairman Shell Malaysia, to formally thank him for the services rendered by Shell (Eastern) Ltd. It was agreed that laboratory staff at Pulau Bukom would take some 30 days later solid samples at stated depths at five points located on a scale map, carry out analysis for organic lead content and notify Octel London of the results.

Opportunity was taken to ensure that Mr. N. Fakes and Mr. R.W. Lerrigo were fully informed on all relevant details.

At the request of Mr. R.W. Lerrigo, Mr. E.R. Harding agreed to visit Pulau Bukom Refinery on Monday 20th September, to discuss problems associated with decontamination, tank cleaning and the use of Uni-jet lead in air testing apparatus.

Saturday 18th September

Preparation of documents, drawings, etc., and rest and recuperation.

Sunday 19th September

Final visit to Pasir Panjang. Lead in air tests taken at centre of the back filled area.

Lead in air

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Lead-in-air</u> <u>mgPb/10m³</u>
19th Sept	1000	62	Centre restricted area	Top soil backfilled Dry conditions	0.3
19th Sept	1030	68	Above centre restricted area		0.3

Solid samples taken by auger at various depths (and subsequently analysed by Research and Engineering Department at Ellesmere Port) were:-

Solid samples

<u>Date</u>	<u>Time</u>	<u>No.</u>	<u>Location</u>	<u>Remarks</u>	<u>Organic lead</u> <u>ppm</u>
19th Sept	1030	63	South east corner 3' deep restricted area	3' depth	5.0
19th Sept	1030	64	North east corner restricted area	4' depth	1.2
19th Sept	1030	65	North corner restricted area	3' depth	5.0
19th Sept	1030	66	South west corner	5' depth	1.24
19th Sept	1030	67	Centre of restricted area	3' depth	1.0

In addition, the points at which the laboratory staff at Pulau Bukum would collect solid samples at a date 30 days hence were firmly marked.

Monday 20th September

Letters of thanks were sent to Shell (Eastern) Ltd., Dr. C.M. Bain, various Chinese contractors and two personal notes to senior partners of Messrs. Swan and MacLaren.

9.30 a.m. - Visit to Pulau Bukum and discussions with Mr. E. Day, Chief Technologist, and laboratory staff.

Tuesday 21st September

KE 0004956

Wednesday 22nd September

London office for verbal report to Sales Manager and Company Secretary.

3. FACTORS AFFECTING SITUATION

The following factors imposed severe limitations upon the methods, control and time element of dealing with the incident.

- 3.1 Inadequacy of factual information on the exact location of the buried drums.
- 3.2 The nature of the sand sub-soil, and the water table.
- 3.3 The proximity of nearby already constructed houses and their pile foundation characteristics.
- 3.4 Indiscriminate dumping of contaminated soil.
- 3.5 Temperature and humidity.

Under 3.1 above efforts ranged from the use of a mine detector, the "revealing" device and boring 186 6" auger holes throughout the area, in addition to numerous small 3' 1/4' excavations in likely spots.

Reference to M.A. Pryke's report (Appendix (1)) shows:

- (a) The drums were buried at least 18 years and possibly as long as 23 years.
- (b) At the time of burial the rolling hoops and outer bungs may well have been missing from both drums.

In addition, personal inspection of buried pipework and "tramp" metal picked up by the detecting equipment showed very pronounced corrosion amounting in some cases to disintegration.

Under 3.2 above, the presence of the water table flow towards the sea gave a much wider spread of contaminated sub-soil than might be normally envisaged. One surprising factor was the uniformity of contamination of the strata throughout the main area save for the several occasions when readily identifiable blue dye seeped into manhole No.6. It was significant that when the main contaminated strata had been removed from the area surrounding the pit all seepage of blue dye ceased.

Under 3.3 above, the presence of nearby houses (in addition to the nature of the soil) and existing excavations completely prohibited the use of mechanical earth moving equipment. Examination of photograph Nos. 10, 11, 19 and 20 will show that it was necessary to excavate under the piled foundations of the house to the north of

manhole No. 6. The method of shoring all excavations and the certain collapse (if the timbers were removed) of the manhole pit dictated the plan of work for decontamination, i.e. it was imperative to avoid at all costs the over-burying of contaminated soil.

Under 3.4 above, the widespread indiscriminate dumping of contaminated sub-soil seriously hampered in the first week the accurate delineation of the contaminated area.

The real breakthrough on identification of the most heavily contaminated soil area occurred when it became possible to remove vertical timber shorings supports to manhole No. 6 and to cut back at 7 to 11' depth at selected points.

Under 3.5 above, average temperature was 92 to 95°F and humidity 80%. The work in respirators in manhole No. 6 and removal of the main contaminated strata meant considerable hardship and discomfort.

4. CONCLUSIONS

4.1 In the opinion of the writer, clear evidence exists to support the conclusion that the unlocated drums were long ago exhausted as a continuing source of contamination.

4.2 The method of shoring the manhole excavation and the related trenches materially contributed towards the formation of very high concentrations of organic lead vapour in the pit. A vertical shaft of 14' excavation and 14' timber extension giving a total of 28' depth (see photograph Nos. 3 and 21) with little or no natural ventilation permitted the build-up of lead levels greatly in excess of the maximum extension of the Uni-jet scale of 21 mgPb/10m³.

These levels indicated the presence of organic lead notwithstanding the absence throughout the whole incident of the "accepted" TEL smell. In addition, the lower vapour pressure and lower volatility of the decomposition products present are known to be incapable of producing the organic lead levels experienced above.

4.3 The re-location and re-design of the sewage system proved to be a simple matter. The cast iron soil pipes coming from the nearest houses will be not less than 24' from the abandoned manhole No. 6 and all service pipes will be either outside the delineated area (Appendix 11) or at a depth of not more than 3' below ground level. It must be emphasised here that the decision to install a PVC membrane and appropriate concrete screed over the delineated area was taken jointly by Mr. W. Watson (Swan and MacLaren) and the Public Health authority. The Company representative present took no part whatsoever in this aspect of the proceedings of the meeting held on Wednesday 5th September, 1965.

4.4 Examination of Appendix (3) will show that certain information is in the hands of the Medical and Health authorities of Singapore. It is stated, for example, that Dr. Sugai of the General Hospital, Singapore, conducted a post mortem on Ramli B. Sampol, one of the deceased. It was assumed throughout the incident that under the terms of his medical consultancy with the Company Dr. C.M. Bain of Singapore would inform the Chief Medical Officer, Dr. P.S.I. Barry on all relevant medical matters.

4.5 It will be noted that the facility now exists to determine, by use of the Uni-jet :-

- (a) Lead-in-air
- (b) Lead in aqueous solutions
- (c) Lead in solids

Under the revised method produced for item (c) at short notice by Research and Engineering Department staff, it was possible, even with the limits imposed by the 20 minute ferry journey each way, to receive stock solutions from the Shell refinery Pulau Bukum later the same day. This enabled determination of amounts of organic lead in soil to be obtained within 10 - 12 hours of taking the original sample.

4.6 It is recommended, to avoid further incidents of this nature, that consideration be given to the issue of an Octel bulletin which should state:

Should it become necessary to dispose of antiknock compound from any leaking drum or container, the methods in order of priority should be:

- (a) Dilution of the Compound in at least 10 volumes of kerosene to 1 volume of Compound and subsequent burning in an open metal container in acceptable small quantities of not more than 3 - 4 gallons.
- (b) Disposal at sea.
- (c) Every effort should be made to avoid burial of any leaking or partially filled containers.

4.7 The writer wishes to acknowledge the very high degree of cooperation and assistance received from all members of the staff of Messrs. Swan and MacLaren, in particular the direct assistance and advice of Mr. W. Watson was of inestimable value.

The extremely practical and efficient contribution from both Shell House - Mr. R.W. Lerrigo and Pulau Bukum Refinery - Mr. E. Day, was a major factor in resolving the issues which developed from the incident.

4.8 After some seven days experience of the initial stages of the incident it became clear that two Company representatives were needed to deal with the incident. The two main aspects of the situation:-

- (a) Site work, sampling, decontamination, etc.
- (b) Contact with public authorities, drafting documents, cables, obtaining supplies, etc.

presented a formidable physical task.

The unusual nature of the assignment (to provide consultant advice to Messrs. Swan and MacLaren at no cost to the Company) inhibited, in great measure, any proposal involving the additional expenditure of sending a second member of the Company to the incident. In the event, the subsequent pattern of the way the work situation improved provided a satisfactory solution.

4.9 In conclusion, the writer wishes to record his appreciation of the informed advice and assistance contained in the cables received from London.

E.R. Harding